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Preface

The 3rd Symposium on Location Based Services and TeleCartography held in Vienna from November 28-30, 2005 continues the series of symposia at the TU Vienna (1st symposium: 2002, 2nd symposium 2004) aiming on offering a forum for research-driven activities related to the context of location and map-based services. Such activities emerged in the last years especially around issues of positioning, spatial modelling, cartographic communication as well as in the fields of ubiquitious cartography, geo-pervasive services, user-centered modelling or geo-wiki activities.

The innovative and contemporary character of the conference leads to a great variety of contributions in terms of interdisciplinarity. Presenters of 18 countries with backgrounds varying from academia to business, from computer science to geodesy covering an enormous number of issues with heterogenous relation to the conference´s main topic.
While contemporary cartography is aiming on looking at new and efficient ways on communicating of spatial information, the development and availability of technologies like mobile networking, mobile devices or short-range sensors lead to interesting new possibilities of achieving this aim. By trying to make use of the available technologies cartography and a variety of related disciplines specifically look at user-centered and context-aware system development as well as new forms of supporting wayfinding and navigation systems.

Like in the forthcoming symposia the current 3rd Symposium on LBS & TeleCartography is organized by the Research Group Cartography of the Vienna University of Technology in close cooperation with the Commission on Maps and the Internet of the International Cartographic Association. This time a collaborative interest has been stated by the Commission on Ubiquitious Cartography of the International Cartographic Association, the Working Group 4.1.2 of the International Association of Geodesy and the Working Group V TC 2 of the International Society for Photogrammetry and Remote Sensing.

The venue is again set at the Vienna University of Technology, where a number of groups are working on research projects related to the symposium´s topic. The TU Vienna is Austria´s well-known research oriented university focusing especially on natural and technical sciences, in which geodesy and cartography have been embedded since the founding of the university. Vienna, as the capital of Austria, is a melting pot of a great variety of business and research activities in the context of LBS and wireless services. The mobile phone penetration in Austria is one of the highest in the world and can be seen as an indicator for the cutting-edge position Austria has reached in the field of wireless communication techniques.

Setting up an event like this during the busy “business-as-usual” program of an academic semester without any specific sponsoring or professional event organizers needs a big portion of enthusiasm and excitement. The staff of the research group Cartography of TU Vienna has again proved, that by collaboratively cooperating the organization of such an event can be succesfully handled. I therefore would like to thank especially the conference secretary DI Markus Jobst and Mrs. Violet Derman for their ambitious work, as well as for the contributions of Dr. M. Lechthaler, E. Wandl, DI V. Radoczky and DI A. Stadler.

In expectation of very useful and interesting presentations, discussions and new ideas, I wish all participants a successful meeting,

Georg Gartner
Chair of the 3rd Symposium on LBS & TeleCartography
Head of the Research Group Cartography, E127/2, TU Vienna

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Theory and development of research in ubiquitous mapping

Takashi Morita

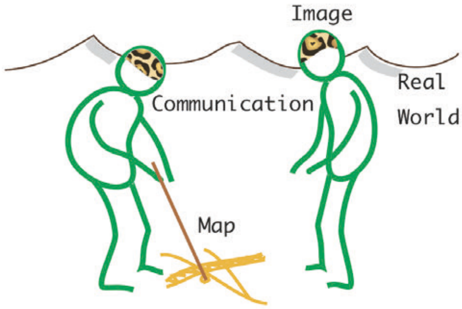
1 Map communication

Ubiquitous Mapping refers to the use and creation of maps by users anywhere and at any time. It is strongly influenced by advances in information technology, such as the development of wireless systems, high-density data storage and broadband communication, which have acted to stimulate and facilitate dynamic and personalized mapping. However, it appears that the fundamental nature of the map has not been changed significantly from its origin. Before examining the notion of Ubiquitous Mapping, it is necessary to review the purposes for which maps have been designed.

Three elements:
At a fundamental level, maps can be considered as providing a framework for depicting location. This location may be relative, a relationship between known and unknown elements, an absolute location, or a coordinate system. This is the most fundamental characteristic of a map. The second characteristic is that maps are primarily represented in visual format. We can easily recognize the relationship between map elements because they are reconstituted in our brain as an image with a spatial component. The ease with which patterns can be recognized is another characteristic of a map. However, the accuracy required to represent this spatial data correctly has resulted in the need for protocol in cartography. The third characteristic is the human-map-space interaction, which can be traced back to early human history.
Origin of Map Communication:
These elements are depicted in Figure-1 where one person is describing the location of an object using a map on the ground to the person facing to him. The object is located beside a route just before the road crosses a river (relative location). It is represented visually by employing different lines, each of which represents a structural pattern. Communication of an object's location is easier and quicker using visual means compared to verbal explanations. Given that this form of communication can exist independently of technological developments, it is likely that communication activities among humans have always employed these techniques
There are three basic components in the aforementioned situation: a map, spatial images in the brain, and the real world.

Scheme of Map Communication:
Figure-2 is a diagram depicting the notion of map-based communication proposed by Rech Ratajski(1) and adapted by the author(2). For map-based communication, there is a sender and a recipient of information. When the sender wants to send map information to a recipient, then that sender has a spatial issue to resolve and one of the ways in which this can be done is to use a map. Once a subject is fixed, the sender collects the information necessary to build a map. The information comes from various materials, databases, and even from other people when seeking assistance. Once sufficient information has been collected and collated, the next step is the design of map symbols and appending a legend. This is very important because the effectiveness of a map depends largely on the design of symbols.
It is through processing spatial data in this order that information the sender wants to convey is transformed into a map. Understanding the contents of the map by the recipient begins with the perception of a spatial image forming in the brain after viewing the map. This is a cognition process using the distribution pattern of map symbols.
It is from this image that a recipient begins to extract the geographic meaning, not only at a detail level (e.g. location of an object through map symbols), but also at the level of the entire image (e.g. I am here on the map, how can I get to the object?). In the latter step, the recipient interprets a map relative to their extant situation; the context. The sender wanted to convey the location of an object while the recipient sought to determine the location of the object and also how to get there. In this case, representation of an object's location, which may be a subsidiary function, has been achieved. However, this function is not satisfied then it is a bad map that renders map-based com-

Fig. 1: Origin of Map Communication



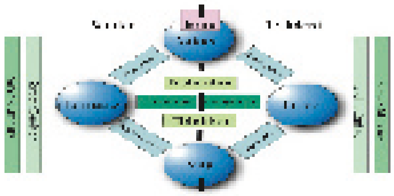


Fig. 2: Map communication

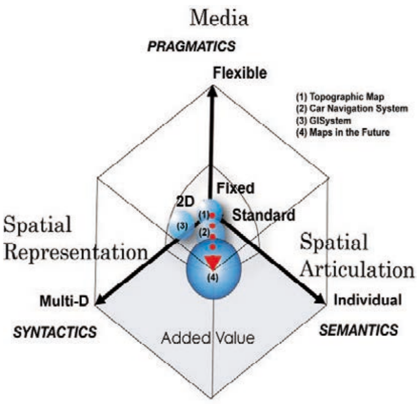


Fig. 3: Mapping World

munication impossible. Map-based communication between a sender and a recipient is considered effective if the object the sender intended to show was recognized by the recipient. Generally, absolute success may not be expected where a raison d'etre for cartographic study exists.

2 Mapping world

Paper maps can be carried in the field. The information on the map is "fixed" on the paper and it is the user who must extract the information they require from the map. However, it is not always possible to find the necessary information because there is a limit to the surface area that can be dedicated to depict the information on the map. There are also differences between maps and reality because of the limits imposed by the frequency of maintenance of updating information. Furthermore, making map production viable demands that a large number of copies be printed within a certain time frame. Thus, there is a need for the development of a new map, one that can be produced on site. Moreover, if it is interactive and can satisfy the specific needs of the individual who requires the map, production can be referred to as on site "mapping".

From "Map" to "Mapping":
Figure 3 shows the mapping world(3) with different types of maps depicted in the cube. This model is composed of three axes was defined by C. Morris as semantics, syntactics and pragmatics(4). In the model, the semantic axis represents spatial articulation (standard vs. individual), the syntactic axis corresponds to the spatial representation (multi-dimensional vs. two-dimensional) while the pragmatic axis represents the type of media (fixed vs. flexible). A paper topographic map would be located in the far lower corner of the cube given that it is a two-dimensional spatial representation on fixed media with standard spatial articulation. In the uppermost corner of the cube is a multi-dimensional spatial representation on flexible media with individual spatial articulation, representing the maps of the future; between these end-points lie systems such as GIS and car-navigation. All map types can be classified within this mapping space, either as a single mapping system or as a set of different systems with different objectives.
Placement of the topographic map in the corner opposite future maps does not mean that the topographic map format is an "old" map because topographic maps already exist in digital format. Rather it means that topographical maps represent the standardized basic map format relative to all other types of maps. Without a basic map format, there would be no common space to improve upon and value-added, systematized maps would not have become possible. Furthermore, the re-evaluation of information from old maps, such as hand-drawn and externalized cognitive maps, is an ongoing process. If a standard base map exists, old maps considered to be inaccurate may be relocated onto it. The base map then becomes a platform upon which various mapping information can be manipulated using modern information technology (IT) systems. However, these inaccurate maps could have significant value as human interfaces. Use of a well-drawn albeit out-of-perspective map - a good generalization in other words - can often meet with favorable results. On road maps for example, the characteristics of the road form are often simplified or exaggerated to make the map easy to read and understand. This illustrates that homogeneous and accurate maps are not always efficient for human interpretation.

Egocentric mapping:
The development of mobile phones equipped with GPS and digital compasses, as well as car-navigation systems, can be considered progenitors of future mapping methods. These mapping methods are personalized, bi-directional and change in real time. The most important characteristic of this style of mapping is that it is egocentric, meaning that a map may be presented on demand in relation to the actual position of the user. "Where am I?" is always the first question any user asks when using a map on site. If the direction of the map is always adjusted to the north then there is parallelism between the map and the surrounding landscape and if a map shows a side view of the users' actual position, it is easier for the user to orientate themselves. Individuals vary in the way they perform spatial tasks, with actions such as going to the bookstore, restaurant, or flower shop, all depending on the situation. This is the notion of context awareness, and it is likely to a key term in the future mapping.

3 Fundamentals of ubiquitous mapping

3.1 Changes in the information and communication environment

Effective communication is facilitated by a physical medium to convey messages between a sender and a recipient. The images in the brain should be externalized and tangible. Drawing a map on the ground with a stick gives the map a real shape. Combination of the ground surface and a stick can be viewed as the technical environment used to facilitate representation of a map, one that may either become redundant or change as new techniques become available.

Visualization of information:
Tribal humans were using maps to communicate spatial concepts considerably before the invention of letters and characters. However, after the development of typesetting, such as was employed to produce the Gutenberg Bible, it became easier to communicate using text than by using graphics. This development resulted in printed characters dominating books for more than five hundreds years. However, subsequent to the development of printing graphics, books came to contain more than only text. Similarly, broadcast communication began with radio using spoken messages before evolving into TV, which incorporated the visual component in addition to sound. It is currently the same for cellular phones, personalized computers, and PDAs (personal digital assistants); portable devices that were previously incapable of sending visual information are now used to send image-rich content. As can be inferred from this convergence, communication with words and visual information are both very important, with the latter being more difficult to represent.

Ubiquitous Computing:
Computers and communication networks are similar to extensions of our cerebral and nervous systems; we have come to expect to use them anywhere and at any time. This situation reflects the goal of developments in information technology. Mobile devices such as cellular phones and PDAs have become pervasive, telecommunication lines are no longer made of copper wire, but rather are made glass optical fiber for broadband - and now even to wireless. Computers are ubiquitous, and can be found in Internet cafés, airports, train stations, hotels, homes and offices, and these are just traditional applications. We already utilize ATMs (Automated teller machines) at banks, ticket-vending machines, route-guiding machine, in-car navigation system, and other machines that incorporate computers for specific purposes. Small IC tags that can be attached to fixed objects such as signposts, or moving objects such as consumer goods, may become information and communication stations, connecting different computers. These are examples of the so-called “ubiquitous computing environment”. In this environment, communication between person-to-person, person-to-machine, machine-to-machine (machine communication: network, human communication: understanding) are bi-modal, interactive, and realized in real time. This is more than an information system, it is a communication system.

3.2 Ubiquitous nature of maps

The contemporary needs for ubiquitous mapping are mentioned above. Now we will examine the potential applications of ubiquitous mapping and its principal characteristics.

Visual perception:
Maps are generally visually perceived. Visual perception is ubiquitous because we can perceive and conceptualize an entire object through pattern recognition. At the same time however, we can observe any given part of the image. This means that we can move freely between the entire image and the partial image. The order of processing data is not predetermined as it is when we are confronted with reading text composed of characters. This ubiquitous nature of vision is very useful for reading maps as thematic images can be superimposed in the background (figure and background) on the same plane. It is thus possible to represent alternative propositions or solutions using the same image, facilitating the rapid and simplified communication of spatial information.

Creation process:
We continually refresh the spatial and temporal attributes of images in the brain and modify these images as necessary depending upon the prevailing situation. Such maps are regenerated from information contained in a database to produce one of two kinds of maps: one is the reproduction of existing map, the other is the creation of a new map in response to specific user requirements that differ in time, space, and personal attributes. This latter map-type can be created using digital systems with specific parameters applied to existing maps that are modified and to which necessary information can be added. Realization of map production in this way has only been made possible through enormous advances in information technology.

Using process:
A map drawn on the ground surface is a type of on demand map. A paper map can be transported and utilized by user at a different location. Such a map can be used anywhere other than its place of origin. However, in order to solve a spatial problem successfully one should attempt to acquire a suitable map. This is usually done by specialists and is difficult for members of the general public. Consequently, it is therefore highly likely that the full potential of maps has not been realized. We have mobile and wireless devices that can display maps and can receive existing maps on demand, and we can also create maps in response to the needs of a user in a particular situation. This enforcement-assistance relationship between map and user was not possible before. Maps too have become ubiquitous and can be made on demand.

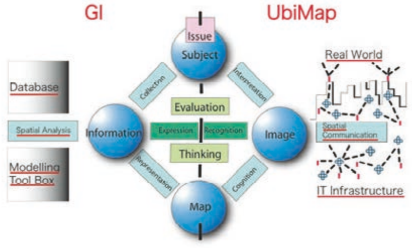


Fig. 4: GI and Ubiquitous Mapping

in anywhere ► where

at anytime ► when

for anybody ► who

Fig. 5: Where-when-who

3.3 Difference between GIS and Ubiquitous Mapping

How does ubiquitous mapping differ from GIS or simple geographic information? In the mapping universe these concepts fall within the same schema. However, if we attempt to distinguish between these systems, it seems that the primary difference is related to the context of "information" and "communication". As shown in Figure-4, GIS emphasizes information processing through data input, database building, data analysis, and data output of spatial information. It is used for spatial analysis using database and modeling toolbox type applications with maps simply being used as the outputs of this information processing.

Conversely, communication is the principal function of ubiquitous mapping. It includes not only map production, but also map use and map communication and considers the interaction between the map, the spatial image, and the real word. Instead of being a "modeling toolbox" as in GIS, there should be "IT infrastructure" for ubiquitous mapping. It is the on-site communication network system connecting the three elements; the map, the spatial image, and the real world. Thus, GIS is oriented toward being a spatial information system for analysis, whereas ubiquitous mapping is concerned with spatial communication; it is a human-oriented system that incorporates spatial cognition, spatial deduction and abduction, and spatial decision making.

4 Research in ubiquitous mapping

What is the future direction of this domain for further studies? Since the domain is in its infancy, we have attempted to provide a working framework and provisional research agenda below. Topics such as social costs, security and cross cultural studies will also be required in the future.

4.1 Elements of context awareness

Since the purpose of Ubiquitous Mapping is to resolve spatial problems and to realize the ability, and consider the environment, of users in the creation and use of maps at any time or location, the most important and novel theme in cartography is the element of context awareness. This element is fundamental because real time mapping applications that are sensitive to context and, "anywhere, any time, and anybody" require that the components of the "where, when, and who" of the users' is known in advance. The system should therefore recognize the following elements:

Three situations

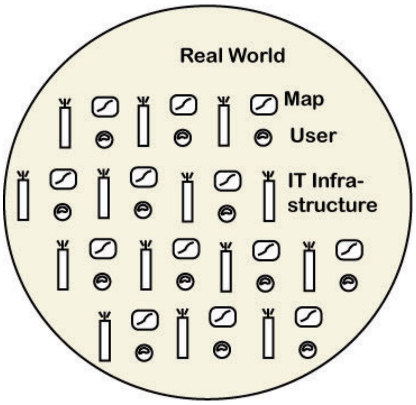
Anywhere: To respond to the question of where you are, one may react using either natural language to indicate the relative position to a known landmark, place name, address, or even a geographical coordinate in an extreme case, or point to a corresponding site on a map.

Any time: A users' temporal characteristics are usually "now", in real time and immediate. However, one may refer to a chronological point in time that differs in a relative sense from the time at which the question was asked, or to a difference in the standard and/or calendar time. Time may be defined using natural language such as in an emergency, the daytime or at night, for example.

Anybody: This includes the attributes of the user and corresponds directly to the objective of the mapping exercise. Characteristics such as gender, age, whether the user is a national of the area or a foreigner, whether they have a mental or physical disability, people in a state of haste and similar characteristics, as well as their intended activity, prescribe the function of map.

Four elements

Fig. 6: Four Basic Elements of Ubiquitous Mapping



Ubiquitous Mapping consists of four basic elements: the real world, the map, the user, and the IT infrastructure with interactions between each element.

The real world: Is taken as the total space required by human beings for living; it is the space consisting of the objects and the backgrounds of our activities. If the characteristics of this space were different, human behavior would also be different.

The map: It is a physical map that is observable by a human sensor and is represented using map symbols. Voice may also be used to augment the data contained in the map. It may be provided on site as a guide map post or on the screen of a mobile device. Here, the notion of a "map" may be replaced with that of "mapping" as digital maps and IT infrastructure allow for real-time creation and manipulation of maps.

The user: It is the subject and the actor who needs to resolve a spatial issue. Individuals have spatial images in their brains that differ from those of other individuals. This is because personal attributes such as objectives, interpretations of spatio-temporal phenomena, personal history and spatial preference, all differ from person to person and are dynamic depending upon a given context.

The IT infrastructure: This is the supporting, spatial communication system that facilitates the interface between the real world, the map, and the user. It is composed

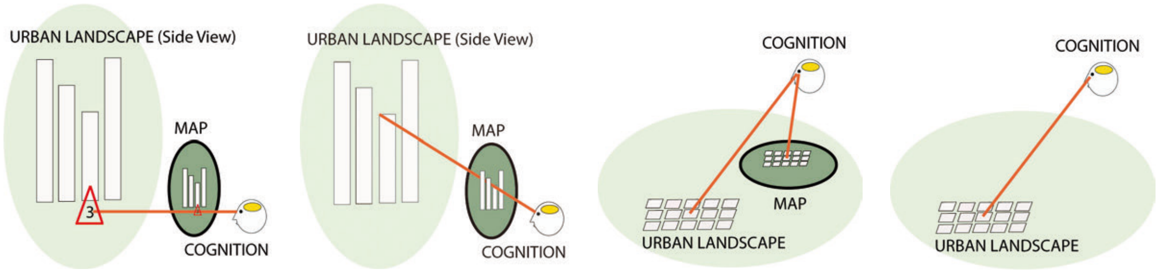


Fig. 7: Map and spatial cognition

of a wireless communication network, spatial communication devices, spatial information databases, mapping software, and similar attributes. Spatial communication devices can be divided into mobile devices and communication posts. The latter are stationary and on-site, and connect the real world, the map, and the users like a street name and house number are used as coordinates on a map.

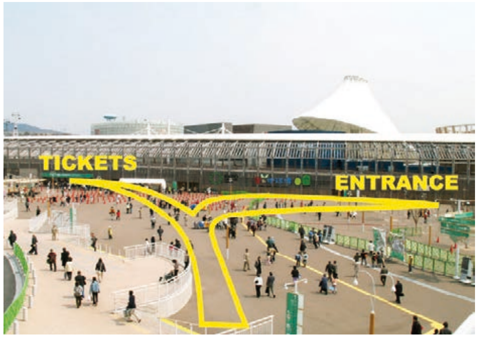


Fig. 8: Mixed reality

Side view (3D view)
The relative position between four elements mentioned above are also central to the context and usability of a system. When people view a townscape, the scenes are usually perceived as side or oblique views, very rarely are they viewed from a vertical angle. Since maps are normally drawn using a vertical projection with the element of cartographic abstraction, users are forced to interpret the side of a location into vertical view, a process that can demand considerable gymnastics of the brain. Thus, it is more convenient for a user if the map is first drawn from a side view perspective and then transformed into a vertical view. However, the characteristics of side views vary with respect to the relationship between the viewpoint and the view angle of the object scene. Consequently, it is not possible to make a side view map from vertically derived cartographic materials. However, the considerable improvements in digital cartography has resolved many of the difficulties formally associated with this problem. We now have 3D urban models with which it has become possible to transform images from side views to vertical views. We have thus gradually resolved many of the problems formally associated with the cartographic abstraction required for generating side views. Photo-realistic images may not be the solution because such methods are always open to misidentification by the user. The object that constitutes "what" is a part or an element of a continuous space. A clear image of spatial elements may be given by cartographic abstraction, which may then be superimposed on to a photo or real scene. This latter approach is a sort of mixed reality where symbols like arrows are directly displayed on the site or on the mobile screen.

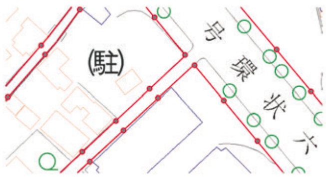


Fig. 9: Reference points of Real-Scale-Map

Fig. 10: Human Navigation System using Cellular Phone

Time representation (4D view)
Time and space are intricately connected, particularly in the context awareness environment because "when" is one of three fundamental parameters referred to above. Three time variables need to be represented. One is that of "real time" where the map on screen is refreshed relative to the location of the user in real time. The second type includes the representation of mobile objects or temporal phenomena that are normally omitted from traditional paper maps. Location monitoring of children using GPS and a wireless network is one such example. Temporal information can be depicted on map-enabled cellular phones and transferred to friends to notify them of a destination to which they should come. The third temporal aspect is an animation showing the movement of a phenomenon. Animated instructions to help users make a decision, such as route guidance using dynamic arrows.

Real scale map
These maps have a scale that is unusual in that it has a real scale (1:1). The abstraction of spatial objects and reduction of the size of spatial phenomena are some of the basic functions of map. However, abstraction really only begins at scales of spatial cognition when we can observe an object scene and recognize the spatial characteristics of the structure. This is so called spatial articulation and is performed by everyone in their daily lives, which is the level at which spatial elements can be distinguished and classified. This process is very similar to cartographic abstraction but it is done using real scale objects and with images being retained within the brain. A map is a product of cartographic abstraction of the real world. When we utilize a map, the on site object depicted by a map must be referenced to real object to verify a position. However, such referencing is not always easy to reference abstractions


Fig. 11: IC tags located in front of a Temple


Fig. 12: IC tag Plate

with the real world using only the characteristics of the feature being represented. Consequently, we often employ signs that are located on site as well as those, like as street names, which can be described on a map. However, because this approach is not always successful, especially at local scales and it is therefore necessary to have more efficient system.
The real scale map proposed here is a map drawn on the real world using well-defined reference points that are visible on site and, simultaneously, as points on a map. Once this has been achieved, all cartographic elements should be defined relative these reference points. The difference between this system and the coordinate system is that the reference points on site are either visible or invisible. Consequently, reference points should be clearly visible and easy to locate. In addition, the orientation of the map should be always synchronized to the north and this could be supported by IT infrastructure.

Connection and transformation between different spatial languages
Location may be represented using natural language, such as address, place name or as “ahead”, “turn right”. Alternately, they may be also indicated on a map, which is more conventionally used to represent spatial information. Thus, while natural language is easier to present, it is less precise than cartographic language. There is thus always a need to transform spatial information between verbal and non-verbal formats and the process of geocoding constitutes the connection between these two spatial languages. In the context awareness environment, both natural and cartographic languages need to be understood as the system should be able to approximate certain parameters on behalf of the user in a given context and also so that users to use both languages unconsciously.

4.2 Applications in Tokyo

In-car navigation systems
A commercial system was introduced in 1981 without any digital information infrastructure. It functioned using an autonomic system that employed a dead reckoning method with gyrocompass and a paper road map. In the mid 1980’s, a beacon system that transmitted traffic information from dedicated transmitters along roads combined with digital road network data for whole country constituted the infrastructure. The use of GPS in 1990 combined with a map-matching method, as well as information on traffic congestion and accidents in real time using FM, subsequently became available. In 2005, more than 15 million in-car navigation units were sold in Japan. Their typical functions include the display of actual geographic location on digital maps in 2D and 3D with landmarks using north up/heading up, congestion/construction information in real time, route guidance (maps, diagrams and voice) to the destination using customized user profiles, queries and different display types (gas station, parking, restaurant, etc.) are also possible. The most recent systems use a hard disk, which calculates appropriate route to a given destination, even when the route is suddenly altered from the initial course.

Cellular phones
“All-in-one” type high-functionality cellular phones have become more popular than PDAs (Palm and Pocket PCs) in Japan. More than 90 million units have been sold and the diffusion rate is more than 70%. Typical specifications of current cellular phones include full-color LCDs, high-resolution display (240 x 320 pixels), 3D graphics engine, Java/flash/SVG compatibility, camera (3M pixels), removable memory, mail, Web, internet, voice recorder, a diary, 2D Bar (QR) Code Reader, GPS, Compass, etc., which can be applied as a human navigation system for route guidance by pedestrians. It proposes alternative routes after considering the various possible modes of transport (on foot, by taxi, by bus, by train, etc.) and provides timetable and tariff information. Once the route has been fixed, the user is provided with step-by-step directions and guided by voice with the map in the heading-up orientation. The destination may be designated directly using an address or a point on a map, or through querying the system using several destination categories. One can communicate one’s actual position using the GPS and a map to the recipient without knowledge of the exact address. Another location-based service involves transmitting the location of the bearer of the equipment (children, grandparents, etc.) to the user via an operation center. The equipment is a modified version of a cellular phone that transmits location information in response to demands sent from the operation center. The user can use the system to determine if the bearer is within a predefined safety zone or the user can request the bearer to push a button to confirm that the bearer is not in trouble. If there is no reaction a member of staff or security services will rush to the site.

IC Tags for navigation
Free Mobility Experiment Project (http://www.tokyo-ubinavi.jp/) organized by the Tokyo Metropolitan Government, the Ministry of Land, Infrastructure and Transport, the Japan Institute of Construction Engineering and the PFY Ubiquitous Networking Laboratory is undertaking a public experiment in Tokyo and Kobe. The objective of the experiment is to verify the functionality of equipment designed for ubiquitous computing that is being applied to navigation in a real city space. The system is consists of an IC tag, wireless marker, infrared marker, ubiquitous communicator, and an electric cart to transport visitors, that all provide route guidance and information necessary for sightseeing. The ubiquitous communicator is a modified PDA with a GPS receiver, wireless antenna with preloaded information detailing the information relevant to the site of interest, identified when the PDA communicates

with the IC tag (non-contact and passive) and a wireless marker (10 m active zone) at the site. The relationship between ubiquitous communicator, the IC tag and wireless marker constitute a location-based context where the real space meets with mapping space. If IC tags and wireless markers constitute a map in real space, then this relationship using various location information becomes a real scale map. A reduced map of this map with the same reference points is thus generated and a user can refer to two points on the map easily and correctly. This relationship is conducive to the creation of mixed reality.

5 Conclusion

In conclusion, ubiquitous mapping is more than a digital map distribution system in that it aims to provide technical solutions associated with map creation and use. Ubiquitous mapping accelerates, facilitates, and stimulates the universal nature of map creation and use through the application of advanced information technologies. Consequently, despite being derived from the most primitive map-types, ubiquitous mapping can be considered as reprehensive of the future map type. Further studies should investigate the potential of applying new technologies and increasing our understanding of the nature of maps.

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From Internet to Mobile Mapping: Contrasts in Development

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Abstract

Although the wireless Internet is a natural and inevitable progression from the wired Internet, the two have developed much differently. The wired Internet was based on existing personal computer and workstation technology that had begun in the early 1980s. Over 1.3 billion computers were already in use when the World Wide Web was introduced a decade later. The browser software was free and no additional hardware was required – beside the use of a modem for connection purposes. The Web was quickly applied for all sorts of information delivery and its use expanded rapidly. In contrast, the development of the mobile Internet is hindered by a number of factors, not the least of which was the development of a wireless infrastructure. To fund the development of a wireless Internet, commercial companies devised new services that would quickly generate revenue. One such revenue scheme was Location Based Services (LBS), a model for informing the mobile phone user where they are currently located and what services are available in the surrounding area. For a variety of reasons to be examined here, LBS has not grown as quickly as had been predicted. While one might blame the small display or conniving telecommunications executives, there are many reasons why the wireless Internet and LBS have not expanded more rapidly.

1 Introduction

Within little more than a decade after the release of Mosaic, the first multimedia web browser, the distribution of maps through the Web – either static or interactive – has become firmly entrenched and has drastically altered the way that people access maps. The Internet, now described as history's most powerful communication tool, has had a profound impact on map delivery. Within a few years in the mid-1990s, the distribution of maps through the Internet grew from almost zero to an estimated 200 million a day. Never in the history of cartography has there been such a dramatic shift in the way maps are delivered to map users. While Internet cartography is still in the process of development, millions of map users now turn to the Internet to access all types of geospatial information.

Concomitant with the growth in the use of the Internet has been the introduction of mobile telecommunication. In recent years, numerous telephone/computer handheld devices have been introduced with varying levels of computer processing and telecommunications capabilities. An attribute shared by all of these devices is a small screen and this constraint has been particularly limiting for the display of maps. For this and a variety of other reasons, mobile mapping has yet to be accepted as a viable technology – besides the larger navigation systems available for cars. Even here, there are reports that car navigation systems that are built into cars are rarely used. The user interface is complicated and the screen is hard to see. The maps are often obsolete and obtaining updated information is very expensive.

In contrast to mobile systems, the development of the Internet was based on existing personal computer and workstation technology which had started to be used in the 1980s. There were over 1.3 million computers connected to the Internet (Kikta et. al. 2003, p. 10), including 225 million personal computers (Computer Industry Almanac 2005), when the World Wide Web was introduced through Mosaic in March 1993. The browser software was free and no additional hardware was required, beside the use of a modem to connect to the Internet. In addition, the Web was quickly used for all sorts of information delivery from news to email, and from commerce to promoting the Jihad. There were few limits to what information was available.

Not to be overlooked is the fact that the personal computers that were in use at that time were mainly designed for text processing. Page layout programs were in wide use by the late 1980s. By the early 1990s, graphic software had been introduced as well. Personal computers had been essentially used to help produce output on paper, consisting of both text and graphics. In fact, concerns were expressed during this time that these so-called paper-saving devices were actually contributing to more paper usage.

Mobile devices developed much differently and were either not connected to the Internet – as with PDAs – or were tied to a commercial mobile phone technology with companies constantly devising new methods to make revenue. One of these revenue schemes was Location Based Services (LBS), a model for informing the mobile phone user where they are located and what services are available in the surrounding area. The complexity of the system, combined with privacy concerns and corporate revenue scheming, transformed a brilliant concept to a bust. The introduction of small GPS devices, often integrated within the mobile device, did little to further the development of mobile LBS.

It is clear that the use of mobile devices is expanding at an exponential rate. The Computer Industry Almanac (2005) reports that worldwide number of cellular subscribers will surpass 2 billion in 2005 — exactly twice as many as use the Internet and up from 11M in 1990 and 750M in 2000. China is the clear leader in cellular subscribers and will reach nearly 400M at year-end 2005. No

other country comes close. Russia has seen tremendous growth in the last few years and is projected to be in third place by year-end 2005. Rapid expansion in India will see a future climb in the rankings to a possible #2 in 2010. Worldwide cellular subscribers are forecasted to reach 3.2B by the end of 2010, approaching one-half of the world's population.
While spatial information delivery has great potential with mobile devices, it has not met the monetary expectations of telecommunications corporate executives. A variety of reasons are examined here for why the development of the wireless Internet, and spatial information delivery in particular, has occurred differently than its wired counterpart. These differences will continue to affect how mobile mapping develops in the future. We begin by examining the differences in the development of these two forms of Internet access.

2 Contrasts in development

2.1 The role of government

With considerable investment in infrastructure, the US government played an important role in the development of the Internet. The initial impetus derived from paranoia, a fear that a nuclear attack by the Soviet Union would render communications systems in the United States inoperable. In 1969 three computers, located remotely from each other, were connected under what was then Advanced Research Projects Agency Network (ARPANET). By 1971, ARPANET computers were connected at nearly two dozen sites, including Harvard University and MIT and protocols for remote terminal access (Telnet) and file transfer (FTP) were defined. As Kitka et. al. (2002, p. 8) point out, sometime during the 1970s an interesting observation took place that ARPANET was really a government subsidized person-to-person communications service more than a system for the sharing of resources. In the 1980s, the Internet transitioned from the control of ARPANET to the US National Science Foundation. Established in 1986, NSFNET had a speed of 56 Kbps and 5000 Internet hosts. While Tim Berners-Lee posts the first computer code for the World Wide Web from Switzerland in 1991, many of the early developments of the Web during the 1990s also came from the United States. Foremost among these in the 1993 introduction of Mosaic, the first graphics-based Web browser. During the following year, traffic on the Internet expanded at a 341,634% annual growth rate. By 1996, when Microsoft Internet Explorer was introduced, there were 12.8 million Internet hosts and 500,000 WWW Sites and the number of users reaches 40 million. By 2001, the United States with less than 4.5% of the world's population represented over 40% of its users.
In contrast, the role of government, and the US government in particular, in the funding and development of mobile networks has been minimal. In Europe, governments have at least helped establish standards that allow interoperability between systems. In the United States, a more laissez-faire approach has led to many cellular systems and most are incompatible with the rest of the world. In terms of cell phone use, the US is far behind other developed, and some lesser-developed countries. It ranks 30th worldwide in cell phones per 100 population behind countries like the Czech Republic, Portugal, and Slovakia (see Table 1). Kitka et. al. (2002, p. 95) state that the most important reason that the US is behind in mobile phone use is geographic size and population density. A smaller investment in infrastructure is needed in Japan and Europe because there is less space to cover and often more people in that smaller space.
While the role of government in the development of technology is not always clear, most would agree that the wired Internet could not have developed in its present form without the funding provided by the US government. In addition, as the largest economy in the world, the US has played a key role in many technological developments in the past century – both through government initiatives and private sector competition. Its lack of direction in the development of the mobile Internet, and mobile phone use in general, has been particularly noticeable.

Rank	Country	per 100 population	Rank	Country	per 100 population
1	Taiwan	106.45	23	Korea, South	67.95
2	Luxembourg	101.34	24	France	64.70
3	Hong Kong	92.98	25	Hungary	64.64
4	Italy	92.65	26	Australia	63.97
5	Iceland	90.28	27	Japan	62.11
6	Sweden	88.50	28	New Zealand	61.84
7	Czech Republic	84.88	29	Slovakia	54.36
8	Finland	84.50	30	United States	48.81
9	United Kingdom	84.49	31	Brunei	40.06
10	Norway	84.33	32	Canada	37.72
11	Greece	83.86	33	Poland	36.26
12	Denmark	83.33	34	Malaysia	34.88
13	Austria	82.85	35	Turkey	34.75
14	Spain	82.28	36	Thailand	26.04
15	Portugal	81.94	37	Mexico	25.45

Rank	Country	per 100 population	Rank	Country	per 100 population
16	Singapore	79.14	38	Philippines	17.77
17	Switzerland	78.75	39	China	16.09
19	Belgium	78.63	40	Indonesia	5.52
20	Ireland	75.53	41	Vietnam	2.34
21	Netherlands	72.24	42	Cambodia	1.66
22	Germany	71.67	43	Laos	1.00
			44	Burma	0.03

Tab. 1: Cell phones per 100 population in 2002. Source: NationalMaster.com

2.2 Content development

If the Internet had no content, it wouldn't be of interest to anyone. Content makes the medium useful and interesting, and the easiest way to add content to a new medium is to copy the old. This fact was recognized as early as 1971 when Michael Hart (1992) started the Gutenberg Project for the online distribution of classical texts – the first being the U.S. Declaration of Independence. The idea was to convert the information on paper to the computer and thereby make it available to more people. The same thought occurred in the 1990s to map librarians at the Perry-Castaňeda Library Map Collection at the University of Texas as they converted their collection of maps to be accessible through the World Wide Web (University of Texas 2005). Most of the maps scanned by the University of Texas Libraries and served from their web site, currently 5715, were produced by the US government (CIA, USGS, National Park Service) and therefore are in the public domain. No permissions are needed to distribute them. The maps are available in ordinary JPEG format, and hundreds of thousands are downloaded every day. Some are even available in PDF format that can take advantage of the better resolution of printers.

In contrast to the large amount of content available through the Internet, information available through mobile phones is very restricted. Among the many reasons for this are slower communications speeds and the need to re-format web pages for a smaller output size. In addition, the cost structure of mobile phone providers is such that access to web content is more expensive than ordinary phone service, either for the mobile phone itself or added charges that may be assessed according to the number of pages viewed. In short, the current mobile phone is not a good medium for information delivery for anything but the human voice, short text messages and small pictures. This situation will certainly change but it will require a considerable investment of capital and time.

2.3 Compatibility with existing media

Alan Kay (1977), who conceived of the Dynabook and whose design work led to the development of the graphical user interface, argues that the computer is not a tool or an instrument, but a medium. A medium is the carrier of information and is used to transmit knowledge and ideas between people. Each medium has a certain potential for communication. The computer, with the help of the Internet, is being used not only as a tool to help make maps, or search a database, but as a medium of communication. It was argued by McLuhan in the 1960s that we live in a rear-view mirror society (Theall 1971). According to McLuhan, all new forms of media take their initial content from what preceded them. Not only is the new medium based upon the old, but society dictates that the only acceptable way of approaching the new medium is by emulating the old – through the rear-view mirror.

In order for a new medium to take its initial content from what precedes it, it must incorporate a delivery mechanism that can display that information. The personal computer made this possible in cartography for everything but large maps – the kind of maps that only a few had access to anyway. However, to preserve the property of mobility, wireless devices cannot display most of the content of paper or the traditional computer medium because of the small display size. Making the display larger would make the devices less than mobile. Funk (2004, p. 44) estimates that doubling the display size doubles the display weight and increases the weight of the plastic housing by 50%. Similarly, a 20% increase in display area leads to a 30% increase in price. The issue, Funk goes on to point out, is whether customers will choose a heavier and more expensive phone in order to have a larger display.

As Rhoton (2002, p. 117) states, it would be convenient if all the applications that been developed over the past years on computers "could simply be dropped into a mobile environment and continue to work without any additional effort." To be backward compatible, the mobile device would have to be able to perform the same function of the previous device in the process of adding new functionality. In addition to the small screen size, Rhoton (2002, p. 117) points out that mobile systems cannot be backward compatible because: 1) Many mobile platforms are closed systems, such as the Blackberry; and 2) there is a great deal of diversity in the machine interfaces of mobile devices. For these reasons and others, the mobile devices that are currently available represent a medium that is not backward compatible with either paper or the Web.

2.4 Developing a user base and paying for information

As Rhoton (2002, p. 9) points out, a computer is not affordable for large segments of the world's population. Even those who can afford it may not feel the value of the Internet is high enough to justify the investment. Wireless devices are smaller and more affordable than desktop systems and more easily deployed in constrained environments. One of the reasons why the wireless Internet has been so popular in Japan is people's mobility and the lack of extra space in people's living areas.

If we want to see the impact that the mobile phone will likely have on our lives, we need to look no further than Japan. In 2002, only about 15% of Japanese consumers and business people were using the Internet through PCs. The remaining 85 percent were willing to accept the limitations of smaller display screens and keyboards on wireless handheld devices (Kitka et.al, 2002, p. 101). It is estimated that the Japanese mobile Internet market represents more than 75% of the global market for mobile Internet services, with Korea a strong second (Funk 2004, p. 7). Mobile phones are already used here as portable entertainment players, cameras, membership and loyalty cards, guidebooks, maps, tickets, watches, alarm clocks and devices for accessing everything from news to corporate databases (Funk 2004, p. 1). It is estimated that within a few years, mobile phones will be used in Japan for train and bus passes, credit and debit cards, keys, identification, and even money.

One reason for Japan's greater success is that the mobile telephone giant NTT DoCoMo created a separate organization to focus on consumers as opposed to business users and devised a micro payment system in which NTT DoCoMo collects charges for content providers (Funk 2004, p. 8). The company earns a 9% fee from providers that charge for their information (Kitka et. al., 2002, p. 99). The lower emphasis placed on business users by Japanese and Korean firms made it easier for them to ignore business users and focus on general consumers in the mobile Internet (Funk 2004, p. 11).

The user base for the Internet developed quickly during the 1990s but the remuneration of content providers on the web is still a major problem. There is still an expectation for free data and many providers of information have yet to devise a reasonable and workable payment system. This has stunted the development of online cartography in that there is little reason to develop new content if cartographers will not be paid for their work.

2.5 Free maps

Paying for maps, for many people, has always been an option, not a necessity. In the US, state road maps are usually provided for free as a way to encourage tourism, and many tourist agencies provide local maps without cost. City maps are often available in the local phone book. Membership in an automobile club also provides "free" access to maps although the annual membership, including a variety of services, can be quite expensive. The Internet has further perpetuated the concept of free maps, with sites like MapQuest and Google making user-defined maps with only the cost of annoying ads. All of these free maps are based on databases that were originally created by the US government.

A considerable monetary investment is required to transform existing maps for use on small display devices. The maps need to be highly generalized and this is not a task that can be easily automated. Car navigation companies re-coup the cost of this new "cartography" through the associated display hardware. There is no special display counterpart with mobile phones and therefore no method to recover costs through the purchase of additional hardware. Providers will be forced to charge for the mobile map product, a practice that will be resisted by the mobile phone user.

2.6 Competition from wired Internet map use

The distribution of spatial information through wireless networks is in competition with more than a decade of development in Internet mapping. Three identifiable trends in this new form of map distribution have already emerged. The first era, from about 1993-1997, consisted of scanning paper maps and limited forms of interactive maps. The second era was dominated by both interactive street mapping (MapQuest along a series of competitors) and online GIS systems. The third development is community mapping, the ability of map users to change and update the content of online maps. Analogous to editing a website, as implemented through sites like Wikipedia (Wikipedia 2005), Google introduced a similar concept for maps allowing users to enter information (Google Maps 2005). Signs of a similar form of growth in the development of the wireless spatial information delivery are hard to find. As mobile mapping develops, it will have to contend with a more mature development platform in its wired counterpart.

3 Changing patterns of map use

It is clear that new forms of map delivery will change how maps are used. The following sections examine these trends.

3.1 Navigation

Many people consider the navigation market to be the largest potential market for mobile Internet services. An indicator is the popularity of car navigation systems. These systems are particularly popular in Japan where there are more than 10 million installed units, about 14% of all vehicles (Funk 2005, p. 125). But, these systems remain expensive. One reason for the high cost of car navigation systems, up to $4000, is that few of the components are standard. Most manufacturers use proprietary CPUs, maps, map engines, operating systems, and displays. Competition forces prices up by adding features such as improved displays, more detailed maps, and DVD movie playback.

Another trend emerging from Japan is that train, bus and destination-information services are far more successful than map services, the latter of which was expected to form the basis for a mobile Internet navigation service (Funk 2004, p. 132). Users of the destination-information services input departure and arrival times and the system responds with information from actual timetables. It is easier to download train information and information on restaurants in text form than to download map information. So, at least in Japan, destination-information and restaurant services have become successful while map services have not (Funk 2004, p. 132).

Mobile map services began in Japan in late 1999 (Funk 2004, p. 137). Similar to online maps with PCs, users input an address to generate a map of the site. The providers offer simple maps for free and charge for more detailed maps (about $2.50 a month). The most popular function is sending maps in mail messages by forwarding the URL of the map. Use of these services is far less than for the destination information services, probably on the order of only 1% in comparable traffic (Funk 2004, p. 137). Not only are the map services more expensive but the small screen and poor resolution make the maps hard to read.

An interesting development in mobile phone mapping in Japan involves the generalization of maps. The small display forces a heavier reliance on landmarks. But, even here, the map provider had to reduce the number of landmarks on the maps because of the available screen space. This reduction in the number of landmarks was too difficult to do manually so the companies relied on an automated system to decide which landmarks could be shown at certain scales. This caused well known landmarks in some areas to be eliminated. Although improved displays will allow more landmarks to be shown, the map provider will have to update the underlying database thus incurring a further cost (Funk 2004, p. 137).

3.2 GPS integration

It is anticipated that the combination of mobile phones and global positioning systems will be the next major development in mobile mapping. However, the power required by the GPS unit has become a major problem. In vehicle navigation systems, there is sufficient power from the car to power the receiver. The power consumption of GPS receiver makes the use of pure GPS with phones more difficult and thus requires some form of "assisted GPS." In A-GPS, most of the GPS calculations are done at the server level. The receiver, being limited in processing power and normally under less than ideal conditions for position fixing, communicates with the "assistance server" that has higher processing power and access to a reference network of locations (Wikipedia 2005). A-GPS reduces power consumption but drives up communication costs. Current communication charges would mean that if a phone's location were updated every 5 minutes over an 8 hour period, a charge of over $80 would be incurred (in 2003). A-GPS is also time-consuming, which will also slow the adoption of this technique. It takes approximately 15 seconds to download the GPS data, 15 seconds to send these data to the server and carry out the calculations, and 15 seconds to download the map (Funk 2004, p. 145).

By the end of 2005, the US Federal Communications Commission (FCC) will require all cell phone carriers to provide the ability to trace cell phone calls to a location within 100 meters or less. In order to comply with these FCC requirements, most carriers have decided to integrate GPS technology into cell phone handsets, rather than overhaul the tower network that could be used to triangulate the position. Most GPS enabled cell phones do not allow the user direct access to the GPS data. The location data will only be sent if an emergency call is made. As the system is being designed for emergencies, it seems unlikely that such a system will provide continuous GPS information – a requirement for effective mobile mapping.

3.3 People tracking

People tracking involves the use of a GPS device to track the location and movements of people. Tracking the location of children, or parolees, or even pets, may provide the impetus to provide the necessary GPS and online tracking infrastructure. Several service providers advertise the capability to track a person or an object on a PC screen. Indeed, most commercial trucks are tracked in such a way. Alan Philips of uLocate.com is optimistic about the future of people tracking, saying "Cell phones are becoming multi-purpose devices capable of much more than simple voice communication. By leveraging the latest in satellite and wireless technology, uLocate is providing a secure, reliable, service that creates value for families, individuals, and small businesses without any additional overhead, hardware or software" (Directions 2003).

Monmonier (2003) examines how mapping is being used to invade privacy. He points out that: "Web cartography is especially valuable—and potentially threatening—because it not only greatly expands the audience of potential watchers (Peterson 2000) but also allows for unprecedented customization of maps that describe local crime patterns, warn of traffic congestion and inclement weather, disclose housing values, or—thanks to the Global Positioning System (GPS) and the new marketplace for "location-based services"—track wayward pets, aging parents, errant teenagers, or unreliable employees" (p. 98). He concludes that: "As society and government work through the significance of locational privacy and decide what legal limitations, if any, are appropriate and permissible, the debate will turn to possible restrictions on Internet cartography…" (p. 111).

4 Mental maps and wayfinding

A mistake is often made in thinking that map use occurs at the instant that the user is examining the map. To think this way is to deny that humans have a memory and are able to process information after an object has been removed from view. It can be argued that the majority of map use occurs without a map being present. Our daily movements within our surroundings, indeed, any thought about the spatial world beyond our immediate view, is based on both first-hand experience and the maps we have seen. Although the depictions of the spatial world we keep in our brains are not always accurate, they suffice to help us find our way through our immediate environment and to think about the world beyond. These *mental or cognitive maps* are the *maps* that we actually use. They are also the representations that give us the comfortable feeling that we know where we are and how to get to places. Mental maps help us feel "found" in the sense that we are aware of our spatial surroundings. In contemplating the future of Internet maps and mobile mapping, we need to examine how maps influence the internalized representations we form from them, and how they help us interact with the world.

4.1 Mental map formation

While we don't know exactly how mental maps form, we do know that they are based both on direct experience with the environment and looking at representations of the environment in the form of maps. The internalization of maps seems to happen without conscious awareness because people can recall the outlines of countries and the shapes of continents without intentionally remembering to do so. In addition, these shapes are remembered quite early as children can recognize outlines of countries and continents at young ages. It seems that maps have a major impact on the formation of mental maps from a very early age.

4.2 Mental map formation in wayfinding

There seems to be close relationship between the formation of mental maps and the process of wayfinding. While the primary purpose of wayfinding is to get to the destination with as little effort as possible, the secondary purpose is to create a mental map of the route, however primitive as first, that will aid in finding the location again without the use of a map. In other words, the purpose of the map in this function is to create a mental construct such that it will be rendered meaningless when the same task is performed again. The map succeeds by becoming useless.

4.3 Creating a permanent dependence

In contrast, when using a mobile device for wayfinding, the user is directed to a location with minimal mental effort by the user. Because there is little coordination between the map and the environment, the quality of the resultant mental map is compromised. In addition, the depictions presented on the mobile device are too schematic to create a functional mental map of the environment. It is very likely that the user will need to get instructions from the device again for not only the return trip but a future trip to the same location. What the LBS has succeeded in doing is creating a permanent dependence on the device. The LBS device succeeds by becoming indispensable.

Being told where you are bypasses the process of finding out where you are and this inhibits the formation of mental maps. Certainly, the process of finding out where you are helps to form a mental map, a mental conception of where you have been and where you need to go. We need to be careful in developing wayfinding tools that we also contribute to the formation of long-term mental maps.

5 Conclusion

It seems that there are major differences in the development of the wired and wireless Internet and these differences will affect how maps and spatial information are delivered to users. The wired Internet was an outgrowth of a government initiative while the wireless Internet is almost totally a commercial enterprise. The commercial aspect of the wireless Internet permeates all aspects of its growth and development.

As Kitka et. al. (2005, p. 106) state, the “wireless Internet will most certainly provide society with new experiences and freedom, and unprecedented access to information.” Funk (2004, p. 51) sees that larger “memory, faster processing capability, and greater network speeds are being used to improve the user interface, and it is possible that they can be used to significantly improve the user interface in the future.” Wiberg (2005, p. 344) adds that the “computers of yesterday were about getting things done as quickly as possible, the computer of tomorrow will help us to prolong, sustain and develop the things we care about the most, i.e., our ongoing interactions with others.

The size of the display remains a concern for the delivery of maps. The most troubling aspect of our dependence on this new technology in cartography is that it may not provide long-lasting spatial information. Rather, the systems will help guide us to a location without providing the type of long-term information that will help us find that location on our own. Further, this dependence will lead to an uneasy relationship with the world around us – and perhaps the feeling of always being lost. If we are to best use these new technologies, we need to remember that the ultimate purpose of a map is to provide a sense of connection with the world around us.

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Mobile landscapes: Graz in real time

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Abstract

The technology for determining the geographic location of cellphones and other hand-held devices is becoming increasingly available. It is opening the way to a wide range of applications, collectively referred to as Location Based Services (LBS), that are primarily aimed at individual users. However, if deployed to retrieve aggregated data in cities, LBS could become a powerful tool for urban cartography. This paper describes preliminary results of the "Mobile Landscapes: Graz in Real Time" project, which was developed as part of the M-City exhibition (Graz Kunsthaus, 1 October 2005 – 8 January 2006, curator Marco De Michelis), in collaboration with the cellphone operator A1/Mobilkom Austria. Three types of maps of the urban area of Graz, Austria, were developed and shown in real-time on the exhibition premises: cellphone traffic intensity, traffic migration (handovers) and traces of registered users as they move through the city. Beyond their novelty and visual interest, results seem to open the way to a new paradigm in urban planning: that of the real-time city.

1 Introduction

The mobile communications industry is booming. Cellphone subscriptions have recorded sustained growth rates in recent years and, according to EITO (2004), reached the astronomic figure of 350 million in Western Europe in 2003 (157 million in the USA).

Why should the cartography and urban planning community be interested in this data? First, the widespread deployment of mobile communications, supported by personal handheld electronics, is having a significant impact on urban life. People are changing their social and working habits because of the new technology (Rheingold, 2002). Activities that once required a fixed location and connection can now be achieved with higher flexibility, resulting in the users' ability to act and move more freely (for an analysis in the corporate working domain, see Duffy, 1997). As a consequence, urban dynamics are becoming more complex and require new analysis techniques. Second, and more importantly in this context, data based on the location of mobile devices could potentially become one of the most exciting new sources of information for urban analysis.

Locational data are becoming increasingly available and their applications are currently a hot topic in the cellphone industry (see for instance www.lbszone.com). They are generally referred to as Location Based Services (LBS) – value-added services for individuals in the form of new utilities embedded in their personal devices. Examples, both implemented and speculative, include systems providing information about one's surroundings (nearby restaurants, museums, emergency shelters, and so on); distributed chat lines aimed at allowing people with similar profiles to encounter each other in space, via a kind of technologically augmented serendipity; and 'digital tapestries' that attach different types of information to physical spaces (see sections below for detailed references). And yet, surprisingly enough, aggregated locational data have not been used to describe urban systems. Research efforts in the area are sparse; the scientific literature mostly ignores themes such as the mapping of the cellphone activity in cities or the visualization of urban metabolism based on handset movements (a notable exceptions are the work of Ahas and Ülar, 2005 and Ratti *et al.*, 2005). How could this be?

We try to guess. The first assumption is that scholarly research has been hampered so far by the difficulty of accessing raw data and developing ad-hoc analysis software and systems in partnership with cellphone companies. The second reason could be traced back to the lack of rules for managing these data and to the increasing privacy concerns that are being raised, often resulting into a situation of stall. In this study, the research team has had the opportunity to establish a partnership with the mobile network operator A1/Mobilkom Austria, which has the largest market share in its own country. Thus, a privileged insight into how aggregated data from mobile devices could reveal urban systems was gained. Furthermore, the occasion of the project was developed in the context of a public architecture and art event, the M-City exhibition (Graz Kunsthaus, 1 October 2005 – 8 January 2006, curator Marco De Michelis). Such a premise seemed ideal in order to remove suspicions of possible privacy abuse and openly engage the public in the issues related to locational data and the way they should be used.

As the exhibition is in progress, only some preliminary results are presented here. Further analyses will be performed in the coming months. However, results seem to open the way to a new approach to the understanding of urban systems, which we have termed "Mobile Landscapes." Mobile Landscapes could give new answers to long-standing questions in architecture and urban planning: how to map vehicle origins and destinations? How to understand the patterns of pedestrian movement? How to highlight critical points in the urban infrastructure? What is the relationship between urban forms and flows? And so on. More generally, information and communication technologies, which previously eluded planners with their "invisible, silent" characteristics (Graham and Marvin, 1996), are becoming of increasing interest. Studies on user behavior (for example Charlot and Duranton, forthcoming; Hampton

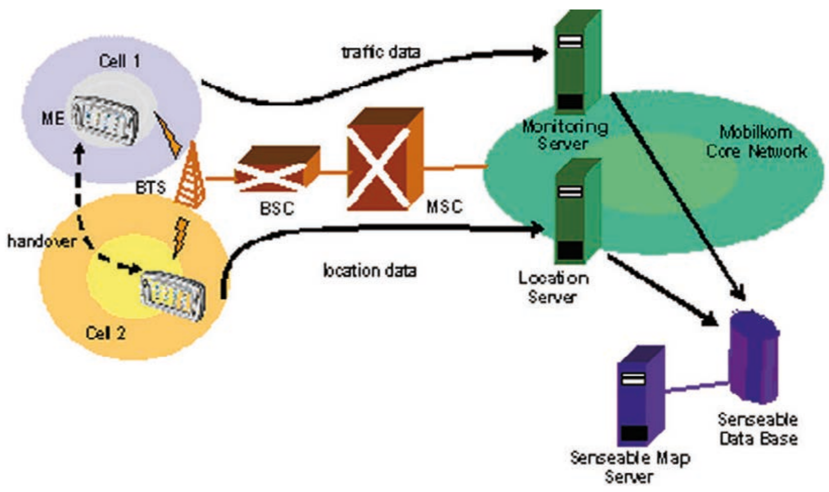


Fig. 1: Data flow in the project M-City

and Wellman, 2000; Gaspar and Glaeser, 1996) are showing that "electronic communications" and the "metropolitan area […] are actually supporting each other" (Graham, 2004). The aim here is to expand upon these methods by integrating a spatial component to visualize telecommunications. Thus, the objectives of our maps are twofold: first, they enable viewers to visualize the city via an otherwise "invisible" feature; second, the maps are animated in a way that can simulate city dynamics in real time.

In a previous paper (Ratti *et al.*, 2005) we have shown how even simple data such as network traffic have a lot to offer to the urban designer or planner. We will describe here how some more complex types of data can be obtained to produce real-time urban maps. In particular, three type of data are provided by the mobile network, namely cellphone traffic intensity, traffic migration (handovers) and traces of registered users as they move through the city.

2 The data

Mobile communication networks are organized in cells. Each cell has an antenna that covers a certain geographical area (usually circular or pie-shaped) and offers mobile communication services to users at that particular location. In the most-common GSM networks, cell sizes vary from the diameter of about 100-300 meters in urban areas to several kilometres in rural areas. Densely inhabited areas require smaller cell sizes, as the maximum amount of data that can be transferred concurrently in one cell is limited and relates to the radio access technology of the network.

Figure 1 shows the basic components of a GSM network and the data flow that was implemented for the Mobile Landscape Graz project. A Mobile Switching Center (MSC) is connected to several Base Station Controllers (BSC). The BSCs control the Base Transceiver Stations (BTS). The Base Transceiver Station houses the radio transceivers that define a cell and handles the radio-link protocols with the Mobile Equipment (ME). The movement of a mobile phone from one cell to another is called 'handover'.

Traffic in the cells of the A1/Mobilkom Austria network is constantly monitored by the Operation and Maintenance division and aggregated performance figures are logged by a Monitoring Server. For the Mobile Landscape Graz project the traffic of all cells in the city of Graz was measured periodically and traffic aggregates where reported at regular intervals to an online database set up by the MIT SENSEable City Laboratory. Traffic intensity of one cell is measured by the number of calls that originate there and by the occupancy of the cell measures in Erlang, a standard unit of measurement of traffic intensity in a telecommunications system (one Erlang is the equivalent of one caller talking for one hour on one telephone or two callers talking for 30 minutes each).

Table 1 shows a sample of traffic intensity data, where BSC is the name of the Base Station Controller, FZA is an identification of the Base Transceiver Station, CI is the cell ID, TCH_ATT gives the number of traffic channel attachments including handovers, Erlang gives the occupancy of the cell and CALL_REQ gives the number of originated calls.

int_id	PERIOD_START_TIME	BSC	FZA	CI	TCH_ATT	ERLANG	CALL_REQ
792903	2005-10-08 05:30:00	Graz_4	G285-1	28516	8	0.13	4
793754	2005-10-08 06:30:00	Graz_4	G285-1	28516	8	0.40	3
794605	2005-10-08 07:30:00	Graz_4	G285-1	28516	38	0.89	17

Tab. 1: Traffic intensity data sample

Traffic migration is measured by the number of active calls that move from one cell to another and is reported to the SENSEable City Laboratory by giving the number of incoming and outgoing handovers between cell pairs.

Table 2 shows a sample of the traffic migration data where the number of inbound and outbound handovers (HO_in, HO_out) are given for source and destination cells (Source_CI, Dest_CI).

int_id	PERIOD_START_T	Source_BSC	Source_FZA	Source_CI	HO_out	HO_in	Dest_CI
7089747	2005-10-10 10:00:00	Graz_1	G200-2	20026	3	4	58236
7089746	2005-10-10 10:00:00	Graz_1	G200-2	20026	2	13	43130
7089745	2005-10-10 10:00:00	Graz_1	G200-2	20026	10	25	43110

Tab. 2: Traffic migration sample data

Traffic intensity and traffic migration are aggregate figures that show in real time where people started their mobile phone calls, how long they talked and where they were moving while talking. The third type of data that was shown on the maps at the M-City exhibition was the movement of individual users. While the measured traffic aggregates collect only data about active phone calls, a cellular network is also able to locate passive mobiles in order to set-up calls towards them. This process is called ‘paging’ and can also be used to request the ID of the cell to which the mobile phone is attached, even if no call is being made. Based on the cell ID, geographical coordinates can be obtained, corresponding to the central point of the GSM cell where the user is attached to the network. Movement tracks can thus be generated by locating the user at regular 5-minute intervals.

A note should be made, however, on the treatment of location data. On the one hand they can be of considerable value to information and communication services. On the other hand, however, they raise privacy issues; users are concerned about revealing their position data to others, especially to un-trusted third party applications. Furthermore, most countries have legal restrictions that regulate processing of personal data and the protection of privacy in electronic communications. It is of utmost importance that the users can control who gets access to their location data and that the transport in the network of such sensitive data is protected by strong security mechanisms.

The Mobile Landscape Graz installation pays respect to privacy concerns by giving users full control over the location service. Only volunteers are tracked and they have to subscribe actively to the service by sending a short message (SMS), where they can also provide a pseudonym (nickname) that is shown on the map. If no pseudonym is provided, a random one is generated. The user can stop the location application at any time by simply sending a second SMS to the subscription application. Even if no second SMS is received, the application stops locating users after 24 hours. Location data is sent to the SENSEable City Laboratory via an encrypted connection and it contains only users’ pseudonyms.

Table 3 shows a data sample where the geographical coordinates in latitude and longitude are given for several pseudonyms at regular intervals.

nick	latitude	longitude	timestamp
Sabine	47.06354	15.454447	20051009-14:32
User940	47.06354	15.454447	20051009-14:32
Wort	0.0	0.0	20051009-14:32
Nyko	47.05407	15.462827	20051009-14:32
OrangeMo	47.10022	15.397057	20051009-14:32
User3346	47.09155	15.7262	20051009-14:32

Tab. 3: User movement sample data

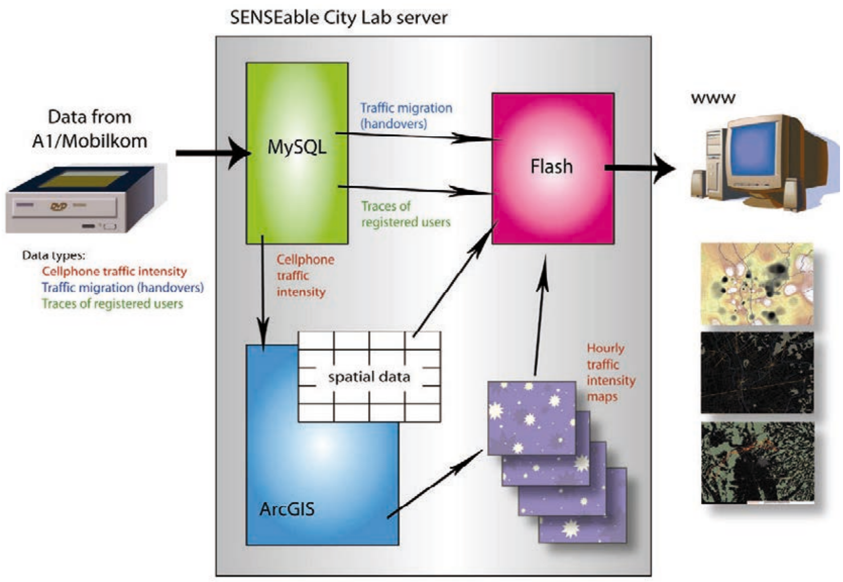
3 The real-time mapping system

A common procedure has been developed for all data types presented above (cellphone traffic intensity, traffic migration and traces of registered users as they move through the city) in order to produce real-time maps at the exhibition premises. Records are collected live by A1/Mobilkom Austria and sent to an ad-hoc set up server at MIT, where they are stored in an open-source MySQL database. The data is then paired using ArcGIS with spatial information on the city of Graz, generously provided by GIS Steiermark (www.gis.steiermark.at). Finally, the whole process is animated using Macromedia Flash. A diagram of the process is shown in Figure 2.

A note should be made on the procedure and on the choice of using Flash. Streaming real-time animations from the MIT SENSEable City Laboratory to the exhibition venue would have been too costly in terms of bandwidth and also unreliable. Flash allowed high compatibility interface, running on most Internet browsers, and also the transfer of a limited amount of data. In the case of the Erlang map, just a maximum of 24 images were transferred from SENSEable City Laboratory and then animated in Flash. In the case of the two other maps, a Flash algorithm running at the exhibition venue retrieved automatically the data from the MySQL database to create the required animations, as detailed below.

Options other than Flash were tested, but did not prove satisfactory. Adopting ArcGIS to produce the animations

Fig. 2: Data flow from the SENSEable City Laboratory server to the final maps



would have required end users to have a GIS viewer – thus limiting the distribution of the images. Options for producing maps on the web without end-user software were also considered, such as Mapserver and ArcIMS; however, both technologies did not have the ability to reproduce the real-time feel of animated images and lacked the graphic qualities we were aiming for.

4 The results

This paper presents work in progress, as the Mobile Landscape Graz project is being exhibited; data acquisition will continue until January 2006 and a larger interpretative effort is planned afterwards. However, this section of the paper presents the maps that are being produced and discusses their meaning.

Using the three types of data transferred by A1/Mobilkom Austria to the SENSEable City Laboratory, three different real-time maps of Graz were obtained: cellphone traffic intensity, traffic migration (handovers) and traces of registered users as they move through the city. These maps visualize different states of cellphone activity in Graz and the emergent movement patterns of cellphone users throughout a day. Our aims were manyfold: first, by cartographically illustrating the raw cellphone traffic data, we were trying to visualize dynamic layers of information, which tend to remain transparent in everyday life. Second, we were trying to use cellphone information as a substitute for other urban information, thus visualizing the city as a real-time, pulsating entity. Third, we were trying to display different types of sensitive information, such as location data, in order to engage the public in the discussion on how it should be treated in the coming years.

More details follow on the three different types of maps, presented in Figure 3.

4.1 Cellphone traffic intensity

The Erlang map shows the most recent distribution of cellphone traffic intensity in Graz. It is animated in such a way to play through a three-minute visualization of the last 24 hours. The data shows total Erlang values of each A1/Mobilkom Austria cell antenna, interpolated using the color-field intensity map shown in the lower right corner of the image. Light and pink colors stand for higher intensity, and green and black for lower or zero intensity respectively. A street and river map of Graz is overlaid on top of the interpolated graph in order to provide location references for exhibition visitors.

4.2 Traffic migration

Similar to the Erlang maps, data is received at hourly installments and then animated in an accelerated way over 15-minute cycles. For each handover, a dynamic orange line is drawn using Flash between its origin and destination. If several handovers happen between the same pair of cells, several lines are drawn over the same trajectory. Already drawn lines slowly fade away in order to make new ones more visible. The animation renders all the phone-calls of a randomly chosen cell in a sequence and then jumps to another cell. This is why star-like shapes appear on the map - a star representing the total incoming and outgoing calls of a given cell. If the origin and destination of a handover lie outside the visible area of the map, then the call is still mapped as a thoroughfare orange line. At the end of a 15 minute cycle, the total activity graph of the last hour becomes visible.

4.3 Traces of registered users

This map allows individual A1/Mobilkom Austria clients who have registered to have their cellphone tracked on the map. The registration process happens by sending an SMS to an activation number. From that moment onwards, the selected nickname of the user appears on the map and her/his position is followed at five-minute intervals. A user can also stop being tracked anytime, by sending a “stop” message to the same number; alternatively, he/she will be automatically withdrawn after 24 hours. Traces are visualized as orange lines on the map, showing movements during the past 24 hours. In order to be able to differentiate between different paths on a complex background generated by multiple user, the following procedure was implemented: one after the other,

Fig. 3: From left to right: visualization of cellphone traffic intensity on 10 October 2005 at 8 pm; visualization of traffic migration (handovers) at the same time; traces of registered users at the same time. During the exhibition period these maps can be seen in real time at the URL: http://senseable.mit.edu/grazrealtime

paths are highlighted in red and scanned by a white ball which replays the past 24 hours, while the nickname of the corresponding user is shown on the lower left corner of the screen.

4.4 Discussion

The maps produced in partnership between A1/Mobilkom Austria and the SENSEable City Laboratory proved to be successful in visualizing the city of Graz in almost real time. This proof of concept seemed quite important, as no similar precedents based on cellphone mapping are found in the scientific literature.
The work also managed to capture wide interest at the exhibition in the Kunsthaus Graz as well as on-line and in the press (some of the published articles and discussion can be found at the URL: http://senseable.mit.edu). Visitors in Graz seemed highly interested in seeing their home-town represented in a new, intangible way and were keen on testing the tracking system to follow their own or their friends' traces. Many reviews on the project also confirmed both the lack and necessity of such cartography to add to our urban knowledge.
The public appearance of the project also brought up many discussions about privacy concerns. Even if they were not so extreme as the 'Geoslavery' fears voiced by Dobson (2003), before the official opening of the exhibition 'big brotherish' comments appeared amongst participants and in the media. However, as privacy procedures were thoroughly respected at every step of the project and individual tracking could only happen on a voluntary basis, none of these points became detrimental. Conversely, they contributed in a certain sense to one of the aims of the project: presenting this new type of sensitive information in order to prompt a discussion on how it should be used.
Practical application for the analysis of the data will be discussed once the exhibition is over. In a previous paper (Ratti *et al.*, 2005), we have shown that even simple cellphone traffic analysis can contribute exceptionally to urban analyses. More generally, there seems to be a large gamut of interests, ranging from the enrichment of people's understanding about urban communications to the unprecedented collection of real-time data about cities (see William Mitchell's (2005) review of the Mobile Landscape Graz project, 'The Real Time City').
Finally, it is worth mentioning some limitations of our process. First, as mentioned above, the accuracy of phone call and user locations are estimated using the latitude and longitude coordinates of cells. This means that the larger the diameter of the cell, the less accurately we can determine the user's exact position. Furthermore, users that are roughly equidistant between two cell antennae may have their signals picked up by either of them, sometimes even bouncing between cells. The bouncing phenomenon can be observed on our traces map: sometimes static users appear to move back and forth repeatedly between neighboring antennae.
Finally, the Flash software lacks ArcGIS's precision to convert geographical coordinates to pixel-based screen coordinates. Although we kept data in ArcGIS for as much of the procedure as possible, the final representation in Flash introduces some distortion in the mapping. This was acceptable in the context of the exhibition, but might require a different treatment in future quantitative analyses.
A last note on the notion of 'real time': while data were collected instantly by the network operator, their transfer to the SENSEable City Lab server was aggregated at 5-minute to 1-hour intervals. This was done to optimize bandwith and processing power, though the same system that was set up could theoretically withstand second-long (or less) frequencies.

5 Conclusions

This paper reports on the Mobile Landscape Graz project, developed by the MIT SENSEable City Laboratory in collaboration with A1/Mobilkom Austria as part of the M-City exhibition (Graz Kunsthaus, 1 October 2005 – 8 January 2006, curator Marco De Michelis). The different types of data (section 2), the procedure set up to transfer them in real time (section 3) and the resulting maps (section 4) are described above and commented. While a larger interpretative effort is planned after the completion of the exhibition, preliminary results suggest that the mapping of cellphone data could open unprecedented perspectives in urban cartography and lead to a new urban paradigm: that of the real time city.

6 Acknowledgements

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Design constraints on operational LBS

Jonathan Raper

1 Introduction

Delivering fully operational location-based services (LBS) is proving to be a difficult task. Only a small number of LBS are operational and revenue earning in 2005 if we define LBS as fully location-aware applications delivering services through client-server or peer to peer architectures over wireless, cellular and satellite communication networks. In one sense this is surprising given the huge interest in LBS, in another sense it seems that LBS are simply following a well worn path through the 'hype cycle' (Gartner 2005). In 2003-4 LBS were passing through the 'peak of inflated expectations', while in 2005 they are in the 'Trough of disillusionment'. If LBS are to progress up the 'Slope of enlightenment' to the 'Plateau of productivity' an assessment is needed of what is needed for LBS to succeed.

This paper is focussed on what the experiences of research and development into LBS have told us about the design constraints on operational LBS. This work is going on in a range of disconnected communities e.g. ubiquitous computing, mobile (geo)web services, geopositioning, telecartography, mobile HCI and personal navigation to name just a few, and few researchers have attempted a synthesis (Lopez 2004). This paper tries to assess what is now known with confidence about LBS design, in order to encourage convergence and greater cooperation between the various players in the chain of LBS relationships required to make these systems work (LBS value chain, figure 1).

Finally, specifying definitions is important in a rapidly developing field. The assumption is adopted here that the following are not LBS within the richer sense defined here:

- autonomous clients with positioning, locally stored content and limited network updates (e.g. in-car navigation tool with traffic updates)
- mobile devices with low resolution geopositioning delivered by mobile telephony such as cell global identity, and simple tiled service scopes, such that the relationship between location and scope is weak (e.g. where's my nearest functions on GPRS equipped phones)

This assumption exposes the author's view that LBS must be able to self-customise their services, based upon high resolution physical location and semantically rich location context, and that this is the definitive core functionality of LBS. This is not to say that web and WAP delivered geographic information is not valuable in itself, merely to emphasise the distinction between Google Local directions on a mobile device and an application like workoutgps.

2 Two LBS that work

LBS are a class of applications where there is a definitive design benefit from actually fully implementing the system in a real environment. Since LBS are distributed, componentised and dependent on a range of associated services such as positioning input, many LBS as designed would not perform acceptably in practice. There is a natural tendency of designers to expect software (re)engineering to solve these performance issues. However, in LBS the performance issues can only be solved by compromises on data models, positional update and user interfaces once the system as a whole can be evaluated in use. This means that effective design requires many cycles of (sometimes comprehensive) redesign in close communication with users, preferably involving

Fig. 1 LBS value chain (courtesy of C. de la Fuente)

users choosing to spend their own money in the later stages of development. Cost is not the only way to improve design, but since LBS are designed as personal services, and services need revenue streams to sustain them, it is one of the most effective drivers. In some cases it may be possible to demonstrate that a technically excellent system cannot be implemented at a price that users among the general public are prepared to pay. This is a real discipline for designers who are used to systems (e.g. GIS) designed for small numbers of (relatively) highly trained users in the professional market.
The following sections introduce some operational LBS to present lessons learned from their development.

2.1 Pedestrian navigation: KDDI EZ Naviwalk

KDDI are a major Japanese mobile phone operator with a dominantly 3G network infrastructure. KDDI operate a positioning service for developers based on gpsOne assisted GPS (A-GPS) technology from Qualcomm, which allows real time positional updates to be calculated on the mobile device after the network-assisted first fix. KDDI phones support GPS-aware applications written in BREW, Qualcomm's mobile device development language.
The EZ Naviwalk service developed by Navitime offers pedestrian navigation support to subscribers at the equivalent of €2 per month, plus the cost of the data package, which is usage-related. The service offers the following functions:

- display of the current position
- origin and destination routing (by use of bar code lookup from map books and magazine adverts) (figure 2)
- voice guidance on routing
- search around current position
- finding nearby stations and their train services
- auto-heading up while moving (with Kyocera A5502K GPS handset with electronic compass)
- ability to record current position in 'My spot' recording service

Maps are downloaded to the device as needed (e.g. when a wrong turn is taken) and the destination can be changed *en route*.

EZ Naviwalk has over 400,000 subscribers on KDDI's network indicating a high level of level of acceptance amongst users. The service has been refined, with feedback from users, to have a fast autonomous positioning mode after the network-assisted first fix, and orientation support with the digital compass as this means that the map is always oriented the way that you hold the device.

2.2 Mobile multimedia location guide: Camineo guides

Camineo is a spinoff company exploiting technology developed during the EU Information Society Technologies programme project 'Webpark'. Camineo Guides are location-sensitive guides for tourism delivered on mobile devices with A-GPS or Bluetooth GPS, web browser and java virtual machine, such as the HP iPAQ 6515 or QTEK.

Fig. 2 Sony Ericsson W21S phone showing EZ Naviwalk directions function

Camineo guides are constructed on a web services model with:
- interfaces to position services such as connected GPS devices or A-GPS
- a mini 'web portal' (web server) on the mobile device itself, to serve web pages with multimedia content, and provides servlet support for java applications;
- a network interface to GPRS and UMTS cellular services to allow access to web services on the Internet/ intranets such as Web Feature Servers;
- java applications generic to the Camineo platform such as map viewer and geo-bookmarking tool (users can place timed and located bookmarks while using the service);
- java applications specifically written for the Camineo guide location (in the SNP these include a hiking progress monitor and animal/ plant species guide, both of which can take advantage of the current position;
- a capability to visualise or explore points/ areas of interest, paths and geo-bookmarks formatted in appropriate web formats and assembled in a database by thematic and geographic criteria;
- an advanced search facility that uses probabilistic search to predict the user's future position and returns results for points/ areas of interest, paths and geo-bookmarks based on current and/or predicted location;
- a web browser interface with a user-friendly 'my Guide' front page (figure 3) which can also run in kiosk mode with reduced buttons and menus.

Camineo guides are being used by national parks such as the Swiss National Park (SNP) and visitor Centres like the Ecomare centre on Texel Island, Netherlands to provide interactive, location-sensitive guides for visitors. Devices are rented out to visitors at the equivalent of €5 per day in the SNP fully inclusive of network and content charges. All available devices have been solidly rented out over the summer 2005 season in the SNP after 3 season-cycles of intensive development/ feedback.

3 What these working LBS show us we need in future

3.1 Concepts of context and activity

LBS are examples of scaleable ubiquitous computing applications designed for use in environments ranging from individual buildings to cities and even whole regions in the case of national parks. As such, LBS must operate with a sense of space and place for context (Raper 2000) through which it can deliver its location sensitivity. The sense of space must encompass a transformation between the location sensor referencing and the service referencing, for example that required by a map. In GPS-focussed services GPS referencing using latitude and longitude on the WGS84 datum must be transformed 'on the fly' to the local/ national coordinates used by the LBS (e.g. Swiss Grid for the Camineo SNP Guides).

Providing the sense of place is the more demanding function for LBS to achieve as this involves the cognitive domain of the user. There appear to be a spectrum of possible approaches, with place ontologies at one end (e.g. legally defined national and local government regions), which need to exhaust space in order to be effective. These approaches often have a poor match with the user's cognitive domain.

At the other end of the spectrum there are cognitive definitions of place defined by the user either passively or actively. These definitions should have a strong correlation with the user's cognitive domain and a complex relationship with the system-implemented sense of space. The Camineo guides have a system to forecast the likely location of the mobile user based on previous behaviour that uses probabilistic approaches to create a future location 'likelihood surface' that can be used to rank information resources (Mountain 2005). This technique is an attempt to model what the user may see as the area from which relevant information resources might be drawn. In geographic information retrieval terms this is the geographic relevance of a query. Raper (in prep) suggests that the identification of geographic relevance of a query may be the way forward in enriching the concepts of place in LBS.

Dransch (2005) has suggested that concepts of context need to be complemented by concepts of task and activity, for example through activity theory. Activity theory models 'a conscious and directed act that is executed to reach a defined goal' (p33) i.e. a cognitive action plan, which is composed of goals, subgoals and actions. Artefacts (such as LBS) are needed to help achieve goals (e.g. wayfinding), although they modify the action plan. A 'gulf of execution' has to be bridged if the artefact is to help, which requires a study of the mediation role of the artefact.

When analysed from this perspective, it is clear that LBS must be designed to help with the next goal in a way that users can accept and control. In the LBS4all project at City University, the user interface to a LBS for people with mobility problems (e.g. visually impaired and older people) based on the Camineo platform, is being evolved from an artefact focussed on wayfinding to one focussed on commentary. On the basis of fully-engaged user testing it is clear that wayfinding still needs to continue to depend on primary navigation tools e.g. the white cane for the blind. Meanwhile the LBS can 'commentate' on the surroundings to open up new opportunities for the user and enrich their knowledge of the physical and informational environment.

Fig. 3 Camineo/ Webpark front page

3.2 Context architectures

Concepts of context and activity need to be operationalised for rich LBS applications. Reichenbacher (2003) has defined (computable) context as a function of the following functions and attributes:

- user (user profile, identity, privacy)
- technology (device capabilities, network, transport protocol)
- activities (the locating, navigating, searching, identifying tools)
- location (mobile positioning, geocoding)
- time (system time, real time)
- information (sources available via WMS, WFS, gazeteers)
- interface (map/ information presentation format).

This context can be defined and maintained using these functions and attributes, although as yet we know little about how to characterise some of them (e.g. privacy) or how they should be combined and traded off (e.g. rich services in poor network environments.

José, Moreira et al. (2003) defined the AROUND context architecture to enable the discovery of LBS on the Internet through proximity models based on distance and service scope (where the service scope is the location context). Location contexts for service scope can be aggregated using spatial semantics, resulting in a graph structure. AROUND supports:
- containment, with many to many relationship allowed between contexts.
- adjacency, allowing contexts to find their neighbours, or to support pre-fetching to allow rapid context changes. The AROUND architecture is implemented as a relation between current 'base' context and metrically or semantically close contexts mediated by a name service to resolve global location context names into references to specific AROUND servers at which they can be accessed using CORBA protocols.

An AROUND city guide client was implemented in java for a connected mobile device, operating in push mode as the user moved through the contexts as part of the Hypergeo project (a precursor project to Webpark). The chief challenges such architectures pose are the creation, maintenance and semantic relations of contexts in a service context with no relevant standards and poor scalability and security to build on. In the development of EZ Naviwalk the context can be based on distance or service scope (e.g. railway stations), although the cognitive domain is not complex.

3.3 Positional fusion and rationalisation

A wide range of sensor technologies, each with their own specific error characteristics, can provide geopositioning for LBS. Rizos (2005) divided the technologies into those that require additional installed infrastructure (such as WLAN/ UWB/ Bluetooth/ RFID technologies), those that can be delivered with existing mobile telephony infrastructures, and those ubiquitous positioning technologies such as GNSS and intertial navigation / dead reckoning systems. Only the latter (specifically GPS and A-GPS) currently provide the combination of service availability and accuracy that has been sufficient to offer geopositioning to revenue earning LBS beyond the simplest 'where's my nearest' services.
Hightower (2002) note that '...each ubiquitous computing system typically treats (location) data in its own idiosyncratic manner' (p22) and that there are lots of new location determination technologies available. This implies that location sensor (data) fusion is likely to become important. Solutions will either be:
(a) rigid vendor-integrated systems for specific applications, or
(b) robust software abstractions connecting multiple sensing technologies and multiple applications

To achieve the latter Hightower (2002) and Graumann (2003) proposed the 'Location Stack', modelled on 7-layer OSI networking model, with the following layers (from bottom up):
- sensors, exporting raw data values
- measurements, raw sensor data plus uncertainty related to the sensing technology
- fusion, of measurements, definition of geodetic frame
- arrangements, reasoning about location information produced
- contextual fusion, merging location and non-location data e.g. states
- activities, relating location to semantic states
- intentions, cognitive desires of users

To date, most LBS have been implemented using single geopositioning solutions to avoid the need to deal with location sensor (data) fusion. The challenges of integration of GNSS and intertial navigation (IN)/ dead reckoning (DR) systems in particular pose significant problems, since there are significant non-linearities and latencies involved in fusing geopositioning derived from time (GNSS) wwith those derived from space (IN/DR) methods.

3.4 Application development

LBS application development poses significant challenges in the light of the length and complexity of the LBS value chain (figure 1) and the need to integrate between the tiers of a client-server architecture. There are three basic elements to a tiered client-server architecture. Firstly, the data storage in a DBMS, secondly the application or 'business logic' (consisting of the communication handling and data processing), and thirdly the graphical presentation through a user interface (GUI) whether that be a standalone application, a Java applet or web browser. There is a spectrum of possible physical implementations ranging from all three elements running on one machine, to each of the three elements running on a separate machine. An 'n-tier' architecture partitions the logic or data onto multiple machines when this is required to handle (or specialise) the load. Most of the LBS solutions available use the client-server approach (Meng, Zipf and Reichenbacher 2005), with the exception of multi-agent designs.

The web services architecture of the W3C is the most generic client-server framework available and has created a universal platform for distributed processing and data. This is the ideal architecture for an open, distributed and co-operating set of services such as those found in the LBS value chain. The advantages and disadvantages of the use of a web services approach for LBS are:

- data can be encoded in XML and GML, but this encoding lacks richer semantics than geometry;
- httpd can be used as a server protocol, but it is intrinsically stateless, making it difficult to maintain sessions;
- web services allow dynamic content to be served using Java servlets, but are not as efficient in transaction handling as CORBA;
- vector graphics can be delivered through SVG, but SVG coordinates are local not global;
- the user interface is a web browser

The Open Geospatial Consortium have defined Open Web Services for Geoservices and with OMA have defined the Open Location Services Geomobility server, both standard architectures for geospatial web services with associated information models allowing application development interoperability and convergence. Overall, the web services approach offers a flexible and standardised distributed application development environment, though it can deliver lower performance and has some semantic limitations in XML and GML. Camineo has used this approach to deliver its guides because standardisation offers guaranteed integration, longevity and the appeal of a familiar user interface.

By contrast KDDI have used a proprietary client server environment based around the gpsONE chip and the Qualcomm BREW development platform to deliver EZ Naviwalk. This environment offers performance and complete control over the user experience, but delivers the LBS through a custom interface and with hardware dependencies. This makes it harder to bring new developers to the platform, although this platform has already reached a considerable scale in Japan. An alternative proprietary LBS platform is the Drill-Down Server offered by Telcontar with its Rich Map Format, as used by Google Maps.

Both of the open and propriatary approaches are viable as demonstrated by the two applications profiled here, and each offers a set of advantages and disadvantages as part of their overall proposition. However, a key advantage of the web services approach is the speed with which it can adapt to the changes in the hardware, network environment and the mobile device operating systems by virtue of the open nature of the platform.

4 Conclusions

These factors reflect a conceptual, operational and commercial view of the elements needed for the performance and functionality of LBS applications at a level of innovation likely to attract the consumer. The challenge for researchers is to demonstrate attractive potential applications: the challenge for the industry is to deliver the elements needed at a price the consumer and business users can accept. However, if either part in the equation is unrealistic, then LBS might not progress to achieve their potential in the next few years.

5 Acknowledgements

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LBS in year 2005 – A reality check

Markus Uhlirz

Abstract

This paper gives an overview of the market situation for commercial LBS offerings as of Year 2005. A short discussion of the nature of LBS and its competitors leads to selection criteria for suitable LBS applications, possible reasons for failure and their critical success factors.

1 Introduction

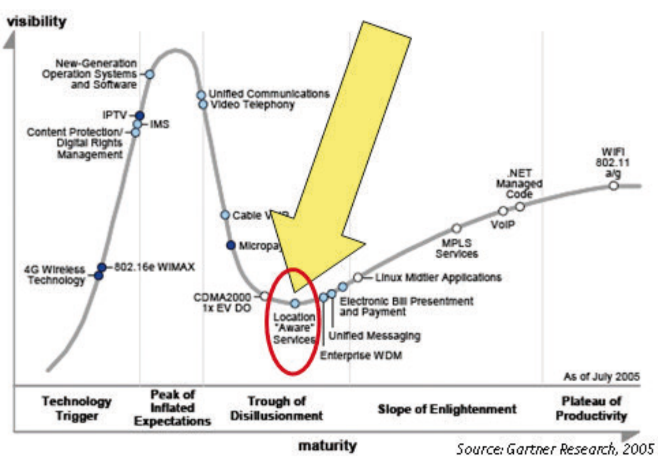
In the absence of a universally accepted definition, the term "Location-Based Services" (LBS) shall be understood within the context of this paper as location-sensitive and location-aware service delivered to users by means of a public mobile telecommunication system.
Ever since 1997, Location-Based Services have been advertised and promoted as one of the "killer applications" for 3rd generation telecom networks. In fact, until today LBS has seen many false starts and even falser prophecies concerning its immediate future. As many other buzz-words, LBS has gone up and down the Telecom "hype curve" and has been surpassed by other hypes and buzz-words that have reached a certain level of commercial importance, however moderate it may be. In contrast, LBS has remained at marginal user acceptance for the last two years, not progressing noticeably.

2 Market trends

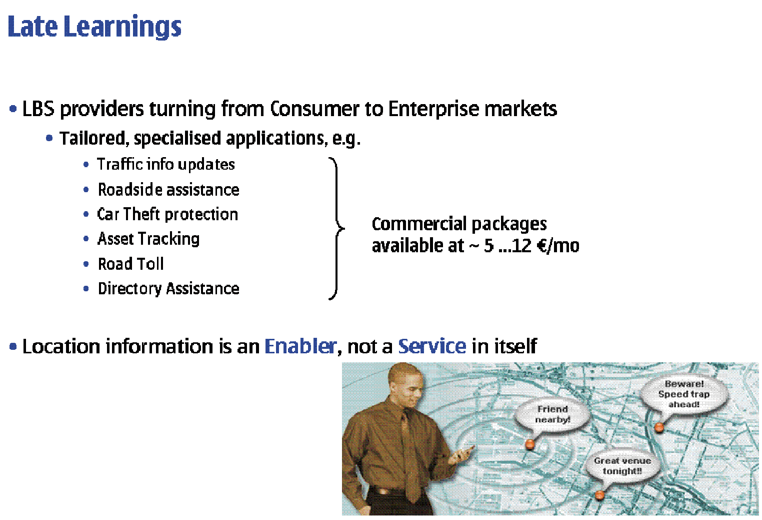
In the last years, market analysts and forecasts have been overly optimistic in estimating commercial importance and user acceptance levels of LBS. There has been a significant political pressure and the push to introduce LBS to the market in the "E-911" requirement in USA (2000/01), but industry has responded reluctantly in fulfilling these requirements. Today, E-911 is still implemented only partially in various degrees of completion.
The supplier companies have re-focussed their attention from broad consumer market to the Corporate world, now providing specialized, tailored applications to a less price-sensitive audience. This move re-positions LBS from a mass-market product to a niche solution. Here it certainly has found its place and will continue to exist for a good while.

Many of the anticipated mass-market applications envisioned in the late 90's have not materialized or have been withdrawn from the market. Winners of this development are manufacturers of internet-based mapping (Google maps, MapQuest etc.) and portable mapping solutions, which are becoming commodity and a standard equipment also for cars in the Compact Class and medium price band (TomTom, Navigon etc.) Losers of this development are telecom carriers with own products and providers of purely telecom-based positioning systems.

Fig. 1: Hype Cycle for Telecommunications, 2005



The learnings of the LBS story has been late, but the message is now clearly understood: Location information is an Enabler technology, but not a sellable service in itself. Location information is only valuable (hence sellable), if bundled with a service requested and desired by the user.
Location information can very well be used to filter the relevant info elements from e.g. a comprehensive response to a Google query. This will immediately add value for the user by making the search results more relevant to his current situation. This is also a sellable item.
As a "Reality Check" in Year 2005, the current situation shows following trends:
- Do it Cheap!: Industry consensus to provide location information, but not at any costs. A cheap solution seems to satisfy most of current needs and re-



quests. Users are generally unwilling to spend big money on location information. Acceptable price ceiling is ~0.20 EUR per location event. (Note: one event may consist of several queries in sequence)

- Limited Granularity is accepted by the users in very most cases. Users are not willing to pay higher price for better resolution of own position. Users are willing to take the risk of 2-min travel distance to wrong direction. For pedestrians this corresponds to ~200m, for urban motorized traffic this is in the order of 1km.
- Positioning solutions have been developed during last decade and have reached an acceptable level of precision and reliability. Various methods for Positioning methods have been widely discussed in scientific community and are well-covered in the literature. The "classical" positioning method for LBS is cell-based triangulation (cell-ID + Timing advance, OTD/ E-OTD methods) and assited GPS (A-GPS). In the non-telecom world, straight-forward GPS positioning has become a commodity. However, this is only applicable for outdoor situations.
- Terminal support is available for LBS, but still not a standard feature for handsets. Most manufacturers have a high-end terminal in their portfolio, which allows positioning, either by an in-built GPS receiver (e.g. Motorola A-1000 (in 2003, now obsolete) or by a near-range connection, e.g. via Bluetooth, to an external GPS-mouse.
- GPS equipment and chipsets have become a commodity and are wiedely available for less than 50 EUR.

Furthermore, there are also clear warning signals on the LBS area:
Unclear business model: No telecom operator has yet come up with a convincing business model how to make money on LBS. Rather, location information is seen as a complimentary, decorative supplementary item to other information provided. To date, no mass-market service is known, that would fail if location information (coordinates or position marker on map) were not available.

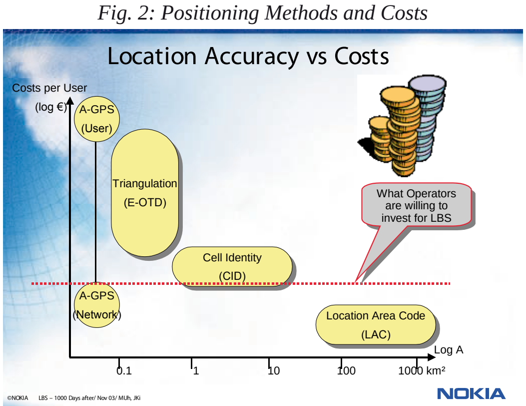
Marginal revenue streams: The net revenues from LBS continue to remain marginal. While data services in general are picking up momentum with introduction and acceptance of 3G services, it seems that LBS is being left behind. This discourages operators from further investments into development of LBS, thus also creating a chicken-and-egg situation.

Not among the Top-10: Recent studies of data volumes in telecom networks show, that no operator worldwide lists LBS among his Top-10 data services. Several operators have actually "pulled the plug" on LBS and have withdrawn it from their service portfolio, due to unfavourable ratio between costs and revenues.
The technology is available and cheap, methods and concepts are developed, ideas are abundant – but why is LBS not as successful as it was thought to be? This question needs some further consideration.

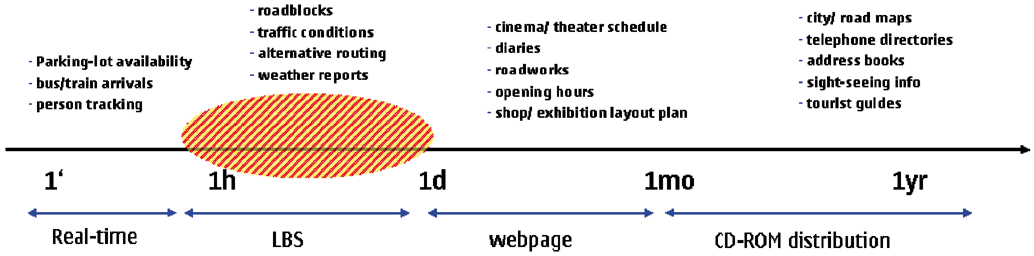
3 The nature of Location Based Service

Obviously, having a feasible, available, usable and cheap technology solution is not sufficient to make LBS a commercially successful service.

Fig. 2: Positioning Methods and Costs



As any other technology, LBS has a number of competitors with a very similar value proposition. To be genuinely successful, LBS needs to convincingly demonstrate its superiority for a specific application situation to the User. Most obvious competitors are live, "real-time" experience, web-pages, portable self-contained navigation systems running on PDA's and CD-ROM media, just to name a few. All these are existing threats, eating into the domain of LBS.
Looking at the time dimension, LBS addresses only a small section of the time-axis. LBS can be considered best suitable in situations where information changes more frequently than once a day, but remains valid for a duration of time in the order of travel-time needed to reach the destination.

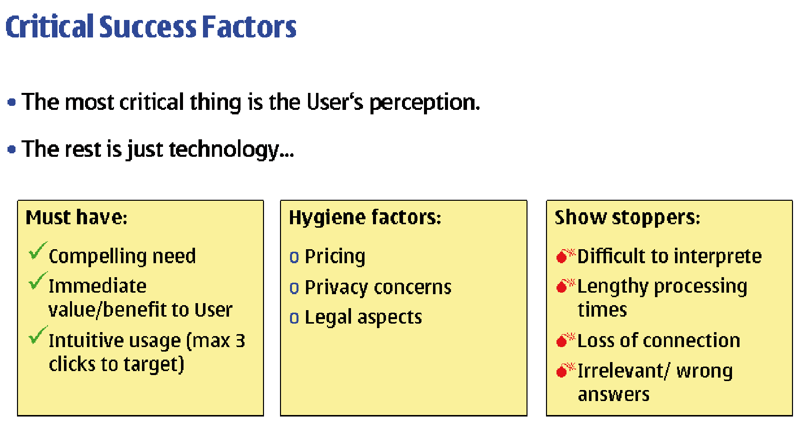


Examples:
- A "Parking-lot finder" is not a suitable application for LBS, because a parking lot's average time to next occupancy in urban areas is substantially shorter than travel time needed to get there [1]). In this case, "real-life experience" is obviously the most suitable medium.
- Similarly, there is no need to locate static objects via a LBS system. Street layouts, telephone directories or tourist guide-books are very static and do not change significantly in the order of months or years. Here, a CD-ROM edition makes very good sense, while a LBS application to provide updates on street-name and -position changes seems rather inadequate.

Items that remain constant for several days or weeks are suitable for publication on webpages (Event locations, cinema program, theater schedules, opening hours for pharmacies/ shops, layout plans for temporary events e.g. trade fairs etc). Here again, applying an LBS seems inadequate effort for too little genuine value.
LBS is most suitable for events without pre-determined locations and that remain valid within the order of several hours, e.g. traffic conditions, temporary roadblocks, weather report, rain radar, traffic cameras etc. This limits the scope of suitable applications to a rather narrow slice, but within this area, LBS can excel [2]). In the competition between static and mobile mapping, LBS will prevail when there is no other viable alternative to retrieve the requested information than via a mobile system.
A large portion of LBS's lack of success is contributes by this inadequacy of service proposition and chosen presentation medium.

4 Critical success factors for LBS

The single, most critical factor for success is the value of service as perceived by the User, irrespective of the technical complexity applied and actual precision of results. If an approximate result is perceived as "true", users will come again. If a scientifically precise-looking result is perceived as "wrong", probability of re-trying is very low.
Based on the experiences of the recent years, the critical success factors for LBS include:
– *Compelling need:* The service must address a real need for users. "Nice-to-have" information is insufficient to sustain a business case. Location information is often seen as a complementary piece of information and readily accepted if free of charge, but seldomly seen as core deliverable.
- *Immediate value* to user: Location information must provide an immediately perceivable value to the user, then they will also be willing to spend money for this information and to use the service again.
- *Simplicity of use:* A key issue for all new technologies. Currently, users rather refrain from using LBS if it requires manual data entries. Usage must be intuitive, results should be reachable within distance of 3 clicks. Ideally, LBS would be voice-driven or produce results by automatic scanning/ reading of external info, e.g. bar codes, RFID chips etc. (voice in –> xml-script out –> input for mapping machine)
- *Quick processing time:* Usability surveys for data services show that users are impatient. Typically, after 6sec a majority of users would tend to cancel the action. Out of these, half would retry, the others will abandon the attempt. A sand-glass as activ-



[1]) Even less sensible would be to advertise spontaneously free parking-lots on web-pages. Issuing a CD-ROM distribution on "Free Parking lots in Vienna, 2005" is even outright ridiculous.
[2]) Mapping company TomTom (NL) offers a supplementary feature for its Route planner product, allowing the user to access up-to-the-hour updates on traffic conditions and automatic re-routing of travel paths. This is a sensible and useful combination of pre-loaded map information on GPS receiver and incremental updates via mobile wireless LBS.

ity indicator apparently is not good enough to keep the interest awake. This also is a main restriction for amount of data that can be transferred in a response to the user. [3])
– *Near-100% hit rate* in answers: Users are unforgiving: irrelevant or wrong answers are not tolerated. Users will accept “wrong” answers typically twice, then abandon the service, disappointed.
- *Low or no price*: Other than ringtones, wallpapers and music tracks, location information is a “non-storeable” item. It is consumed exactly once, then it is worthless. Users are price-sensitive when payment is per event. Currently, the perceived value of location information is around 0.15 .. 0.20 €/event. Location information by itself has no commercial value and needs to be bundled with other services to be a sellable item.

5 Conclusions

- Industry consensus: If you do it, then do it cheap !
- Limited granularity is acceptable for most cases (CID-based methods; ~500m resolution)
- Marginal revenue streams from LBS --> not on Operator’s priority lists
- Multiple technology threats: Mobile Mapping & Navigation. E.g. portable navi systems on PDA’s, CD’s, memory cards (TomTom, NaviGon, MapQuest, ….)
- LBS infrastructure exist in many networks, but not actively promoted or maintained
- Weak overall business case and high maintenance costs (Opex >> Capex)
- Shift in business & revenue model: move risks to LBS suppliers & 3rd Parties (“Managed LBS”)
- Practical views on Legislation problems: Terminal as Network asset; trackable item, no privacy concerns

The immediate perceived value of LBS to the User is still a major issue. LBS products are difficult to communicate. A high level of information abstraction and interpretation of results is needed by the User. Usability of services is not intuitive, requires too much manual input, refinement and validation.
LBS services exist today and will continue to occupy specialized niche markets. LBS is currently not positioned as a mass-market product, no viable candidates for mass-market services are in sight (yet?).

[3]) With current UMTS networks and the severe limitations of TCP/IP protocol over mobile radio links, this time span corresponds to a transfer volume of ca. 50kB of data. This is not a deficiency of 3G networks, but is due to the inadequacy of the protocol design for mobile usage. TCP/IP was designed 20 years ago for fixed networks and does not provide mechanisms to cope with the specifics of mobile radio links. This will change significantly with introduction of IPv6.

Location-Based Services and GIS in perspective

Bin Jiang, Xiaobai Yao

Abstract

This presentation examines location-based services (LBS) from a broad perspective involving definitions, characteristics, and application prospects, in particular when compared to geographic information systems (GIS). We unpack LBS into four important components: users, locations, contexts and data, and briefly reviewed modelling efforts towards the four components. We believe that it is the diversity of users, and consistent changing locations, or contexts in more general sense, that make LBS special from ordinary GIS. Using a list of GIS research challenges as benchmarks, we cross compare LBS and GIS and highlight some research challenges that are particular unique for LBS. These challenges include, but no limited to, naïve users, massive geospatial data analysis and modelling, on-the-fly generalization and visualization, interoperability issues, and privacy and social issues. We conclude our presentation by pointing out that (1) there is no clear-cut boundary of LBS and GIS, and (2) it is the shift of computing platforms from mainframe, to desktop, and nowadays increasing pervasive mobile computers that makes LBS and GIS research special, challenging and more exciting.

Knowledge-based map adaptation for mobile map services

L. Tiina Sarjakoski, Tommi Koivula, Tapani Sarjakoski

Abstract

The evolving map applications for different types of mobile devices present new challenges for mobile services and application providers. One of the crucial challenges faced is as how a single map service could be used to deliver and adapt mobile maps for different kinds of users in different usage situations. In order to be able to utilise and manage various map specifications for the different maps, a Map Specification Knowledge Base approach is introduced and formally described in the paper. A Map Specification Knowledge Base is a set of specification rules, properties and assignments constituting the system's knowledge about the map to be delivered to the mobile user. Such knowledge includes rules connecting context parameters with the parameters for the level of details of the map and map generalisation, and settings for the map layout, symbols, map contents etc. The method uses an object-oriented approach to carry out the multiple-inheritance of the map specification modifiers based on the importance of the rules. To provide third-party service developers with the possibility easily creating and modifying map specifications for their own needs, a web-based editor, called Map Specification Tool was implemented. The innovative aspect of the knowledge-based map specification approach is that the service can deliver various types of maps, which match the current context parameters and user preferences in real-time. The research described in the paper has been part of an EU- project referred to as GiMoDig (Geospatial info-mobility service by real-time data-integration and generalisation). A prototype of a cartographic map service has been created to deliver geospatial data to mobile users in real-time, and is based on emerging standards, such as Extensible Mark-up Language (XML) and Open Geospatial Consortium's (OGC) specifications.

1 Introduction

Background

Out of all the mobile applications, the applications that use the Global Positioning System (GPS) and display the map on a mobile device, are the most in demand at the moment. Thus, the national topographic databases play a key role in applications that need detailed geospatial information. On top of the topographic data provided by the geospatial data services third-party service developers may create various end-user applications and display so called Points of Interest (PoI) data. At the same time, the developers of mobile applications face new challenges when aiming to meet the demands of the various user groups of mobile services.

The research described in this paper is based on the results from an EU-funded project carried out in 2001-2004 called GiMoDig (Geospatial info-mobility service by real-time data-integration and generalisation). In the project, a prototype of a cartographic map service was created to deliver geospatial data for mobile users in real-time. As the overall objective of the GiMoDig project was to improve the accessibility and interoperability of national topographic databases, the data is delivered from the geo-databases in the participating countries' National Mapping Agencies (NMAs) (Finland, Sweden, Denmark and Germany), and results in a vector-formatted high quality Scalable Vector Graphics (SVG) map being displayed on the user's mobile device. The GiMoDig service is based on emerging standards, such as Extensible Mark-up Language (XML) and Open Geospatial Consortium's (OGC) specifications.

The focus of this paper is to describe a mobile map service approach that includes a knowledge base which is used when the service controls in real-time the map adaptation of mobile maps.

Previous research

Today, the ability for adaptation and context sensitiveness are regarded as essential characteristics of Location-Based Services (LBSs) (Meng et al., 2005). According to Oppermann, (1994) an adaptive system is capable of changing its own characteristics automatically according to the user's needs. For example, Baus et al. (2001) describe a system that determines the location of the user and adapts the presentation of route directions according to the characteristics of the user's mobile device as well as to the cognitive resources of the user. Reichenbacher (2001, 2004) was among those who started to study the process of the adaptive and dynamic generation of map visualisations for mobile users in relation to cartographic principles. Nivala and Sarjakoski (2003) reported a study on the mobile contexts relevant for map adaptation.

Cartographic expert systems were intensively studied at the beginning of 90s, for tasks such as cartographic design (Müller and Zeshen, 1990; Forrest, 1993), or map generalisation (Buttenfield and McMaster, 1991). However, the low success rate of such systems was claimed to be due to the lack of the necessary rules or their incompleteness. There has recently been an increasing interest in the research on cartographic expert systems (e.g., Stefanakis and Tsoulos, 2005). Techniques from areas such as the object-oriented approach, constrained or agent-based technology are combined with technology from previous expert systems. In our approach we have adopted some object-oriented techniques to the knowledge-based approach, while attempting to find a solution as how to use only a single map service to deliver different kind of maps and adapt them to various user needs (Sarjakoski and Nivala, 2005).

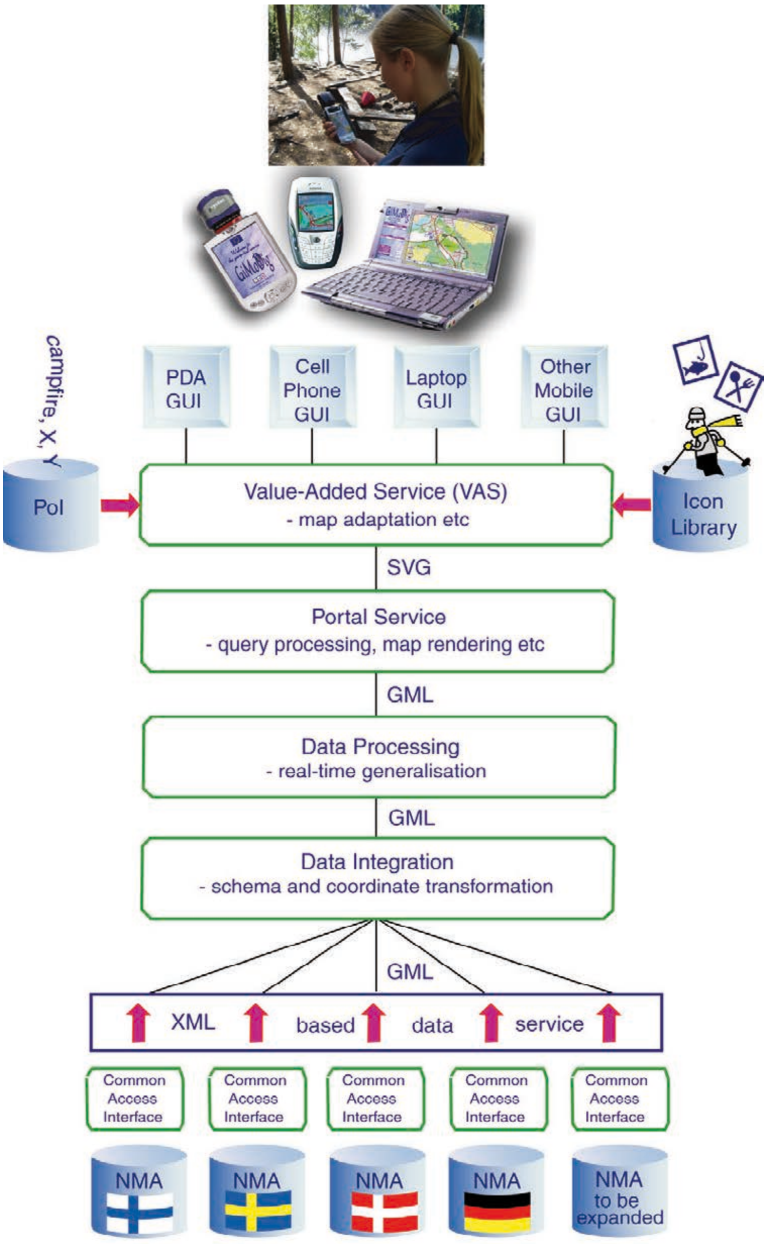
The following section briefly describes GiMoDig service architecture, followed by a formal description and examples of a Map Specification Knowledge Base (MSKB). The implementation of the Map Specification Tool Editor is described in Section 3. Finally, the paper concludes with a brief discussion.

2 GiMoDig - map service

The GiMoDig-service prototype incorporates a number of geo-spatial tasks: data transformation to a common reference frame, thematic harmonisation of geodata according to a global schema, real-time generalisation and the integration of Points of Interest (PoI) data, and applications tailored to meet a range of needs for different mobile users.

The GiMoDig prototype is based on layer-based architecture, consisting of six layers (GiMoDig 2005; Lehto and Sarjakoski 2005). On the first level, the data providers (i.e. in GiMoDig, the NMAs) run a Data Service providing raw spatial data in an XML-encoded form, Figure 1. Above the data services is the Data Integration Service layer, which takes care of e.g. coordinate transformations to a common EUREF- coordinate system, and schema transformations. On the third level in the architecture is the Data Processing layer for processing tasks such as map generalisation or dynamic map labeling. The fourth layer in the system architecture is called Portal Service. The main responsibilities of this layer include processing the service requests coming from the client, subsequently forwarding the request in an appropriate form to the Data Processing layer below, and transforming the resulting piece of geospatial data into a visual representation, according to the capabilities of the client platform in question. It should be noted that in the service architecture the query results are represented in the form of XML-encoded spatial data (i.e. Geography Markup Language (GML) up to the Portal Layer. In this layer the query dataset is transformed into a visual map image (i.e. an SVG map) and styled appropriately for the client environment in use.

Fig.1: The GiMoDig layer-based service architecture (Sarjakoski and Sarjakoski, 2005).



The fifth layer is the so-called Value-Added Service (VAS) layer. The main task of this layer is to control the creation process of the map that will be delivered to client applications, taking into account the parameters related to the adaptive map display. It determines, in particular, the content of the PoI data that is overlaid on the topographic data, and also the selection and style of the topographic data. The service access on the VAS layer is based on a proprietary, use case-specific query interface. One of the main research topics in this respect is the use of context parameters for adaptive maps for different kinds of mobile users. These parameters include the following detailed information being used in the query:

- **usecase** to indicate the activity the requestor is currently involved in
- **lod** (Level of Detail) to set the resolution of the map representation
- **time** for setting the temporal context of the usage situation
- **age** group of the user to affect the map visualisation process based on the user's age group

- **device** to set the context parameters related to the physical device currently in use
- **center** to indicate the location of the map to be requested
- **scale** to set the display scale
- **position** to set the user's current position

Examples of the value sets of the parameters in a query are listed in Table 1.

Parameters	Value sets v_{pi}
p_{USE_CASE}	{„outdoors“, „cycling“, „emergency“, „expert“, *o*}
p_{LOD}	{„detailed“, „basic“, „intermediate“, „overview“, „egm“, *o*}
p_{TIME}	{„winter“, „spring“, „summer“, „autumn“, „day“, „night“, *o*}
p_{AGE}	{ 0-10, 11-17, 18-45, 46-, *o* }
$p_{LANGUAGE}$	{„English“, „Finnish“, „Danish“, „German“, *o*}
p_{DEVICE}	{„ipaq“, „pc“, *o*}

Tab. 1: Context parameters and their value sets selected for the GiMoDig prototype.

The Value-Added Service contains a knowledge base for different contexts and visualisations assigned to them. The VAS also uses an SVG-based icon library and a Points of Interest (PoI) database, which were developed in the GiMoDig-project. The icon library consists of icon sets in four different styles (totally 161 icons), which are selected depending on the age of the user group of the requested map (Sarjakoski et al., 2004; Nivala and Sarjakoski, 2005). The PoI-database contains coordinates of the PoIs (Figure 1). The client applications consisting of four use-case-based applications are on the sixth layer: A Hiker in a National Park (i.e., Outdoors use case), Cycling and Emergency use cases, and a tool for tailoring mobile maps for expert users (Sarjakoski and Sarjakoski 2004; 2005). An advantage of the layer-based architecture approach is that the results can be adapted to various client environments. Three client platforms were considered for implementation: traditional web browsing on a portable PC platform, more restricted web access on Personal Digital Assistant (PDA) devices and a client application on mobile cell phones.

3 Map Specification Knowledge Base (MSKB)

One of the research problems faced in the GiMoDig project was as how a single map service could be used to deliver and adapt mobile maps for various users in different usage situations. In order to be able to utilise and manage various map specifications for the different maps, a Map Specification Knowledge Base approach is needed. A Map Specification Knowledge Base is a set of specification rules, properties and assignments constituting the system's knowledge about the map to be delivered to the mobile user. Such knowledge includes user preferences for the mobile context, parameters for the level of details on the map and map generalisation, and settings for the map layout, symbols, map contents (i.e., displayed map feature classes and icons), etc. However, the large number of combinations of context-parameter values might make it nearly impossible to create specifications one by one. To solve this problem and to minimise the number of specification rules and properties that needs to be entered manually, a method that uses multiple-inheritance of modifiers based on the importance of the conditions is introduced in the following paragraphs. The most common properties (such as "styles of the map") are mapped for the most important conditions (such as "a use case") and then inherited to other less important conditions. The innovative aspect of the Map Specification Knowledge Base and the map specification approach is that the service can deliver various types of maps, which match the current context parameters and user preferences in real-time. In the following paragraphs we give a formal definition of the map specification knowledge base, and we also present an algorithm that can be used to bring this knowledge base into practice.

Context and context parameters

In general, context can be seen as a collection of information to characterise the situation of an entity. Entity is a person, place or an object that is relevant to the interaction between a user and an application, including the user and the applications themselves (Dey and Abowd, 1999). Furthermore, Dey (2001) defined a system to be a context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task. Nivala and Sarjakoski (2003) identified in their study mobile contexts based on user tests of topographic maps in mobile devices. These included location, system, purpose of use, time, physical surroundings, navigational history, orientation, user and cultural and social elements. They proposed that embedding context awareness into the topographic maps in mobile devices could increase the usability of the map service better to support its user.

First we formalise the context into a set of context parameters, which identifies the context itself. Context can be formalised by using dimensions (Tomai and Kavouras, 2005). Dimensions are specific variables when combined to give meaning to information. They describe the surroundings for all the user actions as well as the user application used. Using *n* dimensions, we define context *C* as

$$C=(p_1,\ldots,p_n) \quad \{ v_{p1},\ldots,v_{pn} \mid p_i \in v_{pi} \}, \qquad (1)$$

Fig. 2: Adaptive PDA maps for different seasons for the teenager user group. In the figure, three context parameters control the map: $p_{TIME} \in$ *{"season:winter","season:summer"}* , p_{AGE} *="teenager",* p_{DEVICE} *="PDA". The context parameter* p_{AGE} *reflects to the choice of the style of the icons (for teenagers a comics style used). Depending on the context parameter value for* p_{TIME}*, the delivered map has different contents and colours defined by the map specification modifiers.*

where p_i is the context parameter and v_{pi} is a set of possible values of context parameter p_i. All sets v_{pi} also contain a value that indicates that the actual value of this parameter is unknown. We denote this value as o.

The following example illustrates how contexts are used. Let say we have a context $C=\{p_1,\ldots,p_5\}$ and the values of the context parameters can be the following: v_{p1}={winter,summer,*o*}, v_{p2}={pc,handheld,phone,*o*}, v_{p3}={male,female,*o*}, v_{p4}={age as integer }∪{*o*} and v_{p5}={lod_basic,lod_overview,*o*}. One possible realisation of context C could be *C´* = (o,handheld,o,25,o). It simply states that the user has a handheld device, his/her age is 25, and the gender and season are currently unknown.

In our approach the order of the parameters in a context C is also important. The context is evaluated so that the first parameters are considered to be more important than the last ones. For example, an age greater than 60 may indicate that the mobile map's text fonts should be bigger, and also that when the mobile device is 'phone' fonts should then be smaller than usual. Suppose we have a context C_1=(o,mobile_phone,o,65,o). In this context the outcome would be that the text fonts are smaller than usual since the age parameter is considered to be less important than the device parameter. The purpose of these context assignments is then to control the map contents and visualisation to be delivered in the adapted map. An example of seasonal maps for teenagers on a PDA is shown in Figure 2.

Map specifications

A *map specification* describes all the properties of a map for a given usage situation, e.g. the parameters for the level of details of the map and map generalisation, and settings for the map layout, symbols, map contents, which of the map feature classes should be displayed, in which colour, what should be the width and style of the lines, what kind of map icons are used in the adapted map to be displayed, etc. While the context parameters describe the need for a certain type of map adaptation, a map specification is a solution for this need. A map specification can be related to many contexts, i.e. the same kind of map can be useful in various usage situations.

In a real map specification knowledge base there can easily be dozens of different map specifications. Patterns can often be found among map specifications so that two maps can almost be similar, except for one particular map specification modifier. Therefore, in order to be able to define similar map specifications more easily, we divide them into so-called map specification modifiers. We combine these specification modifiers by using a multiple inheritance-based approach, and thus it is possible to both decrease the amount of manual work and create more generic map specifications. We denote the specification modifier as X_p, defined by the context parameters:

$X_P=(x_1,\ldots,x_m)$, where x_i are properties of the map (2)

There is no need for every map specification modifier to have all properties defined. We denote properties that are not defined as o. For example, a map specification modifier could be

$X_{(o,handheld,o,25,o)} = (x_{1a}, o, o, x_{4a}, o)$, where x_{ia} are some map properties (3)

Map specification M is the result of the interpretation of a set of map specification modifiers by function *h*:
$M = h(\{X_1,\ldots,X_n\}) = (x_1,\ldots,x_m)$ (4)

A map specification cannot have empty values in its property set.

Implemented algorithm
The interpretation function *h* that we implemented into our prototype service uses a method that could be seen as a kind of multiple inheritance. The algorithm applies map specification modifiers ranging from the most common ones to more specific ones. All properties that are present in the 'subclass' will overwrite existing property definitions applied from 'super classes'. This approach makes it possible to have very generic specification modifiers that are useful for sharing common map properties in many map specifications. The following is the pseudo-algorithm we have used to apply map specification $X_{(c1,\ldots,cn)}$:

1. Make a set of map specification modifiers that are 'subclasses' of X,
   i.e. $D = \{ d_P \mid P=(p_0,\ldots,p_n)$, where $\forall i\ (p_i=c_i$ or p_i=o) }.
2. Let i:=1.
3. Apply map specification modifier d_p from D that has $p_i=c_i$. If there are many then apply the one that has the smallest ordering value. The ordering value is the number of the last (i.e. least important) parameter that has a value other than *o*. If there are no such modifiers, go to step 5.
4. Carry out operation X:=inherit(X, d_p).
   Remove d_p from D. Increase *i* by 1. If $i \leq n$ go to step 3, otherwise stop here.

Operation inherit(X,Y) simply overwrites all the map properties in $X=(x_1,\ldots,x_m)$ that are defined in $Y=(y_1,\ldots,y_m)$. More formally:
$\text{inherit}(X, Y) = (a_1,\ldots,a_m \mid \forall i\in[0,\ldots,m],\ a_i = x_i \text{ if } y_i = o \ ;\ y_i \text{ otherwise})$ (5)

Two examples of how the implemented algorithm works are presented in Table 2. M_1 and M_2 represent map specifications generated by the algorithm in given contexts and with specification modifiers W, X, Y and Z. Let's study how the algorithm generates the map specification M_1:

D_{M1} = {W ,Y ,Z} and i:=0: Apply *W* and do inherit(M_1,W) => $M_1=(w_1,w_2,w_3,w_4,w_5)$. Remove W from D_{M1}=>{Y, Z} and increase *i* (*i*=1). Apply *Z* and carry out inherit(M_1,Z) => $M_1=(w_1,w_2,w_3,z_4,z_5)$. Remove Z from D_{M1}=>{Y} and increase *i* (*i*=2). Apply *Y* and carry out inherit(M_1,Y) => $M_1=(w_1,w_2,w_3,y_4,y_5)$. Remove Y from D_{M1}=>{ }and stop.

M_1 has all context parameters defined and modifiers W, Z and Y are applied. Z is applied before Y because Z has a smaller ordering value. The result contains properties only from W and Y because applying Y would overwrite all properties modified in Z. M_2 does not have all context parameters defined, but still it is able to produce a complete set of map properties. M_2 will be constructed from modifiers W, X and Z.

Map specification modifier	Context	Ordering value	Map properties
W	(k,o,o,o,o)	1	(w_1,w_2,w_3,w_4,w_5)
X	(o,o,n,q,o)	4	$(x_1,x_2,o\ ,o\ ,x_5)$
Y	(o,l,o,m,o)	4	$(o\ ,o\ ,o\ ,y_4,y_5)$
Z	(o,l,n,o,o)	3	$(o\ ,o\ ,o\ ,z_4,z_5)$
Specification M_1	(k,l,n,m,p)	-	(w_1,w_2,w_3,y_4,y_5)
Specification M_2	(k,l,n,q,o)	-	(x_1,x_2,w_3,z_4,x_5)

Tab. 2: Two examples of map property sets created by the algorithm using context parameters and map specification modifiers shown in the table. Map specifications M_1 and M_2 result in a different set of map properties depending on their context while the same map specification modifiers are used.

4 Map Specification Tool

In order to provide expert users, such as third-party service developers with the possibility of easily creating, updating and modifying map specifications into the knowledge base for their own needs, a sophisticated web-based Map Specification Tool has been implemented. This allows an easy definition of a wide range of map layouts by connecting the given context parameters to the map properties, Figure 3.
The Map Specification Tool is implemented as a Java servlet, operating fully on a web browser. Map specification modifiers are saved in plain text files on the server disk, so that they can be easily copied to different services. Alternatively, more effective storage, for example a relational database or XML-files, could be used. The Map Specification Tool is connected directly to the Value-Added Service layer (Figure 1) so that the changes are immediately visible in the real service. Thus, Map Specification Tool makes it possible to control the following properties of the map types in real time (Sarjakoski and Sarjakoski, 2004; Sarjakoski et al., 2005):

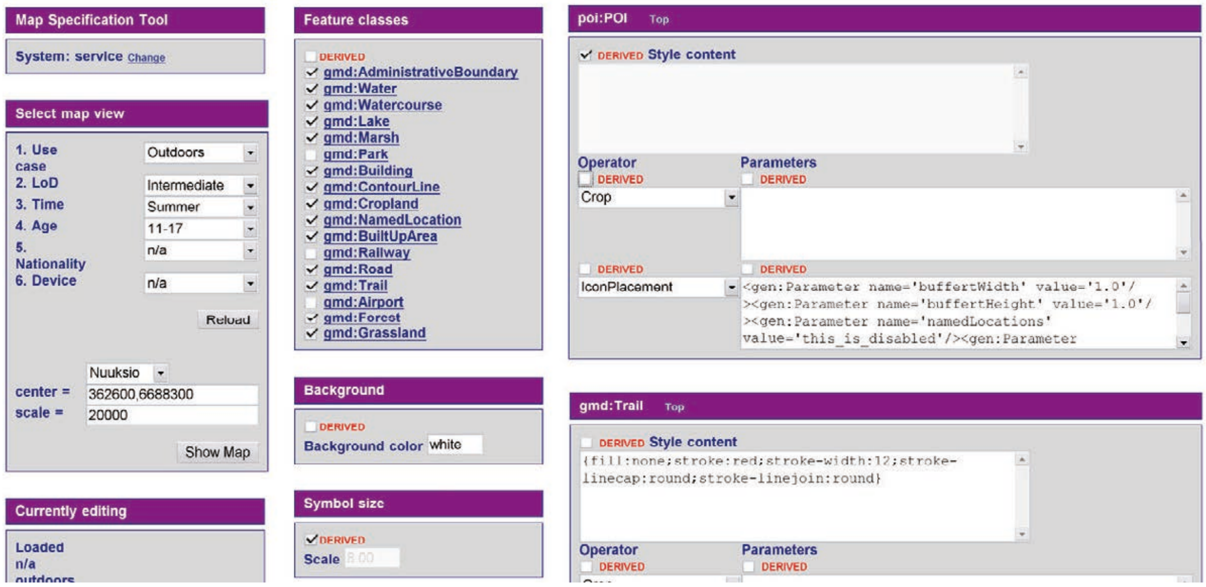


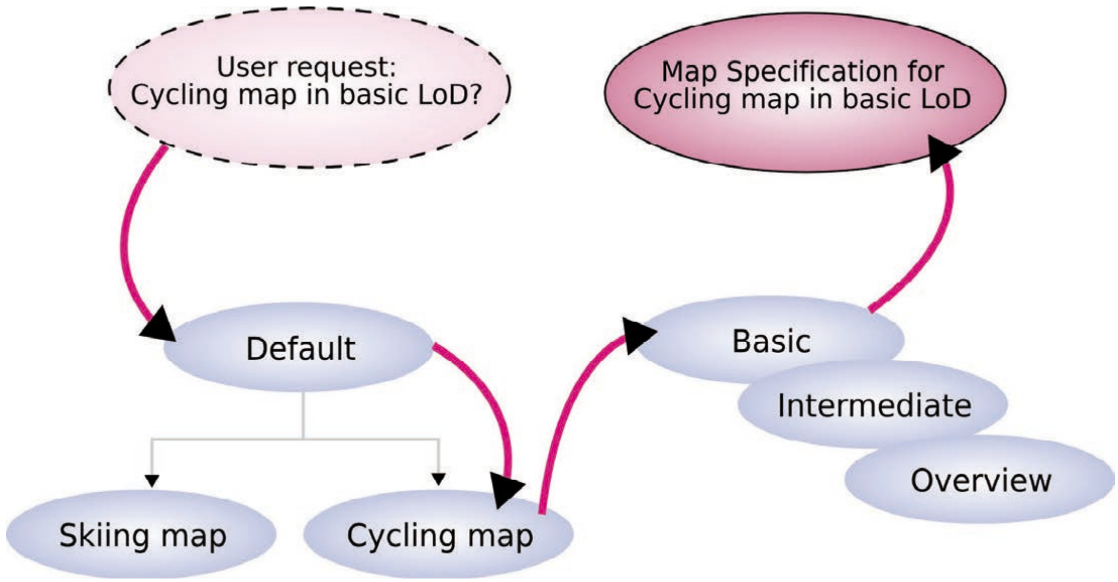
Fig. 3: Screen shots of the graphical user interface for the Map Specification Tool Editor. The service administrator selects a prototype map by the context parameters (left) and then defines the specification modifiers (right). The more context parameters are left unassigned (n/a), the less specialised any given prototype map is. Any part of the specification modifier can be derived or inherited from the less specialised prototype maps.

- Topographic feature classes to be shown on the map
- Poits of Interest/ Areas of Interest/ Lines of Interest (POI/LOI/AOI) data to be shown on the top of the topographic data
- LoD of the map and generalisation operators, and their parameters that are to be executed on the topographic features
- Other visualisation operators to be executed (e.g. icon placement)
- Other map layout (e.g. colours, line widths)

Once the design issues have been carefully resolved, the use of Map Specification Tool can be divided into three phases (Fig. 4):
- Create a complete property set to be used as a default map specification modifier. Doing this guarantees that all the combinations of context parameter values produce a complete map.
- Create all map specification modifiers by moving from the most generic to the most specific.
- Verify and experiment with real contexts and fix/create new modifiers if needed.

Figure 5 shows an example of different kinds of adapted cycling maps for different types of devices. The maps in the figure have been delivered in real time from the GiMoDig service based on the varying context parameters.

Fig. 4: An example of the applying process of map specification modifiers when p_{USE_CASE} = "cycling" and p_{LOD} = "basic".



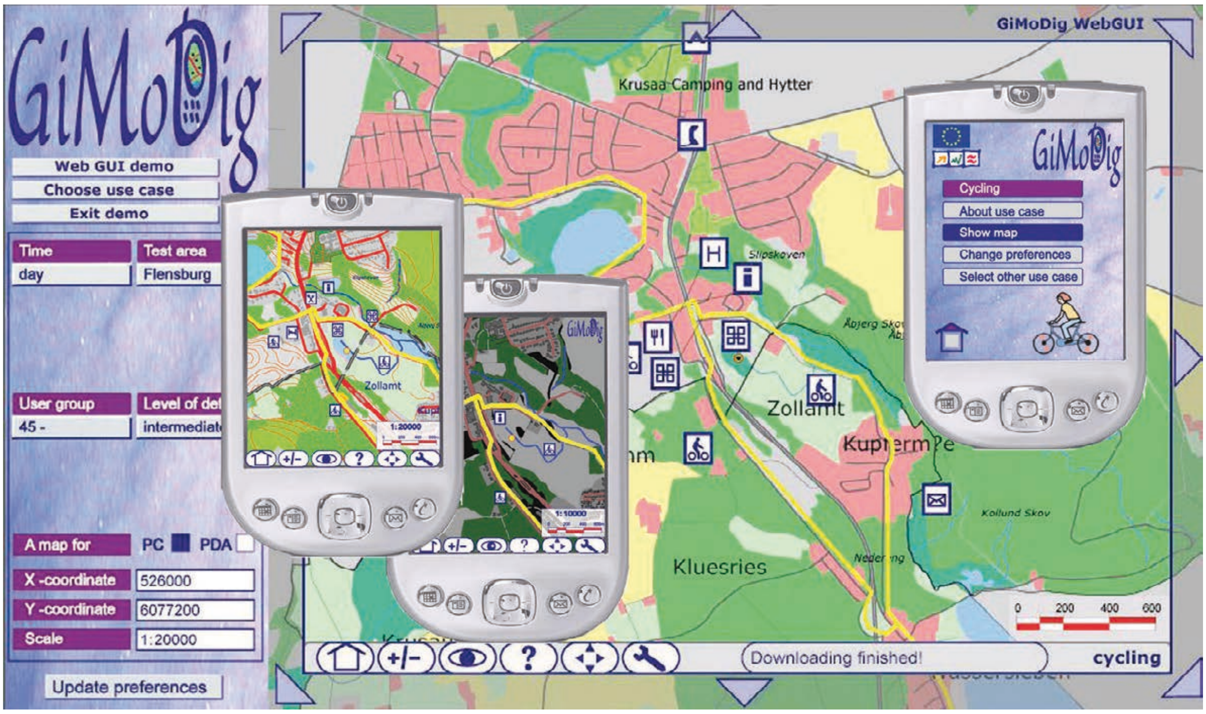


Fig. 5: Different types of cycling maps delivered in real-time by the GiMoDig service. Day and night maps for a PDA and a day cycling map for a laptop PC. Observe the different styles and colours of the maps.

5 Concluding remarks

The paper presented a Map Specification Knowledge Base approach for using and managing different map specifications for the different user needs of mobile maps. Additionally, the web-based Map Specification Tool described in the paper was implemented to provide third-party service developers with the possibility of easily creating and modifying map specifications for their own applications. The tool provides a flexible way for application developers to elaborate in real time with the map properties and immediately get the response map delivered from the service. This helps the designers more effectively to find the best cartographic visualisation for the current purpose of the mobile map.

The innovative aspect of the MSKB and the map specification approach is that the service can deliver various types of maps, which match the current context parameters and user preferences in real-time. While the map specification modifiers are combined by using a multiple inheritance-based approach, it is possible to both decrease the amount of manual work that needs to be done and to create more generic map specifications which makes it easy to use the approach for creating various applications. The importance of meticulous design in creation of a new map specification knowledge base cannot be overestimated. The planned structure of the knowledge base and selection of context parameters that will be used have a great impact on how easy or difficult it is to create specifications. The knowledge-based approach formally described in the paper is implemented in the GiMoDig prototype to deliver adaptive mobile maps for different types of users in different usage situations. Development of the approach will continue towards the creation of an operative system for adaptive maps. Such maps will be an essential part of the LBSs, of the not too distant future.

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The concept of relevance in mobile maps

Tumasch Reichenbacher

Abstract

Mobile map based services and location-based services (LBS) are going places. Yet, they face acceptance problems for such reasons as lacking user focus and relevance. This paper looks on the concept of relevance and its potential for and application to mobile cartography. First, theoretical concepts of relevance from other disciplines are studied followed by an analysis of different approaches for the assessment of relevance. A basic model for the determination of geographic relevance is postulated and the application modes of relevance to mobile cartography are elaborated. Two applications of relevance to mobile cartography are discussed with an emphasis on visualisation techniques for the presentation of relevance in maps. Some final remarks conclude the comments on relevance in mobile maps.

1 Introduction

Mobile usage of digital geographic information is becoming mainstream technology. Several types of applications and services have evolved over the last few years and are already broadly used, e.g. car navigation systems, tour guides, and, of course, Location Based Services (LBS). However, research is still sparse when it comes to developing appropriate visualisations of geographic information for small displays of mobile devices. The major challenge for mobile cartography is a separation of relevant and irrelevant information by finding an acceptable degree of information reduction to the relevant, i.e. presenting as much information as needed and as little as required.

Relevance is becoming an important feature for mobile services in general and especially for LBS and map based mobile services. Raper et al. (2002) for example claim that "… understanding the individual 'geographical relevance' of information will be necessary for location-based services to provide appropriate information …". Geake (2000) mentions among other criteria for successful LBS the *relevance* of delivered information. Similarly Oinas-Kukkonen and Kurkela (2003) propose seven key design principles for highly goal-driven mobile services: (1) provide information addressing the needs of users on the move (mobility), (2) make life easier (usefulness), (3) include relevant information (relevance), (4) simple and easy to use (ease of use), (5) most important information should be the easiest to locate (fluency of information), (6) focus on user's terminology and navigational structure (user-centredness), and (7) they should be adapted to each and every user's own needs and capabilities (personalization) or in short: "A good mobile service provides additional value for the user and is fast and natural to use".

LBS can mainly be seen as a handy supporting tool for spatial problem solving tasks like *localisation* (where am I?), *proximity* (where is the nearest X? How far is it to XY?), *navigating/routing* (how do I get to XY? How long will it take to XY?), *neighbourhood and other relations* (do I pass X on my way to Y?), and *counts* and *clusters* (are there many *N* in the region R? Is there an assembly of objects?). Generally these atomic problem solving tasks are not carried out independently, but rather are embedded in higher-level activities with spatial relations that require special support.

This paper describes the more fundamental concept of relevance and its application or significance to cartography in general and mobile cartography in specific. The major goal of this research is the adequate adaptation of geographic information and its presentation in order to reach a higher degree of relevance for the user as outlined in (Reichenbacher 2005) and to stress the significance of relevance for a successful implementation of mobile cartography in real products and services.

The remainder of the paper will examine the concept of information relevance and its role in visualisation. First, theoretical concepts of relevance from other disciplines are examined, followed by a discussion of different dimensions of relevance and their relation to the usage context. In a further step approaches for the assessment of relevance are analysed serving as a base for a simple method for the calculation of compound geographic relevance values. Moreover, the possible applications of relevance values to mobile cartography are highlighted. Finally, the visualisation of relevance in mobile maps and possible implementations are demonstrated on behalf of map examples.

2 The concept of relevance in other disciplines

Relevance stems from the Latin word *relevare* meaning to raise up, to relieve. Although relevance is a rather fuzzy concept, as humans we intuitively know what relevance is even without having a clear concept of it. In general usage we apply it synonymously for importance or pertinence. Saracevic (1996) offers a general definition of relevance derived from its general qualities: " […] relevance involves an interactive, dynamic establishment of a relation by inference, with intentions toward a context. […] relevance may be defined as a criterion reflecting the effectiveness of exchange of information between people (or between people and objects potentially conveying information) in communicative relation, all within a context." Depending on the relations established Saracevic (1996) distinguishes five manifestations of relevance (see also Fig.2): (1) the system or algorithmic, (2) the topical, (3) the cognitive, (4) the situational, and (5) the motivational relevance that form together a system of relevancies on different levels. However, the concept of relevance has some distinct notions in different scientific disciplines. A major distinction has to be made between *objective* (1) and *subjective* (2-5) relevance.

The former has been the one used for years in information retrieval (IR) where the goal is to "… retrieve all the relevant documents [and] at the same retrieving as few of the non-relevant documents as possible" (van Rijsbergen 1979, p. 6). The efficiency and effectiveness of this retrieval process is generally determined by the measures *precision* and *recall* (Mizzaro 2001). These measures reflect the notion of binary relevance, i.e. the document is either relevant or not. The assumption is that the success, i.e. the relevance of the documents, can be determined independently from the user by a system, hence the relevance is *objective*. However in practice, as it has been pointed out by many researchers (e.g. Saracevic 1996; Wilson and Sperber 2004; Cosijn and Ingwersen 2000), there are grades of relevance rather than a binary relevance and hence degrees of relevance need to be introduced. This is usually done by ranking the retrieved documents based on the similarity of the document and the query. All Internet search engines (e.g. Google) have an implemented ranking mechanism based on the cosine measure (the scalar product of each document vector against the query vector defining the presentation order of the retrieved documents).

In linguistics, pragmatics, and communication science the objective relevance is not sufficient or useful. These disciplines focus on *subjective* relevance. The basic assumption is that the relevance of entities is largely determined by the user. An important contribution is the relevance theory of communication proposed by (Sperber and Wilson 1986; Sperber and Wilson 1995; Wilson and Sperber 2004). The theory is based on cognitive psychology understanding relevance as a judgement criterion during cognitive processes, the criteria for inputs to be relevant to an individual being *effect* and *effort*. The underlying assumption is that human cognition is directed towards maximising relevance. Sperber and Wilson (1995) define relevance as follows: "An assumption is relevant in a context if and only if it has some contextual effect in that context […] An assumption is relevant in a context to the extent that its contextual effects in this context are large […] An assumption is relevant in a context to the extent that the effort to process it in this context is small." Some of these findings can help to grasp the concept of relevance for geographic information, although the extension to the spatial domain presents an even higher degree of complexity.

3 Relevance in mobile cartography

3.1 Relevance and Context

The discussion of relevance in section 2 makes clear that the concept of relevance is very much dependent on context, since the context shapes the boundary between relevancy and irrelevancy. Relevance always exists in relation to a specific context and a change of context alters the relevance. Recent work in the domain of LBS, mobile cartography, and mobile web services is rich on investigations about context-awareness; see for example (Reichenbacher 2004; Nivala and Sarjakoski 2003; Dey and Abowd 1999; Schmidt et al. 1998). As pointed out by the author on other occasions more than the mere spatial relevance is required for suitable adaptation of mobile maps as well as a success of the relevance principle in mobile cartography. Apart from the spatial relation there are other factors and challenges in mobile usage situations originating from physical environmental states, temporal constraints, mobile users' information needs and activities, technical limitations and many more. These factors necessitate an optimal exploitation of the limited map space on mobile devices, i.e. a stringent selection of relevant objects to be displayed. The presented geographic information must be relevant to the context of use, i.e. a mobile map should satisfy the user's contextual information needs and adequately present the respective information objects.

3.2 Relevance types

By combining the manifestations of relevance mentioned above and the contextual factors of importance in mobile environments a set of relevance types for mobile cartographic applications and services can be derived (Fig. 1). The depicted relevance types describe the different relations between geographic information objects and context dimensions. Accordingly objective relevance types that are independent from the user and subjective relevance types related to personal aspects of the user are separated.

An extension of the manifestations of relevance proposed by Saracevic (1996) is the introduction of activity relevance as a super-class of situational and motivational relevance (shaded in grey in Fig. 1). These relevance dimensions represent two different aspects of an activity: the motivation and the embedment in a situation. Yet, it will not always be possible to clearly separate these relevance types, since in practice they often might overlap to some extent.

4 Relevance assessment and relevance measures for mobile cartography

The objective of relevance assessment is to formalise the relation between geospatial objects and the different dimensions shown in Fig. 1. Intuitively we might propose some general rules of thumbs for the assessment of relevance for geospatial objects that build a kind of hierarchy of relevant objects:

– nearer objects are more relevant than objects further away
– visible objects are more relevant than hidden or invisible objects

– audible objects are more relevant than inaudible objects
– important objects, although invisible or inaudible, and most probably further away, can still be relevant due to intrinsic characteristics
– an object or an object's attribute is relevant, if it is needed for the successful completion of an activity
– objects that are linkable to users' prevalent knowledge are more relevant
– objects already well known to users are less relevant

Some of these rules can be formalised as will be discussed below. However, most formal approaches for relevance assessment deal mainly with non-spatial information. Nevertheless, the assessment methods can be adapted for geospatial information.

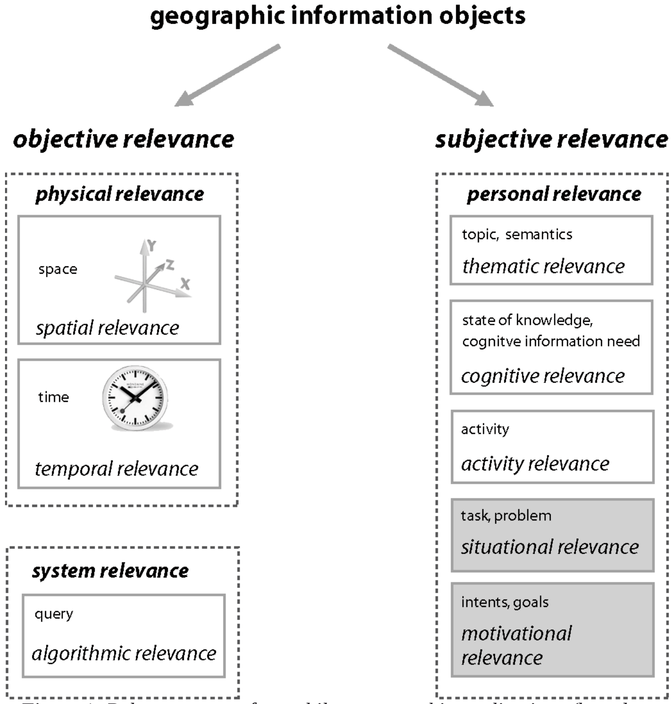


Figure 1: Relevance types for mobile cartographic applications (based on Saracevic, 1996)

4.1 Utility functions

Utility is an economical measure for satisfaction gained from products or services. Utility functions are a widely used tool in economics to model user preferences. A utility function $u : X \rightarrow R$ maps attributes of objects to preferences by assigning scores to alternatives in the set *X* (http://en.wikipedia.org/wiki/Utility; accessed 13/11/2005). If *x* and *y* are alternatives then $u(x) > u(y)$ states that *x* is preferred to *y*. An example of a simple function to model the utility of features dependent on their distance could look like the one depicted in Fig. 2. This function can look differently in different contexts, i.e. it can be adapted for diverse activities. In addition it can be applied to other relevance dimensions as well.

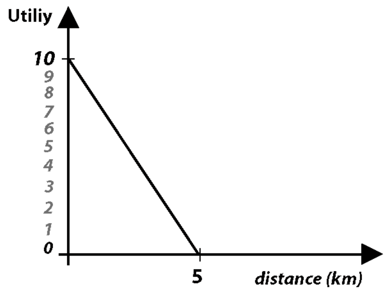


Figure 2: A simple utility function for spatial distance of objects

4.2 Information retrieval functions

Classic IR applies a vector space model for ranking documents according to their *similarity* to a query. IR methods relate the content of documents to the query that represents the user's information need. Classic document retrieval uses methods of semantic distance to evaluate the match of topic. Such techniques can also be used for the selection of topically relevant geospatial features based on their attributes. For a method of defining thematic distances see (Jones et al. 2001). An alternative approach is probabilistic IR aiming at ranking documents according to the evaluated *probability* of relevance to the user's information needs (Crestani et al. 1998).

4.3 Fuzzy sets

Fuzzy set theory proposes a way to model elements that do not belong to a set in a binary way, i.e. is or is not a member of the set. Instead different membership functions can be applied to define the degree of membership to a specific set. A membership function for a fuzzy set *A* looks like $\mu_A(x) \in [0,1]$, i.e. *x* is assigned a value between 0 and 1. Typical membership functions are the triangle or the trapezoid function. Schmidt and Gellersen (2001) propose a model of context validity based on fuzzy set theory that can be easily altered for purposes of geographic relevance. The approach models the spatial and temporal decrease of validity of context in relation to its origin. In the same manner spatial and temporal relevancy can be modelled.

4.4 Observation-based approaches

The relevance of geospatial objects can also be derived from observation. From the knowledge about what feature types are typically associated with and hence relevant for specific activities an enumerative list of typical activity-feature relations can be posted. The spatial range of the activity further defines the set of the spatially relevant objects for that activity. An alternative and more advanced approach is the logging of movement traces and feature selections that can serve as examples for machine learning algorithms to induce rules for feature selection or as the base for calculating a relevance score based on the observed frequency of requested features for a specific activity pattern. Attempts of modelling spatio-temporal behaviour of users for LBS are described in (Mountain and Raper 2002).

4.5 Geographic information relevance assessment

Approaches to formalise relevance or importance of geospatial information are rather rare (Zipf 2003; Reichenbacher 2004; Reichenbacher 2005). The calculation of isolated relevance for the corresponding relevance types might improve the utility of services, but generally interdependencies exist between the single relevance dimensions and a concurrent determination of a compound relevance factor is certainly advantageous. An example of calculating such a compound relevance factor for events based on this approach is described in (Reichenbacher 2004). Individually calculated spatial, temporal, and thematic relevance values are summed up to a total relevance factor indicating the relevance of an event to the user with a specific topic interest at a certain location and time.

The spatial relevance is modelled as a function of spatial distance of the objects (*O*) to the current location (*L*): $R(O) = f\left(dist\,\overline{OL}\right)$ Likewise temporal relevance can be modelled as a function of the temporal distance between the time of usage and a time reference of an object or event: $R(O) = f\left(dist\,\overline{t_O t_L}\right)$. Thematic relevance can be modelled as a function of the distance between feature attribute values and query terms organised as concepts (*C*) in an ontology. Then a semantic distance function could look like: $R(O) = f\left(dist\,\overline{C_O C_q}\right)$. Such methods for computing semantic similarity measures are described for instance in the SPIRIT project (Jones et al. 2001). Simplistically the general relevance R for an object O_i can be modelled as a function:

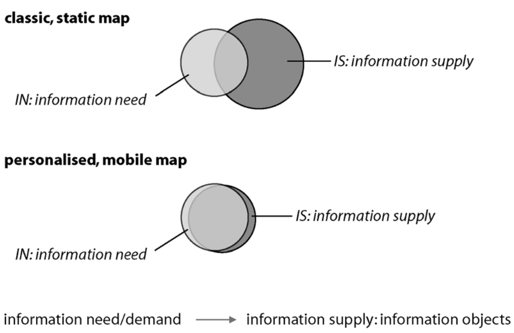
$$R(O_i) = \sum_{j=0}^{n} w_j \bullet r_j \;;$$

where *j* is the relevance type (spatial, temporal, …), r_j is the value for the relevance type j, and w_j is the weight for value j.
The setting of weights for the considered relevance types is dependent on context. In practice not all relevance types have to or can be considered in the function. Yet, the consideration of more than one relevance type produces a more differentiated picture of object relevancies (see Reichenbacher 2005).
Of course the proposed calculation is oversimplified and does so far not take into account mutual influences of the single relevance dimensions. In addition, apart from the spatial distance to the user's position spatial relevance might become apparent as (1) an area of interest (AOI) and (2) an activity or social space. Correspondingly temporal relevance (timeliness) can express itself as (1) a time period or interval (e.g. duration, day, or month) in which a point of interest is relevant or an activity is practicable, (2) reachability (means of transport/timetable; speed; constraints) or (3) qualitatively or socially defined times (e.g. leisure time).

5 Applications of relevance in mobile cartography

The application of relevance to mobile cartography is twofold: 1) relevance of geospatial features in relation to a specific usage situation may be used for selecting or filtering geographic information from geodatabases. 2) relevance measures can be applied to the map graphics to visually encode the differences in relevance. Both applications should improve the usability substantially by increasing the relevance of the presented information. It has to be stressed here that the two different applications reflect together the significant distinction between the terms *relevance* and *saliency*. The former relates to geospatial objects in the (geospatial) *information space*. The latter refers to map objects in the *visual/symbolic map space*. The main task of cartography is to select as many relevant objects as possible and portray them adequately as salient features in a map (Dent 1999). This construction of relevance for mobile usage situations is achieved through personalisation which is not equally feasible with static map products (Fig. 3).
Classic static maps have to supply a greater quantity and more general kind information to meet different information needs not known a priori. Mobile, personalised maps on the other hand can be based on queries that express an information need and can be much more tailored to specific usage contexts. By that they tend to include more of the relevant and fewer of the irrelevant objects.
The design methodology for mobile maps follows quite tightly the thematic mapping approach. The two main parts of the map are the base map layer and the thematic layer.

Figure 3: Relevance enhancement through map personalisation



General and universal information that is more or less equally relevant for all kind of mobile maps is collected in the base map layer. This layer holds the information necessary for orientation and spatial reference. However, referential information can also be selected in a hierarchical manner as distinct levels of detail.
On top of the base map layer specific features relevant for the usage context are composed to one or several thematic layers. The content of such a layer is dependent on the spatial problem to be supported by it. For localisation support the user's position in the map and visible landmarks have to be shown. For way finding support possible routes and route specific landmarks need to be included in the map. In addition features matching the user's interests (e.g. historical sites), special needs (e.g. WC for handicapped) or role (e.g. tourist) might be contained along the route. To support user activities the relevant features for a specific activity are portrayed in

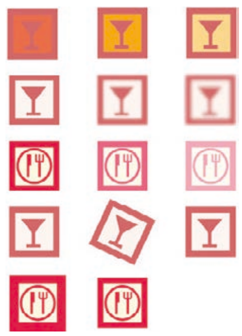
the layer. Features that are of general relevance to the activity can be separated from additional features that are user specific for that activity. For instance, for the activity *biking* the thematic layer might show bike routes depending on user specific characteristics or interests, e.g. young/old, fit/unfit. Features matching the general topic of interest to the user form thematic map layers. The thematic information is either presented as individual points of interest (POI) or areas of interests (AOI) that might be clusters of POI.
The producing of mobile maps starts with filtering geographic information based on relevance. In a first step spatial filtering is accomplished by pre-selecting those features included in an AOI for instance through the activity zone. The application of buffers is an alternative method for pre-selecting relevant objects for specific locations or along routes.
The parameters for a geographical object query can be derived from the context parameter values. The OGC Filter Encoding Implementation Specification (OGC 2001) offers a wide range of operators to build filter expressions for queries. Spatial operators are used for comparing the spatial relations between the query and the features (e.g. *within*, *overlaps*, *intersects*, *contains*, *DWithin*, *BBOX*, etc.). The non-spatial properties can be filtered by comparison operators such as $=$, $\neq$, $<$, $>$, etc. Both types of operators can be composed to more complex filters by applying the logical operators. Temporal relevance filtering can be based on feature information, if a temporal relation is stored as an attribute of the feature. Thematically relevant objects can be filtered by comparing feature attributes with query terms.
Alternatively features might be filtered based on a pre-computed normalised compound relevance measure. The selection of relevant objects against non-relevant would then be determined by the setting of a relevance threshold value, e.g. retrieve all objects with $R > 0.75$.
As explained above there is a difference in relevancy and appropriateness or adequacy of the presentation. A high value of information relevance, i.e. feature filtering, alone does not necessarily lead to a high degree of relevance of visualisation where cartographic knowledge is essential. The overall relevance of a presentation of geographic information might not fully exploit its potential. Through different adaptations in the visualisation domain a higher total relevance of a mobile map service can be realised (Reichenbacher 2004). The next chapter illustrates possible techniques of visualising differences in relevance in mobile maps.

6 Relevance visualisations

Mobile map based services aim at presenting geographic information with the highest possible relevance to the user. First of all the selected or filtered objects need to be appropriately symbolised. An augmentation to the service utility is the visual presentation of the relevance of the objects that can be more efficiently processed when synoptically perceived.
One way to visualise relevance in a mobile map is the direct mapping of relevance values to graphical variables, i.e. the attempt to transform relevance values to salience cues. Thereby either binary relevance, i.e. relevant and non-relevant, or degrees of relevance (relevance order, grades of relevance) can be encoded. The cartographic toolbox is rich in techniques for putting visual emphasis or focus on important features or for emphasising their relevance respectively. Some examples are listed below and also illustrated in Figure 4:
– highlighting the object using luscious colours, e.g. pink or yellow (*colour*)
– focussing the object while blurring the other objects (*clarity*)
– decreasing the opacity of the object against the other objects (*opacity*)
– rotating a symbol against the other symbols of the same kind (*orientation*)
– emphasising the outline of the object (*size*)

Moreover dynamic variables such as *duration*, *frequency*, or *order* can be applied to animations of the classic graphical variables to attract the user's attention, i.e. to show for instance the most relevant object among relevant objects. For such examples like colour transformations, symbol rotation or blinking symbols, or increasing and shrinking, as well as further examples of application of different graphical variables and metaphors (hotspot metaphor, fade-away metaphor) to the relevance visualisation of POI and events see (Reichenbacher 2005). The relevance of POI can intuitively be visualised as different grades of opacity values for the POI symbol (Fig. 5 left). Generally the features of the base map are symbolised in grey or in very light colours as shown in Fig. 5 left and right. However, if single feature classes or features are highly relevant for an activity or context they can be emphasised by showing them in colours commonly used. In the case of an intended 'walk through the nature parts of the city' the green areas and water courses and bodies are relevant and would be specially accentuated (Fig. 5 middle). A possible way to intuitively convey the relevance of different AOI is the cold-hot metaphor. Different grades of blue and red hues are picked to present the hotness or coolness of an area (Fig. 5 right).

Figure 4: Examples of feature emphasising techniques usable for relevance visualisation



Although the usability of mobile map based services is likely to be improved by incorporating relevance, it poses at the same time new problems: so far it is not clear which graphical variables are more apt for efficiently visualising relevance. In addition, the meaning of relevance symbolisation encoded is not always obvious for the user. Colours of map symbols and relevance symbolisation might disturb each other or colours might be already taken by map symbols and may no longer be available for relevance visualisation.
Technically relevance filtering and visualisation are implemented within an adaptive geovisualisation service as described by (Reichenbacher 2004). The service sends requests to a *Web Feature Server* (WFS) which in turn delivers features encoded in GML that can be transformed to *Scalable Vector Graphics* (SVG) encoded maps through *Extensible Stylesheet Language Transformation* (XSLT). This

Figure 5: Relevance of POI encoded with opacity (left); colour-grey contrast (middle); hot-cold metaphor (right). (© base data: Städtisches Vermessungsamt München)

approach offers various possibilities for bringing more relevance into the service. First, filter operations can be included in the WFS request and second the XSL transformation allows for the mapping of context derived relevance values to graphical variables which are mostly easily codable as SVG elements.

7 Conclusions

This paper aimed at unveiling the benefits of a deeper understanding of the relevance concept for mobile cartography and illustrated that applying relevance values to mobile geovisualisation services can enhance the service usability. Further research should focus on connecting typical activities of mobile users, their embedment in contexts with fitting feature sets and the most suitable presentation forms for these activities. The general feasibility and performance efficiency of relevance computation must be proved before an application to mobile services can make sense, since time is one crucial factor in mobile services. Further enhancements should focus on interdependencies of the single relevance dimensions and a more differentiated formalisation of the relevance assessment. The effects of relevance filtering and visualisation within map based mobile services need to be tested in user studies with everyday tasks.

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Wireless Campus LBS - A test bed for cartographically aware database objects

Barend Köbben, Kavitha Muthukrishnan, Nirvana Meratnia, Georgi Koprinkov

1 Introduction

The Wireless Campus LBS project has been started in early 2005. It's an informal co-operation between people at the University of Twente (UT) Computer Architecture Design and Test for Embedded Systems group (Arthur van Bunningen, Kavitha Muthukrishnan, Nirvana Meratnia, Georgi Koprinkov), the UT department of Information Technology, Library & Education (Sander Smit, Jeroen van Ingen Schenau) and the International Institute for Geo-Information Science and Earth Observation (Barend Köbben). The initial ideas for the CampusLBS were reported earlier in the workshop report in [1], its first test phase was executed and reported on during SVG Open 2005, the 4th Annual Conference on Scalable Vector Graphics [2]. The Wireless Campus LBS is intended to *serve as a test bed* for research as well as to *benefit from the outcomes* of this research. The research mentioned goes deeper into Wireless LAN *positioning techniques*, into *context awareness* of ubiquitous data management system, and into adaptive delivery of mapping information for LBS and mobile applications by using *cartographically aware database objects.*
This paper firstly describes the setup of the system as realised until now (September 2005) and reports on the results of the first real use case, providing the participants at SVG Open 2005 with an LBS to help them navigate the conference locations and locate fellow attendants. Secondly the paper will introduce the use of the Wireless Campus LBS as a test bed for the application of cartographically aware database objects.

2 The Wireless Campus at the University of Twente

In June 2003 the "Wireless Campus" was inaugurated at the University of Twente (UT), allowing cable–free internet access to staff and students anywhere on campus. University of Twente is a young university in the Eastern part of The Netherlands. It employs 2 500 people and has over 6 000 students. On its campus, the university has 2,000 student rooms. The university campus is situated between the cities of Enschede and Hengelo, near the Dutch–German border. Spread over the 140–hectare campus 650 individual wireless network access points have been installed, making it Europe's largest uniform wireless hotspot. Anyone with a PC, laptop, PDA or other WiFi (wireless fidelity) enabled device can access the university's network and the internet from any building, the campus park and other facilities without cabling.
University of Twente's Wireless Campus aims at a broad range of research and applications of wireless and mobile telecommunication. Furthermore, a project has just started in cooperation with Enschede Municipality to install further access points to also cover the downtown area of Enschede.
Research projects investigate the technology and the applications of wireless and mobile communication in several ways, mostly in cooperation with industrial and other knowledge partners. The Wireless Campus has become a 'test bed' for wireless and mobile applications. The major part of this research takes place at the Centre for Telematics and Information Technology (CTIT) and the research institute MESA+. Both are key research institutes of the University of Twente. MESA+ is an institute that conducts research in the fields of nanotechnology, microsystems, materials science and microelectronics. CTIT is an academic ICT research institute of the University of Twente. It conducts research on the design of advanced ICT systems and their application in a variety of application domains. Its Computer Architecture Design and Test for Embedded Systems Group became interested in using the WiFi technology in the wider framework of the *SmartSurroundings* research program. This program is "investigating a new paradigm for bringing the flexibility of information technology to bear in every aspect of daily life. It foresees that people will be surrounded by deeply embedded and flexibly networked systems (…). This presents a paradigm shift from personal computing to ubiquitous computing, (…). Relevant knowledge areas include embedded systems, computer architecture, wireless communication, distributed computing, data and knowledge modelling, application platforms, human-computer interaction, industrial design, as well as application research in different settings and sectors" [3]. An important part of such systems is establishing the position of persons, services and devices, and one of the possible strategies to achieve that is to use WiFi technology.

3 Positioning using WiFi technology

Using WiFi technology for positioning is just one of the many wireless techniques available for positioning of mobile users. There are various reasons to choose WiFi based localization. One is the fact that it is an economical solution. Because the wireless network infrastructure already exists, localization can be done by software-only methods without adding any additional hardware. Secondly, compared to other techniques such as InfraRed, Bluetooth or RFID, the range covered by WiFi is larger. Thirdly, such as system is scalable and (re)useable in many situations, because wireless networks are currently being deployed all over the world in places like universities, airports, offices, shopping malls, etc.

3.1 Methodology

As in most WLAN-based indoor positioning systems, our localization algorithm relies on the observed signal strength distribution as its input to determine the location. There are three basic methods of using WiFi signals for determining the location of users [4]: (a) triangulation that requires at least three distinct estimates of the *distance* of a mobile device with a WiFi receiver from known fixed locations, (b) using the direction or *angle of arriva*l of at least two distinct signals from known locations and (c) employing *location fingerprinting* schemes. In indoor areas, the signal will almost always be reflected from various objects (such as walls and ceilings). Because of this multipath environment, techniques that use only triangulation or direction might not be very reliable. Location fingerprinting refers to techniques that match the fingerprint of some characteristic of the signal that is location dependent. The fingerprints of different locations are stored in a database and matched to measured fingerprints at the current location of a receiver. In WLANs, an easily available signal characteristic is the received signal strength (RSS) and this has been used in CampusLBS for fingerprinting.
But the RSS is a highly variable parameter and issues related to positioning systems based on RSS fingerprinting are not understood very well. The big advantage of RSS-based techniques is that we can use the existing infrastructure to deploy a positioning system with minimum additional devices. It is far easier to obtain RSS information than the multipath characteristic, the time or the angle of arrival, these all require additional signal processing. The RSS information can be used to determine the distance between a transmitter and a receiver in two ways. The first approach is to map the path loss of the received signal to the distance travelled by the signal from the transmitter to the receiver. With the knowledge of the RSS from at least three transmitters, we can locate the receiver by using triangulation. The main drawback is the necessary calibration of signal strength as a function of a particular location. There is a trade-off between the amount of effort put into the calibration (it requires lots of time and work and should be performed repeatedly) and the accuracy obtained. Little research as of yet has addressed the issue of optimising the calibration effort.
The current WiFi based component is based upon an earlier project called “FriendFinder” [5], done in 2004 for two specific buildings on the University campus. In this project a prototype client-server architecture was built, where the client program on the mobile device determines its location by detecting the Access Points (APs) in range and comparing them with data about the APs that are in a server-side database. This database stores the location in XYZ of the, their BSSIDs (the unique identifier of an AP), and the strength of their antenna output (in mW).
Tests have shown that the FriendFinder pilot achieved an average positioning accuracy just under 5 meters (4.6m), and only for non-moving devices. In the Wireless Campus LBS project the positioning component is part of a wider PhD research, described in [6], into a variety of positioning techniques for LBS. To achieve this, the research investigates the positioning algorithms, the filters and methods used, and also the effects of signal-reflecting obstacles on the measurements. These obstacles, such as walls and pillars, are included in the geodatabase and could therefore be accounted for in the positioning algorithm. Another area of further research will be the self-learning abilities of the system, that should theoretically make the positioning more accurate over time. One of it’s main research goals will be to have calibration-free localization preserving quality and accuracy.

3.2 Mapping the Access Points

The WiFi based positioning algorithm is dependent on an initial mapping stage, in which the coordinates of all the access points in 3D coordinate system had to be recorded in a database. For the FriendFinder project mentioned above, only a limited number of the Access Points (APs) had been used. As no geoscientists where involved at that stage, their positioning was done in a rather improvised way. The height of the APs especially was a problem, it was determined only by estimate and with respect to the building’s ground floor height. In this limited project that was not a big problem, as only one building was involved, but for the larger project the elevation differences between the buildings (more than 5 meters, which is a lot for the Dutch!) had to be taken into account.
The 650 individual wireless network APs that have been installed were only indicated on paper maps, one map per floor, of the individual buildings of the University. The base maps are print-outs from CAD–drawings (“blue–prints”) maintained by the Facility Management Services that have a high level of detail, but they are not georeferenced and thus have a local, arbitrary, coordinate system that’s basically just ‘paper coordinates’. Furthermore, the location of the APs had been indicated on these maps haphazardly by hand-drawn symbols at the time of installation of the devices.
Therefore the first task has been the digital mapping of the AP locations in a geodatabase. In order to do this, it was decided to digitise all locations using GIS software and digitally georeferenced versions of the CAD-drawings. The georeferencing was achieved by transformation of the CAD drawings, using control points from an overview map of the whole campus that is available in the Dutch national coordinate system “Rijks Driehoeksstelsel” (RD). It was established that it would be possible, when using simple first order transformations, to achieve Root Mean Square Errors of less than 0.1m.
For all buildings a base elevation was determined in meters above NAP (the Dutch vertical datum) by combining the campus map with the Actual Height Model of the Netherlands, a detailed elevation model of the whole country made by airborne laser altimetry, which has a point density of minimal 1 point per 16 square metres and a systematic error of 5 centimetres maximum [URL1]. In order to get precise location measurements, it was deemed necessary to physically visit all APs and use a laser measurement de-

vice to determine the relative location of the AP antenna with respect to the elements of the building present in the CAD drawings (walls, floors, windows). By combining these relative measurements with the georeferenced maps a precise XYZ location has been determined and put into a geodatabase. The added bonus is that all APs have been checked and additional attributes was gathered, such as antenna type, antenna connection length (for estimating signal loss), etc.

3.3 Localization algorithm

The WiFi device inside the laptop or PDA periodically scans its environment to discover access points in the vicinity. During the access point scanning phase, the BSSID address of the access points and their Recorded Signal Strengths (RSS) are determined and stored. At any unknown location ‘n’ in the conference venue, the variation of the signal strength will be:
a*t each n RSS varies as* $0 >= RSS <= MAX$.

However, the signal strengths are usually contaminated by noise. In order to have a better estimation of the actual location, an *exponential moving average filter* is employed to smoothen the signal strength. Equation 1 shows the formula used in doing so, in which
$\alpha = 0.125$ and SS denotes the observed signal strength:

$$\text{Current RSS} = \alpha * (1 - \text{Current RSS}) + \alpha\,(\text{previous RSS}) \qquad \text{(Equation 1)}$$

To compute the users location, the top three access points having the best signal strength are chosen. If the device gets only one or two access points in the scan, it can still estimate a position. But, as triangulation is used, the localization will be of better quality if at least three access points are used.

4 The Wireless Campus Location Based Services

Their has recently been a lot of industry and research activity in the realm of “Location Based Services” (LBS). The purpose of the project described here is not the development of ‘the’ or even ‘a’ Wireless Campus LBS, but rather to investigate and set up the *infrastructure* necessary for LBS’s based on it. It combines input from several research projects with the practical application of new as well as established techniques to provide useful services for the UT campus population.

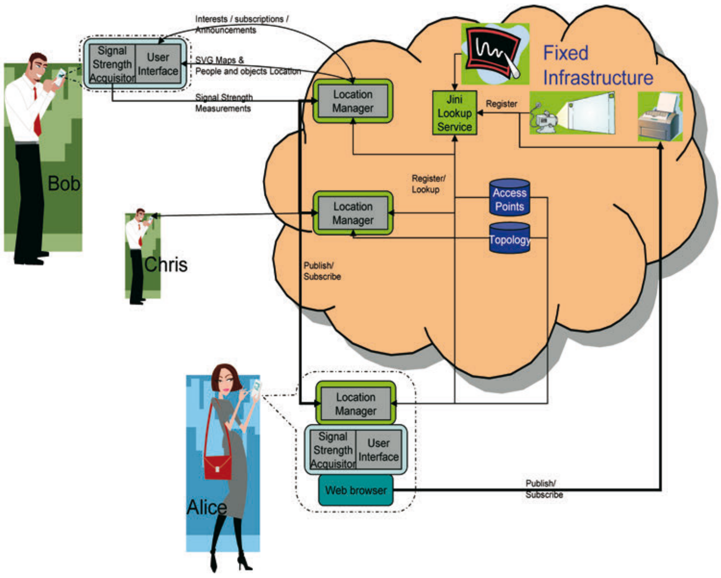
4.1 FLAVOUR: first tests at SVG Open 2005

The first use case test of the Wireless Campus LBS was to provide the participants of a conference held at the UT grounds this summer (15–18 August 2005) with an LBS to help them navigate the conference locations and locate fellow attendants. This conference, SVG Open 2005, the 4th Annual Conference on Scalable Vector Graphics [URL2], was deemed to be a good test bed as it drew a crowd of some 180 people from 20 countries all over the world, from a very wide field of applications: electronic arts & media, geospatial sciences, information technologies, computer sciences, software developers, Web application designers, etc. They share an interest in Scalable Vector Graphics (SVG), the W3C open standard enabling high-quality, dynamic, interactive, styleable graphics to be delivered over the Web using XML. Most of them are technology–oriented and there is a high degree of interest in, and ownership of, mobile devices.

The application built for testing by the participants has been called FLAVOUR (Friendly Location-aware conference Assistant with priVacy Observant architectURe). Services offered by FLAVOUR can be categorized into:

- *Pull services*, in which location of attendants play an important role as the attendants’ request will be replied by the system on the basis of their whereabouts. Examples of pull services offered are:
- Finding fellow attendants;
- Locating resources available in the infrastructure such as printers, copiers, coffee machines etc.
- *Push services*, in which individual and bulk messages are sent to the attendants. This enables the attendants to:
- Be notified about important events by conference organizers;

Fig. 1: FLAVOUR architecture (from [2]).



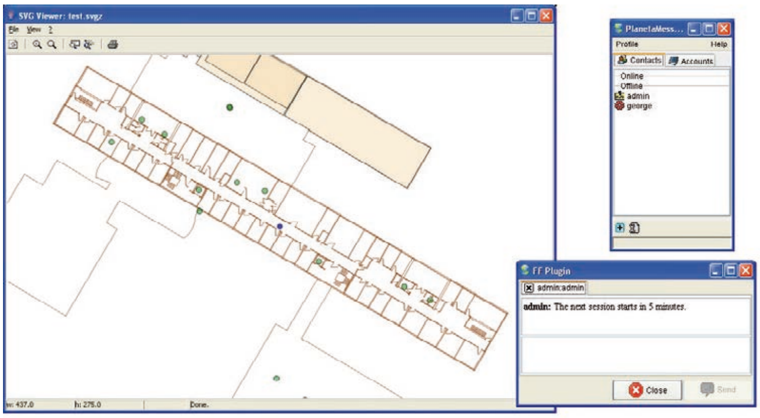


Fig. 2: Screen dump of the FLAVOUR user interface.

- Communicate with their contacts, i.e., colleagues, friends, etc.

The architecture, as seen in figure 1 and described in more detail in [7], is based on a Location Manager, which provides services using the Jini platform [URL3]. Jini is a Java-based open architecture that enables developers to create network-centric services. Each Location Manager registers with the Jini Lookup Service to offer the location of the user it represents. Interested users can look up the service and subscribe to the location of a given conference participant. This is done using publish–subscribe mechanism. The Location Manager uses a privacy policy to decide if a client is allowed to subscribe to the location of its owner (publisher). It also publishes to all the subscribers relevant changes in the location of its owner.

The Jini architecture also provides other kinds of services, such as a message board to which every conference participant can subscribe. The message board can be used by the conference organization to publish changes in the schedule, information related to the social events, etc. Participants can also use the message board to make announcements to the other participants, as for example asking about lost objects, or to chat.

The graphical depiction of the maps and the location of the users is done in SVG, providing vector graphics in high graphical quality with a small memory– and file–footprint. The system also provides the user with an estimation of the current positioning accuracy. A screen dump of the user interface can be seen in figure 2.

The tests at SVG Open 2005 were relatively successful: Most conference participants experimented with the localisation features of the system. The messaging and friend-finder functions were used to a lesser extent. Various extensive interviews have been held with test persons and also written feedback was collected. The localization functionality worked quite reliably, although the accuracy was varying quite a bit over the various conference locations. In the computer science building the results were clearly better then in the main conference halls. The tests still have to be analysed further, but the most obvious reasons are the non-optimal configuration of access points and the fact that the database of these access points still was incomplete at the time of testing.

5 Outlook

The implementation of the Wireless Campus LBS described in this paper has only just started. But as it builds on the solid foundations of the well-established infrastructure of the Campus-wide WLAN at the University of Twente, and has had a successful pilot in the FLAVOUR tests at SVG Open 2005, we expect that it will be put into use and expanding relatively quickly in the coming years.

Probably the most exciting aspect of the project is the fact that it provides the opportunity for a very diverse group of people from quite different disciplines to contribute to a technical infrastructure that can serve as a test bed for their respective researches, and at the same time has the potential to become a useful everyday feature for mobile users at the University Campus.

The research mentioned has a wider scope then just this project: the Wireless Campus LBS is intended *to serve as a test bed for* the research as well as *to benefit from* the outcomes of the research. These research projects include the PhD mentioned in paragraph 3.1 on LBS positioning technologies and another PhD that concentrates on the impact of context awareness on ubiquitous data management [8].

On the client-side of the system, ongoing research at ITC on data dissemination for LBS and mobile applications [9] will be concentrating on the Wireless Campus LBS as a test bed for adaptive, task-oriented delivery of mapping information to mobile users using *cartographically aware database objects.*

5.1 Cartographically aware database objects

Cartography and GIS more and more involve the use of spatial database technology. In the database world, there is a growing focus on *context awareness* of database objects. One of the important context parameters is location awareness, which is important for all spatial applications. Our goal is to extend context awareness with the idea of database objects that are *cartographically aware*.

Traditionally, cartographers have been focussing on methods and techniques for visualising spatial phenomena. As these spatial phenomena are nowadays stored in GIS systems and spatial databases, they have developed the DLM-DCM paradigm: a *Digital Landscape Model* that models the geographic world in geographic objects (point, line, polygon or raster) with attached thematic attributes. And a *Digital Cartographic Model*, that models the various representations of the DLM in graphic objects (point symbols, lines, patches) with their graphic attributes (colour, width, etc.). The theoretical treaties on this paradigm usually do not describe how these two models should or could be connected, if or how the DCMs are to be derived from the DLM, etcetera. Also in practice, surprisingly little has been done in this field. Most GIS systems, for example, do give little or no support to achieve this

DLM–DCM model other than "by hand", or by providing some templates and default settings. Truly 'automated cartography' using this concept has in fact not been made possible.

Connecting this problem with the context awareness research in databases might provide a way forward. Instead of treating the DLM and the DCM as separate parts, why not have single spatial database objects that represent spatial phenomena and that are cartographically aware…? One might think of an object that represents a road. The object would be spatially aware in that it has a spatial representation (eg. as a vector), and may be cartographically aware that to be represented for topographic purposes at scale 1:25 000, its should be a 2 mm wide red line with 0.1 mm black casing. While this concept on first sight might not seem to work out much different than the traditional legend tables of a GIS system, the main strength is in the fact that here the cartographic awareness is on an object level, not on a per layer basis, and could be subject to all kinds of (database) rules and triggers. This way, the cartographic (and other) characteristics of the objects can be influenced by other database objects and their context.

As a simple example one might think of a location map in the Wireless Campus LBS where the spatial distance of the objects to the focus of the map (the users position) influences their representation: Interior walls only show themselves in buildings that the user is in, room numbers only if the user is within reading distance. But more complicated systems could be thought up, which might be especially useful for generalisation techniques that are hard to achieve in traditional layer-based systems. It is our intention to use the Wireless Campus LBS to test these concepts in practice and provide a proof of concept application.

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Towards Orientation-Aware Location Based Mobile Services

Rainer Simon, Harald Kunczier, Hermann Anegg

Abstract

Within this paper we present an approach on how orientation sensors built into mobile devices can enable a new paradigm for mobile service discovery and use: In conjunction with 3D models of urban terrain, mobile devices can act as virtual pointers to services and information anchored at geographic locations such as buildings or landmarks. We outline a system architecture that enables this new form of orientation- and location-sensitive service discovery. We describe our experiences with a prototype device consisting of a plain, mass market mobile phone and a custom-built shell that houses a magnetic compass and a 2-axis tilt sensor. Concluding, we describe our ongoing research project that will apply the described concepts and technologies in practice.

1 Introduction

Location based mobile applications are gradually gaining importance in the consumer electronics and telecommunications market. The growing proliferation of increasingly powerful handheld computing devices and the availability of relatively low-cost, embeddable GPS receivers have made navigation applications for PDAs and smartphones a popular product. At the same time, mobile network operators are adopting location based services (LBS) as an increasingly important component of their service portfolio [15]. Typical examples of LBS offered today are direction finding services or yellow pages-like services (e.g. “Where is the next pharmacy?”). Despite the fact that the success of LBS has as yet been less than anticipated, user evaluations have shown that the demand for location aware information is high [10]: Since users potentially have access to their mobile device all the time, they expect it to be of particular value for accessing information about unfamiliar environments or locations; when looking for a specific service or in emergency situations; or for accessing the kind of information that may change while they are on the move: Examples are traffic information or train schedules with delay information.

We argue that location aware applications offer a real added benefit to the user – provided that they deliver information that is relevant, easy to find and well-focused. Our work is motivated by the assumption that a more natural and intuitive way of discovering and using location aware services is essential for meeting these criteria. It can not only play a key role for an improved awareness and an increased use of current LBS; it can also open up new possibilities and application areas for future mobile service ideas.

This paper is organized as follows: In section 2, we introduce the idea of “Point-to-Discover” – our concept of accessing information and mobile services by pointing at geographic locations with a handheld device – and develop a possible system architecture for a Point-to-Discover service platform. In section 3, we address two technical issues that are crucial for the feasibility of our concept: the accuracy limitations of current positioning methods and orientation sensors and the availability of three dimensional environment models. In section 4, we focus on a prototype of a Point-to-Discover-enabled mobile device we developed. We explain the hardware used and point to related work. Finally, in section 5, we present our ongoing research project, in which we will practically apply the technologies and concepts described in this paper.

2 Point-to-Discover

The advent of 3G technology and more complex mobile devices poses challenges to researchers and designers of mobile applications: The mobile interface is restricted to tiny displays and keypads; information retrieval on the fly is slowed down by bandwidth limitations and network latencies. In all described restrictions we expect advances, but whenever interface components increase in size, they challenge the mobile devices’ mobility. For this reason we introduce a new user interface paradigm for how people can discover information on the go and use mobile services in the future, by combining orientation detection with accurate satellite positioning.

Today, users access mobile services and information through WAP menus or search engines, mobile operator portals or by simply entering a URL in their phone’s browser. We envision a more natural method of discovering services and information: With the help of three-dimensional models of urban terrain, services can be ‘anchored’ virtually at geographic locations. Mobile phones function as pointing devices towards these services. For example, users could access the train schedule, get delay or estimated arrival time information or purchase tickets online by simply pointing their mobile phone towards a train station; or they might participate in a sweepstake by pointing at an advertisement billboard.

An early realization of a similar approach was presented by Wasinger et al [19]: They describe the implementation of a navigation application on a PocketPC PDA. The application uses GPS in conjunction with a magnetic compass and allows the user to indicate

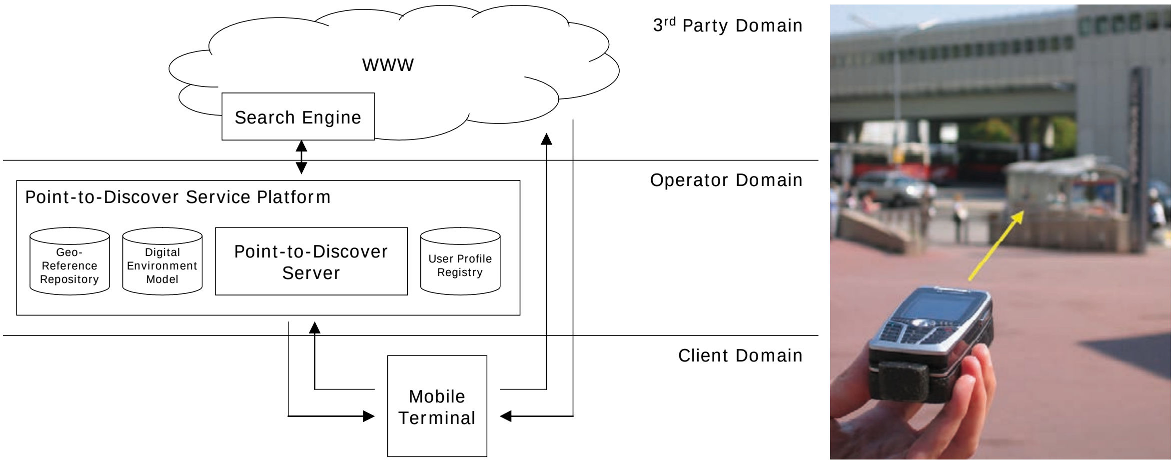


Fig. 1: Point-to-Discover service platform architecture and usage scenario

an area of interest on a two-dimensional map by pointing the device into a direction in the real world. The focus of their work, however, is primarily on multimodal and speech in- and output in the context of mobile navigation and exploration services.

We suggest to enhance the concept presented by Wasinger et al by adding the third dimension: Using the 3D orientation of the device – measured with a magnetic compass and a tilt sensor – and a 3D environment model rather than a 2D map, the system can determine the user's real perspective and specifically select the services that are available within the user's real field of view. Figure 1 portrays the architecture of a Point-to-Discover system as we envision it. Three domains constitute the system: The client domain consists of the user terminal running the necessary client software ("Point-to-Discover Browser"). The operator domain is formed by the Point-to-Discover service platform. The platform stores geo-referenced meta-data as well as geo-referenced links to content and processes the Point-to-Discover requests. It is important to mention that the actual content itself is not held in the operator domain. The operator domain merely provides the "lookup service" for the content offered by external providers over standard WWW infrastructure (3rd party domain). After the lookup, the client device will access the content directly from the 3rd party services, using the links received from the service platform.

The Point-to-Discover service platform consists of a digital environment model, the geo-reference repository, the actual Point-to-Discover server and (optionally) a user profile registry. The service platform can – but need not necessarily be – hosted and maintained by a mobile network operator. When the user points at an object in the real world and triggers a request, the mobile phone transmits its position and orientation sensor readings to the Point-to-Discover server. The server queries the digital environment model and identifies the area of interest that is indicated by the pointing ray (defined by the position coordinates and the orientation vector). With the estimated area as a parameter, the server queries the geo-reference repository.

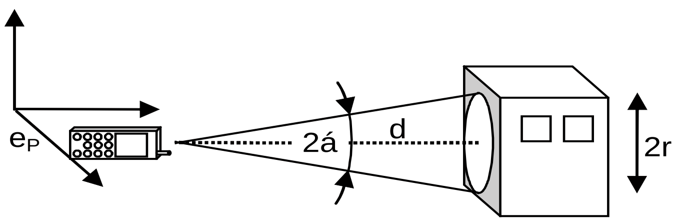
The geo-reference repository is a database that holds a list of geo-referenced links to 3rd party content and services. These links are maintained by the platform operator and therefore allow placement of specially promoted, branded services (such as e.g. the sweepstake linked to the advertisement billboard mentioned in the example above). Optionally, a user profile (stored in the user profile registry) can help to tailor the service selection towards the personalized preferences of the user before the list of service links is returned to the device. In addition to the user profile, the platform might take further external parameters into consideration: Time of day, time of year or the weather at the current location are just a few examples of context parameters that might help to match the service selection better towards the user's current situation.

Additionally, the geo-reference repository also stores geo-referenced meta-data, such as street or landmark names. The Point-to-Discover server can use this meta-data to generate a refined search query for an Internet search engine. That way, the user can obtain information about a landmark (e.g. a particular building of historical relevance) from the World Wide Web without the need to type; and even without the need to know the name of the landmark he or she is pointing at.

3 Technological requirements

For the successful implementation of a Point-to-Discover service platform as described above, two factors are critical: First, there are considerable accuracy constraints on both positioning and orientation detection that influence the quality of service selection. Second, the Point-to-Discover principle heavily depends on the availability of sufficiently accurate 3D environment models. In this section, we therefore first address the factors that lead to accuracy degradation. Secondly, we want to point out the relationship between our digital environment model and geo-reference repository components and Geographic Information Systems (GIS).

Fig. 2: Angular error.



3.1 Selection quality

Two sources of error influence the service selection process: The positioning error and the error introduced by the orientation sensors. Depending on the positioning method, positioning accuracy in the range of several 10 meters can be achieved in urban environment (see [17] for a comparison of different technologies). If we assume that the Point-to-Discover concept is required to identify an object with a radius r, at a distance d, the overall error is given by

$$e = e_P + d\tan(\alpha) \equiv r$$

with e_p being the positioning error and alpha being the angular error as illustrated in Figure 2. If we require to identify an object with a radius r=2.5 meters, at a distance of d=100 meters, the currently deployed terrestrial range based localization technologies are inadequate. The necessary positioning accuracy we would need to achieve is at least 5 meters, with no angular error. Assuming differential code phase GPS, which reaches an accuracy of $e_p \approx 1$ meter, we require a more reasonable angular error of ~1°.

3.2 3D environment models

The capabilities of the digital environment model and the geo-reference repository which are part of our Point-to-Discover service platform are closely related to the capabilities of Geographic Information Systems (GIS). Until recently, GIS were mainly restricted to modeling the world in two dimensions due to the high computational effort required for three-dimensional data manipulation and display and, in particular, the complexity involved with gathering three-dimensional environment data. More recent methods such as automatic or semi-automatic building reconstruction from high-resolution aerial imagery and/or LIDAR (LIght Detection And Ranging) scans, however, make gathering of large-scale three-dimensional environment data feasible [13], [9]. Further techniques, for instance combining aerial imagery with ground-level 3D laser scans and/or geo-referenced photographs [7], [11] even aim at automatically reconstructing detailed textured 3D models of urban environment. We argue that these advances in the area of 3D environment modeling indicate that sufficiently accurate large-scale data will indeed be readily available to enable the Point-to-Discover principle. In fact, our platform's digital environment model/geo-reference repository components can be implemented using commercial off-the-shelf 3D GIS, which are already available from a number of vendors and are e.g. being used by mobile network operators for network planning purposes.

4 Orientation-Aware mobile devices

Based on an ordinary mass-market Java-enabled mobile phone, we developed a prototype for a Point-to-Discover-enabled client device. The phone has a custom-built shell attached to its back that houses a three-axis tilt compensated compass module purchased from a commercial vendor. The module essentially combines a magnetic compass with a 2-axis tilt sensor on a single chip, mounted to a 2.5 by 4.5 cm printed circuit board. The sensor module is connected to the phone via the serial port.

4.1 Magnetic compass

The magnetic compass detects the heading of the device by measuring the direction of the earth's magnetic field. Unlike GPS-based methods, which derive the heading from the sequence of the most recent position fixes, this solution also works for stationary users. Magnetic compasses do not require extensive computational power, nor do they need any prior knowledge about the environment – both of which is the case for approaches based on optical image recognition ([12], [18]). First mobile phone models with comparable embedded magnetic compass sensors are already being introduced by handset manufacturers (e.g. Nokia model 5140). The compass used in our prototype device can reliably resolve <0.07mGauss. Compared to the typical magnetic fields in the x- and y- horizontal plane, which are in the range of 200 mGauss (more at the equator, less near the poles), it achieves a theoretical resolution of 0.02°. This resolution is practically superposed by magnetic sensor errors, variations of the earth's magnetic field, nearby ferrous materials, A/D converter resolution errors and temperature effects (as discussed for instance in [5]), summing up to a total accuracy of about 1-3° and 0.1° resolution.

4.2 Tilt sensor

The 2-axis tilt sensor detects the mobile phone's pitch and roll angles (compare Figure 3) by measuring the acceleration that is exerted on a small mass (or heated gas) by the earth's gravitational field. The mechanic principle of the sensor makes it particularly robust against external influence, such as electrical interference or magnetic fields. Compared to gyroscopes or electrolytic fluid based sensors, no rotating or pendulous parts are required, allowing smaller structures and higher resonant frequencies. The operating frequencies of such sensors easily achieve several 100Hz, thereby allowing the detection of fast user movements.

Similar to the heading error, the tilt error of the sensor used in our prototype is less than 1°, resulting from temperature effects and measurement noise [1]. The acceleration sensor reaches maximum sensitivity when held normal to the gravitational field (parallel to the earth's surface). Since the

Fig. 3: Tilt angle definitions.

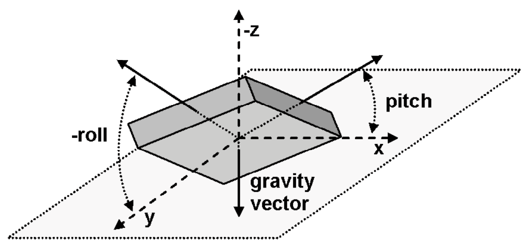


Fig. 4: Device prototype and demonstrator applications

tilt sensor used in our prototype is based on a single acceleration sensor for each axis, the resolution therefore decreases for tilt/roll angles above 60°. Consistent resolution of 1° for the entire range from 0 to 360° can be achieved by combining the measurements of 2 sensors arranged perpendicularly [1].

4.3 Related work

Hinckley et al [8] demonstrated how tilt sensor data can be exploited locally on a PDA device. His experiments were aimed at proving that orientation detection can be used beneficially as a novel input modality that makes single-handed operation more natural and intuitive. Examples from his experiments include the activation of screen-scrolling by tilting the device or the activation of the PDA's voice recording functionality by holding it to the mouth and ear like a phone. Hinckley's experiments also included discussions and measurements of error probabilities and false-positive detection for certain gestures, such as the voice-recording activation gesture. Similarly, Eslambolchilar and Murray-Smith [6] implemented tilt-controlled zooming and scrolling on a PDA device. Their test users found that tilt-based single hand control was an intuitive solution to the problem of navigating large documents on small displays. We implemented a number of applications that also use the orientation of the device for single-handed input. One example is an experimental concept user interface with tilt-controlled slide-in menus. Another example is a dexterity game where the user must guide a ball through a maze without dropping it into holes in the maze floor. A photo of the device prototype, together with pictures of both applications is shown in Figure 4.
Due to an obvious potential for mobile entertainment and gaming (which has already turned into an important revenue channel for mobile network operators, with an estimated market worth $1.2 billion by the year 2006 [3]) and the possibilities for novel input modalities like gesture recognition, handset manufacturers have recently announced a number of mobile phone models which will be equipped with comparable tilt or acceleration sensors. Similar plug-in sensors for PocketPC PDAs are also available commercially.

5 Creative histories mobile viewer

In addition to the local application of orientation awareness, as described in the previous section, we also aim to demonstrate the technical feasibility of the full Point-to-Discover concept in a practical setting: The objective of the "Creative Histories" project [2], [16] is to create a high-quality three-dimensional model of a cultural heritage site. The area being re-created is a square in downtown Vienna, Austria: the Josefsplatz. The virtual 3D model of the Josefsplatz is thereby not just confined to its current constructional state. Rather, it encompasses the constructional state in different historical stages throughout history: Users of the system will be able to navigate through the model in real-time and virtually move back and forth in time. A second objective of the project is to associate a virtual information space with the 3D model: Users can quickly and intuitively retrieve different types of historical information and media (such as textual information, historic images, photos or audio and video documents) related to certain locations, such as buildings or landmarks on the square.
Based on the device prototype introduced above, we are implementing a client application for a mobile smartphone device. With this application, the phone acts as a "real-world navigation tool" to the Creative Histories system: The user's field of view on the square is continuously determined by the on-device GPS and orientation sensors. By downloading appropriate chunks of 3D geometry and suitable textures from the geometry server, the mobile device can render a live simulation of what the user's view looked like in a different historical epoch – the screen acts as an interactive "window to the past". The application also indicates when there's additional information available for a certain building or object. The user can access the information by pointing the device towards the real-world object and selecting it in the 3D simulation [4].
Figure 5 shows a view of the Josefsplatz together with an emulator screenshot from an early version of the viewer application, which features a yet untextured environment model. As can be seen, the application implements the Point-to-Discover metaphor described earlier: Using positioning and orientation detection, the mobile phone functions as pointing device in the virtual 3D model of the real world. Furthermore, the application extends the basic principle by also representing the 3D model itself visually on the screen.

6 Acknowledgements

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Fig. 5: Creative Histories mobile viewer application (untextured model)

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Intuitive GIS-based Interaction for Mobile Services

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Since the introduction of graphical user interfaces the methods of user-computer interaction have mainly remained unchanged. Commonly used modalities like typing and clicking are quite appropriate for standard applications, but they are not suited for more complex tasks like access to geographical data. To improve the communication between human beings and computers in such situations, the department of Graphic Information Systems of the Fraunhofer Institute for Computer Graphics (IGD) have developed a system that addresses effective information visualization by integrating domain knowledge and knowledge about human situation awareness, a well-suited representation of and interaction with multidimensional maps even on mobile devices.

Mobile hardware is continuously getting smaller and lighter; and the communication bandwidth is increasing. Continuing advances in the area of communication technologies enables users to get access to information from everywhere at every time. According to getting cheaper prizes for hardware and communication more and more people are enabled to be part of the computer revolution. Today even a mobile phone is suitable to use mobile services, which may be used by everyday users.

Without long training periods all the users want to get access to information they are looking for. They will use services of other provides, if this is not possible and other solutions are available. Intuitive to use user-computer interfaces are required. But compared to the rapid progresses in the communication technology area, the development results to user-computer interaction are clearly lagging behind. Today's services are mostly simple text-based query and answer systems.

Difficulties becomes apparent when a destination addresses have to be specified that correspond to a user's mental image of a location. If the user doesn't know or simply can not remember e.g. the name of a street, he has to describe the object or the surrounding environment of interest, which he has in mind. Even if a keyboard of a mobile device is available, it's difficult for the users to describe the corresponding query in a verbal way. Even if possible a common presentation of textual information or a fixed map is also not suitable. The understanding of results containing geographic data like the recognition of buildings is not supported.

We are presenting a system, which enables efficient interaction for Location-based Services. Our solution addresses the described functional drawbacks of traditional Geographic Informationsystems (GIS) applications, when using such systems in mobile scenarios. In particular we are presenting a solution based on ontology- and context-driven components, an alternative interaction metaphor, a mapping algorithm suitable for imprecise and ambiguity data and a suitable presentation of results. There may be other important components required to realize specific applications in the area of mobile GI-Systems, but the proposed components can provide a foundation for such systems. They may also be used in other domains like desktop solutions. In particular though, the importance of our approach can be shown in the specific area of mobile applications, where specific characteristics of the usage and the devices have to be taken into account.

We propose a graph- and sketch-based interaction for mobile applications in our paper. The processing of flexible user inputs is helping to realize a more successful communication between man and computer. More directiveness (less difference between the goals of various users, their expectations, proceedings and the user interface) is supported. Applications based on our system enable users to simply sketch objects and gestures as well as to place objects in the query area by use of icons. Spatial relationships can be described simply and effectively and can be very well obtained in a visual manner. In this way, specifications can be reinterpreted more easily. Humans and computers become better aware of the current task. Misunderstandings can be detected and avoided sooner.

In our technology driven paper, we will describe our concept and architecture in detail and how they can be used to build intuitive and efficient mobile systems. We will also describe possible uses of such systems in different scenarios.

Fig. 1: Screenshots of the developed application based on the proposed system with graph- and sketch- interaction

Geo-Services and Computer Vision for Object Awareness in Mobile System Applications

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Abstract

In recent years, location and context aware systems have been presented for the indexing and annotation of both location and user state relevant information to the user. These systems were mostly based on geo-referencing from GPS signals, and driven by changes of the system state in dependence on situations that impact the overall system performance (user pose, energy consumption, responsiveness, etc.).

In this paper we focus attention on a completely innovative aspect of contextual indexing for mobile system applications. We claim that the application of geo-services and vision based sensing enables to determine *object* characteristic information that can be used for *semantic indexing* of information and thereby provides an innovative quality of service. Computer vision can be used to extract object information, such as, the identity of buildings (Figure 1), information signs, persons, etc., and thereby enables object based indexing which can finally be applied to extract a semantic description of the environment. Geo-services are mandatory to support vision based object recognition and semantic indexing in several ways. Firstly, location based sensing provides a prior on the geo-reference of the objects in the field of view, reduces the number of possible object hypotheses and therefore can dramatically simplify the complexity of recognition. Secondly, vision provides an estimate of the user position from the geo-referenced object information. Geo-services can use this to reason more efficiently about a current object and user position.

1 Introduction

Computer vision is an emerging technology for providing reliable vision competences outdoors, dealing with the immense complexity of the visual input and associated degrees of freedom in image understanding. Mobile imaging as an upcoming technology will become ubiquitous such as in camera phones, vision enhanced handhelds, and wearable cameras. Mobile vision technology would make new approaches possible in scenarios of personal assistance, mobile work, assistive services and also in general location based services.

Services, based on location awareness, require the knowledge about the actual location of the user, the current user context and geo-referenced information about areas and points of interest. Different technologies can be used to fulfill these requirements. Location awareness can be provided based on GPS, using wireless network technologies such as GSM and WLAN or using self-location possibilities e.g. based on street names and house numbers. Location awareness for a mobile service in urban areas can, by the use of GPS only, not be assured everywhere and anytime, because of the known weaknesses of GPS signal availability in urban areas. Mobile systems operating in urban environments must take advantage of contexts arising from the spatial and situated information at a current location of the pedestrian user. Therefore, location awareness can be realized based on the knowledge of the location of the geo-referenced objects of interest, which allows also determination of the user position.

In frame of the projects MOBVIS (“Vision Technologies and Intelligent Maps for Mobile Attentive Interfaces in Urban Scenarios”, EC funded project) and “Mobile City Explorer”, which is a national funded project (Austrain Space Agency), a scenario of city exploration (see Fig. 1) is proposed [LPA05], where the tourist pedestrian can send visual queries to a server based object recognition system. The goal of the system is to attain situated object awareness, i.e., to get the semantic information about the environment for object and location identification, to get semantically indexed access to knowledge data bases. This methodology has the advantage that the object information is most appropriate to structure perception, and to structure the indexed search into annotation information.

In the following chapters a mobile application system (see Fig. 2) will be described which offers area-wide location awareness based on a common smart-phone and image based object recognition tool in combination with a GPS module.

2 User scenario

This section briefly describes a user scenario, in case of a city-tourist type pedestrian, focusing on the service of image based object recognition.

The common way of doing city sightseeing is using a printed city map with integrated sightseeing-tours leading the tourist along a pre-defined path from one sight to the next. Brief descriptions of the sights can be found at the backside of the map.

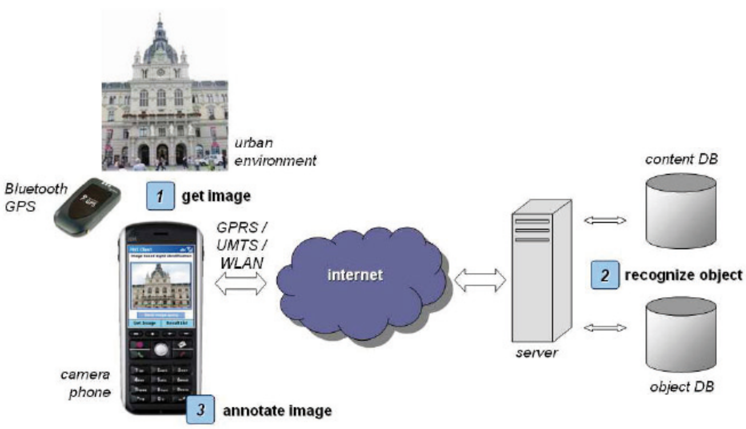
Fig. 1: Scenario: capturing an image about a building object of interest that is to be identified by the system.

By the use of the image based object recognition service the tourist gets the freedom to explore the city without any pre-defined sightseeing tours.
The tourist moves completely free through an unknown area and if he is interested in any object (e.g. a historical building or a statue) he just has to take a picture of it with his camera-phone, with or without GPS device connected, and pressing the "Identify" button. As result he gets a detailed description of the object containing multi-media tourist information. As a second achievement he also gets the position of the identified object which can be used for navigation. As the position is well known from the GPS device or the object recognition the Geo Services are able to render a map showing the surrounding area. This map is also sent to the tourist as part of the response of the object recognition and gives him an overview of the near ambience.
Our user scenario and the role of image recognition in mobile tour guides was well-investigated in an usability study by Nigel Davies, Keith Cheverst, Alan Dix and Andre Hesse [DCDH05]. The result was that there is a very high acceptance for image based object recognition by tourists.

3 System architecture

We will briefly describe how a common smart-phone with built-in digital camera can be used for image based object recognition. A GPS device, built-in or connected to the phone via cable or Bluetooth can help to accelerate the recognition process considerably. The overall concept consists of three main phases.
In the first phase, a software client is activated by a user on his personal smart phone. The software can be directly downloaded from a website to the internet enabled smart-phone and will then be installed on the device. The software-client offers functionality to capture an image of an object the user intends to identify. Next, if available, the smart-phone reads the actual position from the GPS device. If the GPS cannot obtain a position for any reason, the cell information of the phone-network provider can be used to approximate the user location instead. The image of the object and the position of the snapshot-location are combined together into a SOAP Message and send to an image-recognition web-service, running on a dedicated server, over a common wireless internet connection like GPRS or UMTS.
In the second phase, the web-service reads the request from the client (smart-phone) and extracts the image and the GPS position. The image is then analysed by a dedicated recognition algorithm to obtain representative image features like local descriptors that characterize a specific object. Next, these features are compared with reference features stored in an object-database. The database contains images of different objects, with the pre-processed features and the position of the snapshot-point. The object is then identified by matching the features of the user-picture with the features of in the database. This matching process can become, in the case of a large database with many objects, very time consuming and that is where the GPS position can help. To accelerate this process the set of objects under investigation in the database can be selected with the users GPS position. Only those database objects come into account for the matching process, which have corresponding images with a snapshot-point near the users-position. (Fig. 3) Once the object is identified the object-database is queried for some information containing text and pictures. This information is integrated into a SOAP-message and is then send to the smart-phone client as response.

Fig. 2: Overview of the mobile application systems concept



In the third phase the web-service response is presented to the user on the smart-phone. Additional to the object quick information, containing text, pictures and a location based city-map, there is an URL which can be used by the user to obtain detailed information about the object. The URL can be viewed in a common smart-phone internet browser like "Opera" or "Pocket Internet Explorer". The URL contains, as a parameter, the unique identification number of the desired object and links to a dynamic website, which is generated at runtime on the server. The layout of the website is optimized for the requesting hardware platform – because different smart-phones have different display resolutions. Fig. 2 illustrates the complete technical concept and its three phases.

The aim of this client-server architecture is to bring the image based object recognition service to any person using a common camera-phone and to gain scalability in reference of the number of objects in the database and complexity of the image-recognition algorithms.

4 Visual object recognition for object awareness

In contrast to signal based approaches as proposed in most location based services, object awareness points towards semantic indexing which will enable much more flexible interpretation of the information from a local environment. Object awareness relies on a structural matching process of comparing the situated information extracted from the sensor streams with prototypical patterns that were developed from experience. In the case of computer vision, object recognition methods enable to identify characteristic patterns of visual information in the field of view, such as, infrastructure objects (tourist sights, traffic signs, information boards, etc.), people, or objects of every days use (chair, lamp, mobile phone, etc.).

Fig. 3: Geo-Context, e.g., from GPS based position estimates ('M' with blue uncertainty radius), can set priors by geographically indexing into a number of object hypotheses ('X's are coordinates of user positions while capturing images about objects of interest).

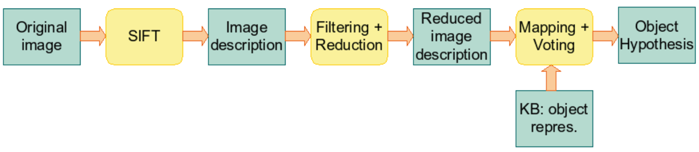
Our proposed image based service for object awareness requires both, robust and fast visual object recognition of typically low-quality outdoor images. We therefore applied a methodology that is highly suited for mobile vision applications, i.e., the Informative Features approach [FSPB04]. This method extracts state-of-the-art local image features, i.e., SIFT (Scale Invariant Feature Transform) descriptors [LOW04], from the greyscale image, in a first step. These texture patterns are then analysed to identify among them the most informative descriptors which are retained to establish a kind of attention filter. Responses in terms of most informative features are then matched to reference descriptors to provide a probability distribution on a pre-determined set of object hypotheses. In addition, the Informative Features approach enables to detect any object presence in the image, and background vice versa [FSPB04]. We also provide a confidence value to quantify the degree of uncertainty in the final object decision, and thereby enable to define a 'quality of service' measure for usability analyses.

5 Geo Services

As already mentioned, the knowledge of the tourist position is a very important fact within the system, not only for routing and guidance purposes but also to support the matching algorithm for the object recognition. Primarily GPS is used for positioning. If GPS is not available, either the cell information of the phone-network provider, a successful accomplished object recognition, or a manual input of the street name and number can be used for position determination. In the later case the street name and number is matched against a database where all buildings are stored with their according coordinates. This is especially in urban areas a method where the user can determine the own position with minimal input an effort.

The actual position is also used to present maps of the surrounding area of the tourist on the mobile device. The maps show a city map for orientation purposes, points of interest with continuative links, the GPS Track of the device and routing information. For the creation a map server application running on the server is used, cf. Fig. 2. In the current projects the map server originally developed by the University of Minnesota (UMN MapServer) is used. The map server primary function is to read data from various sources, which not necessarily need to be stored on the same computer, and pull these layers together into a graphic file. One layer may be the city map, another the points of interest, or the routing information. Each layer is overlaid or drawn on top of the others and then printed into a graphics for the tourist to see on the mobile device. Due to the fact that the map content depends on

Fig. 4: Sketch of the methodology used for object recognition in a robust framework. Local patterns (SIFT) are detected for an image description, filtering using only informative descriptors leads to a reduced description. This sparse description is matched towards a reference description to determine object hypotheses.



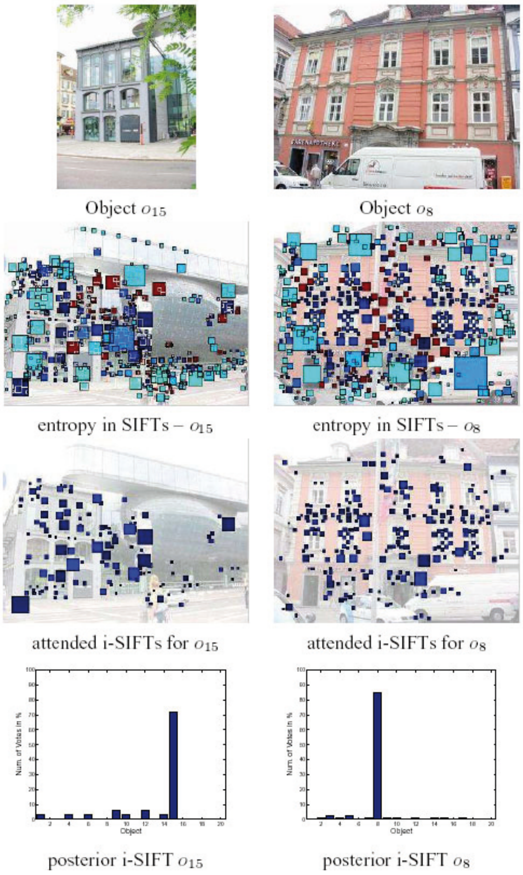


Fig. 5: Sample recognition of objects o_{15} and o_8 ("Kunsthaus", "Bärenapotheke", out of the TSG-20 image reference database [Download at http://dib.joanneum.at/cape/TSG-20]).
Top down: (i) reference images, (ii) location of SIFT descriptors with colour coded quality of service, (iii) selection of high quality descriptors, (iv) distribution on object hypotheses with correct decision based on maximum confidence.

the user profile and interests, a dynamic creation of the content is necessary. This is done by using PHP MapScript, a dynamically loadable PHP module that makes the MapScript functions and classes of the map server available in a PHP environment.

The map server application is able to easily integrate data stored in databases. For applications which bear strong relation to positions on earth the use of databases with support of geographic features is advisable. In a lot commercial and open source databases this support can be found. In the context of the Mobile City Explorer project PostGIS is used. PostGIS adds support for geographic objects to the PostgreSQL object-relational database and follows the OpenGIS "Simple Feature Specification for SQL". PostGIS enables the execution of spatial queries by offering spatial functions, such as Distance(), Intersect(), and Within(), among others, to narrow down the result of the search.

Cartography on mobile devices is not comparable with traditional or digital cartography. The small display size, limited processor power of the device, and varying lightning conditions have to be taken into account. The map must show only the relevant degree of details for the current task to avoid a too noisy overall impression on the small display. The dedicated use of colour and font size shall support the readability under different lightning conditions.

6 Conclusions

Object awareness provides a concept for semantic indexing into huge information spaces where standard approaches suffer from the high complexity in the search processing otherwise, and provide a means to relate the mobile agent to a semantic aspect of the environment. Visual object recognition using innovative and robust pattern recognition methodologies is an emerging technology to be applied in mobile computing services. Due to the many degrees of freedom in visual object recognition, it is highly mandatory to constrain object search by means of context based attention. In this paper we used geo-context to focus object recognition on a specific set of object hypotheses, and demonstrated that the challenging problem of identifying tourist sights in urban environments can become feasible.

In the projects MOBVIS and Mobile City Explorer our work will target at further exploiting contextual relations in order to cut down the complexity in otherwise unconstrained visual object recognition and make mobile services feasible. This challenging research goal will be achieved by identifying and tracking spatio-temporal aspects of the user's task context, improving the representation of geo-context by multi-sensor information fusion, and by applying attention strategies on the visual input. In addition, future research results will be achieved in more developed demonstrators, using camera equipped phones and wearable interfaces as mobile platforms for presentation.

7 Acknowledgments

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8 References

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Syndication of maps through the use of Really Simple Syndication (RSS)

Rex G. Cammack

1 Introduction

In recent years the distribution of maps has changed from a single channel of distribution into a braided channel of distribution (Fig.1). One way of characterizing this change is by displaying media. Cartwright (1999) provides a detailed discussion on many of the newer multimedia technologies available to cartographers. Cartwright (1999) states that the multimedia development started in the mid-1980's with the widespread adoptions of laserdisc and CD-ROMs. A justification for the development of multimedia cartography comes from Peterson's (1999 p.35) view that paper maps were inadequate to "the essence of cartography – the representation and communication of the spatial and dynamic world". As the digital age of cartography developed, cartographers used these new media types to challenge the dominance of the paper media. Along with these new media channels, a complex set of cartographic tools was developed. Currently cartographers must mix and match many of these new technology tools together to develop maps for multimedia, Internet and paper map products.

1.1 Portable maps

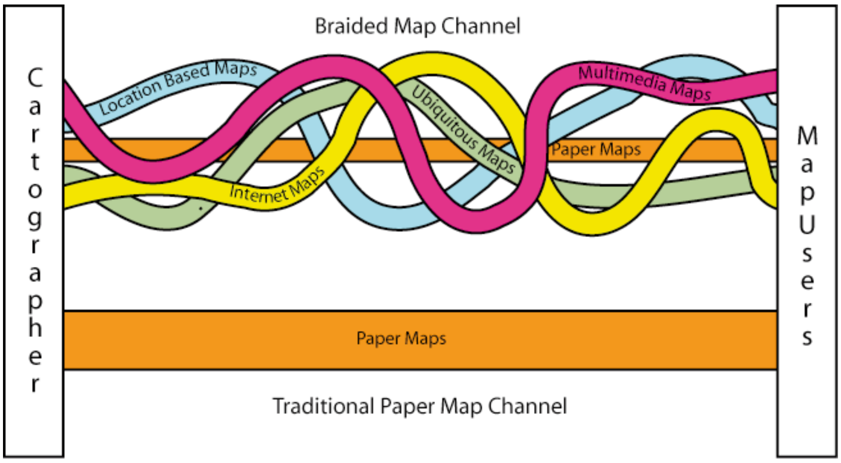
Peterson (1999) identifies two advantages of paper maps. The first being the portability of the paper maps while the second is the better display resolution. Coupled with these advantages the paper map clearly has several disadvantages. Peterson (1999) makes a case that the distribution o paper maps has been superseded by the distribution of Internet maps. By limiting the distribution of map information to the paper channel only, spatial knowledge and understanding is held by the upper classes and/or highly educated. This control of maps reinforces the segregation of society.

Another issue to consider with making maps portable is the detachment of the cartographer from the map. Putting maps on paper and duplicating them for distribution, created a situation where the cartographer no longer accompanied the map and was allowed direct communication with the map user. This communication disconnect has long been a problem for cartography. One of the newer trends in academics is the illustrated paper or poster session at academic conferences. The strength of this type of knowledge distribution channel is that the sender and receiver are once again in direct personal contact. Cartographers could argue that this need for direct personal contact stems from the lack of clear design of the poster. And since the majority of academics are not adequately educated in visual communication they need to rely on personal communication to clarify the message. A different perspective is that cartographers still want to accompany their maps but the distribution efficiencies have made that impossible.

Focusing on distribution efficiencies, Peterson (1999) suggested that the Internet has changed map use. Van Elzakker (2000) added that Internet maps have better accessibility and distribution. Gartner (2003) built on these ideas and coupled them with wireless technology to suggest that Internet maps can play a key role in location-based services on wireless devices. Gartner (2003) called this fusion of ideas and technology "telecartography". Along with telecartography, the term "ubiquitous mapping" (Morita, 2005) has been used to label the combination of mapping technology, mobile display devices, wireless networks and location based services. In this research the term telecartography will be used. It should be noted that from the current literature the two terms have many similarity. In the future telecartography and ubiquitous mapping may be demonstrated to have a clear distinction but as yet they will be treated as the same.

One could argue that the terms Internet mapping and multimedia cartography no longer have a clear distinction for the term cartography. The argument for this perspective would be that the map is a

Fig. 1: Comparison of the traditional paper map and braided map channels of information exchange.



map regardless of the media it's placed on. The function of the map is to store, display and express an idea between a sender and receiver. Most of the argument for the different terms comes from the technology side of the concept. Like multimedia and Internet mapping, telecartography involves a large amount of new technology, using the distinctive term telecartography seems justified.
Ormeling (1999) suggested that maps play many roles in the current Multimedia landscape including:

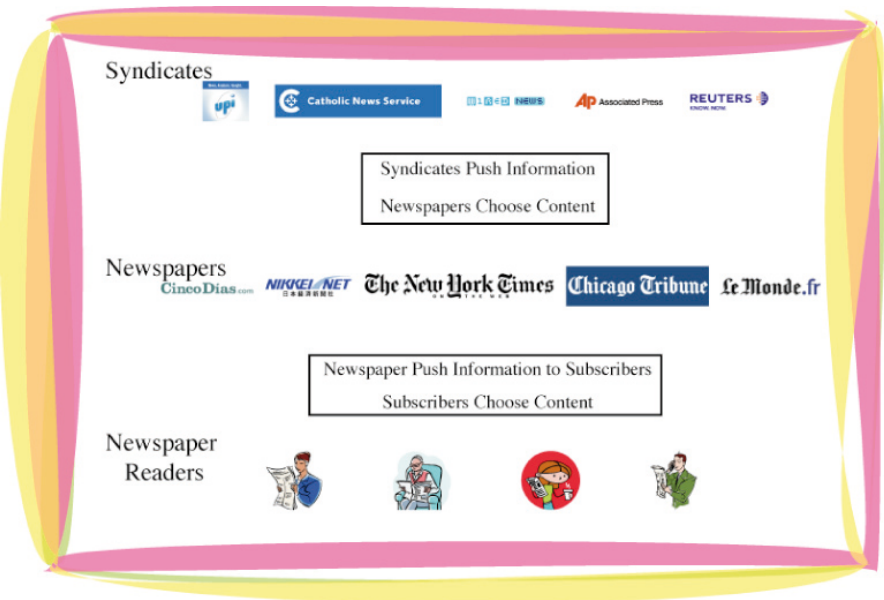
- Models of Spatial Reality
- Providers of Spatial Insight
- Spatial Organizers
- Tools for Accessing Information Elements
- Navigation Tools for the Multimedia Product
- Interface to the Geographic Database
- Multimedia Interface
- Vehicles for Interaction
- Interface to the Cartographic Database
- Tools for Scientific Visualization

This research takes the approach that the word telecartography could be substituted for the word multimedia. By using Ormeling's (1999) map roles conceptualization, a well-defined set of applications for telecartography has been defined.
In this introduction two primary issues have been addressed. The first one is the change in the method of map distribution from a straight paper linkage between map user and cartographer to a braided distribution path. The second issue was the identification and justification for the development of telecartography. The focus of this paper will be on the linking these two issues and examining the role of syndication in map distribution and use. Maps have been a part of the syndication of information for a long time. Yet little examination of the subject has been done in regards to cartography. This research will define the concept of syndication in cartography and show how several aspects of syndication of information can help increase functionality and temporal latency of information in telecartography.

2 Syndication

Syndication as a term comes from the journalism field. The idea of syndication is the process of selling the same work to numerous newspapers to be published at the same time. Many journalist/writers syndicate their work so it is published in hundreds of newspaper throughoutx the world. In the journalism field Ann Landers has the largest syndication with around 1200 newspaper publishing her column daily (Guinness Book of World Records, 2005). A group of people or companies that work together and produce materials used by others to build a newspaper is called a syndicate. In the publishing industry groups like the Associated Press and Reuters are syndicates. Figure 2 shows the flow of information within the newspaper industry. It should be noted that the newspaper looks for content and selects the content that matches with their needs and style.
With this understanding of how syndicates work, this research develops a syndication framework for cartography. As discussed earlier cartographers for a long time have not been able to accompany their map to the map user. As a result of the mass production of maps, cartographers create map product based on speculation. Companies like Michelle and Rand McNally have produced maps for years based on the fact that their products are needed by consumers. The cartographic companies have placed products in the market place hoping that consumers will use the maps. For the consumer getting maps has been a passive activity. Map users for the most part get maps only when they either need them or when it is opportunistic. The majority of map users are not proactive in the acquisition of maps. The passive nature of map acquisition is the opposite of the syndication of news information.
Newspaper subscribers indicate before the newspaper is printed that they want a copy. This active approach to newsgathering has lead to the development of news syndicates. For the most part, map products are not subscribed. So this lack of market demand for daily content

Fig. 2: How information follows through the journalism industry to the newspaper readers.



has led to the passive map use community. It should be noted that one could argue that news information is fundamentally different from maps in the context of timeliness. News information is important for only a short period of time as compared to the information on the map that can be delivered later and used longer. A counter argument to the point is that some maps are timely and need to be delivered daily or in some cases more often. The best example of this timely need to deliver map information is weather maps. A weather map from three days ago does very few people much good while a weather map made ten second ago that shows the current conditions and projected weather over the next four hours can be used by most map users. Weather maps are already a part of most newspapers and some newspapers get their national or regional weather maps through a weather forecasting syndicate.

The idea of syndicating maps is not a novel idea in cartography or geospatial science. The concept of a web mapping service can be considered a type of map syndication. In figure 2 one sees the role of syndicates and newspapers. Figure 3 shows how web mapping services fit in a syndication framework. The most important distinction between the journalism model (figure 2) and the geospatial science model (figure 3) is the concept of a subscription. In the journalism model the user subscribes to a service in the geospatial science model subscribing to a service doesn't exist. This may stem back to the history of maps having passive users. The passiveness of the user might be from the lack of temporal urgency for the map users task. The next step in making a map syndicate is developing an expectation of temporal urgency.

Gartner (2003) has suggested through telecartography an application of maps that has a temporal urgency. The integration of maps into the location based service paradigm has created an environment where maps need to be distributed to map users in a timely manner for any number of purposes. In the location based services, field map information might be available either through map brochures or public posted maps. But as Gartner (2003), Mount, et al. (2005), and Paelke, et al. (2005) show by using different wireless hand held computers, maps and mapping data can be delivered to map users based on positional information of the user. In this example a subscription relation between the map user and the information provided is still missing but they all show a possible application for map subscriptions.

2.1 Syndication for Telecartography

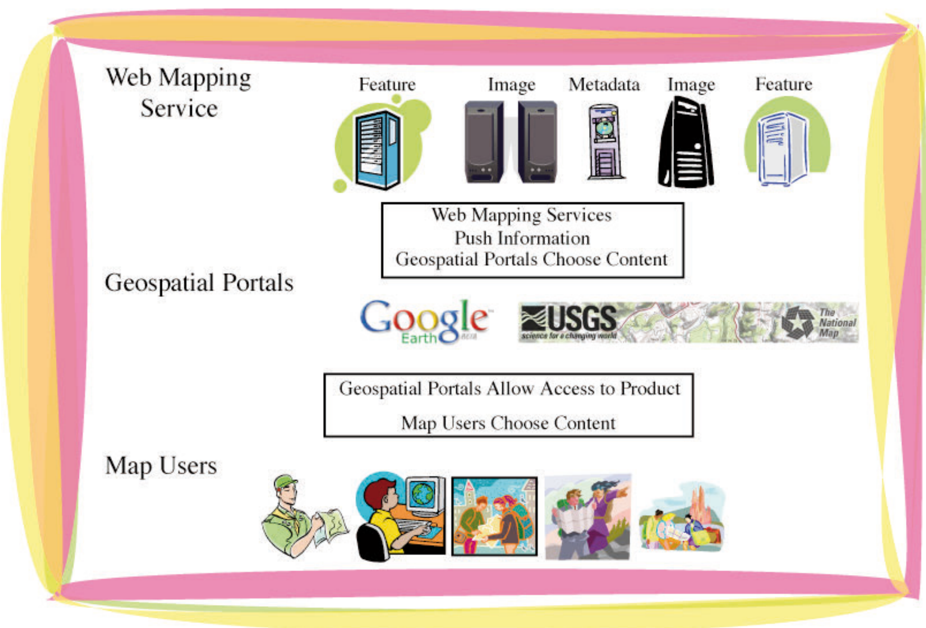
There are two possible types of map related telecartography subscriptions. The first type of subscription is one that delivers maps to the map user based on some set of subscription parameters. A map subscription type of relationship would deliver maps to the map user. An important point here is the concept that the delivery of the maps is active and not passive (Figure 4). A subscription to any media is an active process. The subscriber has stated their intent to receive information based on their knowledge of the media partner before the media is developed. For the media partner, having a subscriber group allows them to tailor their products to their customer base. In the telecartography paradigm a subscriber to a map navigation service would receive map data on demand based on both their current position or navigation destination.

The other type of telecartography subscription is the thematic content only subscription. An example of this type of subscription would be for Automatic Teller Machines (ATMs). One could subscribe to a bank ATM location service and every time the individual was within a set mapping distance they could get the latest information about the ATM such open or closed. The next section describes the technical implementation of both subscription services based on existing Internet technologies.

2.2 Internet Syndication

The most common form of syndication on the Internet is Really Simple Syndication (RSS). The RSS standard has been around for several years and gone through several versions. Ayers and Watt (2005) give a detailed history and explanation of the difference between the different RSS standards (RSS 0.91, 0.92, 1.0 2.0, Atom 0.3 and 1.0). In recent years, the RSS standard was to be replaced by Atom because of confusion regarding the different RSS versions (see Ayers and Watt 2005 for more details). Nearly all syndicates on the Internet use the RSS or Atom standard. The process of syndication on the Internet has three parts: content provider, aggregator and user. The con-

Fig. 3: How web mapping service function in a manner similar to syndicates in the journalism field.



tent provider develops the information to be distributed. The term feeds is currently being used to identify the RSS content stream. What feeds a content provider makes is up to them, but most feed content material that the Internet market space will consume. Currently the most popular feeds are in the field of news, opinion and music/radio. In the last 18 months the number of music/radio feeds has exploded with the development of Podcasting brought on by the popularity of the IPOD mp3 player in the United States. As of the writing of this paper Apple computers ITUNES website had over a thousand Podcasting sites registered with the number growing rapidly. The author has developed a Podcasting site with lecture review for his principles of cartography class.

The second part of the syndication process is the aggregator. Numerous aggregators have been developed to gather information and then deliver the content to the user. Most of the aggregators are websites where information is aggregated at the website and tools like PHP and ASP configure pages at the request of the user. One example of this is the Google.com personal home page. Once a Google user signs into their account Google allows you to configure your page based on user preferences. Most of what Google does is allow you to subscribe to different feeds and the resulting content is arranged to your design. Other aggregators also exist inside other applications. The iTunes software from Apple computers in its 5.0 version included an audio RSS feed handling routing. The iTunes user can select feeds from the iTunes website or any other RSS they have found. RSS feed handle is also being integrated into Internet Web Browsers. Safari has a simple RSS feed aggregator for handling any type of RSS feed.

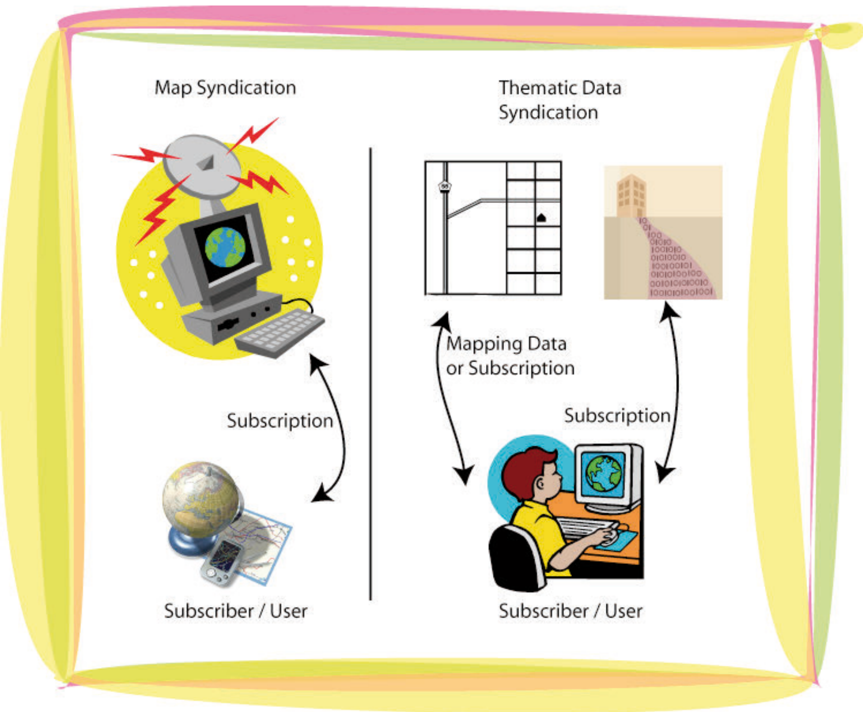
The last of the three parts of Internet syndication is the user. The simplest definition of a user is any person who uses an aggregator and subscribes to any feed. The problem with this definition is the limited nature of the person. As was discussed previously in the journalism field, newspapers subscribe to news syndicates. The newspaper is a user just like my students who subscribe to my course lecture review podcast. So in the context of user, the definition needs to be expanded to include any consumer of the information whether it be an end user or information redistributors.

3 RSS and Atom

RSS and Atom are built using the eXtensive Markup Language (XML). XML 1.0 was released in 1999. Since then numerous other applications of XML have been developed (Means, 2002). Figure 5 is a reproduction of an illustration from Means (2002) showing the framework of XML. Since Means' (2002) book, many other enhancements have been made to XML. One of these new developments is the Geographic Markup Language (GML). The GML standard was put forward by the Open Geospatial Consortium and adopted in 2004 (Open Geospatial Consortium, 2004). A critical development for XML and for the development of RSS was the XML Namespaces specification. Namespaces make it possible to create new markup tags that don't conflict with other tags with the same names. Many of the RSS feeds use their own XML namespaces to specify data for their aggregators. Apple computer has developed a namespace for Podcasting feeds to work efficiently with the iTunes software (see http://phobos.apple .com/static/iTunesrss.html).

Below is an example of a well-formatted XML document that has a RSS feed. The document is has four parts: XML, RSS, channel and item. The XML part of the file defines the use of the 1.0 XML specification with any standard text encoding. The RSS part of the document use the RSS tag to define which version of RSS is used and to include any external XML namespaces developed by Apple Computers for the iTunes aggregator. The XML namespaces is one avenue to deliver maps using RSS. The third part of an RSS document is the channel. The channel tag defines a single feed. An RSS document can contain one or more feeds. In this example there is only one channel titled Cartography Podcasts. Within this channel declaration are several attributes using the iTunes: declaration. The iTunes: declarations are defined by the podcast-1.0.dtd document included by the XML namespaces attribute. The final part of the RSS document is the item. A RSS feed can have any number of items within them. This example has only one item called "Intro to Cartography Podcast." For most RSS feeds the item is a pointer to another file located on a website or record in a database service. One of the features of the item that has made podcasting so simple is the enclosure.

Fig. 4: The two different types of telecartography syndications.



With an enclosure you can send any data type associated with the item to the aggregator. So if the aggregator understands how to use the data type it will use it.

```
<?xml version=”1.0” encoding=”utf-8”?>
<rss xmlns:itunes=”http://www.itunes.com/DTDs/Podcast-1.0.dtd” version=”2.0”>
	<channel>
		<title>Cartography Podcasts</title>
		<itunes:author>Dr. Rex G. Cammack</itunes:author>
		<itunes:subtitle>A show about Mapping</itunes:subtitle>
		<language>en-us</language>
		<copyright>&#x2117; &amp; &#xA9; 2005 Rex Cammack</copyright>
		<itunes:owner>
			<itunes:name>Rex G. Cammack</itunes:name>
			<itunes:email>rexcammack@missouristate.edu</itunes:email>
		</itunes:owner>
		<link>http://maps.missouristate.edu/podcasting/cartography</link>
		<description>Dr. Cammack Cartography Podcasts </description>
		<itunes:category text=”Science”>
		<itunes:category text=”Cartography”/>
		</itunes:category>
		<item>
			<title>Intro to Cartography Podcasting</title>
			<itunes:author>Rex G. Cammack</itunes:author>
			<itunes:subtitle>A short introduction to Cartography Podcasting</itunes:subtitle>
			<enclosure url=http://utah.missouristate.edu/~rexcammack/CartCasting/welcom.mp3 length=”514704” type=”audio/
			mpeg”/>
		</item>
	</channel>
</rss>
```

4 Telecartography through RSS Feeds

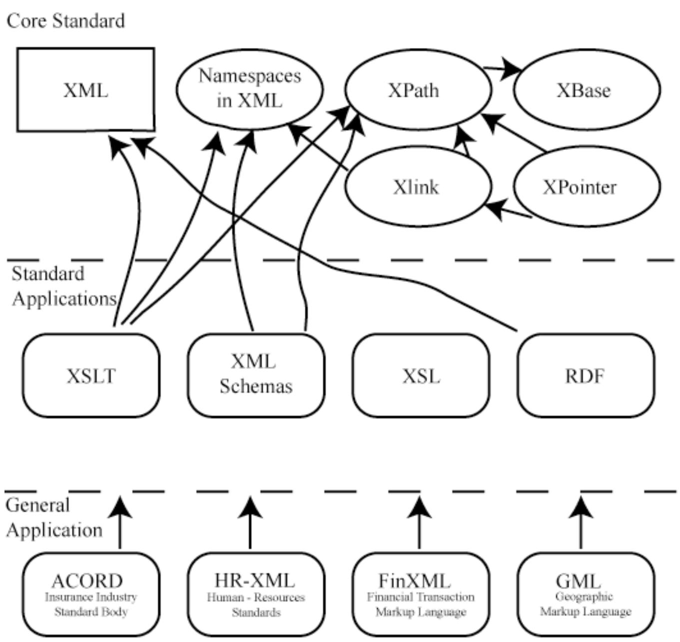
In the context of Location Based Services (LBS), maps via syndication could be delivered several ways. This research examines the delivery of maps as a location based service from two perspectives.

4.1 Base map

The first perspective is the base map. For maps to be used, a base map must be available to the LBS device. It appears that there are three ways to do this currently.
1. Precompiled and stored on the device.
2. Precompiled on servers and download on demand.
3. Dynamically complied on servers and download on demand.

In the designing of a LBS system, the precompiled and stored on the device method is the simplest to develop and test. The major drawback to the method is the need to preinstall the base maps before the user goes to the field. In most cases this approach is possible but not completely infallible. For a traveler who chooses to go to Europe with no itinerary, having the approach base map could be problematic. The second method will solve the wondering travel problem by downloading the base map based on locations when he/she needs them. This method still has the problem of precompilation. Cammack (2006) discusses this issue related to WMS. The synchronous development of base maps and thematic data has been an issue for cartographers for a long time. Cammack (2005) demonstrates when either thematic data or base map data are compiled and held in a static state there is a temporal disconnect between the two parts of a map and cartographic inaccuracy will result and most likely propagate. Cammack (2006)

Fig. 5: The basic framework for XML and associated technologies.



suggests that the base map data and thematic data must be developed and maintained constantly and separately to improve the synchronous accuracy of maps.

For both methods two and three the lack of infrastructure is a major impediment to telecartography. In areas with low population density the likelihood that public wireless networking will be developed is improbable. A historical example of this point is the Tennessee Valley Authority (TVA). In sections of the southern part of the USA electrical networks would have never been built without direct federal government intervention. With the way the publicly accessible wireless network is being created in the USA, low population areas will most likely lag behind the higher population density areas. This is not an unknown factor in LBS and some hope may rest with a space-based solution to this problem. Though this drawback exists it should not deter the development of telecartography for LBS.

To deliver base maps for LBS using RSS requires several steps. The first is to develop an RSS feed similar to the example above. Instead of delivering MP3 files the feed would enclose an Internet standard MIME/TYPE that is a graphic format. The graphic format would need to be consistent with the telecartography LBS application. A key aspect to developing this type of RSS feed is to create standard XML namespaces for this type of RSS feed and enclosure. Apple (2005) created XML namespaces for iTunes and a similar standard could be developed for RSS feeds for telecartography for LBS. The XML namespaces would need to create attributes for RSS enclosures that could be used by the LBS device to select the correct RSS enclosure to display. One must consider what triggering mechanism will be used to get a map for the LBS device. Triggering mechanisms for LBS tend to be locational which is a natural fit for telecartography for LBS. With the development of a RSS feed and a triggering mechanism, the next task is to create an aggregator that will handle the RSS feed subscription and understand the new XML namespaces and MINE/TYPE that the map is delivered in. Currently the XML namespaces and aggregator does exist but development in both areas is underway.

4.2 Thematic data

The second aspect of telecartography for LBS using RSS is the delivery of current thematic data. Currently most LBS are fee-based service. Cost as limiting factor needs to be addressed. Some LBS charge users by either a monthly fees or per use charges. There is probably no way to create a completely free telecartography LBS so cartography must develop a means of controlling costs. One way to control cost is to make access to maps less restricted. The section on base maps shows a possible way to make an open system using RSS that would work with many telecartography providers. A second way the LBS provider makes money is by selling their services to point of delivery business. A point of delivery business is a business that has a store that a customer enters and makes a financial transaction, i.e. bank, supermarket, drugstore or beer hall.

The LBS provider charges fees to the LBS user and the point of delivery business. If a point of delivery business chooses not to pay this service then the user is limited by not knowing about the business. Consider this example, LBS user is in Vienna and hungry for pizza but doesn't know where the pizza businesses are located. Being an LBS user they call up the map based navigational tool and ask for pizza stores. The LBS provider had marketed this service to all the pizza business and some have chosen to pay to advertise on this LBS service. The consumer will only be able to choose from the restricted list. Take this example one step further and the LBS user knows that they want to go to Pizza Mann but Pizza Mann has chosen not to advertise on this LBS. The LBS provider has failed to provide the user with his desired information.

RSS feeds could address this problem. By making a telecartography system that is RSS savvy, user could subscribe to any geolocational RSS feed. The system would work like this. First the point of business would create a RSS feed for store location and information. Within the RSS feed each store location would be enter attributes. What makes this a geolocational RSS feed is the inclusion of the Basic Geo vocabulary (W3C, 2003).

The W3C Semantic Web Interest Group developed the Basic Geo vocabulary. The result of this effect was the creation of a basic geo RDF vocabulary for RDF documents but a second outcome was the use of GEO XML namespaces that is used with RSS feed. Yahoo! Maps (Yahoo!, 2005) used the GEO XML namespaces to interact with the Yahoo! Maps service.

For the cartographer making a telecartography LBS system, making systems that arre RSS savvy and has the ability to geocode simple latitude and longitude coordinates would allow the user to subscribe to any geolocaitonal RSS service and have access to their information in a spatial format. This real-time thematic mapping would eliminate some of the limitations of some of the current LBS systems.

5 Conclusions

This research has examined the role of syndication of maps for telecartography and LBS. The ability to syndicate maps across the Internet is a fundamental change in the information exchange process that cartographers have used for hundreds of years. The syndication process allows the cartographer to have some input from the map user before maps are actually made and distributed. A second point to the research was a detailed examination of existing technologies to see if the tools are currently available to map syndication possible for LBS. The results of the research show by using RSS feeds and developing an image MIME/TYPE aggregator would make it possible to syndicate maps quickly and simply. A third finding shows that thematic data could be syndicated in a geolocational RSS feed using the GEO XML namespaces. By adding a simple geocode function to a RSS aggregator, a telecartography for LBS systems could become a more temporal accurate device.

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GPS-monitored itinerary tracking: Where have you been and how did you get there?

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Abstract

Within research to the objective of itineraries it is a requirement to acquire for a (large) group of respondents during a certain period for each conducted trip the location and time of depart and arrival, the route, travel mode, and also the activity purpose (i.e. travel to work, family visit, or just a walk for leisure). All trips must be reported and for each trip the requested data must be correct, complete and valid. In our research a GPS device is used to track and log the geometry and time for all trips during the research period, and a web map application is used by the respondents to specify the departure, the arrival location and the activity purpose of each trip. In that way we try to avoid errors, log gaps, and invalid entries, and we provide a mean to correct these once they are made. In conjunction existing geo-information is used to automatically interpret the traces and translate these into meaningful trips and activities.

1 Introduction

In order to support urban and transport planners, analyzing and modeling travel patterns have since long been an important area of transportation research. Analyzing and modeling their activity and travel patterns places heavy demands on data collection. Measuring the exact times and locations of journeys taken by individuals is therefore an essential element of travel behavior research.To provide detailed activity and travel data, the use of activity/travel diaries has become much more widespread since the nineties. This data collection method offers in principle the advantage that the complexity of activity patterns can be recorded with much more accuracy than when respondents are asked to reconstruct from memory their past travel behavior and activities. However, it suffers from some disadvantages including the burden on the respondent, the difficulty for respondents to write down exact descriptions of the locations, and inconsistencies between trips and activities.

One method for which there are great expectations in transport research is data acquisition through a Global Positioning System (GPS). This technology uses signals from satellites to determine someone's position within a range of no more than 10 meters. Through a GIS application the travel behavior of the respondent is reproduced on a map for visual validation by the respondent and for automatically classification and justification by GIS network algorithms.

Apart from its benefits, however, this state-of-the-art method has its difficulties as well, including problems with the use of the device, reception of the signal, handling of the data, etc. Worldwide experience with GPS devices for collection of travel data is poor, and mainly related to devices in cars.

The planned destination and goal of the itinerary can be answered before, during or afterwards the trip. In-car route navigation is an example of the first question, as the driver will have to announce the destination to the system. But the destination will only be definitive, when that place has been reached. An interactive system can request the user during the trip to state where he is heading. Again, this will only be true, as long as the destination had been reached. A survey afterwards is the best option, as the visualization of the GPS track (positions and time) is a way to remember it. In the research of Hovgesen (2005) this kind of 'passive GPS registration' is called to be 'a powerful tool for the survey of spatial behavior'. But, 'given the present state of GPS technology, the track points that can be attained from a persons movement over a longer time span is unlikely to be continuous'. So, in the user-interactivity phase, one has to validate the GPS track, or at least the actual depart and arrival locations have to be given, before one can link the destination and the way of transport to the corrected GPS track.

Following this introduction, section two gives an overview of data collection for travel behavior in general and related research with respect to the possibilities and disadvantages of GPS. Section three focuses at our approach of GPS monitored itinerary tracking, where after section four addresses the actual GPS track log processing to meaningful activities and trips. Section five gives some conclusions and recommendation.

2 Data collection for travel behavior research

As has already been indicated in the previous section, measuring the exact times, distances and locations of journeys taken by people is an essential element of research into travel behavior. Information about travel behavior has traditionally been collected from written questionnaires or telephone interviews about aspects of travel behavior. The information gathered includes details on the frequency of commuter travel, daily and occasional shopping trips, visits to public amenities, leisure activities, social calls, and so on. Traveling times and distances are also asked about, as is the means of transport. This approach entails a number of significant disadvantages, however. The range of travel patterns depends on the variation of destinations listed in the questionnaire: destinations that are not included do not appear in the overall pattern. Also, such surveys reflect only the perception of the respondents as regards timings. It has been shown that this is an area subject to systematic distortions: short journeys are often forgotten about, as are those that do not involve a route either starting or ending at home. Furthermore, the various methods of transport and other relevant details are not accurately remembered, with car users underestimating their traveling times and public transport users overestimating theirs (Ettema et al, 1996; Stopher, 1992).

2.1 Related research in itinerary tracking

To avoid these drawbacks, the use of activity and/or travel diaries has become much more widespread since the nineties (for example, see Stopher and Wilmot, 2000; Dijst, 1995; Snellen and Timmermans, 2001; Maat et al, 2004). Respondents use their travel diary for a few days to record departure and arrival times, travel movements, the destination being visited and/or activity being attended, the means of transport and any other information. Activity diaries offer in principle the advantage that the complexity of activity patterns can be recorded with much greater accuracy. However, there are disadvantages as well. First, the burden on the respondent is considerable, as the diary has to be (preferably) carried around on a daily basis, while detailed information about travel times, locations and activities has to be noted down for every movement. The result is that there is a strong possibility of non-response. Second, respondents will tend to postpone writing down their notes so that they ultimately put down inaccurate information about traveling times and locations, or indeed forget about entire journeys altogether. In an evaluation of different types of diary, Arentze et al (2001) reported a systematically more inaccurate and limited pattern of activity on the second day of diary entries. In order to reduce the burden, respondents are usually asked to keep the diary for only a few days (Schönfelder et al, 2002; Schlich and Axhausen, 2003). Third, it seems that giving an exact description of locations is not always easy for respondents: what is the exact location of the post office, the letterbox or the park that has been visited? Finally, paper surveys often contain many inconsistencies as a result of registration errors, such as activities that begin before the previous one has ended, journeys from locations, which were never arrived at in the first place, and unrealistic traveling times.

2.2 Possibilities of GPS in trip and activity recoding

One method for which there are great expectations in transport research is data acquisition through GPS. This technology uses signals from satellites to determine someone's position within a range of no more than 10 meters. Cars are these days more often than not equipped with a kind of route navigation system, i.e. a portable 'Tom Tom Go'. These systems are quite capable to direct the user to the destination by a combination of maps, pictograms, and voice. As 'a Tom Tom' uses a GPS receiver to determine the current position, it is thought that each general GPS device is a kind of route navigation system. It is not; basically a GPS receiver processes the code signals from the GPS satellites in 'line-of-sight' to a location determination in latitude, longitude and elevation according to the WGS-84 reference system. Only the combination of a GPS device, smart software, up-to-date digital maps and an intelligent user interface makes a route navigation system to what it is. To track where you have been seems however not that difficult, as you only have to store the successive GPS locations during the itinerary. By carrying a GPS receiver, the location of a respondent can be registered at any time. The places along the route taken by the respondent are linked to the times at which he was at these places and are stored in the receiver as coordinates. By entering the coordinates in a GIS application, the travel behavior of the respondent is reproduced on a map.

The method has a number of important advantages. Data acquisition via GPS should mean that the research would be one of the first travel behavior studies that do not suffer from the significant shortcomings of the diary method. First, there is much less of a burden on the respondent, so that not only the numbers of non-responses are greatly reduced, but also that information can be gained from a whole week, rather than just a few days. This is an important benefit because travel behavior patterns are becoming more and more varied in time and range, partly as a result of people working part-time or further from home.

Second, the degree of accuracy and completeness this method brings is way beyond anything that can be achieved through conventional paper surveys. Indeed, it is the case that not only the precise starting and finishing points of travel movements are recorded, including the exact times, but that the route itself can also be accurately traced. By linking the details registered in a GIS application to information on the spatial structure, it can be determined which travel mode was used (verify whether journeys were undertaken by road or rail) and which amenities were visited (Schönfelder et al, 2002). An important element in terms of accuracy is that inconsistencies are, to a large degree, avoided. A third advantage is that the data is immediately available in digital form, which eliminates the need for time-consuming and error-prone manual data input.

2.3 Disadvantages of GPS in trip and activity recording

However, there are also highlighted a number of disadvantages in the literature. Firstly, the cost of the equipment is still relatively high. In addition, the method has to be explained in more detail, which means the researcher has to actually deliver the GPS and provide instructions on its use, as well as collect it again at the end of the survey period. Secondly, although the GPS registers time and location, it does not record extra details, such as the reason for the journey. This kind of information will still have to be recorded by hand, be it on paper, on-line, or a combination of the two using a Personal Digital Assistant (PDA). This option simply makes the collection of the data more expensive and entails an even greater burden on the respondent. Thirdly, the presence of buildings in urban areas means that satellites are not always 'in view', leading to the possibility that the location of the respondent cannot always be determined.

2.4 Collaborative GPS tracking

Nowadays Web Map Services (WMS) and Web Feature Services (WFS) are a mean to disseminate geo-data to literally everyone connected by Internet based on the open standards of the Open Geospatial Consortium (OGC, 2000). The providers of these services, however, also decide which data is made available. As shown, GPS devices are a mean to store your own traces. The traces are, if combined with an activity as within the project described in this paper, of interest for other people. This demand is especially an issue when these data are not made available through the regular geo-data providers. Hikes, skate routes, mountain bike trails, holiday trips, or even the location of 'open' wireless local area network (WLAN) hotspots, all these data are likely to be used by a dedicated group of users, most often the ones who will provide their share of the data in the first place.

Some neat examples of these collaborative composed GPS track databases exist. The Geoskating project is among the finest, as it will show through a map interface where to skate, and how well the road is suitable for this kind of activity (Geoskating, URL). This example is however limited in functionality, as it is not possible to upload and download your own skate tracks. This possibility is given among other initiatives, by the GPStracks and MotionBased site (GPStracks, URL; MotionBased, URL). Both initiatives opts the possibility to map the routes by Google Earth. If you want to know which WLAN access points are freely available in your neighborhood the Wardrivemap will give you the answer by a database loaded by GPS enabled WLAN access point tracers (Wardrivemap, URL).

All these examples show the possibilities of collaborative GPS track websites. It is therefore a pity to see that none of these initiatives is yet using OGC compliant solutions for providing maps or data.

2.5 Person-based itinerary GPS tracking

Person-based itinerary GPS tracking systems are not comparable with in-car route navigation systems, although both use GPS to determine their actual position in real time. As most people do have good experiences with this kind of guiding tools, they expect the same characteristics of stand-alone, personal, GPS tracking devices. That is not the case, as in-car systems do have the characteristic to be part of the traffic. In contrast, person-based GPS tracking devices can be, literally, everywhere. In-car systems could work-around the fundamental issue of receiving enough GPS satellite signals – as in GPS hostile environments like tunnels and height rise buildings areas – by extra sensors like an odometer, an electronic compass and an inertial navigations system. Besides, the simple fact that cars drive at streets is used by all kinds of dead-reckoning algorithms to keep and forecast the calculated position at the up-to-date digital road network. Power supply is not an issue at all as it plugged to the battery of the car and the antenna is well positioned at the roof or at the front window. And as cars are normally at the same place as where the driver left it behind the start-up acquisition time of the GPS device is reasonable.

A person is not very well designed to use a GPS device. For the best operation the GPS device should be held in the hand, as this will allow the user to operate it. A position in front of the user is also appropriate to read the display and it provides direct access to the sky for a good satellite reception, but no one wants to hold the device for 24 hours for just to be tracked. Power drain is also an issue and the GPS device should operate without extra sensors, although the combination with an electronic compass is an option.

2.6 Related research in GPS monitored itinerary tracking

Several comparisons were made using a paper diary (see Lee-Gosselin, 2002). The use of GPS is not a new approach in person-based itinerary tracking. The last years several papers and reports on GPS enhanced household travel surveys have been published. These papers describe the possibilities on using GPS in this kind of surveys and the recording of the activity. A separate GPS for registering every journey was provided in only very few cases. (AVV, Draijer et al, 2000). A remarkable issue within the studies conducted outside Europe is the focus on the car as the only possible travel mode. This will reduce all kind of problems in power supply and GPS reception, i.e. in the study in Texas, USA (Forest, 2005) the power supply of a GeoStats GeoLogger is attached to the cigarette lighter socket in the vehicle and the antenna is mounted to the roof. Also in (Wolf, 2001) a study in Georgia, USA is described where the only travel mode under consideration is the personal vehicle. The study described in Sidney, Australia (Stopher, 2003) is again an in-vehicle travel-mode study with the GeoStats GeoLogger. This rugged device is quite heavy and bulky, mainly due to the battery pack to operate it over three days. For the study in London, UK (Steer, 2005) that characteristic was not a limitation to use it as a normal personal travel-tracking device. But the far better wearable Garmin Foretrex was used for the survey in Denmark (Hovgesen, 2005). Here in this European city the individuals carrying these kind of person-based GPS devices registered very accurately transportation on foot, bicycle or private motorcars. The use within public transportation, like busses and

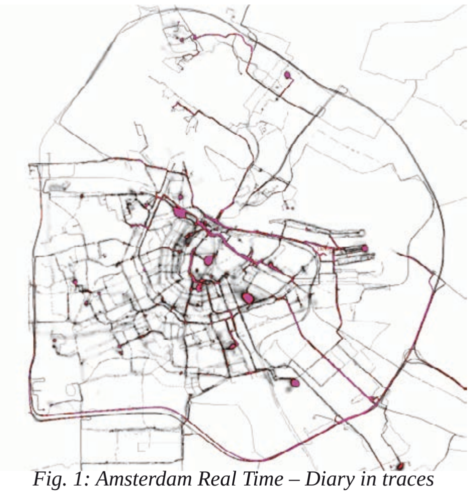

Fig. 1: Amsterdam Real Time – Diary in traces

Fig. 2: Garmin Foretrex 201

trains, posed greater challenges to GPS as a survey tool as the signal reception by the GPS antenna is much more difficult to control.

3 GPS itinerary tracking

3.1 System requirements of person-based GPS itinerary tracking

To track someone by means of a GPS device during a longer period is a quite demanding task. First and for all, the device should acquire its location during the trip, or more specific: the trip track points should be logged. Several options are possible to perform that task.

One can use a GPS device equipped with internal memory to store thousands of track points at the device and download those after the survey by a serial or USB connection to a computer and upload the track logs to a central database. All commercial available ‘outdoor’ GPS devices, like the Garmin and Magallen products, offer this possibility. They differ with respect to the track log only by the available memory for storage; most models offer 10,000 points. Another problem is the use of a proprietary communication protocol, which demands special programs to download the data. Ones downloaded the user has to choose from a bunch of file formats; although the XML based GPX format is regarded as an industry standard (Topographix, URL). A last barrier is caused by the serial connection that is still used by even the latest models like the Garmin Forerunners. The .gpx file could now be uploaded to a server. It is possible to use these kind of .gpx files, but as GPX is XML based, a XSLT transformation can be applied to create the insert statements to store the track points in a geo-database like PostgreSQL/PostGIS (PostGIS, URL). Another option is to connect a basic GPS device by wire or wireless (Bluetooth) to store the track points directly at a separate logging device like a PDA, or through a mobile ‘smart phone’ that will send the tracks by GPRS or UMTS directly to a central database. Although these last options do have a lot of advantages, like real-time access to the trip-track data, and also the possibility to inquire the respondent about the trip activity right ahead, it doubles the risk on power drain. But there exist some neat examples of this kind of activity reporting, like the Amsterdam Real Time – Diary in traces project where the mobile behavior of users in the city is visualized, see Figure 1 (Waag, URL). Another example is given by the GeoSkating project that aims to automate the creation of interactive, multimedial skate maps (Geoskating, URL).

The last option works very well, but we have decided to use a ‘stand-alone’ GPS device for both acquiring the track points and store them. The main reason for that approach is to make the system robust by avoiding as much as possible power-drain and dependences on all kinds of wireless communication between devices. A second reason is the GPS device of choice itself. The Garmin Foretrex 201(see: Figure 2) is well designed light and very wearable at the wrist, it has a running time of more than 14 hours, and it has a track log capacity of 10,000 points which will be maintained in memory even as the battery is drown. The use of a rechargeable battery has, besides the environmental advantage, the benefit to be a kind of a reminder to download the track log right ahead when the device is plugged to the AC-adapter.

3.2 Determining itineraries from GPS track logs

An itinerary is a trip from a departure to a destination. The GPS devices, however, will only start to track and store the locations as soon as the receiver has a position-fix. It is to a certain extent possible that this start of a recording is not at the actual location of departure, but somewhere along the route, because it might take some time before the first position determination takes place. If the almanac data – the course orbital parameters for all satellites – is unknown by the receiver, this information is first to be received from one of the GPS satellites. Once known, the receiver knows where to expect a certain satellite at the given time. For exact positioning however the ephemeris data – the precise orbital and clock correction data – has to be received from the GPS satellites used. As this information is only broadcasted each 30 seconds this will delay the positioning. But it not as bad as it sounds, as long as the receiver is within a range of 300 kilometers from the last use, the almanac can be used. So the receiver knows where to expect the satellites. The ephemeris data is ‘fresh’ for a certain period, thus if the receiver is powered off for only a couple of hours, the receiver knows the position of the satellites and it will restart positioning with a so-called warm-start within a couple of seconds.

3.3 Validation and interpretation of GPS track logs

To be sure the receiver starts logging at the departure; it is a recommendation to the respondents to examine whether or not the GPS device is powered and positioned before moving. This departure location can be marked at the receiver explicitly by user-specified waypoints. But as this action will require an extra awareness and user interaction of the respondent of the itinerary survey, this option will not be regarded as an option in the test conducted. Besides, in most of the cases the respondent will depart from a location arrived at the previous trip, so this position could be derived from the history. Within the web-based itinerary survey afterwards the user has anyway the possibility to pin-point characteristic locations, like home, work, public transportation stops, etc., explicitly. This will open the possibility to 'link' the start and finish of a track log to these locations.

During the route itself the GPS will record positions only at discrete locations, i.e. at turns. This will reduce the total storage of the track log of an itinerary undertaken considerably. The receiver has also a so-called auto stop mode, where a certain track point is marked as 'start of this trip' when the receiver resumes moving from a location where it has been stayed for a specified time. This 'start of the trip' mark is thus also given at the actual start of an itinerary. The total track log of a day will thus be separated in logical parts by the GPS device itself.

It is predictable that each part of the track log is undertaken with a specific travel mode. As the speed of travel is to be determined from the track log data, it is possible to validate the user's input; it is quite unlikely to bike with a speed of 80 km/hour.

How well modern GPS receivers operate these days, there will be always gaps in the recoding; either by bad satellite reception, or by misuse of the GPS receiver by the respondent. As we are not interested in a complete coverage of the trip by GPS track points, but in the itinerary itself, this omission does not have to be a problem, as long as the main characteristics of the trip itself can be recovered. One possibility to determine the route of the trip is by a shortest path analysis based on an up-to-date road network. If all track points are to be reached in time order, this network analysis will result in the most predictable route on the network. This kind of validation works however only if the travel mode is known, and the network data (road, railroad) with relation to these models (car, train) is available.

4 GPS track log processing

4.1 Conceptual model

When people communicate or when systems have to be developed it is important that the involved parties do agree on the meaning of the used terms. That is, for a given term they associate similar concepts. This may sound trivial but in reality this is not the case, therefore attempts are made to formalize the meaning of concepts (and the associated terms). One approach is to describe the concepts in a graphical way and depict associations with others terms/concepts; such as specialization (refined more specific concept), aggregation (collection of other elements), etc. Within the Unified Modeling Language (UML) this is called a class diagram (Booch, Rumbaugh, and Jacobson, 1999). In addition to these associations also properties (attributes) belonging to the concepts may be specified (e.g. a person has a name and a day of birth). These properties further describe the concepts by listing the relevant attribute names and types (e.g. string and date in our example). It is also possible that certain types of operations (methods) do belong to a class (e.g. compute the age of a person).

So, when setting up an itinerary tracking system, researchers have to communicate with the persons who's itineraries are being investigated. They have to agree on the meaning of concepts such as Trip&Activity, KnowLocation, Trace, TracePoint, Person, GeoObject, etc. The UML class diagram is given in Figure 3.

In the UML class diagram the different symbols have a well-defined meaning: a concept or class is depicted by a box of three compartments: 1. class name (e.g. Person), 2. attributes (e.g. name: String) and 3. operators. A normal association between two classes is indicated by a solid line (without arrowhead); for example the association 'LivesAt' between the classes Person and KnowLocation. The multiplicity of the association is indicated at both sides: '*' at the side of Person meaning that at a given KnowLocation *n* Persons may live and '0..1' at the side of KnowLocation meaning that a given Person may live at 0 or 1 KnowLocations.

An important object in GPS monitoring of itineraries is the Trace, which belongs to exactly one Person; this multiplicity of the association is indicated with a '1', which is normally not depicted in a UML class diagram. Reversely a Person may have a Trace or not yet have a Trace (indicated with the '0..1' multiplicity). A Trace has attributes such as begin and end date. More important a Trace can be seen as an aggregate of TracePoints (indicated via the solid line with a black diamond at the side of the Trace). Again the multiplicities are indicated near the ends of the solid line depicting the aggregation. In this case it is stated that a TracePoint belongs to exactly one Trace ('1', not depicted) and that a Trace consists of one ore more TracePoints ('1..*'). The attributes of a trace point are the time and x, y and z coordinates of the location. Note that a TracePoint has also an association with itself: 'next', indicating the next TracePoint within a Trace. Operations available for the TracePoint are speed and acceleration, which can be computed based on the location and time stamps of successive TracePoints.

The collection of known geographic objects ('the map') is modeled with the class GeoObject, which has two specializations: GeoLocation and GeoInfra. A solid line indicates the fact that something is a specialization of another class with an open arrowhead in the direction of the more generic class. KnowLocations in our model (such as houses, shops, offices, etc.) are associated with exactly one 'map' GeoLocation object (the reverse is not true: there is not a KnowLocation of every GeoLocation). At a KnownLocation a certain type of activity can take place. The types of recognized activities are given in the enumeration type ActivityType and include: live (at home), work, recreate, shop,… (not indicated in the UML class diagram). The GeoLocation objects are point

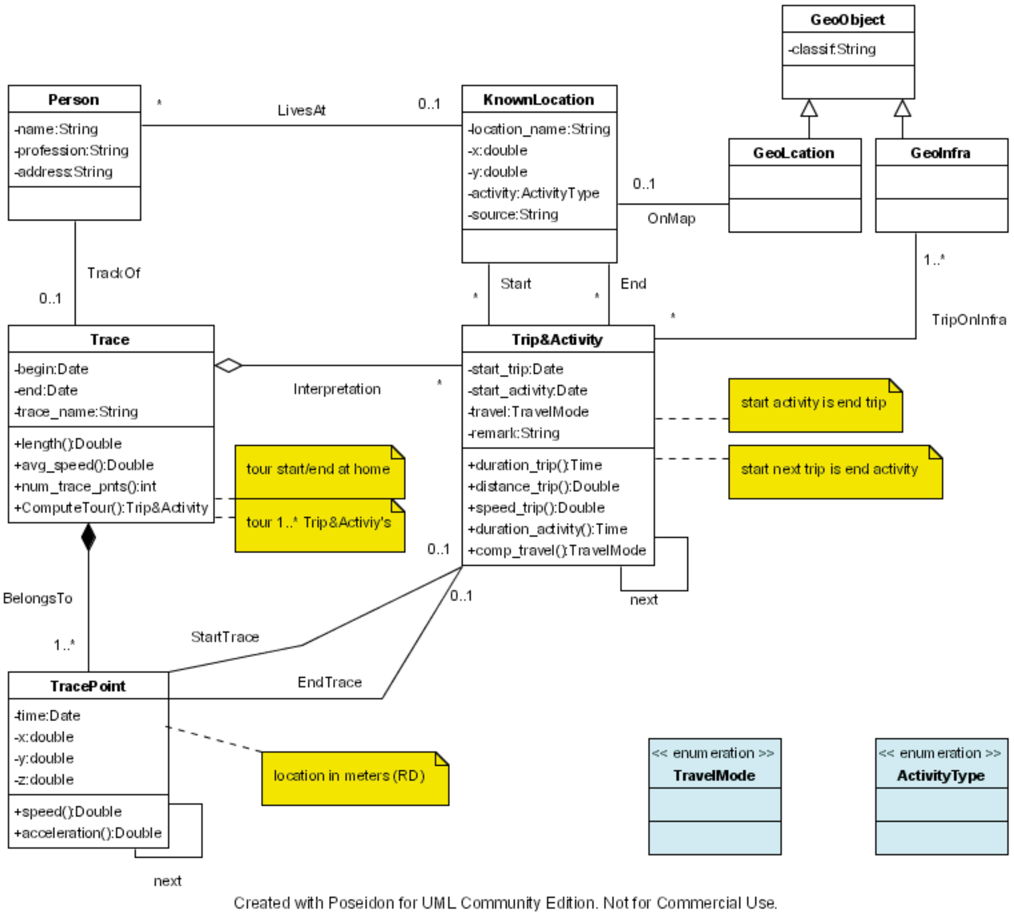

Fig. 3: UML class diagram depicting the relevant concepts in itinerary tracking

objects (again not indicated in the UML class diagram). The GeoInfra objects are line objects representing transportation infrastructure: roads, railways, waterways, bicycle paths, footpaths, etc.

The central concept in our model is Trip&Activity, which covers two aspects in one concept: first the trip (traveling, varying location) and second the activity (at a fixed KnowLocation). The Trip&Activity concept has a start_trip and a start_activity time (date). Actually the 'trip' part ends at the start_activity. The 'activity' part ends at the start of the subsequent trip (next Trip&Activity). The possible manners of traveling are given in the enumeration type TravelMode, which could contain values such as: car, train, boat, bike, etc. (not indicated in UML class diagram). In the GPS monitored itinerary tracking a Trip&Activity can be linked to one Trace (and reversely a Trace represents a number of Trip&Activity's). Again this is an aggregation, but in this case an open diamond is used in order to indicate that the elements could exist without the composite object. One last important concept is Tour; the smallest sequence of subsequent Trip&Activity with the characteristic that begin and end location are the same. However, this is not modeled as a class but as a method of Trace (as it can be computed and does not have to be stored explicitly).

This conceptual model does not only allow people to communicate in an unambiguous way, it is also the basis for system implementation. First of all, the model can be used to define the database schema or model, which is used to store the captured data. Further, the model may be used to build the user interface: input forms may be derived from the class (concept) definition; e.g. the form to define a new person. Also the output may be presented in a tabular form based on the class definition; e.g. the discovered Trip&Activity's (grouped per tour) table. The nice thing is that these can (for a large extend) be created automatically. This concept is known as the Model Driven Architecture (MDA). The implementation of (large parts) of the system is automatically derived from the (formal) model.

4.2 Web map client to determine reliable itineraries by user-responses

To assist the end-user with the processing of their daily activities, an interactive map with the GPS log combined with reference data will be displayed in the browser of the user. In order to create this combined map, the GPS data is first transmitted to the server, there it is processed and stored in a database. Once it is in the database, it is available for interactive display via a Web Map Server (WMS). Below the two separate processes: getting the GPS data to the database and getting a map back to the user are described.

In the first step of the process, the GPS data needs to be transferred from the GPS device of the respondent to the database server. The process takes place in a few steps:

– The respondent connects the GPS to the PC and uploads the GPS data to the computer and save the track data to a GPS file
– Via a web interface the GPX file is uploaded to the web server.
– In the web server the GPX file is converted to the database insert statements and sent to the database server.

Now, the data is in the database and is available for analyses, but it can also be displayed on the respondent's web interface as an image. For this MapServer is used. MapServer is an open source development environment for constructing spatially enabled Internet web applications (Mapserver, URL). In MapServer the GPS data of the respondent is combined with a background map and converted into an image (GIF, JPG) that can be displayed in the web browser of the respondent.
At the respondents' side, this map is very useful as a reference when the respondent is asked to completely describe their daily activities. The web map will be incorporated at the client side as a reference. It will contain four layers in total: (1) Background map; (2) KnownLocations; (3) Processed GPS points; (4) Non-processed GPS points.
Every time a respondent has entered an itinerary, it will be posted to the web server and at the same time a fresh version of the web map will be requested. All of the GPS points that fall within a time-period that has already been logged as an itinerary, will be placed in the layer named "processed GPS points" and will receive other color identifications to separate them from the "non-processed GPS points". Besides that, there will be some basic controls as zoom functionality, dragging and requesting point information (date, time).
Existing geo-information (map) and derived movement information (speed, acceleration) can be used to automatically interpret the traces and translate these into more meaningful trips and activities. One thing that only the user can enter is the remark associated with a Trip&Activity; e.g. indicating motivation or purpose. When filling in the logbook in case of less (or none) automatic interpretation of the traces, the user is asked to enter itineraries (their movements between locations where they show a certain main activity). To enter an itinerary, one needs to specify a point of departure and a point of arrival. The choice has been made that these must be KnownLocations to ensure that a user is spared the effort of entering the same location information several times. Since every person has repetitive behavior, the use of KnownLocations will save time and energy in the end. All in all, the user must be able to add KnownLocations through the map interface.
So all in all, the map and the web forms are strongly interconnected. When the form posts its data, the map adjusts its content in conjunction with the updated database. Next to that, the user is able to generate his or her personal KnownLocations to streamline their data processing.

5 Conclusions and recommendations

It is to be expected that GPS monitored itinerary tracking will replace the use of 'old-fashion' paper travel diaries in the near future. However, the gathering of a complete and correct database of the itineraries of a large group of respondents by equipping this group with GPS tracking devices is not an obvious task. The disruptions in the receiving of satellite signals have to decrease, and besides that limitation, only the recording of locations during the day gives not enough information to provide a detailed overview of trips and activities. Within this research project the feedback of the respondent to validate and correct the recordings is done by a well-designed, web-based, map-oriented trip and activities processing application. Intelligent data processing algorithms will support this process.
In the near future a kind of GPS logging is used by a large group of people to record a variety of activities. The processing, storage and dissemination of this special kind of spatio-temporal data will be supported by the development of collaborative GIS environments. For that reason the current available geo-portals have to be extended with functionality for standardized user input, processing and presentation of spatio-temporal data.

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3-D Position determination in a multi-storey building using a Pedestrian Navigation System

Günther Retscher

Abstract

Using pedestrian navigation and guidance services in indoor areas, a challenging task is to determine the correct floor of a user in a multi-storey building as most common indoor location techniques provide only 2-D position determination. In this case it can be recommended to augment the position determination system with a barometric pressure sensor for direct observation of height differences. In the research project NAVIO (Pedestrian **Nav**igation Systems in Combined **I**ndoor/**O**utdoor Environements) tests with different sensors have been performed and their results are presented in the paper. The tests show that it is possible to determine the correct floor of a user using a barometric pressure sensor as the standard deviation of the estimation of the height differences is better than ± 1 m.

1 Introduction

In recent years new technologies and methods for positioning in indoor environments have been developed. Useable geolocation techniques include cellular phone positioning, the use of WLAN (wireless local area networks), UWB (ultra-wide band), RFID (radio frequency identification), Bluetooth and other systems using infrared, ultrasonic and radio signals (see e.g. Retscher, 2005b). In this paper an overview of some of these technolgies that can be employed for personal navigation systems is given. Most of the systems, however, are able to locate the user only in two dimensions and the height is not determined. Then the height has to be observed using an additional sensor to be able to locate a user on the correct floor of a multi-storey building. In the research project NAVIO (Gartner et al., 2004) at our University the use of a barometric pressure sensor for the direct observation of height differences is suggested. Test measurements performed in our 5-storey office building are presented in the paper.

2 Indoor positioning systems

For indoor positioning different location techniques have been developed which use signals such as infra red, ultra sonic, radio signals or visible light (Retscher and Kistenich, 2005a). Methods for position determination include Cell of Origin (CoO) where the location of the user is described in a certain cell area around the transmitter, Time of Arrival (ToA) where the travel time of a signal between a transmitter and receiver is obtained, Time Difference of Arrival (TDoA) where the time difference of signals sent from a transmitter is determined at two receiving stations, signal strenght measurement for location determination using fingerprint (e.g. WLAN fingerprint, see Retscher, 2004) where the signal strenght values are compared with previous stored values in a database and the location of the user is obtained using a matching approach, and location determination using digital images (Retscher and Kistenich, 2005a). Table 1 gives an overview about different indoor location techniques.

System name	Signal	Method	Absolute Positioning	Relative Positioning	Positioning	Tracking	Geometrical	Symbolic	Costs	Positioning Accuracy [m]
Active Badge	IR	CoO	✓			✓		✓	low	room
WIPS	IR	CoO	✓		✓			✓	low	room
Active Bat	US	ToA	✓			✓	✓		low	0,1

Cricket	US	ToA	✓	✓	✓			✓	low	1,2
GSM	RS	TDoA/AoA	✓			✓	✓		low	50-100
A-GPS	RS	ToA	✓		✓		✓		high	20-25
Locata	RS	ToA	✓		✓		✓		high	0,1-1
Radar	RS	SS	✓		✓	✓	✓		high	3-4
IMST ipos	RS	SS	✓			✓	✓		high	1-3
Ekahau	RS	SS	✓		N/A	N/A	✓		high	1-3
WhereNet	RS	SS	✓		N/A	N/A	✓		N/A	N/A
UWB	RS	ToA/TDoA	✓		✓		✓		high	0,2
Bluetooth	RS	CoO	✓		✓	✓	✓		average	10
SpotON	RS	SS	✓	✓	✓	✓	✓		average	1 m^3
RFID	RS	CoO		✓		✓		✓	low	1-20
CyberCode	VL	DI		✓	✓			✓	average	variable
Ubitrack	VL	DI		✓		✓	✓		N/A	N/A
EasyLiving	VL	DI	✓			✓	✓		high	variable

Tab. 1: Comparison of indoor location techniques

The following abbreviations are used in Tabel 1:

Signals:
IR....... Infra red
US...... Ultra sonic
RS...... Radio signals
VL...... Visible light

Postioning Methods:
CoO.... Cell of Origin
ToA.... Time of Arrival
TDoA.. Time Difference of Arrival
AoA.... Angle of Arrival
SS…... Signal strenght measurement
DI…… Digital images

N/A..... not available

The systems Active Badge (Want et al., 1992) and WIPS (Roth, 2004) employ infra red signals for location determination, Active Bat (Hightower und Boriello, 2001) and Cricket (Roth, 2004) use ultra sonic signals. For the location of cellular phones ToA or TDoA measurements can be performed (Retscher, 2002). Satellite or similar signals are also employed for the location of cellular phones using Assisted GPS (A-GPS) or for the Australian system Locata (Barnes et al., 2003) which makes use of standard RTK positioning with GPS similar signals. For indoor positioning the use of WLAN (Wireless Local Area Networks) has become popular and the systems Radar (Bahl and Padmanabhan, 2000), IMST ipos (Imst, 2004), Ekahau (Ekahau, 2005) and WhereNet (WhereNet, 2005) are using WLAN. Apart from WLAN also Ultra Wide Band (UWB) signals and Bluetooth (Hallberg et al., 2003) can be employed. SpotON employs also radio signals and perfoms signal strenght measurements (Hightower et al., 2000). Table 1 also contains three systems using digital images for location determination, i.e., CyberCode (Rekimoto et al., 2000), Ubitrack (Newman et al., 2004) and EasyLiving (Brumitt et al., 2000). For a further description of the systems see e.g. Retscher and Kistenich (2005a).

For navigation and wayfinding in smart environments the use of RFID (Radio Frequency Identification) for ubiquitous positioning is also a promising solution. RFID is a method of remotely storing and retrieving data using devices called RFID tags. An RFID tag is a small object, such as an adhesive sticker, that can be attached to or incorporated into a product. RFID tags contain antennas to enable them to receive and respond to radio-frequency queries from an RFID transceiver. For location determination RFID tags can be placed on active landmarks or on known locations in the surrounding environment. If the user pases by with an RFID reader the tag ID and additional information (e.g. the 3-D coordinates of the tag) are retrieved. Thereby the range between the tag and reader in which a connection between the two devices can be established depends on the type of tag. RFID tags can be either active or passive. Passive RFID tags do not have their own power supply and the read range is less than for active tags. They have practical read ranges that vary from about 10 mm up to about 5 m. Active RFID tags, on the other hand, must have a power source, and may have longer ranges and larger memories than passive tags, as well as the ability to store additional information sent by the transceiver. At present, the smallest active tags are about the size of a coin. Many active tags have practical ranges of tens of metres, and a battery life of up to several years. The location method is Cell of Origin (CoO) and the size of the cell is defined by the range of the tags. Using active RFID tags therefore the positioning accuracy ranges between a few metres up to tens of metres and with passive tags up to about 5 m. Altough this positioning accuracy can be low for some applications, RFID positioning can be very useful in combination with other sensors.

3 Locating the user on the correct floor in a multi-storey building

In the research project NAVIO the Vaisala pressure sensor PTB220A (see Figure 1) is employed for the determination of height differences from changes of the air pressure. The PTB220A is designed for measurements in a wide environmental pressure and temperature range with an extremely high accuracy (Vaisala, 2005). Starting from a given height the pressure changes can be converted in changes in height using the following equation:

Fig. 1: Vaisala pressure sensor PTB220A

$$\Delta H = H_2 - H_1 = \\ = 18464 \cdot (1 + 0{,}0037 \cdot t_m) \cdot (\lg B_1 - \lg B_2) \quad (1)$$

where ΔH is the height difference between two stations 1 and 2, B_1 and B_2 are the pressure observations at station 1 and 2 and t_m is the mean value of the temperature of both stations. It must be notetd that this equation is an approximation formula that is valid for central Europe only (Kahmen, 1997). Tests showed that there is no significant difference between the results using the approximation formula and an equation derived from Jordan which is also valid for other parts in the world and takes into account the geographic location of the two stations. Recently performed tests have shown that we are able to determine the correct floor of a user in a multi-storey building using this sensor and they are described in the following (Retscher and Kistenich, 2005b). First of all the drift of the sensor was analyzed in several long term tests. Then it was investigated if a functional connection between the observed pressure differences and the height differences can be derived. This connection can be described using characterisic curves. Finally the accuracy of the height determination was analyzed.

Figure 2 shows the test area which is in our office building of the Vienna University of Technology. The trajectory leads from the main entrance of the building via two staircases to our Institute which is located in the third floor of the 5-storey building.

4 Determination of the sensor drift

Figure 3 shows an observation of the sensor over two hours performed on a benchmark located on the roof of our building. The height of the benchmark is 200.05 m. The sampling rate of the observations was one second. The temperature droped from 16.5° C to 15.8° C during the two hour observation period. The maximum deviations from the given height reaches values of + 0.42 m and – 0.64 m in the first half hour. Thereby the observations can vary randomly in this range of about 1.06 m. Some discontinuous variations are also caused by the wind during the observation period. In summary, it can be concluded that no significant drift rates could be seen during severeral long term tests. The influence of wind, temperature changes and the air conditioning system inside the building, however, can be clearly seen in the observations. For the first half hour of operation variations of the air pressure in the range of ± 0.15 hPa could be seen. Considering the resolution of the sensor which is 0.01 hPa the sensor can be regarded as stable and no drift rate will be considered in the following.

Determination of a characteristic curve for the barometric pressure sensor

A characteristic curve shows a functional connection between the observed pressure differences and the height differences. If such a curve exists and the functional connection is linear then the pressure differences can be converted into height differences. For this purpose observations in the building have been carried out during different times of the day. Figure 4 shows six observations in the morning of one day and the resulting linear charac-

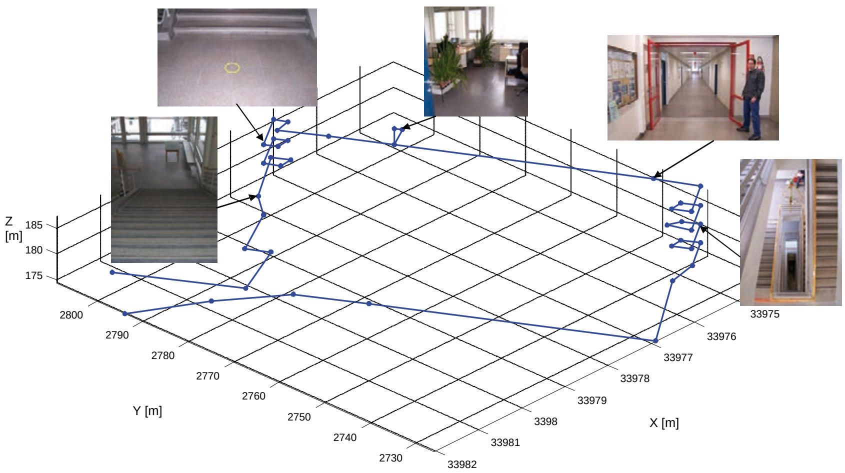


Fig. 2: Indoor trajectory in our office building of the Vienna University of Technology from the main entrance onwards to our Institute in the third floor of the building

teristic curve. The start point of three of this observations was on the ground floor and for the other three on the roof of the building. The characteristic curve is given by the following equation:

$$\Delta h = 8.769 \cdot \Delta p$$

where Δh is the height difference and where Δp is the difference in air pressure.

As can be seen from Figure 4 the measurement series show a good agreement with the resulting characteristic curve. There is also no difference if the observations begin either on the ground floor or on the roof of the building. Further characteristic curves have been obtained from different measurement series and can be found in (Kistenich, 2005). As a result it can be seen that we are able to calculate a linear characteristic curve which describes a linear functional connection between the air pressure observations and the changes in height.

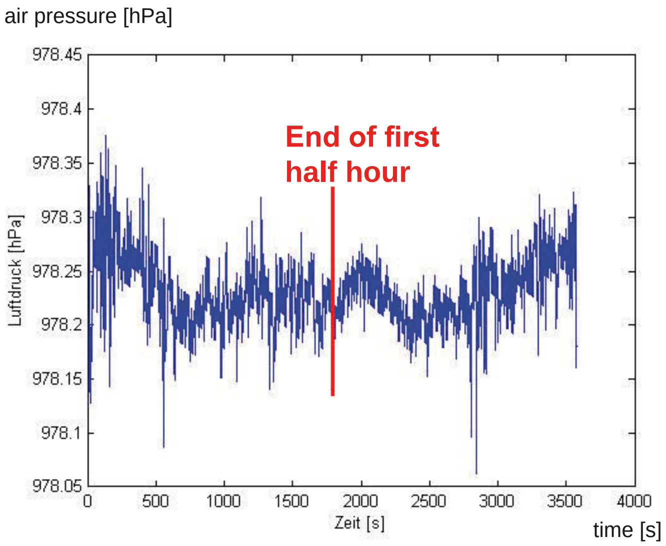


Fig. 3: Long term sensor observations with the Vaisala pressure sensor PTB220A on benchmark No. 11 on the roof of our building

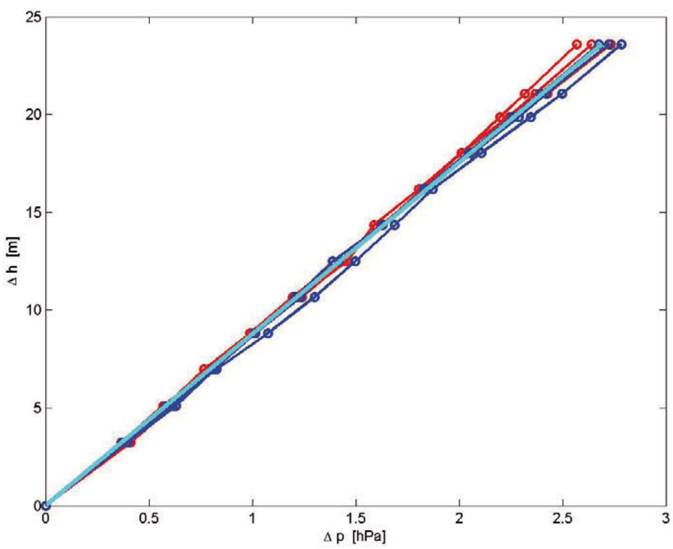
5 Determination of the height in the buidling

Figure 5 shows observations with the Vaisala pressure sensor PTB220A in our office building starting from the main entrance up to the third floor of the building where our institute is located. It can be clearly seen that the sensor is able to determine the correct floor of the user with a high precision. The standard deviation of the pressure observation is in the range of ± 0.2 hPa and the maximum deviation of the determined height is less than ± 1 m for 91 % of the observations. Thereby the deviations depend also on the time of day; higher deviations are obtained during noon where usually more people are inside the building and higher variations of the air pressure occur caused by higher air circulation due to frequent opening of doors and windows. The maximum outlier during noon reaches values of about 1.4 m. In summary, it can be concluded that the sensor is able to locate the user on the correct floor.

6 Conclusions and Outlook

For the location of persons and objects in buildings a variety of systems have been developed in recent years. In this paper an overview about their principle of operation and their performance is given. They provide mostly only 2-D location determination of the user and the determination of the correct floor is a very challenging task. Therefore in the research project NAVIO the use of a barometric pressure sensor for direct observations of the altitude is investigated. From the presented sensor tests can be seen that a high precision and relability for the location of a pedestrian on the correct floor of a multi-storey building can be achieved if a barometric pressure sensor is employed. Then in combination with other indoor location techniques and dead reckoning sensors a continouous 3-D position determination in indoor environments is possible. The observations of all sensors have to be combined and an integrated position solution has to be obtained. For the integration of all observations a multi-sensor fusion model based on an extended Kalman filter which makes use of a knowledge-based preprocessing of the sensor observations shall be applied. The principle of this approach is presented in (Retscher, 2005a). The fusion model consists of two steps, i.e., a knowledge-based prepro-

Fig. 4: Linear characteristic curve of six observations in our office building between the ground floor and the roof (6th floor)



cessing filter followed by a central Kalman filter for optimal estimation of the current users's 3-D position. The knowledge-based preprocessing filter represents an extension of common multi-sensor fusion models in a way that the data based system analysis and modeling is supplemented by a knowledge-based component and therefore not directly quantifiable information is implemented through formulation and application of rules. This rules are tested in the preprocessing step and if they are fulfilled certain actions are executed. Due to the knowledge-based analysis of the sensor observations gross errors and outliers can be detected and eliminated in this processing step. In addition, the preprocessing filter supplies input values for the stochastic model of the central Kalman filter. Therefore the weightings of the sensor observations can be adjusted in the Kalman filter depending on the availability and quality of the current observations. This integration approach will be implemented and further sensor tests will be carried out to test and analyze this approach. Due to the development of new advanced sensors it can be expected that multi-sensor solutions which provide location capabilities in outdoor and indoor environments will be deployed in pedestrians navigation services in the near future. We believe that these services will play an important role in the field of location-based services.

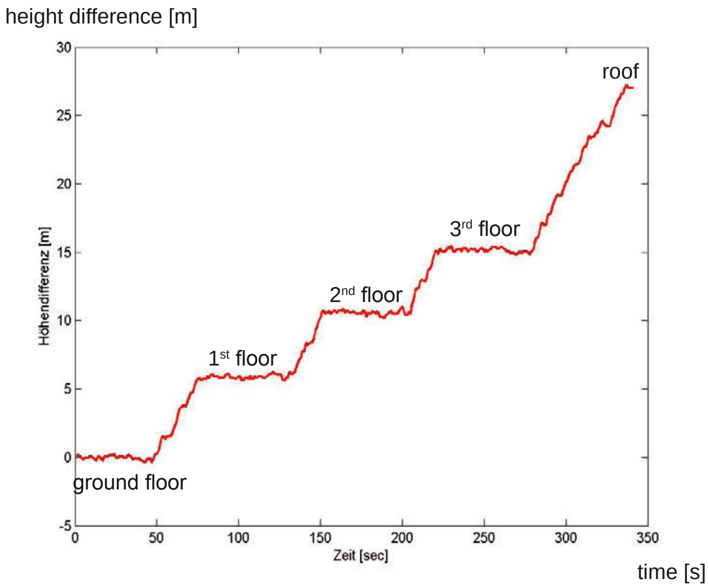


Fig. 5: Test measurements with the Vaisala pressure sensor PTB220A in our office building of the Vienna University of Technology

7 Acknowledgments

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A-GPS Positioning in today‘s mobile networks

Zvonimir Vukovic

Abstract

This paper presents an innovative way for positioning subscribers of mobile networks using Assisted GPS (A-GPS) technology. A-GPS offers substantial benefits for the end user compared with both traditional network-based positioning methods and with well known GPS positioning methods. These benefits are primarily high accuracy and availability with low market introduction costs. The standardization efforts by Open Mobile Alliance (OMA) have recently been undertaken to offer a clear and unambiguous standard called Secure User Plane Location (SUPL). These efforts will make it possible to develop standard conformed A-GPS enabled handheld devices and application platforms offering a variety of new and innovative location based services and solutions for the world market.

1 Introduction

Generally speaking, the location of a mobile subscriber can be obtained either by using mobile network architecture for positioning, or by using GPS positioning methods or by combining these two technologies into what we call Assisted GPS (A-GPS) positioning. Network based and GPS based positioning methods offer a number of advantages as well as disadvantages. The third way, A-GPS, combines the previously mentioned technologies into a new one by targeting the advantages of both of them.

2 Objectives

The objectives of this paper are following:

- to give an overview of the A-GPS technology
- to compare A-GPS positioning technology with network based positioning and GPS based positioning technologies
- to present the standardisation efforts undertaken to bring clear and unambiguous standards for the world market
- to present development results achieved by Siemens in implementing a standardized platform for location based services called “Location Platform 3.5”

3 Technology description

As already mentioned, A-GPS technology is derived from both, network based and GPS based positioning technologies, offering superior accuracy and availability with low investments into existing mobile network infrastructure.

3.1 Network based positioning

Network based positioning methods rely entirely on the capabilities of the underlying infrastructure of the mobile network and, compared with the other two technologies, do not depend on the capabilities of the handset. The subscribers’ position estimates are calculated out of the available cell information. It is possible to request a position estimate of any mobile subscriber including self positioning. Depending on the coverage and capabilities of the mobile network elements the available positioning data can be more or less appropriate for calculating a good quality position estimate, thereby delivering more or less accurate results. In urban areas it can be expected to get better quality positioning estimates since it is likely to have better coverage and more cell information; in rural areas low quality position estimates can be expected due to lower coverage and less available cell data. In general, for network based positioning attempts delivered accuracy starts with 300 m and can go far beyond that. Furthermore, location requests issued against a mobile network consume a certain amount of resources of the mobile network thereby reducing the available bandwidth for voice and data calls. This means, network operators have to invest money into network infrastructure. Also, roaming scenarios may require roaming access to foreign mobile networks and this raises further compatibility and billing problems. The reality has shown that in most cases, due to different versions of network elements and different supported standards, positioning estimates are not better than a simple translation of the serving cells’ coordinates. This is, unfortunately, not good enough for most location-based applications.

3.2 GPS

The Global Positioning System (GPS) consists of 24 satellites, which are placed in six orbital planes at 20200 km above the Earth. From the point of view of mobile networks, pure GPS positioning does not relay on mobile network infrastructure in any way. To be positioned, a user needs to have a GPS compatible handset and a clear view to the skies to get the signal from at least three satellites. This makes it impossible to execute positioning within buildings or urban areas with huge skyscrapers. Furthermore, a GPS receiver needs up to several minutes from the "cold" start to be able to deliver the first position estimate (time-to-first-fix). If all the necessary circumstances are met, one can position itself with an accuracy of 10 m.
GPS positioning does not raise coverage and roaming issues as in case of network based positioning.
Handheld devices, such as mobile phones, can be equipped with GPS receivers and provide interfaces towards the mobile network for exchange of positioning estimates between different users and/or to report the location of a user to the appropriate authority (e.g. for emergency reasons). This opens the door for a number of commercial use cases involving the mobile network as a bearer of position estimates.
From the point of view of the small handset devices, necessary calculating power and battery consumption for the full GPS chipset have a significant impact on the size and weight of such devices making them bigger and heavier.

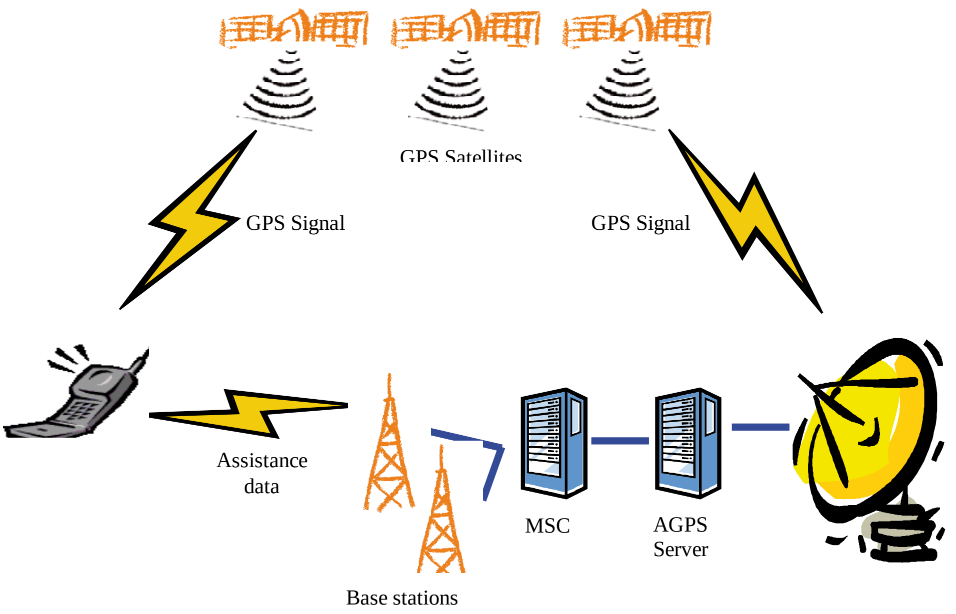
3.3 A-GPS

Assisted GPS (A-GPS) is a positioning method that is a combination of both, network and GPS based positioning, where advantages of both of them have been taken into consideration. In an A-GPS system outside sources, such as assistance server and reference network, are providing help for a partial GPS receiver (built into a mobile phone or similar handheld device) to perform tasks necessary for delivering position estimates. The partial GPS receiver is built into a mobile device; it communicates with an assistance server via mobile network. The mobile network provides an initial approximate location of the receiver using available cell data. For this a simple translation of the serving cell identification into coordinates is sufficient. This approximate position (which is in network based positioning scenarios sometimes the final result, the best one can get) is forwarded to the Assistance Server. The Assistance Server is responsible for data exchange with the GPS reference network and for execution of complex calculations. Based on these calculations a partial GPS receiver is able to more quickly and efficiently find appropriate satellite frequencies and lock onto them. In this scenario weaker satellite signals than those required by pure GPS can be efficiently used. Reduced search space leads to shortening the time necessary to get the final position estimate from minutes to seconds. Furthermore, since assistance is obtained from the mobile network, the necessary power consumption and calculating power of the built-in receiver is lower making it more appropriate for rather small mobile devices such as mobile phones. Furthermore, indoor coverage becomes reality.

3.4 Overview of achieved accuracy using different positioning technologies

The following diagram presents the accuracy that can be expected from different positioning methods nowadays available within mobile networks.

Fig. 1: Overview of A-GPS positioning technology



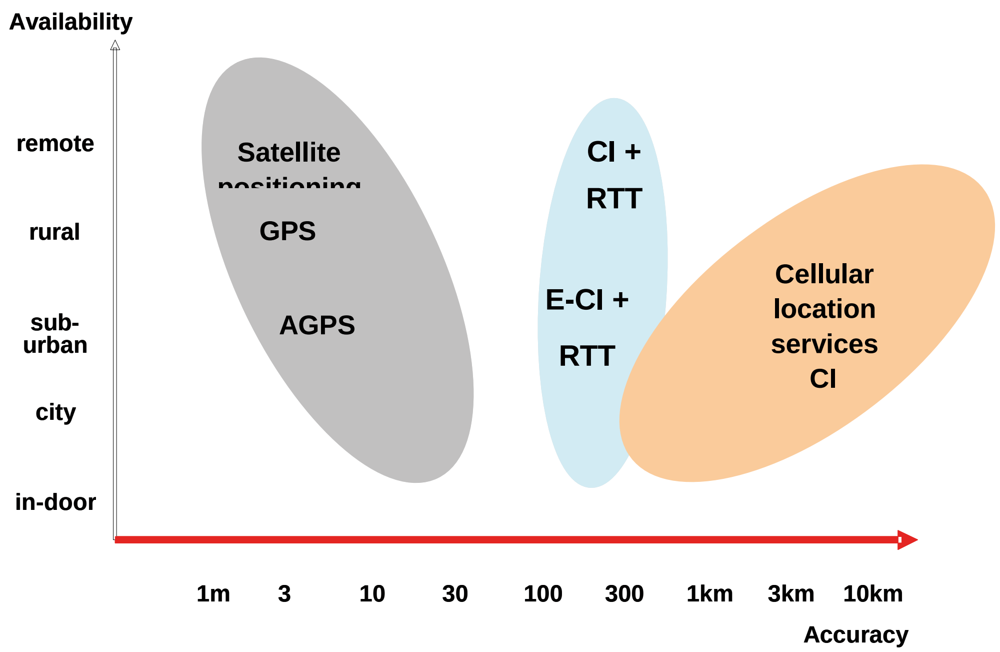


Fig. 2: Accuracy of different positioning gtechnologies

3.5 Strength and weaknesses of positioning technologies

The following table presents an overview of strength and weaknesses of available positioning technologies

Positioning technology	Strengths	Weaknesses
Network based positioning	Availability with all mobile phones, no additional costs for the user; Quick response from the network; Mobile network offers tracking capabilities	Additional investments in mobile network infrastructure; Low accuracy
GPS	No mobile network infrastructure investments; High accuracy; High Coverage	Mobile devices with integrated GPS chipset are necessary; Increased cost and complexity; Poor indoor coverage; Long time to first fix
A-GPS	High accuracy; High availability; Indoor coverage; Short time to first fix; Low network traffic	Mobile devices with integrated partial GPS receiver are necessary; Standardization of interfaces between network and mobile phones is necessary

Tab. 1: Strengths and weaknesses of positioning methods

3.6 Standardization efforts

Standardization efforts have recently been undertaken by the Open Mobile Alliance (OMA) to bring a new unambiguous standard for A-GPS positioning in mobile networks. OMA includes nearly 200 world’s leading mobile operators, device and network suppliers, information technology companies and content and service providers. One of the main goals of OMA is to “deliver high quality, open technical specifications based upon market requirements that drive modularity, extensibility, and consistency amongst enablers to reduce industry implementation efforts”. This ensures that any standardization effort of such kind will push all involved sides, e.g. network operators, mobile phones manufacturers and solution providers, to promptly deploy services and solutions worldwide.

Siemens as one of the OMA members has provided significant contributions into developing a new standard for A-GPS positioning called Secure User Plane Location (SUPL). This standard is planned for end of June 2005 to get finalized with good quality drafts already available. It is focused on definition of all necessary interfaces and protocols used by mobile devices utilizing both, A-GPS and (full) GPS receivers, and mobile networks in the following use cases: mobile initiated positioning and network initiated positioning. The standardization takes into consideration all security and authorization issues as well.

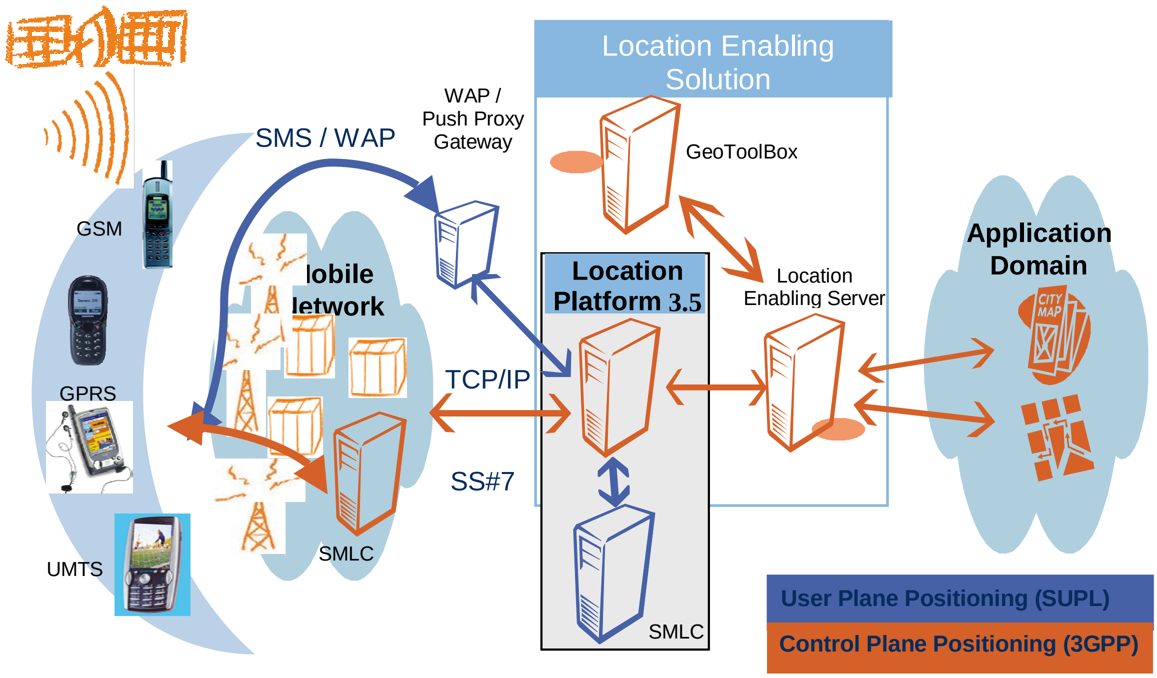


Figure 3: Overview of Location Platform 3.5 solution

The use case ”mobile initiated positioning” describes a situation where a user of a mobile device provides its own location to the network. Such use case is, among other cases, especially interesting for situations where a proper authority should be informed about an emergency situation.

The use case ”network initiated positioning” describes a situation where a request for positioning of a certain mobile device (thereby a user of this mobile device) has been submitted to the mobile network. The mobile network initiates positioning of the requested device considering all relevant security and authorization issues and delivers the result to the requesting party.

3.7 Developments

Development of location based solutions has already been a topic by all major competitors in the telecommunication business for some time now. A number of different applications are already deployed worldwide. But the expected business volume has still not been met due to a number of reasons, some of them being low precision, coverage problems and lack of standardization.

Siemens has developed a product called “Location Platform 3.5”. The “Location Platform 3.5” retrieves the mobile device’s position and subscriber state information from the mobile network and delivers this information to interrogating applications. This future-oriented platform supports 2G, 2,5G and 3G networks. It supports cell-id based positioning based on the MAP and CAMEL standard as well as higher accuracy positioning technologies in cooperation with an SMLC according to the 3GPP standard for Location Services. Fully based on standards, LP 3.5 supports multi-vendor environments both, within a single network and in roaming scenarios. For GPS and A-GPS positioning scenarios, a brand new SUPL standard has been implemented (up to the latest standardization results at the time of writing this document, with strong intension to track all changes and updates) to support all current and future implementations of GPS and/or A-GPS devices and applications.

Due to the fact that all three technologies presented here (network based positioning, GPS positioning and A-GPS positioning), and all positioning scenarios (network initiated and SET initiated) are supported, the “Location Platform 3.5” is able to perform an automatic fallback from one positioning method to another one if the initial positioning attempt fails due to any reason.

The following picture gives a rough overview of the “Location Platform 3.5“ solution, showing different interfaces and supported positioning methods.

4 Results

Existing results in development of A-GPS based positioning services have a lack of standardization due to the fact that the SUPL standard will be finalized by end of June 2005. Nevertheless, pre-standard solutions are being developed and integrated to provide complete solutions. Siemens is closely monitoring finalization of the SUPL standard and acts accordingly to provide a reference implementation.

5 Conclusions

A-GPS is a rather new positioning technology supported by an unambiguous standard and a number of companies (either mobile network operators, mobile phones manufacturers or solution providers). It is a hybrid solution that offers superior positioning accuracy and coverage with low investments and cost sharing among network providers, mobile manufacturers and solution providers. It has all it needs to become a bearer of standardized solutions and services on a worldwide level offering a new dimension in everyday usage of mobile phones and other mobile devices. For a common user, a mobile phone becomes not only a simple communication device but also a useful travel companion or context provider.
Critical issues, at the time being, are the finalization of the SUPL standardization and availability of compatible mobile devices on the market. There are companies though, such as Siemens, who are already prepared for all the challenges of this technology.

6 Abbreviations

2G	2nd Generation
2.5G	2.5 Generation
3G	3rd Generation
3GPP	3rd Generation Partnership Project
A-GPS	Assisted GPS
CAMEL	Customized Applications for Mobile network Enhanced Logic
CI	Cell Identity
E-CITA	Enhanced Cell Identifier Timing Advance
GSM	Global System for Mobile Communication
GPRS	General Packet Radio Service
MAP	Mobile Application Part
RTT	Round Trip Time
SMLC	Serving Mobile Location Centre
SMS	Short Message Service
UMTS	Universal Mobile Telecommunications System
WAP	Wireless Application Protocol

Table 2: Abbreviations

7 References

[1] Goran M. Djuknic, Robert E. Richton, “Geolocation and Assisted GPS”, February 2001
[2] Jimmy LaMance, Javier DeSalas, Jani Jarvinen, “Assisted GPS. A Low-Infrastructure Approach”, GPS World, Mar 1. 2002
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Terminal-Centric Location Services in the IP Multimedia Subsystem

Rudolf Pailer, Florian Wegscheider, Joachim Fabini

Abstract

Location-based services in 3G and beyond networks depend on high-accuracy location data. Today's 2G and 3G access networks determine user location in a network-centric manner. The accuracy of these location mechanisms depends on the radio infrastructure near the user's geographical position and is typically limited to hundreds or thousands of meters. This precision is inadequate for typical location-based services like city maps or route planners.

In this paper we present a terminal-centric location enabler that integrates seamless with the existing IP Multimedia Subsystem presence architecture and interoperates with network-centric location mechanisms. We argue that the optimal accuracy is achieved by determining the location on the user terminal, which can be equipped with location sources like Global Positioning System (GPS) receivers. In consequence, the user terminal should be used as the primary source for location information. We extend the existing and well-known concept of presence by defining location as a type of presence information that is of interest to users. Terminal-based triggers and filters reduce the amount of traffic on the air interface and enable a scalable location architecture.

This paper describes the system architecture for a terminal-based location service enabler in the 3G IP Multimedia Subsystem (IMS).

1 Introduction

Location Based Services (LBS) are services that require information about the physical position of a user in order to provide 'added-value' to services in a 3rd generation (3G) network. Location data may be plain geographical coordinates, access point cell ids, civil location in form of postal addresses or more abstract definitions like 'in the office', 'at home'. Example services are a map showing the user's current location or triggering a switch of the user profile when entering a specified area.

Service enablers, defined to expose network functionality to external service providers, are becoming the cornerstones of modern service architectures defined by the Parlay Group, the Open Mobile Alliance (OMA) or in the IP Multimedia Subsystem (IMS). A Location Service Enabler is a functional entity in the network enabling value-added services to query the current position of a user or to request a trigger when a specified area is entered or left.

Many mobile and fixed network operators have already started to migrate their telecommunication networks towards an All-IP infrastructure where voice loses its dominancy and becomes just one among many services. The IP Multimedia Subsystem (IMS) [1], standardized by the 3rd Generation Partnership Project (3GPP), is the most promising candidate for replacing legacy, voice-dedicated mobile networks with an All-IP technology. As opposed to traditional IP-based networks, the IMS guarantees end-to-end Quality of Service (QoS) in the network. The IMS creates an infrastructure that enables the fast deployment of new IP-based services and flexible billing while still maintaining compatibility with existing applications. The 3GPP IMS location specifications [2] adopt a network-centric location mechanism based on the Gateway Mobile Location Centre (GMLC) as primary location source for LBS. The accuracy of this network-centric positioning mechanism is dynamic. Depending on the radio infrastructure near the user's geographical location the GMLC typically positions a user within an area of several thousand square meters in urban area to several square kilometers in rural area. This accuracy is not satisfactory for many LBS. High investments are required to implement network-centric location mechanism enhancements like Network Assisted GPS (A-GPS) or Idle Period Downlink- Observed Time Difference Of Arrival (IPDL-OTDOA).

We argue in this paper that the optimal source for location data is the user's terminal. If the terminal is equipped with some generic location technology (e.g. a GPS receiver), it can deliver the most accurate positioning information to the system. We thus propose a handset-based Location Service Enabler.

Many countries impose legal restrictions that regulate the processing of personal data and the protection of privacy in electronic communications. Furthermore users want to control who gets access to their location data and want to be sure that the transport in the network of such sensitive data is protected by strong security mechanisms.

Our analysis of the IMS presence system shows that the requirements regarding access authorization, encryption and privacy for presence are indeed identical to those for location. The concept of presence was introduced in instant messaging systems. Presence is information about the online status of other users. A watcher can subscribe to notifications about the state of a watched user, called 'presentity'. Classical presence information is defined as the willingness of the presentity to communicate.

We argue in this paper that location data can be regarded as a special type of presence information that we will subsequently call location presence data. The proposed architecture for an IMS Location Service Enabler is thus an extension of the existing IMS presence system. Our system design builds on the request routing, authorization, encryption and privacy mechanisms of the IMS presence enabler, but extends the existing specifications in order to support a distributed terminal-based Location Service Enabler.

2 The IP Multimedia Subsystem - IMS

The IP Multimedia Subsystem is an overlay network specified by the 3GPP in the last years and is currently in the roll-out phase. The IMS makes heavy use of the Session Initiation Protocol (SIP) [3] and its extensions and defines several service enablers such as voice over IP (VoIP), multimedia streaming, presence, instant messaging, push to talk, etc. Initial focus of 3GPP's IMS specification was on UMTS and GPRS networks but the concept of IMS is access-independent. I.e., IMS can use WiMax, WLAN or fixed networks in the access providing a guaranteed end-to-end QoS to customers. Whereas most UMTS applications can be realized without the IMS, the specified mechanisms promise a uniform, standardized way of handling: quality of service, charging, roaming and integration of different applications and services.

The core IMS network uses three component classes: the Call-Session Control Functions (CSCF), which route SIP messages and control basic session establishment, Application Servers (AS) which are also SIP-enabled and implement services in the IMS network and finally the Home Subscriber Server (HSS), which is the user data repository in the home network (see Figure 1).

The User Equipment (UE) registers with the IMS network by sending its SIP registration request to the Proxy Call-Session Control Function (P-CSCF), which was assigned to the UE by the network (DHCP, PDP context activation). The P-CSCF forwards all messages it receives from the UE to the Interrogating CSCF (I-CSCF) which serves the user's home domain. The I-CSCF contacts the HSS, selects a Serving CSCF (S-CSCF) based on the services the user has subscribed to, and forwards the registration message to the selected S-CSCF. The S-CSCF is the service access point and service dispatcher within the IMS network. It authenticates the user and registers him with the IMS network. Depending on the user profile, the S-CSCF redirects calls from or to a specific user to AS like the Presence AS shown in the figure.

For simplicity the picture does not show interfaces towards legacy application servers like CAMEL or OSA/PARLAY, as well as gateways towards legacy networks.

3 Location mechanisms and standards

Current GSM/GPRS and UMTS networks use a network-based Location Service Enabler to provide location data to location applications. 3GPP specification TS 22.071 [4] gives a general description of location services (LCS) and service requirements for 3rd generation networks. It identifies four reasons for implementing LBS in IMS:

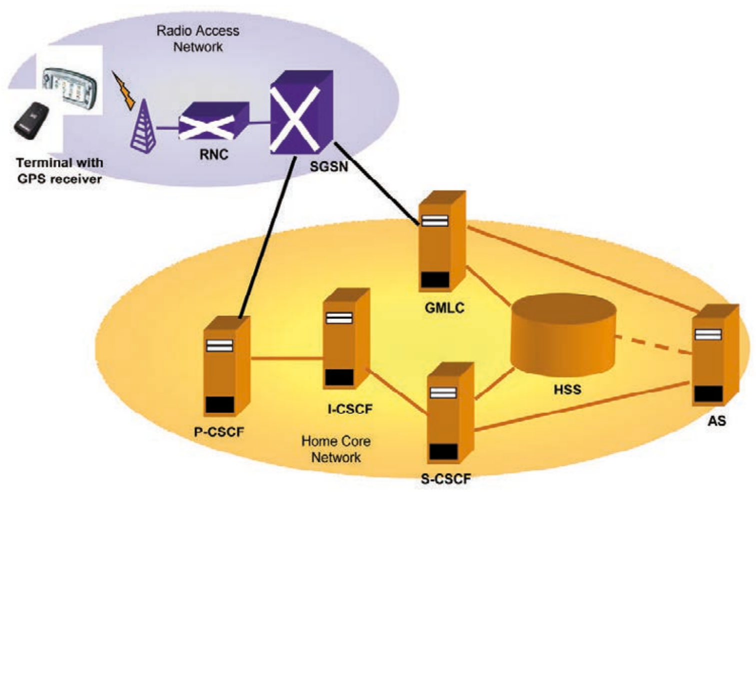
1. Provide value-added services to customers
2. Operators can use LBS for network optimization and OAM services.
3. Emergency services
4. Lawful intercept

3GPP TS 23.271 [5] specifies the mechanisms to support mobile location services for operators, subscribers and third party service providers. The radio signals of the wireless network are used to determine the (geographic) location of the user equipment (UE). The specification explicitly assumes that "positioning methods are Access Network specific, although commonalties should be encouraged between Access Networks".

Interworking with the IMS has been introduced in version 6.7.0 for UMTS release 6 in March 2004. The central component in the 3GPP LCS design is the Gateway Mobile Location Center (GMLC) that offers location services.

The following network-based positioning methods are specified in the 3G documents:

Fig. 1: IMS Components



Cell Coverage Based. The cell ID is either known to the radio network or can be obtained by paging the terminal. The accuracy of this method depends on the cell size and is typically in the range of 300 m in urban areas.

Idle Period Downlink- Observed Time Difference Of Arrival (IPDL-OTDOA). This method measures the relative time of arrival of pilot signals from different base stations. At least three stations have to be visible to calculate a location. Network planning however optimizes a cellular network for available bandwidth which means reducing unnecessary overlapping of cells. Thus the accuracy of the IPDL-OTDOA method is not satisfying in real networks (about 50m – 150m) and the technology requires a substantial up-front investment in the radio access network.

Network Assisted GPS (A-GPS). The network sends assistance data to a GPS receiver in the terminal in order to speed up the position calculation and to provide service in areas where GPS signals are weak (e.g. inside buildings). Assistance data contains precise GPS satellite orbit and clock information, initial position and satellite selection. A-GPS offers good position accuracy (5 m) but requires a GPS assistance service and necessitates a medium up-front investment in the 3G network. Furthermore A-GPS enabled terminals are not available on the market yet.

A terminal based location enabler on the other hand, such as a built-in GPS sensor or a Bluetooth GPS module, is a relatively inexpensive hardware feature and allows upgrading only those terminals whose users subscribe to or want to use location enabled services. A terminal based location enabler can be accessed in a peer-to-peer mode with minimal impact on network resources, thus making a highly scalable solution possible. Since a terminal centric solution is totally independent of the underlying network technology or the network provider it enables vertical handover (e.g. UMTS - WLAN) and works in roaming scenarios.

4 IMS Presence Location Client Architecture

The concept of presence was introduced in instant messaging systems. Presence is information about the online status of other users. A watcher can subscribe to notifications about this state. The watched user is called 'presentity'. Classical presence information is defined as the willingness of the presentity to communicate.

The presence enabler in the IMS is based on the SIP Instant Messaging and Presence Leveraging Extensions (SIMPLE [6]). The SIMPLE specifications in turn make use of the SIP event system [7] and use its subscribe-notify mechanism. The presence system of the IMS is specified in [8], the presence event package in [9].

The fundamental assumption that leads us to the reuse of the presence architecture is that we regard location information as a kind of presence information. The location of a user may be related to his presence state. The access to both presence and location data has the same requirements regarding security and privacy.

We propose the use of the Geography Markup Language (GML, [10]) to include location information in PIDF documents. Since both languages are XML based, GML elements can be integrated in Presence Information Data Format (PIDF) documents [11] easily.

Notification filters enable more complex notifications than pure location updates. The filter is sent within the subscribe message from the watcher to the presence server. For example the filter "(longitude TO centre BY distance) OR (latitude TO centre BY distance)" will send a notification whenever the presentity enters a rectangle around the centre coordinates. This reduces traffic over the air interface (single notification instead of constant location updates) at the price of added complexity at the presentity's terminal.

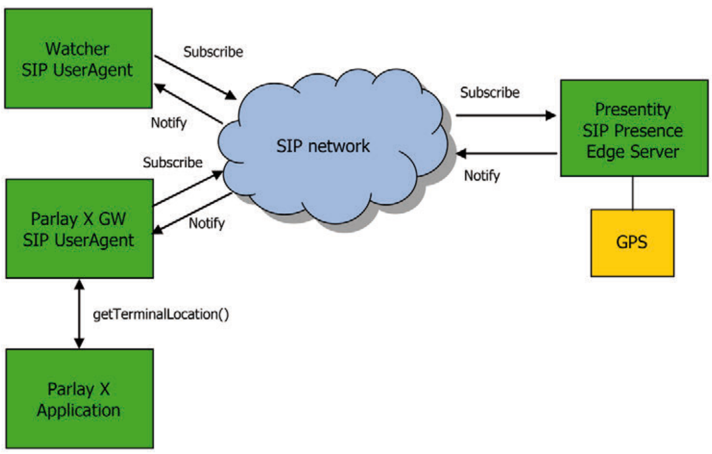
In order to access a terminal based location enabler, we propose to install a SIP Presence Edge Server at the GPS enabled user terminal. An edge presence server is a presence agent that is co-located with a Presence User Agent (PUA).

The simplest form of the proposed system architecture is sketched in Figure 1: a peer-to-peer location presence system. The user's terminal hosts an edge presence server for location presence information. It allows 3rd party applications or other users to subscribe to location presence data notifications. A watcher application may use SIP messaging or interfaces like the ParlayX location API [12] to request presence location data. The client software in the user's terminal uses the J2ME Location API [13] to access the GPS module providing the physical location.

In order to support network-based location for terminals without a GPS receiver, we propose to use a Presence Agent in the network that aggregates presence data. The Presence Aggregator intercepts all subscription messages. Based on a user data base or on subscription policies, it decides how to locate the presentity. If the location is only available in the network the subscription is forwarded to the presence server. If the user has an active GPS receiver, the subscription will be sent to the terminal. If both options are available the aggregator can check the data for reliability. (Are the GPS coordinates within the cell?).

Location presence data shows some essential differences from other presence data. First, location data is semantically different from classic presence data due to the almost continuous state space. Second, location data originates from different sources than normal presence state. As location data is calculated in the presentity's terminal it requires a distributed approach. We therefore propose to separate subscriptions and notifications for location presence data from classic presence by introducing a new locpres: URI-scheme. The intended usage of the locpres: URI follows closely the usage of the pres: URI. However, it allows routing a subscription for presence location data to the presentity's terminal by addressing a subscription request to the locpres: URI of the target. In order to implement dedicated presence location access policies, filtering mechanisms and caching disciplines we propose publishing a locpres: URI of a presence location server that is dedicated to the handling of location data.

Fig. 2: Peer-to-Peer system Architecture

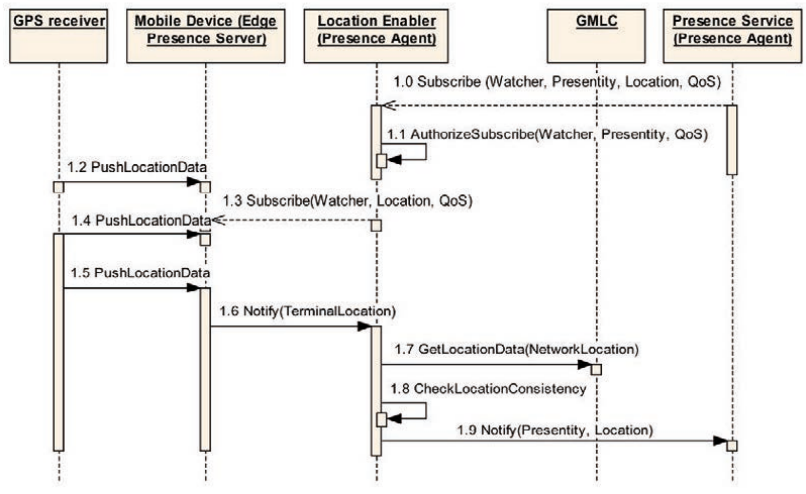


The bottleneck of today's mobile communication networks is the wireless access network – both in terms of delay and bandwidth. The communication between the mobile terminal and the location server uses the wireless access network so traffic over this interface must be reduced to a minimum for optimum performance.
We argue that terminal-based filters can significantly reduce the amount of traffic on the air interface. The mobile terminal is not required to forward the location stream it receives from the GPS receiver to the LE.
The solution that we have chosen is to provide the mobile terminal with filter information within the location presence subscribe messages. Along with the description of the location presence event these messages contain an area and the action to be taken. E.g. the subscribe message requests the mobile terminal to generate a notification on entering or leaving a rectangle area specified by centre coordinates, length and width.
The sequence diagram in Figure 2 shows the message sequence for a terminal-centric location service's operation.
The figure omits the watcher who subscribed for the specific service. E.g., user Alice asks for the service "notify me if Bob is in his office". The presence service maps the logical location information "Bob's office" onto the corresponding geographical location data – e.g. a rectangle defined by its center coordinates, length and width. The presence service contacts the Location Enabler (LE) on behalf of the watcher Alice by sending a SIP subscribe message (1.0). Part of the subscribe message is the GML-encoded location that Alice is interested in and a description of the expected QoS: location accuracy, timing requirements, etc. The LE authorizes the subscribe request (1.1) and, if successful, forwards the subscribe message to the Edge presence Server (EPS) on Bob's mobile device (1.3). Depending on the policy configured by Bob, the mobile device might ask interactively for Bob's explicit permission before accepting Alice's location request.
The GPS receiver sends continuous location updates to the mobile device, which are forwarded via the JSR179 interface [13] to the terminal's EPS (1.2, 1.4, and 1.5). The EPS detects on receipt of message 1.5 that Bob is located within the rectangle area the LE has subscribed to and that the QoS conditions are satisfied (accuracy is within limits). The EPS then sends a SIP notify message (1.7) to the LE. Depending on the QoS requested by Alice, the LE might decide to invoke a network-centric location mechanism (1.8) to do a consistency check (1.9) on Bob's location data. E.g., Alice might be a lawful authority representative who set the location request's QoS to the highest possible location reliability.
The LE then forwards the SIP notify message to the presence service (1.9), which processes the location data and then contacts the watcher Alice.

5 IMS Presence location performance

A network-based positioning method requires request routing, access authorization and privacy control. Even if requester and target are connected to the same network, these functions are not trivial. In a roaming scenario, however, where a location request from a requesting network has to reach a location enabler in the visited network where the target terminal is actually roaming, is indeed a complex task, especially when access policies and privacy settings should be respected. The 3GPP Location Enabler architecture hence requires complex request routing between Requesting-, Home- and Visited network components in order to resolve the GMLC responsible for the user's terminal.
In an IMS-enabled system, however, the MSISDN based routing of a GMLC should be replaced by SIP message routing with its positive implications regarding performance, network management and security. Therefore our proposal is to send the location request directly to the user's URI using plain SIP message routing instead of introducing complex interworking functions in order to address a network-based location enabler.
Furthermore, the existing network-based positioning methods are either insufficient regarding accuracy or require up-front investments in the core network. Using a terminal-based GPS receiver as a source for location data is a network technology independent solution. It offers satisfactory accuracy while requiring only investments in those customers who want to use a location service.

Fig. 3: Terminal-centric location enabler operation



Privacy requirements and mechanisms proposed by 3GPP standardization for Location Services are similar to those of presence systems [4] [14]. Beyond the specified functions, a real world location service system requires components that allow provisioning, user access and user control of privacy parameters. It seems reasonable to re-use the IMS presence infrastructure for subscription, authorization and privacy management of Location Based Services.
Finally, a network-based positioning method is forced to implement triggered location updates through polling. In order to conserve battery power mobile terminals tend to be in an idle state most of the time. Hence position changes are not visible to the network. We propose to imple-

ment trigger logic in the terminal so that necessary location updates are kept to an absolute minimum and scarce resources in the radio access network are used in the most economic way.

6 Related work

The Geographical Location and Privacy (GEOPRIV) working group of the IETF [15] has investigated a number of problems related to the distribution of geographical information on the Internet, from both a security and a policy angle. The result of this work is a generic framework for the creation and distribution of location information on the Internet that enables confidentiality and policy directives, which are abstracted from the format of the location information.
Küpper and Treu propose complex location update strategies in the mobile terminal in order to realize scalable Location Based Services [16]. Shaham et al. propose to use SIP event mechanism to transport location data [17].
Polk and Rosen present a framework and requirements for usage of SIP to convey user location information and consider cases where message routing by intermediaries is influenced by the location of the session initiator [18].

7 Conclusion and future work

In this paper we have presented the architecture of a terminal-centric IMS location enabler. Our solution scales better and is more accurate, efficient and cost effective than current network-based location enablers.
Our group is currently working on an extension of SIP event filtering specifications and mechanisms in order to express and implement complex triggering criteria in the mobile terminal. Furthermore we are in the course of implementing a prototype system in order to prove our concept in a reference implementation.
Finally, we intend to contribute to the 3GPP/IMS standardization process with the aim to add the IMS location enabler to the family of basic enablers such as presence and messaging.

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WiKaF - A knowledge-based Kalman-Filter for pedestrian positioning

Michael Thienelt, Andreas Eichhorn, Alexander Reiterer

Abstract

The precise, reliable and preferably everywhere available positioning of mobile users is a substantial precondition for the provision of location and situation based information by Location Based Services. Within these applications locating of pedestrians in ‘passive environments’ represents a special challenge. In this paper a new knowledge-based approach for the improvement of position quality is presented.

1 Introduction

Within the last years there was an enormous increase of various navigation applications. Especially vehicle navigation systems made the evolution from the research labs to the user segment. Now the next logical step is to navigate the individual person. Cellular phone network operators already show a massive presence at the navigation market. This is motivied by the necessity to amortise their investments in expensive UMTS licenses introducing new profitable customer services, especially so called location based services (LBS). Many of these services offer location based information for users with mobile devices (e.g. PDA, mobile phone etc.). The service is performed dependending on the current position/situation of the user. Typical examples are “Friendfinding” or monitoring of nearest restaurants respectively shopping possibilities.

The reorganization of the American army has also led to an intensified research work with LBS. One important emphasis is the positioning of pedestrians (infantry). Navigation supported by mobile devices aims at a faster and less error-prone orientation in unknown areas.

Civil applications are mainly focussed on tourist navigation. The individual pedestrian shall be able to explore a city in an independent and comfortable way. Depending on his present position he gets additional information, for example of sights and shopping facilities.

Depending from the type of environment the methods for positioning (locating) can be divided in two groups: (1) locating in passive and (2) locating in active environments. Passive enviroments have no active sensor infrastructure. The locating of the user is realized autonomously by mobile devices with several sensors like GPS, mobile phone, digital compass or pedometer [1].

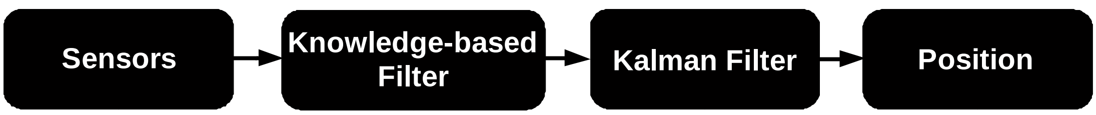
Active environments contain active landmarks. Active landmarks are single sensors or sensor networks which connect themselves with a mobile device transferring information about its present position. A successful application is realized in museums by infrared interfaces [2]. The exhibits locate the visitor and submit relevant information (e.g. historical data) to his mobile device. Using WLAN active Landmarks can also be realized in urban areas. Current research activities try to integrate the RFID[1] technology into this development.

The common goal of all different positioning methods is to provide a precise, reliable and preferably everywhere available position information of the mobile users. It is a substantial precondition for the application of LBS. Especially the autonomous positioning of pedestrians in passive environments is influenced by many quality restrictions and consequently a special challenge. This contribution presents a new knowledge-based approach for the significant improvement of position quality: WiKaF (= ‘**Wi**ssensbasiertes **K**alman-**F**ilter’, see [3]).

2 System architecture

In Figure 1 the process chain for the positioning of pedestrians with knowledge-based Kalman-filtering is presented. A multi-sensor platform acquires absolute and relative position data of the pedestrian. In a knowledge-based preprocessing the measuring data is

Fig. 1: Process chain of the WiKaF-System



[1]) RFID (radio frequency identification) is a method for wireless reading and storing data. The data will be stored on special RFID tags. RFID contains the tags, a transmission/receiver unit and the integration of this components in an existing server system [5].

checked for plausibility and quality. Rough errors are eliminated and adequate stochastical models are selected/adapted dependent on the current environmental conditions of the pedestrian. In the next step a KALMAN-filter performs the combination of the hybrid sensor information (= multi-sensor integration) to an optimal estimation of the kinematic state of the pedestrian (e.g. position, speed and direction of the movement). In the following section the individual components of the process chain are described.

2.1 Sensors

WiKaF uses the following sensors: Vaisala PTB 220, Honeywell HMR 3000, Garmin eTrex Summit and a Dead Reckoning module (DRM III) from the company PointResearch. All sensors have been acquired in the NAVIO project [4] and are presented in Figure 2.

The **PTB220** is a fully compensated digital barometer and covers a wide measuring range of air pressure: 500 to 1100 hPa. It has a special silicon-sensor that was developed by the company Vaisala for precise barometric measurements. The sensor is non-sensitive to changes in temperature (range of application: -40 to +60°C), vibrations and shows a good longterm stability [5]. In WiKaF it shall be used for indoor navigation (detection of different floors in buildings).

The **HMR 3000** is a compass module which consists of three magnetoresistive sensors and a two-axis tilt sensor to produce tilt compensated heading data [6]. The determination of the heading is an important precondition for positioning in a dead reckoning scenario.

The **eTrex Summit** is a 12-channel handheld GPS receiver [7]. It consists of an integrated GPS anntenna, a digital compass and a barometric altimeter. It runs up to 22hours with batteries (save mode) and was choosen to get redundant GPS data (see also DRM III).

The **DRM III** is a commercial sensor module for pedestrian navigation [8]. It combines a data acquisition (absolute and relative sensors) with a processing component (KALMAN-filter). In WiKaF the module is only used for data acquisition. Data processing will be realized with the new knowledge-based KALMAN-filter. Nevertheless the trajectory processed by the DRM III can be used for comparison and evaluation of the results.

The module consists of a 12 channel GPS receiver with antenna, a digital compass, a triax accelerometer (usable for step recognition), a barometer and a gyro. The GPS antenna can be fastened on the head of the pedestrian. The azimuth of the movement is determined by a combination of digital compass and RateGyro. Number of steps and a scale factor (step length) enable to derive the covered distance. For step recognition it is very important that the module is centrically fastened at the belt (back, see Figure 2) of the user. The correct adaptation of the module has a significant influence on the quality of step recognition.

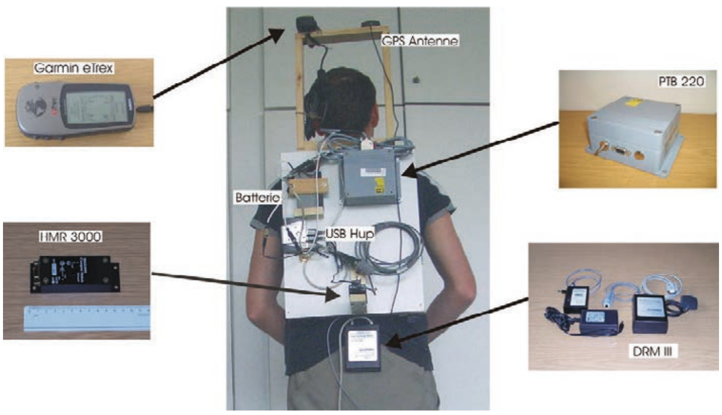
2.2 Knowledge-based filtering

After the data acquisition by the multi-sensor system the measuring quantities are submitted to a first filter process. The task is to detect disturbances and outliers (which shall not influence the KALMAN-filter), to eliminate them and to create specific error models for the measuring data adapted to the current environmental situation. For successful filtering extensive 'knowledge engineering' has to be done within a recursive process (see Figure 6). Therefore a complete decoupling of this system component is envisaged. On basis of this requirement the filtering is realized as a knowledge-based component. The separation of problem knowledge and knowledge processing enables a more easily extension, modification or exchange of the knowledge base.

The advantages of a knowledge-based approach in comparison with a conventional one (realized in Delphi, Fortran or C++) are: (1) the knowledge about the problem domain is seperated from general problem-solving knowledge (makes it easier for the knowledge engineer to manipulate this knowledge); (2) experts-knowledge, exists very often in form of rules, can be captured in this form without converting into forests of data definitions and procedures.

Independent from the point of view, knowledge-based systems consist of the following major components: a knowledge base, an inference engine, an user interface,a knowledge acquisition tool and an explanation tool [9]. The knowledge base, the most important component of a knowledge-based system, contains the relevant domain-knowledge that the knowledge engineer has implemented in the course of the development process. The process of deriving a solution for a problem can be viewed simplistically as one of finding a connection between the input and the conclusion; this process is accomplished by the inference engine. The user interface (UI) serves to provide the end user and the knowledge engineer with a friendly means of communication with the program system. The knowledge engineer has to interact with the domain specialist to acquire knowledge about the problem domain and to implement this knowledge in the knowledge base. The knowledge acquisition tool assists the knowledge engineer in this work. The explanation facility helps the user to understand the knowledge reasoning of the system. Explanations (automatically or if

Fig. 2: Integration of the sensors into a multi-sensor system



required) enhance the usefulness and acceptance of knowledge-based systems.
Several declarative knowledge representation schemas are commonly used: predicate logic, production rules, semantic nets, frames and others. Our knowledge base is realised as a rule based/object-oriented approach. Rule-based programming is one of the most commonly used techniques for implementation of a knowledge base. Rules are used to represent heuristics, or 'rules of thumb', which specify a set of relationships. A rule-based approach consists of two parts: a set of rules and a working memory. A rule is divided into two parts, namely the lefthand side (LHS) and the righthand side (RHS). In the LHS, we formulate the preconditions of the rule, whereas in the RHS, the actions are formulated. A rule can be applied (or fired) if all its preconditions are satisfied; the actions specified in the RHS are then executed. The second component of a rule-based system, the working memory, is a collection of working memory elements, which itself are instantiations of a working memory type (WMT). WMTs can be considered as record declarations in PASCAL or struct declarations in C. There are algorithms for the matching phase, i.e., the phase where all rules are checked against all working memory elements, which are efficient in practice. The result of the matching phase is the conflict set, which includes all rule instances 'ready to be fired'. A conflict resolution strategy selects one rule instance which is actually fired.

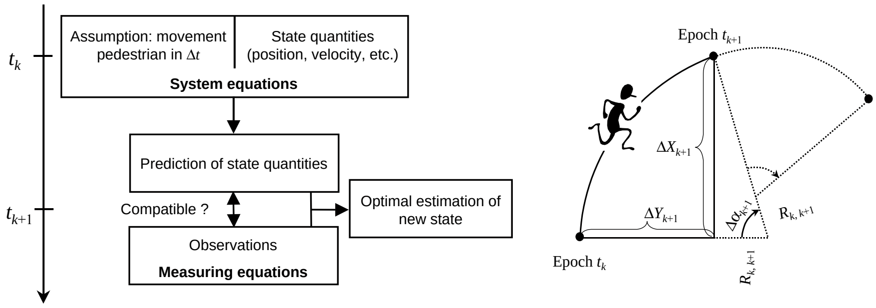


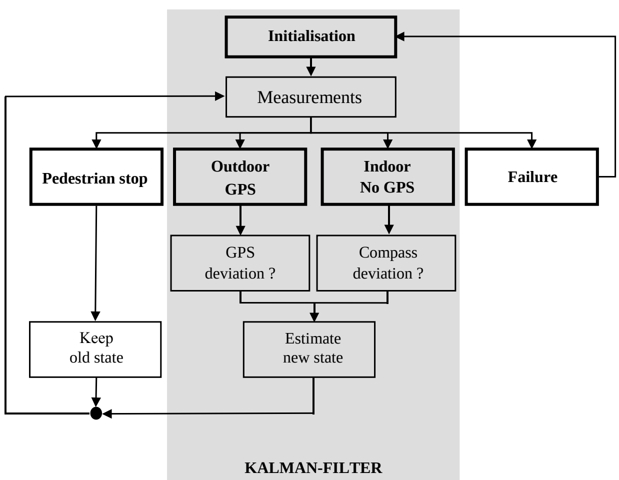
Fig. 3: KALMAN-filter and constant circular motion (2D)

2.3 Central KALMAN-filter for optimal multi-sensor integration

The purpose of the multi-sensor integration is to merge the (knowledge-based) preprocessed measuring data to an accurate, reliable and preferably everywhere available position information. The fusion shall be realized by the creation of a 'Position Finding Module (PFM)' with a central KALMAN-filter. Using theoretical assumptions concerning the motion of the pedestrian in one scanning interval (system equations) and empirical measurements (measuring equations) KALMAN-filtering enables the optimal estimation of the state of motion of the pedestrian in each epoch (see Figure 3, left).
Between two filter epochs t_k and t_{k+1} the (non-disturbed) motion of the pedestrian is assumed to be constant circular. For 2D-coordinates a possible analytical model is a series of circular arcs with common tangents (see Figure 3, right). An integrated 3D-model (helix) is used in [10]. In case of sudden changes of orientation of the pedestrian kinematic models normally show a certain inertia. This effect can be significantly reduced by integration of additional measured correcting variables into the system equations. The 'causative modification' of kinematic models is sucessfully applied in [11].
In Figure 4 the architecture of the PFM is shown. It contains of 4 sub-modules which consider the environment ('Outdoor' and 'Indoor'), the kinematic state of the pedestrian ('Pedestrian stop') and emergency situations ('Failure').
The detection of bad GPS quality (multipath effects etc.) in outdoor situations is a special challenge for the PFM. Using the results from the knowledge-based preprocessing the KALMAN-filter enables an additional statistical analysis of the contradictions between motion model and GPS-observations (i.e. innovation-tests).
In geodetic applications the stochastical models of measuring and disturbance quantities are usually assumed to be white noise processes with no correlations in time. In the case of high measuring frequencies there often appear high autocorrelations (coloured noise) between succeeding observations. Using a 'form-filter' extension these correlations can be integrated into the classical KALMAN-filter algorithm. The central problem is the determination of the correct parameters of the noise process. One goal of WiKaF is to investigate the possibilities and the efficiency of the quantification of autocorrelation functions with different strategies:

1. Determination of the relevant parameters of the autocorrelation functions by a priori time-series analysis

Fig. 4: Architecture of the PFM



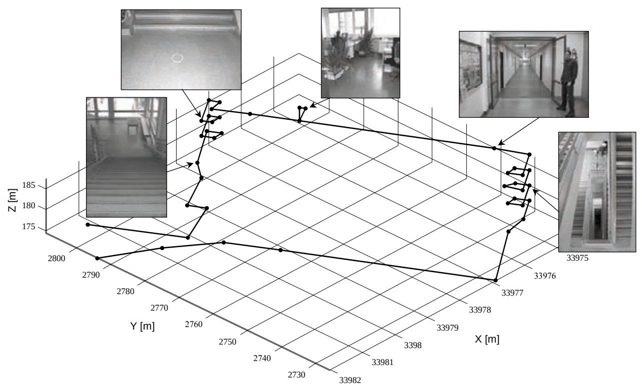


Fig. 5: Indoor trajectory of the test-area 3 (TA-3)

2. Estimation of the parameters during the filter process using an adaptive extension (adaptive KALMAN-filtering)

3 Further workflow of WiKaF

Having shown the theoretical fundamentals and the system architecture the workflow for the realization of WiKaF is pointed out. It includes the definition of suitable test-areas and the detailed planning of the individual levels of development.

3.1 Test-areas

The development and implementation of the knowledge-based KALMAN-filter requires the definition of different types of representative test-areas. In the beginning of the project three scenarios were selected: two outdoor scenarios and one indoor scenario.
Test-area 1 (TA-1) is realized at the park of the castle Schoenbrunn in Vienna and offers excellent GPS-quality. Test-area 2 (TA-2) is next to the centre of the city and stretches a triangle of 140m x 200m x 250m. This area is located in an urban environment with partly poor or no GPS availability. 3D-reference trajectories are realized by tacheometry and precise levelling.
In Figure 5 the 3D-reference trajectory for the indoor scenario is shown. In test-area 3 (TA-3) the trajectory is realized from the ground to the third floor of the electrotechnical building of Vienna University of Technology. At the half distance there is a little 'side trip' to a room which is accessible from the corridor. The endings of TA-3 are directly connected with TA-2 and enable the change from an outdoor to an indoor scenario.

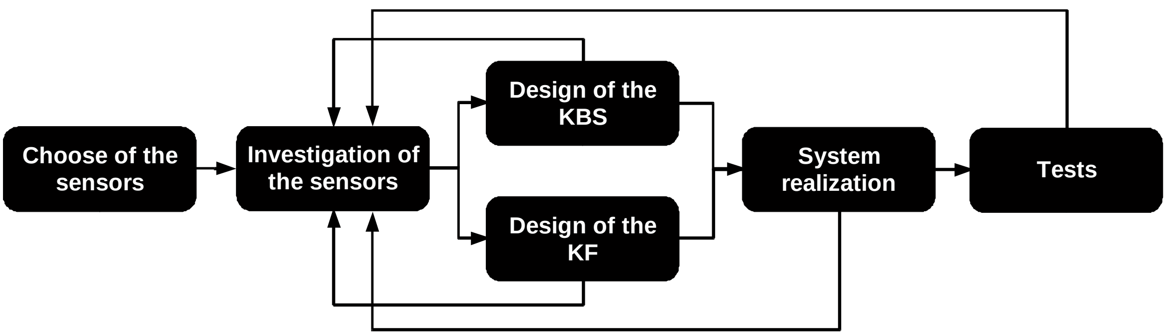
3.2 Workflow of WiKaF

At the end of the conceptual description the further project steps will be briefly presented. A rough overview of the most important project phases is shown in Figure 6.
The selection of the different types of sensors (see also Section 2.1) and the creation of representative reference trajectories is completed. The sensor investigation and the derivation of deterministic and stochastic sensor and disturbance models is just in work. As main part of the 'knowledge engineering' these investigations represent one of the most important steps within the WiKaF project. The collected knowledge will be directly integrated into the two following development steps.
The parallel and in most parts independent development of knowledge-based system and KALMAN-filter (PFM) leads to functionally autonomous system components. It enables the establishment of a modular system and a more simple evaluation of the knowlegde-based approach against 'classical' KALMAN-filtering by activating/deactivating of one system component.
After finishing the conceptual design the complete positioning system will be realized by two different software solutions. The implementation of the knowledge-based system component will be carried out by Clips respectively WxClips. Clips is a programming language especially designed for the creation of rule-based expert systems (see [12]). The KALMAN-filter and the PFM will be realized by Matlab. Data exchange (interfaces) between the different software modules happens by standardized ASCII-files.

4 Conclusions and perspectives

The concept of knowledge-based KALMAN-filtering (WiKaF) is an 'intelligent' extension of the data-based multi-sensor integration. It enables the utilization of not only quantitative (measurements) but also qualitative information by the definition of rules.

Fig. 6: Workflow of WiKaF



The major goal is to support the filter in detecting and eliminating of incorrect sensor data and selecting suitable (situation related) stochastical models. In this contribution we report on the architecture and the functionality of WiKaF and its present stage of development.
Using the reference trajectories described in Section 3.1 the next part of the project deals with the investigation of the single sensor systems. In this context the time series analysis of the sensor data, the sensor calibration and the evaluation and classification of topographical (disturbance) influences are important tasks and represent the basis for the design of the knowledge-based component. A special emphasis is set on the determination of auto-correlation functions as input for the form-filter (see Section 2.3).

5 Acknowledgements

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Map-independent positioning of land vehicles with causative modified motion equations

Andreas Eichhorn

Abstract

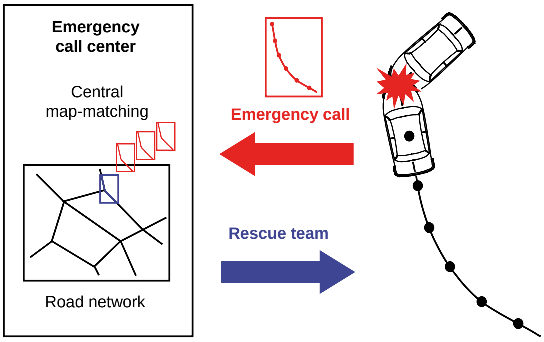
In this paper some results of the project 'Positioning Component' are presented, which was subject of a cooperation between the University of Stuttgart and DaimlerChrysler AG. The aim of the project was to develop a map-independent module for the autonomous positioning of vehicles within the framework of Location Based Services (LBS). The integration of the absolute position information (GPS) and the relative information (differential odometer and gyro) is realized with a central KALMAN-filter. The system equations of this filter originally base on a kinematic model (constant velocity in one sampling interval). To reduce the filters inertia in the case of fast cornering it is necessary to modify theses equations in a causative sense: the measured yawing (derived from the gyro) is used as a 'geometrical' correcting variable. The presented examples of filter results show different representative driving scenarios in inner urban areas with bad GPS quality and on highways. The mean errors of the estimated postions vary from ca. s_P = 1,9 m (on highways) to 3,0 m (in urban areas with dense buildings and tunnels). The accuracy and availibilty requirements of the car manufacturer are achieved.

1 Motivation

In future many applications linked with Location Based Services (LBS) will need at each time an accurate and in particular a reliable positioning of the vehicle. A typical application is the automatic emergency call in case of a traffic accident. The additional transmission of the last sequence of georeferenced vehicle positions to an emergency call center enables the guidance of rescue teams to the scene of accident (see Figure 1).
In contrast to common car navigation systems this service does not need a digital map onboard. The navigation is realized by a map-matching process which is directly executed in the emergency call center itself. The central storage of road data is more cost effective and easier to keep up-to-date. Consequently the bordautonomous part of this process is map-independent.
The project 'Positioning Component' (see [1], [2] and [3]) was subject of a cooperation between the University of Stuttgart and DaimlerChrysler AG. The aim of the project was to develop a map-independent module for the autonomous positioning of vehicles. The main requirements were defined as:
- Real-time capability of the algorithm, this means calculation of the vehicles position with a time delay of max. some msec.
- No highly accurate ($\sigma_Y = \sigma_X < 4$ m) but track stable position results
- Good geometrical representation of the passed trajectory (especially turns) as precondition for the central map-matching process realized by a sample rate of 1 Hz
- Reliable and always available position information using lowcost sensors from the vehicles standard equipment (i.e. GPS, differential odometer from the antilock breaking system and gyro from the stabilization system)
- Application in different driving scenarios, this means public traffic on highways and in cities with partly very bad GPS-quality respectively no GPS available.

The creation of a 'Position Finding Module' integrating a multi-sensor system in a central KALMAN-filter was decided to be the best strategy for fulfilling all requirements.

Fig. 1: Automatic emergency call with central a map-matching process



2 Multi-sensor system

As shown in Figure 2 the chosen sensor configuration consists of GPS, differential odometer (from anti-lock braking system) and a gyro (from the stabilization system).
The sensors are representing a combination of absolute (GPS) and relative position information (differential odometer and gyro). In

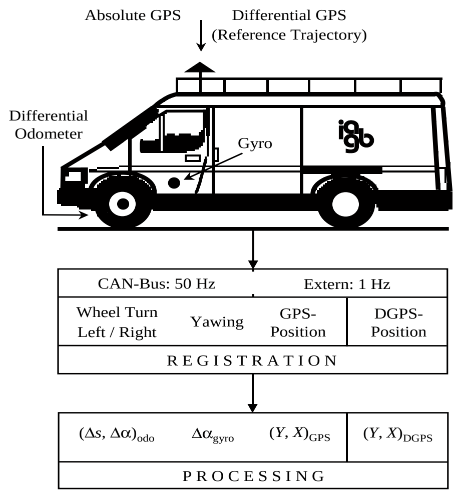


Fig. 2: Sensor configuration and derivation of geometrical quantities

the case of no GPS available (e.g. in tunnels) it is possible to caculate the vehicles position in dead reckoning. Redundant position information enables mutual control and error detection. Using this combination, reliability as well as availibility of the individual sensor is increased.

During the test-drives the registration of differential odometer and gyro was realized via the vehicles CAN-bus (CAN = Controller Area Network) with a frequency of 50 Hz. Absolute GPS and differential GPS (DGPS) were separately registrated with a frequency of 1 Hz. DGPS was not used for position finding, but to derive the reference trajectories for quality control of the results. The synchronization of all signals was better than 2 ms. Assuming a velocity of 200 km/h this means a position error (longitudinal deviation) of only 10 cm [4].

The second step contains the derivation of geometrical quantities from the original signals. The wheel turn impulses are integrated from 50 Hz to 1 Hz and multiplied with a scale factor (from calibration) to calculate the distance covered and the change in the vehicles direction. Integration of the gyro signal although delivers the change in direction as redundant information. A detailed description of the formulas can be found in [5]. The resulting position information (per s) is:

$$\boldsymbol{L}(t_{k+1}) = \boldsymbol{L}_{k+1} = \begin{pmatrix} Y_{\mathrm{DGPS}} & X_{\mathrm{DGPS}} \\ \hline Y_{\mathrm{GPS}} & X_{\mathrm{GPS}} \\ \Delta s_{\mathrm{odo}} & \Delta\alpha_{\mathrm{odo}} \\ \Delta\alpha_{\mathrm{gyro}} & \end{pmatrix}_{k+1} \quad (1)$$

Sensor examination and calibration was realized by test-drives in three different scenarios: inner urban areas, highways with high velocity and winding country roads. The empirical standard deviations of the geometrical quantities (1) are shown in Table 1.

	velocity [m/s]		
	0-5	5-15	> 15
$(s_Y, s_X)_{\mathrm{GPS}}$	1,5 m		
$s_{\Delta s,\,\mathrm{odo}}$ per s	0,2 m		0,3 m
$s_{\Delta\alpha,\,\mathrm{odo}}$ per s	2 gon		1 gon
$s_{\Delta\alpha,\,\mathrm{gyro}}$ per s	2 gon	1 gon	

Tab. 1: Stochastical model of the multi-sensor system

3 KALMAN-filter algorithm with causative motion equations

To bring together all different sensor information under additional consideration of its individual stochastical features, a central KALMAN-filter (see i.e. [6] or [7]) is used. The recurrent construction of the algorithm enables at each time t_k the optimal estimation of vehicles position and other kinematic parameters (e.g. velocitiy). The KALMAN-filter is a suitable tool for real-time position finding and error detection.

3.1 Fundamentals

The KALMAN-Filter consists of two parts:

1. The theoretical system equations contain geometrical and physical assumptions concerning the motion of the vehicle in one scanning interval Δt (= 1 s).
2. The measuring equations represent the empirical part containing the observations derived from the sensors.

The combination of prediction (from system equations) and measurements enables to calculate the optimal estimation of the state vector, which contains the unknown kinematic parameters: vehicles position $(Y, X)_{k+1}$, orientation α_{k+1} and velocitiy v_{k+1}. One important feature of the algorithm is the possibility to test the compatibility of predicted and measured motion. Consequently the test provides the basic information for the detection of bad GPS-quality in inner urban areas.

3.2 Causative modified motion equations

The geometrical and physical fundamentals of the kinematic model are based on [8]. In one scanning interval Δt the vehicle is assumed to perform a constant circular motion (see Figure 3). This means constant velocity v, angular velocity $\dot{\alpha}$ and curvature $1/R$ in $[t_k, t_{k+1}]$.

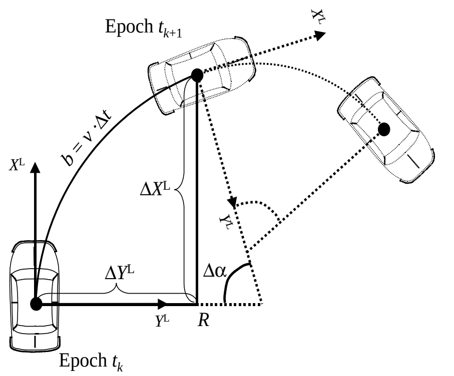


Fig. 3: Constant circurlar motion

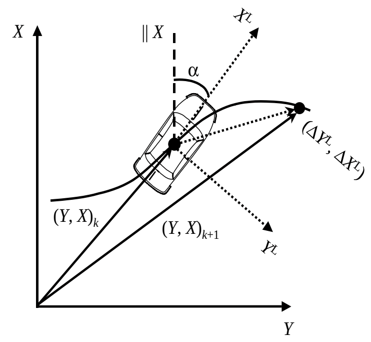


Fig. 4: Transformation into ref. frame

These assumptions are motivied by observations of vehicles kinematics. Possible accelerations are considered as disturbances w. The derivation of the deterministic system equations is realized in two steps. In the first step the motion is quantified in a local coordinate system (Figure 3) which in the second step is transformed into the global reference frame (Figure 4). The resulting recurrend non-linear system equations are shown in (2).

$$\begin{pmatrix} Y_{k+1} \\ X_{k+1} \end{pmatrix} = \begin{pmatrix} Y_k \\ X_k \end{pmatrix} + \frac{v_k\,\Delta t}{\Delta\alpha_{k+1}} \begin{pmatrix} \cos(\alpha_k) & \sin(\alpha_k) \\ -\sin(\alpha_k) & \cos(\alpha_k) \end{pmatrix} \begin{pmatrix} 1-\cos(\Delta\alpha_{k+1}) \\ \sin(\Delta\alpha_{k+1}) \end{pmatrix}$$

$$\alpha_{k+1} = \alpha_k + \Delta\alpha_{k+1}$$

$$v_{k+1} = v_k \qquad (2)$$

The state vector $\boldsymbol{x}$ consists of four elements: coordinates (Y, X), orientation (azimuth) α and velocity v of the vehicle. In difference to [8] the filter progress is realized using the change in direction $\Delta\alpha_{k+1}$ as correcting variable u, derived by gyro observations (see (1)). The main advantage of this 'causative modification' is the reduction of the filters inertia in the case of fast cornering. Extreme small radiusses are passed without any oscillations in the estimated trajectory. Representing the non-linear equations (2) by a vectorial function Ψ the causative modification is illustrated in (3) and (4):

$$\boldsymbol{x}_{k+1} = \Psi\,(\boldsymbol{x}_k, u_k = \Delta\alpha_{\text{gyro},k+1}) \quad \text{nonlinear model} \quad (3)$$

$$\underset{4,1}{\underline{\boldsymbol{x}_{k+1}}} = \underset{4,4}{\underline{\boldsymbol{T}_{k+1,k}}}\,\underset{4,1}{\underline{\boldsymbol{x}_k}} + \underset{4,1}{\underline{\boldsymbol{B}_{k+1,k}}}\,\underset{1,1}{\underline{u_k}} + \underset{4,1}{\underline{\boldsymbol{S}_{k+1,k}}}\,\underset{1,1}{\underline{w_k}} \quad \text{linearized model} \quad (4)$$

In (4) additional disturbance accelerations ($w = 1$ m/s^2) are added. The Jacobi-matrices are indicated with $\boldsymbol{T}$ = transition matrix, $\boldsymbol{B}$ = coefficient matrix of correcting variable and $\boldsymbol{S}$ = coefficient matrix of disturbance variable.

The measuring equations are derived using the remaining position information of absolute GPS and differential odometer.

$$\begin{aligned} Y_{\text{GPS},k+1} &- \varepsilon_Y &= Y_{k+1} \\ X_{\text{GPS},k+1} &- \varepsilon_X &= X_{k+1} \\ \Delta s_{\text{odo},k+1} &- \varepsilon_{\Delta s} &= v_{k+1}\,\Delta t \\ \Delta\alpha_{\text{odo},k+1} &- \varepsilon_{\Delta\alpha} &= \alpha_{k+1} - \alpha_k \end{aligned} \qquad (5)$$

4 Creation of a 'Position Finding Module'

To accomplish the requirements defined in section 1 and as precondition for operational use the Kalman-filter is embedded in a 'Position Finding Module' (PFM). The architecture of the module is shown in Figure 5.
The main task of the PFM is to create highly available and reliable position information which is directly linked with a stable filter progress. The module consists of four submodules containing alternative strategies for position finding. The submodules 'GPS available' and 'No GPS available' represent the central elements of PFM and will be shortly characterized.

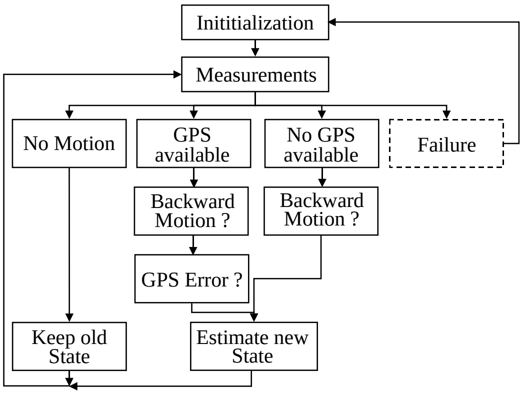


Fig. 5: Architecture of the PFM

In the case of GPS available (existing observation at filter input), several testing strategies are effected to judge its quality. The basic idea is to calculate the deviations between predicted (2) and observed vehicle position (5).

$$\boldsymbol{d}_{k+1} = \begin{pmatrix} d_{Y_{\mathrm{GPS}},k+1} \\ d_{X_{\mathrm{GPS}},k+1} \end{pmatrix} = \begin{pmatrix} Y_{\mathrm{GPS},k+1} - Y_{k+1} \\ X_{\mathrm{GPS},k+1} - X_{k+1} \end{pmatrix} \quad (6)$$

In inner urban areas multipath-effects and bad satellite geometry often cause large errors in GPS-position (> 10 m). Using the coordinate innovations (6) it's very simple to detect single outliers. A more pretentious task is the detection of parallel shifted trajectories which show nearly no difference in inner geometry but may induce a position error of more than 20 m. In PFM the identification is realized checking the profile of succeeding coordinate innovations. In case of a parallel trajectory the innovations are not randomly distributed but possess a systematic progress (see Figure 6-b). Replacing the absolute GPS-observations by GPS-differences

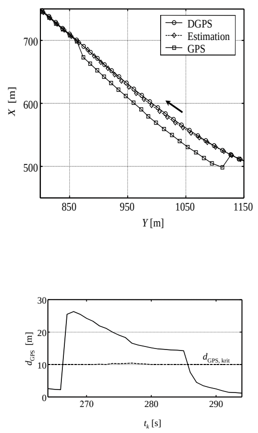
$$\begin{pmatrix} \Delta_{Y_{\mathrm{GPS}},k+1} \\ \Delta_{X_{\mathrm{GPS}},k+1} \end{pmatrix} = \begin{pmatrix} Y_{\mathrm{GPS},k+1} - Y_{\mathrm{GPS},k} \\ X_{\mathrm{GPS},k+1} - X_{\mathrm{GPS},k} \end{pmatrix} \quad (7)$$

the maintenance of inner geometry is used in dead reckoning to support differential odometer and gyro. In Figure 6-a a successful detected parallel GPS-trajectory with a length of more than 300 m and its correction in PFM are shown.
In the case of no GPS available (e.g. in tunnels) the accurate position is estimated in dead reckoning using only the causative modified motion equations and relative position information derived from differential odometer and gyro.

5 Results from different test-drives

Showing sections of representative test-drives some results are presented. In Figure 7 a typical scenario from inner urban area is presented. Shortly after cornering GPS-quality (square) breaks down and induces maximal position-errors of more than 20 m. Consequently PFM has to estimate (diamond) the reference-trajectory (circle) reducing GPS-weights and increasing the influence of differential odometer and gyro. Using this relative position information and the inertia reduced causative motion equations the geometry of the turn is very well represented by estimation. Transforming the filter results in a digital map it can be shown that the deviations with measured reference trajectory are caused by a systematic drift in DGPS.
As part of a highway-drive PFM passes in Figure 8 a 500 m tunnel in dead reckoning, this means no GPS available for 83 s and 44 s on both ways. The filter results never lose their relationship to the road, which demonstrates the rise of availibility using PFM. At the beginning of the tunnel the cornerings again represent very well the geometry of the turns.

Fig. 6: Detection of systematic GPS-deviations



The quality of the results is evaluated calculating empirical accuracy-measures derived from estimated trajectory and DGPS-position (high available differential-code-solution), i.e. s_{abs} (= standard deviation calculated with residuals from estimation ⇔ DGPS representing the absolute accuracy of position finding). Some results derived from several test-drive scenarios are presented in Table 2.

Scenario	Length [km]	Filter epochs	Good GPS quality [%]	s_{abs} [m]
Inner urban areas	12,8	2097	76	**2,85**
High-density area	7,1	1425	72	**3,04**
Low-density area	5,7	672	85	**2,49**
Highways	27,5	1402	87	**1,85**

Tab. 2: Quality results from test-drives

The mean absolute accuracy of PFM can be specified within a range of $s_{\mathrm{abs}} \approx 1{,}9$ m (highways with good GPS quality) to $s_{\mathrm{abs}} \approx 3{,}0$ m (inner urban areas with dense buildings and decreasing GPS quality). There are no significant differences between longitudinal and transverse deviations. Consquently the correct weighting of the different sensors can be assumed.

6 Conclusions

The examinations have shown, that using PFM the requirements defined at the beginning could be achieved. The accuracy is significant better than the boundaries defined with $\sigma_Y = \sigma_X < 4$ m. It is also shown that the causative modification of the motion equations reduces the filters inertia and enables a good geometrical representation of passed turns.
Bad results were obtained in the case of dead reckoning with wrong initial orientation of the vehicle (e.g. some test-drives through tunnels). In this case the information derived from motion equations and remaining relative position sensors is not sufficient to detect a rotation in the estimated trajectory which at its end may induce a deviation of several hundreds of meters. This effect defines the PFM's limits. It can only be compensated using additional absolute sensors (e.g. a compass) or information from a digital map.

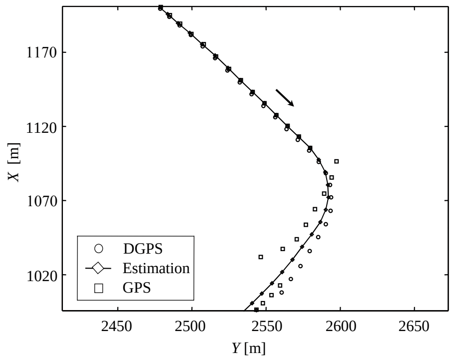


Fig. 7: Inner urban area: 90 degree cornering with bad GPS

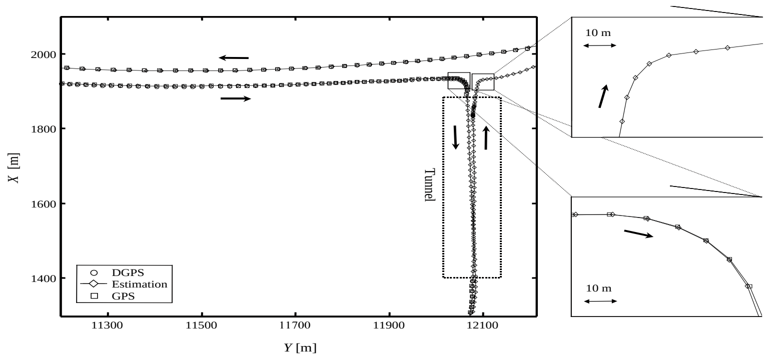


Fig. 8: Passing a 500 m tunnel to a highway in dead reckoning

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“First Have a Plan then Make Sure It Is a Good Plan” or dealing with underspecified spatio-temporal relations in unfamiliar large-scale environments

Inessa Seifert

Abstract

This paper introduces an approach for dealing with underspecified spatial and temporal relations during early stage spatio-temporal planning in large-scale unfamiliar environments. For that purpose a partial spatio-temporal constraint satisfaction algorithm is introduced. The algorithm operates on a qualitative as well as metric representation of the given spatio-temporal relations. In order to reduce the computational complexity *structuring criteria* of the problem space are introduced. The paper outlines procedures for handling of overspecified spatio-temporal relations by removing of location assignments or fixed points in time, or shortening durations of events under consideration of the corresponding priorities. The algorithm concludes with ordering procedure for events with no temporal order but specified spatial assignments. The alternative spatial locations for events with underspecified spatial assignment are represented using a *qualitative distance scheme* or *region-based mapping* to the environment structure.

1 Introduction

Spatio-temporal planning is difficult and often annoying; especially in a large-scale unfamiliar environment which is experienced only seldom, e.g., an exhibition or a trade fair. The scientifically correct term for “difficult and annoying” is cognitively demanding.

Imagine a situation where you have to plan a trade fair visit. Having a spatial layout of a trade fair and a list of events at hand try to answer the following questions:

- Do you have enough time to follow a hint of your boss to visit some particular exhibit?
- What can you do instead of listening to a scientific talk after you realized it’s been already full as you’ve arrived at the conference pavilion?

The illustrated problem domain comprises different events like presentations, tasks, meetings with people or inspections of trade fair booths. Such events are interrelated with each other through a set of spatio-temporal constraints: e.g. distances between the locations of booths and feasible temporal order of visits to the booths.

The main goal of a human spatio-temporal planning task is a compilation of a sequence of activities in a given environment. (cf. “*…human cognition is for action*”, Wilson, 2002). Ideally, such set of activities consists of a well-defined temporal order of events (e.g., e1 *before* e2, e2 *before* e3, etc.) and the corresponding locations. However, in the real world spatio-temporal events and relations between them are specified only to a certain degree, e.g., qualitatively, and go through a lot of changes especially during the early stage planning. Moreover, some of the constraints are even hard to verbalize due to user’s personal preferences or even to emotions (cf. Schlieder & Hagen, 2000). Consequently, the given spatio-temporal problem domain is ill-structured, i.e., there is no “perfect” plan (i.e., optimal solution) for there is no specific definition of such optimum and the important constraint satisfaction criteria (e.g., personal moods and emotions) cannot be mechanized (cf. Simon, 1973). Consequently, spatio-temporal problem solving cannot be totally outsourced to a computational constraint solver but rather requires collaboration with a human. Nevertheless, a typical spatio-temporal planning task can be outlined as follows:

First, events and relations between them which describe a spatio-temporal configuration should be specified. The second step is to identify possible contradiction resulting from overspecified relations. After that the contradictions should be relaxed in order to achieve a feasible order of activities. During the relaxation process some of the relations may become underspecified. The alternative arrangements caused by the underspecified relations should be compared to each other before a decision is made which of them can be taken as a result. The selected solution is a basis for accomplishing of activities in a given environment.

In order to figure out how collaborative assistance can be implemented, we have to consider the following questions:

- Which kind of spatio-temporal information is relevant for a spatio-temporal planning task (i.e., dimensions to be handled) and how can reasoning about spatio-temporal constraints be shared between a human and a collaborative assistance system?
- How can contradictions be resolved and constraints be relaxed by an assistance system in order to generate feasible solutions?
- How can appropriated subsets of feasible spatio-temporal solutions be selected or classified in order to reduce the cognitive load during human mental processing of the provided alternatives?

In the following, I'm going to refer to the results of the exploration studies described in (Seifert, 2005) which address spatio-temporal planning and reasoning problems and outline the common strategies to deal with underspecified relations. Subsequently, the requirements on the representation of the dimensions and the corresponding operations will be derived from exploration studies as well as from the literature concerned with human processing of spatial and temporal information. To obtain feasible solutions for a given problem the demonstrated dimensions are represented in form of a *constraint network*. Subsequently, a procedure to gain partial solutions will be outlined. A partial constraint satisfaction algorithm which operates on qualitative as well as metric spatio-temporal representation of events and relations between them will be demonstrated. Finally, it will be described how one of the possible selection criteria, i.e., region-based fine-to-coarse planning heuristic introduced by (Wiener & Mallot, 2003) can be applied to the generated partial solutions. The paper ends with a discussion of further selection criteria, outlook, open questions, and plans for future work.

2 What, where and when?

The exploration studies described in (Seifert, 2005) aimed at finding common human reasoning behavior during spatio-temporal planning tasks and strategies for dealing with overspecified and underspecified spatio-temporal relations.
The subjects have been given a list of events with overspecified as well as underspecified spatio-temporal events with a task to find an optimal and consistent temporal order of events. The description of binary constraints consisted of events and temporal orders which should hold between them: e.g. *before*, *after*, *meets*, *met-by*. The spatial constraints were expressed by assignment of certain locations and according distances between the events. The setting of events consisted of a topic, starting point in time, location, duration, and priority. The events in the given spatio-temporal configurations had at least a specified topic or location, and an optional indication of a point in time or location.
The protocols of the exploration studies have shown that subjects preferred to operate on qualitative rather than quantitative relations between the events during spatio-temporal planning. That corresponds to common findings which can be found in the literature concerned with cognitive aspects of spatial (e.g., Freksa, 1992) and temporal reasoning (e.g., Allen, 1983; Knauff et. al, 1995).
Violations of temporal constraints were caused by fixed points in time and corresponding spatial constraints, i.e., too large distances between some of the events. In order to achieve a feasible order of events the subjects preferred to shorten durations of events, or to change locations, and finally to relax points in time and temporal orders. Moreover, reasoning about temporal order of events was much affected by the corresponding priorities: e.g., "*low*", "*middle*" and "*high*", so it can be considered as *hierarchical* (cf., Qu & Beale, 1999). First, events with high priorities were considered, than with middle and after that those of the lowers priorities. Distances were often handled as temporal intervals to get from one location to another: e.g. a "*near"* distance can be reached within five minutes.
In the following, the properties of an atomic spatio-temporal event and consequently the dimension of the spatio-temporal problem domain are described by *topic*, *point in time*, *location*, *duration,* and *priority*. An event instance is identified by its topic or location and requires a minimal duration.

3 Requirements on the representation of the spatio-temporal problem domain

The requirements on the representation of the spatio-temporal problem domain for an artificial constraint solver can be summarized as follows:

- It should allow for qualitative temporal reasoning,
- Handle qualitative measures of distances and durations,
- Allow for mapping of distance into temporal intervals,
- And deal with hierarchical priorities.

Furthermore, it should provide precise information about spatial structure of a given environment, in order to generate feasible solutions calculating distances and handle precisely specified assignments for location or point in time. In the following, I'm going to provide a brief overview about existing techniques for dealing with such types of problems.

4 Existing approaches for spatio-temporal reasoning and partial constraint satisfaction problems

Since several decades, temporal and spatial reasoning has been in the focus of intensive research. Typically, two representation schemes, i.e., *interval based* (cf. Allen, 1983) and *point based* (cf. Vilain, Kautz, & van Beek, 1989) and various combinations (cf. Dechter, Meiri, & Pearl, 1991) are utilized for reasoning about temporal relations. Although, there are a set of temporal constraint satisfaction (TCSP) approaches, their main disadvantage is that they stop searching for a feasible solution as soon as no further valid assignments can be found. In order to solve overconstrained temporal reasoning problems another technique, called Partial Constraint Satisfaction (cf. Freuder & Wallace, 1992) stands in the focus of the investigations introduced by (Beaumont, et. al., 2001). However, the (PCS) algorithms proposed by this group operate primarily on interval-based representation of temporal constraints, produce partial solutions by weakening of temporal constraints, don't consider distances between the temporal intervals, and don't allow for handling of priorities.

In the following, reasoning about spatial constraints can be considered as one-dimensional and eventually mapped to temporal intervals. However, the operations handling distance intervals should be considered differently.

5 Representation of the spatio-temporal events and relations

The main goal of a common spatio-temporal problem solving task is to obtain an optimal temporal order of events which are interrelated through spatial and temporal constraints. Current Temporal Constraint Satisfaction algorithms aim at finding complete solution or determining one or more consistent scenarios (cf. Schwalb & Dechter, 1997). However, what we need is a set of partial solutions, where the spatial or temporal constraints can be widened or removed and allow the solution to be found (cf. Freuder & Wallace, 1992).

In order to obtain a feasible solution for a given problem the constraints are represented in a *constraint network (CN)* which consist of a set of variables $X = \{X1, …., Xn\}$. Each of the variables is associated with a *domain* of discrete values: $D1, …., Dn$ and a set of constraints, $\{C1, …., Cn\}$ which is expressed as a relation defined on some subset of variables (cf. Dechter, 1992).

In the given problem domain the variables are spatio-temporal events and the binary constraints which guarantee a feasible temporal order of events can be expressed: {*before, after, meets, met-by}.* Spatial constraints are expressed by corresponding distances between the events, which can be specified as temporal intervals. The *domain* of the variables is defined by a set of the introduced dimensions *{topic, time, location, duration, priority}.* For the corresponding domain values the following conditions hold:

– Each event is valid if a topic or location is specified, i.e., (topic ≠ *{Ø}* or location ≠ *{Ø}*) and duration is not zero, i.e., (duration ≠ *{Ø}*).
– **Topic** is specified by a string containing a name of the event or its description or *{Ø}*.
– **Time** is defined by starting point in time of the event in the format: (*hours, minutes*) or *{Ø}.*
– **Location** is specified by metric *(x, y)* coordinates on a given floor plan represented as a two dimensional matrix consisting of raster points, or *{Ø}*.
– **Duration** is specified either by precise temporal measures, e.g., in minutes and qualitatively: *{short, middle, long}*.
– **Priority** is defined as *{low, middle, high}.*

In contrast to classical temporal reasoning problems each binary relation between pairs of events has to be obtained not only from temporal information, but also from the time required to overcome the distance between the corresponding locations of events. In the following the binary relation including distance between the corresponding locations of events is termed as *spatio-temporal relation.*

Spatio-temporal relations between events can be defined by the thirteen qualitative relations described in (Allen, 1983) in his interval algebra, denoted by the labels before (*b*), after (*bi*), during (*d*), contains (*di*), overlaps (*o*), overlapped-by (*oi*), meets (*m*), met-by (*mi*), starts (*s*), started-by (*si*), finishes (*f*), finished-by (*fi*), and equals (*e*). In the following, I'm going to refer to a subset of the introduced relations which are relevant for identification of constraint violations consisting of 9 relations, where the 4 relations: starts (*s*), started by (*si*), finishes (*f*), and finished by (*fi*) are combined into a single during (*d*) relation.

The following table comprises a mapping from points in time into the basic qualitative relations including distance between a pair of events denoted as *t* and *s*, where *tStart* is a starting point and *tEnd = tStart + duration* the ending point of the event *t,* and accordingly *sStart* is a starting point and *sEnd* = *sStart + duration* an ending point of the event *s*:

Relation between t and s	point-based expression
before (*b*)	*tEnd + distance < sStart*
after (*bi*)	*tStart > sEnd + distance*
equals (*e*)	*(tStart = sStart) and (tEnd = sEnd or tEnd+distance=sEnd or sEnd+distance=tEnd)*
overlaps (*o*)	*(tStart < sStart) and (tEnd + distance > sStart) and (tEnd + distance < sEnd)*
overlapped-by (*oi*)	*(tStart > sStart) and (tStart < sEnd + distance) and (tEnd > sEnd + distance)*
meets (*m*)	*(tEnd + distance = sStart)*
met-by (*mi*)	*(sEnd + distance = tStart)*
during (*d*)	*((tStart > sStart) and ((tEnd = sEnd + distance) or (tEnd > sEnd + distance)) or ((tStart > sStart or tStart=sStart) and (tEnd < sEnd + distance)))*
contains (*di*)	*((tStart < sStart) and ((tEnd+ distance = sEnd) or (tEnd + distance > sEnd))) or ((tStart < sStart or tStart=sStart) and (tEnd + distance > sEnd)*

Table 1. Qualitative spatio-temporal relations including distance between the events

In order to obtain feasible partial solutions classical backtracking algorithms and specialized variations are utilized (cf., Dechter, Schwalb & Dechter, Beaumont et. al.). Such algorithms provide an exhaustive search through the problem space consisting of all possible instantiations of the variables and corresponding relations. However, there are methods to reduce the search space: dividing the problem space into smaller sub-problems reduces its computational complexity. Furthermore, searching in a sorted problem space requires less backtracking (cf., Dechter, 1992) and achieves the largest, i.e., "best", solution more quickly. Therefore, the given spatio-temporal problem space can be classified and sorted due to the specified and underspecified dimensions of the spatio-temporal events: e.g., events with no defined location but point in time, or in opposite events with defined locations and various combinations.
In the following, I'm going to describe the procedure for generation of alternative partial solutions.

6 Generation of partial solutions

First, the set of all events, building a spatio-temporal configuration should be cut into the following subsets:
Spatio-temporal events: events with both fixed point in time and an assignment of location.
Temporal-only events: events with only a fixed point in time.
Temporal events: events with fixed points in time, in other words a union of a set of spatio-temporal events and *temporal-only* events.
Spatial-only events: events with an assignment of location.
Other events: events with no particular assignment of either time or location.
Each of the obtained subsets divides the spatio-temporal problem domain in sub spaces, which can be handled separately according to the specified dimensions of the corresponding events.
The set of temporal events is used to identify overconstrained situations and generate alternative temporal orders by weakening assignments of fixed points in time or locations. The subset of spatio-temporal events derived from the resulting feasible set of temporal events builds a set of *spatio-temporal reference intervals* (cf. Allen, 1983). The spatio-temporal reference intervals are handled separately to obtain a feasible order of *temporal-only* as well as *spatial-only* events lying between the two corresponding edge points and locations.
Consequently, the main procedure for dealing with overspecified as well as underspecified sets of events can be described as follows:

1. Order the set of temporal events by time,
2. Generate partial solutions by relaxation of fixed point in time, shortening of duration to a tolerable degree or removing the assignment of location,
3. Select the largest solutions, with the least changes.
4. Initialize the reference intervals with corresponding *temporal* and *reachable-spatial-only* events,
5. Generate alternative orders of events for each of the spatio-temporal reference intervals,
6. Select the largest feasible solutions,

7a. Apply region-based structuring to the generated solutions,
7b. Represent alternative allocations of events by qualitative distance scheme.

In subsequent sections, I'm going to describe each step of the introduced procedure in detail.

6.1 Handling overspecified events

A partial solution consists of a set of all available events structured into the following subsets: a sorted list of *temporal events*, list of *reference intervals,* list of *spatial-only* events, list of *temporal-only* events and list of events which have duration, but neither temporal nor spatial assignment, termed *other-events* and a list with the *resulting order* of events. There are several methods that can be used to obtain a partial solution (Freuder & Wallace, 1992):

- Remove variables from the problem,
- Remove constraints from the problem,
- Weaken constraints in a problem,
- Widen the domains of variables to include extra values.

Removing a variable from the problem is a very drastic approach to obtain a partial solution. Conversely, if we remove the binary temporal constraint which holds between each pair of events, we won't be able to obtain a feasible order of events. Weakening the temporal constraints is equal to removing those constraints. However, weakening a spatial constraint, i.e., an assignment of some particular location to reduce the distance between the events can be taken into consideration. Subsequently, in order to keep the temporal order of events valid also the fourth method can be applied: e.g., relaxation of fixed points in time between overlapping events, and shortening duration of a corresponding event with lower priority. The procedure to deal with overspecified events can be described as follows:

1. Take an event from the list of temporal events, in the following, termed as the current event,
2. If the current event is the last one, do nothing and stop searching,
3. Take the next event from the list of temporal events,
4. Prove the spatio-temporal relation between the events,

5. If no contradiction occurs, repeat the procedure with next event.
6. If there is a conflict, try to shorten the duration of the first event in the pair to a tolerable degree, but only if its priority is lower than of the second event.
7. Repeat the procedure with the changed duration.
8. If the duration cannot be shortened, weaken the location or/and time assignment under consideration of respective priorities of events.
9. If the location of the first event in the pair is assigned, propagate the location constraint to the weakened event.
10. Move the corresponding weakened events into the appropriated *spatial-only, temporal-only* or *other-events* subsets.
11. Repeat the procedure with the changed values of events.

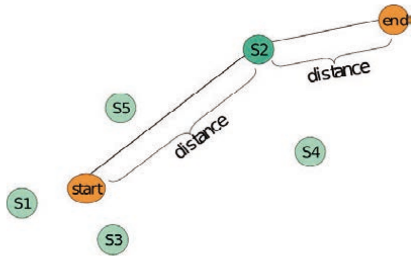


Fig. 1: Example of a spatio-temporal reference interval with the corresponding reachable spatial-only events: distance sum (S2) = distance (start, S2) + distance (S2, end) + duration (S2).

The partial solution with the least modifications is the "best" one. The usage of priorities allows on the one hand for avoiding of unnecessary search through the problem space; however, equal priorities contribute to branching of the possible partial solutions, which must be taken into account. The resulting partial solutions with alternative *temporal event* lists can be handled now separately.

6.2 Handling underspecified events

After obtaining a feasible temporal order of events with specified points in time the herewith temporally structured problem space can be cut into *spatio-temporal reference intervals,* further called just reference intervals. A reference interval contains the following:

- Two temporally ordered events holding a valid fully specified spatio-temporal relation, so called *edge points* with fixed points in time and assigned locations, in the following termed as *start* and *end*,
- A set of *temporal-only* events with no spatial assignment during the given reference interval,
- A set of *reachable-spatial-only* events, which are obtained with help of the following heuristic, whereas *distance sum* is the distance from the given *spatial-only* event to *start* edge point plus distance from the given *spatial-only* event to *end* edge point, plus *duration* of event: (see Figure 1):

duration of the reference interval - ∑ durations of the temporal events – *distance sum* > 0.

After dividing the problem space into sub spaces consisting of reference intervals with corresponding *temporal-only* and *reachable-spatial-only* events the search for a feasible order of *reachable-spatial-only* events which each reference interval can be started. However, the introduced heuristic doesn't guarantee that every *reachable-spatial-only* event fits only in a single reference interval. From that follows, the *reachable-spatial-only* events should provide a list of reference intervals, during which they can be accessed.

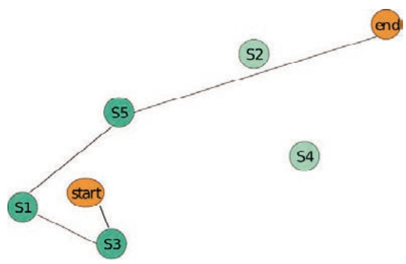
6.3 Generating a feasible order of spatial only events

First, we have to obtain the order of the *reachable spatial-only* events included in the reference interval. For this purpose a classical branch and bound algorithm with a corresponding *path cost* is used. The *path cost* consists of summarized distances and durations of events in the preliminary resulting order of events including the *start* edge point, the duration of the current event, and the distance between the current event and the *end* edge point: (see Figure 2).

The algorithm takes a *reachable-spatial-only* list of events as input, sorted by the *distance sum* of the spatial events (see Figure1). The resulting shortest path with the biggest number of events provides the best partial solution. In the best case the algorithm terminates as soon as the number of the available *reachable-spatial-only* events is exceeded. However, what should be done if too many events are hypothetically reachable but not all of them fit into the given interval due to their duration and the corresponding *path cost*? In the worst case the *reachable-spatial-only* events should be handled according to their priority or the possibility to be reached during another reference interval. The procedure to resolve such conflicts can be described as follows: if the number of the available *reachable-spatial-only* events has not been yet exceeded but the *path cost* is greater then the duration capacity of the reference interval:

- Find in the list of the preliminary order an event with the longest *distance sum* and the lowest priority.
- If the next event from the set of the *reachable-spatial-only* events has a larger *distance sum* and a lower priority compared to the event found in the resulting set, skip the event form the list of available events. Repeat the procedure with the next event of the list of available *reachable-spatial-only* events.

Fig. 2: Example of a path cost for the branch and bound algorithm: path cost (S5) = distance (start, S3) + duration (S3) + distance (S3, S1) + duration (S1) + distance(S1, S5) + duration(S5) + distance(S5, end)



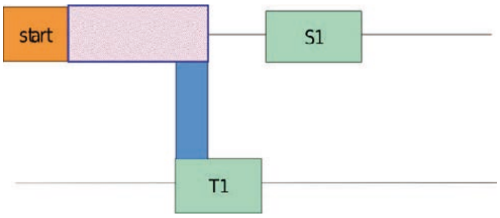


Fig. 3: Determining the order of temporal only and spatial events represented on the two parallel temporal axes.

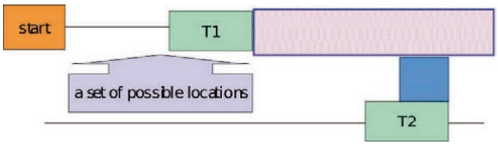


Fig. 4: Repeating the procedure for the next triple of events represented on the two parallel temporal axes.

- If the found event has the same or a lower priority and a larger *distance sum* remove this event from the preliminary resulting list and repeat the procedure with consequently reduced *path cost*.
However, if both events have the same priority and *distance sum*, the possibility to reach those events during other reference intervals has to be considered. Finally, the partial solution with the largest number of events that can be reached during the given interval provides the "best" solution.

6.4 Determining the resulting order of events

Now we have a set of reference intervals with ordered *spatial-only* events and corresponding *temporal-only* events. In order to obtain the resulting order of events the procedure can be described as follows (see Figure 3):

- Take the a pair of events from the resulting order of the spatio-temporal events, included the first edge point event *start,* (for example *start* and *S3*), and a temporal event (*T1*) from the list of *temporal-only* events,
- Determine a preliminary ending point in time of the corresponding spatial event *S3*.
- Build a new temporal interval *I* which begins with the end of the *start* and ends with the preliminary ending point of *S3* (see Figure 3).
- Determine a qualitative temporal relation between *I* and the temporal event *T1*.
- If the obtained temporal relation is *during* or *overlaps* put *T1* before the *spatial-only* event *S3*.
- Calculate the preliminary starting point for *S3* taking into account the duration and point in time of *T1,* in case it has been placed before *S3*.
- Repeat the procedure with the next triple of events (*S3*, *S1* and *T2*).

In opposite to the *spatial-only* events ordering of *temporal-only* events can be determined in a single spatio-temporal reference interval. That means that some of the reference intervals may contain redundant assignments of *spatial-only* events of the resulting spatio-temporal orders. There are several possibilities to handle this problem. The first one is to merge the reference intervals before handling the *temporal-only events* and obtain the shortest path considering all possible resulting orders of spatial events. The second one is to apply the *region-based selection criterion* described in the following section and hope that the redundancies can be eliminated. Another option is to let the user decide which of the spatio-temporal configuration she prefers. Therefore, a user-friendly interaction model adapted to the human spatio-temporal planning and reasoning strategies is needed. However, such interaction model is a subject of further research.

6.5 Representing alternative locations using qualitative distance scheme

Due to points in time of temporal events as well as time available during each spatio-temporal reference interval, many possible locations for the corresponding *temporal-only* events can be taken into consideration.
Since distances between the spatio-temporal events can be expressed qualitatively, the alternative assignment of locations for *temporal-only* and the remaining events (i.e., *other-events*) can be represented trough a qualitative distance scheme: "*near*", "*not-so-far*", and "*far-away*" regarding the corresponding *spatial-only* and events with high priority or the *edge points* of the reference intervals.

6.6 Region-based representation of alternative locations

Series of psychological experiments done by (Wiener & Mallot, 2003) concerned with processing of spatial environment structured in geographic regions have shown that humans avoid changing of regions during spatial problem solving tasks like navigation and route-planning. Furthermore, human processing of spatial knowledge is considered hierarchical (cf. Hirtle, 1998; Tversky, 1993). Consequently, the alternative sets of spatial assignments can be combined into spatial regions, which can be also structured hierarchically. However, such regions should be mapped to the spatial structure of the given environment. At this juncture some of the possible spatial assignments and redundancies in the allocation of the *spatial-only* events can be omitted.

7 Outlook and future work

In the scope of the paper I've introduced procedures for dealing with overspecified as well as underspecified spatio-temporal relations under consideration of temporal as well as spatial constraints. Algorithms and corresponding structuring criteria of the problem space for generation of alternative spatio-temporal orders of events were discussed. However, in order to achieve an adequate or "optimal" solution, collaboration between a human and an artificial constraint solver is required. User-friendly collaboration can be achieved by introducing the possible alternatives in form of qualitative distance schemes, as well as hierarchical or region-based representation of alternative spatial allocations of events.

However, a suitable interaction model for collaborative spatio-temporal planning and reasoning remains a subject of further research.

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A logic-based foundation for spatial relationships in mobile GIS environment

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Abstract

The mobile computing is a new revolutionary style of technology that enables us to access information anywhere and anytime. Mobile GIS as an integrating system of mobile computing and some GIS capabilities has fostered a great interest in the GIS field. Although the mobile computing has been increasingly grown in the past decade; there still exist some important constraints that complicate work with a mobile information system. The limited resources on the mobile computing would restrict some features that are available on the traditional computing technology. This article attempts to provide a paradigm to treat moving objects in mobile GIS environment. An idea based on space and time partitioning is suggested. A logic-based framework for representing and reasoning about qualitative spatial relations over moving objects in space and time is proposed. We provide convincing evidence of this theory, by demonstrating how it can provide a framework model of topological relations in space and time. The expressivity power of the proposed framework is shown with some new topological relationships between moving objects and describing the coaching problem in a mobile environment. The latter finds its application in RoboCup championship and battlefield, as well.

1 Introduction

Mobile computing is a new revolutionary style of technology emerging of the advances in the development of portable hardware and wireless communications [23, 25]. It enables us to access information anywhere and anytime. Advances in location-based engines and on-board positioning sensors lead to mobile geospatial information system (GIS) [27, 31]. Mobile GIS as an integrating system of mobile computing and some GIS capabilities has fostered a great interest in the GIS field [21]. It becomes a new branch of GIS and brings the GIS into a new stage of development.

Although the mobile computing has been increasingly grown in the past decade, there still exist some important constraints which complicate the design of mobile information systems. The limited resources on the mobile computing would restrict some features available on the traditional computing. The resources include computational resources (e.g., processor speed and memory), user interfaces (e.g., display and pointing device), bandwidth of mobile connectivity, and energy source [4, 16, 18, 19, 34, 36, 45]. In addition, it is assumed that in a mobile GIS environment, sensors of user side could not access all relevant information about other users (not complete data) and they are concerned to the user and its neighbors (not global data).

Among of the most important characteristics of qualitative properties of spatial data and perhaps the most fundamental aspect of space are topology and topological relationships. Topological relations between spatial objects are such relationships that are invariant with respect to specific transformations due to homeomorphism. The study of topological relationships is firmly evolving as an important area of research in the mobile GIS [34, 36]. Though in some respects, it closely resembles topological relationships in the traditional desktop GIS, the unique properties of mobile GIS environment demand its careful and separate study. Hence, it makes us to pay attention to this topic.

In this paper, in order to provide a paradigm that treats with moving objects in mobile GIS environment, a logical framework is presented. In this framework the concept of spatial influenceability from relativistic physics, is combined with the partition and conquer idea from computer science. It means dividing the space and time into small parts; say space-time cell; and using influenceability concept presented in this article, provides a theoretical framework of mobile objects in space-time. In our view, influenceability which stands for spatial causal relations, i.e. objects must come in contact with one another; is primary an order relation.

We provide convincing evidence of this theory, by demonstrating how it can provide a framework model of topological relations in space as well as in time. The expressivity power of the proposed framework is shown with some new topological relationships between moving objects and describing the coaching problem in a mobile environment. The latter finds its application in RoboCup championship and battlefield, as well.

The remainder of the paper is structured as follows. Section 2 reviews related works. Section 3 shall present the fundamental concepts. Section 3 introduces our suggested model. In section 4 we discuss some examples of spatio-temporal relationships between two moving agents and its application in coaching. Finally, we draw some conclusions.

2 Related work

During recent years, topological relations have been much investigated in the static environments [29, 49]. Algebraic topological model for spatial objects was introduced in [49]. Thirteen topological relations between two temporal intervals were identified by [1]. After 4-intersection model [11, 12], the famous 9-intersection approach [13, 14] was proposed for formalism of topological relations. This approach is based on point-set topological concepts. Some drawbacks of such point-based topological approach is reported in [22]. The other significant approach known as RCC (Region-Connection Calculus) has been provided by [7, 8, 9, 22]. RCC as a pointless topology is based upon a single primitive contact relation, called connection, between regions. In this logic-based approach, the notion of a region as consisting of a set of points is not used at all. A similar method, so-called Mereotopology, is developed in [2, 47].

Due to problems of updating current location continuously or even per some seconds, such as bandwidth consumption, update transaction problem and query transaction problem [5, 6, 27], it is reasonable that instead of updating continuously, a predicting method will be used. The works [41, 26] and [39] offered a framework for modeling the movement of objects or individuals, processing of queries and multiple granularities. Assuming two known locations and a certain velocity are given, they modeled geospatial lifeline by **lifeline bead.** A lifeline bead consists of intersection of two inverted cones.

A method for reducing the size of computation is computation slice[20, 42]. The computation slicing as an extension of program slicing is useful to narrow the size of the program. It can be used as a tool in program debugging, testing, and software maintenance. Unlike a partitioning in space and time, which always exists, a distributed computation slice may not always exist [20].

Among others, two works using divide and conquer idea, called honeycomb and space-time grid, are closer to our proposal. The honeycomb model [15] focuses on temporal evolution of subdivisions of the map, called spatial partitions, and give a formal semantics for them. This model develops to deal with map and temporal map only. In [6, 7] the concept of space-time grid is introduced. Based upon the space-time grid, they developed a system to manage dynamically changing information. In the latter, they attempt to use the partitioning approach instead of an indexing one. This method can be used for storing and retrieving the future location of moving object.

In the previous work of the authors [32-38] applications of partitioning in space-time and using influenceability in motion planning, finding a collision-free path and relief management was demonstrated. This article can be considered as a theoretical extension of them.

3 Preliminaries

Causality is a well-known concept. There is much literature on causality, extending philosophy, physics, artificial intelligence, cognitive science and so on (e.g. [3, 30, 48]). In our view, influenceability stands for spatial causal relation, i.e. objects must come in contact with one another; cf. [3]. Although influenceability as a primary relation does not need to prove, it has some exclusive properties which show why it is selected. Influenceability supports contextual information and can be served as a basis for context aware mobile computing which has attracted researchers in recent years [17, 43]. This relation can play the role of any kind of accident and collision. It is well-known that the accident is the key parameter in most transportation systems (for example see [44]). As an example the probability of collision defines the GPS navigation integrity requirement. In addition, this model due to considering causal relation is closer to a naïve theory of motion [40].

In the relativistic physics [28, 46] based on the postulate that the vacuum velocity of light ***c*** is constant and maximum velocity, the light cone can be defined as a portion of space-time containing all locations which light signals could reach from a particular location (Figure 1). With respect to a given event, its light cone separates space-time into three parts, inside and on the future light cone, inside and on the past light cone, and elsewhere. An event ***A*** can influence (influenced by) another event; ***B***; only when ***B*** (***A***) lies in the light cone of ***A*** (***B***). In a similar way, the aforementioned model can be applied for moving objects. Henceforth, a cone is describing an agent in mobile GIS environment for a fixed time interval. That means, a moving object is defined by a well-known acute cone model in space-time[24, 26]. This cone is formed of all possible locations that an individual could feasibly pass through or visit. The current location or apex vertex and speed of object is reported by navigational system or by prediction. The hyper surface of the cone becomes a base model for spatio-temporal relationships, and therefore enables analysis and further calculations in space-time. It also indicates fundamental topological and metric properties of space-time.

As described in Malek [34, 36], the movement modeling, are expressed in differential equation defined over a 4-dimensional space-time continuum. The assumption of a 4-dimensional continuum implies the existence of 4-dimensional spatio-temporal parts. It is assumable to consider a continuous movement on a differential manifold ***M*** which represents such parts in space and time. That means every point of it has a neighborhood homeomorphic to an open set in $\boldsymbol{R}^n$. A path through ***M*** is the image of a continuous map from a real interval into ***M***. The homeomorphism at each point of ***M*** determines a Cartesian coordinate system (x_0, x_1, x_2, x_3) over the neighborhood. The coordinate x_0 is called time. In addition, we assume that the manifold ***M*** can be covered by a finite union of neighborhoods. Generally speaking, this axiom gives ability to extend coordinate system to the larger area. This area shall interpret as one cell or portion of space-time. The partitioning method is application dependent. The partitioning method depends on application purposes [5, 49] on the one hand, and limitation of the processor speed, storage capacity, bandwidth, and size of display screen [50] on the other hand.

4 Algebraic and topological structure

Let us take influenceability as an order relation (symbolized by $\prec$) be primitive relation. It is natural to postulate that influenceability is irreflexive, antisymmetric, but transitive, i.e.,

$$(x \prec y) \wedge (y \prec z) \Rightarrow x \prec z$$

Thus, it can play the role of ‘after’.

Definition 1 (Temporal order): Let x and y be two moving objects with t_x and t_y corresponding temporal orders, respectively. Then,

$$(x \prec y) \Rightarrow (t_x < t_y)$$

Connection as a reflexive and symmetric relation [10]can be defined by influenceability as follows:

Definition 2 (Connect relation): Two moving objects x and y are connected if the following equation holds;

$$(\forall xy)C(x,y) := [(x \prec y) \vee (y \prec x)] \wedge \{\neg(\exists a)[(x \prec a \prec y) \vee (y \prec a \prec x)]\}$$

Consequently, all other exhaustive and pairwise disjoint relations in region connected calculus (RCC), i.e., *disconnection* (DC), *proper part* (PP), *externally connection* (EC), *identity* (EQ), *partially overlap* (PO), *tangential proper part* (TPP), *nontangential proper part* (NTPP), and the inverses of the last two; TPPi and NTPPi; can be defined.

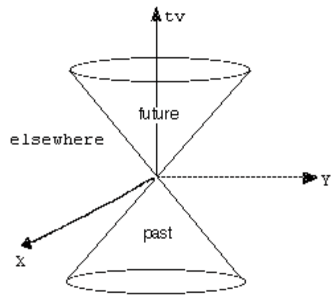


Fig. 1. A cone separates space-time into 3 zones, past, future, and elsewhere.

Definition 3 (Immediately before): Let x and y be two moving objects with t_x and t_y corresponding temporal orders, respectively. Then, x is immediately before y (y is immediately after x) if:

$$t_x << t_y := [(t_x < t_y) \wedge (\neg \exists z(x \prec z \prec y)]$$

The consensus task as an acceptance of the unique framework in mobile network can not be solved in a completely asynchronous system, but as indicated by Malek [34] with the help of influenceability and partitioning concept, it can be solved. Another task in mobile network is leader election. The leader, say *a*, can be elected by the following conditions:

$$\forall x \in \{The\ set\ of\ \ moving\ objects\} : a \prec x$$

Furthermore, some other relations can be defined, such as which termed as *speed*-connection (SC) and time proper overlap (TPO) (see Figure 2):

$$SC(x,y) := \neg EQ(x,y) \wedge$$
$$\{[C(x,y) \wedge (\forall ab)(EC(x,a) \wedge (EC(x,b) \wedge EC(y,a) \wedge EC(y,b)] \Rightarrow C(a,b)\}$$

5 Expressivity power

What has been shown so far is that if we regard a moving agent in mobile GIS environment as a cone then we can express certain important relations over agents purely in terms of the influenceability. In [36] we illustrated the expressive power of the theory. As an example four different relations between two objects; say A and B; can be discriminated by influenceability when A is before B and they are partial overlap. We are going to continue by some other relations and coaching problem, as well.

5.1 Qualitative geometry

Influenceability can be served as a basis of affine geometry. We are not going into detail, however, just offer collinearity conditions which are very important for building a qualitative affine geometry.

Collinearity in time axis (COLT): Let x and y be two moving objects. They are collinear in time axis if

$$COLT(x,y) := \{EQ(x,y) \vee [\exists z((TPO(x,z) \Rightarrow TPO(z,y)) \vee (TPO(y,z) \Rightarrow TPO(z,x))]\}$$

Collinearity in space (COLS): Let x, y and z be three moving objects. They are collinear in space (Figure 3) if

$$COLS(x,y,z) := \{EQ(x,z) \vee EQ(y,z) \vee [\forall a((C(x,a) \wedge C(y,a)) \Rightarrow C(z,a))]\}.$$

Fig. 2. a) Speed-connection relation and b) Time-proper relation between two objects

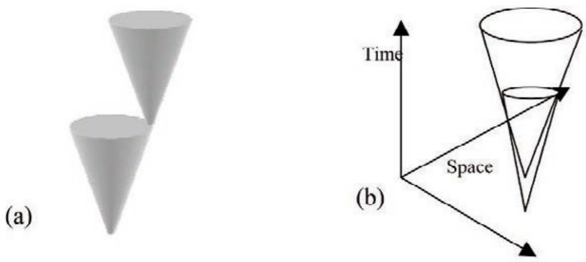
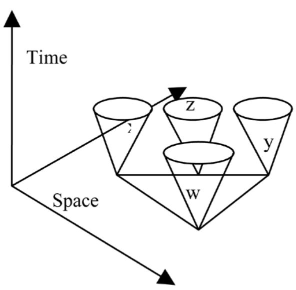


Fig. 3. x, y and z are collinear, but x, y and w are not.



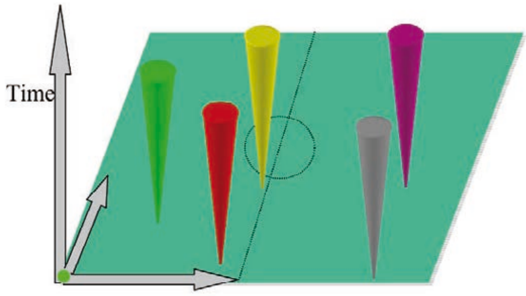
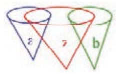


Fig. 4. Robocup soccer from influenceability view point

5.2 Coaching

Team arrangement is an important task of any team coaching. Team arrangement in a mobile environment finds its applications not only in online problems such as Robocup (Robot World Cup) or battlefield problem, but also in offline coaching. The main assumptions about mobile environment are valid in the usual coaching problem. Robocup is a well known application area of this problem. It plays the role of a benchmark for many artificial intelligence and computation algorithms. In this scenario players can be modeled with a cone based on their estimated speed and position (Figure 4).
Table 1 shows some different situations between players and their correspond relations.

Presentation	Application	Relation
	Design of the defense players	Players A and B overlap
	Man-to-man type of defense	Player A covers B completely
	Arrangement of players to minimize empty space	Externally connection
	Player z can attack from gap between a and b	C(a,z) and C(b,z) but ¬ C(a,b)

Tab. 1. Some relations between players and their presentations

6 Conclusion and further work

There still exists shortcoming of a theoretical framework for qualitative spatial reasoning, especially for topological relationships in a mobile GIS environment. This paper has demonstrated that concerns to mobile GIS theory can profitably be addressed in terms of the partition and conquer idea, and influenceability relation. Of particular significance is the fact that the suggested idea can be given in a way that a context-aware and unique framework is prepared for mobile GIS environment. The expressive power of this idea is shown by some examples in section 4.
There are some possible directions for further work. Preparing a qualitative geometry based on influenceability is one of our future works. In addition, if it is possible to use a distributive lattice to describe influenceability, then, using Birkhoff's Representation Theorem [10] has significant computational advantages.

7 Acknowledgement

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Shortest path search in Multi-Representation Street Databases

Steffen Volz

Abstract

The fact that mobile users of location-based services (LBS) have to be able to go anywhere on earth without changing the application brings up a major requirement: there has to be one global platform that provides a transborder and continuous access to the information necessary for this kind of information systems – and the most important information source for location-based services is geospatial data. However, the world of geospatial data is split into pieces, and the integration of those pieces is a difficult task since the data are highly heterogeneous: they have been acquired according to differing conceptual schemas (or application perspectives), they are available in different formats and scales, with different accuracies, etc. The main problem concerning spatial data integration results from the fact that the same real world objects are stored in multiple, inconsistent representations (MRep) in different spatial databases. Thus, in order to achieve a common view on the underlying spatial data within a global information platform for location-based services, mainly the inconsistencies between multiple representations have to be considered and dealt with adequately.

The problem can be depicted by means of a navigation service. Consider the task of finding the shortest car route between Stuttgart/Germany and Vienna/Austria. You will not have any problems to find a solution if you have one single, continuous street data set comprising the whole query area. However, you will encounter difficulties in case you have two or more separate, partly overlapping source data sets (or patches) that you have to assemble (like a mosaic) in order to form the query area. In this case your navigation application has to be able to merge (or conflate) the source data sets that contain multiple conflicting representations of one and the same real world (street) object in the overlapping areas to again create one consistent, single representation (SRep) street database on which the navigation algorithms can operate. The merge operation, though, is time consuming. This paper describes an approach to find an optimized solution for the navigation in MRep street networks by generating explicit relations between multiple representations and by exploiting them during shortest path search.

1 Introduction

The Nexus project that is currently being carried out at the University of Stuttgart [7] aims at developing a global and generic platform for different kinds of location-based services (LBS). It is based on the idea to provide an integration schema for spatial data, the so-called Augmented World Schema (AWS), into which all the available data sources of the highly distributed spatial database servers all over the world can be converted. If the data are finally formatted according to the AWS standard and made available within the Nexus platform, the problem of multiple representations (MRep) of spatial data arises since different data providers might have captured the same real world entity. As a solution, we propose to link corresponding spatial representations existing in different data sets by explicit relations, so-called MRep Relations. These MRep Relations store, amongst others, measures to express the geometric, topological and thematic similarity (or consistence) of the representations that have been assigned to each other during a matching process.

MRep Relations can on the one hand be used to support update processes within the Nexus platform and on the other hand to merge (or conflate) data sets containing multiple representations into one resulting, consistent data set that merely contains one single representation for each real world object (SRep). On such single representation data sets, conventional spatial algorithms necessary for LBS can work. Conflation, however, even of small areas, is a time-consuming process and it is illusive that a consolidated data set can be created for each client query, not to mention the efforts to produce one consistent data set for the whole world and to update it regularly. Therefore, other mechanisms have to be invented.

In this paper, we suggest that MRep Relations can also be used to avoid the conflation of corresponding objects into a single representation by developing algorithms that are able to exploit the information stored in MRep Relations during the analysis process. Since navigation is one of the most important services for location-based systems, we verify our approach by means of this application and describe a shortest path algorithm that can be used in multi-representation databases (i.e. to solve scenarios like the one sketched in the abstract paragraph). For our investigation, we use street data sets from different spatial databases, namely Geographic Data Files (GDF) [4] and the German Authoritative Topographic Cartographic Information System (ATKIS) [11] which have been transformed into the AWS format. GDF is an international standard that has especially been developed for car navigation applications and thus is used to describe and transfer street networks whereas ATKIS is more comprehensive and contains data of different topographic categories like settlement, vegetation, traffic, etc. Both data models capture street objects as linear features in approximately the same scale (1:25 000).

The remainder of this paper is organized as follows: section 2 describes related work in the field of matching and conflation of multi-representation databases. Section 3 briefly introduces the Nexus project and in section 4 the idea of MRep Relations is presented. Section 5 contains a detailed description of the navigation approach in multi-representation databases. Finally, section 6 summarizes this paper and gives an outlook on future issues.

2 Related work

Interoperability of spatial databases is one of the main research topics in the GIS domain. Amongst others, it comprises the field of integrating multiple, potentially contradictory representations of one and the same real world object.
In order to identify corresponding representations in different databases, matching techniques are developed. For example, [2] has implemented an approach for matching street network nodes of two different GDF datasets which have been acquired by different companies (NAVTEQ and TeleAtlas). The algorithm developed here is based on the idea of describing intersections of streets, i.e. nodes of a street network, by a code. This code consists of point coordinates and the number, abbreviations and names of incident streets. For each intersection, such a code is created. By comparing the codes of the intersections within the different GDF data sets and by assigning the intersections with the most similar codes to each other, references can be derived.
A fundamental, line-based matching approach for street network data of ATKIS and GDF has been presented by [10]. In a first step, the algorithm finds all potential correspondences of topologically connected line elements in two source data sets by performing a buffer operation. The matching candidates are stored in a list. This list is ambiguous and typically contains a large amount of *n:m* matching pairs. Then, unlikely matching pairs are identified and eliminated using relational parameters like topological information and feature-based parameters like line angles. The result is a smaller but still ambiguous list with potential matching pairs. These matching pairs are evaluated with a merit function in order to compute a unique combination of matching pairs which represents the solution of the matching problem. This is a combinatorial problem which is solved with an A* algorithm.

The problem of spatial data fusion or conflation is for example being tackled by [3]. The merging process is defined here as “feature deconfliction”, where all parts of a matched feature pair are unified into a single “better” feature. The conflation algorithm has to decide, which properties are preserved in the resulting instance. In their approach, the authors are also taking into account the data quality information of the corresponding instances in order to derive SRep data. Also in [5] it is dealt with the fusion of multi-source vector data. The integration process is divided into a “linking” phase where homologous objects are identified and a “best map” phase that assembles the linked objects. During best map, so-called connectivity vectors are placed at the boundaries of linked objects in order to connect the geometries of corresponding representations. Similarly to our approach, a “best path” application was developed that allows finding shortest paths between low-resolution and high-resolution street data sets. However, unlike in our work, linking does not produce any information about the degree of similarity of the linked objects that could be exploited during data analysis.

3 A short introduction to Nexus

The goal of the Nexus project is to provide a platform for different kinds of location-based applications. This platform is organized as a federation that provides the Augmented World Schema (AWS) – a spatial integration schema, i.e. a common conceptual schema especially designed for LBS – into which the data of autonomous spatial databases (so-called context servers, CS) have to be transformed [8]. This involves the solution of semantic issues (see [9]). Just like in the WWW, anyone who wants to participate in the Nexus system can provide an own context server that merely has to be registered at the Area Service Register (ASR) component, a spatial lookup service that is utilized to find the data necessary to answer a client query. Anytime a new context server is registered, the MRep Builder is triggered to find corresponding representations in the spatial databases already available in Nexus and in the newly added one and generates MRep Relations between them. All MRep Relations are stored in special context servers, the MRep Relation Servers that also have to be registered at the ASR. If an LBS client query has to be processed, the Federation finds out via the ASR which spatial data servers and MRep Relation Servers have to be accessed to gather the query relevant data. Those services which are capable of using MRep Relations within their analysis algorithms (MRep Services) do not need any further integration steps and can create their version of a Unified Context Model. Other services, like e.g. a map service, which need to produce an SRep data set (Non-MRep Services), exploit MRep Relations in the merging process to assemble the different context models (or patches) and create another version of a Unified Context Model. Finally, the results produced by the services can be returned to the application (see Figure 1).

4 The concept of MRep relations

The first step in integrating heterogeneous databases consists of feature matching [3], i.e. representations of the same real world object within different databases have to be identified. The matches between corresponding instances can basically be stored as simple pointers within a bidirectional list, displaying that an object O_{Ak} or an object set $\{O_{A1, \ldots,} O_{Ak}\}$ of data set A can be assigned to an object O_{Bn} or an object set $\{O_{B1, \ldots,} O_{Bn}\}$ of data set B (e.g. $O_{A1} \leftrightarrow O_{B1}$, $\{O_{A3}, O_{A5}\} \leftrightarrow O_{B2}$, $\{O_{A6}, O_{A9}\} \leftrightarrow \{O_{B4}, O_{B7}\}$, etc.). However, during matching more information like geometric, topologic and attributive similarity measures for corresponding representations can be derived. This additional information is according to our approach represented in an own formal structure, the MRep Relation, which can be exploited for multiple purposes. One of these purposes is the shortest path search in multi-representation databases.

4.1 MRep relations

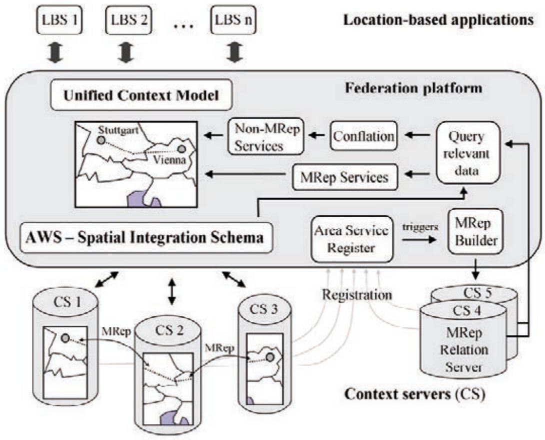


Fig. 1: Architecture of the Nexus platform

MRep Relations can contain several structural elements like their position (in order to allow a spatial search of MRep Relations), identifiers of related objects, cardinality of the matches (1:1 … n:m), comparisons of data quality parameters, etc. With respect to our work, only the similarity measures that are created for corresponding representations are of relevance. Since the presented application focuses on the investigation of linear street data and potentially useful attributive information (like street names) was not available, only geometric and topological similarity indicators were generated for the linear representations to be matched. The assessment of geometric similarity was based on the comparison of angle and length differences and distance values like the average line distance and the Hausdorff distance. Adjacency relations (node degree differences) of corresponding street representations were used to detect the topological similarity. The different partial similarity measures were eventually aggregated into a total similarity value using a simple weighted sum approach: the absolute values of the individual similarity measures were first divided into 7 classes from 0 (lowest similarity) to 6 (highest similarity) to obtain so-called evaluation values. Then, each evaluation value was weighted with a factor. The weight factors were specified on the basis of the operator's expertise regarding the influence of the different partial similarity values on the total similarity. The total similarity value was normalized onto an interval ranging from 0 to 100, with 100 representing the highest similarity.

MRep Relations are stored and exchanged using an XML-based format called **M**ulti**R**epresentational **R**elation **L**anguage (MRRL) which was specified within this work. The following extract of MRRL shows the basic structure of an MRep Relation (see Fig.2).

4.2 Generating MReprelations

For a test area in the inner city of Stuttgart/Germany, two different street databases originally stemming from ATKIS and GDF have been transformed into the exchange format of Nexus. Then, after reducing the global geometric deviation of the data sets by a rubber-sheeting transformation, MRep Relations have been created for the multiple representations in the overlapping areas of the two data sets. For the acquisition of MRep Relations, a semi-automatic software, the so-called Relation Builder Toolbox, has been developed (see Figure 3). It has been implemented within the framework of the publicly available Java-based GIS environment JUMP [6]. Using this tool, a human operator can manually select the instances of corresponding representations by analyzing geometric and topological criteria. For the matching, the operator is provided with a set of rules that are necessary in order to achieve replicable results amongst different operators (see [9] for further details). If the corresponding representations have been selected, MRep Relations (including the similarity values) are created automatically by the software. Currently, we are working on automated matching algorithms to minimize the intervention of human operators.

Fig. 2: Part of an MRRL instance file displaying some structural elements of an MRep Relation

```
<mreprelation>
 <mrep_id /> <position />
 <attributes>
  <general_atts>
    <source_ids>atkis_awml.349;</source_ids>
    <target_ids>gdf_awml.826;gdf_awml.827;</target_ids>
    <cardinality>1:2</cardinality>
    <total_similarity>90.56</total_similarity>
  </general_atts>
  <semantic_atts />
  <geometric_atts>
    <length_difference>13.84</length_difference>
    <avg_line_distance>8.83</avg_line_distance>
    <hausdorff_distance>11.45</hausdorff_distance>
       ...
  </geometric_atts>
  <topologic_atts>
    <startnode_deg_diff>0</startnode_deg_diff>
    ...
  </topologic_atts>
       ...
 </attributes>
</mreprelation>
```

5 An approach for shortest path search in MRep databases

In the following sections, the steps to achieve a shortest path search in MRep databases are presented and the developed sample application is briefly outlined.

5.1 Generating an integrated navigation graph

The principal goal of the navigation approach in multi-representation databases is to find the shortest path from a starting node in street network (or graph) I to a target node in street network (or graph) II. Switching from graph I to graph II is allowed arbitrarily often. The situation is illustrated in Figure 4 where two small, undirected graphs are displayed. From both graphs three edges and four nodes are available as multiple representations (MRep Edges

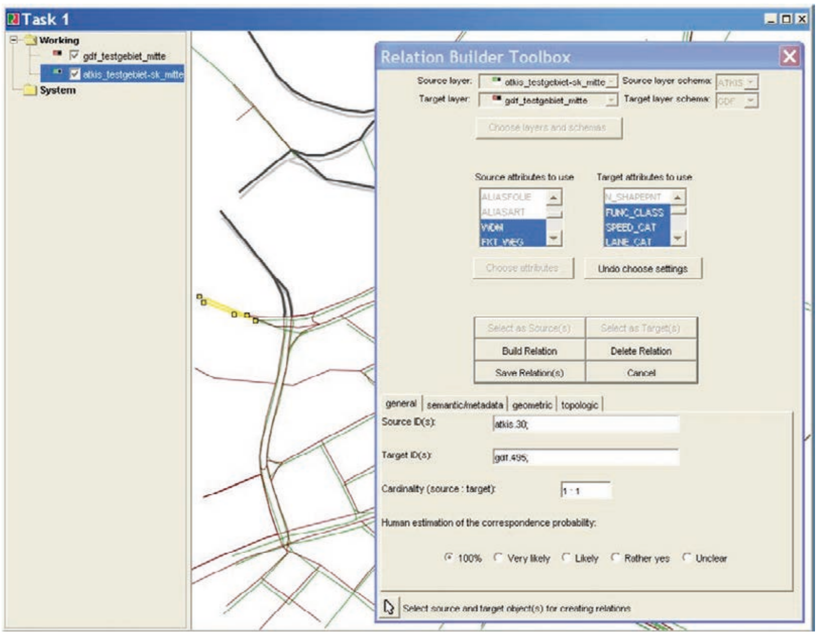


Fig. 3: The MRep Relation Builder Toolbox allows a manual matching of corresponding street representations

and MRep Nodes). MRep Relations were only created for the edges, but not for the nodes, i.e. similarity measures are only available for the MRep Edges.

In order to create *one* consistent navigation graph from the two underlying source graphs, two options are possible: First, MRep Nodes and MRep Edges could be topologically (not geometrically) aggregated to derive the final navigation graph. However, using this option the information stored in the similarity measures would get lost. For this reason it was decided to realize the second option by introducing so-called transition edges from one graph to the other between MRep Nodes (see Figure 5). Thus, it is possible to determine the uncertainty that arises when a switch-over from one graph to the other is performed. The uncertainty results from the fact that two MRep Nodes might in reality not be identical which is expressed by the similarity measure.

5.2 Determining possible paths

Algorithms for shortest path search can be based on adjacency matrices like e.g. the Dikstra or Floyd algorithm. However, an adjacency matrix can also be transformed into a tree structure where the start node is represented as the root. On tree structures, several search algorithms can operate (see [1] for an overview). We decided to apply a depth-first search to find all possible ways between a source and a target node.

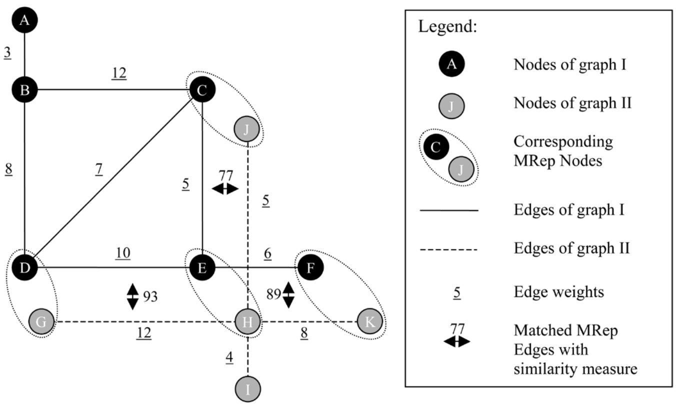
5.3 Calculating the costs

When all possible paths within the integrated navigation graph have been determined by a depth-first search, the total costs of the traversed edges (C_W) can be calculated. It can be defined as the sum of the costs of all real edges (C_{RE}) plus the sum of the costs of all transition edges (C_{TE}).

$$C_W = \sum_{i=0}^{n} C_{REi} + \sum_{k=0}^{m} C_{TEk}$$

Remember that multiple switch-overs from one graph to the other are allowed, that's why there can be more than one transition edge. For the calculation of the costs for the traversal of transition edges it has to be considered that there are only similarity measures available between corresponding multiple representation edges (MRep Edges), but not for their start and end nodes (the MRep Nodes). However, to determine the cost of a transition edge, the similarity measures for the MRep Nodes have to be known. Therefore, the similarity values of MRep Edges have to be converted to similarity values of the MRep Nodes and then the costs for transition edges can be derived.

Fig. 4: A multi-representation graph



In those cases where MRep Nodes only have one incident MRep Edge (e.g. MRep Nodes C and J in Figure 5), we can simply use the similarity measure of the incident MRep Edges (CE and JH = 77) as the similarity measure of the MRep Nodes. Whenever MRep Nodes do have more than one incident MRep Edge (like E and H), we chose the arithmetic mean value of the similarity values of all incident MRep Edges (for E,H = (77 + 89 + 93) /3 = 86,33) as an acceptable approximation for the similarity of the respective MRep Nodes.

The costs of each transition edge (C_{TE}) can finally be calculated by a simple cost function

$$C_{TE} = (Sim_{max} – Sim_{TE}) * \omega$$

where Sim_{max} is the maximum similarity value between MRep Nodes (100) and Sim_{TE} is the similarity value of the investigated MRep Nodes (e.g. 86,33 for E and H), i.e. the higher the similarity of MRep Nodes (Sim_{TE}), the lower the cost for traversing the transition edge. The influence of the transitions during the shortest path calculation can be weighted by a factor ω (with $\omega \in [0..n]$) and so the uncertainty which results from switching graphs can be expressed to a degree necessary for the application. The value of ω has to be chosen based on empirical observations and depends on the data sets involved. One strategy to determine a reliable result of the shortest path search could also be to neglect all paths containing transition edges with a cost above a certain threshold (e.g. above 15 for ω = 1).

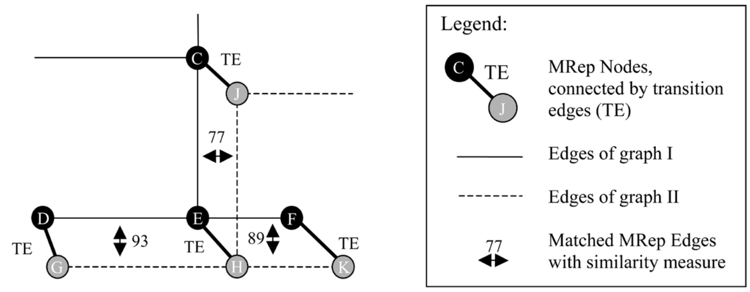
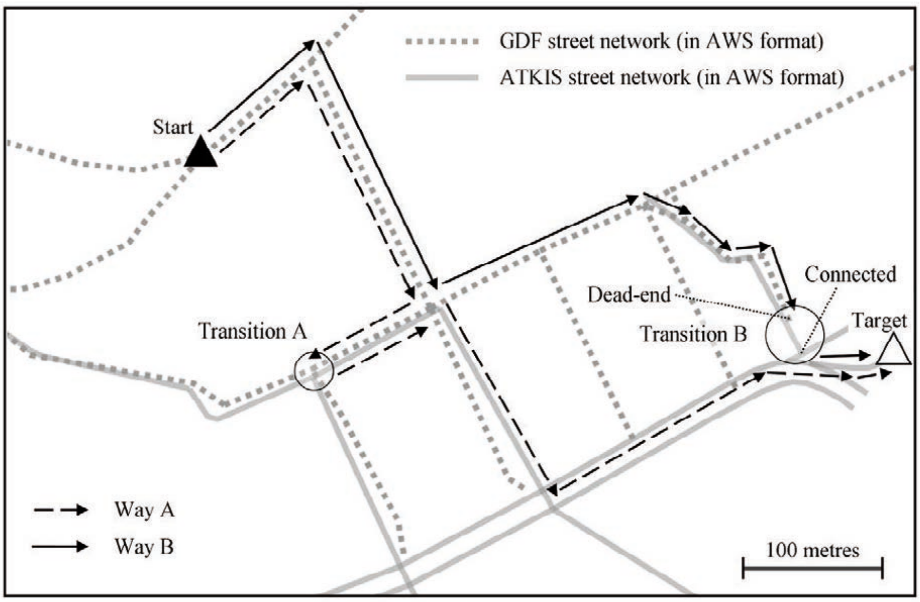


Fig. 5: The costs of transition edges have to be calculated regarding the similarity values of the MRep Nodes

5.4 Realization of the approach

The approach has been implemented as a sample application called MRep Network Analysis Tool within the JUMP environment. The user can select a start and a target node in either of the two source street networks which originally stem from GDF and ATKIS and have been translated in the AWS format. Depending on the ω value of the cost function, there can be different results for the shortest path (see Figure 6, ways A and B). Concerning way A, ω is large and so the cost function for the transition edges yields large values since the application requires a high reliability of the resulting way, i.e. the application demands that the transition has a strong influence on the length of the shortest path. Therefore, the actual transition rather takes place at those MRep Nodes that show the highest similarity (at transition A), i.e. at the place where the transition costs are minimal. As it is depicted in Figure 6, this constraint leads to a considerable detour. In the case where the transition takes place at B, the costs for the transition edges are comparably low (since ω is low), i.e. the transition has only a small influence on the length of the shortest path since the application allows a certain degree of uncertainty of the resulting path. The reason for the uncertainty in the described example results from the fact that the MRep Edge with GDF origin might be a dead-end street at transition B (although all streets directly at the boundary appear as dead-ends), whereas the corresponding ATKIS representation is connected to other roads at transition B.

Fig. 6: Clipping of a boundary zone of different street networks. Between the MRep Edges, MRep Relations have been defined.



6 Summary and outlook

In this paper we showed that explicitly linking corresponding objects in multi-representation databases through MRep Relations is an alternative to the conflation of multiple representations into a single representation (SRep) data set since GIS algorithms can be adapted to exploit MRep Relations during data analysis. We have verified our approach by means of a shortest path search in multi-representation street databases: First, we created MRep Relations between corresponding street objects (MRep Edges) within the originally separate GDF and ATKIS networks. Second, in order to connect the graph structures derived from the street networks, we introduced transition edges between MRep Nodes. The costs for traversing these transition edges depend on the similarity values stored in MRep Relations and can be further adjusted according to the reliability requirements of the applications. Third, we applied a depth-first search algorithm that allows finding the shortest path between any two nodes in the unified graph. The approach was finally implemented in a sample application.
In the future, some of the processes that are part of our approach have to be extended and enhanced. Currently we are working on algorithms to automate the generation of MRep Relations as far as possible. Furthermore, issues of optimizing the tree search are being dealt with. Eventually, the creation of MRep Relations has to be adapted to other object and geometry types (e.g. buildings represented by aerial geometries) and it has to be investigated how other GIS algorithms like buffering, intersection, etc. can be extended to be able to exploit MRep Relations in the analysis process.

7 Acknowledgements

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Geocoding walking directions using Sidewalk Network Databases

Masatoshi Arikawa, Kouzou Noaki

Abstract

This paper proposes an advanced method of geocoding for walking directions in documents using daily local expressions. Walking directions are usually described in casual expressions, but not in regular ones like address. Thus, it has been considered practically impossible to geocode walking directions. However, sidewalk network databases in major cities of Japan have been available for human navigation services with GPS-equipped mobile phones since 2003. The databases can be expected to enable more advanced geocoding for larger scale natural language expressions. We first introduce the core schema of sidewalk network databases. Then, we explain a structure of walking directions in Japanese, and propose FRS (Formal Route Statement) to represent and process walking directions by means of a computer. Finally, prototype systems which have been developed based on our proposed framework are presented.

1 Introduction

When we want to have a tasty meal with our friends, we get information of restaurants from the Internet using search engines for some keywords. However, it is not easy to get exact information because there are billions of documents and the number of them is increasing. It may cause us inconvenience when we find information using computers, especially local information like restaurants. We assume that the inconvenience stems from the difference in the framework of managing information between our brains and the current computer systems. One of people's methods of memorizing information is associated with locations. Examples of this thinking are "Mr. Suzuki who lives in Tokyo", "a good Chinese noodle shop under the elevated rail" and "an important file in the second drawer of my desk". In other words, locations remind people of their memories. We define these descriptions which correspond to the region in the real world as geo-referenced descriptions. The purpose of this research is to consider the framework to deal with information using geo-referenced descriptions as one of the important keys referring to the information.

We have studied a method of converting geo-referenced descriptions like addresses and place names into their corresponding geographic coordinates [1]. The process of converting descriptions into coordinates is called geocoding. In this paper, we focus on walking directions as a new type of target to geocode.

2 Sidewalk Network Databases

Sidewalk network databases store underground walks, footbridges and cross walks for pedestrians. Sidewalk network databases are simply structured as nodes and links. A node has geometric coordinates. A link is defined as a vector between two nodes. Sidewalk network databases are provided as commercial products by Shobunsha Publications Inc. [2]. The commercial sidewalk network databases presently cover major cities in Japan.

Before the emergence of sidewalk network databases, there have been popular geographic network databases such as road networks for car navigations, railroads, facilities networks and so on. However, the previous geographic network databases were all designed for small scale uses, not for large scale uses such as human navigations. On the other hand, sidewalk network databases for walkers are getting popular for human navigation systems since 2003 in Japan. Some services and products using sidewalk network database have already been on the market. "EZnaviwalk" provided by KDDI au is one of the most popular human navigation services using cell phone, GPS, and electronic compass [3]. With sidewalk network databases, train timetables and airline timetables, EZnaviwalk finds the most direct, time-saving or money-saving route. This service has begun since October 2003.

The sidewalk network database used in our research is simply structured as nodes and links. A node has not only geometric attributes like coordinates but non-geometrical attributes like name of spatial entity, its class and related url. A link has a distance and an angle from its start node to its end node. Users can extend the integrated database by entering additional nodes and links or inputting text data. In particular, "intersection", "street" or "slope street" is shaped with the multiple nodes and links. For example, at least four nodes are needed to shape an intersection (Fig.1.). Figure 2 shows the core schema of sidewalk network databases. A node has attributes, that is, *id* (the identifier of a node), *name* (a spatial entity's name which corresponds to the node), *coordinates* (tuples of longitude and latitude), *in* (a name of a street or an area both of which are constructed of multiple nodes and links), *class* (a class of spatial object), *incoming link* (*id* of an incoming link), *outgoing link* (*id* of an outgoing link) and *poi* (additional information concerning the point of interest except for *name*, *class* and *url*)". A link has its *id* (the identifier of the link), *start_node* (*id*

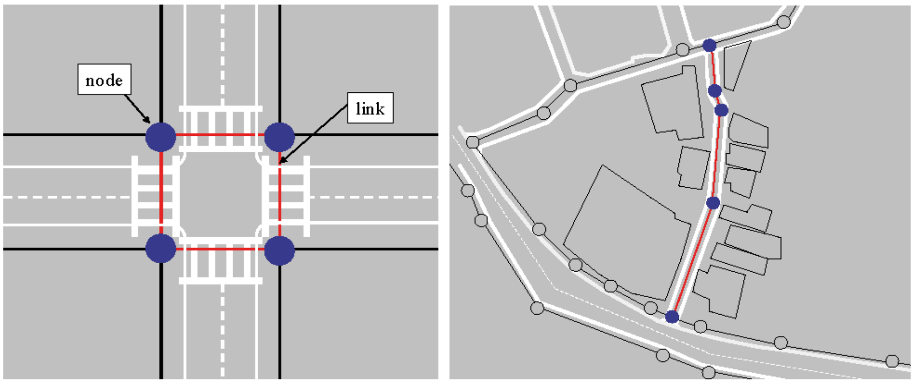


Fig. 1. Examples of nodes and links stored in sidewalk network databases. The left figure shows an intersection and the right one shows a slope street

of the node from which the link starts), *end_node* (*id* of the node at which the link arrives), *direction* (of the link in degree) and *distance* (of the link in meter).

Sidewalk network DB :	(*Nodes*, *Links*)
Nodes :	a set of *node*
Links :	a set of *link*
node :	(*id*, *name*, *coordinates*, *in*, *class*, *incoming_link*, *outgoing_link*, *poi*)
link :	(*id*, *start_node*, *end_node*, *direction*, *distance*)
node.id :	*id* of the node
Node.name :	*name* of the node
node.coordinate :	*coordinates* (*longitude*, *latitude*)
node.in :	*name* of group
node.class :	*class* of spatial object
node.incoming_link :	*id* of the incoming link
node.outgoing_link :	*id* of the outgoing link
node.poi :	information for the point of interest
link.id :	*id* of the link
link.start_node :	*id* of the start node
link.end_node :	*id* of the end node
link.direction :	its direction in degree
link.distance :	its distance in meter

Fig. 2. Core schema of the sidewalk network databases used in our research

3 Natural and formal route descriptions

3.1 Structure of walking directions

A walking direction can be divided into noun phrases and verbal phrases. For example, the description “渋谷駅ハチ公口を出て道玄坂を上り交差点を右へ曲がる (You exit from the Shibuya Hachiko Exit and go up Dogen-zaka Slope Street, and then turn right at the intersection)” is divided as follows:

```
渋谷駅ハチ公口を出て道玄坂を上り交差点を
右へ曲がる
          ↓
[渋谷駅ハチ公口][を出て][道玄坂][を上り]
[交差点][を右へ曲がる]
          ↓
noun phrases: [渋谷駅ハチ公口],[道玄坂],[交差点]
verbal phrases: [を出て],[を上り],[を右へ曲がる]
```

All of the above noun phrases have a place name. A place name refers to the unique place in the real world and works as a reference point for the next verbal phrase. The above verbal phrase has a preposition such as “を(at, from or through)”, a verb such as “曲がる(turn)” or “出る(exit)” and an adjunct such as “右へ(right)”, “100メートル(100meter)” or “5分(5minutes)”. It is usual for Japanese people that an agent noun for the verbal phrase is often omitted in a description. A person who is referred by an omitted agent noun is a walker who is a writer of a description or third person.

We call a noun phrase in a walking direction *spatial anchor description*. Spatial anchor description includes unique noun and general noun. A general noun such as “intersection” is deduced from context of a description and situation. Spatial anchor descriptions referring those places can be used as start points, passage points and end points of routes in walking directions. These verbal phrases are the expressions of a walker’s action on the route. Walker’s actions on the walking direction denote topology between places. We call a verbal phrase in a walking direction *spatial relationship description*.

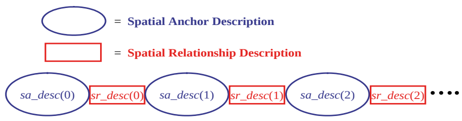


Fig. 3. Image of model for walking directions

3.2 Simple model of walking directions

We simplify walking directions, such as a list structure in Figure 3. A description of spatial anchor corresponds to an ellipse and spatial relationship description corresponds to a rectangle in Figure 3. Figure 4 illustrates the image of geocoding a walking direction into spatial database. Constructing a walking direction can be compared to sticking of pins and stretching of a thread between pins on a map. Using this simple model, we define the formal statement of walking directions.

3.3 Grammar of Formal Route Statement (FRS)

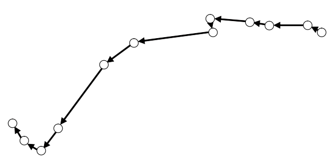
Formal statements are necessary for computers to indirectly deal with walking directions. On the assumption that all of walking directions can be expressed with nodes and links, we propose *Formal Route Statement (FRS)* to represent and process walking directions. FRS also works as a query language for sidewalk network databases. Using FRS, a walking direction is represented as a sub-graph of a directed graph of sidewalk networks (Figure 5).
Figure 6 shows the grammar of FRS. Generalization tables are indispensable for converting various casual descriptions into regular ones, one of which is FRS (Table 1). A use case of the generalization tables is to make an instance of the spatial relationship as a value of the attribute “*link.connect*” in Figure 6. The attribute “*link.connect*” plays an important role to find a spatial object when a name referring to the next place is omitted.

FRS ::=	*sa_desc*(0)(:*sr_desc*(*i*):*sa_desc*(*i*+1))* [*i*={0,...,*n*}];
sa_desc(*i*) ::=	*node*(*i*).*node_attribute_list*
node_attribute_list ::=	*none* | *node_attribute_value* (&*node_attribute_value*)*
Node_attibute_value ::=	*node_attribute* = *value*
node_attribute ::=	*id* | *name* | *coordinate* | *class* | *status*
value ::=	*numerical_value* | *stirng_value* | *url* | *status_values* | *connect_values*
status_values ::=	*start* | *end* | *via*
connect_values::=	*straight* | *right* | *left*
sr_desc(*i*) ::=	*link*(*i*).*link_attribute_list*
link_attribute_list ::=	*none* | *link_attribute_value* (&*link_attribute_value*)*
link_attibute_value ::=	*link_attribute* = *value*
link_attribute ::=	*id* | *start_node*(*id*) | *end_node*(*id*) | *direction* | *connect* | *distance*

Fig. 6. Grammar of Formal Route Statement

Fig. 4. Image of geocoding a walking direction with a spatial database through the intermediary of simple model

Fig. 5. Sub-graph G which is the result of FRS(route_desc), where route_desc is a text string of a walking direction.



Specialized descriptions for spatial relationships	Generalized descriptions for spatial relationship (values of *link.connect*)
go forward, go ahead, advance	Straight
turn to the right, on the right, on one's right	Right
turn to the left, on the left, on one's left	Left

Tab. 1. A generalization table for descriptions of spatial relationship and values of the attribute "link.connect"

4 Prototype of Sidewalk Network Database Management System

We have developed a naive management system for sidewalk network databases. We explain each component in the user interface (Figure 7) as follows.
(A) Menu button: Users can change the operation mode by the menu buttons. Main functions are (1) loading and saving sidewalk network data which are XML formatted and (2) adding, erasing and moving both nodes and links. Furthermore, we select functions of referring to node information (e.g., a name of a place) and filling it using the entry form.
(B) Map area: Sidewalk network databases and a map image in the selected area are overlapped and visualized.
(C) Display of node information: This area allows users to see values of attributes, a name, a class and a picture for an instance of a spatial object in the map area.

5 Prototype of Geoparser for walking directions

We have developed a prototype system, which processes a walking direction in Japanese, and then visualize it as a polyline on the map using a sidewalk network database. Each component in the user interface (Figure 8) is as follows:
(A) Input text form: Users can input a walking direction using this text form.
(B) Output text form: A result of separating input text and validating separated elements is displayed in this form.
(C) Output map area: A route is visualized on the sidewalk network database as a result of geocoding a walking direction.

Using a walking direction as an example of an input text, Figure 9 shows a behavior of the geocoding process for an example of a walking direction. The captions of the figures explain the details of the behavior.

6 Conclusion

This study proposed one of the advanced methods of geocoding geo-referenced descriptions. As a result of establishment of these methods, we will be able to get local information using the spatial representation among ever-increasing digital data. This paper showed a basic framework to geocode walking directions for pedestrians walking through an urban city by means of sidewalk network databases. On the basis of the structure of walking directions, we clarified three significant ideas as follows:

- Formal Route Statement
- Schema of extended sidewalk network databases
- A method to validate Formal Route Statement

Fig. 7. Graphical user interface of the prototype system for managing sidewalk networks

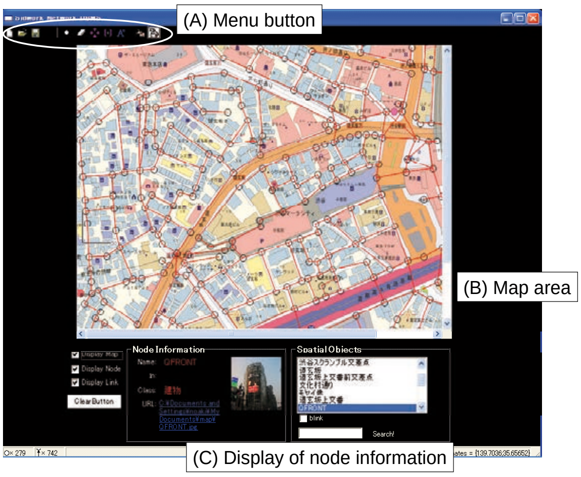
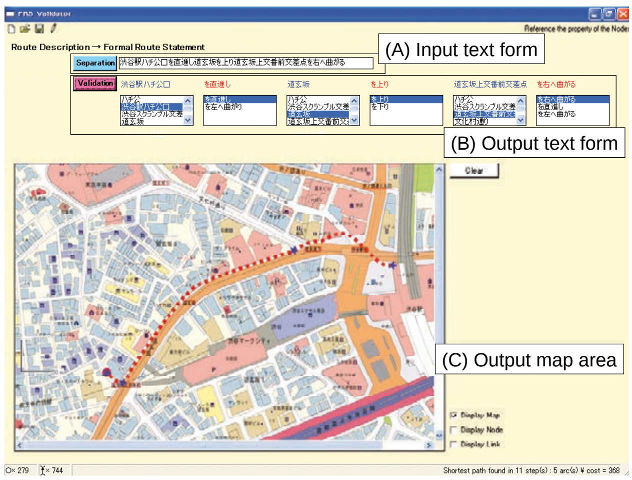


Fig. 8. Graphical user interface of the prototype system for geocoding walking directions.



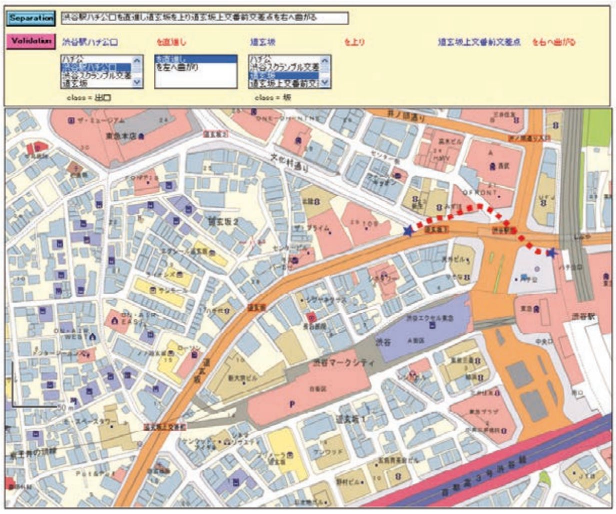


Fig. 9(a). The prototype system searches the shortest path (the dashed line) from the node matched sa_desc(0) to the nearest one of the nodes making up sa_desc(1). sr_desc(0) is also matched with the sidewalk network database. This figure shows the result of processing sa_desc(0) + sr_desc(0) + sa_desc(1).

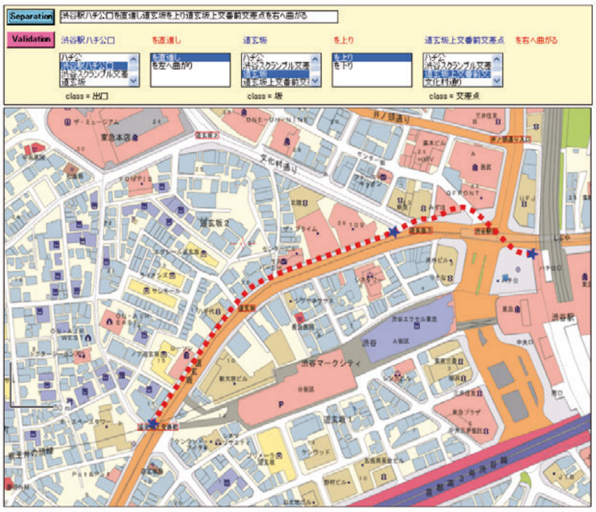


Fig. 9(b). The system searches the shortest path to the nearest one of nodes matched with sa_desc(2). This figure shows the result of processing sa_desc(0) + sr_desc(0) + sa_desc(1) + sr_desc(1) + sa_desc(2).

We aim for the realization of the robust system. For example, the system corrects route descriptions when invalid route descriptions are detected. In addition, there is a problem about ambiguity of natural language. In that case, multiple solutions, which are possible routes to a destination, should be ranked by some criteria of quality of the geocoding results.

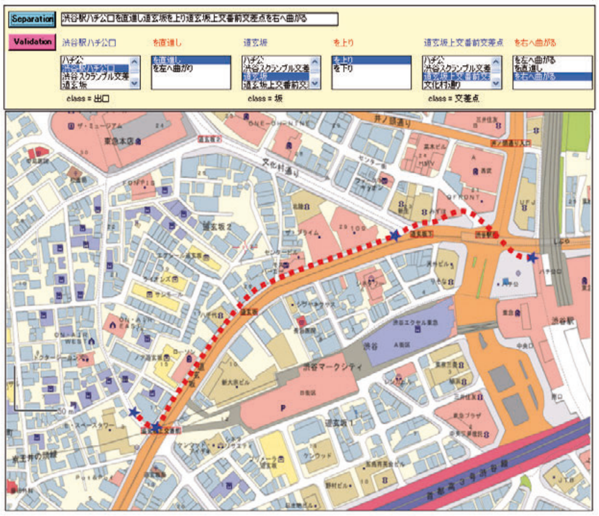


Fig. 9(c). The end node is deduced from the description of sr_desc(2) and the direction of the last matched link. This figure shows the result of processing sa_desc(0) + sr_desc(0) + sa_desc(1) + sr_desc(1) + sa_desc(2) + sr_desc(2).

7 Acknowledgements

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Dancing without gravity. A story of interface design

Ken Francis, Peter Williams

1 introduction

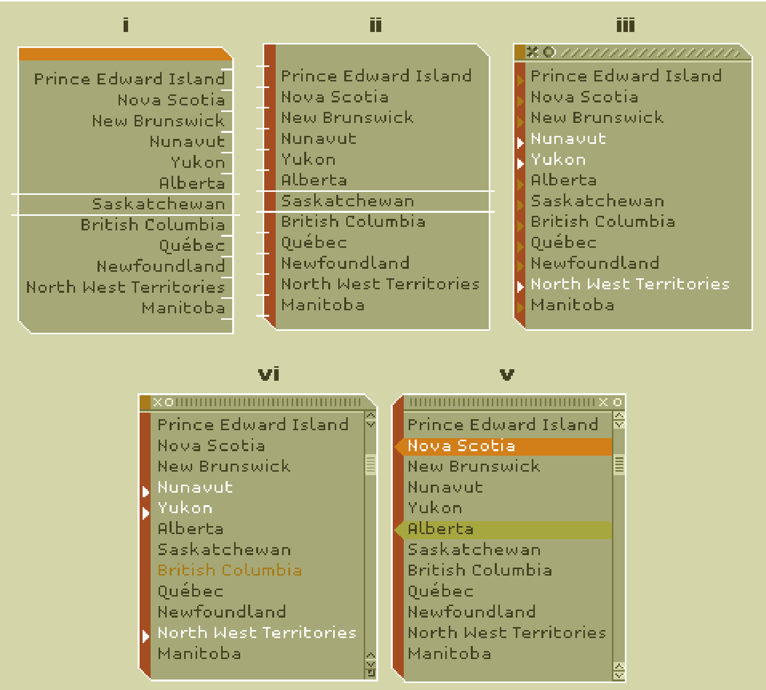
An interface must perform just one function: to serve as the mediator between the user's wishes and the abilities of the machine. Good interface design has this goal as its beginning, but moves forward to advance the properties of ease, logic, elegance, consistency, wit and beauty in its form.
The digital cartographic commodity as ideal map vernacular proposes an extension of the possibility of the paper map. This is only realizable if we remove the map from allegory and free it from metaphor. Interface metaphors have become redundant and clumsy, dampening the experience of "using the map". As much as possible, the map must serve as the means by which the user explores the information. It is through this confrontation with the programmatic agenda that a rich form/content dialectic can be engendered.
These are the understandings that served as the starting point for problematizing the design of interfaces used in a decision-making environment developed in the Earth Sciences Sector of Natural Resources Canada and the Canadian Geomatics industry. This paper will discuss these approaches.
The Scalable Vector Graphics (SVG) format is most suitable to create dynamic web-based visualizations in the Internet environment. The functionality of SVG for interface development and display of geo-spatial information is based on user selected attributes, from distributed, web-enabled, data services will be examined.
The illustrations selected intend to explore interface design that uses Scalable Vector Graphics in an application that presents urban land use data.

2 positioning_our_work

A thoughtfully crafted map offers information as a complex of understandings rather than a monologue of absolute facts. The possibility of the map to be an enriched field of user exploration, inquiry and intent depends entirely on thoughtful, carefully considered design that seeks to maximize the variability of possible understandings. When fully realized, the interface is an arena to hybridize data, interface and information display. It invites the user to work toward a trans-figurative position, to find new contexts and ways of mixing the imagined and the hypothesized. It is dependent upon creating a space for agency rather than one of unilateral transference, upon staging the information for consideration rather than enclosing it, upon the production of variability rather than the illusory pursuit of received truth.
Our work moves outward from an Activity-Centered Design approach where activities are comprised of tasks which are comprised of operations http://www.jnd.org/dn.mss/human-centered_desig.html). We relied on its focus on "work to be accomplished with the interface" and its hierarchical logic as a way to ground the way we problematized each emerging design question, rather than pinning our work on it as a totalizing theory. Also, working from the idea of Activity-Centered Design displaces attempts to produce a privileged user group. The interface opens up many points of access to maintain a universal and democratic position.
This paper is about how we have engaged with the design questions presented to us, and the work we have produced. The solutions at which we have arrived are not singularly useful to any one application. In fact, our work has been energized by the experience of so many other designers. Little of what is here is ours alone; we have learned from the www, and an endless list of interface environments both material and computational. We offer this paper as our design statement and hope our experience will be useful to other map designers and interface designers as they search for solutions to thier own design questions.

3 dancing_without_gravity

Design for the Ottawa Land Inventory Map module a grew out of a loosely expressed and often shifting list of needs. Scope of work, audience, functions, land use types to be included all were redefined throughout the life cycle of the design. This necessarily meant we had to adopt an approach that "over shot" any stated goals when formulating our design brief. Although this strategy demanded greater design output, the output could be edited in ways that could respond to a variety of anticipated needs. Additionally, the strategy forced deeper examinations of possibilities that constitute a record of valuable design research.
A constant in our mandate was that we should implement our work through Scaleable Vector Graphics (SVG). SVG is an open, vendor neutral, XML (Extensible Markup Language) based vector graphics standard for the depiction of resolution and device



independent two-dimensional vector and raster data. At present SVG is a W3C recommendation (w3c.org). SVG supports animation though start time, duration, and attribute values. It implements animation by supporting the modification of graphic objects colour values, coordinate values, and transformation values. It also permits motion of an object along a path.

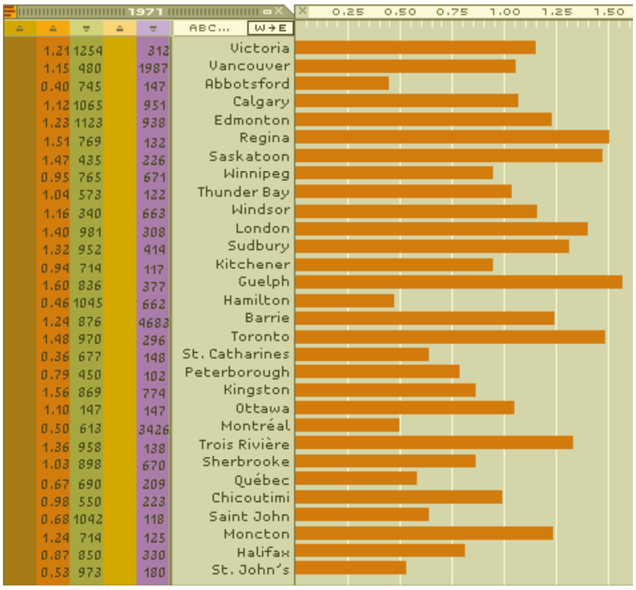
4 our_approach

To design an interface for the Ottawa Land Use Inventory Map we found that we needed to extend our consideration beyond the singular program of the map to the relationships presented in the wider interactive field. This lead to an investigation of the information space as a formal typology. By problematizing the information space as a formal typology, elemental structures are free to assume distinct yet co-ordinated roles. These roles are articulated through a precise graphic vocabulary which is directly responsive to user events.
Within the interactive field, we located projected points of coincidence, inertia, likeness/difference, and imagined how to maximize these potentials. The strategy was one of anticipation of to-be-delivered information and insertion of interface/information programmes. We adopted a formal critique of programme intent. This allowed the graphic interventions that came to define the interface/information space to respond to generally defined requirements. Parallels were recognized between the dialogue of use/intent and graphic response/shape, and the already established dialogue of programme insertion and orientation to site. Information display and information manipulation have been collapsed into simple graphic gestures that will accept a user's gaze, focus and consideration. This seemlessness optimizes exploration and understanding of the information.
We considered ways to create integration of various indicators—in maps, graphs, text and image—while maintaining a graphic signature for each theme. Identifying graphic signatures assures the user still can clearly read the individual themes even while information from two or more sources is juxtaposed in graphing displays. The work was informed by digital form and space, merging of information and display typologies, linked action/reaction interface repetoires and a search for gestural operations.
We developed the work as a cohesive, understandable product that mirrors the intentions of the user rather than that of the author. Important to achieving this is the effort to produce neutral space. Without deconstructing an already turbulent discourse, an examination of the idea of spatial neutrality informed an intention that was an underpinning of how the work was art-directed. The aesthetic propensities of the art-director will surface; it would be disingenuous to suggest differently. However, the construction of the "neutral field" is used as a strategy to open up the possibilities within the information space by staging the information for consideration rather than enclosing it. This provides the best possibility for user intention to direct how the work will unfold.

5 the_work

Basic graphic forms were explored in studies for a text menu window design, as it is the ubiquitous frame for all information in our interface design.
study i — A coloured bar tops the menu window. This stabilizes the form and becomes user affordance for dragging and repositioning the window. Angled corners adds tension and visual interest to the form.
study ii — The coloured bar has been reoriented and now precedes the menu items, providing a directional field for cursor movement.
study iii — A textured dragger bar expresses user affordance more clearly. “Collapse” and “close” controls are introduced. Now placed vertically, the colour bar accepts user feedback/ cursor tracker responsibilities, making it a focus of user interactivity for the window.
study iv — The dragger bar is given a less heavy-handed texture (borrowed from Sun JAVA’s flush 3D style). The “collapse” and “close” controls are redrawn to reflect this new subtlety. A scroll bar is added, with an “expand window” control at the bottom. Cursor tracking migrates to typography, with colour delivering the feedback message. This cleans the colour bar of the visually intense tracking display. The result is a greater focus on selected items, with less visual clutter.
study v — The tracking devices of the vertical colour bar have been extruded into ribbon forms extending across the type field. Tracking and selection functions are signaled through colour shifts of the ribbon with a reserved out menu element reinforcing the visual cue of the selected state.

ix

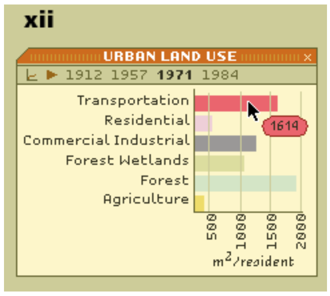


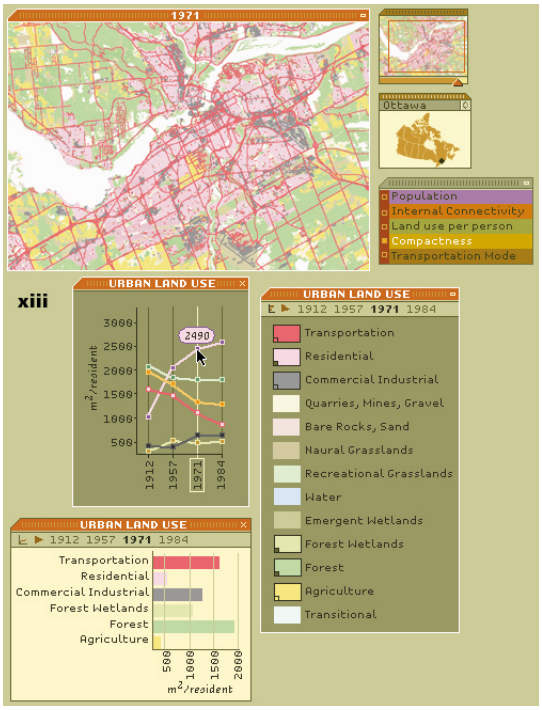
6 art_direction

The colour story has been taken out of the palette of 216 web safe colours and is maintained throughout the work. This insures cross-platform consistency, although with current monitor colour depth and resolution, that requirement is vestigial. It is an art-director imposed restraint to build a tightly composed working vocabulary. Typography is executed with Unibody-8 (underware.nl), a type family designed specifically for screen use and to maintain it’s integrity on both Mac and PC operating systems. As it contains roman, italic, bold, black, and small caps fonts, it is possible to set type for every need in the interface. These carefully applied restraints collects all interface elements in easily recognized relationships that remove former vernaculars while celebrating new graphic languages.

7 map_design

A map of Canada serves as the starting point for a user’s examination of the urban land use indicators. An oblique orthographic projection was selected for the base map. This reduces the northern land mass as it curves over the horizon, and focuses the user’s attention on the cities in the southern portion of the country. It is a dynamic effect with a sense of depth and movement. Land mass and water bodies are rendered in an intentionally muted palette of neutral mid-tones and visual clutter is minimized by removing shore lines. In this context, boundaries are useful references but not important information, so they have become undifferentiated white lines to merge with the negative space. The base recedes allowing the point symbols, typography and indicator numbers to be read without competition. Great care was taken in the execution of typography for this map. A subtractive strategy was used in this design to ensure maximum clarity of type and indicator numbers.
A window listing indicators and available years of Canada Land Inventory Land Use data is the entry and circulation space for user investigation. From here, indicators may be selected to be shown, on roll over, on a city map of Canada, as well as being graphed as histograms. The histograms and numeric lists of indicator values, are dynamically generated SVG data views. Indicator values are organized in a cities list window which can be collapsed and closed, letting the user control a potentially visually intense display. By respecting human cognituve processes, complexity is elegantly managed through this strategy of window control while continuing to reveal the structure of how the data are orgainized.





8 ways_of_looking

When the indicator numbers are listed with the city names, certain possibilities became evident. We offered sorting methods based on ascending or descending values of indicators, east/west, west/east location of cities, as well as alphabetically by city name. As the data are manipulated, the histograms are also re-ordered. Each sorting method has the potential to reveal a fresh look at the nature of the data, letting the user understand its structure in new and useful ways. It does not require a 3D fly-over, or an animated sequence. Nor does it require a map. These discoveries happen in a simple list of city names paired with statistical values. This seems to be closer to the essential idea of visualization as being about ways of looking, rather than being necessarily bound to the latest, trendy widget.

Urban land use is a subject matter that is necessarily technically dense. To lessen this esoteric situation, a glossary of definitions for indicators and land cover types is proposed. The definition is presented in a window which appears when the user clicks on an indicator name from the main selection window or a land cover entry from the legend.

The national module is an avenue into a city scale study of urban land use. At any time in the user's exploration, the user may leave this national scale module and move to an urban scale view of the data by clicking on a city from either the map or the list of city names.

Through static and dynamically generated hyperlinks, Scaleable Vector Graphics permits users access to more detailed views of indicator values. This is the means to allow users to move from the national view to an urban view as well as to plot graphs and historgrams of layer values already selected in the legend. Scaleable Vector Graphics may also be used to dynamically generate attribute information analysis through animating these histograms and graphs.

Spatio-temporal analysis may be performed using Scaleable Vector Graphics to dynamically access web map server and web feature server data to select a series of temporal moments so as to detect areal change over time.

vi (1/2 size) — This view of the main control window shows several states: the selected year is 1971 and the compactness indicator is on.

vii (1/2 size) — This explanation of compactness is revealed by clicking on the indicator name.

viii (1/2 size) — The national view map showing a roll over of Ottawa with the compactness indicator selected, and a roll over of Winnipeg as it would appear with all the indicators on.

ix — The cities list with the histogram window open. We see three indicators are turned on, compactness is plotted and the list is sorted by city from west to east.

9 interface/information collapse

Interface/information collapse is evident in the overview map/navigation device/scale control. This combines two interface devices in transparent, gestural operations available in one location. User affordance is provided through a cursor change when rolling over the device. When the pointer is inside perimeter of the rectangle, it is replaced by the often-seen dragger hand. On mouse down, the user can drag to reposition the rectangle, and so reorient the map inside the neat line. Our improvement to the scaling operation is a combination of enlargement and reduction in a simple appliance: a slider bar. When the control/indicator is moved to right, the scale is increased. When it is moved to the left, the scale is reduced. Needed understandings of relative scale are read from the ratio of the map outline:entire overview map. (Please see the navigator window in Adobe Photoshop version 5.0 and the panning device implemented at yoox.com and earth.google.com)

x — The legend is the year selector/layer control for the map. It also lets the user to make active other data display types, as well as playing an animation, which cycles through the years. Clicking on the legend's colour blocks turns layers on or off. Infotips roll overs are managed through the square inside the "on" layer's colour block. In this screen capture, data for 1971 is being explored. The transportation layer is on, but roll overs for the layer is off. Roll overs is turned on for the residential layer. Forest wetlands is highlighted (feedback) before it is clicked to open a window giving it's definition.

xi — The scaling/navigation device showing the dragger hand. The popup scrollable menu of city names. Ottawa is the current city being examined and the new selection will be Toronto.

xii — A plot of histograms of the currently selected layers. An exact value for "transportation" is given as a roll over. Year selection, animation through data years and a graphing window are all available from the top of this window.

xiii — A composition of map interface elements. The scale/navigation device and city selector device are permanent elements. In this illustration, the window of graphed land cover values also takes advantage of roll overs to give exact values of each plotted point. The indicator selection window affords examination of other land use themes.

A small map of Canada is paired with a popup menu of city names. This provides a means for the user to select a new city or to return to the national view of cities and indicators.
Function/information coincidence is best illustrated in the legend window. Roll over control, legend, map item on/off control are collected in one collapsible window. The window-as-interface is further developed by including “year selection” and “show histogram” controls at top. The legend’s essential role in traditional map design (that of typological clarifier) is taken up and advanced in our design.
User intention is carried across interface/information devices. Those layers “turned on” in the legend window will be shown in the histogram and graph windows. Standard SVG roll over functions are explored in these graphing windows. An overview and general trends are available to the user from the graphs, with exact values given when the user rolls over a histogram or a graph node.

10 conclusion

What we set out to accomplish in our work to design this interface give the user a sence of control and understanding. We wanted the user to understand the purposes of the interface and it’s responses to actions. And we want that to translate into the user’s understanding of the information that is available.
“Weightless” is an adjetive we kept in mind during this dance. We have placed our focus on the idea of a weightless experience that does not feel like work, but feels like an natural extention of a user’s intensions. This allowed us to substitute simplicity for complexity and to propose an interface design that offers ease of use, and thoughtful ways to engage the information.

Evaluating maps for mobile display

Julie Dillemuth

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Abstract

Digital maps on mobile devices present new capabilities and challenges that differ from using paper maps in a mobile setting or viewing digital maps on a desktop computer. How people interact with and use such maps is not well understood, yet such knowledge is critical for informing cartographic design for mobile devices and contributing to a better understanding of human spatial behavior. This research investigates human-map interaction through a study that evaluated maps on a mobile device used for a field-based, pedestrian navigation task. Map representations at two levels of generalization were compared by analyzing subject performance in a route-following task, with the maps on a handheld computer used as a navigation aid. Subject time to route completion, accuracy and interaction with the map during the task were measured. Self-report data on spatial ability, familiarity with the area, and map and mobile device experience were also considered. Significant differences between the representation types carry implications for map design for small, mobile displays and identify factors that affect the use of maps while moving.

1 Introduction

The power of cartography lies in the ability to reduce a map's complexity to represent only the information relevant to the map user. But for a digital map on a small mobile device, what *is* the critical amount of information? Further, with the constraints of the display size and the capability of adding or removing information for different situations, what type of information do people rely upon to orient themselves and navigate in a mobile context? Does that critical information change when the support of location based services (LBS) is incorporated? Such questions must be answered in order to determine appropriate representations of spatial information for mobile devices. This research begins to address these issues through a field-based study that tested user interaction with variations of a map representation displayed on a handheld mobile device.

Using a map on a mobile device carries implications for mobile map use that are different from those for either static or online maps. A small display window limits the extent and amount of detail that can be represented in a single field of view, but zooming in or out changes those limits. Location information from the global positioning system (GPS) can be incorporated, providing directional cues to the user or automatically orienting a map to the user's cardinal direction. In addition, maps are traditionally designed to serve a specific purpose – a road map assists a driver with navigation, for example. A mobile map user, however, may be engaged in multiple activities, such as navigation and data collection, which are likely to require different types of representations. Finally, a mobile user's attention is not fully focused on the map, but divided among a primary activity, monitoring his or her surroundings, and other factors besides interacting with the map.

While mobile maps are gaining momentum due to improving technology and the benefits associated with taking the capabilities of geographic information systems (GIS) into the field (Clarke 2004), porting representations from a desktop computer to a handheld device presents challenges to users. Test implementations of mobile GIS on handheld computers in the field cite the small display as a major difficulty for viewing and working with maps (U.S. Census Bureau 2003; Tsou 2004). Images and interfaces that are effective for a stationary user paying full attention to his or her desktop monitor are not appropriate for a distracted, mobile user viewing a small display (Clarke 2001). This study complements continuing research on spatial information delivery for mobile devices, and is unique in considering controlled variations of map generalization in a field-based task with a digital map. It is intended as the first part of a series of studies to systematically test carefully controlled variations of representations to determine what makes effective mobile cartography, and why.

Dynamic, digital maps are key applications for mobile devices, especially for providing navigation assistance to non-expert users, or assisting scientists and others who work with spatial data in the field. Although commercial products such as in-car navigation systems are already available to consumers, cartographic research has not kept pace with the technology. There are no cartographic design guidelines yet for digital maps, for desktop viewing or otherwise, as there are for traditional paper ones (Meng 2003). There is a growing body of research investigating the variety of spatial information presentation types available for handheld and wearable mobile devices: visual maps in 2D and 3D, text/audio descriptions, schematic diagrams, ground-view photography or video, or combinations of these (Urquhart et al. 2003 provides an overview of major projects; see Reichenbacher 2004 for a thorough summary). Many of these studies are concerned with how well a navigation system works as a whole and on a technological or usability level, such as which representation type or modality is more effective, rather than trying to determine *why* one representa-

(a) (b)

Fig. 1: (a) generalized map display with route 1, (b) aerial photograph display with route 2

tion method is better in light of how users interact with the information.

Map generalization research for small display is faced with the technological challenge associated with the limited screen space of mobile devices, and is driven by the need for automatic methods of creating representations that can adapt to the user's context (Edwardes et al. 2003; Hampe and Elias 2004; Nivala and Sarjakoski 2003), or can change scales and levels of detail in real-time (Hampe and Sester 2002). One of the primary problems of automatic generalization is devising a way to represent only the information that is relevant to the user at a particular time (Agrawala and Stolte 2001). The question of what that relevant information *is* remains to be determined.

2 Methods

In order to investigate user interaction with maps on a mobile display, an experiment was designed to have subjects use a map on a handheld computer to complete a real-world navigation task. This study sought, on one level, to test for differences between maps at two levels of generalization used for the navigation task and, on a broader level, to consider subject behavior with the maps on a mobile device: interaction with the map and the device, patterns of error, and relationship of spatial ability to performance on the task.

2.1 Participants and materials

Research subjects were 28 students, mostly graduate students, from various departments at the University of California, Santa Barbara (UCSB). Fourteen males and fourteen females participated, ages ranging from 19 to 37.

Representations starting at the least-generalized end of a representation spectrum were chosen for this study: a photorealistic image and a manually-created generalized map (Figure 1). A color aerial photograph at a scale of 1:12,000 was scanned to digital format and used as one display condition. Taken 14 months prior to the study, it portrays the actual environment in terms of detail and color, with no cartographic design applied. The generalized map is a classified and simplified version of the aerial photograph, digitized from the aerial photograph using a GIS. All readily-distinguishable landscape features on the photograph were manually traced, then the polygons were color-coded according to feature type: buildings, sidewalks, grass and other vegetation, trees, paved roads, sand and water. The objective was to evaluate two representations that were equivalent in feature information, with the only difference in the level of generalization being a reduction of detail and classification of features.

The use of the aerial photograph for this study represents a baseline "map", or even a worst-case scenario in terms of map design, since there has been no design applied. In testing the photograph against a generalized version, the differences are attributable to the level of generalization, rather than to labels or symbology that would typically be present in a map created by a cartographer. In terms of realism as a representation style, it has been argued (Bishop 1994) that the general public is more comfortable viewing realistic maps than generalized maps, since interpreting a realistic scene is more intuitive than interpreting an abstract scene, especially to an inexperienced map user. However, for use in a mobile, navigational context, the high level of detail in the aerial photograph carries the potential to overwhelm the user or make the map impossible to read on a small display. A generalized map may reduce cognitive load in terms of the user visually processing the image, but reconciling the abstract representation to the real environment may introduce another burden (Bishop 1994). From a practical-application perspective, in circumstances such as military or emergency response operations aerial photography or satellite imagery may be the best or only source of spatial information. For such time-critical situations, it is important to know how well an aerial photograph or satellite image can be used as a map.

It should be noted that no location information appeared on the map. This first study was concerned with how subjects performed with just the map and the route, requiring subjects to maintain their location themselves. An important follow-up study will be to replicate the experiment with GPS location information in order to understand the effects of such assistance.

2.2 Task

The experimental task entailed walking along a route displayed on the map on a tablet PC, using the map as a navigation aid. Subjects were instructed to complete the route as accurately as possible, walking at their normal pace. Subjects did the task with both display conditions (Figure 1), following a different route each time. Each route was the same length, 0.74 km, contained the same number of turns (19), and covered similar-sized, non-overlapping areas of the UCSB campus. Routes and map order were systematically varied among participants to avoid confounds from any differences in the two routes or from practice effects. Prior to starting the task, subjects received training with the tablet PC and completed short practice routes with each map type, to get familiar with the interface, display and task instructions. The navigation task was designed so that subjects would need to interact with the device continually, referring to the map in determining where to walk.

The hardware platform was a ruggedized tablet PC (Figure 2a), and a Java application displayed the map image in a 6 x 6 cm window, the size of the display dimensions of a typical PDA-sized handheld computer (Figure 2b). A pan frame surrounded the four sides of the image, with incremental zoom-in and zoom-out buttons below the image window (Figure 3). All buttons were selected by touching the screen with a finger. Maps were oriented on the device the conventional north-up, but subjects were free to physically rotate the device to rotate the map. Indeed, all subjects rotated the map during the navigation task according to the direction in which they were heading, consistent with findings in other research that users prefer to use a map oriented to their direction of travel (Warren and Scott 1993; Bornträger et al. 2003). Such physical rotation of the map, or of one's body, in order to line up the orientation of the map to the real world reduces the amount of mental rotation required of the subject to reconcile the map with the real environment (Aretz and Wickens 1992).

(a) (b)

Fig. 2: (a) tablet PC, (b) PDA handheld device

Data was collected in the form of computer log files tracking subjects' time and zoom/pan interactions with the device, researcher observations on where and when subjects stopped or made errors, and through questionnaires completed by subjects before and after the task. Spatial ability was assessed using a self-report survey that reliably measures sense of direction (Hegarty et al. 2002).

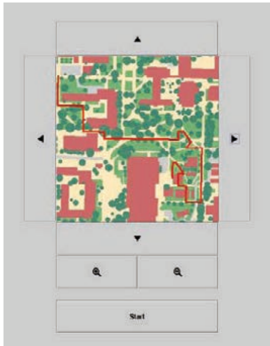

Fig. 3: Map display interface

3 Results

Paired t-tests at a .05 significance level were used to compare subjects' performance from one display condition to the other for the variables of: time to route completion, number of different zoom levels used during the task, number of times a subject changed zoom level, number of errors made with respect to features (i.e. walking around the wrong side of a tree) and direction, and the number of stops made during the task (Table 1). For the individual differences data, correlation tests were conducted to assess the relationships between variables and spatial ability, map and PDA experience, and general familiarity with the area covered by the route (Table 2). Correlations are significant at the .01 level (2-tailed) except where noted. Shading in the tables indicates significant results.

	Time to route completion	**Browsing: # zoom levels used**	**Browsing: # zoom level changes**	**Accuracy (# errors during task)**	**# stops during route**
Map Type: GM vs. AP	GM mean: 10:46 AP mean: 12:16 **p = .001**	GM mean: 1.9 AP mean: 2.8 **p = .002**	GM mean: 3.2 AP mean: 8.7 **p = .004**	GM mean: 1.8 AP mean: 2.1 p= .39	GM mean: 4.8 AP mean: 7.0 **p= .01**

Tab. 1: Significance results from paired t-tests

	Time to route completion	**Browsing: # zoom levels used**	**Browsing: # zoom level changes**	**Accuracy (# errors during task)**	**# stops during route**
Environmental Spatial Ability	**GM: -.51** AP: -.36	GM: .11 AP: .21	GM: .05 AP: .14	GM: -.23 AP: -.26	**GM: -.40** **AP: -.39** (.05 sig)
Map Experience	**GM: .61** **AP: .54**	GM : -.01 AP: .10	GM: -.15 AP: .08	GM: .26 AP: .21	GM: .28 **AP: .40** (.05 sig)
PDA Experience	GM: .21 AP: -.03	GM: .12 AP: -.09	GM: .14 AP: -.004	GM = .24 AP = -.06	GM: .31 AP: .11
Familiarity with Route Area	Rte1: -.14 Rte2: .01	Rte1: -.12 Rte2: .10	Rte 1: -.27 Rte2: .10	Rte1: -.10 Rte2: -.09	Rte1: -.06 Rte2: .20

Tab. 2: Correlations

In addition to testing the main variables, tests for route equivalency were conducted to be sure that differences between the routes were not of magnitude to affect the analysis. A one-way ANOVA comparing the dependent variables by route showed that differences in the routes were not significant. Subjects' varying walking paces are accounted for in this test, since each subject completed both routes.

On the first level of comparing the effects of the generalization, the generalized map resulted in overall faster time to route completion, less map browsing, and fewer stops compared with the aerial photograph. Map representation did not influence the number of errors made during the task. Taking a broader view, when subjects' performance is considered based on spatial ability, different patterns emerge. The difference in representation types seemed to have a stronger effect on the subjects of higher spatial ability, with those subjects performing much faster with the generalized map, while those of lower spatial ability did not exhibit a great difference in performance between map types. Grouping subjects into "higher" and "lower" spatial ability categories based on their spatial ability score being above or below the median revealed that those with higher spatial ability completed the task on the whole faster regardless of map type; that is, the mean of the times to route completion for the higher ability group (both generalized map and aerial photo) were significantly different from the mean times for the lower ability subjects ($p=.001$).

Map experience strongly correlated with time performance and spatial ability. Subjects reporting more extensive map experience completed the route faster than those with less experience using maps, and high spatial ability was correlated with more extensive map experience. These results raise questions about the effects of practice with maps and mobile devices on spatial ability, which may also relate to familiarity with an area. Familiarity with the study area was not a significant factor here, perhaps because all subjects were generally familiar with the UCSB campus.

Although the number of errors made was not different between map conditions, locations of commonly-made errors can provide insights about map misinterpretation, which could be used to predict and modify potential trouble spots in maps. In this experiment, there were two points on each route where more than half of subjects made errors. One error location correlated with spatial ability, in particular where the route was ambiguous due to occlusion by tree cover. Two error locations appeared related to map representation, since most of those errors were made with the aerial photo. And one location of error resulted from insufficient information about a wall feature in the map. Since maps will by definition have only a subset of real-world features, what is the effect of insufficient information? This question is particularly pertinent with the display of a GPS signal on a map, which may not be accurate enough at a certain zoom level or spatial resolution.

A factor that has not been considered in other studies of mobile map use is the size of the area covered by the map and its correspondence with real-world area. In this study, the most often used field of view covered an area of about 2.4 hectares, no matter the type of map. The entirety of route 1 and nearly the entirety of route 2 could be viewed at the next zoom level out, which displayed an area of 9.5 hectares; in other words, as long as a subject could get his or her bearings with that view, there was no need, in terms of viewing the extent of the route, to zoom out further. Subjects' concurrence of behavior in terms of zoom levels indicates there is a specific range of viewing area that is useful for this task and in this particular landscape: a great enough area to see the extent of the route, and an area not smaller than about 0.6 hectares (as a reference, roughly the size of a football field). With further empirical evidence and verification, guidelines could be developed relating area extent to level of detail and zoom level, which would assist in the mapmaking process for small displays. Zoom levels below a threshold of utility need not be provided to a user, and an appropriate zoom could be determined for a default view.

4 Discussion

The results show that in general, spatial ability plays a significant role in subject performance for this type of route-following task, and, in particular, suggest that the generalized map representation helped people with higher spatial abilities more than it helped those with lower spatial abilities. It is important that mobile maps be appropriate for people of either high or low spatial ability, and it could be argued that people of poorer spatial ability stand to benefit the most from this kind of tool. Indeed, since subjects of low spatial ability overall took longer to complete the routes with either map, can a representation style be found that would improve their performance? Further studies could test whether additional information, in particular a GPS location indicator, or information presented in a different modality, would provide the support needed by those with poor sense of direction.

Overall the generalization proved superior to the photorealistic representation, statistically and according to subjects' reported preference. But, both representations did, in fact, work: all subjects were able to complete the task with both map types. The advantage of photography or other remotely sensed imagery is that it can be more up-to-date than a designed map, and requires minimal processing. Maps used in a mobile context may be for time-critical military or disaster situations where a changing landscape renders existing maps obsolete. In that case, what is the tradeoff between current, relatively raw imagery, and an older but carefully designed map? This question underscores the importance of research to determine what information is important for spatial decision making in a mobile context, and how people interpret various types of representations on a small, dynamic, digital display.

Finally, the locations and types of errors subjects made were important factors in the analysis in that patterns were revealed that were masked by the statistical analysis of the data taken as a whole. The causes of and influences on the errors described here are subject to interpretation, but provide a foundation for further research to test specific situations in which there is ambiguity in the map due to obscured features, missing information, or other reasons that cause the map user to make fallacious assumptions or interpretations. Such research can lend insight in anticipating problem areas during map creation, and can inform design decisions to try to prevent confusion for the user.

As the first of a series of studies, priorities for follow-up research include testing additional types of generalized maps, and assessing the effect of GPS location information. Subjects commented that keeping track of where they were on the route and which direction they were heading was difficult at times. Reducing the burden for the user of determining his or her current location by incorporating GPS information supports more effective movement through an environment (Suomela et al. 2003). In that case, what bearing does location information have on the map representation? Can the map then be generalized to a minimalist schematic, or do users still need a certain amount of detail for context? How much detail?

The results here are specific to the type of environment of the study area and the activity of route-following, and would likely be different if the experiment were replicated in a different type of landscape, with a different sized study area, and if subjects were finding their way to a destination point rather than following a given route. Systematically considering maps in a variety of contexts is a necessary step towards a more complete understanding of how people interact with maps while mobile. This knowledge will inform generalization techniques, such as in determining just what level of detail is necessary, or to what extent features can be aggregated or simplified to fit in the display and still be effective.

5 Conclusion

Maps for mobile devices present new and critical issues to cartographers, such as the amount of spatial information that is critical to represent on a small, dynamic display. Understanding how users interact with digital maps while moving, and how the interaction varies with different activities or situations is essential for effective mobile cartography. The relatively small variation in level of generalization in this study resulted in significant differences in subjects' time performance and amount of interaction with the maps. On a broader level, individual differences of spatial ability and map experience were shown to have an influence on subject performance for this route-following activity. Such differences illustrate the need for appropriately designed map representations for mobile devices, and point to the variety of factors involved in using maps in a mobile context. An understanding of how people interact with digital maps while moving will provide insight on why one representation is better than another, and more broadly will contribute to cognitive and cartographic theory.

6 Acknowledgements

Aerial photograph used with permission of Pacific Western Aerial Surveys, Santa Barbara, CA. Research supervised by Dr. Keith C. Clarke and Dr. Tobias Höllerer, and supported by the National Science Foundation IGERT Program in Interactive Digital Multimedia (Award #DGE-0221713) at University of California, Santa Barbara.

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Concepts for the cartographic visualization of landmarks

Birgit Elias, Volker Paelke, Sascha Kuhnt

Abstract

Landmarks are an indispensable part of maps in mobile cartography applications. In this paper we propose a design concept for the visualization of building landmarks in mobile maps. We consider four categories of building landmarks: well-known shops (trade chains), shops referenced by their type, buildings with a specific name or function and buildings described by characteristic visual aspects and examine how each of these groups is most effectively visualized. Possible visualizations differ in their abstraction levels, ranging from photo realistic image presentations, over drawings, sketches and icons to abstract symbols and words. As a guideline to designers we provide a matrix representation of the design space from which possible and recommended presentation styles for each building type can be identified.

1 Introduction

Maps are a very important means to provide spatial knowledge and communicate route information (MacEachren 1995, Kray et al. 2003). Therefore, pedestrian navigation systems rely heavily on maps in addition to positioning and routing functionality to convey wayfinding information to their users. Many recent research projects have developed prototypes for mobile services like GiMoDig, NEXUS, LoL@ and NAVIO. While some have focused on the technical aspects of mobile applications, others have examined the cartographic repercussions of small displays (Radoczky and Gartner 2005, Gartner and Uhlirz 2001). The effective integration of landmarks into such maps has not been examined in detail so far.

Research in the field of spatial cognition investigates the structure and elements of wayfinding instructions and provides another important foundation for the design of pedestrian navigation systems. Daniel and Denis (1998) have identified route actions (instructions about the next movement), orientations and landmarks as the basic components of (verbal) route directions. Further experiments have shown that the integration of landmarks into routing instructions enhances the perceived quality of the description (Denis et al. 1999). Tversky and Lee (1999) have compared the basic elements of route maps and route directions and found that both consist of the same underlying structure and semantic content.

Consequently, a good pedestrian route map should include the same elements as verbal directions. Landmarks will therefore form an indispensable part of maps in mobile cartography applications and appropriate visualization techniques for their effective presentation must be provided to designers.

2 Related work

2.1 Landmarks in wayfinding instructions

Landmarks are significant physical, built, or culturally defined objects that stand out from their surroundings and therefore help locating the geographic position (Golledge 1999). They are classified as local and global or on-route and off-route landmarks (directly neighboured to the route or in the far distance like a tower or mountain chain). Furthermore, on-route landmarks are positioned between nodes, at decision points (a junction where a navigation decision is to be done) or at potential decision points (where a navigation decision is possible but the route goes straight on) (Lovelace et al. 1999).

Currently, landmarks are not part of commercial navigation data sets. In fact, all available route planning and guidance applications use data sets that are tailored to the requirements of car navigation. With the increasing amount of pedestrian navigation applications on mobile devices, the urge to integrate important information for pedestrians rises, but is not incorporated in the databases yet. If information about landmarks were available, it could be integrated into the database and used for wayfinding descriptions.

Different research approaches try to develop formal models or extract landmarks automatically from databases and focus on local landmarks at (potential) decision points (Raubal and Winter 2001, Elias 2003, Elias and Brenner 2004). While these approaches currently confine themselves to the investigating of buildings as landmark objects, other topographic objects like parks, bridges, and railroad tracks are also suitable as landmarks and can be extracted from existing databases (Elias and Sester 2002).

The integration of landmarks into wayfinding descriptions requires a detailed analysis of the elements and structure of verbal wayfinding instructions. Research in this direction has resulted in an ontology for the wayfinding task (Winter 2002). As an alternative, the concept of wayfinding choremes (Klippel 2003) can be applied to fit the landmarks in the context of each route (Klippel and Winter 2005).

2.2 Graphic design of landmarks

For pedestrian navigation it is most important, that the user is able to recognize the landmark information provided by the system in his real environment without significant effort. Further constraints for the presentation are implied by the mobile context of use, e.g. a low cognitive load for the user and the requirement to derive landmark data efficiently (by automatic means) from existing information. The mode of presentation can either be verbal instruction transferred via speech output (problematic in public environments), textual instructions on the display (requiring high levels of attention) or a graphical map-like depiction of the situation. Here we focus on the visualization of landmark information with cartographic instruments for optimal communication.

Obviously, the user's perception of visualizations is the key to their effective use. Therefore, the design of visual representations of landmarks should be informed by knowledge about their recognition and interpretation. Designers as well as perceptual psychologists study the recognition and interpretation of visual information by users. Cartographer typically rely on empirical know-how: For conventional 2D maps practical experience over centuries of use has evolved into a collection of visual presentation techniques, design principles and guidelines that are widely accepted by designers (e.g. Bertin 1973). However, such empirical guidelines are difficult to apply outside their source domain as evidenced by the absence of directly applicable guidelines for the visualization of landmarks and for new forms of geo-visualization (e.g. 3D maps) in general. Several researchers have examined the impact of different visual designs in navigation applications:

Deakin (1996) examined the integration of landmarks into graphic representations or maps for wayfinding purposes and discussed several aspects. The user test with street maps indicates that supplemental landmarks improve navigation performance. In this study two different kinds of landmark portrayals were used: a geometric, symbol-like representation and pictorial, stereotype sketches. It was assumed that the stereotype sketches would provoke a strong natural association for the map user and would therefore be more effective than abstract geometric symbols. However, no significant difference between the two presentation styles could be found.

A test in the field of car navigation systems by Pauzie et al. (1997) investigated how landmarks could be represented in guidance systems. In their system the background portrayal on the screen was reduced to a turn-by-turn instruction represented by an arrow indicating the next driving action. Two types of pictorial designs were examined: a generic and a specific presentation of the landmark information. The generic pictogram was relevant for all cases belonging to the same category (like church, bridge, park, shop, bank). The specific one represented each landmark object located at the route in a realistic manner.

The experiment found that the way the landmarks were presented did not have a strong impact in terms of visual workload. The analysis of a follow-up questionnaire indicated that users preferred a generic portrayal for some of the object categories (church, bar, pharmacy, bridge) while a specific drawing was seen as more useful to represent other objects (bank, fast food, garage, supermarket). The difference depends mostly on the use of trade marks (or logos) as highly familiar elements in the graphics. The study concluded that the recognition and understanding of a landmark is closely linked with its familiarity to the driver (regardless of generic or specific characteristics of its design).

In Lee et al. (2001) a prototype for visual navigation using a multi-media map was developed. It used photographic images to represent landmarks and matched them directly on a perspective view of the map. Furthermore, full panoramic views from road nodes or sequential photographs along a path were used to provide visual information. The evaluation of the prototype has shown that landmark photographs must be taken from the line of sight in which the object is approached. Therefore several images for one landmark are required. Additionally, a truly effective landmark photograph should only show the landmark itself, and visual clutter like neighbouring buildings have to be removed. Radoczky (2003) also recommends photorealistic images for the presentation of landmarks, because no generalization operations are needed. The hitch with such an approach is the need for consistency with the real environment, requiring not only appropriate images for different seasons but also updates when structural changes are made to the landmark object.

A further aspect is to visualize salient objects by means of cartographic generalization. For example important information in a map can be emphasized by using generalization operations like enhancement of the target object itself and simplification or aggregation of the background objects (Sester 2002).

2.3 Aspects of visual cognition

Another source for information on how users interpret what they see is the domain of perceptual psychology, where researchers aim to develop a detailed understanding of the function of the human visual system. Two prominent theories aim to describe how objects are recognized visually: Image-based object recognition and structure-based object recognition. The first proposes that we recognize an object by matching the visual image with a snapshot stored in our memory. The second follows the idea that objects are analysed in terms of primitive 3D forms (geons theory) und structural interrelationships (Ware 2004).

While significant progress has been made in the understanding of individual processing steps within the human visual system, it is currently not possible to derive accurate predictions regarding the effectiveness of visualization techniques from these, as many processes remain active areas of research and complex interdependencies are involved in the whole process that are still little understood. However, design guidelines can be derived for perceptual psychology research with regards to the (potential) impact of certain visual features like texture patterns, preattentive visual features as well as silhouettes and contours.

Silhouettes as part of the structure-based object recognition assume an important role in perceiving the structure of objects. Simplified line drawings are often equal to silhouettes and many objects have particular silhouettes that are easily to recognize. One of the consequences of structural theories of perception is that certain simplified views should be easier to read. So a depiction of a hand could be perceived more rapidly in the form of a simplified line drawing than in the form of a photograph. But others studies show that time is needed to perceive details, so simplified line drawings may be most appropriate only when rapid responses are required (Ware 2004).

If the necessary information is not perceivable from the silhouette itself, line drawings are the least effective mode of presentation: Ryan and Schwartz (1956) tested the speed of perception of relevant details in different presentation forms. The four principal illustration modes analysed were photographs of the object, shaded drawings, line drawings and cartoons (comparable to cartographic generalized depictions: the original figure is distorted to emphasize the essential spatial relationships). The time needed to perceive the detailed structure was measured and it showed that cartoons were the most quickly perceived group and line drawings were the most difficult to perceive. Photograph and shaded drawings were about equivalent and fall somewhere between the others.

The adequate presentation of point information should take into account the research of ergonomic guidelines for the design of pictorial information (Bruyas et al. 1998): Basic requirements regarding recognition and understanding of symbolic information demand fast understanding with no ambiguity of graphical representations. Well designed pictorial messages enable quick visual information processing in comparison to textual messages. And because of their compactness pictograms are more efficient than textual information in case of limited surface display. The recognition performance depends on the combination of essential, neutral and additional elements in the pictogram: Essential elements are the typical attributes that are necessary to recognize the object at all, but too much unnecessary detail disturbs the quick understanding of a symbol. Whether confusion of the sign with similar objects occurs, depends on the familiarity of the user with the typical attributes of the object. This can be different according to the user's population, his culture and his belonging to a generation.

For the development of appropriate visual presentation techniques for landmarks and corresponding design guidelines this suggests an approach that builds on existing design and cartographic expertise and insights from perceptual psychology to explore the options of the design space in a systematic way. The different options for presentation techniques are systematically examined to select promising options and refine the designs that are then evaluated in user studies.

3 Types of landmarks

3.1 Classification of features types

As part of a master thesis a user questionnaire was conducted in which 20 people were asked to describe two different pedestrian routes in the city of Hanover (Lübke 2004). One of the routes leads from the main train station to the main university building, crossing the inner city centre with shops and pedestrian areas. The other leads from a student resident building to the cafeteria of the university, crossing a residential district of the city. Both routes are about 2 kilometres long. The participants were 10 male and 10 female students of the university that have all lived in Hanover for several years. They were instructed to recall the routes from their mind and to write down the wayfinding instructions for a pedestrian unfamiliar with the area. The routes were given by naming the start and end points of the route. For both routes the descriptions resulted in a number of different route choices, so not all descriptions have the same content.

The route descriptions were analysed with regards to the landmarks used. All referenced objects were counted and divided into groups of object types. Here five different groups were distinguished: Buildings, monuments (statues), plazas (like market squares or big traffic junctions), references to public transport (underground stations, bus stops, tram tracks) and others (parks, bridges, pedestrian zones, stairs, cemeteries). The distribution of the objects in the route descriptions is shown in Table 1.

Object Type	**Route 1 (University District)**	**Route 2 (City Centre)**
Buildings	20 (50 %)	32 (55 %)
Monuments	1 (2,5 %)	6 (10 %)
Plazas	3 (7,5 %)	5 (8 %)
Public Transport	6 (15 %)	7 (12 %)
Other	10 (25 %)	9 (15%)
Total	**40 (100 %)**	**59 (100 %)**

Tab. 1: Distribution of object types in route descriptions

Despite the fact that the routes differ significantly in their environment (Route 2 leads through the shopping area in the pedestrian zone, Route 1 leads through a typical residential area and the university campus), in both routes about 50 % of the referenced objects are related to buildings. The proportions of the other groups stay the same. It should be kept in mind, that these are only preliminary observations, since only two different routes described by twenty people were examined so no assured statistic statement is possible. Based on the previous research on landmark use and backed by these findings we focus on the visualization of buildings as landmarks. Since most navigation aids are used in urban areas, an optimal representation of buildings as landmarks is a central issue.

3.2 Characteristics of landmarks

Buildings can be further divided into groups depending on the function or kind of description of the building in the route instructions. For the purpose of this study we distinguish four, groups (see Table 2). The first group consists of shops and restaurants referenced by their trade name (like H&M, Kaufhof, McDonalds), the second group of other businesses is described more general with the type of function (like hotel, pharmacy, hairdresser, butcher). A third category is formed by buildings that are referenced by their general function (library, church, university building or unique name (like Anzeigerhochhaus, Regenwaldhaus). In most cases the proper name is combined with the function (Luther church), so we combine those. The fourth category covers buildings that are specified by a description of specific visual aspects (the large yellow house, the red clinker brick building).

Building Type	**Route 1 (University District)**	**Route 2 (City Centre)**
Shop (referenced by name)	4 (20 %)	18 (56 %)
Shop (referenced by type)	3 (15 %)	8 (25 %)
Function / Name	7 (35 %)	6 (19 %)
Visual Aspect	6 (30 %)	0 (0 %)
Total	**20 (100%)**	**32 (100 %)**

Tab. 2: Distribution of different building types in route description

If we compare the distribution of objects, it seems that the route environment determines the kind of landmark building description. In the city centre the trade names of shops are preferred, whereas in areas where no trade chains are available other building descriptions using the function or the visual appearance of the object are given. Consequently, it can be hypothesised that the communication and recognition of trademarks is easier than the comprehension of a more complex description of individual visual aspects.

4 Designing visualizations

4.1 Developing guidelines for visualization

Because the building landmarks separate into four categories, we propose an individual designed visualization for each group to communicate the landmark information in an ideal way. This means that the user must be able to recognize the graphics fast and identify its correspondence in the environment easily. Several approaches to the visualization of buildings have been proposed. Some of them are used especially for landmarks, others stem from the field of 3D-City Models: In Lee et al. (2001) cutouts from photographs are taken and put directly on a map to illustrate the individual facades of landmarks. In contrast to this, non-photorealistic rendering techniques abandon the idea of images close to reality and present 3D city models in a comic-strip like style rendered by computers (Döllner et al. 2005). This kind of design is comparable to traditional Bollmann maps and is now often used for touristic maps to present important tourist sights as a 3D-representation on a 2D-map (see Figure 3). A further cartographic technique is to substitute the original object with a map mark whose style may range from mimetic to arbitrary (see Figure 1). If the presentation is shrunk to a point symbol, there are different ways to compose the sign (see Figure 2): the iconicity of the symbol is very high if the sign is pictorial designed, and very low if the sign is a geometric, abstract marker (MacEachren 1995). Pictorial signs have the advantage to be recognised easily, because no sign interpretation process is necessary. It is sufficient to match the pattern of the sign to the environment. This requires that the sign is not too detailed or confusable (Bruyas et al. 1998). From this point of view logos of trademarks represent pictorial symbols and are therefore useful candidates to depict trade name shop landmarks (see Figure 4). Altogether, these kinds of depictions form a continuum of different levels of abstractions: on the one side realistic reproduction (in form of a photographic image or realistic textured 3D-model) on the other side abstracted presentation as (geometric) symbols or even as words (considering the alphabet as abstract signs) (see Figure 5). A key challenge for map designers is to select appropriate visual presentations while considering secondary design constraints (e.g. desired visual style, restricted color schemes or consistent visual appearance). Also aspects of cartographic generalization have to be taken into account: the image of the original object has to be scaled down to a size suited for a representation in a map. Therefore, some of the conditions under which generalization

Fig. 2: Abstractness of point symbols (taken from (MacEachren 1995), pp. 262)

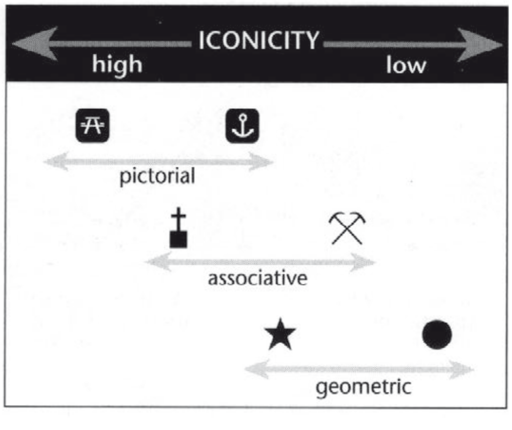
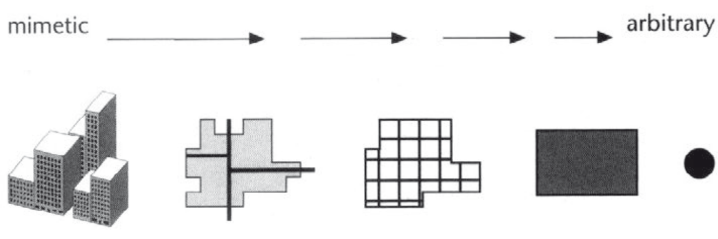


Fig. 1: Mimetic to arbitrary continuum of map markers (taken from (MacEachren 1995), pp.259)



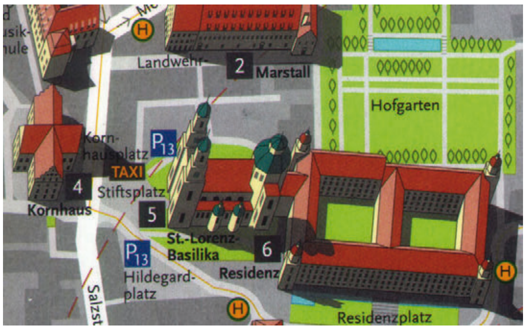


Fig. 3: Touristic map with 3D-tourist sights (taken from touristic map of city Kempten)

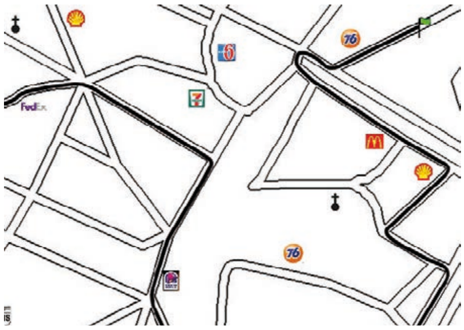


Fig. 4: Logo icons as landmark representations (cut-out taken from (Klippel 2003))

procedures have to be used in maps also apply here (Shea and McMaster 1989): congestion (too many features in limited space), alescence (visible details depend on resolution of output device) and imperceptibility (feature falls below a minimal portrayal size) necessitate the abstraction of the visualization of an object.

To provide designers with a systematic approach we propose to base the visualization of landmarks on different levels of abstractions in order to communicate the different landmark characteristics appropriately. The combinations of landmark types with possible visualization styles spans a design space that can be represented as a matrix. In this matrix each landmark type is associated with one or more adequate abstraction levels for their visual representation (see Table 3). The information in this matrix captures experience in practical use and can serve as a guideline to designers. Of course, using words is always possible to convey the information properly, but is not the best choice regarding visual and cognitive workload (time needed to process the information). Therefore, words are only regarded as appropriate presentation form if there is no better way to convey it with graphical depictions.

	Image	Drawing	Sketch	Icon	Sign	Words
Shop (Name)			(+)	+		
Shop (Type)				+	+	+
Function/Name	+	+	+			+
Visual Aspect	+	+				

Tab. 3: Design proposals for landmarks

A trademark logo is accounted as something generally well known and easy to recognise, so a pictorial icon is the easiest form to convey the landmark information. Generally, no building description is necessary, but if the building is something (architectural) singular, a sketch with the outline the building may be useful additionally. If the shop is only referenced generically, especially designed pictorial icons or associative signs are suitable. In case there is no appropriate graphical sign to portray the shop type, words have to be used. Generally, the outline or visual details of the building have no relevance for the landmark information. Specific building functions are often linked to a particular appearance of the building, e.g. typical silhouettes (churches) or size, position and style (town halls and opera buildings are often large, singular buildings, sometimes built in a historic architecture style). Therefore, at least a sketch from the silhouette of the building, sometimes a drawing or image with more details about the façade is needed to recognize the object. The only solution to convey a proper name of a building is to reference it by name with words. If visual aspects are the important facts to describe the landmark, they have to be depicted by a detailed drawing or image of the object.

Fig. 5: Level of Abstractions for Visualization

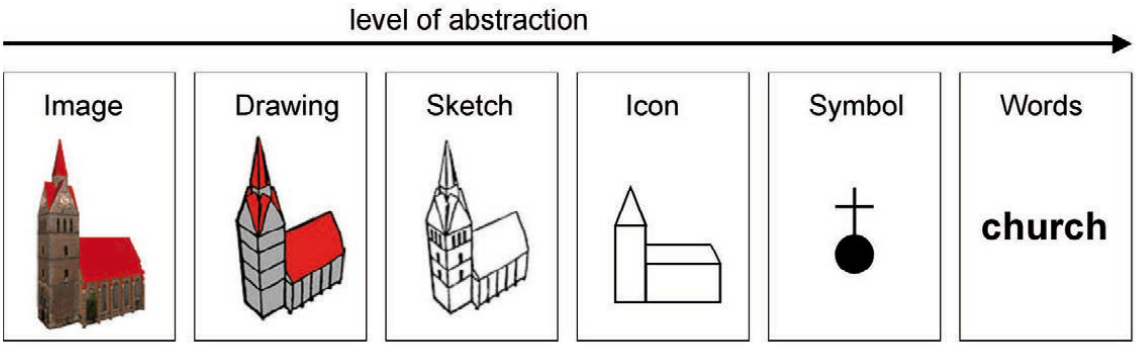


Fig. 6: Image of function building

Fig. 7: Drawing of function building

Fig. 8: Icon of shop logo

4.2 Design examples

To receive an impression, first drafts of visualizations are designed. As we focus on pedestrian navigation services with mobile maps, we target small PDA and smartphone displays (specifically the HP hx4700) (see Figures 6-8). The drafts depict a reduced background map for navigating through a city environment: streets with names and building outlines are given. The colours are reduced to grey scale to improve the figure-ground contrast of the landmark objects. The landmarks are positioned at their original geographic location; therefore parts of the map are overlapped and not visible.

The hypothesis of the design matrix has to be proved by a user test. The next step is to develop an adequate user test to provide evidence for appropriate abstraction levels. Therefore, for each building type visual representations of all abstraction levels (see Figure 5) are generated. These will be presented to test users checking if the kind of depiction is recognizable and convey the landmark information completely. Besides the subjects will be asked, how they liked the type of illustration (to check if their anticipation about visualization is fulfilled). The results will allow to compare the relative usefulness of different landmark presentations and can serve as the basis to improve the design matrix for the visualization of building landmarks.

5 Conclusion and outlook

The approach presented here is work in progress and proposes a design matrix as a visualization guideline for landmarks.

We have examined the different feature types that are useful as landmarks. We have found that about 50 % of all landmarks used in common wayfinding instructions are buildings and identified 4 different categories of building landmarks (well-known shops (trade chains), shops referenced by their type, buildings with specific name or function and building described by their visual appearance). For the visualization of landmarks from each of these categories the impact of different abstraction levels in visual design were examined, based on knowledge from cartography and perceptual psychology. These resulted in design recommendations that are captured in a design matrix that proposes different levels of abstractions as appropriate visualizations for different categories of building landmarks.

The next step of future work is to test these recommendations as experimental hypotheses with a user test. The results of this study will allow to replace the general judgments in the current matrix with detailed information on effectiveness and user preferences.

As a further outlook this knowledge could eventually be used in an automatic tool to provide designers with advice or provide a set of rules to produce the visualizations automatically from databases. Further work is necessary to understand the dependencies between user und preferred visualization. With this it would be possible to automatically adapt the visual presentation to a user and his specific task at runtime.

At last, the building landmarks discussed here represent only half of all landmarks used in common wayfinding descriptions. The extension of the approach to other types of landmarks is therefore another obvious direction for future work.

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Supporting wayfinding by multimedia cartography means

Verena Radoczky

Abstract

The fast transfer rates via UMTS and their corresponding high-tech devices provide the opportunity to develop easily accessible Location Based Services. Mobile phones with high-resolution cameras, MP3-players and Java applications are part of our everyday life. Many drivers rely on car navigation systems that provide route information, and pedestrians also often need help in unfamiliar environments. The utilisation of multimedia presentation forms while guiding a pedestrian to a desired destination could support the wayfinding process and facilitate ongoing tasks.

In this paper general considerations about multimedia presentation forms in pedestrian navigation are discussed, their applicability on modern devices is investigated and restrictions regarding their mutual use are defined.

1 Introduction

Within the last few years car navigation systems have started to conquer the market in the Western World. Car drivers have started to trust in the guiding instructions of the system, and once they got used to it, they do not want to miss it anymore. Other than that navigation systems are not very popular until today. Pedestrians usually consult paper maps when looking for a destination. Some prototypes of portable tourist information systems (Modsching et al. 2005; Uhlirz & Lechthaler 2002; Zipf et al. 1999) are available today, but user acceptance does not seem to be very high so far (Forum Mobilkommunikation 2002, Kölmel & Wirsing 2002). Beside the costs possible reasons for this might be the lack of information provided to the user. In contrast to car drivers, pedestrians do not need to be as concentrated on traffic and can therefore process a lot more information. Often a pedestrian does have a little bit of extra time and would appreciate some additional information about his current environment, which is usually not included in today's commercial navigation software. This type of auxiliary information could be presented best in the form of multimedia-based data, which has hardly been taken into account so far. It should also be considered that the moment special stops at shops or sights are included, operating the program could become very complicated and demands a lot of patience from the user, which is why an emphasis on user interface design needs to be regarded.

Moreover the range of possible paths for pedestrians is a lot higher than the street graph based routes of vehicle drivers and it gets nearly impossible to create a network that includes them all, especially when expanded with indoor paths. Indoor navigation as such is yet a very new and unexplored branch of navigation. Some museums use PDA-based navigation systems to guide visitors through an exhibition (Oppermann 2003, Chan et al. 2005) but they merely concentrate on this very specialised application area. Also wayfinding experiments within airports have been conducted by Raubal (2001) which give a deeper insight into preferred paths of travellers and route choices at public transport stations, but research on visualisation aspects of combined indoor and outdoor routes is rare (Baus et al. 2002). Contrary to outdoor urban environments, where the third dimension can mostly be neglected when visualising a route, buildings require the depiction of floor levels, staircases and elevators. This demands either the switch to a 3D presentation form or a well considered design of floor plans. Since it is more likely to lose orientation within a building than outside (Hohenschuh 2004, Radoczky 2003), it is also desirable to use indoor landmarks which on their part are harder to define than outdoor landmarks.

Nevertheless route guidance within large buildings like shopping centers, universities or official buildings in junction with outdoor routes would often be desirable. Users often get into the situation where they arrive at a subway station and look for the way to a specific room in a nearby public building. With the help of multimedia presentation forms this task could be assisted by a user-friendly navigation system.

Additionally to navigation support it could be beneficial to supply the user with information that is adapted to the current task. For instance when visiting a shopping centre, information about bargains at favoured shops could be displayed, or when strolling around an airport or train station, information about departing planes or trains that concern the user could be provided. The technical requirements for these types of online services are mostly not achieved today, but it is imaginable that future systems will provide them in more variety.

The paper is therefore organised as follows: In section 2 the term multimedia is introduced and it's significance concerning cartography is described, in chapter 3 multimedia elements for pedestrian navigation are analysed, section 4 investigates their applicabilitiy, chapter 5 analyses the reasonable combination of different presentation forms in a pedestrian navigation system, and finally the findings of the previous chapters are summarised in the conclusion chapter.

2 Multimedia in cartographic applications

Within the last 10 years multimedia has become an indispensable part of computer science. In 1995 multimedia was even selected by the German Language Society as the "word of the year" (GfdS, 1995). It is thus not surprising that multimedia has also entered the world of cartography. Static maps can now be extended and complemented by other presentation forms like audio, animation and video in order to provide information in a more demonstrative and user-friendly way. Interactivity can be used to reach a new level of detail and to influence the visualisation itself. Beside static depictions also dynamic presentation forms like animation and video are applicable and spatial data can be explained with the help of audio files. Typical application areas are hypermedia atlases or the very popular Google Earth (http://earth.google.com).

This form of multicoding and user interaction is also a very efficient tool in pedestrian navigation systems. In the following chapter different elements which could be applied in navigation systems are described.

3 Multimedia in pedestrian navigation

Many different communication forms are imaginable when supporting pedestrian wayfinding in urban environments. Each of them has advantages and disadvantages that need to be taken into account when combining them.

3.1 Maps

Tests have shown that maps are the most important presentation form when communicating spatial information (Reichl 2003, Radoczky 2003). They give a universally understandable overview of an area and support orientation in unfamiliar environments (Kray et al. 2003). Yet the design of a map can differ dramatically depending on the region where they come from. City maps in the USA typically show a network of street graphs whereas European maps usually depict building blocks. Sometimes users prefer a more sketchy style (Döllner & Walther, 2003) and users who are very familiar with an area could even favour a schematic map that concentrates on topology rather than on topography (Agrawala & Stolte 2000, Radoczky 2005). Therefore the design of a map needs to be adapted to the region and the purpose of use.

Moreover the map should be available in different scales with different levels of detail. That way the whole route which is demanded by the user can be shown on the display of the device as an overview map without any need to scroll or pan. The moment guidance begins, an automatic zoom can switch to a larger scale with more detail, maybe even including house numbers. During navigation it would also be advisable to automatically twist the map to an egocentric map view, in which case the north direction should always be marked on the map (Radoczky 2003, Zipf & Jöst 2004, Hohenschuh 2004). That way mistakes at crossings can be avoided because turning points can be viewed as simple left and right turns. Certainly it would be possible to twist and turn the usually small handheld device by the user himself, but that way labels and other additional information would lack readability.

Another explicit advantage of maps in comparison to pure textual or oral guiding instructions is the possibility to include multimedia features with the help of interactivity. Hot spots can act as obvious hiding places for landmark information and other additional information sources (Uhlirz 2001, Nagi 2004).

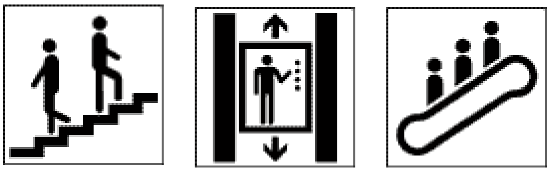
3.2 Floor plans

Floor plans are the obvious presentation form when moving inside a building and so far they have also proven to be the most effective ones (Radoczky 2003, Ortag 2005, Werner & Long 2003). They have similar properties as maps and are therefore rather easy to read. Yet they are not suitable for representing the switch between different floor levels when walking up/down stairs or using an elevator. An alternative would be the representation of 3D models, but most users hardly have any experience with three-dimensional representations and therefore often feel overstrained (Radoczky 2003), which is why a two-dimensional depiction is usually more advisable. To overcome the problem of vertical movement while using a 2D map, universally understandable pictograms that symbolise stairs, elevators or escalators can be displayed (see figures 1-3).

3.3 Route visualisation

To guarantee an efficient communication of route information, the entire route should be plotted so that the user perceives an overview of the whole path. Preferably the trail should be visible to the user at any time and the distinction between the past and the future path should be unambiguous. One possible solution to this visualisation problem could be to make the trail such that it disappears over time, but this could lead to confusion, "[…] since it no longer tells the navigator that this place has been visited before, only that it hasn't been visited lately." (Darken & Peterson, 1999). To overcome this problem the past trail could be dyed in a very light colour. This type of route visualisation is only reasonable though, if the user's position is updated dynamically.

Figs. 1-3: Symbols for stairs, elevators and escalators



3.4 Audio guidance

Verbal guiding instructions have also shown to be a helpful tool for pedestrians. A test by Ortag (2005) indicated that test candidates who had to find part of a route with the help of a map and the other part with

audio guidance did not show major performance changes after switching the presentation form. Only when being asked about the preferred mode, a slight tendency towards map presentation was observable.
When being used to a personal device with earphones, oral information can be very useful in quiet environments because noise disturbance can be kept to a minimum. In noisy areas it can be difficult for the user to understand the electronic voice. Sentences should then be repeated until the information is definitely perceived by the user, which decreases the effectiveness of this method.
Concerning the configuration of "good" route instructions, some guidelines should be followed (Lovelace et al. 1999, Habel 1987, Kray et al. 2003):

- Users should be prepared for upcoming decision points.
- Instructions should be kept simple and clear.
- Landmarks should be included in descriptions.
- Street names (or corridor numbers) should be mentioned, but only, if they are usually displayed in the network of the respective city (or building).
- In case information about the segment is rare, distances can be mentioned.
- The user should have the possibility to replay the last sentences.

The realisation of an audio guidance system is rather simple. Different programs convert text into voices or in case the amount of words extends a certain limit, concatentive synthesis can be applied, where real voices are divided into individual parts and can then be assembled in another sequence (Lemmetty 1999).

3.5 Textual guidance

Textual guidance is the most simple presentation form for navigation systems. They are easy to create and do not require a lot of memory. Guidelines for their configuration are very similar to audio guidance, with the advantage that sentences must not be kept to a minimum and can be written out in full. Yet the main disadvantage of written text is the problem that the user spends more time reading and might not be as attentive to his environment.

3.6 Visualisation of landmarks

The importance of landmarks for wayfinding has extensively been discussed in several publications (e.g.: Michon & Denis 2001, Foltz 1998, Lynch 1960, Golledge 1999). Undisputedly they are not only important but even necessary features in pedestrian navigation. Yet the derivation of landmarks is a very individual process that can change from one person to another (Gartner et al. 2005). Some outstanding buildings, though, can act as universal landmarks that are distinctive to almost everybody and thus should be included as orientation points in the guiding instructions. Their visualisation should be adapted to their function. A shop or a restaurant like H&M or McDonalds is represented best by its individual label, whereas historic buildings could be visualised with the help of pictograms. The user should also be able to define his own landmarks by placing labelled flag-like symbols on the map. Moreover the system itself could remember start or destination points of elapsed routes and place the flags automatically.

3.7 Textual information about landmarks

Landmarks should be clearly marked and labelled on the underlying map. The best way to access additional information about the landmark is by using "on mouse-click" functions, where a little window with text pops up. The amount of text to be displayed should not be restricted by any regulations.

3.8 Audio information about landmarks

Audio files could contain spoken text, significant sounds or music that help to describe and understand the landmark. An opera house, for example, could be associated with arias and a church could be represented by the sound of its bell. In case verbal information is provided, it is important to keep it short in order to be able to follow and comprehend coherences.

3.9 Music

Pedestrians often carry portable radios, mp3-player or CD-player which are sometimes even integrated in their PDA or mobile phone. Many people appreciate some background music while walking around and do not want to abandon it when using a navigation system. In case the utilised device is equipped with an mp3-player or radio, it is advisable to abstain from audio guiding information or only interrupt the background music by very important instructions.

3.10 Photographs

An image can be a helpful presentation form in a navigation system, even though it is not really valuable as a navigation aid (Radoczky 2003, Heidmann & Hermann 2003). Users need a lot of time to compare reality with the photograph which is why it is advisable to merely use them when describing start point, destination or landmarks. Even here it should be ensured, that the depicted building is very distinctive. To be on the safe side, photographs could be an optional choice that people, who are not familiar with the environment and who are not in a hurry, can choose to gain additional information. The same holds for panorama views. They contain a lot more information than ordinary photographs and they can look very impressive and professional, but since not many users are familiar with panorama views (Radoczky 2003) they should only be scarcely used to avoid confusion.

3.11 Videos

Videos have similar properties as photographs and their potential as route information aids can be rated as rather low. Objects and streets can be directly compared and identified with reality, but the quick movement often provoke the loss of orientation. In a survey by Reichl (2003) subjects noted that they would not appreciate a navigation system that uses videos. Nevertheless videos can be used as optional information about landmarks and sights.

3.12 3D presentation

Generally 3D presentation forms are very effective representations of space. They can give a good overview of our environment and can contain a lot more detail than traditional maps. Especially the visualisation of buildings could be made more effective and unambiguous than floor plans. Unfortunately it is very difficult and sometimes even impossible to use them as navigation aids. One of the main disadvantages lies in the large data files and their high requirements on memory space, but since memory rates are developing very fast, it is assumed that this problem can be overcome in the near future. A more precarious problem is the demand on display size that is necessary to present the complexity of a three-dimensional file. Today users are used to mobile phones the size of a credit card and definitely do not want to carry around a device larger than a standard PDA. It is though possible, that future devices will look different, like electronic paper or glasses with installed augmented reality systems. In that case the usage of 3D visualisation will have to be reconsidered.

3.13 Online services

Even though their availability is scarce today, online services that provide the user with additional up-to-date location based information are desirable. Similar to landmarks information could be accessed via a simple mouse click on the display where an information window pops up to inform the user about special menus of restaurants, upcoming shows in cinemas, availability and prices of tickets or opening hours of shops. This form of online advertisement could become very profitable to businesses the higher the distribution rate of location based services rises. Moreover locations of pharmacies that are open at night and timetables of public transport lines could be of use for pedestrians. Equivalent to traffic information in car navigation systems, pedestrian navigation systems could provide similar services like business disruptions of public transport or construction sites at diverse sights.

4 Applicability of multimedia presentation forms on today’s devices

Mobile phones have become a necessary part of our everyday life. The Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR-GmbH) announced that in the first quarter of the year 2005 the mobile phone penetration in Austria reached the level of 100%, and it is yet rising (RTR 2005). Mobile phones with an integrated camera that also function as mp3-players are not uncommon anymore and users demand more and more functions from their device that should be kept to a minimum in size. The only problem that still does not seem to be solved completely is the durability of the rechargeable battery. The more we demand from working memory, which is usually the case with multimedia applications, the sooner the device runs out of battery and therefore strains the patience of the user. Nevertheless, mobile devices have developed rapidly in the last 10 years and probably will for another 10 years. Basically we can distinguish between three main types of mobile devices which are described in the following:

4.1 Mobile phones

The main focus of mobile phones is the functionality of telephone calls. Yet today’s mobile phones typically contain a lot of additional features. When comparing the newest devices that enter the market in 2005 and at the beginning of 2006, we can find the following features[1]:

- Display size: 128x128 to 329x240 pixels
- E-mail and internet access (XHTML): standard
- Java applications: standard
- Bluetooth: standard
- USB port: standard
- IrDA: standard
- WLAN: only integrated in Nokia N91
- GPS: only integrated in Siemens SXG75
- Camera: standard, usually 2 MP
- Sound: MP3 standard, radio available in some models

1 The examination considered the mobile phones Nokia 6822/N90/N91/6111/3250/6270/6280 (www.nokia.com), Samsung SGH D500/SGH Z300 (www.samsung.com), Siemens SXG75 (www.siemens.com), Sony Ericsson W550i (www.sonyericsson.com). September 2005.

4.2 PDAs

Personal Digital Assistants are handheld devices that act like a portable mini-computer and can be synchronised with the personal computer. They are not designed as mobile phones but usually contain a lot of online features and because of their relatively high computer memory and processors they are an ideal tool for navigation systems. 9 different PDAs have been compared with each other[2]:

- Display size: 160x160 to 480x320 pixels
- E-mail and internet access: standard
- Java applications: standard
- Bluetooth: standard
- USB port: standard
- IrDA: standard
- WLAN: standard
- GPS with integrated Navigation Software: 2 out of 9, usually extendable with GPS jacket and extra software
- Camera: usually no camera
- Sound: different sound formats, loudspeakers, stereo headphones

4.3 Smartphones

Smartphones are a combination of mobile phones and PDAs. Their share in the market has risen in the last few years. 12 up-to-date devices have been investigated on their functionality[3]:

- Display size: 240x160 to 640x200 pixels
- E-mail and internet access: standard
- Java applications: standard
- Bluetooth: standard
- USB port: standard
- IrDA: standard
- WLAN: 8 out of 12
- GPS: 3 out of 12
- Camera: 5 out of 12
- Sound: different sound formats, loudspeakers, stereo headphones

Recapitulating we can say that a lot of multimedia presentation forms can already be used on mobile devices. The following table concludes, which features can be used on today's mobile devices:

	Mobile Phone	**PDA**	**Smartphone**
Maps + floor plans with route visualisation	○	YES	YES
Audio Guidance	YES	YES	YES
Textual Guidance	YES	YES	YES
Visualisation of LMs	■	■	■
Textual information about LMs	Labelled: ■ Textual information: NO	Labelled: ■ Textual information in pop-up window: YES	Labelled: ■ Textual information in pop-up window: YES
Audio information about LMs	Short description in audio guidance: YES Additional information on-mouse-click: NO	Short description in audio guidance: YES Additional information on-mouse-click: YES	Short description in audio guidance: YES Additional information on-mouse-click: YES
Labelling of personal LMs	NO	YES	YES
Music	YES	YES	YES
Photographs	NO	On-mouse-click: YES	On-mouse-click: YES
Panorama Views	NO	On-mouse-click: YES	On-mouse-click: YES
Videos	NO	On-mouse-click: YES	On-mouse-click: YES
3D presentation	NO	Very limited content: YES	Very limited content: YES
"on-mouse"-functions	NO	YES	YES
Online services	NO	YES	YES

○…. The use of maps and floor plans on mobile phones should be dependant on the screen size. At a display smaller than 160x160 pixels the map area would be too small to detect any details and should be replaced by textual or audio guidance.

■…. Visualisation of landmarks is bound to map display (see 1). The amount of landmarks to be displayed is furthermore dependant on the display size, especially if they are labelled. More than one landmark on an area of 50x50 or 80x80 pixels (depending

2 The examination considered the PDAs Palm Z22/PAM2461 (www.palm.com), HP-IPAQ hw6515/rx1955/rx3115/rx3715/rz3710 (www.ipaq.com), Acer n35 GPS/n50 premium (http://global.acer.com). September 2005.

3 The examination considered the smartphones Blackberry 7290/7730/7100t/7100v (www.blackberry.com), Palm Treo 700w (www.palm.com), Nokia E60/E61/E70/9300, HP-IPAQ h6315/h6325 (www.nokia.com), Sony Ericsson P990 (www.sonyericsson.com). September 2005.

on the size of the landmark) does not seem reasonable, because map details and route visualisation could affect the readability of the map.

5 Combination of different presentation forms

In the last chapter we could see that a lot of presentation forms are applicable on today's mobile devices. A combination of most of them is technically possible, but the question remains, if it is actually reasonable to utilise the maximum availability of multimedia contents. Singular information can cause irritation, whereas too much information can slow down decision making (Klippel, 2003). The optimum amount of multicoding is hard to define, but the following table shows which presentation forms can be combined and which are not reasonable to combine.

	Maps & Floor Plans with route visualisation	3D (+ route visualisation)	Audio Guidance (+ short description of LMs)	Textual Guidance	Visualisation of LMs	Labelled LMs	Textual information about LMs (pop-up window)	Audio information about LMs (on-mouse)	Labelling of personal LMs	Music	Photographs (on-mouse)	Panorama views (on-mouse)	Videos (on-mouse)	"on-mouse"-functions	Online services
	either or				■	■	■	■	■		either or				
	2 out of 3														
Maps & Floor Plans with route visualisation		#	+	+	++	++	+	+	++	+	+	+	+	+	+
3D (+route visualisation)			+	+	++	++	+	+	++	+	+	+	+	+	+
Audio Guidance (+ short description of LMs)				+	+	+	#	#	+	-	#	#	-	+	+
Textual Guidance					+	+	#	#	+	+	+	+	+	+	+
Visualisation of LMs						++	+	+	++	+	+	+	+	+	+
Labelled LMs							+	+	+	+	+	+	+	+	+
Textual information about LMs (pop-up-window)								#	+	+	+	+	+	+	+
Audio information about LMs (on-mouse)									+	-	+	+	-	+	+
Labelling of personal LMs										+	+	+	+	+	+
Music											+	+	-	+	+
Photographs (on-mouse)												#	#	+	+
Panorama views (on-mouse)													#	+	+
Videos (on-mouse)														+	+
"on-mouse"-functions															+

+… possible - not advisable ++... advisable #…not simultaneously

■…. Visualisation of landmarks is bound to map display. The amount of landmarks to be displayed is furthermore dependant on the display size, especially if they are labelled. More than one landmark on an area of 50x50 or 80x80 pixels (depending on the size of the landmark) does not seem reasonable, because map details and route visualisation could affect the readability of the map.

6 Conclusions

Navigation systems that aim on pedestrians are scarce today. In many cases car navigation systems provide the possibility to switch to a pedestrian mode, but usually this mode is not as frequently used as the car navigation service. Preconditions of pedestrians differ enormously to drivers and the usage of the same data does not seem to suffice their requirements. Walking speed is a lot slower than driving speed and attention to traffic is not as important which gives the pedestrian a lot of time to concentrate on his environment. Because of this added possibility to process information, the potential to add multimedia presentation forms to the system, that help the user to access more details and background information about his environment, can be utilised.
This contribution indicates, which presentation forms can be valuable for pedestrians. Beside a map, where not only the route to be followed, but also landmarks and linked hot spots should be marked, verbal and textual guiding instructions and landmark information in the form of photographs, panorama views or videos can be represented in a multimedia system. Furthermore links to diverse online services are eligible that provide the user with up-to-date information about important objects and refer to special incidents and events. Yet the simultaneous application of all available media is not always reasonable and sometimes not even possible on the used device. An overload of information can provoke that the user is overstrained and does not accept the system. On this behalf restrictions are defined which should avoid this effect.

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Comparing the effects of 2D and 3D representations on human wayfinding

Michael Wood, David G. Pearson, Colin Calder, David Miller, Alan Tinto

Abstract

This paper reports on new research comparing the effectiveness of conventional topographic maps and computer-based geovisualisation systems as aids to navigation in wilderness mountain areas in Scotland. The programme considers both the cartographic products and the mental processes involved in their use and this paper concentrates on some fundamental issues and the results of the first experiment which trialled main procedures and concepts. In both this and the main experiment participants were asked to judge gradients and journey times for various routes presented on maps and interactive animated terrain displays. The first experiment compared only terrain models but the second included the essential comparative component of the title, the 2D map. Although work is incomplete, preliminary analysis of the second experiment indicates that one important factor likely to impact on performance is level of expertise in both map-reading and route finding in the field. This research will provide an important evidence base for future mapping system producers seeking to develop generally accessible terrain visualization tools.

1 Introduction

Tangible cognitive maps, exhibiting topographically organized spatial tessellated structures anchored to external landmarks, have been associated with the region of the hippocampus of rats (Hafting, *et al,* 2005). Although the full relevance of this to humans is yet to emerge there is increasing recognition that the internal (cognitive) representation of spatial environmental knowledge is not only fundamental to humans but essential for spatial decision-making, especially in the context of wayfinding. Most perceptual information employed in wayfinding activities is obtained from direct environmental experience. However, since the emergence of what has been called the writing-based 'theoretic culture' (since c. 45 000 BP) and the associated invention of visiographics and external memory (Donald, 1991), external facilities such as maps and other related images have become increasingly common and are believed to influence the nature and content of cognitive maps and the wayfinding strategies which result.

Although traditional paper maps have been valuable sources of geospatial information for travellers, complex environments lead to graphic complexity which has challenged both map makers and users. Good cartographic design and appropriate map use training have helped to accommodate such complexity, but creative application of new computer based technologies can now add significantly to knowledge acquisition and enhance decision making processes. Of course in the current period of transition, customised paper maps still exist side by side with new computer based tools such as Memory-Map (URL 1) and Anquet Maps (URL 2), which provide users with interesting alternatives. Printed topographic maps have been the tools of choice for route finding in mountains but they demand perceptual and cognitive effort for their interpretation. Understanding elevation contour patterns requires special knowledge of symbol systems, the landforms depicted and the navigation task. It has been reported that orienteers, for instance, develop a view of how parts of the terrain will appear. This "pre-experience," impression derived from the map will later have to be attuned to the real terrain (Ottosson, 1996). Some experienced orienteers can, while running, develop and maintain a mental 'map model' (a form of cognitive map) of the competition area over considerable time periods and refer to it intermittently, without the need to look at the physical map. Others must keep checking back to the map to strengthen their mental image[1]. As the expertise required for this kind of mental modelling involves the user possibly imagining the interpreted landscape as a 3D image, this study is investigating the potential of new geovisualization techniques (compared to traditional maps) to augment these abilities. If screen based computer generated models, resembling those derived mentally from contour maps by some experts, can now be created and viewed interactively on computer screens, less experienced users may also be able to acquire some of the advantages of those with greater skill and training in traditional map reading.

The programme described in this paper is comparing the value of certain new computer based cartographic products with conventional maps, and also seeking answers to psychological questions about the nature of the interaction between them and mental representations – largely ignored by current theories of human working memory[2]. Put simply, if mental representations from experience of reality are many times better than those gained from reading static 2D maps, does learning from dynamic 3D models give results somewhere in between? The study is also addressing some of the 'research challenges' - specifically cognitive/usability issues - of geovisualization tools (MacEachren and Kraak, 2001). Separate experiments examine the relative effectiveness of in-

1 The sport of orienteering permits only the basic tools of map and compass to help navigate between checkpoints along an unfamiliar course. Modern aids such as GPS and other Location-based services are illegal.

2 The part of the brain that provides temporary storage and allows manipulation of the information being used in complex cognitive tasks such as learning, and reasoning.

teractive, animated 3D terrain models, and traditional contour maps, as external aids for the tasks of estimating the slope gradients of mountain paths and the time taken to complete predetermined mountain walking routes. Recognition memory for 2D and 3D representations is also being explored.

2 Some preliminary studies

Although pictorial maps and panoramas, often of high artistic quality, have been created during recent centuries (Wood, 2000), few would have satisfied the more rigorous characteristics of both reliable consistency and 'visual friendliness' required by unskilled map readers to support spatial reasoning tasks such as detailed wayfinding. By the 1980s digital terrain modelling software had been developed for the production of fixed views, but not until the 1990s was it sufficiently user friendly or could offer visually acceptable output. Pilot studies with two such earlier systems – LaserScan Horizon and ESRI's Arc/Info - laid some of the groundwork for the present investigation. In one case 3D terrain images were created to support map reading experiments with geography undergraduates (Wood & McCrorie, 1993). Results suggested that such views *could* help with contour reading, but a more significant discovery was of the considerable difficulty encountered by many participants when trying to interpret contour patterns from the maps themselves, reflecting very limited map based knowledge or experience. If this condition proved widespread, the need for new and more powerful visual tools would increase. In another study (Wood & Goodwin, 1995) static 3D views were again created, this time using ESRI Arc/Info, with draped satellite images and overlaid with selected vectors (footpaths and streams). Test participants were grouped by level of knowledge and experience of map reading and mountaineering into 'real experts' (serious amateurs, rescue team members), 'regular leisure walkers', 'occasional walkers', and inexperienced 'opportunists' (such as motor tourists who reach a mountain car park in good weather and decide to take a walk!). A smaller pilot study with real experts (serious mountaineers) led to the following observations about the potential of the more limited symbolically enhanced 3D views they had experienced in 1995:

– Useful for route planning but less suited to ongoing navigation *(through lack of detail).*
– With improved realism of surface representation such views might provide sufficient information without the support of a map *(e.g. with a full vector drape of topographic symbology).*
– There was modest recognition of the possibility that the ready availability of higher quality (perhaps more realistic) representations could benefit mountain safety *(although these were not available to these participants).*

New generation terrain modelling software offers much greater potential for the support of external cognition, including better surface rendering, interactivity and animation. Output options ranging from orthographic 2D maps to 3D terrain models viewed from any angle and incorporating rotation, zooming and 'flythro' capability, provide the flexibility required for the proposed research programme.

3 The current project: background and experimental strategy

The increasing availability of computer based visualisation and multimedia technologies to supplement or even replace conventional printed maps, has been partly driven by the general assumption that dynamic 3D representations can provide more effective support than 2D maps alone. Few studies, however, have examined whether this assumption is correct (Scaife and Rogers, 1996). Most previous findings on perception and cognition in wayfinding are based on static paper maps, and much less is known about issues associated with 3D and dynamic displays (Slocum et al, 2001). It is well documented that mental representation of environments stimulated by 2D maps is quantifiably different from representations produced by direct experience (e.g. Thorndyke and Hayes-Roth, 1982; Moeser, 1988). It is therefore important to investigate whether learning, using 3D terrain models (which more closely approximate reality than maps do) produces different or superior memory than learning using 2D maps of equivalent geospatial data. Another neglected area of research is on effects of expertise in the use of 2D and 3D representations. Users ranging from serious mountaineers to casual weekend walkers regularly visit areas such as the Scottish Cairngorm Mountains. Recent theories of expert cognition in orienteering (e.g. Eccles et al., 2002) are naturally based solely on the use of 2D maps. The majority of previous studies has largely ignored direct comparison of 2D and 3D representations, and has focused on urban/manmade settings rather than wilderness environments, or on development and application of the technology for implementing such representations for prospective users (Moore et al., 1999; Morrison and Purves, 2001). The social, economic and environmental importance of mountain regions in many countries has been steadily increasing over recent years, with an associated increase in the use of such areas for recreational activities. An important aim of the current project is to help establish a source of data (based on scientifically rigorous investigation) on whether or not interactive, animated 3D terrain models do provide better cognitive support than traditional static 2D maps, and to produce empirical evidence that could contribute to better evaluation of the potential impact of such geovisualisation tools for recreational use in mountain environments. The introductory phase of the programme comprised two experiments. The first, a pilot study, was primarily used to trial concepts, materials and procedures. The second focused on the interpretation of 2D and 3D geospatial data. The remainder of this paper concentrates on the first experiment, but provides an outline of the second.

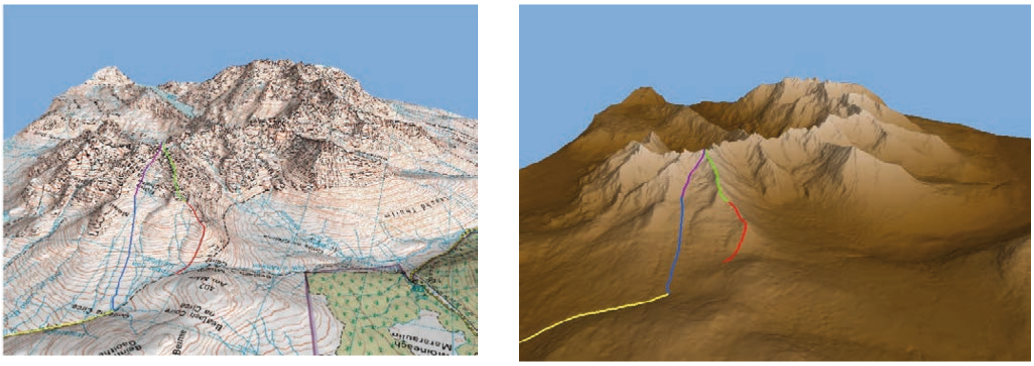

Fig. 1: Model of Bruach na Frithe, Cuillin, Skye, Scotland, showing Route 6 (draped and undraped)

3.1 The stimuli used in both experiments

Three stimuli were prepared, one onscreen topographic map and two versions of a terrain model of the same area. Using ESRI ArcGIS/ArcMap/ArcScene software, models were created of twelve separate 10 km² tiles selected from different high level mountain regions in Scotland. Ordnance Survey (OS) 1:25 000 scale digital data were used. The two versions of the models to be used in the experiments had shading from oblique illumination and one had a draped image – the raster version of the 1:50 000 OS map. The other ('undraped') was rendered only in a plain colour, graded using the sequence 'the higher-the-lighter' (Fig. 1). A walking route was clearly marked on each map/model, subdivided into five colour-coded sections and depicted by a line located 10m above the model surface to avoid visual confusion with underlying symbols. The ArcScene interface is interactive, allowing participants to manipulate the image and view it from any angle, distance or direction. The extent of zoom is limited visually by the increasing courseness of the raster elements of the OS map drape. It is also possible to 'fly', with some degree of control, across the landscape at any altitude and at various speeds. The flat maps were also viewed with ArcScene but fewer interactive facilities were employed. A Pentium 4 laptop computer was used to deliver the map and model images during the experimental sessions, with control through mouse and keyboard.

3.2 Experiment 1: pilot study

In this first experiment only terrain models were used (without comparison to the 2D maps), the focus of interest being on how differing levels of information on the models (the draped and undraped conditions, as described above) would affect their perception, value as an information source and ease of use.

The main hypothesis was that there *would* be a difference between judgements made from the two model types. This hypothesis, however, was non-directional, with two outcomes possible:

a)That the version draped with OS data might be easier to use due to the greater level of information (such as grid squares and contours) available to the user.

b)That, if the draped information is ignored (i.e. not used in calculations), estimations would inevitably end up being based on spatial perception alone. In fact in such cases the draped versions might also overload the user with unnecessary or undesired symbolism and even hinder judgement.

Twenty-four student undergraduates took part (12 female and 12 male), aged between 19 and 31. The experiment was designed with both between and within subject comparisons to avoid bias. The tasks (dependent variables) were the estimations of the slope angles/gradients of each (coloured) section of the depicted routes, and the walking time estimates for each entire route. The independent variable was the model type, draped and undraped.

3.3 Procedure

Following an introductory session which included familiarisation with the computer (using a training map), the participants then completed twelve trials, each with a different model. They were shown each of the twelve landscapes once, six with the 'draped' version and six with the undraped. However map types presented were different for different participants i.e. while half saw models 1-6 draped and 7-12 undraped, the other half received the opposite combination. Also to minimise practice effects, the order in which they were presented was counter-balanced.

In each trial participants were asked to do the following:

1. Observe the walking route, and for each of the colour-coded sections (A-E) were asked to
    a. assign a gradient rating based on a 5-point scale (essentially flat, gentle, medium, steep, extreme)
    b. assign an angle estimation (from a 90º diagram with 10º steps)

The angle judgement was included to allow for personal bias on slope severity *(a 'moderate' gradient for one might be 'steep' for another).* Specific angle estimations could also be compared later with the actual gradients, measured from the maps.

2. Consider the entire route, and estimate the time taken, in hours and minutes, to walk it.

When carrying out these tasks, participants could make full use of the interactive facilities of zooming, rotating, etc., with no time restrictions.

When the experiment session ended each participant completed a short questionnaire to identify any previous experience in map reading or navigation, and also to check for their familiarity with any of the Scottish regions from which the models had been created. This was necessary to ensure that judgements had not been made from personal knowledge rather than direct observation of the models alone. They were also asked to select which of the two models they had preferred or found easier to use. Although there were no time restrictions during the trials, the overall time taken was recorded for each participant as it could be a factor influencing performance. Estimation data was also retained for later analysis.

3.4 Results

Even after careful analysis of the data, no significant differences in walking times or gradient/angle estimations were detected between the draped and undraped models.

Estimations of gradient also compared well with actual gradient values (computed from the maps) and walking times (from Naismith's Rule[3]). This would show if one model type affected accuracy judgements, but there was still no significant difference in walking time estimations between the two model types. Mean real gradients/angles also correlated well with estimations in both conditions. Times taken by participants when using their 'preferred' **draped** maps were slightly longer, but with no differences in performance. Equally, there were no significant differences in performance between those with high and low self-reported measures of hill-walking frequency in either draped or undraped condition. There was also wide and variable experience/ability in map-reading among the participants, but this was not formally assessed in the first experiment.

3.5 Discussion

The main experimental hypothesis was not supported. No differences were found between responses for the two models, draped and undraped, estimations of gradients/angles being very similar in accuracy and magnitude. However these results are striking as they might not have been anticipated! Why were there no differences in response between the model types? The OS data seemed neither to help nor hinder the estimation process. Was this extra information regarded as unnecessary or did it even lead to perceptual or cognitive overload for the user? This is probably unlikely as if it had been a hindrance, greater success would have been recorded with the undraped model, and this was not the case. Also more than 66% of the participants preferred the draped model and so this extra information could not have been recognised as a problem. Apart from a very few who used the OS grid squares to help with distance estimation, most participants did not use the OS data, as the accuracy ratings were no better in the draped than the undraped condition. Most participants just seemed to estimate. Although the draped models did have more altitude information (contours) this was not used when estimating slope angles. Only if the task had required calculations would the contour data have been of direct use.

In such studies, especially utilising flexible interactive scene manipulation, it is very difficult to control the variables, especially how participants carry out the tasks. As with walking time estimations, where a few participants did refer to grid lines, only some made more use of the visual interactive facilities than others. This information was not recorded or tested but the procedures adopted were intended to resemble normal experience with such facilities and so variations were inevitable. One trend noted was the tendency for participants to make some reference to estimates from previous models as reference points for the next task. Did the route look longer or shorter than the last? A few were confused by the fact that some route sections covered very rough surfaces where no obvious single gradient seemed to apply, but, as the routes were intended to be authentic, this too was regarded as an inevitable feature of the exercise.

In this study expertise and experience were not formally measured and participants were not in expertise groups. This was certainly considered in the main experiment as it could affect the strategies employed. For instance someone very familiar with one type of map (such as the 1:50 000 OS scale used on the draped model) may be able to mentally visualize the models more easily. Future participant selection, therefore, would include experts such as mountain rescue team members and orienteers.

3.6 Experiment 2 – interpretation of 2D and 3D visualizations

The content and structure of the remaining experiment was informed and enhanced by the results of the pilot project. Most significantly expertise groups were assembled and modifications were made to the recording procedures for the experimental sessions. For example the experimenter kept a record of how participants interacted with the software; i.e. number of rotations, number of zooms etc. This allowed greater insight into any expertise differences in how participants responded to the different forms of representation. Fifty four participants were tested with 18 per expertise group, namely novices (with little of no experience of mountain

3 Naismith's Rule provides a means of estimating route times in the hills, by taking into account both the distance to be walked and height to be climbed: Time (excluding rest breaks) (mins) = 12 x the distance walked (km) + 0.1 x the height climbed (m).

environments), intermediates (casual weekend walkers), and experts (with extensive orienteering-style experience). A map was added to the experimental stimuli to meet the original plan to compare the effectiveness of 2D maps with 3D interactive models. The 12 terrain models of Scotland were used once again, and other materials and procedures were as before. Each participant viewed all twelve model/regions; four through sight of the map alone, four with the undraped model, and four with the contour map drape. The experiment adopted a repeated measures counter balanced design to ensure that each of the twelve model/regions was presented an equal number of times across participants as a
map, undraped model, or contour map drape. This allowed a direct comparison of participants' performance using 2D maps and 3D models generated from the same geospatial data. The average session time was ninety minutes.
Although this work is incomplete one interesting observation can be made about the preparatory stage. It proved quite difficult to identify clearly defined expertise categories. For example some who claimed to be very regular hill walkers were also members of formal clubs or informal groups and, when questioned, it became evident that they rarely took any responsibility for, or participated in wayfinding decisions. Work on the main experiment is ongoing at the time of writing and preliminary results are not yet available. When completed the data will be analysed to test a number of hypotheses concerning gradient estimation in different map and model conditions. Supporting information is more explicit in the terrain model/3D imagery than in the map and it is expected that the impact of this on performance may strongly interact with expertise.

4 Conclusion

Although some research studies have been done on the value of animated and interactive terrain modelling in support of various tasks, most have not followed a strictly experimental approach. In view of the rapidly growing popularity of leisure walking (see walkingworld.com) and growing anecdotal evidence of the attractiveness and popularity of new animated and interactive cartographic products (e.g. Memory-Map, Anquet Maps), the authors of this paper advise that their nature and use should be examined with some scientific rigour. Only through such methods can a suitably rich and dependable source of empirical evidence be assembled which can be of value to:

1. Product designers seeking to assess the degree of realism or symbolic support required from the displays
2. Psychologists seeking to extend their knowledge of visuo spatial cognition and mental imagery
3. Those responsible for giving advice and training to different categories of mountain visitor
4. Environmental managers and planners.

This could also lead to new and valuable Internet resources and further opportunities to offer advice and pass on information about techniques for planning leisure journeys and for use with PDAs (or new-generation mobile phones!) in the field. It is also hoped that when completed these experiments will contribute to a greater understanding of geovisualization methods in general.

5 Acknowledgements

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URL1: Anquet Maps, www.anquet.co.uk
URL2: Memory-map, www.memory-map.co.uk

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An approach towards semantics-based navigation in 3D City Models on mobile devices

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Abstract

This paper outlines a novel approach for user navigation in complex virtual 3D city models on mobile devices. Users navigate within the virtual 3D city model by sketching navigation commands in the perspective view on the mobile client. The sketches are sent to the server, which reprojects the sketches onto the 3D scene, interprets these sketches in terms of navigation commands, and sends the resulting video-encoded image stream to the mobile client. This approach allows us to provide interactivity for complex virtual 3D city models on resource and bandwidth limited mobile clients. A high degree of usability is achieved because users can trigger complex navigation commands in a task and goal oriented way taking advantage of the navigation properties and affordances inherent to elements of geovirtual environments.

1 Motivation

Virtual 3D city models represent urban spatial and geo-referenced data by 3D geovirtual environments (GeoVE) that include terrain models, building models, vegetation models as well as models of roads and transportation systems. In general, these models serve to present, explore, analyze, and manage these urban information spaces and, therefore, constitute a major user-interface paradigm for 3D geoinformation systems.

An increasing number of applications and systems incorporate virtual 3D city models as essential system components such as for facility management, logistics, security, telecommunication, disaster management, location-based services, real estate portals as well as entertainment and education products. Consequently, a large number of potential users and usages require an efficient and effective mobile access to virtual 3D city models and their contents.

We present a novel solution for accessing virtual 3D city models on mobile devices. The user controls the navigation within the virtual 3D city model by navigation command sketches drawn directly on the view-plane of the mobile client (Fig. 1). The sketches are sent to the server, which reprojects the sketches onto the 3D scene correlating the sketches to scene objects, interprets these sketches in terms of navigation commands, and sends the resulting video-encoded image stream to the mobile client. That is, the mobile client enables users to specify and retrieve step-by-step created video sequences that correspond to their navigation intentions.

2 Related work and challenges of Mobile 3D City Models

Mobile applications of virtual 3D city models represent a major and complex research challenge due to limited bandwidth and graphics capabilities, restricted interaction capabilities, data standardizations and distribution techniques, and digital rights issues.

Fig. 1: Sketching the navigation command "look around" (left). Sketching the navigation command "walk along the path and, finally, look at the indicated building" (right).

2.1 Mobile 3D rendering

In 3D computer graphics, numerous rendering techniques are available to cope with complex virtual environments, including discrete and continuous multi-resolution geometry and texture representations, view-frustum culling, occlusion culling, imposter techniques, and scene-graph optimizations (Akine-Möller and Haines 2002). Virtual 3D city model visualizations require an efficient management of large-scale texture data, e.g., for aerial photography and building facades (Buchholz and Döllner 2005), and level-of-detail management for large heterogeneous 3D object collections (Davis et al. 1999) and 3D terrain surfaces (Döllner et al. 2000). Although these rendering techniques enable real-time rendering of complex 3D scenes, they generally cannot be transferred directly on mobile devices due to limited computational resources and power.

One principal approach to efficient *mobile 3D rendering* consists in the adaptive, progressive, and compressed transmission of 3D graphics data to mobile clients. For example, Royan et al. (2003) describe client-server architecture for mobile 3D virtual city visualizations based on a progressive and hierarchical representation for GeoVEs. The server pre-computes multi-resolution representations of terrain models and building models, and progressively sends data about visible areas to the mobile clients. The clients allow users to interact with the 3D city model (e.g., virtual walk-throughs, fly-overs, etc.). However, the limited 3D graphics acceleration on today's mobile devices makes it difficult to implement fully featured 3D rendering techniques for virtual 3D city models. Furthermore, the implementation is complicated due to the broad variety of hardware and software solutions for mobile 3D graphics (e.g., OpenGL ES, Mobile 3D Graphics API for J2ME).

Another principle solution consists in *server-side 3D rendering* and the progressive, compressed transmission of image sequences. For example, Cheng et al. (2004) investigate a client-server approach for visualizing complex 3D models on thin clients applying real-time MPEG-4 streaming to compress, transmit, and visualize rendered image sequences. They identify the MPEG-4 encoding speed as bottleneck of client-server 3D rendering, and devise a fast motion estimation process for the MPEG-4 encoding process.

2.2 Mobile 3D interaction

To achieve a high degree of usability, mobile applications require goal-oriented and task-oriented interaction techniques that take into account the specific restrictions of mobile devices, e.g., no mouse, no desk, or one-handed operation. For this reason, approaches for automating user interaction are crucial for effective mobile user interaction. Of course, these approaches are also faced with the general problems of navigating in virtual worlds (Russo et al. 2000).

A critical task in applications of GeoVE represents the process of navigation, "whereby people determine where they are, where everything else is, and how to get to particular objects or places" (Jul and Furnas 1997). Navigation as the primary interaction can be distinguished into three kinds, naive search, targeted search, and exploration (Darken and Sibert 1996) and serves to explore, analyze, and gather geoinformation as well as to trigger object-specific interaction. To do this, users generally move the virtual camera or an avatar through the GeoVE. This way the user builds up a mental model of the GeoVE by forming linear maps and combining them to spatial maps (Ingram and Benford 1995). Wernert and Hanson (1999) incorporate task-based constraints on the navigation parameters (e.g., viewer position and orientation) to enable the designer of GeoVE "to provide extra assistance to keep the user's explorational wanderings and attention focused on the task objectives".

Common navigation controls for GeoVE include world-in-hand controls, fly-over controls, and virtual trackballs. Burtnyk et al. (2002) introduce a general approach of facilitating navigation in GeoVE based on explicitly designed navigation spaces using integrated spatial and temporal controls. Buchholz et al. (2005) describe a concept of smart and physically-based navigation techniques, controlling the user's movement similar to an assistance system preserving users from being disoriented or getting lost in the GeoVE. It constrains the movements to be inside the GeoVE, hinders collisions with buildings, controls the gaze direction at the terrain borders, and facilitates the switch between navigation modes. For mobile applications, semantics-based navigation control can integrate and extend these concepts.

Igarashi et al. (1998) develop an intuitive approach for specifying navigation commands: The user draws the intended navigation path as a curve on the view plane. This path is mapped to the 3D scene and determines the 3D path the avatar moves along. This way, the user can specify not only the final position, but also the route and the camera direction at the goal with a single stroke. Our approach also has been motivated by the metaphor-aware 3D navigation technique (Russo et al. 2000) and specialized for virtual 3D city models.

2.3 Standardization and distribution

Applications of virtual 3D city models also suffer from a lack of data standards and flexible distribution techniques. Virtual 3D city models frequently are implemented as graphical models without explicitly modeling semantic and topological relations. Therefore, they can almost only be used for visualization purposes but not as a data basis for higher-level functionality such as simulations, analysis tasks, or spatial data mining. The limited reusability and interoperability inhibits the broader use of virtual 3D city models. CityGML represents a first XML and GML-based format for storing and exchanging virtual 3D city models (Kolbe et al. 2005), which also represents semantic and thematic properties, taxonomies and aggregations.

With respect to distribution, a complete delivery of city model data would result in massive data transfers. Even if only a part of a complex virtual 3D city model is required (e.g., view-dependent multiresolution selections), the costs for geometry and texture data for high-quality photorealistic models typically exceed current and future transmission capabilities.

2.4 Digital rights management

Protecting the contents of 3D city models is one of the most critical aspects of real-world business models underlying 3D city model applications (Döllner 2005). The transmission of raw city model data or derived detailed 3D graphics data imply severe drawbacks for copyright issues and controlling usage and distribution. For this reason, we transmit only video sequences but no raw data to the mobile clients.

3 Sketch-based navigation commands

3.1 Real-time interaction vs. selective interaction

Common navigation techniques allow users to control their movement within the virtual environment in real-time. For mobile devices, however, real-time 3D rendering of virtual 3D city models is not practically possible due to limited computation resources and bandwidth as well as the non-stable data transmission. In contrast to the real-time user reaction that characterizes most games taking place in virtual environments, real-time 3D interaction is not crucial for many applications and systems of virtual 3D city models because exploration and analysis tasks performed by users are based on a selective, targeted access of spatial information. That is, the delay between issuing interaction commands on the mobile device and the execution of the commands is acceptable and corresponds to the expectation of the user.

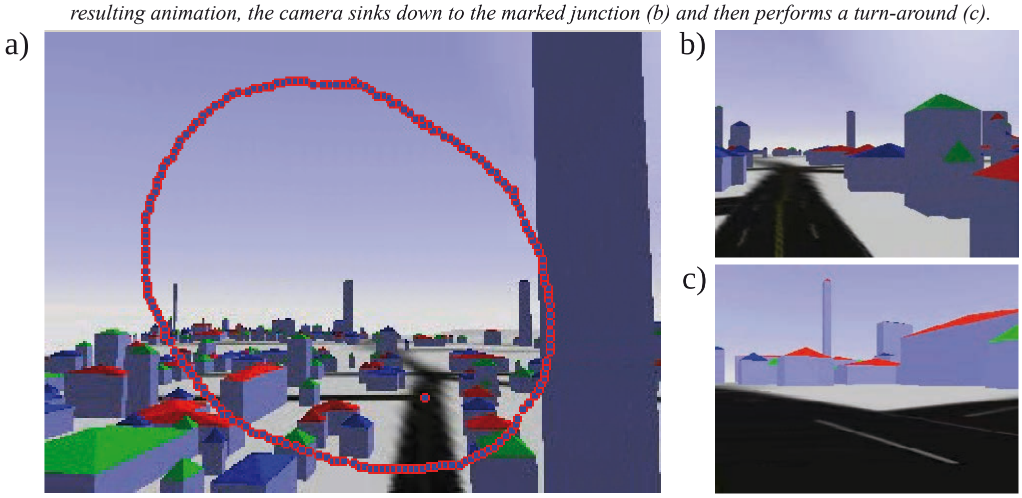
3.2 Concepts of sketch-based navigation

In our approach, navigation commands are graphically specified in the perspective view of the virtual 3D city model on the mobile client, e.g., drawing a line along a street, pointing to a building or the sky. The sketches are correlated with the objects of the GeoVE by reprojecting the sketched shapes onto the 3D scene. The sketch-based navigation commands are interpreted based on the semantics of sketch-correlated objects and their inherent navigation affordances.
We distinguish between three types of information used for interpreting the commands:

- *Spatial context*: The spatial context refers to the virtual location to which the sketch is aligned or associated. For example, the user can draw a path along a street or mark a specific building.
- *Temporal context*: The temporal context refers to the order in which the user composes the sketch elements. For example, as first step the user draws a path along a street, and then marks the building.
- *Sketch geometry*: The elements include points, lines, and polygons drawn in the perspective view. They can be grouped and interpreted by higher-level sketch geometry such as circle-like paths or u-like paths.

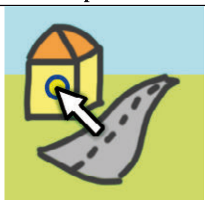
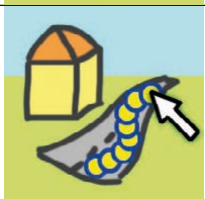
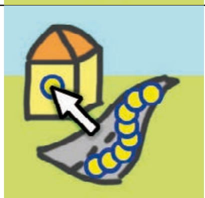
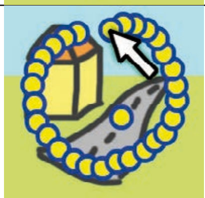
The sketches can be differentiated into *location-aware sketches* and *gestures*. Location-aware sketches refer to a spatial context, whereas gestures do not. From a technical point of view, gesture recognition requires large, screen-wide drawings for correct identification. For example, a circle gesture cannot be drawn close to the corners of the screen. Gestures are known from computer games, from several navigation-aware applications, or as utility programs that can be used for desktop interaction.
We allow for concatenating and building up a temporal context for the navigation command sketches. For high usability and consistency of the user interface it must be considered that sketches might a) represent a place to go to or a path to go along, b) mean one ore more points to gaze at, or c) conclude both, place and direction of view. By combining gestures with other sketches we can introduce spatial context to gestures, too (Fig. 2).

Fig. 2: The user sketches a point on a junction and adds a circle-like gesture as secondary input (a). In the resulting animation, the camera sinks down to the marked junction (b) and then performs a turn-around (c).



3.3 Sketch-based navigation vocabulary

A first collection of spatial and temporal contexts together with sketch elements is illustrated in Table 1. Gabbard (1997) points out that “when assessing metaphors for navigation and locomotion in VEs, it is important to consider mappings of integral navigation and locomotion components to metaphor gestures or mechanisms.” The sketch-based navigation commands within their spatial and temporal context provide such mechanisms. For example, drawing a single, straight path along a street object indicates, “walk along the street”. A circle-like (close or nearly closed) path drawn on the terrain surface indicates “look around” using a drawn point as camera position. A path drawn along a street with a final indicated u-turn indicates, “walk along to the end of the street, turn around, and walk back”.

Name & Context	Example Sketch	Navigation Sketch	Navigation Action
Point-House		Point on a building.	Finding shortest path to the building, going there, and looking at the building.
Point-Roof		Point on a building’s roof.	Flying up to the roof, placing the camera on top, and looking around.
Curve-Street		Curve or polygon on a street.	Walking on street and looking back finally.
Curve-Street, Point-House		Curve on a street and point on a building.	Walking along the street and looking at the building finally.
Point-Ground, Point-House		Point on the ground and point on a building.	Flying to the marked ground point and looking at the building finally.
Point-Street, Circle Gesture		Point on the street and circle-shaped gesture.	Flying to the marked ground point and looking around.
Point-Sky		Point on the sky.	Soaring above ground for overview.

Tab. 1: Overview of sketch-based navigation commands.

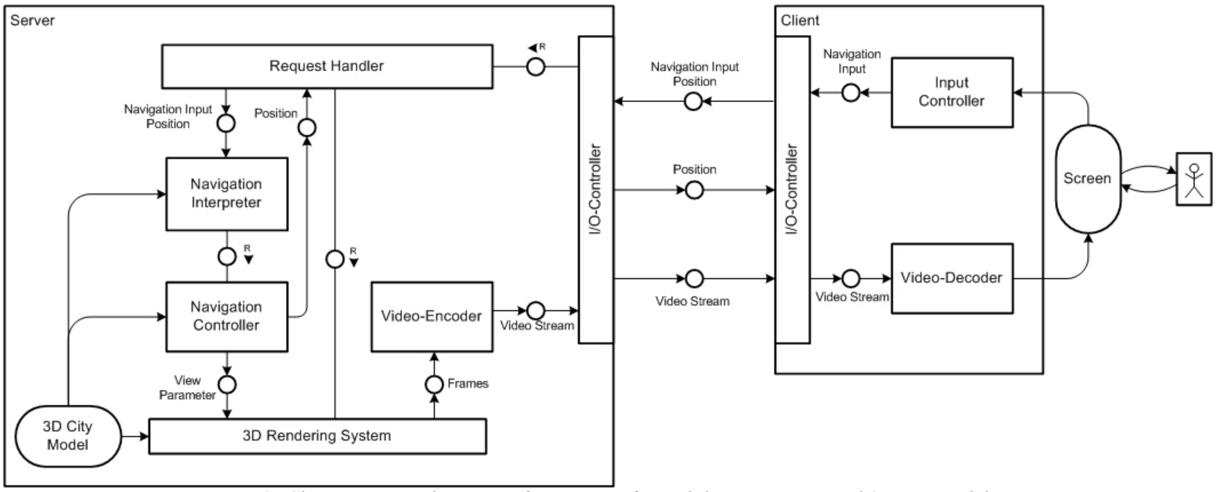


Fig. 3: Client-server architecture of our system for mobile access to virtual 3D city models.

4 Client-Server Architecture for 3D visualization

The presented approach has been implemented based on a client-server architecture outlined in Fig. 3. We assume that the 3D city model is hosted on the server and that the mobile devices efficiently support encoded video streams.

4.1 Server system

The server system is responsible for handling requests sent from the clients, for interpreting and controlling sketch-based navigation commands, for 3D rendering, and the video-stream encoding. It provides a web service interface to the virtual 3D city model. The clients can communicate with the server by exchanging SOAP messages. The interface supports three main operations:

- *GetCapabilities*: Provides the service metadata including information about the used streaming protocol and available start positions. The clients call the operation at the beginning of the communication.
- *GetStartPosition:* Renders and transmits an image of the start position. This image provides the spatial context for the user's first navigation inputs.
- *GetMotion:* Interprets sketch-based navigation commands and initiates the rendering of the camera animation. Because the server is stateless, it has to reconstruct what the user of the client saw while drawing the sketches. Therefore, the request contains the final camera position of the preceding request. If the user stopped before the end of the animation for a new input, the client's position can be determined by the start position and inputs of the previous navigation and the point in time the user stopped the video. Both camera positions, at the beginning and the end of navigation, are included in the response message.

The *navigation interpreter* detects the semantics of sketch-correlated scene elements and identifies the classes to which hit objects belong. For a sketch that has more than one input point we determine which object type occurs most frequently such as in the case of a path on a street whereby not all of the input points are placed exactly. The *navigation controller* calculates the resulting animations (Christianson et al. 1996; Mackinlay et al. 1990). Special navigation controllers use a navigation network geometry that provides paths that can be used to walk along. The position to look at a house is determined as the nearest point on such a path element. For an effective 3D overview for the rise-to-the-sky navigation we provide a map of view directions as introduced by Hanson and Wernert (1997). It allows us to determine a suitable direction to look at from a specific point to gain as much spatial information as possible. The current implementation is based on height-defined landmarks. The *rendering component* encodes the animation frames into an MPEG-4 video stream (Cheng et al. 2004; Noimark and Cohen-Or 2003) by the *video encoder*. The resulting video stream is transmitted to the client immediately using a standard streaming protocol. So, the client can start the video playback as soon as possible.
We have implemented and tested a server that uses DIME attachments to deliver the video to the client. The DIME standard is similar to MIME and defines a way to send arbitrary binary data along with SOAP messages. Because the data is sent in chunked data blocks, it allows starting the streaming of the produced video while the rendering process has not been completed. Instead of DIME, any other streaming protocol could be used. In this case, the server's response message must include the parameters necessary to connect to the streaming protocol or server.

4.2 Client system

The thin client system does not contain application logic, it only needs capabilities for receiving and playing the MPEG-4 video streams, capturing the user input and sending and receiving SOAP messages. While receiving a video stream, the client simultane-

ously decodes and displays the video. Most mobile devices provide built-in support for these tasks. For drawing new navigation sketches, the user can wait for the end of the video or he can stop it at any point of time.
The client records the user inputs as a set of 2D points representing the screen coordinates of the navigation sketches. The temporal context of the input can be determined by the drawing order of the points and the classification of single sketches.

5 Conclusions

We have presented an approach towards semantics-based navigation control for mobile virtual 3D city models. A high degree of usability is achieved because sketch-based navigation commands allow users to trigger effectively complex navigation intentions taking advantage of the navigation properties and affordances inherent to elements of geovirtual environments. In addition, it is perfectly suited for the input devices and usage situation of mobile devices where generally no mouse and no desktop can be assumed. From a technical perspective, the presented approach allows mobile applications to provide users interactive access to complex 3D city models including high-resolution 3D terrain geometry, 3D building geometry, and textures exceeding several hundreds of GB of storage. In particular, the server can be optimized for processing large-scale 3D city models using high-end computer graphics hardware, whereas only multimedia capabilities are required from the mobile client.
In our future work, we will address general sketch-based interaction commands and visual feedbacks about the automated navigation. We also plan to include in the video stream meta-information about the scene and its objects.

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Towards an understanding of the importance of landmarks to assist perceptions of a space in web-delivered 3D worlds

William Cartwright

Abstract

This paper reports on a research programme that is building and testing a 3D tool for Community Collaborative decision-making. It concentrates on the stage of the research that focuses-on the question: How does a priori knowledge of an area change navigation and exploration abilities when 'moving through' and exploring the Virtual World? That is, how is the perception of a place, built through the use of a virtual environment, modified by prior knowledge of an area being studied / explored? As well, does this effect a user's ability to explore a virtual geography more effectively? We wish to ascertain how the users' prior knowledge about the real world can be applied to building more effective virtual environments.

From naive user to expert user we wish to find-out what elements need to be 'built' into the model to support wayfinding, exploration and subsequent data visualization and decision-making. A priori knowledge and previous experience and methods of map and other geographical information artefact usage will also be considered, as it will provide important clues about 'preferred' methods of tool use.

The paper will provide a description of the project and its potential use in an urban planning context, briefly provide the results of previous research that form part of the project and provide results regarding how users perceive an urban space through the use of a combination of landmarks and simple 'block' building shapes.

1 Overview

A project is underway to supplement the community decision-making process with a World Wide Web (Web)-delivered interactive 3D tool. This involves building and testing a 3D tool for Community Collaborative decision-making. A research team at RMIT is building virtual 3D audiovisual models of urban spaces to test their potential to enhance community discussions of future neighbourhood developments. Of great interest to the team is how successful these simulations are, especially when delivered through the sometimes restricted 'pipe' of the Internet. Also of interest is how these tools are accepted by the user group and how the tools might best be designed and delivered to suit community use.

A VRML world was created for the study area. The VRML world is shown in figure 1.

The world was developed as a test bed to determine 1. What the model should contain – a trade-off between development costs and usability, 2. How much information needs to be included for professional and public users and 3. How landmarks might be incorporated to facilitate a 'balance' between minimal information provision and usability.

An initial evaluation of the tools was made with a focus group to provide general feedback. A second evaluation was conducted so as to better understand how complex a computer graphics 3D environment needed to be for community discussion of urban planning developments. This paper reports on the last Stage of an evaluation project which was undertaken to ascertain how landmarks and the users' familiarity of a study area can be used to build simpler and thus more economical virtual worlds.

A problem for developers of decision support tools is to provide adequate assistance to all stakeholders in the decision-making process. Tools must be developed for expert and non-expert alike. In inner urban areas, where a plethora of building types abound, and historical knowledge is hidebound to understanding how an area 'works', it is important to provide visualizations that support the visualization process. However, many of those involved in the decision-making process may only have a very naïve understanding of an area. For these users perhaps a more detailed model is needed, and for those with a greater knowledge of an area the model could provide less detail. The focus of this evaluation was to determine the level of detail that would be 'acceptable' for a 3D urban visualization tool.

If users cannot recognise where they are they will endure stress, and search for geographical information that puts things in (spa-

Fig. 1: VRML world.

tial) perspective (eg finding their bearings, orientation to north etc.). According to Golledge (2000, p. 1) "We often assume there is no need to learn this type of geography because we already "know" it! And, we have not bothered to make this underlying geography explicit. Golledge thinks that naïve geography gives an implicit knowledge via environmental perception and that landmark or feature recognition and an awareness of the built environment is part of geographical understanding. He says that "People who claim they 'can't do' geography can provide accurate assessments of their local area. …"Users 'already know it" (Golledge, 2000, p. 1). For example, aspects of the geography of daily life that we "implicitly "know" but have not bothered to make the underlying geography explicit (*ibid*, p. 7). Naïve geography gives an implicit knowledge via environmental perception, through the use of landmark or feature recognition (*op cit*.).

Navigating in the real world can be difficult for users who need to travel through unfamiliar terrain. This difficulty is enlarged when they have little local knowledge of an area as well. When users have to navigate in virtual worlds the problems can be different, but still certain 'knowledge' of landscapes could assist with wayfinding in this synthetic reality. So, what happens when inexperienced users are 'plunged' into a virtual world, and asked to explore and understand a geography they may not properly understand? And, how do they best navigate through this world? When users wayfind and explore in Virtual Worlds severe problems do exist (Darken and Sibert, 1996). Without cues users can become disoriented and may not be able to properly use a virtual environment package. According to Darken and Sibert, wayfinding strategies and behaviours are strongly influenced by environmental cues. In the type of environment that is being simulated – an inner urban environment, consisting of a diverse range of building types and different densities – the environmental cues are mainly buildings, with few other cues or landmarks to assist location determination and wayfinding (in the virtual world). Knowing about an environment prior to undertaking a study using a virtual environment can make it easier to interpret n urban simulation. Conversely, little knowledge of an area can make it very difficult to visualize a real space by using a synthesis of it. Therefore, does a done model need to be provided for a user who is knowledgeable about an area and another to someone unfamiliar with that area?

What this stage of the research focusses-on is the question: How does a priori knowledge of an area change navigation and exploration abilities when 'moving through' and exploring the Virtual World? That is, how is the perception of a place, built through the use of a virtual environment, modified by prior knowledge of an area being studied / explored? As well, does this effect a user's ability to explore a virtual geography more effectively? We wish to ascertain how the users' prior knowledge about the real world can be applied to building more effective virtual environments.

From naive user to expert user we wish to find-out what elements need to be 'built' into the model to support wayfinding, exploration and subsequent data visualization and decision-making. A priori knowledge and previous experience and methods of map and other geographical information artefact usage will also be considered, as it will provide important clues about 'preferred' methods of tool use.

We are interested in ascertaining the users' Spatial Knowledge (Darken and Sibert, 1996), which is based on <u>survey knowledge</u> – the ability to conceptualise a space as a whole, enhancing wayfinding skills (Thorndyke and Goldin, 1983, cited in Darken and Sibert, 1996). This is different from procedural knowledge (defined as the sequence of actions required to follow a particular route). It can be acquired from map use and it is also based on <u>landmark knowledge</u> (static information about the visual details of a specific location (Darken and Sibert, 1996).

The evaluation was based on the three primary wayfinding tasks specified by Darken and Sibert (1996). These are:

- Naïve search – where the navigator has no a priori knowledge of the whereabouts of the target, requiring an exhaustive search;
- Primed search – where the navigator knows the location of the target, performing a non-exhaustive search; and
- Exploration – where there is no target.

The naïve search, as Darken and Sibert note, is rare in the real world, but common with first-time users of a virtual space. Naive search will therefore rely on certain wayfinding aids to support their movement through the virtual world. Darken and Sibert (1996, p. 4) proposed that the basic principles of organising an environment to support wayfinding were to:

1. Divide the large-scale world into small, distinct small parts, preserving a sense of 'place';
2. Organise the small parts under a simple organisational principle; and
3. Provide frequent directional cues.

They also recommended that map design principles should be applied to the model, providing an orientation-independent representation of the environment. This entails:

- Showing all organisational elements, roads, landmarks, districts, etc.) and the organisational principle;
- Indicating the observer's position; and
- Orient the model with regard to the 'forward-up' equivalence of map reading (ie having the 'forward' direction of travel aligned with the map).

The last requirement demands interesting 'cartographic callisthenics', as maps are rotated this way and that, so that the map is oriented with the forward direction of travel, with the final destination being always placed furthermost from the user's body. But, when moving / navigating through virtual worlds this is done automatically as the user is unable to rotate the screen. It is argued that this would impose a greater cognitive load.

This stage of the evaluation process will have as its goal the determination of what users need to know or understand about SPACE (general information about the 'area' being studied) and PLACE (dictated / determined by location and purpose-specific elements that are unique to the particular user and their usage requirements). What needed to be resolved were

– users' concepts of space;
– their concept of place;
– how they navigate through space; and
– how they navigate through their personal place.

2 Evaluation

29 candidates participated in the evaluation. Their age range was 18-25 and all had competent to efficient map use skills. The test candidates were split into two groups: Group 1 - identified as having a priori knowledge of the area. 12 candidates were identified as belonging to this group. Group 2 had relatively no knowledge of the area.. 17 candidates belonged to this group. Then each of these groups was further split into two sub-groups: Group 1a and 1b, Group 2a and 2b.
The Candidates first completed a profile proforma to glean information about their proficiency in map and map-related tool use and also their perceived knowledge of the area.
The session operated thus:

1. Groups 1a and 2a were taken on a 'guided tour' of the area.
2. During this time Groups 1b and 2b undertook the evaluation / feedback of the VRML model.

This took approximately 1 hour.
Then this process was reversed.

3. Groups 1b and 2b were taken on a 'guided tour' of the area.
4. During this time Groups 1a and 2a undertook the evaluation / feedback of the VRML model.

GROUP			
1. Local Knowledge		2. No Local Knowledge	
1a Tour 1	1b Tour 2	2a Tour	2b Tour 2

Fig. 2: Groups

Candidates were asked to conduct two searches of the 3D model of the study area, one as a general 'exploration' of the area and the other a task-related search. In the task-related search they were required to find specific buildings that are typical in the study area. These searches will be 1. Naïve (the candidates had no knowledge about where they were located) and 2. Primed (they knew the area after a walking tour prior to the evaluation). Here they were asked to view two 'virtual tours' of the study area, one as a general 'exploration' of the area and the other a task-related search. In the task-related search users were asked to identify the different building types that are typical in the study area. Here they were also asked to note the buildings that you think are the key, or landmark buildings.

Fig. 3: VRML model.

Fig. 4: Landmark building.

The model of the study area used is shown in figure 3.
Finally, candidates were asked to make general comments at the end of all tours and product evaluations.

3 Results

3.1 Level of detail

Candidates firstly considered whether the amount of detail provided was sufficient for them to understand the general geography of the area. Did it provide sufficient information for them to be able to make informed comments about potential developments in the area?
1. The amount of detail is sufficient.
All groups found that there was sufficient detail to understand the area.
2. There are adequate landmarks to assist in orienting oneself.
Landmarks in the area, as previously noted are mainly prominent buildings. One of these buildings is depicted in figure 4.
All found that they had adequate landmarks to assist, except Group 2a. This group had no prior knowledge of the area, and they had been on a tour of the area prior to undertaking the evaluation. Here, the users identified that even though they had been on a tour, they thought that extra information was required.
3. Having all buildings in full detail is necessary.
All groups except 1a thought that there was sufficient detail. This is interesting, as group 1a were knowledgeable about the area and they had completed a tour prior to the evaluation. Therefore their comments will need to be further investigated.
4. I could understand the area with less detail in this 3D model, which would provide me with an adequate mental representation of the area.
Group 2b thought that more detail was required. This group had no prior knowledge of the area and they had not been on a tour prior to the evaluation. The other part of the ‘no knowledge’ group (2a) thought that the level of detail was sufficient, but they did not indicate a full support of the amount of detail. Therefore, when users have little knowledge of the area they will respond better to the model if a tour is conducted prior to actually using the tool.
5. Less information / detail would still allow me to build a mental image of the area.
Again, those who had no knowledge of the area could not accept a model with less detail. And, the members of this group who did not undertake the tour indicated that they could not work with less detail. This again supported the concepts that having knowledge of the area allows for a simpler model to be provided, and that a pre-use tour assists in better exploiting the model.
6. Having all elements in full detail makes the image too complex. (ie it has a negative effect, rather than improving the model)
All candidates generally disagreed with this statement. The level of detail did not make the tool more complex.
7. I need the addition of street signs for me to orientate myself.
Street signs were added to the model after feedback from previous evaluations. A typical street sign is shown in figure 5.

The inclusion of the street signs were supported, but less so by groups 1b and 2a. (Later comments about the inclusion of the street signs included: “Street signs also provide human scale in terms of height”.
8. ‘End-of-the world’ images makes the 3D image look more real. These images were added to the model so that it did not appear to ‘end’ at the edge of the VRML world.
All candidates supported the inclusion of end-of-the-world images.

9. Adding light poles and wires makes the 3D image look more like an inner Melbourne shopping strip.
This inner urban area ahs the usual trappings of overhead wires, poles and banners. The test prototype provides the option of having these items 'on' or 'off'. The images in figure 7 illustrates this.
All candidates thought that the addition of these items was necessary.
10. Changed environmental conditions make the 3D world more appropriate for better visualizing local conditions.
The prototype model allows for the environmental conditions to be changed – sunny to overcast, day to night. These items can be chosen by selecting the appropriate radio buttons in the interface. However, the test candidates did not think that the addition of this function enhanced the tool use. These different environmental conditions are shown in figure 8.
11. The area consists mainly of small shops.

Fig. 5: Street sign.

Fig. 6: End-of-world image

Fig. 7: World with and without wires, poles, etc.

Fig. 8: From top: during the day and sunny, overcast and at night.

All candidates thought that this was the general concept of the area, both before and after the tour. Group 2a thought that the area consisted of more than ‘just shops’. This perception of the area was considered in the next question.
12. The area consists of shops and some significant buildings.
All candidates agreed with this statement. Therefore, it is thought that all of these elements must be provided in the model.
A summary of the results from the evaluations is provided in the following table (table 1).

		Group 1		Group 2	
No.	**Questions**	a	b	a	b
1	The amount of detail is sufficient.	☺	☺	☺	☺
2	There are adequate landmarks to assist me in orienting myself.	☺	☺	😐	☺
3	Having all buildings in full detail is necessary.	☺	😐	😐	😐
4	I could understand the area with less detail in this 3D model, providing me with an adequate mental representation of the area.	☺	😐	😐	☹
5	Less information/detail would still allow me to build a mental image of the area	☺	☺	😐	☹
6	Having all elements in full detail makes the image too complex. (i.e. it has a negative effect, rather than improving the model)	☹	☹	😐	☹
7	I need the addition of street signs for me to orientate myself.	☺	😐	😐	☺
8	‚End-of-the-world‘ images makes the 3D image look more real.	☺	☺	☺	☺

9	Adding light poles and wires makes the 3D image look more like an inner Melbourne shopping strip.	☺	☺	😐	☺
10	Changed environmental conditions makes the 3D world more appropriate for better visualizing local conditions.	😐	☺	😐	😐
11	The area consists mainly of small shops.	☺	☺	😐	☺
12	The area consists of shops and some significant buildings	☺	☺	☺	☺

Tab. 1: Summary of questionnaire results.

3.2 Landmarks

Candidates were asked to identify what they thought were the landmark buildings in the area. That is, if only some buildings could be shown in full detail and others in outline mode only, which buildings must remain in full detail to allow you to properly navigate through the area. As well, these 'landmark' buildings, plus all other buildings as outlines would enable candidates to build a 'mental image of the area. They were asked to consider that the model must provide them with sufficient information for them to be able to make informed comments about potential developments in the area.

Landmark recall was best for those groups who undertook the tour, and worst for the group with little local knowledge and no tour.

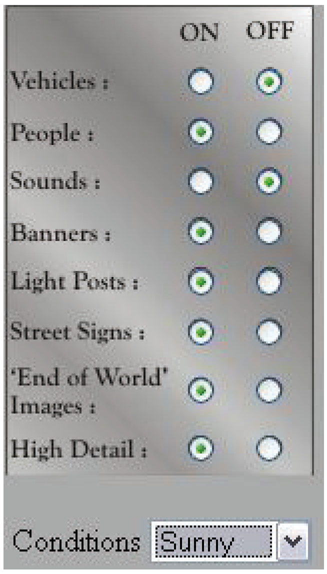
Candidates indicated that all landmark buildings must remain in the model.

3.3 Inclusions

The final section was a general discussion with the entire group. Here we wanted to find out what the best combination of the world might be. We wished to ascertain which additional world elements are appropriate for inclusion in a model that consists of only landmarks, outline only secondary buildings and additional elements.

During this part of the evaluation candidates were asked as a group to decide which elements should be included – using the ON/OFF buttons that the demonstrator clicked. These buttons are right of the Web page shown in figure 3. An enlarged section of this figure is shown in figure below:

Fig. 9: Control panel.



In addition, candidates were asked to provide information about the combination of items that they thought should be included. This was a combination of the on/off elements shown in figure 9.

Those with a local knowledge of the area wanted traffic to be added and that street signs were necessary. Those with no local knowledge liked the night/day function and they thought that the street signs were useful. They indicated that perhaps the model would be improved if we were to add signs to specific features, like the railway station. They also thought that the model needs cars in the street and landmark buildings. They generally thought that the more detail the better.

General comments were also solicited from the group. Their comments are summarized below

Group 1 – Local Knowledge

- – If detail could be added, it should, as it improves the understanding of the area.
- – As the area has heavy traffic, this should be added.
- – Street signs are an excellent inclusion.
- – Less detail means that the 'feel' of the environment is lost.

Group 2 – no local knowledge.

- – Night/day function useful.
- – Street signs useful.
- – Perhaps add signs to specific features, like the railway station.
- – Needs cars in the street.
- – Needs landmark buildings.
- – The more detail the better.

And general comments from both groups:

- – Include end of the world images
- – Landmarks need to be left at street corners.
- – If only landmarks are shown, then the character of the area is lost.

4 Conclusion

This research project has evaluation 3D models for community collaborate decision-making support in three stages:

1. An initial qualitative evaluation of an Alpha product with an expert group of users;
2. Testing how the 'geographical dirtiness' of the Virtual Environment changes the perception of a space; and
3. Discovering the appropriate wayfinding aids needed in the model to support searching and exploration.

This paper has reported on the last of these stages. It focussed-on two questions: 1. What is the minimum number of landmark buildings that should be included in the model so that it provides adequate information about the area? And, how does a priori knowledge of an area change navigation and exploration abilities when 'moving through' and exploring the Virtual World? That is, how is the perception of a place, built through the use of a virtual environment, modified by prior knowledge of an area being studied / explored? The study was done with two evaluation groups – one with knowledge of the area and another without this knowledge. As well, tours of the area were conducted to ascertain the trade-off between time taken to tour the area and the time involved in further enhancing the model.

The results reported in this paper will be used to further enhance the model and to make it more useful for community groups involved in 'grassroots' planning deliberations.

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The third dimension in LBS: the steps to go

Sisi Zlatanova, Edward Verbree

Abstract

Computer technology has evolved to a position of being able to handle large three-dimensional (3D) data sets. The third dimension is already taken for granted for visualisation on desktop machines. Nasa World Wind and Google Earth demonstrate the possibilities of 3D to all users of the Web. The same way, mobile computing is experiencing a similar evolution. Despite the fact that 3D mobile hardware and software technologies are currently still behind desktop 3D in terms of capabilities, the expectations are for 2-3 times faster maturing. Are the geo-specials ready to step into the third dimension?
Location-based services (LBS) are among the first applications that naturally should consider the third dimension. In this paper we analyze the readiness for 3D LBS. The paper concludes on the role of the geo-specialist in this process.

1 Introduction

Location Based Services (LBS) are often referred to as 'location-dependent' GIS. Starting form this point, the analogy between 3D GIS and 3D LBS is quite straightforward. LBS have two more components compared to GIS: position determination and wireless communication. The simplest, trivial way of position determination is using global navigation satellite system. The accuracy and reliability of 3D satellite positioning has improved drastically in the last several years and the GPS receivers have become cheaper and affordable for everyday use. The bandwidth of the communications also increases. In many countries UMTS is already operational, which promises sufficient speed for transmissions of 3D data (often resulting in large amounts). What are then the bottlenecks for 3D LBS?
Open Geospatial Consortium (OGC) has prepared Location Services (OpenLS) Implementation Specifications for core services. In these specifications, the role of 'GeoMobility Server' is providing requested information considering the location of the user. The minimum number of services is also defined as *directory*, *navigation* (route), *location utility*, *gateway* and *presentation* (see Figure 1). The five core services are considered sufficient for a variety of use cases such as proximity (find something in a given area), fencing (alert users in a given area), navigation (compute route) and tracking ('record' the way a user) as specified in Torg et al 2005.
3D LBS have to be able to ensure the same set of services, i.e. proximity, fencing, routing and tracking but in 3D. Example of 3D requests would be 'show to me all the electrical switches in a building' (proximity) (see Figure 2), 'tell me when I am outside a dangerous section of a building '(fencing), 'compute a route to a safe exit' (routing), 'track this visitor all the way in the shopping centre' (tracking).
In terms of core services as specified in OpenLS, 3D LBS have to provide:

- 3D location utility, i.e. 3D positioning and geo-coding
- 3D navigation, i.e. route in multilevel constructions (buildings, viaducts, bridges, etc.)
- 3D directory, i.e. access to 3D data for example for tracking and fencing
- 3D presentation, i.e. 3D visualisation on mobile, hand-held devices and the appropriate interface for this.

Fig. 1: Request/response of GeoMobility Server as the position is provided by the communication netwrok

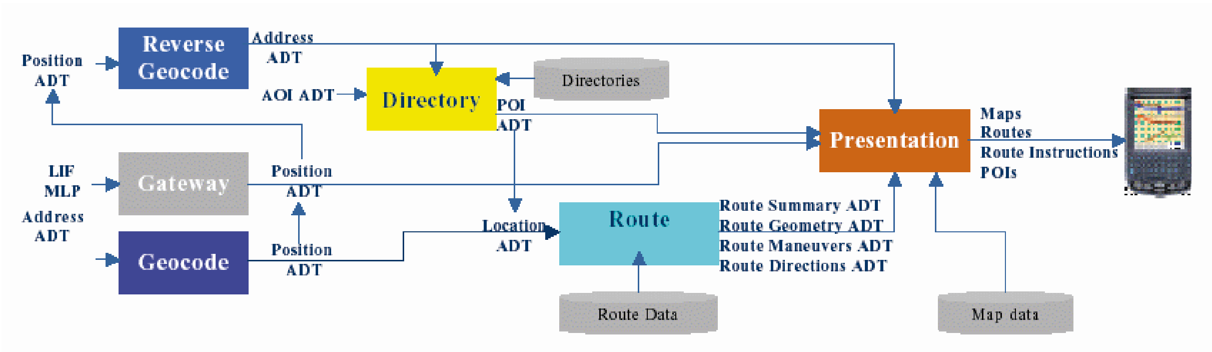


Fig. 2: request/response 'important power supply'

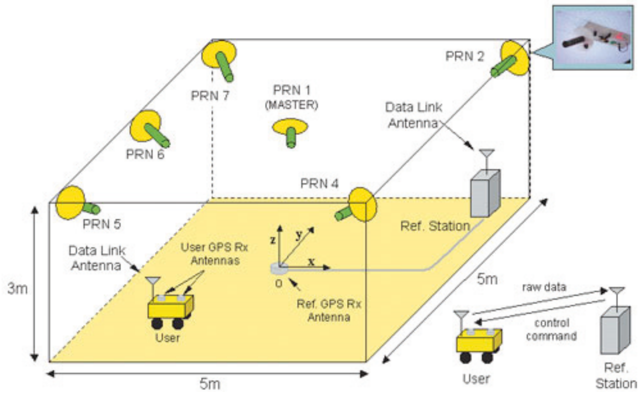


Fig. 3: Centimeter-Accuracy Indoor Navigation Using GPS-Like Pseudolites

The following sections address these challenging aspects in detail.

2 3D positioning and geo-coding

It is also in the name: a location-based service needs to be aware of the location of the user. Position determination can be done is several ways: by coordinates, address, ZIP code, etc. In fact, coordinates are hardly used. Descriptive postcodes and addresses, and linear reference systems like mileages marks along roads, are far more common to express a location than Cartesian reference systems. However, none of the exciting LBS or GIS-packages offer a kind of a Z-coding, thus a translation of e.g. 'at the base of this dyke' to '4.73 meter above NAP'. And no LBS can tell you what floor you are when you specify your location by only a GPS-coordinate.

2.1 3D positioning with GNSS

Theoretically, obtaining 3D coordinates at global scale is available. GPS-devices, and other receivers to Global Navigation Satellite Systems (GNSS) like Galileo can compute either Cartesian (X,Y,Z) or ellipsoidal (latitude, longitude, height) WGS84 coordinates. In multi-level 3D structures, the problem may come from two sides: geo-coding of the height and availability of satellites. The altitude is given as the distance to the WGS84 rotational ellipsoid and it is difficult to be linked to expressions used in daily (3D) life by references like 'on/under the bridge', 'floor', 'base', 'ceiling', 'top', etc. It is well-know that a GNSS-receiver cannot work inside or at other places with a poor satellite coverage. Many systems exists that claim to solve that problem by applying another type of measurement technique, although all these systems are bases at either a kind of distance measure, a kind of angle measurement, or a combination of both. If it is not possible to detect enough GPS satellites in line-of-sight, some close-range pseudolites transmitters could be also used. For example, the company Novariant offers the so-called Teralite XPS systems, a single frequency ground-based signal generator broadcasting XPS signals to mobile GPS+XPS receivers, (www.novariant.com/mining/index.cfm). For indoor use a more dedicated pseudolite-only setup could be used, like the system shown in Figure 3, (Kee, 2001). However, if the user is free to move in height, the transmitters should be arranged in a more enclosed setting to obtain a reliable 3D-position fix.
It seams improbable, but television synchronization signals may be used to position a range of wireless devices that require location information. The system developed by Rosum provides according to their website: 'accurate, reliable location indoors, outdoors and in dense urban location' (www.rosum.com). The Rosum TV Measurement Module (RTMM) receives local TV and GPS signals, measures their timing, computes the pseudoranges and sends that information to the Location Server (LS). The LS computes the position of the RTMM and sends that location back to the RTMM or to the tracking application server (see Figure 4). In addition to the wide-area positioning system, Rosum also develops a limited-area, 3D positioning system. This system is used by first responders in emergency situations. Rescue personnel can be tracked from a field command center, reducing precious time spent giving location updates and eliminating blind searches in man-down situations, (see Figure 5).
Assisted GPS (AGPS) combines the better of two worlds: GPS and Mobile Networks. Simple stated (www.snaptrack.com/pdf/How_aGPS_works.pdf): When a caller makes a location request, the wireless network sends the approximate location of the handset (generally the location of the closest cell site) to the location server. The location server then tells the handset which GPS satellites should be relevant for calculating its position. The handset then takes a reading of the proper GPS signals, calculates its distance from all satellites in view and sends this information back to the location server. But still, in hard conditions like inside locations, it is still difficult to impossible to 'see' enough satellites and thus to obtain a position fix. Moreover, inside conditions and urban canyons are known to have multi-path problems, causing unreliable pseudo-ranges and thus fault determined positions.

2.2 Sound based position

Bats are known to use ultra sound for tracking themselves. This property is also used by the Norwegian Sonitor Indoor Positioning System (IPS) to track and position tagged equipment and people indoors (www.sonitor.com). The tags transmit ultrasound and ones

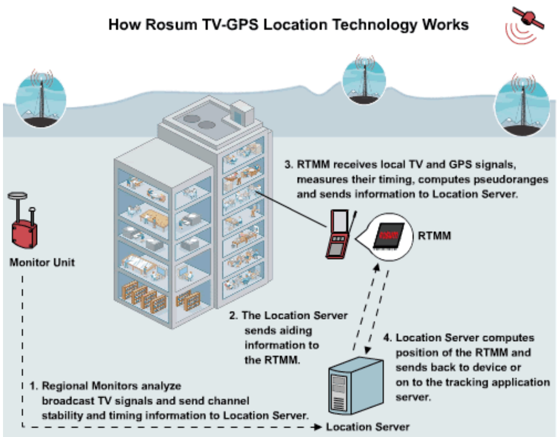


Fig. 4: Rosum TV-GPS Location Technology

Fig. 5: TV-GPS Plus Fireground First Responder Tracking Application

received by a set of microphones inside a room or corridor the positions and movement is calculated in real time, see. This kind of systems works only in special equipped environments, e.g. buildings.

2.3 Positioning using telecom networks

Mobile communication networks, like GSM, are used for commercial LBS applications as it is quite easy to reach a group of cellular phone users within the area of a certain base station (Cell of Origin) and send them for example an advertisement SMS. It is however also possible to position the users within a certain sector and range of the base station by Uplink Time Difference of Arrival. If that information is monitored over time and combined with a road network, the position of the cellular phone user can be detected in a more precise manner. The company LogicaCMG has developed the so-called Mobile Traffic Service where these locations are aggregated to real-time traffic information for the Dutch province of Brabant (www.mts-live.com), (actueleverkeers-informatie.brabant.nl).
Precise Mobile Network positioning requires considerable adjustments to the current GSM network setup, or the use of next generation networks like UMTS. But due to the more or less planner configuration of the GSM/UMTS beacons, accurate and reliable 3D-positioning by mobile networks is not possible.

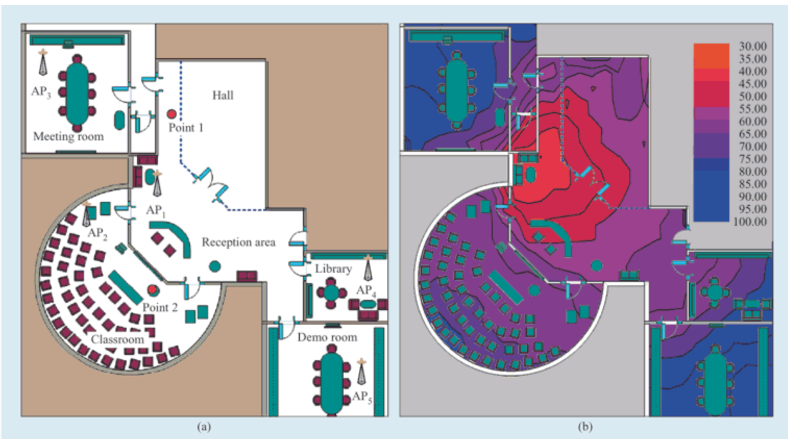
2.4 WLAN positioning

Each WLAN (Wi-Fi) network can be location enabled by signal strength calibration and fingerprinting. Within a neighborhood, i.e. an office, a map is made by a site survey of the reception of the WLAN access points. That is a challenging task, as the WLAN signals appear in an irregular pattern, since the propagation of signals is heavily affected by multipath effects, dead spots, noise, and interference in an indoor environment, see Figure 6 (Xiang, 2004) (Kaemarungsi, 2005). Once known, this map is 'turn around', to pin-point the location by a certain signal reception. One of the premier systems using this kind of 'fingerprinting' is the Ekahau's patented positioning technology (www.ekahau.com). One limitation is the calibration of the system; first of all known positions should be linked to the signal strength of the WLAN access points. This process should be repeated when a major change in the configuration of the WLAN access points is made.

2.5 RFID-UWB positioning and Sensor Networks

Radio frequency identification (RFID) is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. There are different systems. Ultra Wide Band radio systems can be accurate to about 6 inch (15cm) indoors because they are much less affected by multipath distortion than conventional RF systems. Ubisense uses both Time Difference Of Arrival (TDOA) and Angle of Arrival (AOA) which greatly reduces the density of sensors required to cover an area over systems that use just TDOA (www.ubisense.net).

Fig. 6: Layout testarea (a) and Contours (b) indicating the signal strength of Access Points



3 3D data management

Once the 3D position is determined, 3D data have to be available and accessible. Currently, most of the 3D data are available as 2.5 surface data, 3D city models and 3D CAD models. Furthermore the 3D information exists but is 'split ' between different organizations. For example, within the Netherlands the planimetry and height are maintained by two governmental organizations. The 'Kadaster' is responsible for the 'horizontal component' and 'Rijkswaterstaat' manage the 'vertical component' through the NAP benchmarks. One consequence of that organization is the mapping of the topography, as in the Dutch 1:10.000 scale TOP10Vector, which does not take the height value into account. At the moment the relative vertical situation is only expressed at certain 'levels'.

Depending on the position and the requested service different types of models and spatial operations could be needed. If the user is on the street, perhaps a 3D city model will suffice. If the user is inside a building, a tunnel or a bridge, a detailed 3D interior model might be required. Furthermore, 3D outputs for LBS can be in two forms: only retrieval of data for 3D visualisation and performing spatial operations (which are needed for example for 3D route calculations, 3D proximity, etc). Currently, retrieval of 3D data can be relatively easily organized (via Open Web services) from any system. Spatial analysis (3D routing, proximity) would require spatial operations. The common problem here is a lack of 3D operations and functions. Mathematical background for such operations exists but it still needs to be implemented in the systems.

In this respect, last developments in Geo-DBMS are quite promising. Currently geo-DBMS can maintain different models *geometry*, *topology*, and *graph*. While the geometric structure provides direct access to the coordinates of individual objects, the topological structure encapsulates information about their spatial relationships. A geometry model has been implemented in all mainstream DBMS (e.g. Oracle Spatial, Informix, Ingress, PostGIS, MySQL). Although the implemented spatial data types are 2D, 3D objects still can be stored. Topological implementation specifications are still under development, but commercial topological structures are already available (Laser-Scan Radius and Oracle Spatial 10g). A graph model is currently offered only by Oracle Spatial 10g. The combination of geometry model and graph model, i.e. the Network Data Model, can become a quite appropriate structure for 3D route calculations. While route calculations can be performed on the graph, 3D geometry can be applied for 3D navigation along the route.

4 Protocols/standards for data exchange

Present specifications allow even at this moment 3D outputs. The work of the Open Geospatial Consortium (OGC) and the World Wide Web Consortium (W3C) is the most relevant to the geo-information specialists with their specification for Web services and eXtensible 3D language (X3D). The Web services define request/respond interfaces between an application (e.g. running on a handheld) and GeoServer and X3D is the XML-based standard for 3D visualisation.

The Web services are currently four (WMS, WFS, WTS and WCS). The Web service for 3D is the Web Terrain Service (WTS). WTS specification defines a standard interface for requesting 3D terrain scenes from a server capable of their generation. A WTS service supports two operations: GetCapabilities and GetView. The view is defined as a perspective image. To be able to create this view, a number of parameters have to be provided to the server: Point-of-Interest (POI), i.e. x,y,z of user focus; distance between the user and the POI; the vertical angle between the user and the POI; the horizontal angle between the north direction and the horizontal projection of the 'user-POI' line; and the Angle of View. The server returns a raster image of the 3D data. To be able to use this service for 3D navigation for example, a series of images have to be generated (at the server) by continuous round-trips to the server. The images can be further organized in a movie and send to the user. The disadvantage is that an interaction with/navigation trough data would not be possible.

The Web Feature Service (WFS) is much more promising. The GetFeature request is an XML stream of vector data, i.e. Geography Markup Language (GML). GML geometry types allow for x, y and z-coordinates. Moreover GML version 3.0 introduces the 'Solid' geometry type, which can be used for 'full' 3D objects. GML 3.0 also offers the possibility to use a topological data structure (a 3D object as a TopoSolid with references to Faces, Edges and Nodes). This is to say theoretically GML does not have any limitations in maintaining 3D objects (geometry and/or topology).

However, the GML output of a WFS service is not a 3D scene yet. It has to be transformed into a graphic format for which visualization software is available. In this respect the best candidate is X3D. X3D is the XML version of the Virtual Reality Modeling Language (VRML). VRML was launched in the nineties and became an ISO standard in 1997, but never was widely used for geo-applications. The size of the VRML file could become very big (due to lack of appropriate streaming and compressing techniques), which could result easily in bad performance. X3D has improved structure (i.e. Core profile, Interactive profile, Interchange profile, and MPEG-4 interactive profile) and much more possibilities to control the size of the file and render efficiently. It is actually designed for implementation using a 'low-footprint engine' as on mobile devices. X3D was approved by ISO as International Standard ISO/IEC 19775 in early 2005.

To be able to visualize the 3D data, a X3D viewer has to run at the client (e.g. Cortona). De Vries and Zlatanova 2004 discuss an architecture that allows an application to request a 3D vector data. This approach can be applied for LBS as well, once accepted that the result of the request can be not only image but also other formats from the Standards Framework. The GeoMobility server then will act as a client to any GeoServer that contains 3D data.

5 3D presentation

Presentation of 3D data is still tricky. 3D visualisation (rendering) of the 3D outputs can be done in different ways: as a static 3D image, a video and as a vector model (allowing interaction). Furthermore, the parameters of the mobile devices can vary significantly: special devices (e.g. see-through glasses), portable PC to mobile cells. The type of device has huge influence on the possibilities for 3D visualization. In contrast to portable PC and tables, hand-held devices have many limitations: available memory, screen resolution and CPU. The type of operation system (Windows Mobile, SymbianOS, Smartphone, PalmOS, JV-Lite2, Linux, etc.) also varies. With these limitations even low-quality streaming video can be problematic.
Currently most of the 3D visualization on mobile is provided as a streamed video (Zlatanova et al 2004). VRML browsers for 3D interaction are offered only for PocketPC by ParallelGraphics (i.e. Pocket Cortona http://www.parallelgraphics.com/products/).
As discussed in the previous section interfaces between GeoMobility server and mobile devices are based on Web technologies. In this respect, several technologies might be important for 3D rendering on mobile: X3D, MPEG-4 and PDF. X3D is quite promising technology not only because of the features offered but also because of the attempts of the W3C to come to an agreement with other groups developing standards. Moving Picture Experts Group (MPEG) has accepted X3D for the 3D capabilities of MPEG-4. Furthermore special mobile 3D technologies to extend X3D are also being defined for MPEG-4. Adobe Acrobat also has step into third dimension and provided interactive 3D browser inside the PDF file (http://www.adobe.com/products/acrobat/aec.html). Since PDF reader is already offered for hand-held under Windows Mobile, it could be expected that the next step will be a 3D PDF file for hand-held. The size of the PDF file (rounding to MB) and the lack of PDF streaming technology are currently the main drawbacks.
In general, the use of these standards in 3D application development for low-end consumer and embedded devices is still problematic, mostly because of the large footprint imposed by underlying implementations and heavy utilization of hardware acceleration. The two Java technology specifications the Mobile 3D Graphics API for J2ME (JSR 184) and the Java Bindings for OpenGL ES specification (JSR 239) were expected to help significantly in accelerating this process. Nokia working in collaboration with Motorola, Intel, Sony Ericsson, Symbian, Cingular Wireless and France Telecom led the Mobile 3D Graphics API. The Java Bindings was led by Sun Microsystems. While successful for game industry, they did not have a lot of influence on geo-applications. As it is well-known a large amount of geo-applications are running nowadays under Windows. But, Microsoft also increases its investments in mobile developments. For example Mio A701, the first GPS-enabled smart phone with Windows Mobile 5, is already on the market. The Microsoft interest in mobile computing can be a stimulator for many GIS vendors to provide browsers and applications for mobile.
Other non-standard solutions are also showing up. The typical polygon (triangle) rendering has a volume-based graphics, which might bring advantages also for mobile computing (http://www.ngrain.com/alliances/files/NGrain2.pdf). A very elegant way of 3D LBS might be the usage of see-through glasses based on augmented reality approaches. Augmented reality offers a lot of advantages compared to traditional desktop and especially telephone cells due to: better understanding (the background view is real world) and faster retrieval and rendering (e.g. only the computed 3D route is visualised). However these systems are still unreliable and quite expensive for a daily use.

6 Conclusions

This paper has discussed four critical components of LBS in the light of the third dimension: positioning, interfaces, data management and visualization. The general conclusion is that sufficient technology possibilities for 3D exist (also Zlatanova and Verbree, 2003) but they have to be appropriately combined and connected. The role of geo-specialist in 3D LBS is to provide the 3D position and find (and deliver) the requested 3D data.
Regarding 3D positioning we can conclude:

- As all systems are based on the same set of observable quantities (distance and angle) many correspondences exists in techniques and methodologies. To choose with system performs best in certain conditions depend on these circumstances. Important factors are: inside conditions, user controlled setup and maintenance of the reference beacons, active or passive targets, and the role of a GeoMobility Server.
- The integrity of the 'space segment' (the beacons) of all presented systems, except GNSS like GPS, is not controlled and maintained. This will lead to unreliable positioning of the targets.
- Most systems are presented as 'stand alone' solutions, due to commercial interests. As no system operates best under all circumstances, the reliability will be improved and ensured when the systems are more integrated.
- The OpenLS specification has to be further extended to work with Z-coordinates and provide 3D geo-coding.

Regarding the interface, we firmly believe that the communication between GeoMobility Server and the mobile client will be based on Open Web Services, which still require appropriate 3D adaptations, e.g. for exchange of parameters needed to complete WTS and WFS.
Apparently, it will not be possible to organize all the 3D data needed for 3D routing and other analysis on the same server where the GeoMobilty server will operate. 3D LBS will be based on a distributed system combining GIS, CAD and geo-DBMS. This poses great challenges to geo-specialist towards improving the performance by developing better 3D data organization, indexing, generalization and compression. All issues are already addressed in literature on 3D GIS.

3D visualization on mobile is not a problem anymore, but the geo-data have to be adapted for the device and the user. 3D generalization, usage of textures (or not), 3D symbolization, visualization clues for attention attraction, etc. are all tasks of geo-specialists.

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“Cross the river and then follow the tracks”: overview information on the way to take

Kai-Florian Richter

Abstract

Wayfinding support is an important application of mobile systems and often an (integral) part of location based services (LBS). If needed, these systems may offer their users information on getting to a specific destination. Usually, these instructions are given incrementally, i.e. only the next decision due is communicated to the user. Thus, such systems do not offer any survey information; users get no idea on what to expect along their trip. To reduce this limiting dependency and to be able to cope for potential system‘s failures, users should be provided with an overview on the route to take. In this paper, we present work in progress on an approach to generate this overview information. It provides in-advance information on the crucial parts of a route—the major reorientation points. The presented methods are based on our model for context-specific route directions: the generation process results in an abstract relational specification of the instructions reflecting conceptual elements of route information, which may then be externalized in different modalities. We argue that presenting overview information on a route that concentrates on the relevant reorientation points enhances navigation systems without distracting a user with unnecessary detail.

1 Introduction

One major application of today‘s mobile systems is wayfinding support. Nowadays, car navigation systems are in wide use and more and more systems for bikers and pedestrians can be bought off the shelf. Even if wayfinding support is not the system‘s main purpose, such as is the case with location based services (LBS)—their aim is to provide a user with location-specific information on her current requests—usually there is still some underlying functionality that supports wayfinding: in the case of LBS, for example, to provide users with instructions to a requested shop or gas station in the vincinity of their current position.

We term such instructions for getting to a specific destination route directions (e.g., Denis, 1997). They are task-oriented specifications to be carried out to reach the destination (e.g., Tversky & Lee, 1998; Schweizer et al., 2000). We use the term route directions generically to refer to any form of instructions for following a route; verbal, graphical, gestures, or a mixture of these. Route following comprises two basic processes: getting to a decision point and once there, determining the further direction to take (e.g., Daniel & Denis, 1998). That is, the main purpose of route directions is to support a wayfinder in deciding on how to proceed at a decision point.

Route directions can be distinguished into two broad categories: in-advance and incremental route directions. In-advance directions are presented to the user before the trip starts. They provide instructions on the complete route, i.e. on every decision point between origin and destination. This kind of route directions is, for example, generated by internet route planners. In incremental route directions, instructions are given step-wise, a single instruction for just the decision point the wayfinder is currently approaching. Such instructions are typically generated by mobile systems as here the device‘s location is assumed to be co-located with the user‘s, which enables the device to determine the required timing of the issue of the next instruction (cf. also Maaß, 1993; Habel, 2003).

While the latter—incremental route directions—are sufficient to keep users on track and allow them to keep their cognitive load low as they do not need to remember any instructions, they do not offer them any survey information, i.e. users have no idea on what to expect along their trip. This forces them to rely completely on the system in their wayfinding. To reduce this limiting dependency and to be able to cope for potential system‘s failures, users should be provided with an overview on the route to take before their trip starts—or in fact any time they feel like it. In the following, we present an approach to generate such descriptions. The approach is based on the model for context-specific route directions (Richter & Klippel, 2005), which is designed to produce complete in-advance route directions but can be extended to match our purposes.

The next section introduces the model for context-specific route directions, focusing especially on its underlying systematics of route direction elements. Section 3 then discusses benefits and properties of the aimed for overview information in more detail, while Section 4 presents an outline of principles and methods to generate such overview information.

2 Context-specific route directions

In our research on route directions, we focus on people‘s conceptualization of routes and the actions necessary to (successfully) follow them. We define conceptualization to be the (process of forming a) mental representation of a route. A route is represented as

a sequence of decision point / action pairs (cf. also Daniel & Denis, 1998). Hence, more precisely, conceptualization is (the process of forming a) mental representation of an (expected) decision point sequence with their accompanying actions. We have developed a model that aims at creating route directions supporting this conceptualization: the generated route directions should be easy to process, i.e. they should support forming and processing a representation of the corresponding route. This also eases route following as understanding a route direction is a prerequisite for using it (cf. Dale et al., 2003).
We coin the route directions generated by our model context-specific route directions. We use this term to emphasize that our model explicitly adapts the resulting route directions to the situation at hand, i.e. to the current action to take in the current surrounding environment. This reflects Dey and Abbowd‘s definition of context: “[...] any information that can be used to characterize the situation of an entity” (2000, p.3). For this adaptation, we need to account for the characteristics (the structure) of the environment in which route following takes place; the structure of an environment strongly influences the kind of instruction that can be given. The following structural aspects contribute to this influence: the embedding of the path—that is induced by the route—in the spatial structure surrounding the path, the structure of that path itself, path annotations, and landmarks that are visible along the path. Furthermore, different reference systems provide alternatives to describe necessary actions to follow a route (cf., e.g., Tenbrink, 2005). An analysis of routes and route directions as well as the spatial knowledge required to determine and interpret them results in a systematics of elements that may be used in route directions (cf. Richter et al., 2004; Richter & Klippel, 2005). This systematics is summarized in Table 1; it is the basis for our generation process of context-specific route directions.

Global References	Paths, Routes, and Landmarks
cardinal directions	egocentric references
global landmarks	routemarks at decision point
Environmental Structure	routemarks between decision points
edges	distant routemarks
districts	linear routemarks
slant	path annotations

Tab. 1: Systematics of Route Direction Elements

In our model, route directions are represented as abstract, relational terms. They are a conceptual representation of the action to take at a decision point. For each element of the systematics, we define corresponding relational terms, which instantiate all possibilities of referring to the elements in route directions. As an example, consider a situation where the required action at the first decision point of a route is to take the left branch, which is also marked by a sign leading to a train station. The instruction corresponding to the required action may be represented as (DP1, left)—using egocentric references; as an alternative, the same action may be represented as (DP1, follow / sign ‚station‘)—using the sign to the train station as path annotation.
To generate context-specific route directions, we need to choose from all possibilities to represent an action the one that best fits our aim to ease conceptualization of the route to take. That is, for each decision point along the route we choose an abstract instruction, whose externalization most likely eases its conceptualization. This choice may depend on the kind of instruction chosen for previous or following decision points. Accordingly, the generation of context-specific route directions is realized as an optimization process: initially, for each decision point all possible instructions are generated, i.e. each description that unambiguously marks the action to take. Then, in the optimization step, from each decision points‘ set of possibilities the instruction that is best according to the chosen optimization criterion is chosen (cf. Richter & Klippel, 2005, for a discussion of possible optimization criteria). In optimizing, the model exploits an important principle of conceptualizing routes and giving route directions: spatial chunking, the combination of several decision points into a single instruction as it, for example, becomes apparent in instructions like “turn left at the third intersection” (cf. Klippel et al., 2003).
The model has been designed to produce complete in-advance route directions covering all decision points. But it can be extended to the generation of coarse route directions that provide an (in-advance) overview on a route; this is further elaborated in Section 4. The next section discusses properties of such overview information.

3 Overview information on the way to take

Route directions as discussed in the introduction offer information on how to proceed for every decision point along a route—be it that the information is presented all at once (in-advance) or step-wise (incremental route directions). This information is needed to correctly execute route following, i.e. to get from origin to destination along a specified route. Such route directions are segmented at decision points. Each instruction covers one or several decision points and following an instruction a wayfinder always ends at a decision point (cf. Habel, 1988; Klippel et al., 2003).

Overview information on the way to take, on the other hand, provides only coarse route directions. Such route directions are well suited for an initial, quick overview; they allow a wayfinder to get an idea on what to expect along the route. That is, they provide a supplement to incremental route directions as offered by mobile systems. They limit a user‘s (felt) dependency on the device during wayfinding since she does not need to follow the device‘s instructions blindly anymore. To account for restrictions that play a role in developing and using such applications, like small display size of mobile devices and users‘ limited cognitive capacity (cf.

also Wahlster et al., 2001), we need to take account of certain principles of generating coarse route directions: even more than in ordinary route directions (cf. Denis, 1997), coarse route directions should not distract and bother users with unnecessary detail. Therefore, we concentrate on those points along a route, which are crucial to keep the right (overall) direction. At these points, significant changes occur; they are the major reorientation points along a route.

Concentrating on major reorientation points corresponds to the planning level in wayfinding as explained, for example, in Timpf et al. (1992). While the level of actions requires information on all decision points in order to take the correct turn, the planning level requires less granularity in information, i.e. less detail. On this level, coarse information is sufficient as the aim is to provide just an overview without bothering users with details on how to actually execute route following. This is, for example, reflected in the approach by Höök (1991), who generates route directions for local residents who are assumed to know the place fairly well. In this case, several roads are subsumed into a high-level instruction and details, like small roads, are omitted. Hence, conceptualization of such coarse route directions can also be just coarse and leaves many parts of the route underdetermined.

Coarse route directions do not guarantee that a wayfinder strictly follows the intended route, i.e. the route determined by the computational system. This is because segmentation of a route is not done at decision points, but is based on major reorientation points. These points divide a route into regions. The regions comprise of the area between two reorientation points; each instruction in a coarse route direction covers one such region. Coarse route directions guide a wayfinder from one region to another without fixing a specific route between these regions. Consequently, if just relying on coarse directions, it is up to the wayfinder to fill these gaps with her own decisions on the exact route to take (for an overview on human region-based navigation see Wiener & Mallot, 2003). In case of combining coarse route directions with incremental route directions, the mobile device may provide information for these in-between routes.

4 Generating Overview Information: An Outline

In order to generate overview information on a route, i.e. coarse route directions, the major reorientation points along the route at hand and their accompanying regions need to be identified and instructions providing coarse information on how to reach these points need to be generated. To that end, we make use of the elements of the systematics (Table 1) that are applicable in coarse route directions. Looking at this systematics, those elements on coarser levels of granularity, i.e. those that abstract from single decision point / action pairs to a great extend, are suited for generating overview information. This holds especially for elements of the first two levels of the systematics—the level of global references and the level of environmental structure. From the level of paths, routes, and routemarks the elements distant routemark, linear routemark, and path annotation are used, as they also strongly abstract from single decision point / action pairs.

Except for cardinal directions, instructions using these elements need to include a statement announcing until which point they hold, i.e. when the corresponding action like following a linear landmark ends and a change of action occurs. We term such a statement end qualifier; an example for an end qualifier is "until the gas station" in an instruction like "follow the river until the gas station". End qualifiers are required with those systematics' elements that allow to combine (potentially) many decision points into a single instruction (cf. Klippel et al., 2003; Richter & Klippel, 2005); they announce changes of action after a (potentially) considerable part of a route. Hence, end qualifiers play an important role in coarse route directions. As argued in the last section, segmentation of coarse route directions is done along major reorientation points, not at decision points. End qualifiers are well suited to mark these reorientation points. In the same line, confirmation information, which is used in detailed route directions to assure a wayfinder that she is still on the right track, may become "real" instructions in coarse route directions. Coarse directions are supposed to indicate the overall direction towards the destination. Confirmation annotations, like "cross the river", are well suited to indicate this direction—since that is exactly what they are used for in detailed route directions.

Consequently, for generating coarse route directions there are two elements of our route's representation that may be exploited: first, those decision points that mark the end of a chunk, i.e. at which an environment's feature, usually a routemark, may be exploited as an end qualifier for instructions. Second, route segments along which confirmation annotations can be determined —that are based on references to edges (‚cross edge') or routemarks between decision points (‚pass routemark')—may be part of a representation of coarse route directions. These route's elements mark the border of a region, which a wayfinder may pass without (significant) change of action; termed region of equal directedness. This directedness is equal relative to some feature, i.e. to one of the route direction's elements. Examples include "follow the river" or "go in direction of the TV tower". In the former example, a linear routemark induces the directedness—'keep next to the river'—in the latter, a distant routemark sets the direction—'lessen your distance to the tower and keep it in front of you'.

Such directions typically hold for several consecutive decision points. This sub-sequence of a route's decision points makes up one of the regions induced by major reorientation points. Now, to fullfil the requirements of overview information discussed in Section 3, i.e. providing an initial idea on the route without distracting a user with a lot of details, the aim in generating coarse route directions should be to cover as much of the route with as few reorientation points as possible. That is, coarse route directions should comprise of a few, large regions. Like in the original model for context-specific route directions (see Section 2), generating overview information can be solved as an optimization problem. The optimization process is very similar to the original one—accordingly, we can re-use the same algorithms.

Determining coarse route directions then requires some heuristics. First of all, if we aim for as few reorientation points as possible, we, consequently, aim for as few chunks as possible. Put in other words, we are looking for chunks that cover as much decision points as possible: the optimization criterion is to aim for the miminal number of chunks. For optimization purposes, we need to determine the chunks using the systematics' elements suitable for coarse route directions; just as with context-specific route direc-

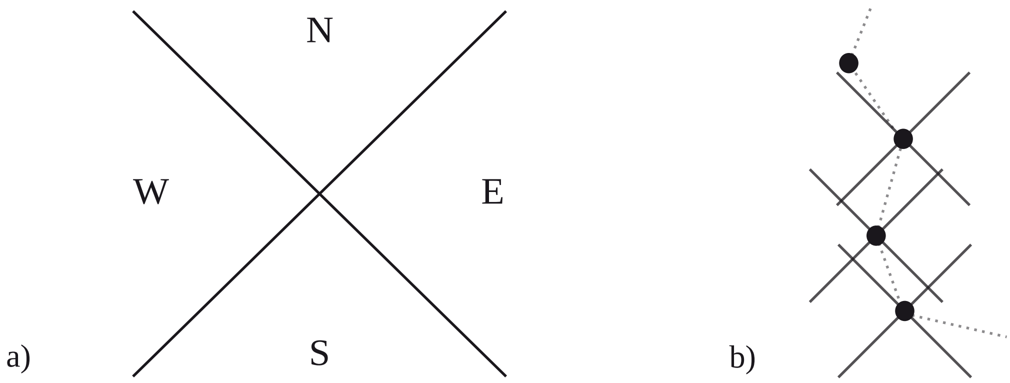

Fig. 1: a) four-sector model of cardinal directions (cf. Frank, 1992); b) chunking decision points (the dots) of a route (the dashed line) with equal directedness based on the four-sector model.

tions, we start by creating every possible chunk and use this set of chunks as basis for optimization. This way, it is guaranteed that we cover the complete route; however, this may not be desired as it may lead to more detail in the coarse directions than necessary. Therefore, we need to apply additional heuristics, which on the one hand allow leaving parts of the route unconsidered, and on the other coarsening instructions by abandoning the need to generate directions that are necessarily unambiguous.

Development of these heuristics is current work. As an example, let us consider generating coarse direction information using cardinal directions. First, to determine such directions, we need a cardinal direction model like, for example, one of those presented by Frank (1992). This allows calculating the cardinal direction to take (e.g. ‚north‘, ‚southeast‘, etc.) at each decision point; for our purposes of coarse directions we choose a four-sector model (‚north‘, ‚east‘, ‚south‘, ‚west‘) that itself already provides just coarse information (see Fig. 1a). A possible heuristic is to add decision points to the cardinal direction-chunk as long as the decision point at hand lies in the previous sector and the direction to take corresponds to the initial direction (Fig. 1b).

As an open issue remains the question how we can deal with minor deviations from the overall direction? That is, we need to extend the heuristics in such a way that in determining coarse cardinal directions it ignores small route-segments that lead in different directions. To that end, two factors may be used for a threshold: the length of the deviating route-segment and the degree of deviation, i.e. the deviating angle‘s size. Similar heuristics need to be applied for generating coarse directions employing the other systematics‘ elements.

Another open issue is the externalization of coarse route directions, i.e. ways to present this information to users. Verbal presentation—either written or spoken—is easily realizable by developing a parser for the abstract directions generated by our model and seems to be well suited, since verbal instructions typically are underdetermined and may leave many relations unspecified. Graphical presentation, on the other hand, needs to settle for exactly one instantiation due to the representation medium‘s properties; it is, therefore, often taken to represent veridical information. Hence, suitable schematization means need to be developed to indicate that the information presented is only coarse and may not be complete (cf., e.g., Agrawala & Stolte, 2001; Klippel et al., 2005, for such approaches).

5 Summary

In this paper, we presented ongoing work on an approach for providing overview information on the way to take. It is based on our model for context-specific route directions, which allows generating in-advance route directions that aim at being easily conceptualizable. This model can be extended to determine coarse route directions, which concentrate on the major reorientation points along a route; we outlined how to determine these reorientation points based on an optimization process and suggested some initial heuristics for further abstractions needed to concentrate just on the crucial information.

Coarse route directions provide an initial overview on the route to take, i.e. allow a wayfinder to get an idea of what to expect along a route, without bothering and distracting her with unnecessary detail. In mobile systems providing incremental route directions a user is forced to rely completely on the system in her wayfinding. Overview information relieves a user from this (felt) dependency as she does not need to follow the instructions blindly anymore. Hence, we argue that such coarse route directions ideally supplement incremental route directions as provided by mobile systems and should be incorporated in such systems as an option a user can choose.

Future work comprises development of additional abstraction heuristics, (graphical) externalization means for coarse route directions, and an evaluation of the model‘s performance.

6 Acknowledgements

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The least risk path in 3d: the "use case" of indoor navigation

Eva Grum

Abstract

The intention of the work in the area of pedestrian navigation is to combine the risk value of getting lost for the outdoor area and the indoor area. Previous work was the definition of the least risk path of getting lost (Grum, 2005) and the calculation of this path in the *two*-dimensional outdoor area. The formula for finding the least risk path must include a risk value of decision points and a cost value of street segments (Grum, 2005). For getting a formula for the indoor navigation the height must be considered.

1 Introduction

Getting lost in indoor areas is an important aspect considering the risk of getting lost. "Wayfinding in Build Enivironment" (Raubal, 2002) takes navigation in airports as an example to address this issue.
Previous work shows the possibility to calculate the risk of getting lost of a path. This risk is measured in a value that is called the risk value. This risk value is defined by the costs of a path. With the result of this calculation the least risk path can be defined.
"Modeling Costs of Turns in Route Planning" (Winter 2002) proposes a way to model costs of turns. What Winter in his paper calls "reaching the end of an edge" corresponds to "decision points" in our definition of the least risk path. In both cases the user has to make a decision at this point and select where to continue. The least risk path of getting lost is additionally defined by costs. These are costs of making wrong decisions added up with costs that depend on the length of the path. The result is a risk value of a whole path that can be transformed to costs.
The remainder of the paper is organized as following. Chapter two defines the least risk path. In the third chapter the risk value is explained and the content of chapter four is the calculation of the risk value. This part is split in the calculation for the outdoor and the indoor area. The combination of the calculation of these two areas is done in chapter five. Conclusions are presented in the last chapter.

2 The least risk path

The least risk path is defined by the least risk of getting lost in outdoor and indoor areas. Using this path is the optimal and securest way to the destination without getting lost. The assumption for the user is that he can follow a wrong path but he recognizes this on the next decision point and turns back to the last decision point where he was sure that he was right. Included in this path are all possibilities to make wrong decisions and to follow wrong paths. But the values of the street segments of the wrong paths are not as high as the values of the street segments on the other paths. Other paths are all possibilities to move from the starting point to the destination in a street network. The shortest path (Dijkstra) and the simplest path (Duckham) are both feasible to calculate and are also included in the terms "other paths". The condition for the path with least risk of getting lost is, that the sum of the street segments that would be wrong, is smaller than on all other possible paths between the starting point and the destination. The length of the path with the least risk of getting lost is in the most cases higher (longer) than on the shortest path (Dijkstra) and on the simplest path (Duckham).
Result of previous work was the formula to calculate the risk value of getting lost for the outdoor area. The path with the smallest risk value, i.e., with as less costs as possible is the least risk path. The calculation for this path is shown in the fourth chapter of this paper.

3 The risk value

This value is a combination of the length of the street segments between the decision points, the values of the decision points, and the values of the street segments that would be wrong. Decision points are all crossings where the user has to make a decision, even if the instruction for the user tells one to follow the street straight ahead. The result of this calculation is the cost of the path. These costs can be transformed in risk units. The risk of getting lost is increasing the more costs accumulate on that path. For finding the path with least risk the costs of every decision point in the area must be calculated. The costs of all street segments that are considered in this area must be calculated as well. Finding the least risk path means searching for the way with as little costs as possible.

4 The calculation of the risk value

For the calculation of a path with least risk of getting lost, that includes outdoor and indoor areas, two kinds of navigation have to be combined. The navigation for the outdoor area includes *two-dimensional* areas whereas the indoor navigation includes *three-*

dimensional areas. Hence follow two different formulas and two different types of locating the user. For getting one result for an inquiry of a route for pedestrians that includes as well an outdoor as an indoor area these problems must be solved. How to calculate the risk value in the outdoor and the indoor area is shown in the next two sections.

Outdoor navigation

The calculation for the risk value of getting lost of a path for outdoor navigation includes the risk value of decision points and the value of the street segments. Each crossing where the agent can make a decision is defined as a decision point. The value of the street segments depends on their lengths. The risk value of a decision point includes the number of possibilities to walk, the number of possible choices, and two times the length of the wrong choices. With the assumption that the agent returns the same way after realizing at the next decision point that he is wrong, the length of the wrong choices have to be multiplied by two. The way the agent comes along is excluded. Possible choices are one more than wrong choices.

$$r_d = \frac{2 * \sum_{i=1}^{n-1} l_i}{n} \qquad r_p = \sum_{i=1}^{n-1} r_d + \sum_{i=1}^{n-1} l_s$$

Fig. 1: The calculation of the risk value of a decision point

r_p = risk value of the whole path
r_d = risk value of a decision point
l_i = length of the path that is wrong
n = degree of node minus 1
l_s = length of the segments that are right
n_d = number of decision points (nodes)

By adding the results of the calculation of the risk value of all decision points to the result of adding the values of all street segments the total risk value of the whole path can be calculated.

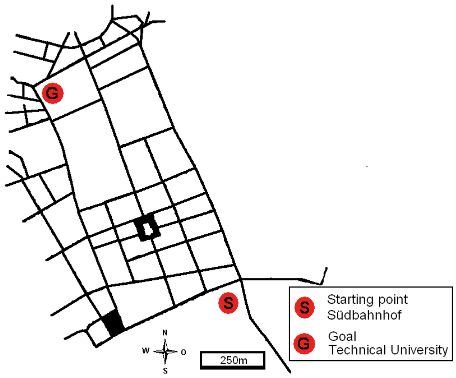

Fig. 2: The street network of the test area

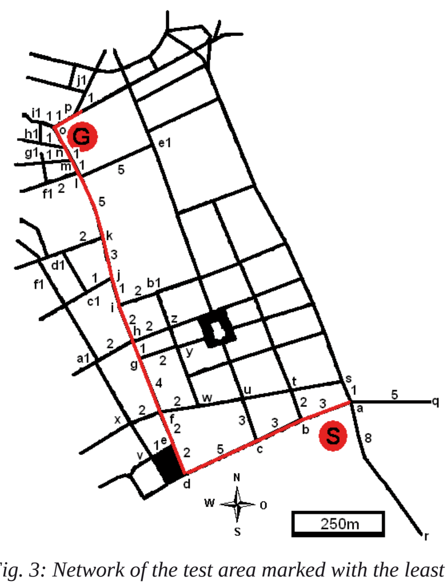

Fig. 3: Network of the test area marked with the least risk path, the length values of the street segments, and the label of the decision points.

The test area for the formula is the area between the station Südbahnhof and the building of the University in Vienna. The following figure shows the street network of this area.

The following figure shows the street network of the test area where the least risk path is marked. The numbers are the values of the street segments that depend on their length and the letters are the labels of the decision points. It is possible to see that the street segments that would be wrong have small values. This is the most important step of finding the least risk path in a street network. In the following figure the values of the decision points of the least risk path from our test area are shown. The risk values of the decision points of the other paths are higher because of the lengths of the possible wrong choices. The risk value of a path depends predominantly on the length of these wrong choices.

Indoor navigation

As base for the formula for indoor navigation the formula for outdoor navigation was applied. For the indoor navigation the third dimension, the height, has to be taken into account. For the three-dimensional indoor navigation the existing formula had to be transformed. Height differences in both directions, uphill and downhill, had to be included. Given that movement speed on the same level is about 5 km per hour, movement speed for uphill and downhill must be less. The standard assumption for uphill is 300 meters and for downhill 500 meters per hour. Going uphill is more exhausting than going downhill or moving on the same level. Thus the relation between the same level and uphill is 1:17 and between the same level and downhill 1:10.

A mean value of 3 meters of room height and 0,5 meters for the thickness of the ceiling is the assumption for the height difference between the floors to get an approximate valid for all buildings. This can be used to translate floor levels into height meters.

In the following mathematical constraint the three different possibilities to walk are defined:

h_c = height of the ceiling
h_r = height of the room
h = height difference between two floors
n = number of floors
l_s = length of the segments that are right

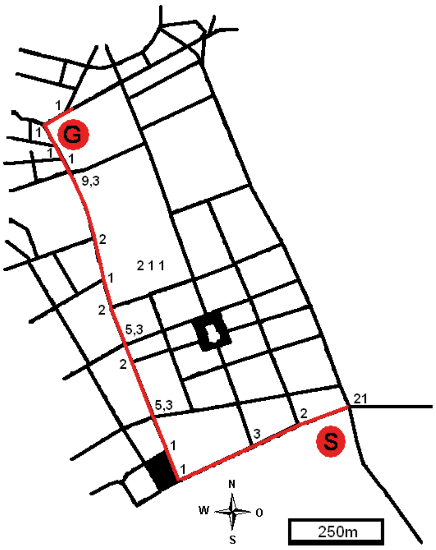

Fig. 4: Network of the test area marked with the least risk path and the risk values of the decision points

$h = h_{c} + h_{r}$
$f_1 < f_2$: costs = h * n * 17
$f_1 = f_2$: costs = l_s
$f_1 > f_2$: costs = h * n * 10

f_1 is the initial floor in a building and f_2 is the destination floor. If f_1 is 0 and f_2 is 3 the client has to move from the ground floor to the third floor, i.e., he has to go uphill. The relation from moving uphill to the value of the corridor segments with the same geometrical distance on the same level is 1:17.

This system should be usable for everybody and therefore it must be possible to start the path already in an indoor area. Thus, it could be that the system, first, has to calculate the least risk path for indoor navigation, then for outdoor navigation, and finally, a second time for indoor navigation.

The corridor segments in the indoor area substitute the street segments of the outdoor area. The values also depend on their lengths. These lengths can again be transformed to cost units. The result of the combined risk value of outdoor and indoor navigation is also a cost value.

For calculating the risk value of getting lost in indoor navigation we assume that the user takes the stairs and not the elevator. The reason therefore is that every building has stairs but not every building has an elevator. This assumption has to be made to get a general formula valid for all buildings.

At the indoor navigation decision points are points where the user has to make a decision. The difference to the outdoor navigation is that the user has at nearly each point also the possibility do go up or down.

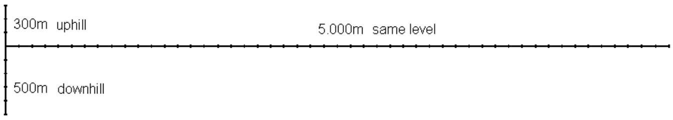

Fig. 5: The relations between going uphill, downhill, and on the same level

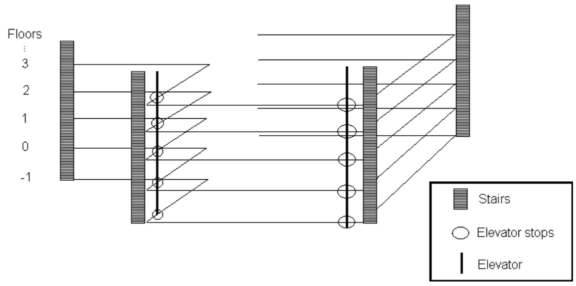

Fig. 6: The base structure of the building of the Technical University of Vienna

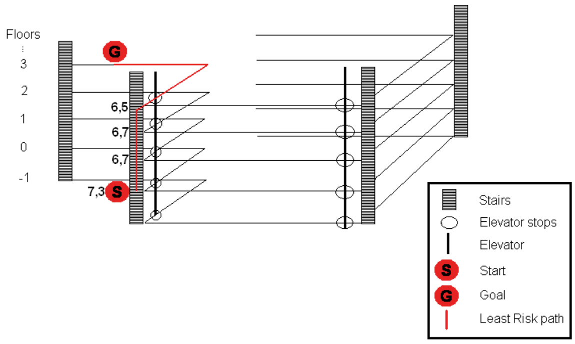

Fig. 7: The base structure of the building of the Technical University of Vienna marked with the least risk path of getting lost and the risk values of the decision points from the main entrance to my office.

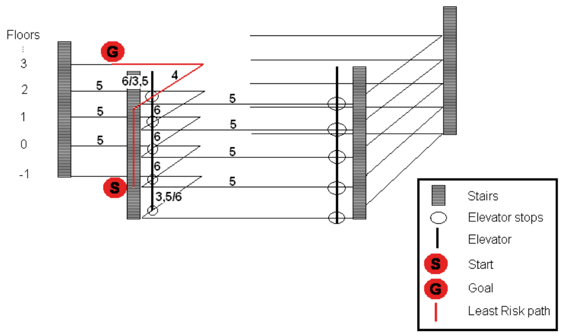

Fig. 8: The building of the Technical University of Vienna with the length values of the corridor segments that are needed to calculate the least risk path.

As with the formula for the outdoor navigation the decision points get a separate calculation for their risk value. This formula is similar to the one for the outdoor navigation. The difference is the adequate height value that will be explained afterwards in this chapter. Two times the length of the wrong choices with the adequate height value divided by the number of possible choices. The value of the corridor segments of the same level depends on their lengths. The value of the possibilities up or down has to be seen as the relation that is shown in Figure 4.

The second part of the formula for the length value of the corridor segments is also similar to the formula of the outdoor area. This is the sum of the corridor segments also with the adequate height values of the right path.

Moving one floor uphill gives a value of 6 because we assume 3,5 meters per floor and the relation to moving on the same level is 1:17. The result of ~ 60 is divided by 10 for easy calculation. A wrong corridor segment where the user first moves up a floor and afterwards moves down a floor is a combination of the relations of going uphill and downhill.

In this example the user starts at the main entrance on the ground floor and has to move to the third floor to my office. He uses the stairs to reach the third floor, has to turn left and follow the corridor until he reaches the room with the number "CD 0336".

This figure shows all necessary values to calculate the least risk value of getting lost to reach my office from the main entrance. Included are the risk values of the decision points, the values of the corridor segments, and the values of the height differences. The costs for walking to the n^{th} floor are calculated as following:

$$r_d = \frac{2 * \sum_{i=1}^{n-1} l'_i}{n} \qquad r_p = \sum_{i=1}^{n-1} r_d + \sum_{i=1}^{n-1} l_s$$

Fig. 9: The formula for the calculation of the risk value of the decision points and of the risk value of the whole path in indoor areas.

r_p = risk value of the whole path
r_d = risk value of a decision point
l_i = length of the path that is wrong
n = degree of node minus 1
l_s = length of the segments that are right
n_d = number of decision points (nodes)
l'_i = adjusted length of the 3D path that is wrong
n_f = number of floor

$$l'_i = h * n_f * k$$

$$k = \begin{cases} 17 & \text{if } f_1 < f_2 \\ 10 & \text{if } f_1 > f_2 \end{cases}$$

The way of calculating the risk value of a path in the indoor area is similar to the outdoor area. First, the risk values of the decision points have to be calculated. Afterwards, the values of the corridor segments with the adequate height value that are right have to be added. Different to the outdoor area is that the height has to be involved in the formula. Movements uphill or downhill have to be taken into account since movements uphill and downhill cause more cost than moving on the same level.

5 The combination of indoor and outdoor navigation

For a complete indoor and outdoor navigation the two formulas have to be connected. The system must be able to change between the calculation of the risk value for the outdoor area and the indoor area. This means to use different possibilities to locate the position of the user.
To reach a positioning of the user in the outdoor area with sensors would also be a possibility but is not feasible at the moment.
Two assumptions were made for the indoor navigation:

- Every building has only one main entrance and
- By entering a building the position of the user is definitely identified.

The first point must be documented given that there are also buildings that have more than one entrance. In most cases there is only one main entrance. For calculating the least risk path for an indoor area we assume that the navigation system navigates the user to the main entrance. This assumption reduces the risk of making mistakes and getting lost.
The second point results from the first point. A really precise positioning is not really complicated if the user is clearly identified by entering a building if there is only one possibility to enter. At this position the user has to realize if he is right or wrong. If he is wrong he has to turn back and go to the last decision point where he was sure that he was still right. For getting this information the system must be able to combine the outdoor and indoor navigation.
To get a complete risk value of a combined outdoor and indoor path the system must calculate the risk value of the two areas separately and add the results. On the screen the user gets the result of the whole path and the exact description he has to follow.
Thus the system should be able to switch immediately between sensor positioning and satellite positioning. For the sensor positioning the handhold computer must be able to connect to the sensors for example via Bluetooth. The satellite positioning needs a connection to a minimum of three satellites in the outdoor area. Therefore the handhold computer must be able to connect with the satellites.

6 Conclusion

The intention of the previous work in the outdoor area that is shown in chapter 4.1 and the work in the indoor area that is shown in chapter 4.2 is to reach a combined outdoor and indoor navigation system. At the moment the most important users are pedestrians. These calculations can not be used by driving a car because one ways and pedestrian zones have not been considered.
This system should be, for example, for persons that have never been in a city, arrived at a station, and search for the least risk path of getting lost to reach a special office per pedes. This work is part of a project that is financed by the FWF and is called NAVIO.

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A framework for decision-centred visualisation in civil crisis management

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1 Introduction

This paper describes a framework for intelligent visualisation to be applied in emergency situations for supporting the crisis management personnel and for informing and instructing the population. The research and development work on this topic is being done within OASIS – an Integrated Project focused on the Crisis Management part of the programme "improving risk management" of IST (IST-2003-004677, see http://www.oasis-fp6.org/). Conducted over 48 months (started in September 2004), OASIS aims at defining a generic crisis management system to support the response and rescue operations in case of large-scale disasters. The project is coordinated by EADS (France). The work on intelligent visualisation is a part of the subproject dedicated to applied research and development of innovative tools for advanced decision support in emergency situations [1].

Intelligent visualisation that supports decision making in emergency situations can be viewed as an instantiation of the concept of decision-centred visualisation (DCV), which has been introduced in mid-nineties in the context of US military contracts. Essentially, DCV means the usage of problem-oriented domain knowledge for intelligent data search, processing, analysis, and visualisation in time-critical applications [2]. An ultimate goal of DCV is to optimize the overall decision-making process and improve the quality of decisions on the basis of intelligent visualisation and related scientific disciplines and technologies. DCV is usually applied in conflict domains such as military mission planning, counter-terror intelligence etc. DCV is used in these areas as a core component of modern control rooms. Public sources point to significant investments to the DCV development [3].

Within OASIS, we are going to apply, adapt, and extend the DCV concept to the tasks arising in civil protection and crisis management. In particular, intelligent visualisation is planned to be used not only for supporting decision makers in control rooms but also for alerting, informing, and instructing the on-site personnel, the population at risk, and the general public (through mass media).

2 Problem statement

The objective of intelligent visualisation may be formulated as "give everybody the right information at the right time and in the right way". Two parts are present here:

1. "Right information at the right time" means that a person or organisation should be able to get the information that is necessary for the adequate behaviour in the current situation or fulfilling this person's or organisation's tasks. The relevant information should be provided at the time when it is needed.

2. "In the right way" means that the information should be presented in a way promoting its rapid perception, proper understanding, and effective use.

The first part refers to the problem of the selection of the relevant information, depending on the situation and the needs, goals, and characteristics of the intended recipient. The second part refers to the problem of effective preparation, organisation, and representation of the relevant information. This, again, depends on the goals and characteristics of the intended recipient and should take into account the specific constraints of emergency situations, in particular, the time pressure and stress factor. The general requirements include:

- Reduce the information load on the recipient: not only irrelevant information should be excluded but also the relevant information should be adequately aggregated and generalised leaving out unnecessary details.
- Increase the clarity of the information presentation so that the information can be appropriately understood despite of the emotions and distractions involved in an emergency situation.
- Use such methods of representation that allow quick recognition of the meaning of the information conveyed.
- Take into account the characteristics of the medium used for receiving the information.

Intelligent visualisation supposes that both the selection of the relevant information and the subsequent processing, organisation, and representation of the selected information are automated. This may be done by applying the knowledge base technology, i.e. incorporating expert knowledge in the visualisation software.

3 Actors and their information needs

To be able to select the information relevant for a specific addressee, the software must understand the needs of the addressee. The needs depend, among others, on the *role* of the addressee in the emergency situation. The following generic roles may be considered:

– **Analyst**: a person (typically in the situation control room) that needs to understand the current situation and its development, identify problems, and find proper ways of solving the problems.
– **Decision maker**: a person who chooses a specific action course to take in the current situation on the basis of an overall view of the situation, identified problems, and possible ways of solving them. In principle, one and the same person can play the roles of both an analyst and a decision maker.
– **Planner**: a person who builds a plan for realising a chosen way of solving a problem or achieving a specific goal, with assigning tasks to performers and allocating available resources to the tasks. Again, this may be the same person as the analyst and/or decision maker.
– **Performer**: a person, group, or organisation fulfilling a particular task or sequence of tasks. A performer may need to make various tactical decisions depending on the specifics of the situation and its changes.
– **Sufferer**: a person, group, or organisation that is exposed or may be exposed to some of the danger factors of the emergency situation.
– **Observer**: a person or organisation that is not directly involved in the emergency situation but is interested in receiving information about it. This includes, in particular, the mass media, which distribute information about the situation among the general population.

The knowledge base of the intelligent system should specify the typical information needs for each of the roles. As an example, let us consider the needs of an analyst. An analyst deals with two sorts of information:
– **Situational data** characterising the current emergency situation and its progress over time.
– **Reference data** (long-term) characterising the area where the situation occurs, the objects and population in this area, the road and service infrastructure, etc.

An intelligent system can help the analyst by automatic retrieval of relevant reference data on the basis of situational data. For example, the system can automatically find the objects located in the danger zone and requiring particular attention as potential sources of danger (e.g. a petrol station close to a fire or a chemical factory in an area that may be flooded) or valuables that must be protected (e.g. a historical building, library, or art gallery). The system can also retrieve data about the population in the danger zone, estimate the total number and the number of persons of the most vulnerable categories such as children, elderly, and disabled. It can also find the locations of people that may need special care: hospitals, schools, kindergartens, homes for elderly, etc., taking into account the current day and time. Thus, the system can look for the data concerning schools and kindergartens only in a case when the emergency situation occurs on a weekday during the working hours. The system can also find buildings or places outside the danger zone that can be used for sheltering people or animals, and so on.
Unlike an analyst, a decision maker does not need detailed information about the situation and every item requiring attention. For example, for making the decision whether to evacuate the population from the danger zone and, if yes, in what way (centralised or allowing people to evacuate on their own using the private cars), the decision maker needs to know the number of population at risk, the risk probability, the potential consequences of no action, and the time and resources required for each variant of evacuation. This information can be prepared by the analyst with the help of the intelligent system, and the system can present in an adequate form.
A planner does not need all information concerning the current situation but only the information relevant to the particular problem the planner needs to solve at the moment. For example, the planner's current goal may be to build a plan for the evacuation of the patients of a particular hospital. For this purpose, the planner needs the information about the location of this hospital, the number of patients and their specific needs (e.g. special equipment may be necessary for the transportation of some patients), the hospitals outside the danger zone, their profiles, and the availability of beds in them, the available roads, transportation means, etc. This information can be automatically retrieved and appropriately presented to the planner.
A performer needs the information relevant to the task to be performed. This includes the description of the task, the place, the time frame, and the resources and infrastructure to use. This information is prepared by the planner while the system can take care of organising and appropriately presenting it. Additionally, the system can automatically supply the performer with the information as to how to get to the place, how to protect the personnel, what sources to use for renewing consumed resources (e.g. water or fuel), what roads are destroyed or blocked, etc.
A sufferer may need information on how to get out from the danger zone, how to protect himself and/or his property, what kind of help is available and how to get it. Actually, a sufferer may simultaneously be a performer when he/she is supposed to follow certain specific instructions, for example, concerning the evacuation. In this case, the sufferer needs the task-relevant information: what to do, where, when, and how. The information can be automatically retrieved and prepared individually for each sufferer/performer on the basis of the general evacuation plan. The system can take into account the location of the sufferer and his specific (dis)abilities and needs if this information is available or can be inquired from the sufferer. For example, the system can send an alarming and instructing message to sufferer's mobile device and ask the sufferer to specify what kind of assistance is needed, if any.
An observer needs general information concerning the character of the event (e.g. fire or flooding), its location, history and development forecast, number of casualties, and the measures undertaken for managing the situation. The information can be automatically retrieved, summarised, and suitably represented. The system can take into account the location of the observer in relation to the emergency site. Thus, if this is the same city or town, the observer is interested in the exact location of the event, which can be shown on a map of the town or city district. For an observer from another town in the same country, it is sufficient to indicate the

location of the incident on a country map while an observer from another country should be informed where the country in which the incident occurred is situated.

For satisfying these different information needs, various output media can be used. Thus, for situation analysis, decision making, and planning, the emergency management personnel may use a big screen in a control room or a standard screen of a desktop or laptop computer. Performers on site may be informed and instructed by means of hand-held or head-mounted devices but also on paper (e.g. by fax). People in the danger zone can be alarmed, warned, and instructed through their mobile phones and electronic information boards while information kiosks may provide additional information when appropriate. General public (observers) is usually informed by means of TV and newspapers. Each type of media imposes its specific constraints on how information can be presented and further dealt with. The intelligent visualisation support system must take these constraints into proper account.

4 Knowledge

Let us analyse what sorts of knowledge are needed for an intelligent software system providing visualisation support to people and agencies involved in emergency situations.

In order to provide the intelligent services outlined in the previous section, the system must understand the meaning (semantics) of the situational and reference data. For this purpose, the system must be aware of various general notions relevant to the domain of emergency management and the relations between those notions. Such a system of interrelated notions is usually called domain ontology. The general ontology of the domain of emergency management is not linked to a particular emergency situation or geographical area. However, the ontology may be used for indexing various situation- and area-specific data, which allows the system to “understand” the meaning of these data.

To enable the understanding the situational and reference data pertinent to emergency management, the domain ontology must contain several categories of knowledge. One of them describes the **danger factors** that may be involved in emergency situations: fire, explosions, water, wind, contamination of air, water, or soil, disease, etc. For each possible danger factor, the following general knowledge is needed:

- Existential behaviour: does the danger factor effect momentarily (e.g. an explosion or earthquake) or over an extended time period (e.g. a fire or contamination)? Does it cease by itself or has to be stopped? Can the danger re-occur?
- Spatial characteristics: is the danger factor localised in space or extended over an area or dispersed (i.e. occurs in many disjoint locations)?
- Changes of the spatial characteristics over time: static (no changes), moving (change of the position), spreading or shrinking (change of the extent), dispersing or concentrating (change of the distribution).
- Attributes characterising the danger factor, e.g. the speed of a wind, the level of water, or the concentration of a dangerous substance.
- What object categories can be affected: people, buildings, roads, service infrastructure, environment, … For each potentially affected item, the following information needs to be known:
  - Possible results of being affected: destroying, damage, loss of utility, transformation into a danger factor, …
  - Dependence of the effect on the spatial and temporal distance from the danger and on its attributes.
  - Possible measures to prevent or mitigate the effects of the danger, e.g. removal (evacuation) from the danger zone or protection.
  - What to do if the effect already took place, e.g. repair, remove, restrict access, neutralise, …

Another category of knowledge describes the generic tasks that are often involved in emergency management, such as evacuation of people, animals, and valuable objects from the danger zone. The system needs to understand what sorts of places or buildings can be used for sheltering various categories of items, for example, that patients from a hospital must be moved to other hospitals with appropriate equipment, depending on the state of a patient. The system must also know what categories of people need special means of transportation and/or assistance for embarking and disembarking.

To support decision making and planning, the ontology must contain knowledge about the types of resources and infrastructure that may be needed for managing emergency situations. This includes people, teams, and organisations (e.g. a fire brigade or a bus company), transportation means, roads, sources of power, fuel, and water, and so on.

As we already indicated, the system should also have knowledge about the possible actors and their typical information needs. The actors may be defined in terms of their roles in an emergency situation.

Besides the various categories of knowledge specific to the domain of emergency management, the intelligent system needs to know how to manipulate, organise, and present various types of data. It must be able to build different types of displays (maps, graphs, diagrams, charts, tables, etc.) and know what kind of data each display is suitable for. The system should also be able to combine several displays in a single presentation by designing an appropriate arrangement of the components and establishing links between them. It must know the properties and rules of the use of different visual variables [4]: position within the display area, size, colour, texture, etc. The system must be able to build dynamic (animated) presentations and to supply the displays being generated with various interactive facilities such as zoom, pan, rotate, focus, query, mark, filter, or follow a hyperlink.

These sorts of knowledge and abilities are, in principle, domain-independent. They can be represented and used separately from the domain-specific knowledge concerning various dangers and ways of handling them. This approach allows the visualisation knowledge to be reused for other applications. Therefore, our plan is to separate the emergency management-specific knowledge from the knowledge on visualisation design, which is specified as domain-independent. Accordingly, domain-specific reasoning used for the selection of appropriate information is separated from domain-independent reasoning in the process of designing the presentation of the selected information.

The entire intelligent system can be viewed as consisting of two cooperating expert subsystems, which may be called "emergency management expert" and "visualisation expert". First, the emergency management expert selects the necessary information depending on the needs of the intended recipient determined by recipient's role and the current status of the situation. Then the visualisation expert finds appropriate methods for transformation and presentation of the selected information.

5 Meta-information

For appropriate processing of the selected information and designing its presentation, the visualisation expert must take into account various characteristics of this information and how it is supposed to be used as well as the constraints imposed by the target output medium and some characteristics of the intended recipient. Let us use the term *meta-information* to refer to the factors influencing the ways of information processing and presentation. More specifically, meta-information includes the following items:

– Type of the entities the information refers to: movable or unmovable objects, places, processes, actions, or relations.

– Structure of the data and types of the components they consist of: spatial, temporal, numeric, ordinal, or categorical.

– Quality of the information: does the information result from actual measurements or observations or this is a forecast or estimation? What is its degree of accuracy or certainty?

– The goal of providing the information to the addressee:

  - **alert**, attract attention to something unexpected like an impending threat;
  - **inform**: what, where, when, how. The information may be expected by the addressee, e.g. come in response to a query;
  - **suggest**, e.g. some action to take or additional aspect to consider;
  - **enable**: analysis, reasoning, decision making, or action planning;
  - **instruct**: what, where, when, how to do or to avoid;
  - **explain** or justify, e.g. a decision made.

– Degree of relevance to the goal: information of primary importance, supporting information (e.g. orientation clues), irrelevant information.

– Degree of novelty to the addressee: completely unexpected, partly expected (e.g. an analyst may expect that some buildings could collapse in result of a earthquake but not know what buildings and where), well known and expected.

– Criticality, i.e. whether an information item requires immediate attention of the addressee.

– The expected level of addressee's knowledge concerning the topic of the information and the geographical area the information refers to.

– Characteristics of the output medium to be used for presenting the information: size, resolution, available colours, possibilities for dynamic output and user interaction, memory capacity, individual or public use.

According to our approach, the emergency management expert supplies the required meta-information to the visualisation expert together with the information to be presented. The meta-information concerning the character, structure, and properties of the information comes from the indexing of the information items in terms of the domain ontology. However, the emergency management expert must specify this meta-information in a domain-independent manner so that the visualisation expert could use it without having any domain knowledge. The meta-information concerning the goal for which the information is to be used comes from the user of the intelligent system. In some cases, the user is the same person as the intended recipient. Thus, an analyst or planner can directly interact with the system in the course of analysis or planning. In this case, the system presents the relevant information directly to the user. In other cases, the user employs the system for preparing and presenting information to other actors. Thus, an analyst may prepare a summary of the situation and possible ways of handling it for communicating to a decision maker. A performer who received the task to alert and instruct the sufferers may use the system for preparing an appropriate presentation or even let the system construct a personalised message for every individual or family in the danger zone.

So, the user somehow lets the system know for whom and what purpose the information is needed. Basically, the system needs to be aware of the recipient's role in the current situation and his/her geographical location. Sometimes, this sort of meta-information is clear from the context of the system use and does not need to be explicitly specified. On the basis of the meta-information concerning the recipient and the stated or implied goal of information use, the emergency management expert can estimate the degree of relevance, novelty, and criticality of each information item for the recipient. For this purpose, it uses the domain knowledge concerning the actors (roles) and their typical information needs. The same knowledge allows the expert to estimate the probable level of addressee's thematic and geographic knowledge. Thus, an analyst may be qualified as an expert in emergency management issues but the level of knowledge concerning the area of the incident may be low. In opposite, the local population to be alerted may know the area quite well but be unaware of the character of the particular threat and the possible consequences.

Hence, by reasoning with the use of the domain-specific knowledge, the emergency management expert not only finds and retrieves the relevant information but also supplies it with meta-information that allows the visualisation expert to interpret, process, and present this information adequately. The meta-information is specified in a domain-independent manner so that no domain knowledge is needed for utilising it. Additionally to this, the visualisation expert needs to know the characteristics of the output medium. This information either comes from the context of the system use (when the information is intended directly for the system user) or the user specifies it explicitly (when the information is to be communicated to someone else).

The organisation and functioning of the intelligent visualisation system can be schematically represented as is shown in Figure 1.

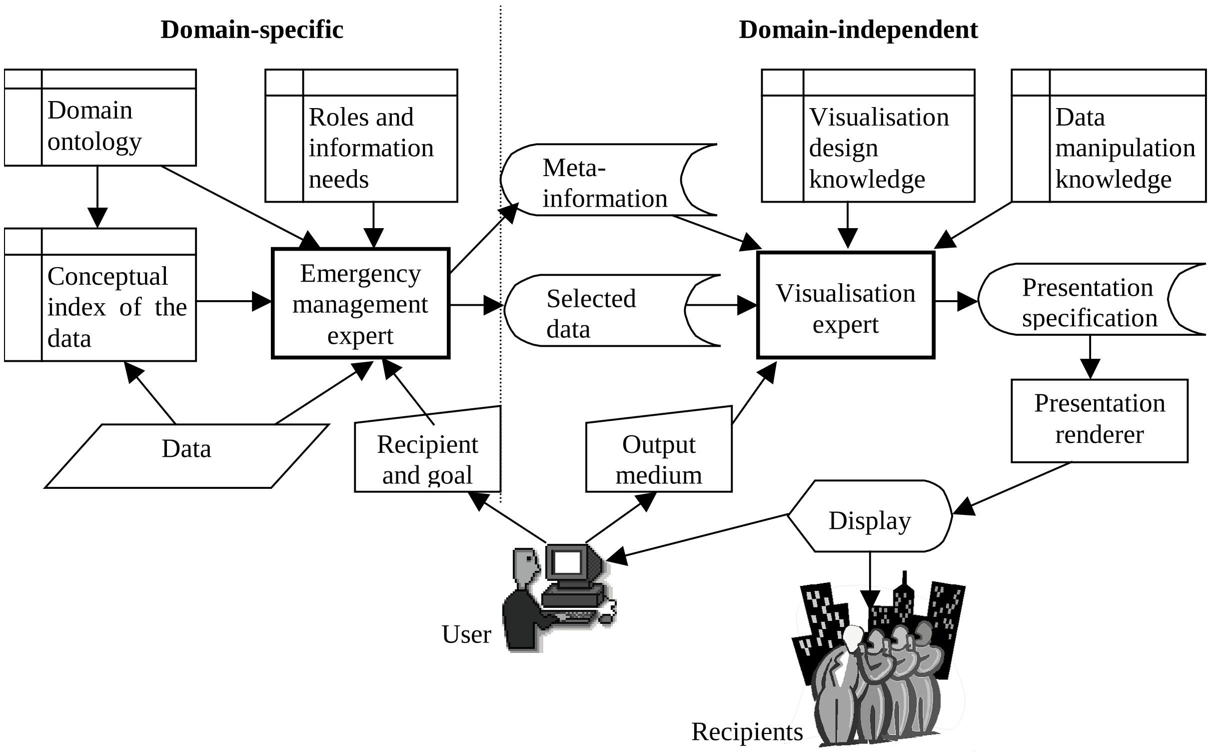

Fig. 1: A schematic representation of the structure and functioning of the intelligent visualisation system for emergency management.

6 Knowledge sources

As may be seen from the scheme, the intelligent system will use several categories of knowledge:

- Emergency management domain ontology;
- Knowledge about the roles and information needs of people and organisations that may be involved in an emergency situation;
- Knowledge on visualisation design, including techniques of interactive display manipulation and mechanisms of coordination of multiple displays;
- Knowledge concerning techniques of data manipulation, e.g. aggregation, filtering, smoothing, interpolation, statistical processing, etc.

The first two categories of knowledge are specific to the domain of emergency management. This knowledge is currently being constructed mainly by analysing available reports describing real incidents and generalising from these cases. Some comprehensive analytical reports can be found in the literature [5, 6]. Much information concerning the management of real disasters can be found in the news reports from various news agencies available, in particular, in the Web. Thus, using the Web, we have compiled a rather detailed description of the course and management of the flood in Czech and Germany in August 2002.

The second two categories of knowledge come from the extensive literature on information visualisation, geographic visualisation, data analysis, and graphics design. We have recently summarised the current state-of-the-art in these areas with the focus on techniques and tools supporting data exploration and analysis [7]. However, the intelligent system for decision-centred visualisation will also need the knowledge concerning effective information presentation according to the intended communication goals. The relevant literature is rather abundant and includes both theoretical studies (e.g. [8]) and descriptions of practical approaches to automated presentation design (e.g. [9]). Our orientation to various types of output media necessitates the use of knowledge concerning the possible ways of presenting information on these media. In particular, we can use some recent research results concerning information visualisation on mobile devices [10, 11].

7 Conclusion

The realisation of the proposed framework is a very ambitious and complex task. It is hardly possible to fulfil it completely in the course of the OASIS project. Therefore, we aim at a partial realisation that would be sufficient for the demonstration of the feasibility of the approach and the potential benefits for the emergency management personnel and for the population. We are starting with one example scenario of managing a specific emergency situation and developing a prototype oriented to this scenario. On this stage, we shall restrict the scope of our work to only some of the roles and some types of the output media. After testing and refining the prototype, we shall extend it to further types of emergency situations and the remaining roles and media types.

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A visual editor for generating OGC Styled Layer Descriptor (SLD) files for automating configuration of Web Map Server (WMS) maps

Albrecht Weiser, Alexander Zipf

1 Introduction

The OGC Styled Layer Descriptor (SLD) specification [28] allows to describe the design and contents of a map – in particular a map served by a SLD-WMS – in a formal way through the use of a strict XML schema. The specification is getting more and more used and supported by several implementations of Web Map Servers, but it still has some weaknesses – especially for use in LBS, see e.g. [2]. On the other hand in LBS or UbiGIS maps need to be generated dynamically taking a lot of factors into account – in particular also attributes describing the current user, the situation and general context [23, 24, 25,9]. In order to use this kind of parameter and information in an automated map service on the internet or on mobile devices we need also formal representations for this type of information – e.g. also as XML files following a specific schema. Then we need to combine the information from this context models and the base map repesented as SLD file to automatically generate adapted maps according to these parameters. The result is again an SLD file describing the adapted map, which then can be used within a request to an SLD-enabled WMS. So the first task is to generate the SLD for the base map. In order to automate the task of designing maps for Web Map Servers serving maps to the Web or the Wireless Web we will introduce a tool that we developed called ArcMap2SLD-Generator. This tool is helpful as it allows to generate a valid SLD-file from the design of a base map within ESRI ArcMap. The resulting SLD in turn acts as a base for further modifications through user and context models in order to generate "adapted maps" [24] in a standard-conformant way. The SLD acts herby as parameter within an ordinary WMS request results.

2 Using the OGC styled layer descriptor specification for the formal representation of maps

The OGC Styled Layer Descriptor Specification [OGC] defines a XML Schema to describe the appearance of the layers a map. The general model (simplified version) is depicted as UML class diagram in figure 1. A SLD document is a XML file that can be validated against this model. SLDs are getting more popular in Web Mapping applications with the growing availability for SLD support in WMS. But until recently these SLDs are more or less hand-made or application specific. But as SLDs provide the means to specify the look of map in a domain and vendor-neutral way it is a good choice for a formal representation of maps in general.
The question is now how to go beyond these hand-made SLDs and generate these in an automated way (using Open Standards predominantly). This is a technical question and can be solved using a software tool we have developed. This tool is a SLD generator for ESRI ArcMap maps. This can be used not only in WMS requests or for configuring WMSs (as in the case of the deegree WMS), but also when producing vector based maps in SVG. Merdes et al. [11] present an example of using SLD and GML from WFS requests with a cascade of several XSLT transformations in order to generate a SVG map from GML and SLD. We will explain and extend this approach in order to produce context adapted maps later. First we will briefly introduce our application that generates SLD files from existing maps in commercial Desktop GIS.

3 The ArcMap2SLD converter

In this section we want to explain the functionality and the benefits of ArcMap2SLD-Converter.
The first question is: What is this tool designed for at all? The answer is that it was developed mainly for supporting the setup of a Web Mapping Service. One of the most exhausting works in setting up a WMS is to write the code for the symbolization prescription of the configuration file. If you want to setup a large project with various layers and many classes, by far the most effort is to code the hundreds (or even thousands) of lines of the symbolization prescription. So the question arizes how we can automate this to minimize these efforts? In the best case we could reuse the effort and work, that was already invested in setting up a project and dsigning a map with a common desktop GIS. This would allow to take the power of Desktop GIS for aiding in the symbolization process of desktop GIS also for Web-based maps. If we would be able to analyze the symbolization of a desktop GIS and transform the informations in SLD (which is the portrayal prescription of an enhanced WMS), the most time-consuming activity in setting up a WMS would be done.
Therefore we developed a tool for converting the symbolization of a ArcMap project into the SLD standard format. The ArcMap2SLD-Converter analyzes the symbolization of an ArcMap-map by stepping through each layer of the project and each class of the layer. It stores the symbol properties and further properties of the layers and the project in special data structures. This allows a

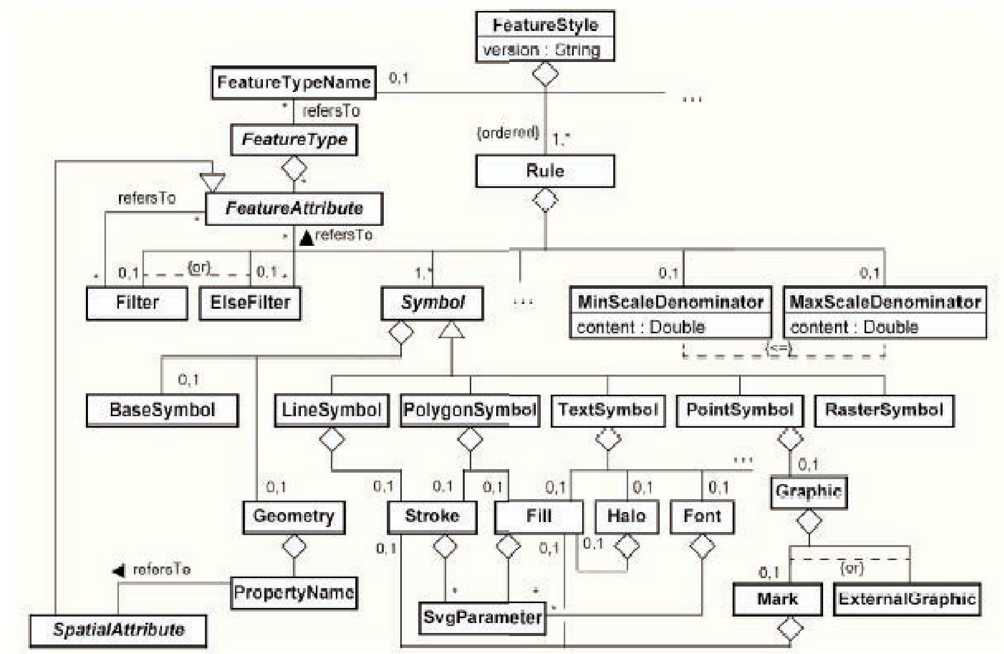


Fig. 1: Simplified Data Model of SLD according to (OGC 2003).

very dynamic analysis also of the complex symbol objects like MultiLayer-symbols of ArcMap. After finishing the analysis, all data stored in these data structures is beeing transformed into SLD and exported into a SLD-file. It is also possible to check the validity of the resulting SLD by integrating the latest SLD schema-file(s) from OGC. The SLD can then be referenced by the WMS in the reqest-URL, like following example shows:

```
http://127.0.0.1/mapserver?SERVICE=WMS&VERSION=1.1.1&REQUEST=GetMap&Layers=Guek300_Poly&STYLES=&SLD=http://127.0.0.1/Maps/SLD/GUEK300.sld&BBOX=3377854,5471076,3592188,5728258
```

The reason to take the system ArcGIS from ESRI as starting point of the analysis was its widespread distribution as market leader at the GIS market. So more GIS user participate in the benefits of ArcMap2SLD-Converter.
Here are some of the technical design parameters of the ArcMap2SLD-Converter:

- The application was developed in Visual Basic.NET
- It uses the ArcObjects framework from ESRI for accessing ArcGIS-functionalities
- The navigation in the SLD-file is performed by XPath (XML Path Language)
- Syntactic changes of the SLD specification can be adjusted in a configuration file

Implementation of ArcMap2SLD-Converter:
The tool currently supports the most important ways of thematic classification within ArcMap:

- Features (Single Symbol)
- Categories (Unique values; Unique values, many fields)
- Quantities (Graduated colors)

Further Marker-, Line- and Polygon-features are also supported by the application. Even multilayer-symbols are supported for these features (multilayer-symbols are able to depict complex symbolization like the filling of an area with repeating patterns).
After we now have the possibility to derive complex SLD files of "standard" maps in an quite easy way we now want to discuss how we can use these to derive user or context adapted map representations.
The results of applying the generated SLD file to a WMS can be seen in figure 3, which compares the map to the original ArcMap display. One can recognize from figure 3 that it is still not possible to achieve 100% the same look using the WMS on the one hand and the original ArcMap map on the other, but a very good compromise can be achieved. Where does the different look come from? The fact is that SLD is still not a technically mature standard of the OGC. It is still under development and its contents increases step by step during the suggestions of its members. For example until now SLD still has no possibilties to generate a vector-based hatching for polygons, because the SLD-element *Graphic* of the SLD-element *PolygonSymblizer* has only two successor-elements: *Mark* and *ExternalGraphic*. This implies SLD can only generate vector-based area filling patterns with marker symbols because a successor-element *Line* is missing at present. Among others this is a reason for the different looks of the source map and the resulting map. Nevertheless, SLD is sufficiently extensive to portray a complex symbolized map to distinguish all containing classes in a satisfyingly adequate way.

Some map server currently still offer even less support then the ones we used for all the parameters defined in SLD and therefore result in maps still may look more differently. It is hopefully only a matter of time until this varying support of the SLD has reached a more stable situation and the different render engines produce very similar maps from the same SLD configuration. In order to achieve this also the SLD specification needs further extensions in order to clarify how to represent a range of symbolization issues.

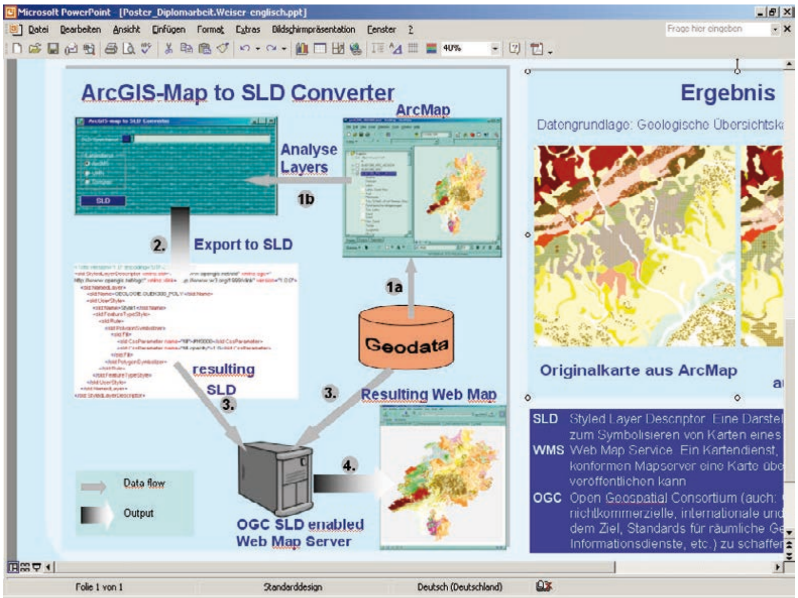


Fig. 2: Process of designing a map in ArcMap and exporting it to a SLD document, that can be used to configure WMS servers or to issue user-specific requests to SLD Web Map Services.

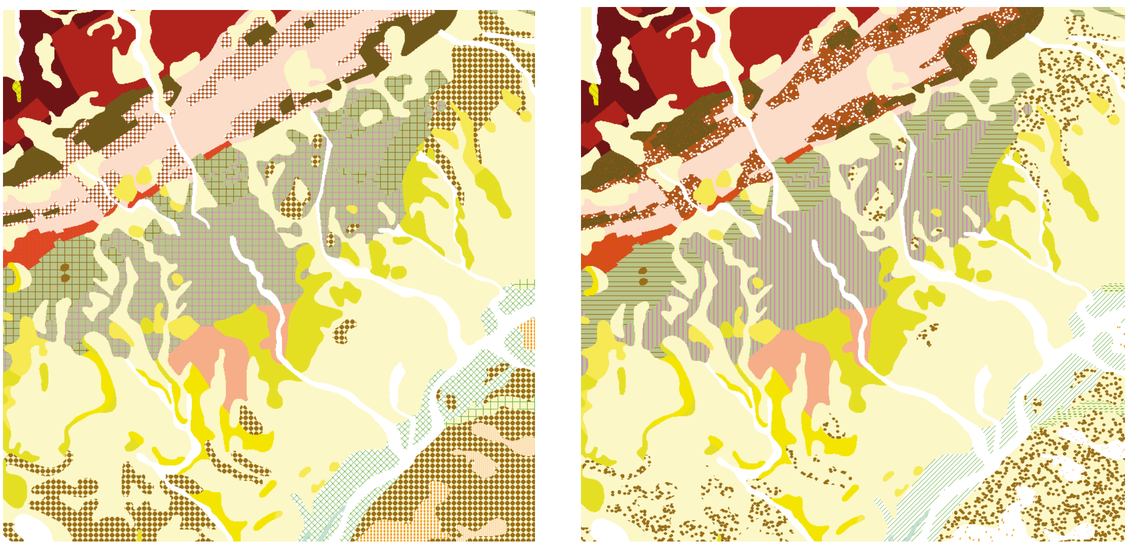
4 User and context modelling for adaptive GI Services

We propose to use this base map SLD as a fundament for further modifications according to some user and context models. Since a few years it has become more and more accepted, that the design of electronic maps – in particular mobile maps - needs to consider a much broader range of influences than conventional maps in order to present just the right information needed in the current situation by the current user of such a map-based system (21, 22, 23). After focusing on technical limitations of mobile devices (storage, processing, interaction, display size, bandwidth etc.) the focus of research in mobile maps shifted recently to cognitive aspects (9, 21), e.g. navigation and wayfinding support [8, 11, 16]. Further examples for adaptive GI applications include e.g. the computation of routes based on context-related criteria [7] or user-aware spatial push of information [24].

In order to actually apply the ideas presented there to an automated system we need to consider three different main aspects:

- What are the indicators influencing the design of a map (which attributed describing the current task, user, situation etc. – we can refer to this as the *User Model* and *Context Model*. They (are sometimes combined) and deliver the structure and possible value domains describing the situation.
- How do these attributes actually influence the design of the map? For answering this we need to components: a.) knowledge about cognitive aspects how to present which information the best way to the user and b.) a mathematical or computational framework for actually applying this within a computerized system – telling how to calculate the values for the weighting the adaptation etc. See [25] for details.
- A technical framework how to apply this in a standards-based open system.

Fig. 3: Comparison of the resulting map (detail) from the dynamically generated SLD description renderend by UMN Mapserver by SLD (right side) and the original map in ArcMap (left side). Example: Geologische Übersichtskarte 1:300.000, GÜK 300, Hessisches Landesamt für Umwelt und Geologie (HLUG) (Geological Map 1:300.000)



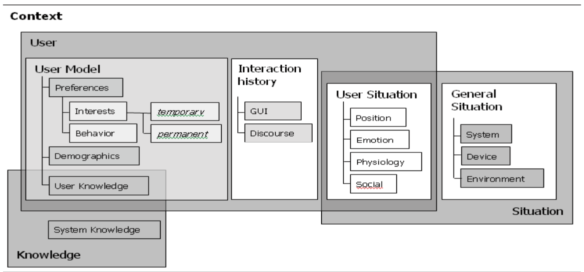


Fig. 4: Integrated User and Context model [18]

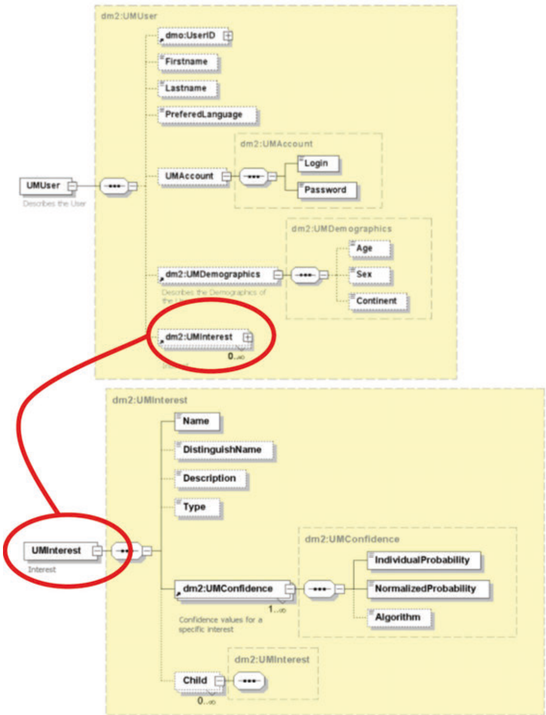


Fig. 5: User Model User XML Schema & UMInterest including confidence elements [18]

We will only very shortly introduce the state of art for the first two aspects and then will focus on proposing a generic technical framework that makes use of open GI standards only. In spite of much research the terms context, situation and user model etc. are still quite vague. A range of definitions and proposals exist – mainly originating from work in Ubiquitous Computing, which also has been tried to adopt within the GI community. We do not consider that it is helpful to argue about "THE RIGHT" model here (if one exists at all), as this is a question for philosophy, but argue, that we need some interoperable way to transform between the different flavors of application and domain specific classifications. As one example we present a suggestion by [18] adapting ideas from [5] and [6] that was used for some research prototypes.

For further discussions of these topics see [4, 5, 6]. As such models are nowadays typically expressed using XML we can expect that there will be ways to transform these into the actually needed representation (or even a standard ontology, once a more widely accepted one appears) quite easily (e.g. using XSLT). What we have to note here is that we do need not only a theoretical construct, but really a formal representation of the relevant concepts, their value domains and relationships, e.g. using the OWL language. OWL allows to define and instantiate ontologies, which are explicit formal descriptions of concepts or classes in a domain of discourse, which express a shared specification of a conceptualization. OWL thus provides the possibility of expressing information associated with people, events, devices, places, time, and space etc. Moreover, it provides means for sharing such context knowledge, thereby minimizing the cost of sensing.

4.1 Applying user modeling for adaptive GI Services

As an important example we focus now on how to model the user within such an adaptive map-based system. [18] propose an ontology-based approach for their own realizations of adaptive GI services that employs different machine learning methods based on stereotype reasoning, domain inference etc. [3] in order to calculate dynamic user properties as for example the current interest of the user in specific types of objects. They present a XML schema (see figure 5) for a user model that consists of basic user properties (UserID, name, preferred language etc.).

It also includes demographic attributes and account data. But the most important property is the different *interests* of the user modelled as "*UMInterest*". This is described by name, description and further type definition. Within the *UMConfidence* property the probabilities (individual and normalized over all users) calculated by a software module, that calculates individual user preferences and their probabilities dynamically from the different data sources are stored as well as the algorithm used for this. This gives a measure for the validity of the calculated interest values. Storing this explicitly allows taking them into account when applying the interest values for adapting a service offered to the user

One of the dominant factors for adaptation is the task the user wants to perform - what does the user wants to do at all. As all parameters relevant for adaptation the relevant factors need to be represented formally within the system. Therefore we present shortly an example of an ontology for tasks the user wants to perform with a mobile map. The idea is that user activities can be described in an ontology. See figure 6 for a recent example of a task ontology that has been newly developed by [18] based on the ideas of [12].

5.1 Generic transformations in order to produce maps

For a generic application the gml2svg transformation script cannot be a static document because both the structure of the GML data as well the styling of the presentation depend on the specific application. Therefore the script must be computed dynamically. As the presentation information is contained in an SLD document it is possible to generate the gml2svg script in another XSL transformation from the SLD document. Figure 7 shows the three XSL transformations differentiating between 'runtime transformation' being executed after a specific query and 'parameterization transformation' which can be executed earlier. It shows the complete transformation cascade that needs be executed in order to display geodata from a WFS as an SVG document based on an XML schema from the WFS and an application-specific SLD document in a completely generic way.

5.2 Generating user adaptive SLDs

Now we want to extend this approach by also generating the still static SLD document also dynamically - taking user and context information into account. Here come the user and context models introduced earlier into play: First we need a base map, or more precisely a base SLD describing the not-adapted map. This can be generated from desktop GIS like ArcMap as explained in section 4 or from another SLD generator tool that certainly will appear soon. But certainly somewhere we need basic signature rules in some format for the first step. So let's take the mentioned base SLD. Now we have the task to combine this base SLD with the user and context model. This can be achieved by generating a XSL transformation script from both the user and context model that transforms the base SLD into an adapted SLD. This generation of the transform script includes the knowledge of how to adapt a base SLD according to specific user and context values. This approach leads to the incorporation of the adaptation knowledge into "hard coded" rules that generate the XSL. This is a situation that should also be improved. This means instead of writing the rules into the code it would be wishful to have some declarative language or representation that describes the adaptation rules in a language independent way. As such a declarative rule representation is not yet available we propose the future definition of such a rule base. The following figure shows the approach. The resulting "*Adapted SLD*" then can act as input for the transformation cascade introduced by [10].

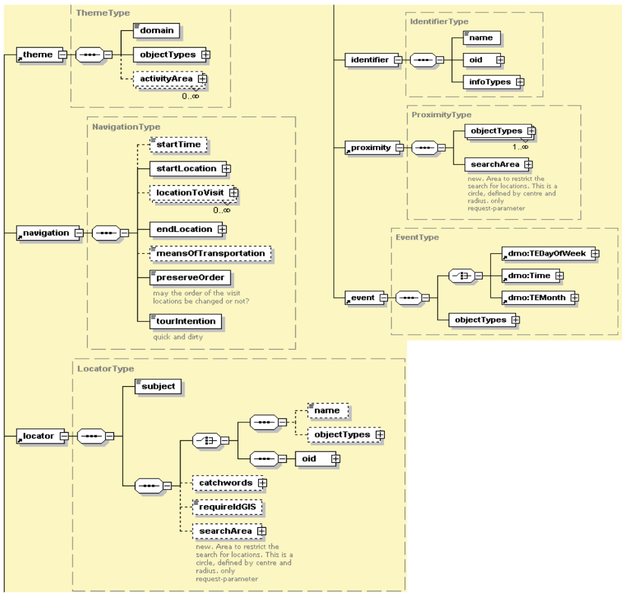


Fig. 6: Extract of XML schema of the "MapTask" model (see [18] extending work by [12]).

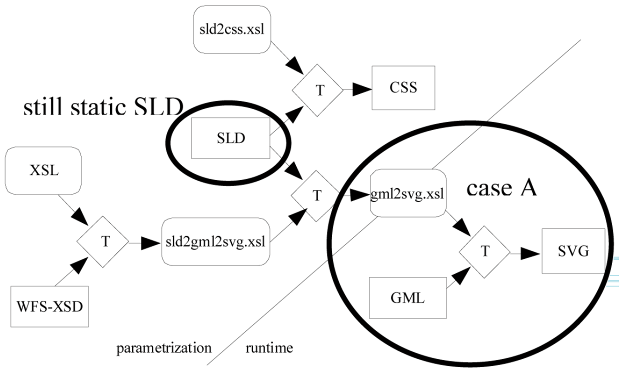


Fig. 7: Complete transformation cascade for a generic application-parameterized generation of SVG from GML data with styling information from an SLD document [10]. T stands for executing a XSL Transformation.

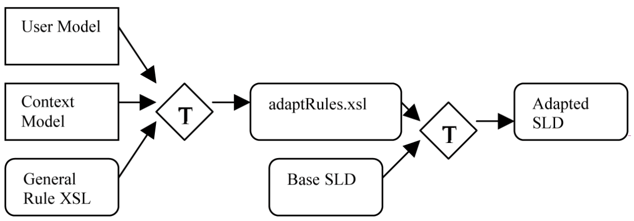


Fig. 8: Extension of the transformation cascade in order to generated an adapted SLD from User and Context Models and general rules how to apply these (specified in XSL).

6 Summary and outlook

In this paper we have presented several novel ideas for generating adaptive GI services for mobile applications using dynamic personalization as well as context factors. Possibilities for future enhancements include first of all a more specific definition of the rules how to adapt the SLD in what way for specific parameters. It is an innovative approach of applying adaptation techniques like learning of user models in the domain of geographic information services that opens a new area of research within GIScience.

A lot of further work is necessary to develop a solid theory for this kind of adaptation to GI services. While we have shown that it is possible to adapt GI services dynamically to context and user properties in general - how to actually do this (what parameters to choose, how to weight them and what types of adaptation to realize) the best way in order to achieve optimal results - is yet open. This requires further empirical tests, evaluations as well as theoretical work.

7 Acknowledgements

I like to thank all former and current colleagues for their inspiration and help.

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Providing an information infrastructure for MapBased LBS

Erich Wilmersdorf

1 Introduction

Densely populated regions are marked by a high density of objects but also by dynamic changes. Therefore the requirements for LBS are especially challenging, not only detailed information in respect of space but also timely aspects are in the focus. The utmost in topicality of data with geographic reference have to be available on call to get reliable information about the kind of service asked for, which is provided by private companies or by public authorities. Urban administrations play two roles in managing space: as a producer of changes in the urban region itself and as a controlling unit, supervising the evolution of the urban area according to the legal framework of the zoning regulations defined by the masterplan. So the administrative body has the possibility to play an important role in building up a sound infrastructure for LBS, based on geo-related information.
For three decades the urban administration of Vienna is collecting digital geodata in its own interest: they represent a geographic knowledge base, which alleviates decision making in internal processes with local relationship. On the other hand mapbased Web-services had been installed offering information to the public. Therefore the administration of the City of Vienna can be seen as a service providing enterprise for citizen and economy, but also in a global respect for everybody, who is interested in information about Vienna.
Past experiences of the WebServices have shown the requirements for LBS. The strategic approach of the City of Vienna for mobile applications are outlined.

2 The components of Geodata-Warehouse

2.1 Data requirements of LBS

LBS claim high demands on the availability of data. The need for data especially in urban regions is voluminous. In the focus are data about space:

-Geographic position
-Geometry of objects
-Topological connexions (e.g. network of public transport)

But also attributes of single objects and events are of importance:

-detailed classification of services,
-scope of products
-business hours,
-recent status (vacation),
-state of affairs,
-time tables
-etc....

2.2 Fundamental data bases for LBS

In order to cope with these fundamental requirements several data bases are necessary:

2.2.1 Meta-data base

A meta-database represents a catalogue of the geodata warehouse. It covers the specifications of the data especially in geographic regard:

-data type
-reference system (coordinates)
-geographic extent
-attributes
-object class

-data quality
-maintenance information (e.g. update cycle)
-responsible person

The metadatabase of Vienna is based on ISO 19 115 specifications. According to those characteristics it is possible to decide if the data are suitable and also relevant for a new LBS Service envisaged and how they can be accessed and incorporated.

2.2.2 Geographic Identifier (gazetteer)

Localisation is of utmost importance in the field of LBS. There are many kinds of positional definitions applied in every day life when entering into a LBS. Apart from the self positioning by GPS or apart from the provision of the coordinates of the telecommunication cell a large scope of user defined popular terms of locations must be supported. Besides the most frequently used house number other definitions such as object names (e.g. "Schönbrunn" as a name of a landmark) have to be stored geocoded. Not only the position but also the size of the map extent can be derived automatically from the gazetteer data base, which includes the dimensions of the object (see "Stadtplan mit Adressensuche": http://www.wien.gv.at/wiengrafik).
This set of local and regional identifiers alleviates the spatial analysis within LBS processing.

2.2.3 Geographic Reference System

The Reference System of Vienna (RBW) represents a generalized model of the urban structure furnished with a set of identification keys for blocs and street network. The postal address is geo-coded and linked twice: to the bloc and to the adjacent street segment.
These elements offer LBS logistic information. It is linked with the gazetteer data base too. So it forms a solid basis for the search function via an address and for the examination of networks to get a suitable route from the starting point to the target point suggested by LBS.

2.2.4 Topographic data base

The City of Vienna decided to build up a digital model of high resolution in the nineteeneighties. The complete area was surveyed by techniques of tacheometry and photogrammetry, recording directly in digital mode. The data base represents a detailed description of the geography and geometry of objects. It is an outstanding coverage because of the high resolution of the model describing the complete "urban landscape" digitally. The composing even of 3D objects (buildings) is under way.
Viewed by LBS it is a powerful data base: Due to the high resolution this database offers a detailed object inventory even about small objects. So it can be seen as a collection of points of interest for different object classes.
The second function is important for LBS as well. The neighbourhood can be visualised by a city map derived from this database by cartographic modelling.

2.2.5 Cartographic data bases

There are only few cartographic databases maintained periodically as in general cartographic visualisation is covered by real time processes (see 4.2: Real Time Cartography). For LBS two databases are of interest. They are used as background maps for the purpose of orientation:

City map

The city map is derived automatically from the Reference System of Vienna (RBW), from the land use data base and/or from the topographic data base. It is periodically updated by automated cartographic modelling, and by rendering for different ranges of scales. For each object class the cartographic visualisation is defined by rules. The map processing is finished by a vector/raster-conversion.

Orthophotomap

For many purposes a photographic "snapshot" of the urban landscape is advantageous when background information true to nature is needed: a detailed illustration of the real world in homogenous and current manner in terms of time. Such a detailed geographic visualisation of the surface never can be provided so quickly and substantial by a map derived out of the topographic database, which represents a generalised model and is updated in a three years cycle.

3 Maintenance of Geodata Warehouse

3.1 Completion of digital geodata warehouse

The City of Vienna is already equipped additionally with voluminous databases of special fields, storing vast data about the urban area representing a detailed geocoded object inventory of the urban microcosmos e.g. a full coverage of the street network (mate-

rial of the coverage). So the quality of the pavement can be analysed automatically (obstacles as staircases, street furniture, bottlenecks of width), in order to recommend a route for handicapped people.
Additionally attribute data and other digital images of objects (photos, detailed site drawings and maps for emergency cases) are stored in a geocoded way. Due to the important role of time in LBS also short term objects are incorporated into the data warehouse, e.g. the construction sites in the road network as obstacles for routing during a predefined period.

Despite this considerable Geodata-Warehouse - already existing -, there are lacks (e.g. the network of paths and passages for pedestrians), which represent obstacles for automated information processing especially for LBS purposes. The "GIS-Masterplan" of the City of Vienna -passed 2004- is a development scheme for the urban GIS. It envisages the penetration of the administration with GIS facilities and it focuses on the gaps in the recent ViennaGIS GeodataWarehouse to be filled until 2007/2008.
On the other hand it is obvious, that the service of the public administration is only one part, the other are the many data bases of private service providing companies which must be available and updated as quickly as possible too. Detailed information about the kind of service and restriction in time must be maintained in a reliable manner, so that LBS get confidence into its services which is needed for acceptance.

3.2 Utmost efforts for quick updating

To cope with the demand for utmost topicality changes in the metropolitan area have to be recorded digitally as soon as possible. Digital recording facilities are placed in those branches of the administration, where changes are observed at first (e.g. where building permissions are given) or where changes are caused (e.g. public projects). Especially the integration of GIS- functionality into administrative processes is expected to contribute to these efforts: data are collected in the daily workflow. Early bird information about pending changes can be recorded automatically by tapping data flow of processes.

Update methods

Many ways of updating are applied: Electronic measuring techniques in the field, CAD input imported directly from private contractors, GIS workstations for sophisticated editing in house but also a WebEditor, which can be made available on a standard PC without a GIS software licence. So the urban administration is able to take charge of updating geodata on those working places, where new data occur at first. This Web-Editor offers functions for recording geo-related data on each PC in the urban telecommunication network: simple geometric input together with object`s identification keys and attributes. Telecartography helps to improve the updating in time and in quality. A mobile version of this WebEditor is planned to support directly the collection of data in the field. It applies these methods in order to cover updating in an economic way and in the state of art. All these efforts together should guarantee that the urban administration of Vienna contributes his part to completeness and topicality of its overall Geodatawarehouse.

4 Service providing geoservices

4.1 Analytical features

LBS are faced by individual requests (localisation and different points or area of interest). So a flexible combination of themes and quick response in the assembling of the adequate information package is asked for. Analysis services have to be offered as well: spatial retrieval in combination with selected attributes and object classes. Several functions for the acquirement of selected information should be provided, e.g.:

-Position of the object and its spatial extent
-localisation of the route (starting point A/target B)
selection of an appropriate target point B due to its spatial and attributive characteristic
and the proposition of a route from A to B, taking care of barriers like stair cases or construction sites. Corresponding to the individual demand the network for public transport, street network but also footpaths for pedestrians has to be analysed.
-extraction of objects according to the request (e.g. office of a medical practitioner)

Public authority has to offer analytical tools for those sectors which are maintained within the administration.

4.2 Real Time Cartography

The visualisation is the final stage of LBS processing, marked by adaptive adjustment of the cartographic output according to the individual demands with regard to the restrictions of mobile equipement. To provide the utmost topicality of information, the building up of the cartographic model must be possible on call, exploiting the current state of the databases. Real time processing of the map is the answer.
Cartographic compilation is executed basically according to the following guideline:
Cartographic modelling is generally executed in a processing stage on demand, generating cartographic objects derived from the original object data set. The objects are stored in an abstract way, to make use of them for many purposes in a flexible way. The

cartographic compilation is executed on basis of rules for visualisation for each object class and attribute. There are many kinds of cartographic presentation, dependent on the scale, the level of detail and the set of themes. Many aspects have to be covered:

-visualisation has to be adjusted to fit the individual demand for geographic information, so to speak “maps made to measure” (e.g. scale dependent construction according to interactively defined space and content, automated text placing)
-the visualisation has to fit the requirements of the output device (size and resolution of the display) .
-additional information offered in a dialogue by clicking on an object in the map to get information about the object in a separate window.

4.3 Providing Web Services

4.3.1 Infrastructure

Map based WebServices claim computing power. Therefore a solid infrastructure of servers is necessary. To cope with the workload, processing is distributed on different servers executing special tasks in parallel mode as far as possible: checking input especially the local address, address localisation, calculation of the map extent, selection of the themes, constructing the map image. The services have to be available permanently, 7 x 24 hours a week. There are three levels of Webservices:

4.3.2 Map-based Internet service

The challenge: Individual questions have to be answered customer related.
Prefabricated applications - furnished with GIS functions for identifying locally - offer information processing guided in a dialogue. Individual navigation and geographic analysis allow the creation of flexible maps on the display e.g. the “Stadtplan mit Adressensuche” for mobile equipment (PDAs) takes care of the reduced size of the display of the PDA.

All Internet services of the City of Vienna with geographic aspects are based on:

-real time cartography
-Standard Browser (no Plug In)
-customer´s interaction
-flexibility in conveying georelated information

4.3.3 WebMapServices (WMS)

The municipality supports also private projects for geographic information services.
Standards according to OGC are applied to support the transfer of cartographic data on call to external customers. Via a request over the client spatial ID and selection criteria defined in the parameter list are transferred to the Web Server, the spatial extent is calculated and according to the parameters the map image is constructed. The platform independent map images (raster data) can be integrated into applications of the customer and put together with his own geodata.

4.3.4 WebFeature Service (WFS)

This kind of Webservice, based on OGC Standards also, allows the download of digital vector data exactly to the requirements of the user. According to the customer`s request certain object classes are selected within the defined space. Identification and selection routines generate an individual package of data converted into the data exchange format and map projection asked for.

5 Conclusion

Municipalities have to build up voluminous knowledge data bases in order to manage its portfolio and to control the development of the urban region. So municipalities play a key role as an information dispensing authority. This infrastructure has to be improved, to fit the special requirements of map based LBS by:

-comprehensive data capture
-quick updating
-installation of platforms for tapping geographic information

Municipalities are expected to act not only as distributor of geocoded data but also as service provider of georelated information.
The City of Vienna has declared it as a strategic goal to promote the installation of a framework of GIS and telecommunication, to support the effective exploitation of its Geodata-Warehouse inhouse and from outside. Information should not be available in the body of the administration only, information has to be transferred where it is needed: directly to the customer. Realisation is committed to standards, which allow open services, marked by flexibility and interoperability.
The infrastructure outlined aims at the ability, that LBS-requests can be answered in time, in a reliable and complete manner. Future developments are focussed on generating software on Webservices and especially on real time cartography, to improve the user interface for LBS.

MoGeo: A location-based educational service

David A. Bennett, Marc P. Armstrong, Jerry D. Mount

Abstract

The classroom is an efficient venue for conveying theories and concepts in many disciplines. In geography, however, students often have difficulty understanding spatio-temporal processes that are represented abstractly. Though field-based classes embed students in the environment they are studying, they are decoupled from supplemental information that often catalyzes learning. In this paper we present a location-based service for geographic education: the **Mo**bile **Geo**graphic Education (***MoGeo***) System**.** ***MoGeo*** design is based on contextually-aware computing and integrates the following technologies: GPS receivers, GIS software, wireless networks, mobile computers (PDAs or tablets), and centralized computers (*e.g*., servers). Using this assemblage of technologies, we integrate the important elements of the classroom and computer laboratory into a field-based learning environment by providing remote, real-time access to: 1) context-specific educational materials; 2) sophisticated spatial analyses; 3) high-end visualization and simulations; 4) feedback and evaluation; and 5) instructors and peers. The overall experience is analogous to the guided tours available at many museums, but is richer and more conducive to intellectual exploration (*e.g.,* through simulation, visualization, and experimentation) and collaboration (*e.g.,* through audio/visual communication and real time tracking of classmates).

1 Introduction

The purpose of our ongoing research project is to promote geographic understanding through experiential, field-based learning opportunities supported and enhanced by location-based educational service technologies. The use of these technologies allows students to take the classroom, computer laboratory, library, and Internet with them into the field. By integrating the best elements of these more traditional learning opportunities, complex and abstract spatial concepts come alive and assume greater real-world meaning for students (Armstrong and Bennett 2005). This educational experience is referred to as **Mo**bile **Geo**graphic Education (***MoGeo***). In the ***MoGeo*** framework, "where" is both paramount and, paradoxically, irrelevant. The delivery of place-specific, highly contextualized information about what students are to learn, given their current location on the landscape, is what makes ***MoGeo*** unique and powerful—the "where" matters when learning about geographic processes. On the other hand, recent advances in mobile computing technology provide access to instructors, peers, knowledge repositories, data, and computational power from almost any location—"where" no longer matters when it comes to the provision of educational materials. These characteristics of ***MoGeo*** have challenged us to rethink the way knowledge is transmitted as we disconnect educational processes from traditional classroom settings and embed them into the system under study.

To understand the conceptual framework on which ***MoGeo*** is built, it is useful to make a comparison between the production of knowledge through scientific inquiry and its dissemination in higher education. First, consider how knowledge is produced (Figure 1). Reality is observed and measured. To better understand what we empirically observe we develop theories about how reality works. Experiments and models are constructed to help us examine the validity of our theories in manageable, simplified settings; experiments and models provide a bridge from theory to reality. What we learn from these experiments and models helps us rethink our theories, and what we learn about our theories can change the way we view reality. Now consider how these three elements of knowing (empirical observation, theory development, and experimentation/model building) are translated into three common teaching environments, the classroom, laboratory (here we constrain discussion to the computer laboratory), and field class.

For centuries, the classroom has proven to be an efficient, if imperfect, mechanism through which theories and concepts can be conveyed. Although the classroom provides a forum for the presentation and discussion of ideas, the representation of many spatio-temporal phenomena of interest to geographers is restricted to highly abstract diagrams or static images of reality because of the scale of observed processes. In laboratories students get a "hands-on" feel for the interrelationships that drive dynamic spatial processes through space and time using visualization and simulation software. Furthermore, students can augment their knowledge through the review of related resources that are accessible from the Internet. While there is no consensus on whether or not internet sources improve learning, students tend to place value on multiple data sources that present information in alternative forms (Chrisman and Harvey 1998; Ritter and Lemke 2000; Jain and Getis 2003). However, two problems often constrain the learning process in computer laboratories. First, traditional laboratories are ill-suited to collaborative learning (Reed and Mitchell 2001)— too often students sit in front of their machine focused on the implementation of complicated computer instructions, taking little opportunity for the kinds of discussions that can occur in classrooms, or group problem solving activities that often occur in the field. Discussion and group problem solving, we maintain, assume importance when students are asked to make a cognitive connection between

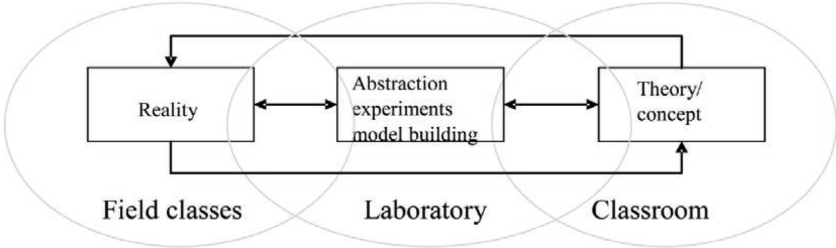

Fig. 1: Knowledge is produced through a highly integrated process of observation, experimentation, and theory development. These three "elements of knowing" are often fractionated when knowledge is disseminated in higher education.

model and theory. Similarly, the bridge from simplified model to a complex reality can remain tenuous because of the level of abstraction needed to implement models in laboratory settings.

Field-based classes link the student to reality and many studies document the importance placed on field-based experiences by students (see, for example, Kent, Gilbertson and Hunt 1997; Fuller, Rawlinson and Bevan 2000; Pawson and Teather 2002; and Fuller, Gaskin and Scott 2003). However, field-based classes have historically been isolated teaching environments because of: 1) difficulties associated with accessing the kinds of supplemental material that help catalyze learning; and 2) logistics, if students become too dispersed they cannot effectively interact with the instructors or each other.

The highly integrated process of knowing, therefore, becomes transformed into a decidedly more fractionalized process of teaching. ***MoGeo*** is intended to overcome this difficulty by fusing the important elements of the class, laboratory, and field into a single learning environment that provide students with *in situ* access to: 1) knowledge and data resources stored in web accessible repositories; 2) state-of-the-science spatial analytical tools; 3) the knowledge of teachers and peers; 4) a way to communicate at a distance; 5) models and visualizations of processes under study; and 6) real-world geographic context. By providing the communication and computation tools needed to take the classroom and the computer laboratory to the field, ***MoGeo*** promotes scientific discovery and, we maintain, the dissemination of knowledge becomes more closely bound to to the production of knowledge.

2 Principles to guide the application of *MoGeo* in higher education

Ten prescriptive principles for ***MoGeo*** application design were presented in an earlier paper (Armstrong and Bennett 2005). While we do not expect that all projects will strictly adhere to every principle, the relevancy of each should be considered as one designs ***MoGeo*** enhanced laboratory exercises. These principles are summarized as follows (for greater detail please refer to Armstrong and Bennett 2005):

1. Promote *in situ* learning experiences- Directly couple *in situ* field experience to data and knowledge repositories accessible via the World Wide Web to help students contextualize abstract concepts and explore related concepts.
2. Use locational triggers (intelligent landmarks)- Turn the field experience into a self-guided tour analogous to those available at many museums by monitoring students' positions and delivering context-specific information at appropriate times and locations.
3. Accommodate multiple learning styles- Support alternative learning styles by producing class materials in graphical, textual, auditory, and symbolic (mathematical) form (Ritter and Lemke 2000; Smith 2002).
4. Produce interactive, dynamic, and student-centered learning experiences- Engage students in the learning process by promoting hands-on problem solving activities and context specific interaction.
5. Teach about the importance of spatial relationships and their digital representation- Produce laboratory exercises that require students to conceptualize and implement strategies for the representation and capture of attribute, geometrical, and topological data.
6. Teach about proper editing practices and the importance of metadata- Promote the proper and confident use of geographical data by requiring the development and maintenance of metadata that traces the history of alterations made by data users.
7. Teach about privacy and the ethical use of ***MoGeo*** technologies- Promote the ethical use of mobile computing technologies (Armstrong 2002; Monmonier 2002; Beresford and Stajano 2003; Myles, Friday and Davis 2003; Gruteser et al. 2004) by illustrating responsible use of the technologies (CSTB 2003).
8. Promote personal safety- Make sure that laboratory exercises do not expose students to danger or cause them to behave in unlawful ways.
9. Promote the safe and secure use of wireless technologies- Be sure that the use of wireless technologies in laboratory exercises does not to expose campus computer systems to unauthorized use or malicious attacks.
10. Develop efficient code for mobile devices- When developing laboratory exercises always consider the limited computing resources associated with mobile computing technologies (Viredaz, Brakmo, and Hamburgen 2004) and avoid the frustrations associated with slow or inconsistent technologies.

When considered collectively, three overarching themes emerge from these principles. First, context is important. We must know who the students are and the environment in which they are working. Second, the system must be flexible. It should be possible to easily modify a ***MoGeo*** learning environment to, for example, represent a new landmark or support alternative learning styles. The final theme is responsibility. The potential for abuse with mobile technologies, by both instructor and student, is clear and steps must be taken to insure that all parties understand their responsibility for the ethical use of these devices.

3 *MoGeo* Technology

The design of ***MoGeo*** is based on the concept of contextually-aware computing. The system serves educational material to a student when and where it is needed. To accomplish this coordinated push and pull of information we must know who students are and the class in which they are enrolled. We must also know the laboratory exercise particular students are attempting to complete and where they are located in the landscape. Given this information we can match the students' context (***i.e.,*** location and laboratory assignment) to a set of intelligent landmarks stored in the system. Each landmark is associated with a spatial feature we want students to learn about (***e.g.,*** a wetland or particular land use) or locations at which we want them to perform some task (***e.g.,*** collect data or modify a spatial database). Persistent agents, instantiated on the server, monitor student context, match student context to landmark characteristics, and, if appropriate, coordinate the push and pull of context-specific information. Using contextually triggered "pop quizzes", we are able to assess how well students meet learning objectives, identify where mistakes were made (***e.g.,*** discrepancies between the students work and expected product), and take remedial actions while the student is actively engaged in the learning process. The student could, for example, be directed to recapture points that were incorrectly located, complete a step that was inadvertently skipped, search web-based resources that describe a particular concept in greater detail, or "get a call" from the instructor using VOIP.

The ***MoGeo*** system consists of the following components: 1) mobile computing devices; 2) GPS receivers; 3) WiFi wireless communication cards; 3) GIS software; 5) a notebook or desktop-based server; 6) wireless communication access points; and 7) communication software. These components are deployable in two configurations. The server can be attached directly to the hardwired campus communication network and linked to the mobile devices via outdoor wireless access points installed on campus buildings. This configuration provides users with full access to network accessible knowledge repositories, but restricts the spatial range of the system to those areas covered by installed access points—an area less then $1km^2$ given current technology. A field-based configuration can also be deployed. In this situation, a wireless access point and directional antenna is attached to a notebook computer. This configuration frees the system from the campus backbone and, thus, allows it to be used at almost any location. If an Internet connection is unavailable for the notebook system, however, a knowledge repository must be developed and installed on it before going to the field. This limited connectivity, of course, reduces the total volume of information available to students. With WiMax and the proliferation of next generation cellular technologies, however, connecting to the Internet should not be a long term impediment to ***MoGeo*** (at least in and around urban areas).

Figure 2 illustrates the interactions among various ***MoGeo*** software and hardware components. Students log into the system, linking their digital identity to a class, laboratory exercise, and location stream (the stream of points produced as a student moves across the landscape). The GPS samples the students location at regular intervals (***e.g.***, every three seconds) and software loaded on the PDA sends a "who, what, when, and where" information packet to the server through the wireless communication link. In our current system, the software used to capture, store and query data on the server side is SQL Server. Controlling logic written in XML queries these data to determine if students are within a trigger space associated with their current laboratory exercise. What happens when a trigger event occurs is, of course, dependent on the laboratory exercise. Higher level spatial analyses are sent to the server and processed using tools stored in ESRI's ArcObject library. PDAs and tablet computers are the two most practical computing form factors available at this time for supporting ***MoGeo***. At roughly one third the cost of a tablet, PDAs are clearly the most cost effective solution, but they have two significant limitations. First, with a display area of approximately $50cm^2$; these devices have a limited ability to present the kinds of cartographic representations that GIS users have come to expect. Second, these devices have limited computing power and, thus, cannot perform computationally intensive geographical analyses. To overcome this problem requests for such analyses can be uploaded to compute servers and the results sent back to the mobile device. The implementation of such a solution, however, has required custom software development.

We have been developing ***MoGeo***-style capabilities for about 1.5 years—supported by internal seed grants and our own curiosity about the utility of mobile technologies in the classroom. We currently deploy 20 PDAs (Compaq IPAQ model 3850, purchased in 2003) each of which runs a mobile GIS software package (ESRI ArcPad) and software developed "in house" to support communication among components and the transformation of incoming data to a GIS format (Figure 3). These devices are equipped with WAAS compatible GPS units and WiFi network interface cards. The compute server is a 3.4 GHz Pentium 4 notebook computer with 1GB of RAM and a 100 GB disk. This server is equipped with a WiFi network interface card, GIS software (ESRI's ArcMap 9.1, associated extensions and ArcObjects), and SQL Server. Persistent agents running on the server provide two main location-based services for the user. First, they collect incoming data from mobile devices and coordinate the push and pull of context specific information. Second, these agents perform analytical tasks that are beyond the capability of the mobile GIS software or the PDA. These tasks are executed using calls to ArcObjects.

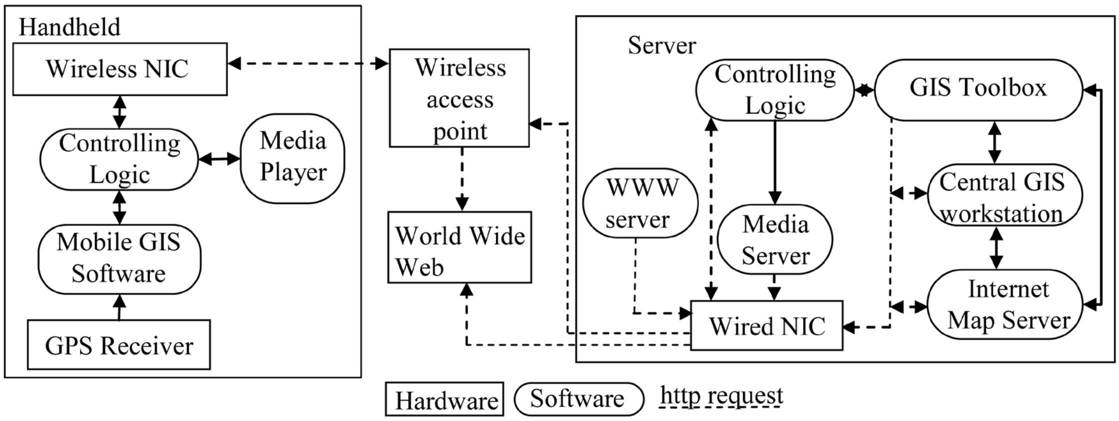

*Fig. 2: Schematic of **MoGeo** implementation.*

4 Teaching the four traditions of geography with *MoGeo*

In 1964 William Pattison established four themes that he believed captured the intellectual core of geographic enquiry (Pattison 1964). These "four traditions of geography" are: 1) spatial; 2) area studies; 3) man/land (what we now refer to as human/environment); and 4) earth science. Twelve years latter, Robinson (1976) found that these traditions retained their relevance to the discipline. While some may debate whether additional subdisciplines should be added to this list (we can, after all, forgive Robinson and, in particular, Pattison for not foreseeing the importance of GIScience in the days of the mainframe, key punch, and line printer), this set remains relevant today and is sufficiently diverse to illustrate the range of educational applications to which ***MoGeo*** can be applied. We are creating ***MoGeo*** enhanced laboratory exercise that teaches concepts associated with each of the four traditions of geography. The production of such exercises requires the development of spatial databases, the identification and integration of supporting resources (web links, video, articles), and the extension of existing ***MoGeo*** capabilities. We have completed a first step toward this goal by implementing a laboratory exercise in the "spatial tradition."

This exercise is inspired by "Modelling Access with GIS in Urban Systems" (Mathews *et al*. 2003) that evaluated how urban infrastructure impacts the movement of individuals who use wheelchairs. Students produce spatial datasets that capture travel impedance using guidelines documented in Mathews *et al.* (2003) and the American Disabilities Act. These data are developed into a network model of wheelchair accessibility in the laboratory. Students then return to the field and, using the original and modified network datasets, produce and traverse shortest paths using GIS software. The compute server is be used to calculate alternative paths for the students in real-time based on alternative assumptions about impediments to travel.

5 Future work

We have only just begun to explore the possibilities of ***MoGeo*** and further work is needed on all aspects of this endeavor. We need, for example, to:

1. rigorously evaluate the impact of ***MoGeo*** on the learning process;
2. explore the utility of multiple communication channels (i.e., voice, video, data);
3. evaluate the impact of potential technological constraints, such as bandwidth, response time, and distance, on user satisfaction;
4. design, implement, and evaluate human-computer interfaces that facilitate the ***MoGeo*** learning process;
5. design, implement, and evaluate cartographic and geovisualization products well suited to the ***MeoGeo*** learning process; and
6. evaluate the utility of real-time feedback to students during the learning process.

*Fig. 3: A **MoGeo** device consists of a mobile computer (handheld or tablet), a global positioning system receiver, wireless access, GIS software, and communication software.*

6 Conclusions

Locationally enabled mobile computing is beginning to routinely affect our daily lives. As a consequence, it is important that geography students, in general, and GIScience students, in particular, understand the strengths and weaknesses of emerging technologies by learning to use and apply them properly. Such understanding and hands-on experiences will give our students the knowledge needed to: 1) compete successfully in a rapidly changing technological world; and 2) use advanced geospatial and mobile technologies in an appropriate and ethical manner. We further contend that the need for such an understanding is, in fact, widespread within the academy and that the activities described in this paper will have important ramifications on a wide range of disciplines, literally from Anthropology (e.g., studying the ecological context of ancient sites) to Zoology (e.g., calculating habitat suitability while conducting field surveys

While an educational example is described in this paper, the concepts embedded in ***MoGeo*** are portable to LBS in general. For example, conceptual maps derived from user interaction can attach "value added" information to landmarks (***e.g.***, individuals who found this attraction interesting, also enjoyed these attractions…), while virtual locks monitored by persistent assistants can filter out unwanted solicitations (***e.g***., forward only those services associated with landmarks containing historical information). The opportunities seem endless. The trends we observe today in mobile, embedded, ubiquitous, and pervasive computing are, after all, just the metaphorical tip of a very large iceberg.

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What makes Location-Based Services fail?

Gerhard Navratil, Eva Grum

Abstract

A lot of research projects deal with location-based services and also telephone providers started services. Some services fail to become an economic success. In this paper we investigate possible pitfalls for location-based services. The categories of pitfalls are technical possibilities, legal restrictions, and usability. Using two example services we show how to determine the possible pitfalls.

1 Introduction

Discussions on location-based services (LBS) started in 2000 (Laurini 2000; Winter, Pontikakis et al. 2001). Since then a number of LBS was started by mobile operators. According to Berg Insight AB (2005) the revenues from LBS's for Europe in 2004 was over 100 million Euro and they expect the number to grow by 2000% in 5 years. Not all LBS's are economically successful. The Austrian mobile operator ONE, for example, cut the efforts on the sector of LBS in 2004.

Failure of a service can be viewed from two perspectives. The user defines failure as 'costs are higher than the benefit'. This includes, for example, wrong or too expensive information. The service provider defines failure as 'not profitable'. If the costs for the service are higher than the revenue (including indirect revenue like advertisement) the service is a failure. In this paper we discuss the problem from the view of a service provider.

Services create costs for the service provider and thus the service should produce benefit for the service provider to justify the expenses. Pitfalls may prohibit the benefit. Thus identifying pitfalls is important for developing location-based services.

Availability of data sets is influenced by three major aspects: Technical possibility, legal restrictions, usability (Navratil and Frank 2005). We assume that this structure does also apply for the success of LBS and the aspects, which let LBS fail, can be grouped into technology, legality, and usability and their interrelations.

In this paper we use two examples to show how to identify possible pitfalls. The examples are LBS, which do not yet exist but could be implemented. We assume that the LBS is designed for mobile phones only since according to Rümenapp and Gutsche until 2015 98% of the population in Germany between 15 and 55 years own a mobile phone (Rüpemapp and Gutsche 2003). Other European countries will have similar numbers.

We discuss the examples from the different perspectives defined above. In the first step we look at the technical status. The next step refers to limitations imposed by the Austrian law. Finally we look at the usability. In the end we discuss interrelations between these aspects. This discussion shows that the aspects are often linked together.

2 Examples

Two examples shall provide the framework for this paper. The first example shows how LBS can be used to improve the international emergency call 122. The second example deals with pedestrian navigation in a very specific case: navigation at dealer shows.

2.1 LBS for emergency calls

The phone number 112 without any prefix is a European emergency call. 47 countries are involved in this program (European Union 2005). A call to 122 is routed to the closest emergency operator. He is connected to the emergency services in his area like police, ambulance, and fire brigade.

The operator needs information about the incident - what happened and where. Depending on the incident he will react in one of two possible ways:

1. If the incident requires help on the location the operator will contact the accordant local emergency services and send them to the place of incident. The local emergency services will send one or more units to the place of incident and therefore need the address of the location or a route description. This information must be provided by the user (caller) and is forwarded by the operator. In some areas specifying a location or providing a route description is difficult, e.g. if a climber has an accident on a mountain. Route descriptions in rural areas are different than those in cities. There are no street names and house numbers, which

can be used to describe the route. Thus different concepts like easily recognizable trees, rock formations, or clearings have to be used to describe the route.

2. It may also be that the user needs the location for the next office of an emergency service, e.g., the police. The operator must know the position of the user and can then provide a route description to the next police office.

Incidents usually require quick reactions and thus it would be helpful if the operator knew the approximate position of the user immediately. Then the operator can ask more specific questions and the system can automatically support him with additional information like, e.g., a topographic map.

2.2 LBS for dealer shows

Dealer shows are an opportunity for companies to present their new products to potential customers. This requires a booth large enough to present the products. The corridors between the booths are kept as narrow as possible to fit the largest possible number of booths in the area available for the dealer show. The result is a situation where a large number of booths is situated in a small area and visitors gathering around booths block the corridors. Moving along the corridors is difficult.

Visitors face a problem if they want to find the booth of a specific company. Walking in a crowded area makes navigation more difficult. Looking at booth maps in a crowded area may even be impossible if the map is too large. Another problem with such maps is finding the current position by matching the visible companies with companies shown in the map. This is also a drawback for companies if they cannot be found. Thus an easy to use system for navigation would benefit both visitors and companies as we learned in discussions with journalists (Fürnkranz 2005, Katz 2005).

A navigation system for dealer shows can adapt results from pedestrian navigation services (Gartner, Frank et al. 2004). The user sends an SMS (short message service) to the service containing the name of the company he is looking for. The user then receives a description of the path to the booth of that company. This description may be either a unique message or a continuous stream of information. In the first case the quality of the description must be high enough to prevent errors and in the later case the service will have to track the mobile phone of the user and give directions when necessary.

3 Technical solutions and their pitfalls

Both examples comprise three steps. In the beginning the user accesses the service. Then the service processes the inquiry. Finally, the service provides information to the user. There are differences in the processing methodology of the two examples but the steps are the same.

A major difference between the two services is that the emergency call must not fail. Emergency services must be accessible anytime. Since emergency calls shall save lives considerations of costs are limited. The service for dealer shows should make profit and thus price and reliability of the solution must be balanced.

3.1 Access to the service

The user must access the service. The access method for the emergency service is calling from a mobile phone. Depending on the rough location of the user the call is directed to an emergency response centre where a human operator receives the call.

The service for a dealer show must use an automatic method. Having a response centre in addition to the information desk, which is usually available, is not useful. Since the service shall relieve the information desk, connecting the service to the information desk is not wise. Thus, the access must use a method provided by mobile phones. Possible solutions are

- sending an SMS or
- using a WAP-service (wireless application protocol).

The user must provides the following information:

- Identification of the user for locating, response and payment
- Name of the company to be found

The telephone number provides unique identification of the mobile phone. The assumption is that the momentary user of the mobile phone is also the person registered at the telephone company. Problems with the identification may occur with pre-paid telephones because there is not necessarily a name and an address connected to them and thus billing may be difficult. Special treatment of such mobile phones may be necessary.

Another problem is the spelling of the company name. The service could provide a list of possible names if no perfect match is found. The user then corrects the name and again accesses the service.

3.2 Processing the inquiry

A human operator is necessary to process incoming calls for the emergency call while the dealer show service requires an automatic response. The operator for the emergency call must provide help fast and efficient. The LBS can support him by supplying useful information. There is a list of questions to be asked by the operator to provide the following information:

- What happened?
- Where did it happen?
- Who is calling?

The system can automatically provide hints for the last two questions. The system can identify the owner of the mobile phone. This information can help reduce response times assuming that in general the caller will be the owner of the mobile phone. The system can also provide a position of the mobile phone and automatically come up with a map of that area. The operator can concentrate on the first question.

Maps can be provided in different ways. The easiest method would be using a web-map-service as provided by mapping agencies. Unfortunately response times depend on the workload of the web server used. A breakdown of this server could lead to a situation where the operator has no other information than the one provided by the caller. This is fatal if the operators are trained to follow a specific procedure, which depends on the availability of the map. A faster and more reliable solution would be to set up such a server within the local computer network. The agency then has full access to the server and can take precautions that backup servers are available. However, this solution requires more personnel and the emergency agency must pay attention to the quality of the data used, i.e., the agency must purchase and install data updates.

The operator finally has to decide if he sends an emergency unit (ambulance, police, etc.) to the location of the user or if he guides the user to a location where he can get help. Depending on the situation only one of those possibilities may be applicable. In both cases the operator must provide instructions. Emergency units require less information than the users of the service, since emergency vehicles can be equipped with navigation systems. A route description for the user must consider that the user may be unfamiliar with the surroundings and thus needs detailed (and maybe even redundant) information.

In case of the dealer show the system must determine the current position of the user and the path to the position of the company's booth. The current position can be detected automatically (e.g., by the cell ID or a GPS receiver within the mobile phone or connected to it). The quality of the detection (Retscher and Thienelt 2004) must fit the requirements of the service.

The definition of the path should be done using a suitable algorithm. A simple solution following the Dijkstra-algorithm (Dijkstra 1959) will not be sufficient because the path may become complicated. Different additions have been proposed by Duckham (2003), Grum (2005) and others (see for example Winter 2001; Beer 2002; Winter 2002).

3.3 Transfer of instructions

The result of the service must be transferred to the user. The transfer of the location of incident to an emergency unit can be done as usual. A map of the area as used by the operator can be sent if necessary. Sending the path description to the mobile phone of a user is more difficult. The description must use landmarks and street names to describe the path. The transfer can then be done either as in form of an SMS for short paths or as a multi-media service (MMS). The advantage of SMS is that all mobile phones can process it. Older mobile phones may not have the capabilities to process an MMS. The disadvantage of SMS is the size limitation and the restriction to text. SMS do not allow images or maps.

4 Legal restrictions

Legal restrictions for LBS originate from different parts of the law. Data is protected by copyright, programs may be subject to patent law (compare the discussion on software patents), and the user himself has privacy rights. These influences dictate procedures and may result in additional costs, e.g., for licenses.

The emergency call provides a more complicated case for a legal assessment than the dealer show. As said in 2.1 the emergency call works in 47 countries. Each of these countries has different laws. Some legal problems may only occur in some countries but not in others.

4.1 Access to the service

Accessing the service is not restricted as long as there is no hidden data transfer to the service provider. An automatic download of the user's telephone directory, for example, would be illegal. Data transfer is necessary in different cases but it must be clear for the user which data is transferred.

It is also legal to charge higher rates than for normal telephone calls. However, the rates must be visible for the user. Since the emergency call is free of charge, this only applies to the dealer show example.

4.2 Processing the inquiry

Both examples include locating the mobile phone. In case of the emergency call the user must tell the operator where he is. As said in 3.2 processing of the emergency call can be accelerated by automatically detecting the location of the mobile phone. The problem with this solution is that the mobile operator is not allowed to track the mobile phone. This includes storing previous positions as well as passing the positions to third parties. The service provider needs the permission of the user to do this. In traditional solution the user must agree that his telephone is located. The agreement specifies who may receive the data and how long it is stored. The agreement can either be sent by SMS or as a signed form by mail. This is possible for the dealer show but is inappropriate for the emergency call. There are two possible solutions:

– Users of the emergency call need help. The help either includes sending emergency units to the location of the user or telling the user where he has to go to find help. In both cases the user must provide his current position. Thus automatically sending the location of the mobile phone to the emergency service may be legal.

The fact that emergency services shall save lives and thus the processing should be as fast as possible supports this hypothesis. As described in 3.2 the automatic location of the mobile phone helps the operator to react more accurate.

– Users must orally agree to locate the mobile phone. This could be done at the beginning of the call and recording the call provides proof if necessary.

Processing the request requires data and software. Data are protected by copyright law. The service provider must have the right to use the data. The result of the process may be a map, which is transferred to the user or third parties (e.g. emergency units). This must be covered by the contract. The same is valid for programs. Programs written specifically for the service provider must be checked for collisions with patents. Software patents, as discussed in the European Union, may have a large influence in this area. Violations of patents or copyright laws may lead to lawsuits and, as a result, fines. Companies like Google register a large number of patents on software to avoid paying for other companies patents. They exchange their patents free of charge (Henzinger 2005). However, this is only possible if a company develops software or algorithms.

4.3 Transfer of instructions

Also during the transfer of instructions conflicts with patents and copyright law may occur. Transfer protocols and file formats may be protected. As said above also maps are protected by copyright law and using them (e.g., as a background) requires a license.

5 Usability

Usability has a different status in the two examples. The emergency call is free of charge. Simplicity and availability must be achieved at all costs to save lives. Finding the right way at a dealer show is convenience the user has to pay for. Problems with the speed of reaction may annoy the user but will not be as critical as in the emergency example.

5.1 Access to the service

Accessing the emergency call should be as simple as possible. The steps of the process must be straightforward. The user should not get confused by tape instructions. A typical user of an emergency calls is nervous because he wants to report an incident and may be injured. Thus calming the caller is important. This can only be achieved by human operators who ask the user for all necessary data.

Accessing the service for the dealer show is different. Although the user will be in a crowded area, he will be less nervous than the user of the emergency service. Here the user wants to know two things before accessing the service:

– How do I access the service and how do I provide my destination?
– How much does the service cost me?

The user must also be capable of performing the task. The user must know how to write an SMS if this is the method to access the service. The second piece of information determines if the user accesses the service at all. The user will not use the service if the costs are higher than his benefits. This also includes the question if the costs will rise if the user misspells the name of the company. Since the benefit does not change costs should not rise.

5.2 Processing the inquiry

Usability for processing emergency calls must be discussed from two perspectives: The user and the operator. The user wants to get help as fast as possible. Thus usability for the user is a measure for the response time and the capability of the service to adjust to user needs. The operator, on the other hand, defines usability in a more technical term: How much support does he get from the system?

The users define the quality of the service mainly by response time. The calls from February 23rd 2005 to April 21st 2005 in the hotline of the ambulance call center of Lower Austria contained (Bachinger 2005)

– 21 positive response and
– 115 negative Responses.

The negative responses covered, among others, the following topics directly related to response time:

– Patient died due to late response (close examination showed no evidence for a connection between the call center efficiency and the death of the patient)
– Unnecessary questions asked
– Ambulance did not find the way

European emergency call will be confronted with similar complaints. Especially the problems of finding the way and asking for necessary information will occur. The complexity of the European system is higher than that of the Austrian system because more types of incidents must be handled. The operator has more possibilities to react and must ask questions to decide on one of the possibilities. The sequence of questions is important to provide help fast. Also language problems may occur if the user speaks a different language than the operator.

The operators need efficient methods for data collection and decision of further actions to minimize the response time. Automatic processes can support the operator. An example is the automatic detection of the user’s position. The system then can present the correct section of a map. The system can also support the operator when transferring necessary information to the necessary emergency organizations like police, ambulance, or fire brigade.

Usability of the LBS for the dealer show must only consider the user's perspective. The user has a simple definition of usability: Does the service provide all necessary information to reach the booth of the company and does the service provide this information in an acceptable time span? Usability of the instructions will be discussed in the next section. The important aspect here is the amount of time between requesting the information from the service and receiving the instructions. Users will find the system inconvenient if the delay is too long. Response times for information systems should be a few seconds when sitting in front of the system. Users of an LBS also want the answer in reasonable time. This limits the amount of time the system has to process the inquiry. The response should be faster than queuing up at the information desk. Users will be uncertain, if their request reached the system when the delay is too long and will try different methods to obtain the information.

5.3 Transfer of instructions

The result of the service is a path description for the user or emergency vehicles. Only the emergency service may result in a path description for an emergency vehicle. A path description for the user is the result for the dealer show service but it can also occur in case of the emergency call service. The requirements for these two cases are different.
Guiding emergency vehicles to a specific location requires unambiguous identification of the location. Coordinates in a standard coordinate system may provide this reference. In rare cases additional information may be necessary, for example, the floor number if the location is within a building. Problems may occur if the location of the incident is a tunnel. Then the emergency organizations may be more interested in the entrance position to the tunnel and a route description within the tunnel. In general however, a single set of coordinates will be sufficient and navigation systems within the vehicles then lead the vehicle to the location of the incident.
Providing route descriptions for the user cannot assume the existence of a navigation system. Maps are difficult to read on the screens of mobile phones due to the limited resolution of mobile phones. Textual descriptions (e.g., lists of instructions) may be easier to understand but it is more difficult to create them automatically. In addition they usually provide less feedback for the user because there is only limited redundant information. Redundant information is necessary to ensure the user that he is still on the correct path.
All types of path descriptions should include landmarks because they deal with two problems: They allow setting the starting direction ('move towards the traffic light' is usually more helpful than 'move south') and they provide feedback. Raubal and Winter (2002) showed how to use landmarks in path descriptions. The selection of landmarks for route descriptions has been described in literature (Winter 2003; Nothegger, Winter et al. 2004). Logos of companies along the route provide landmarks for the dealer show example. The logos will be clearly visible since they shall attract potential customers. Since they are also distinct from each other they can be used as landmarks.

6 Combined influences

Until now we discussed the influences independent of each other. Sometimes the influences are interrelated. The technical solution may, for example, have an influence on the usability of the service or may include some problematic legal aspects. In this section we will discuss the relations between the influences.

6.1 Technology – Usability

A combination of technical solution and usability provides the cost balance. The technical solution determines the costs. The provider of the service must pay for development of the service, acquisition of data, and running the system. The costs for each of these parts are determined by the technical solution. The users pay for the service creating income for the provider. The usability determines the number of users. If, for example, the user cannot determine the costs of the service in advance, he will not use the service. Thus the providers shall aim at technical solutions that include low costs and provide usable systems. This connection is usually discussed in a feasibility study.

6.2 Technology – Legality

Not all is legal that is technically possible. It is possible for the provider to locate a mobile phone. Locating the position of the mobile phone in relation to the network of the mobile operator is even necessary, if the provider must establish a connection (someone is calling). It is not allowed to store the location or to transfer the location to a third party. This creates problems if the LBS is provided by a company different from the mobile operator since that company will not have data on the users position. The solution must thus not only deal with the technical process of getting the location from the telephone provider, but also with getting the agreement from the owner of the telephone.
Another problem is using data formats or algorithms. The technical solution may ask for specific formats or algorithms. Relying on specific technology may create legal problems with software patents. Acquisition of licenses for a patent results in additional costs that have to be considered.

6.3 Legality – Usability

Sometimes specific treatment may be convenient for the user. Fleet management requires information on the position of the fleet members. A simple way to determine the position is locating the mobile phones and using their position. As discussed in 4.2 the mobile operator is not allowed to transfer the position to a third party. The only way to provide this information is letting the users of the mobile phone agree to the transfer. In Austria this is even necessary if the company using the fleet management is the owner of the mobile phones.

7 Discussion and conclusions

In this paper we showed that technical solutions, legal restrictions and usability influence the design and efficiency of LBS. Some mobile operators offered LBS but failed to get a positive financial statement from the service. The important question is why some LBS work and others do not. A reason for failure could be that one of the three influences limits the service. It may be that the technology simply does not allow locating the mobile phone accurate enough or the LBS is not accepted because it is too difficult to use. Also threats of a lawsuit for violation of patents or copyright law may stop an LBS.
When designing an LBS we thus have to answer three questions: Is this technically possible to provide the information? Is it legal to provide the information? It is possible to provide the information in a usable way? If the answers to all three questions are positive we can continue with the discussion. The topic then will shift to more economic questions, e.g. "Will we have more income than costs?" However, we must first make sure, that the LBS is possible, legal, and usable. In the paper we showed with two examples how the questions can be addressed to assess the potential and possible pitfalls of the service in discussion.

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Development of Cultural Inheritance Information System using LBS technologies for tourists

Byoung-Jun Kang, Yosoon Choi and Hyeong-Dong Park

Abstract

The object of this study is to propose a prototype of cultural inheritance information system that provides tourists with more interactive and dynamic information using Location-Based Service (LBS) technology. Using the Personal Digital Assistants (PDA) and Global Positioning System (GPS), tourists can acquire various information of cultural inheritance when they approach cultural inheritance at place. Geographic Information System (GIS) database about the Deoksugung Palace, which is one of the most famous cultural inheritances in Seoul, South Korea, was constructed and dynamic functions connecting location information with cultural contents in GIS database were implemented. As a result, it is expected that the dynamic system will contribute to tourist industry by providing location-related information to tourists.

1 Introduction

LBS can integrate various mobile hardware devices, wireless communication networks, industry specific software applications with geographic information to provide users with location-related guidance. As the wireless communication and GPS technologies have continuously advanced, LBS expands its application areas to military and government industries, emergency responses, and other commercial sectors (Montoya, 2003; Spinuzzi, 2003; Schiller and Voisard, 2004; Wiafe and Davenhall, 2005). Tourist industry can be also one of commercial application areas that have potential market values for LBS (Schiller and Voisard, 2004); the study on specific LBS applications in tourist industry, however, is a new challenge in academic and industrial communities. In recent years, various GIS-based applications have been developed in the tourist industry (e.g., Akcay and Altan, 2003). They were focused on only static information without consideration of the real-time location of tourists. The real-time location of tourists is one of the critical factors for interactive and dynamic information services; the development of new LBS-based application is needed. This paper addresses a prototype of cultural inheritance information system for more interactive and dynamic tourist information services. The following section presents an example of the system on the Deoksugung Palace in Seoul, South Korea.

2 Motivation and Site Information

Recently, the number of foreign tourists visiting Korea has increased and tourist industry of Korea has expanded its market areas. Comparing from the year of 1996, there was a 56.8 % expansion of tourist industry of Korea in 2004 and a further expansion is expected this year. Despite its obvious growth, however, the quality of information services for foreign tourists has not improved. Only a few inheritances in metropolitan areas provide volunteers and tour guides who are good at foreign language. Moreover, foreign tourists can use the cultural inheritance services at the limited space and within the fixed time schedule. Tourists need more flexible services which can provide useful information about cultural inheritances any time and any where. LBS technology can be an optimal solution to improve the service quality, because it is suited to ubiquitous service framework (any time and any where). Using novel Information Technology (IT) infrastructures of Korea, successful development of LBS-based application for tourist industry can be possible.

In this study, Deoksugung Palace is used for displaying example of cultural inheritance information system. Deoksugung Palace (Fig. 1) is built in 1593 and it is one of the most famous cultural inheritances in Seoul, South Korea. Deoksugung Palace is, among other things, a palace famous for its elegant stone-wall road. It is the only one that has western style buildings beside it, which adds to the uniqueness of the scenery (Kim, 1994).

3 System Architecture

Figure 2 shows the system architecture of the cultural inheritance information system. The system consists of mobile clients running on the Window CE-based Pocket PC and a GIS server running on desktop PC. Mobile clients provide the on-site inheritance information to tourists. A GPS receiver is linked to the Pocket PC through a Bluetooth connection, and is used to capture the location of tourist. Based on the location of tourists, the cultural inheritance system operates in the PDA. As a result, using the PDA and GPS, the on-site inheritance information system provides tourists various information of cultural inheritance.

Fig. 1: Panoramic view of Deoksugung Palace.

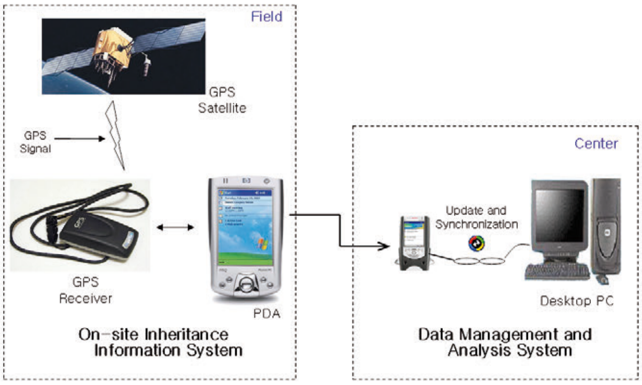

Fig. 2: Architecture of the system.

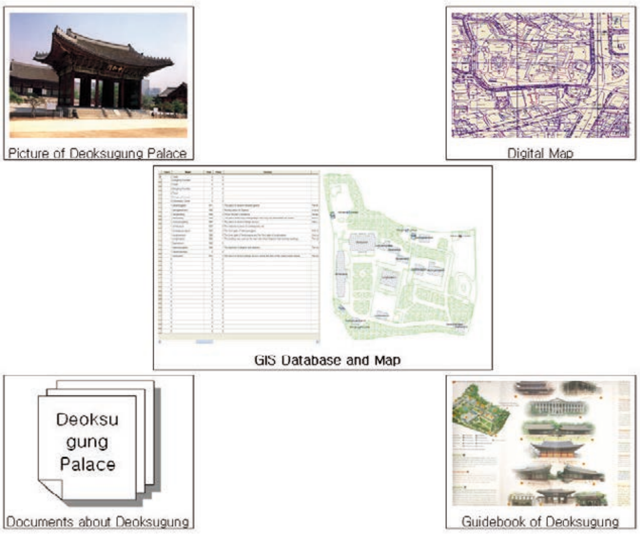

Fig. 3: Construction of GIS database and map.

GIS running on desktop PC is the data management and analysis subsystem which is a decision-making system. This system provides inheritance administrator with tools for managing the application database as well as statistical analysis of tourists' main path and length of their stay.

4 System Implementation

4.1 Database design and construction

Database of cultural inheritance information system consists of a digital map and pictures of Deoksugung Palace, documents, and the guidebook of Deoksugung Palace (Fig. 3). Based on these data, five thematic layers of Deoksugung Palace were created and assembled in GIS: (1) pedestrian passage layer, (2) circumference layer, (3) facility layer, (4) Deoksugung Palace layer, (5) main polygon layer. Main polygon layer includes spatial and historical information of cultural inheritances, facilities, and a pedestrian passage. All five layers were created in vector data structure with first two using polyline, and next three using polygon, respectively.

4.2 User interface

Figure 4 shows the user interface of the cultural inheritance information system. The user interface includes toolbars (i.e., main toolbar, browse toolbar, cultural inheritance information toolbar) Tools of cultural inheritance information toolbar, from left to right, are used to show Deoksugung Palace map, display location of the information center and facilities, exhibit recommended tour paths, identify information of cultural inheritance, and start Cultural Inheritance Information System.

4.3 Main service 1

As shown in Figure 5, clicking the "Deoksugung Palace Information" icon will present layers related with Deoksugung Palace. These layers show information about arrangement of cultural inheritances, facilities, and a pedestrian passage. When these layers zoom in below 1:3000, the labels of inheritances and facilities will be presented.

4.4 Main service 2

Figure 6 displays that clicking the "Path Information" icon will present layers related with Deoksugung Palace and a pedestrian passage. These layers show information about location of cultural inheritances and recommended tour paths. The recommended tour paths are the shortest courses which enable to watch all cultural inheritances of Deoksugung Palace. When these layers zoom in below 1:3000, the labels of inheritances and facilities will be presented.

4.5 Main service 3

Figure 7 shows that clicking the "Cultural Inheritance Information System" icon will activate customized inheritance information system. Using ArcPAD Application Builder and the GPS technology, the layers related with Deoksugung Palace and the tracking information of the tourist is displayed. Through the customized system, the tourist can acquire various dynamic information of cultural inheritance when he approaches cultural inheritance below five meters.

5 Conclusion

This paper presents a prototype of cultural inheritance information system for more interactive tourist information services. The system consists of two components: the on-site client and desktop server for management and analysis. The system records the location of tourists, and automatically connects the location information with cultural inheritance contents of GIS database. A pilot study on Deoksugung Palace shows that the developed system can provide interactive information with tourists visiting the cultural inheritance and effective tools for facility analysis with managers of cultural inheritance. As a result, it is expected that the dynamic system will contribute to promote tourist industry by providing location related information to tourists.

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Fig. 4: Customized toolbars of the system.

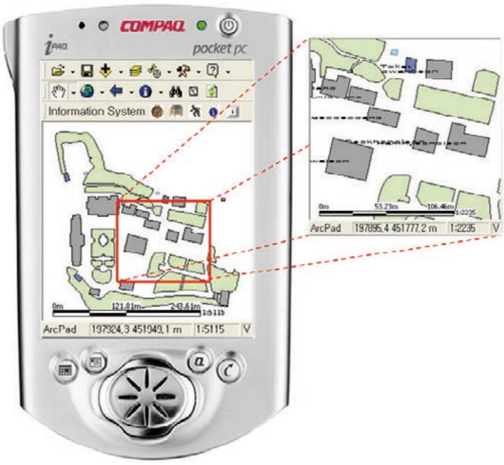
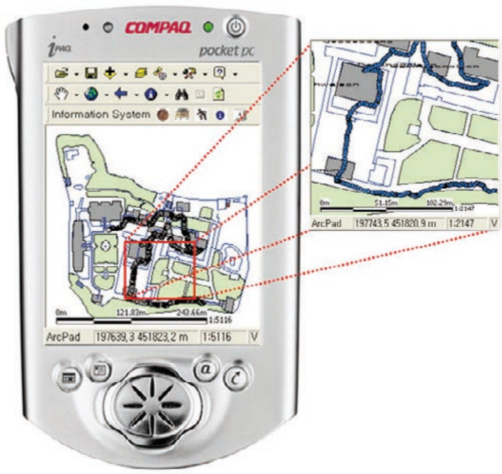


Fig. 5: Interface of the Deoksugung Palace Information.

Fig. 6: Interface of the Path Information.

Fig. 7: Interface of the Cultural Inheritance Information System.



Mobile City Explorer - An innovative GPS and camera phone based travel assistant for city tourists

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Abstract

1 Introduction

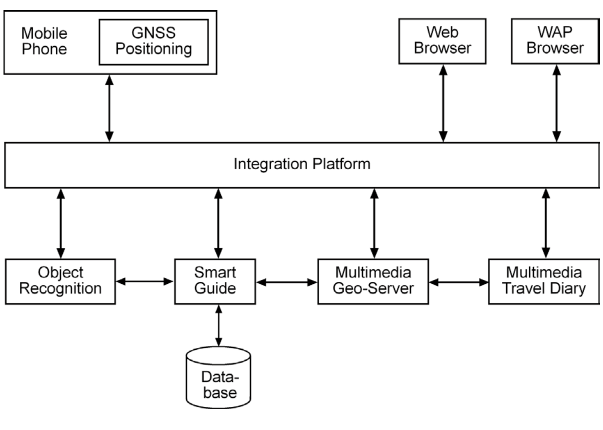
MOBILE CITY EXPLORER is an ongoing research and development project aiming to develop an innovative, intelligent, location based, and value added service for city tourists that is based on GPS and camera phone technology and that will be tested under real world conditions.
The project was ranked first in the 2nd call of the ARTIST research program and is co-funded by the Austrian Ministry of Transport, Innovation and Technology (BMVIT). The project is currently in an early prototyping stage. This conceptual paper gives an overview of the MOBILE CITY EXPLORER system and describes its components. Only the functional concept will be presented at the conference, first results are expected by beginning of 2006.
The travel assistant navigates the user to the most interesting tourist places, automatically recognizes photographed objects of interest and displays the corresponding tourist information. At the same time the personal multimedia travel diary of the travel assistant collects pictures, descriptions and acoustic impressions taken by the user along the route. This saves the user from the tedious work of documenting, cataloguing, and processing his pictures and enables the tourist to "relive" his travel experience post-trip. Figure 1 shows an on-trip scenario of a tourist using the system.

2 System components

The system consists of six major components, as illustrated in figure 2.
On-trip the tourist carries a **mobile camera phone** with an internal or external GPS receiver. The user can thus take pictures of tourist sights, which are transmitted together with the GPS coordinates to the server system.
The **object recognition** component recognizes tourist relevant objects like sights, objects on squares, and parts of buildings from the mobile imagery. The component extracts and analyzes the image attributes, and compares the results with stored attributes from geo-coded reference objects. The identity of the object is identified by probability based methods and enables a subsequent preparation of context relevant information to the tourist. As the location of recognized objects is well known, the vision module can also provide location awareness within the MOBILE CITY EXPLORER system. The recognition component is developed in cooperation with research efforts outlined within the EU-IST project MOBVIS.
The **smart guide** operates as an electronic travel companion taking the tourist to interesting places and sights along tours which are calculated based on pre-selected user interest profiles (e. g. architecture, museums, shopping, …). Comparing the actual GPS

Fig. 1: MOBILE CITY EXPLORER User Scenario

Fig. 2: MOBILE CITY EXPLORER System Components



location of the tourist with the previously calculated route, the smart guide either guides the tourist back to the calculated route or adapts to the user behavior and recalculates a new tour of points of interest, thereby letting the user more freedom in exploring new paths.

The **multimedia travel diary** is the interactive turntable of the travel impressions for the tourist. Pictures and audio clips taken with the camera phone are collected and are automatically assigned to visited locations by recording the user's GPS location. The travel diary is accessible via the internet and on-trip via WAP and offers the functionality of cataloguing, editing, and sharing of the stored travel impressions. This saves the user from the tedious work of documenting his travel experiences.

The **multimedia geo-server** provides multimedia tourist information supplemented by a cartographic representation of the surrounding of the tourist's actual position. This is vital for the orientation and information of the tourist on-trip and also for the presentation of the visited sites post-trip. The cartographic representation is rendered for small displays.

The **integration platform** provides the technical infrastructure for coordinating the different components and acts as an interface to the infrastructure of mobile communication providers. It is also the interface for mobile and web presentation of tourist content.

Combined indoor/outdoor Smartphone navigation for public transport travellers

Karl Rehrl, Nicolas Göll, Sven Leitinger, Stefan Bruntsch

Abstract

Pedestrian navigation on Smartphones has recently gained high attention due to capable devices, off-board based navigation software and increased transmit rates of cellular networks. However, most of the available applications for pedestrian navigation are slightly adapted car-navigation systems and do not cope with specific requirements. Thus, in this paper we describe basic concepts of pedestrian navigation in indoor and outdoor environments. We focus on aspects of orientation and guidance for public transport travellers in complex interchange buildings. Moreover the paper describes the implementation of the proposed concepts on Off-the-shelf Smartphones.

1 Introduction

Due to the constantly increasing technical advantages of Smartphones, pedestrian navigation recently has gained high interest as one of the potential mobile killer-applications in the near future. Whereas in-car navigation systems have already reached a certain level of maturity, pedestrian navigation on Smartphones is still in its infancies. Most of the commercially available systems were designed as car navigation systems which are now sold as pedestrian navigation systems with only minor modifications. However, at a closer look, there can be identified a very clear set of differing requirements and conceptual shortcomings, which make the available navigation solutions useless when applied for pedestrian navigation purposes. In order to show the shortcomings of recent pedestrian navigation systems we give three examples.

Firstly, when we talk of pedestrian navigation on Smartphones, we talk about an off-board navigation, which allows route calculation to be done on a server and the Smartphone is used for navigating the pedestrians on a pre-calculated route. The basis for route calculation on the server has to be a pedestrian footpath network which is specifically targeted at modelling the environment from a pedestrian's point of view. However, most of the available solutions use the standard street network for route calculation.

Another important aspect is, that pedestrians can use navigation for different purposes. We can think of tourists using the navigation for exploring the sights of a city or public transport travellers using it for finding the stop for the next transportation mean. Pedestrian navigation systems have to be designed to consider these different situations and to provide users with the possibility to adapt the application to their information and guidance needs.

A third crucial requirement is that pedestrian navigation should not be limited to outdoor environments. Especially in cities, pedestrians spend a lot of their time in different kinds of buildings. Smartphone-based pedestrian navigation has all the pre-requisites to provide reliable combined indoor/outdoor guidance.

Having the different aspects of pedestrian navigation in mind, in this paper we focus on pedestrian navigation for public transport travellers. Wayfinding in public transport networks can currently be accomplished by means of timetable information and multimodal journey planners. As long as travellers are using the public transport network, ways are fixed in time and space. The situation becomes complex [10] whenever travellers have to leave the transport network as pedestrians for finding an address or changing to another mean of transportation. In towns, the situation of interchange mainly takes place in complex public interchange nodes. Orientation and guidance could help inexperienced travellers to navigate from one public transport stop to another or to find the most suitable exit on the way to a certain address.

Our concept for a multimodal travel assistance application on Smartphones combines two modules. The first is a browser-based mobile access to a server-based multimodal journey planner which allows users to calculate multimodal routes between given start and end points. The result is composed of individual trip segments with information about type of transportation and estimated travel time. The second provides an off-board navigation service that guides the user on outdoor as well as indoor pedestrian routes. Both components are integrated in a mobile application called the personal travel companion that can be accessed by public transport travellers whenever and wherever they want or need to.

The work presented in this paper was done in the Austrian research project Open-SPIRIT, which is partly funded by the Austrian federal ministry of transport, innovation and technology.

The paper is structured as follows: First we take a look at related work. We continue with describing the data model with focus on the modelling of buildings. The following sections describe route calculation, guidance and positioning. We finish with aspects of implementation, conclusion and ongoing work.

2 Related work

We classify related work in the following categories: pedestrian navigation pilot systems, outdoor and indoor positioning technologies and conceptional models of wayfinding in public transport buildings.
In the project REAL [1] a hybrid navigation system for indoor and outdoor use has been developed. The indoor navigation component has been built with infrared transmitters mounted at the ceiling of buildings, the outdoor component works with a GPS system. In addition to the different positioning technologies the REAL project deals with the presentation of route directions on different output devices. The NAVIO project [7] analyzes major aspects being important when designing a pedestrian navigation system for indoor and outdoor environments. The main parts of the project are integrated positioning technologies, multi-criteria route planning and multimedia route communication. One part of the project LoL@ [3] describes the cartographic visualisation of multimedia content on Smartphones.
Retscher and Thienelt [18] discuss suitable location technologies for pedestrians. In their study they test and demonstrate different positioning technologies like satellite-positioning technologies, cellular phone positioning, dead reckoning sensors for measurement of heading and travelled distance as well as barometric pressure sensors for height determination. Especially for indoor positioning technologies, most of the prototypes are based on Infrared, WLAN or Bluetooth ([5], [11], [13], [22]). Whereas Infrared needs line of sight, WLAN positioning needs costly calibration and can not be accessed by typical Smartphones. Bluetooth positioning systems are mainly server-based and thus require a costly installation procedure.
The human navigation and wayfinding process is based on concepts of human cognition ([4], [9]). Rüetschi and Timpf ([19], [20]) developed a conceptual model for describing the wayfinding process in public transport stations. They differ between the network space (the public transport network itself) and the scene space (the nodes of the public transport network, e.g. interchange facilities). The scene space is modelled by the schematic geometry, which is based on image schemes [12] and affordances [8]. In another study Fontaine und Denis [6] analyse the spatial human cognition in subway stations. One of the results of the study with several users is that direction signs are important elements for the navigation and wayfinding in public transport stations. The signposts are significant elements for the orientation at decision points. This result is also confirmed in a requirement study of pedestrian navigation [16].
However, as far as we know, there is no existing pilot system, which focuses on guidance of public transport passengers in interchange facilities.

3 Data model

In this section we take a look at the data model which was designed for pedestrian navigation in general but with a special focus on indoor navigation in public interchange buildings. Following theoretical concepts of wayfinding ([19], [20]) we model buildings with a logical representation of the scene space:

- Building
- Floors
- Regions
- Gateways
- Items

Buildings can be structured in different floors. A region is a coherent space on a single floor with specific characteristics. Instances could be a room, an entrance hall together with connected corridors or an entire floor, depending on the desired granularity. Regions are connected through gateways that indicate possible transitions between them. Typical representations are stairs, elevators, escalators and ramps. Items are specific objects from the scene space and can be linked to regions. Items can be used to model landmarks like signs and shops. The information from the scene space is mainly used to give users a detailed virtual representation of the physical environment and to generate precise textual route descriptions.
For route calculation, map generation and navigation we have connected the logical, hierarchical model of buildings with a geographical model based on a coordinate system. The resulting model is a hybrid location model [14]. All the regions are modeled with non-overlapping polygons, so-called zones. Gateways have gateway areas (polygons) in the origin region and target coordinates in the destination region. The coordinate system was extended with a third parameter called level, which indicates the floor of the building. Gateways are used for transitions between regions and floors.
The pedestrian network is built of decision and orientation points and segments connecting these points. Segments can have detailed attributes describing the nature of the footpath segment. Items from the scene space are linked to the directed footpath segments and can thus be used for the generation of textual path descriptions. Orientation points are used as anchor points for the navigation. The model is suited for outdoor environments as well. Regions can either be determined automatically along the calculated footpath or regions can also be pre-defined, which is suitable for town areas.
With this hybrid location model it is possible to do pedestrian route calculation, to use information from the virtual representation of the scene space for detailed textual route descriptions and map generation and to use the model for navigating users along pre-calculated pedestrian routes. Moreover, the model is the foundation for automatic positioning along the route and indoor/outdoor transitions.

4 Route calculation

Multimodal route calculation is done between two points. These points may be addresses, specific points of interest or coordinates provided by an automatic positioning system.
For route calculation an integrated routing network that is made up of the public transport network, the street network and the pedestrian network is used. Transitions between the networks take place at public transport stops.

The pedestrian footpath network is a graph-based network consisting of nodes and segments. Each node or segment holds specific attributes that provide detailed information for the computation of the route as well as the generation of path descriptions.
Among other things the attributes give information about the type of the segment. It can be an ordinary path segment, a stair, an escalator, an elevator or a ramp. With this information we are able to realise a selective route computation on the basis of personal demands to optimise interchange times, route complexity or walking effort [10]. Additionally, each segment can have specific attributes indicating the direction of escalators or the number of stairs. This way we can differentiate between stairs connecting floors and single step stairs that are hardly percepted by normal people but form an obstacle to wheel chair users.
Another important factor for determining the ideal route is the time needed for walking along a specific segment. This value is not fixed but is dependent on the user. In order to provide personalized interchange times we use time factors together with a configurable walking speed that is part of the traveller's personal profile.

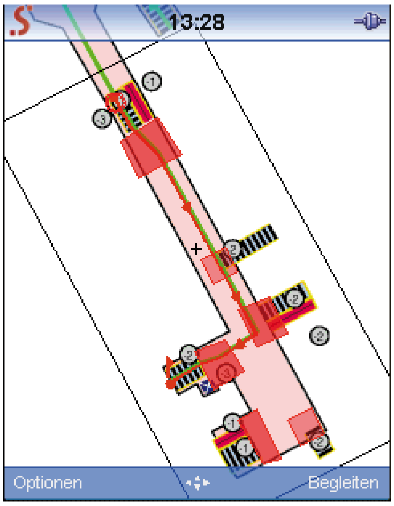


Fig. 1: Navigable maps on the Smartphone

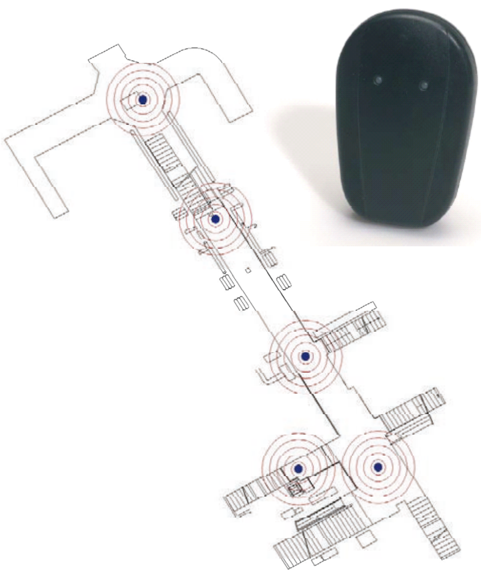
5 Guidance

We define guidance as an information technology based tool assisting pedestrians in the process of wayfinding, which means a purposeful interaction with an environment where the purpose is to reach a certain place or goal ([19], [20]). Our guidance system provides the following services:

- to select an optimised footpath according to the user's profile given a starting point and a destination (an address or public transport stop)
- to give instructions for pedestrians in order to optimise their interchange and to improve their orientation
- to select the most relevant information out of the scene space based on the calculated footpath in order to improve the interaction between wayfinders and the environment
- to reduce the complexity of the pedestrian's navigation task by giving him a digital personal travel assistant at hand

Our system uses two guidance concepts: maps and textual instructions. Tiny screens and scarce resources make the use of maps on mobile devices a challenging task. We opted for a simplified presentation that includes only data that is relevant for the chosen route like floor plans, walkable regions, calculated route segments, gateways, signs and optional orientation marks. Therefore the maps are generated dynamically out of the geographical model. For outdoor areas existing data like city maps or ortho-photos can be adopted.
Regarding the instructions it was important to us to avoid simple turn-by-turn instructions that are solely based on geometric information of the form "Walk nine meters straight and turn left." Instead instructions should be more natural sounding and contain references to objects in the scene space in order to improve the interaction of pedestrians and the environment. Referenced objects can be gateways, signs or orientation marks. The generation of route instructions is based on a set of standardised text building blocks which allow us to create appropriate path descriptions for most cases. For complex scenes it is possible to link manual route directions to a specific path segment that will be integrated. This basic path description is combined with information from nearby landmarks and signs that are stored in the database. This way it is possible to reference signs that do not explicitly refer to the traveller's destination but point at the right direction. In this fashion we are able to automatically generate instructions like "Walk to the lower end of the stairs marked with the sign 'Neubaugasse'. Walk up the stairs."

Fig. 2: Bluetooth beacon and plan of beacon positions



6 Positioning

The proposed system is able to guide travellers by a list of step-by-step instructions. Manual acknowledgement of passed route segments is necessary. However, we feel that automatic positioning increases convenience of use and improves orientation.
For indoor positioning there exist numerous different approaches that vary greatly in terms of accuracy, cost and used technology ([11], [16]). In order to be applicable for our scenario we determined the following criteria:

- to provide high enough accuracy to determine the region where the user is currently in
- to have broad support of end user devices (Smartphones)
- to work without (GSM-)network connection
- to be cost effective
- to require little installation effort

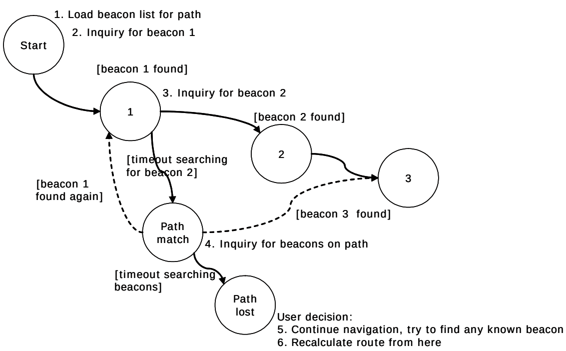


Fig. 3: Schematic overview of Bluetooth inquiry

We opted for a Bluetooth based solution, because it met our requirements most closely. First of all a great share of the Smartphones sold today incorporate this technology and thus will support automatic positioning without additional hardware on the client side. Furthermore we felt confident to reach a high enough accuracy for providing orientation and useful instructions for the wayfinding process.

Most of the commercially available location systems based on Bluetooth (e.g. [23], [15], [2]) use an infrastructure of interconnected Bluetooth access points. These access points permanently execute inquiries in order to detect nearby Bluetooth devices. Once discovered, their location is determined on the server side and appropriate information is pushed onto the detected device. In large public transport stations, however, it would be very resource consuming or even impossible to install a LAN interconnecting the access points.

Our approach to a cell-based positioning system makes use of a client-side inquiry and a set of passive Bluetooth beacons. The Smartphone clients are constantly looking for beacons in the proximity that broadcast their unique ID. After receiving a beacon ID the client looks up the associated position information in a list that is part of the building description. If all the relevant data for an interchange building is cached on the device, navigation will work without any network connection. This is a crucial requirement for underground stations suffering from low cellular network coverage.

The beacons utilised for this project (BlueLon Bodytags [2]) have an adjustable transmit power which makes them very flexible, because we can control the cell size. This way we are able to adapt it to the needed accuracy or to the room topology at hand (i.e. hall, room or corridor). Ideally cell sizes should be selected in a way that the covered area is not overlapping with other beacons, otherwise this would result in an ambiguous position.

Due to the signals' spherical propagation behaviour however, it is not always possible to completely separate individual cells (i.e. signals crossing floor bounds). To overcome this problem we exploit the data model's hierarchical nature and use knowledge from the calculated path as well as information known from history. In a first step we sort out detected beacons that are outside the current region. Furthermore we can determine a sequence of beacons that will be passed when walking along the calculated route. If still more than one beacon is seen and one of them is the next expected beacon, it is assumed that the user most probably moved one step further along the way. Likewise, if the next logical beacon is not found but the one following thereafter, we consider one beacon has been skipped.

Another challenging characteristic of the Bluetooth technology is the rather long delay from entering a device's transmit range until its actual detection. This can take up to 13 seconds and imposes a lower bound to the usable cell sizes, because a user may have passed the beacon without detecting it. However, most of the time beacons are found within the first five seconds [21]. Practical tests have shown that restarting the inquiry after this duration yields higher detection probability. Together with the fault tolerant mechanism outlined above we achieved a usable cell size of down to 4 meters which is sufficient for providing useful route instructions.

Outdoor positioning is supported as well through the use of a GPS receiver in combination with a route matching algorithm. Automatic transition from indoor to outdoor or vice versa is achieved through tagging regions with information on the positioning system. This approach works well for outdoor to indoor transitions, where the navigation application simply disconnects from the GPS receiver and starts searching for Bluetooth beacons. When leaving a building and entering an outdoor area however, we are facing the problem that currently available GPS receivers need an initialization time of about 30 seconds up to several minutes to deliver a reliable position. We try to address the problem by pretending to the user he is constantly moving along the calculated route until we are able to determine the exact location. In most of the cases this behaviour will lead to better results, because there is the chance of leaving the shadowed area during walk.

7 Implementation

In this section we give some implementation specific details on the prototype application called the personal travel companion. The application is split up in a server side and a client side part. For the multimodal trip planning on the server-side we use the Intermodal Journey Planner [17]. This service was adopted for calculating pedestrian routes and providing maps, path descriptions and data of interchange buildings. Communication between client and server or vice versa is done via XML. Maps are delivered as geo-referenced bitmaps and can be split up in single tiles in order to improve loading times.

The client running on the Smartphone is realized with J2ME. The test platform was the Off-the-Shelf Smartphone Nokia 6630. A micro browser is used for interaction with the journey planner and rendering server-generated pages containing an XML-based markup language . The markup pages may contain anchor elements for small functional modules called Smartlets that extend the browser's functionality. This mechanism guarantees a trade-off between server-generated user interfaces where design and content is easily exchangeable and additional functionality which allows for better use of local resources.

The navigation module called Navigation Smartlet is implemented to use a local data cache for accessing trip data. The cache decides whether trip data is locally available on the Smartphone or it has to be fetched from the server. This mechanism allows for preloading of data for a whole journey or at least parts of it. The Navigation Smartlet then gets the user's position from the location service that is fed by several location providers. Once the traveller's position is known the Navigation Smartlet determines the associated region and route segment and presents the map and route instructions to the user.

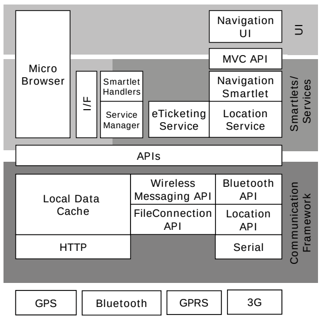


Fig 4: System architecture of the J2ME-Client

8 Conclusion and ongoing work

Smartphone-based pedestrian navigation can provide orientation and guidance not only to public transport travellers. During summer we conducted a small user survey with an early prototype of the personal travel companion and an amount of about 20 participants. Their technical proficiency ranged from sketchy to profound.

The participants were asked to navigate along three pre-calculated routes, one of which was located completely indoors, one led from an outdoor starting point to an indoor destination and one incorporated an indoor to outdoor transition. Most people found the provided maps useful for orientation. The automatic transition from indoor to outdoor or vice versa was on of the most astonishing features. Although we were facing some technical problems, the participants liked the idea to be continuously guided from a bus stop to certain rooms inside buildings.

We are planning a larger survey in the Vienna underground tram station Matzleinsdorferplatz in the middle of October in order to test the system in a larger test setting and to get profound feedback from a larger group of participants.

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LWD-Infosystem Tirol: Visual information about the current avalanche situation via mobile devices

Michaela Kinberger, Karel Kriz, Patrick Nairz

Abstract

The Avalanche Warning Center Tyrol (Innsbruck, Austria) together with the Department of Geography and Regional Research at the University of Vienna have developed a complex and very powerful database driven online decision support system for visualization and analysis of current avalanche relevant factors in the Tyrolean Alps. In order to understand the avalanche situation it is important to have spatial coverage of meteorological and snow pack factors as well as information covering the avalanche danger scale and topographic situation. All information can be interactively made accessible to the user and includes for example current snow depth, amount of snow accumulation within the last 24 hours, temperature, wind speed and direction as well as the regional distribution of the avalanche danger scale including height and temporal dependencies. Spatial depiction of this information can help comprehend the situation. The faster this information is made accessible the more useful it can be. For this reason the partners of the project decided to adapt the online maps for the presentation on mobile devices like mobile phone and personal digital assistant (PDA).

In December 2004 the first images were presented on mobile devices. The main problem was to provide the same information included in the Internet maps on a significant smaller display. The results are simplified depictions of the current snow depth, amount of snow accumulation and the predicted avalanche danger scale for small screens in two different sizes.

This contribution will give an overview of the application, focusing on its latest developments as well as planned extensions.

1 Introduction

A permanent changing environment requires a rapid flow of information to users and decision makers. Modern information technologies like the Internet and mobile communication makes it possible to collect important information and to publish reports about the current state of our environment almost in real-time. By incorporating GIS and cartographic expertise relevant facts with spatial relation can be depicted in an easily understandable visual form. The data transfer via Internet and SMS/MMS to a computer screen or the display of a mobile phone guarantees a fast circulation of current information. For different user devices with a screen size from 120x160 up to 1024x768 pixels the same geodata have to be preprocessed, selected and visualized in a different way. The aim is the production and quick update of maps for visual communication of avalanche relevant facts covering mountainous regions.

2 Topic

One of the main duties of all Avalanche Warning Center's today has not changed since their foundation – prevention of avalanche fatalities by informing the public about the current snow and avalanche situation in different regions. The big difference to former times is however the utilization of new possibilities and techniques of data-collection, spatial depiction and information transfer.

The Avalanche Warning Center Tyrol has developed into a high-tech institution with comparatively high-quality standards. Due to sufficient financial support by the local government there is not only an exhaustive network of observers but also one of the highest densities of high-alpine automatic weather stations in the world (see figure 1).

Since the first construction of such weather stations a lot of experience has been achieved. Surprisingly enough their reliability in severe conditions is amazing, however their limits become also visible under such circumstances. In order to receive reliable data, which is one of the bases for work and the herein described developments, a comprehensive analysis of every potential location has to be undertaken before building them. The succeeding correction of data even with special software is much too time consuming and imprecise.

Some years ago the Avalanche Warning Center Tyrol started a very fruitful collaboration with the Department of Geography and Regional Research at the University of Vienna. At the beginning work concentrated on verifying and formatting the available meteorological data. The next step was the automatic transfer of confirmed data by the Avalanche Warning Center to the Department of Geography and Regional Research. The Department itself developed an online decision support tool where different types of maps are made accessible during the winter season for any given time period. The aim was a faster and easier perception of important snow- and avalanche-relevant data. The results should assist the forecaster's work as well as support the user's needs and hopefully help reduce avalanche accidents.

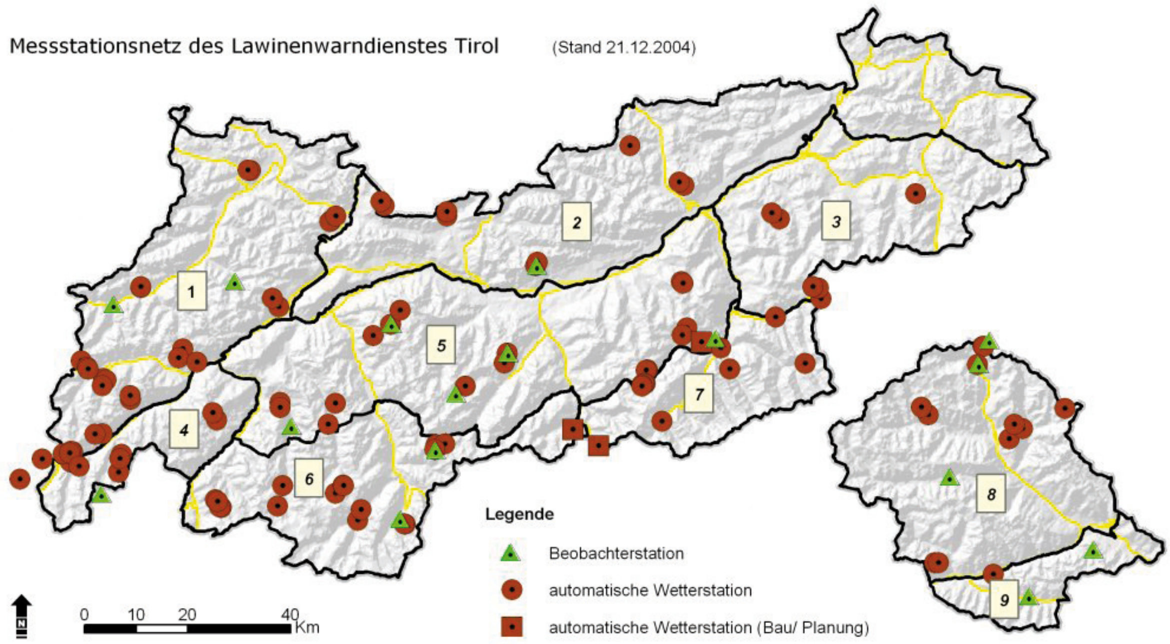


Fig. 1: Network of observers and automated weather stations

In the winter season 2003/2004 the online decision support tool provided cartographic visualization of the current snow depth, the amount of snow accumulation within the last 24, 48 and 72 hours as well as the regional distribution of the avalanche danger scale including height and temporal dependencies. To reach an even broader user group it was necessary to expand the scope of the project and provide a cartographic depiction for the access with mobile devices. After a methodical and conceptual processing phase the first maps for smaller displays were ready in December 2004. The maps were then transferred via multimedia messaging service (MMS) to mobile phones and PDA. The main problem was to provide the same information included in the Internet maps on a significant smaller display. The results are simplified depictions of the current snow depth, amount of snow accumulation and the predicted avalanche danger scale for small screens in two different sizes (mobile phone and PDA).

3 Conception and implementation

The advantages of cartographic representations on the Internet can be seen in up-to-dateness, interactivity, spatial communication as well as efficient and cost-effective dissemination. In order to benefit from such an interactive communication platform for environmental strategic decisions support it is important to make use of automated cartographic procedures. This is possible by utilizing standardized cartographic methods with combined access to permanently available thematic geodata that allow the production of spatial output. Thereby cartographic layout and design aspects play an important role within such a workflow. Geometric data is in most cases static and therefore does not heavily influence the overall work procedure. Thematic data such as weather data, that changes rapidly is considered variable and is controlled by a time-dependent process.

In many cases interactive cartographic visualization with graphic software slows down the workflow. The graphic realization can therefore be the bottleneck within such automated systems. Time plays an important role if up-to-date information must be transported to the user. If design and layout take up too much time cartographic output becomes worthless. In order to accelerate the procedure and keep the output time lag low operation of cartographic realization in batch mode can be utilized. With the help of such automated time-dependent systems short-updating cycles and high efficiency can be achieved.

Working in batch mode enables the system to execute tasks without interaction of a user. With the help of batch mode processing a time-controlled system can achieve very short updating times. The advantages are actuality but also in the long run cost effectiveness, consistent quality and worldwide distribution. However one has to keep in mind that extensive development is needed to set up such a system and maintenance work has to be considered in order to keep the system running.

In order to utilize a fully automated cartographic visualization workflow specific system components are needed. These components consist of a user interface for the World Wide Web, a system interpreter that controls the time-dependent procedural workflow of the system, graphic tools that enable a profound cartographic representation, thematic and geometric data that is either accessed internally or externally and stored in a database management system as well as a GIS that controls the interpolated surface creation.

Another possibility to control a process in batch mode is to start the automated cartographic visualization workflow with the occurrence of a certain event. Contrary to the production of maps of the meteorological factors, where the production process begins at a certain time, the maps of the regional avalanches dangers steps are produced event-controlled. Therefore these maps can be updated immediately after the forecast by an expert of the Avalanche Warning Center in Tyrol.

4 Results

Besides Internet portals, mobile information services are important for the distribution of short living information. With the adapted Internet maps for mobile device access, the user is able to receive important information by the means of modern, locally independent communication technology. In the following the main focus points of work during the last winter (2004/2005) will be described. More examples can be found on the homepage of the project partners (see References and Links).

Fig. 2: Maps for mobile phones

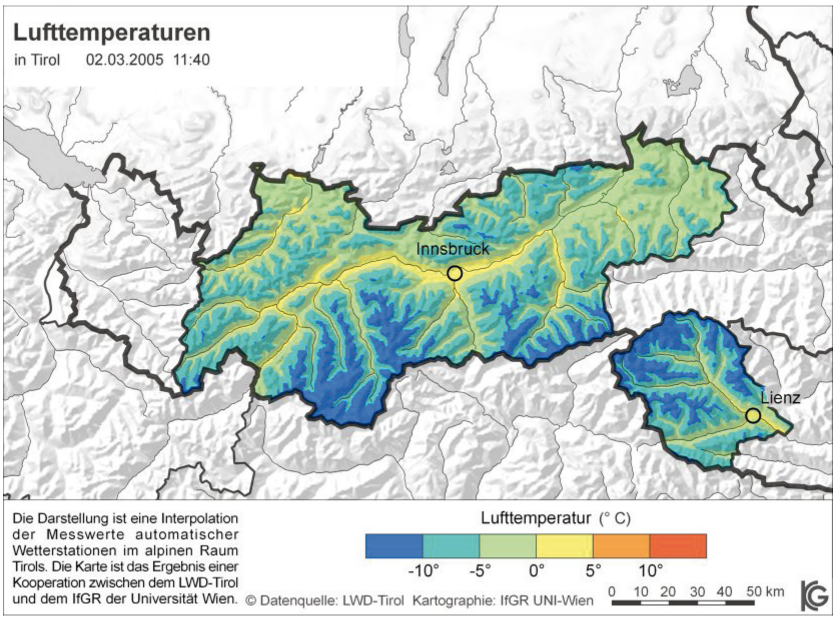
4.1 Maps for mobile devices

In the summer of the year 2004 the project team decided that users of mobile devices, such as mobile phones and PDAs, should also get access to the information provided by the “LWD-Online-Maps”. Today many mobile devices have a color display, even if it is very small. Therefore it is possible to receive and view a simplified version of the online maps on any mobile device.
However, the maps available must be optimized for the small screens of mobile devices. It is absolutely necessary to reduce the content of the graphics without loosing information, so that the cartographic depiction can be represented on the substantially smaller area. The generated maps were integrated in a mobile information system. Members of the local avalanche committees receive daily updated representations of the current snow depth, amount of snow accumulation and the predicted avalanche danger scale on their mobile phone.
Due to the smaller size of the display important topographic elements used in the Internet maps had to be excluded from the maps for the mobile view. In the map of the predicted avalanche danger scale the user can localize his area of interest by following the region boarders. In the maps of the current snow depth and the amount of snow accumulation within the last 24, 48 and 72 hours the selected hydrographic network makes orientation easier.
Avalanche danger in particular regions is often time dependent. To show the changing avalanche danger scale over time animation is used for the Internet maps. The mobile maps are not animated, instead two single depictions are sent to the user. One picture with “AM” for the predicted avalanche danger scale in the morning and the other one with “PM” for the predicted avalanche danger scale in the afternoon. All mobile maps are depicted in two different sizes. For the smaller mobile phone display pictures with the size of 133x100 pixel are produced (see **figure 2**). For PDA displays images with the size of 200x150 pixel are generated.

4.2 Maps representing the current air temperature, wind speed and direction

Besides the information on the current snow depth and the accumulation within the last 24 hours the automated weather stations in the Tyrolean Alps also collect values on the current air temperature, wind speed and wind direction. All these meteorological factors are transferred and stored in a centralized database.
For the visualization of the current air temperature in degree Celsius the values of the single weather stations are interpolated dependent on their heights, classified and colored (see **figure 3**). The class limits depend on significant values of the air temperature that are important for the formation of the snow pack. The class borders can still be changed at a later time by the request of experts.
Current wind speed and wind direction are represented in one map. An arrow signature, pointing at the geographic position of the weather station, gives information about the dominating wind direction. The wind speed is depicted by the color of the arrow.

Fig. 3: Map representing the air temperature



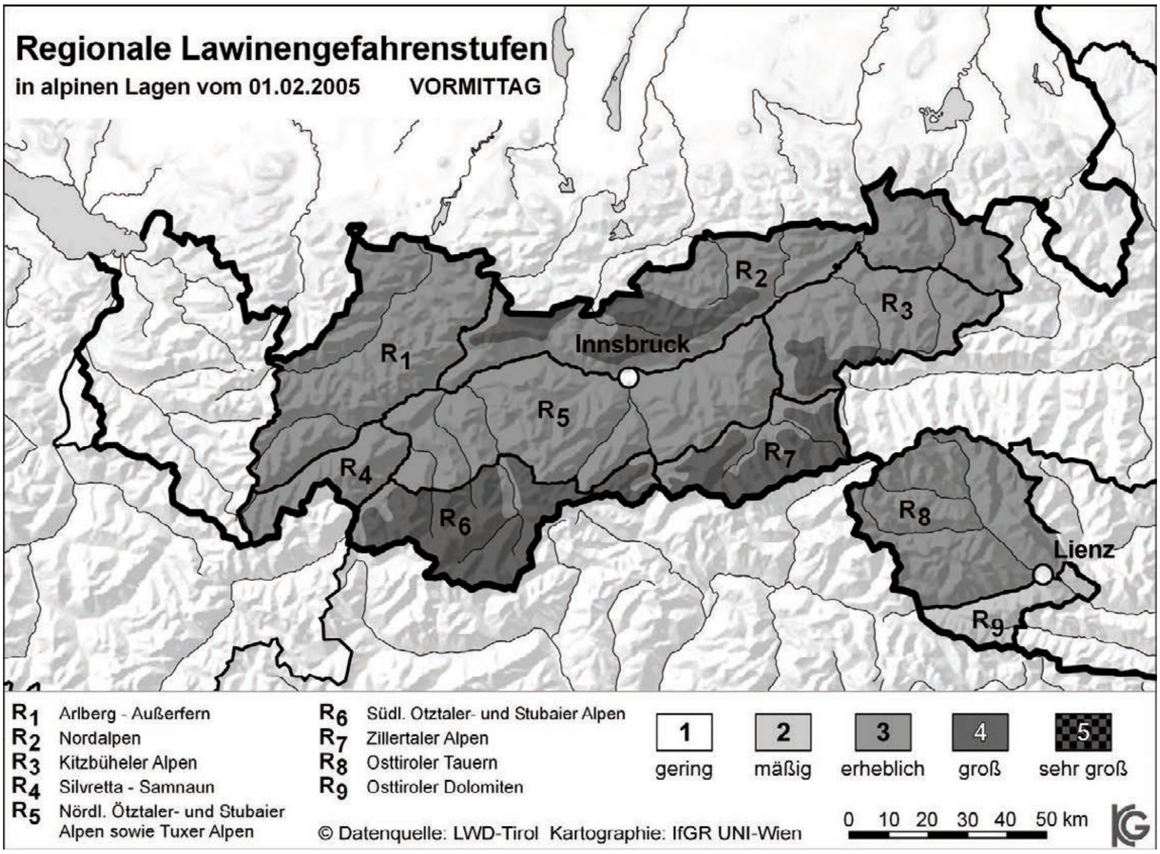


Fig. 4: Grayscale representation of the regional avalanche danger scale

4.3 Maps representing the regional avalanche danger scale for color-blind people

In order to assist color-blind users and in agreement with experts, the necessity of a grayscale cartographic representation of the regional avalanche danger scale was implemented (see figure 4). Up to now these maps for color-blind users were only generated for the Internet, but not for the access with mobile devices. A variation of the grayscale representation for smaller displays is considered for the coming season.

5 Outlook

A permanent changing environment requires a rapid flow of information to users and decision makers. This paper describes one possibility of prompt and efficient cartographic visualization utilizing the web and mobile information services that can be accessed for environmental issues such as avalanche forecasting. During the past winter seasons the reliability and the accuracy of the online maps produced have been monitored. The high amount of user access showed the tremendous public interest in online visualization of the snow and avalanche danger situation in Tyrol. In the future it should be possible to provide this important information not only for Tyrol but for the entire Austrian Alps.

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Tiroler Lawinenwarndienst: http://www.lawine.at/tirol

IfGR Kartographie und Geoinformation – Uni Wien: http://www.gis.univie.ac.at/karto

Investigation system for rock slope using mobile device

Chang-Yub Jeong, Chang-Uk Hyun, Yo-soon Choi, Hyeong-Dong Park

Abstract

Location-based information service using mobile device, such as PDA, mobile telephone, etc, can be quite useful to geological survey which be generally carried out the out-door investigation with various locations. Geologic informations collected in the field, such as geometric shape, crack, distribution of plants, rock quality, have been saved and delivered in analog format. However, it takes long time to transform information, occurs duplicate process, and causes inaccurate measurement. Therefore, it is necessary to introduce a real time digital picture acquisition and mobile system to process information, for rapid information transport and efficient operation, in the field research. The objective of this research is to develop the digital information processing system which stores and analyzes real time digital picture of rock slope, other geological information, and spatial information.

1 Introduction

An effective communication between a field surveyor and a head office is an important factor for project management in Civil Engineering. Geologic informations have collected in the field, such as geometric shape, crack, distribution of plants, rock quality, have been saved and delivered in analog format. It takes long time to transform information, occurs duplicate process, and causes inaccurate measurement. Therefore, it is necessary to introduce a real time digital picture acquisition and mobile system to process information, for rapid information transport and efficient operation, in the field research.

Currently, mobile device based information systems are offered by reports such as those that have presented the PDAs and laptops currently available for use in wireless GIS systems and its capabilities(Casademont et al., 2004) and alternatives to PC-based resources such as personal digital assistants (PDA) or phones are needed for information access in Civil Engineering(Mora and Dwivedi, 2002) and geo-data acquisition using mobile GIS can be used for the management of geodatabase(Montoya, 2003).

In this paper, attempts were made to develop the investigate system to generate the digital trace map of the rock slope and to store real time digital information; picture of rock slope, other geological information and spatial information in the database. For this, the collaborative and expansible Geographic Information System with mobile device, wireless network and CDMA are offered. It is intended to monitor field data in the office and to connect geological information digitalized in the field with wireless internet technology.

2 Investigation system for rock slope

It should be developed field application of the PDA S/W suitable for the used mobile device to consider the specified I/O interface, limited memory storage, low-CPU and device platform. Table 1. shows the specifications of the programs and equipments using this research.

	Specification
OS	Windows CE 4.2
SDK	PocketPC 2003 SDK
Language	Visual Baseic.NETed 2003
CPU	ARM

Tab. 1: Development Environment

2.1 System architecture

In order to generate digital trace mapping real-time-data in field, a possible system architecture is shown in Fig. 1. It illustrates that a client-side application is composed of a field data acquisition part, a data management part and data delivery part. It is generated a digital trace mapping real-time data from a digital picture of rock slope using an image processing module in data management part. We use the the Sobel-filter for extraction of the trace map (Fig.2). Extract. It is possible to edit the extracted digital trace map on PDA and to transport it to the office server for the separated image-format.

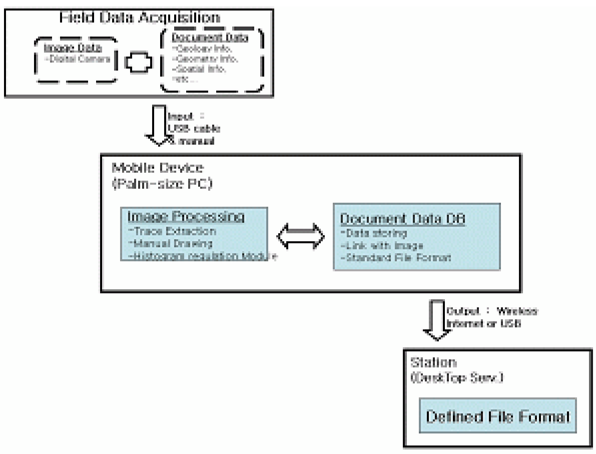

Fig.1: System Architecture

$$\text{Sobel} \quad \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$$

Fig.2: Sobel-filter

3 Experimental implementation

3.1 Target area

Image processing module on PDA is applied the target area in Figure 1. The site seems hard to be difficult of access and the test sample has the moderate trace of the slope, so it is suitable to apply this trace extraction technique using image processing on PDA

3.2 Field survey

It is obtained Digital image of rock slope by a digital camera and spatial information by a DGPS(Fig.4). The obtained data can be stored directly to the PDA from USB-cable or memory card and it can be displayed the site using spatial information(Fig.5)

3.3 Image processing

In order to provide the real-time data in field survey, it has been developed the image processing module on PDA based on the development pipeline(Fig.6). The module operates on the mobile device that has the specification by Table 1. It is possible to predict the geometry of each jointed rock blocks using extracted trace map of rock slope by image processing module on PDA.

4 Conclusions

Alternatives to conventional methods to generate the trace map, it has been developed investigation system for rock slope using mobile devices (PDA) which stores and analyzes real time digital trace map of rock slope, geological information and spatial information. In this system, it could be obtained the exact position of site by DGPS and digital image of a rock slope by digital camera, and it is stored the digital trace map generated from digital image of rock slope using the image processing on PDA. The surveyor can edit the trace map in form of image file(.JPEG, .BMP etc)digital in field and, accessing the network, transport the geological data working on site to the desktop server in an office.

It will be undertaken a research about open and expansible GIS (Geographic Information System) which makes it possible real time field data monitoring in office and which is connecting geological information digitalized in the field with wireless internet technology.

Fig.3: Image of rock face in Hongje-Dong

Fig.4: Digital image and spatial data acquisition using digital camera and DGPS

Fig.5: *Location mapping from spatial imformation using ArcPAD in field*

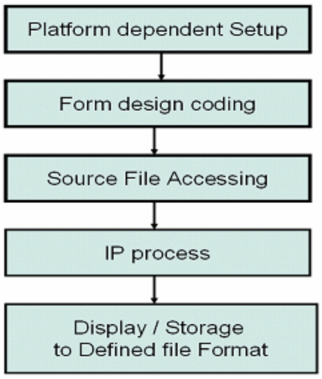

Fig.6: *IP-module Development pipeline*

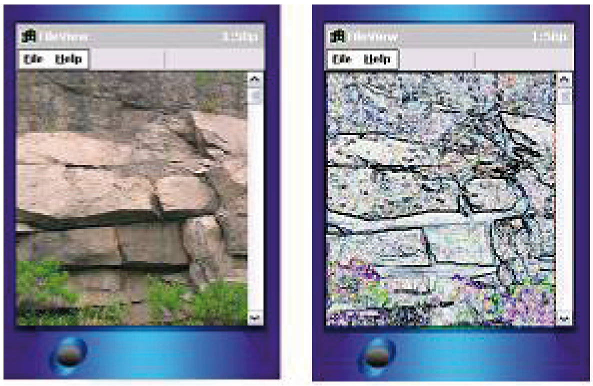

Fig.7: *Displayed rock slope on virtual PDA (left) and extracted trace using IP-module(right)*

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LBS in orienteering sport

László Zentai

Abstract

Nowadays every sport is going to be more media friendly. Orienteering has never been very popular in most countries (except Scandinavia) and it is not present in television: the orienteering events are hidden in the forest. The GPS receivers can help to locate the orienteers' position, but how can we make it interesting for non-orienteers in the media? Which "telemap" can be interesting enough for the televiewers? Orienteering maps are too complicated for non-orienteers, so we have to use special, generalized maps for them. How can we use the new technologies on the main events, how can we present the excitement of sport on a television screen?

On the 19th World Orienteering Championships in 2001, in Finland the competitors were equipped with small GPS receivers and their position was reported on the large screens in the finish area. The organizers had to keep the secrecy, but these new chances can effect or alter the essence of the sport. We would rather put these new technologies to show the sport for the other people - we have to show exciting maps, actions: location based services are one of the technologies that we can use.

1 Trends in sport

This paper presents a special application of location based services and telecartography. This is really an application helping to promote sport in television. Every sport is going to be media friendly. Some traditional sports even change their rules to make sport more visible, more exciting for the audience and/or for the televiewers or just to survive (biathlon, modern pentathlon, fencing). Sport is more and more a business, and to be attractive and interesting is vital for most sports: to stay in the Olympic programme or to be in the Olympics.

2 Specialities of orienteering sport

Orienteering has never been very popular in most countries (except Scandinavia) and it is not present in television. The orienteering sport has some specialities, which do not make the media friendly transformation easy:

- Orienteering events mostly take place in forest areas, where to assure the infrastructure is not easy or expensive.
- The competition map and course is secret. If we give an on-line broadcast we had to have extra effort to avoid unwanted information handover to the competitors. The preparation work of the broadcast may require some outsiders to be included in the secret part of the organizing.
- Orienteering maps are very special products; they are interesting and legible only for the "experts" (competitors, fans): we have to transform the orienteering map to a media friendly, attractive screen image to make the broadcast interesting. This is a real telecartography task: how can we visualize the reality for the users.
- One of the key elements of orienteering sport is a route choice: the shortest way in time between to control points depends on different factors (weather, training, physical condition of the competitor). GPS can help us to follow the winner's route during the course, but there are several problems to solve.
- The competitors have to carry a GPS receiver with them and another device to report their position. These devices must be very small and they cannot effect the competitors performance.

3 Tracing the route

Techniques to track a route in real time are available. In a vehicle, tracing software can help to adjust the position to the road network. On an orienteering event the competitors can run everywhere, so we cannot use any software for adjusting the position. But we have additional problems to solve:

How can we get GPS signals on steep slopes in the forest, where the receiver cannot see enough satellites?

How can we send back the competitor's position if there is no reliable GSM coverage in the area?

4 World Orienteering Championships 2001 (Tampere, Finland)

Finland promised to have a competitor tracking system in the World Orienteering Championships (WOC) 2001 events, when Tampere applied to become the WOC 2001 organizer. The promise given to the International Orienteering Federation (IOF) in 1996 stated that:

– The tracking system will be satellite based.
– Competitor equipment will weight less than 250 g.
– Accuracy of the system will be better or equal to 10 meters (comparable to the orienteering map).
– Tracking data will be available real-time in TV broadcasting.

WOC 2001 needed a long period of time to look for suitable and interested partners to build the whole system. After a very large number of possible partner contacts and even demos with various partner candidates, Benefon and Novo Group were selected as the main partners.
The goal of the tracking project was for the first time in orienteering sport have satellite based tracking of competitors in live TV broadcasting.

– Benefon is a Finnish mobile phone manufacturer, who has special products where the GPS receivers are integrated into a mobile phone. The responsibility of Benefon was to develop and provide the required amount of suitable devices with all the required special accessories for the event (vest, mobile device).
– Novo Group is a Finnish IT company. Their responsibility as the system integrator was to develop and operate the tracking system.
– Sonera is a Finnish telecom operator. They were responsible for providing required network coverage and capacity for transferring the location data from orienteers to the network.

The basic operation of the system was:

1. The Benefon Track GSM received signal from GPS satellites and determined the position of the competitor every second.
2. The position was sent in every 20 seconds as an SMS via special network.
3. A server connected to the short message centre received the position and stored it in a special database.
4. According to the instructions from the TV director, predefined parts of the map with selected competitor(s) were be retrieved and their route drawn with special software as a still image including the competitor names.
5. The image was transferred into the system to be seen by the TV director and being available for live broadcasting 15 seconds behind the real situation (nearly real-time) on the average.

The signalling load of tracking SMS traffic was monitored during the tests and it was concluded to be adequate for the WOC events. Sonera had a local base station in the event centre during the WOC 2001 events so that the GSM traffic by the audience did not give any load to the competition area.

In general, the system worked the way planned and tested and the project goal was considered achieved.

– The amount of captured tracking routes was less than expected by the experts. The main reason for this was the GPS geometry during the competition. This had some impact on the TV visibility, since 2-3 images requested by the TV director were discarded due to incomplete or useless data. It has been concluded that nothing could have been done to improve this. In this geographical area, in a Finnish forest with constantly moving objects, the GPS geometry is the key factor that cannot be compensated within the GPS device. GPS geometry can be estimated using software and for better results the race should have taken place in another time. It is impossible to estimate the GPS geometry accurately more than 6 months in advance.
– The still image generation for TV picture in the software became slower when the amount of data increased in the systems database due to a software design error. This error also caused a decrease in the TV visibility, since the timing is the key factor in a live TV broadcasting.
– The used technology led to a system that was not as much a real-time system as the TV director had wished. Using SMS technology and a relative slow update frequency is best suited to see the overall picture of route choices and mistakes, but is not suitable for providing data into a really live broadcasting that tries to capture the struggle and live action.
– The tracking system did not show any dramatic mistakes of competitors in TV. The main reason for this was not a bad working system, but rather that there were very few mistakes and different route choices made by the top runners.

For the future developers of tracking systems a few lessons can be summarized.

– **Good partners.** The partners must have a real incentive to participate and they have to be experienced.
– **Co-operation with TV.** TV is today the most important consumer of tracking information. TV is a very demanding channel and requires a large amount of preparations.
– **GPS is tricky.** Dealing with GPS requires expert knowledge of its behaviour. The theory is relatively simple, but the real world with constantly moving satellites and weak signal impacted by various external interfering elements is hard to manage and estimate.
– **Understanding project timing.** WOC competitions are organized mostly by volunteers, and not by full-time employers. When a company from the IT world creates a tracking system their project schedules and the way of project execution are from the IT world. This may cause conflicts with rest of the organization.

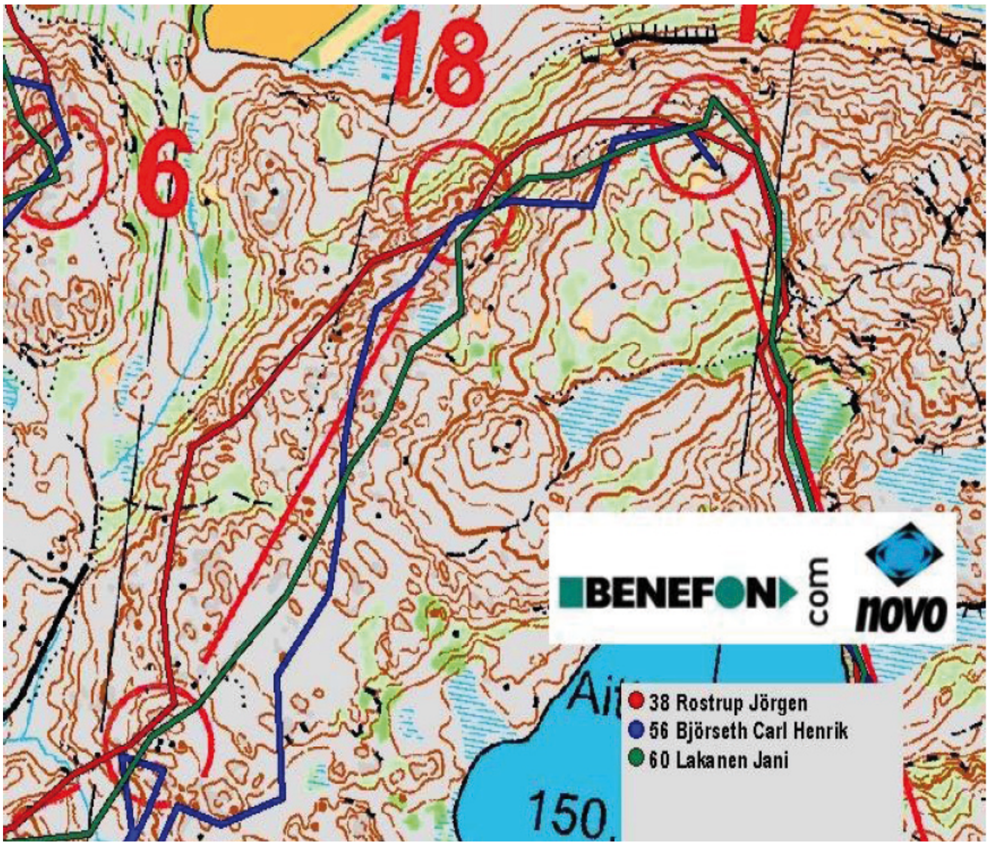

Fig. 1: Still image of the TV coverage (WOC2001, Tampere)

As you can see there were no changes in the map outlook on the screen: it is a real, complicated orienteering map. In Finland and in the other countries where the programme was shown (Sweden, Norway, Switzerland), orienteering is a well-known sport and they had no problems to understand the map. The live program had an audience of 250 000 people.
The following world championships were organized in Switzerland (2003), Sweden (2004), Japan (2005). Even the sport is popular and well developed in these countries it was never planned to use a tracking system in the world championship: everybody thought that the use of these systems is very expensive compared to the value the organizers got.

5 Showing the orienteering map on the screen

As mentioned previously, we have to deal with the screen representation of orienteering maps to let the less trained spectators, televiewers enjoy (or even just understand) the broadcast. There are too many details in orienteering maps: the spectators cannot interpret all details, so the transformed map must show clear and simplified alternatives. The three dimensional representation can make the image more interesting, but it is more difficult to generate and it can be more complicated to interpret such representations for the audience. We have to find a good compromise.
Orienteering maps are drawn by computer, the most frequently used software is OCAD, which is mostly drawing software (only the latest version offers limited GIS functions). OCAD is very user-friendly software, but does not support 3D representation, so special programming skills are required for these kinds of representations.
The 3D terrain representation must be simplified and it is difficult to show the whole area on a screen. It is necessary to create different maps:

- a most simplified one to help the general overview of the area (we can add virtual landscape features like trees, buildings, but it is not suitable to show the course);
- less simplified ones to show only a part of a course (one-two legs with different route choices).

Orienteering is regularly shown in television broadcast in the Nordic countries, so they have enough experience how to do it efficiently. In most cases there is no time for map preparation or it would require too much extra effort or the organizers are keen on secrecy (and very few orienteering events are so important that they get remarkable broadcast time, which would give the opportunity to present competition maps). In exceptional cases tracking system with minimal map preparation were used. In the Nordic Championships (2005, Norway) a new, special form of orienteering were introduced at international level (micro sprint). This new form was unknown for the audience so a graphic representation helped the audience to understand the new rules.

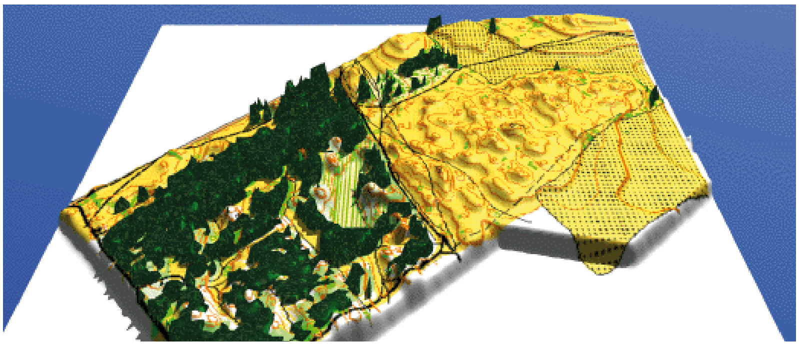

Fig. 2: An early 3D image generated from the OCAD file of 1996 World University Orienteering Championship map – courtesy of Tamás Heckenast (Hungary)

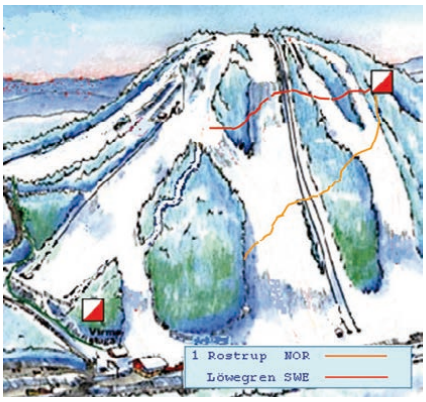

Fig. 3: 3D-like representation of an orienteering map (Showing the route choice and the running speed of the best competitors in a leg)

6 References

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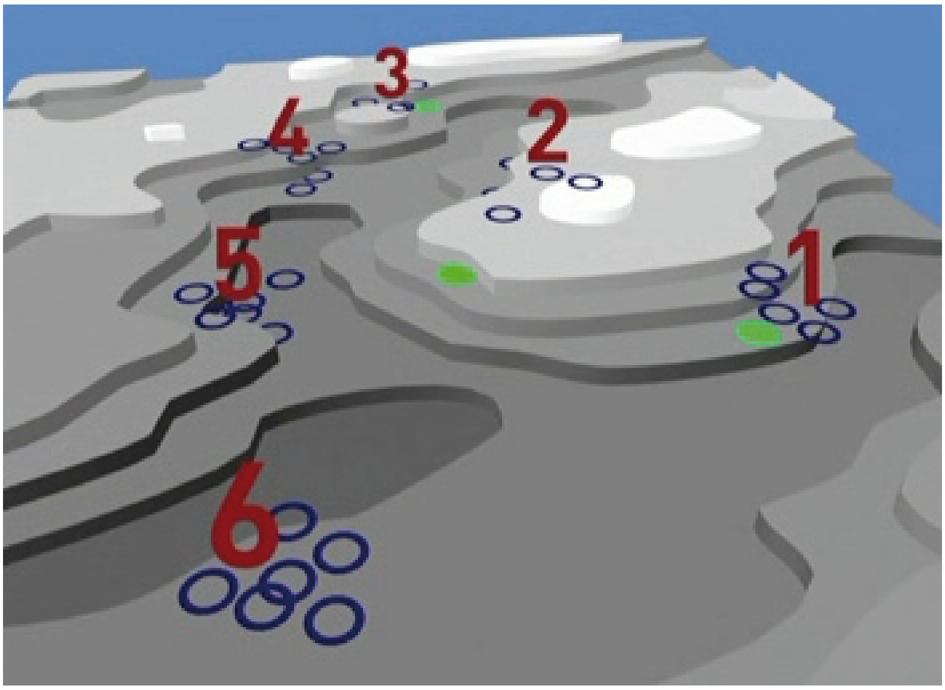
Fig. 4: A simplified 3D representation of the Nordic Championship terrain (Norway, 2005)



The World as a User Interface: Augmented Reality for Ubiquitous Computing

Dieter Schmalstieg, Gerhard Reitmayr

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Abstract

We discuss the possibilities of augmented reality (AR) as a ubiquitous user interface to the real world. A mobile AR system can constantly provide guidance to its user through visual annotation of the physical environment. The first part of the paper discusses the necessary ingredients for ubiquitous AR, on which we have worked in the recent past, namely mobile AR hardware, wide area tracking, unobtrusive user interfaces, application prototypes, and geographic data models suitable for AR. The second part of the paper examines future requirements of such data models in greater detail. Based on the lessons learned in our previous work, we identify shortcoming of existing standards for geographic information systems and visualization models. Ubiquitous AR requires independence of the data model from specific applications and their implicit assumptions. A semantic network model of geo-referenced data provides such a data model. We examine how such a model fits the requirements of AR applications, and how it can be implemented in practice.

1 Introduction

Augmented reality (AR) is an excellent user interface for mobile computing applications, because it allows intuitive information browsing of location-referenced information. In an AR environment, the user's perception of the real world is enhanced by computer-generated entities such as 3D objects and spatialized audio [Azu97]. Interaction with these entities occurs in real-time providing convincing feedback to the user and giving the impression of natural interaction. Augmented reality as a user interface becomes particularly powerful when the computer has access to location-based information so that it can seemingly merge virtual entities with real world objects in a convincing manner.

Over the last years, we have created a mobile augmented reality system and a set of applications to gather experience of ubiquitous augmented reality applications. We focused on navigation and created solutions for both indoor and outdoor navigation. Both applications require extensive 3D models and information which is presented to the user. Accurate and complete models of buildings and their interiors are required for rendering occlusions and highlights of buildings. Different navigation models for indoor or outdoor use were developed to fit specific requirements.

The first part of this paper summarizes our work on mobile indoor and outdoor AR: presenting various hardware platforms for mobile computing and graphics; hybrid indoor/outdoor tracking solutions; user interface considerations and test applications. The second part introduces the concept of a semantic world model for AR, which directly derives from an analysis of the requirements of applying AR techniques within ubiquitous computing applications. We review recent developments in the geographic information systems (GIS) community, and how they can be used by mobile AR systems. As part of this approach, we present a conceptual design for a semantic network for AR, which can serve as a computational back end providing a new level of contextual information for AR and other types of ubiquitous computing services.

Fig. 1: The backpack system is based on a conventional notebook computer displaying stereoscopic graphics overlays in an optical see-through head mounted display.

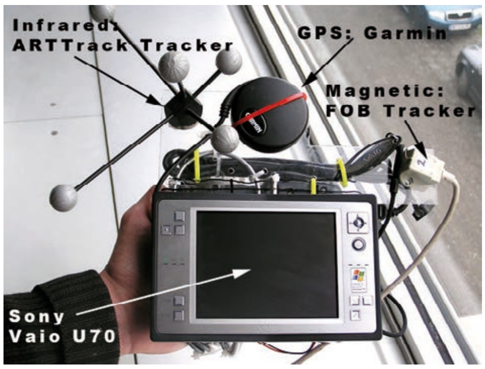


Fig. 2: This handheld AR platform is based on a mini tablet PC that is operated as a video-see through "magic lens" device. It currently supports five different tracking technologies (3 shown) and weighs less than 1.5kg.

Fig. 3: The smallest fully featured AR platform to date is based on commercial PocketPC 2003 handheld computers. Using an embedded camera, these devices can perform optical marker tracking and real-time 3D graphics at ~20fps. Shown is the "Invisible Train" multi-user game successfully demonstrated at SIGGRAPH 2004.

2 Mobile augmented reality platform

2.1 Hardware and software

The successful delivery of mobile Augmented Reality (AR) is an ongoing challenge, as interactive 3D applications must be implemented on constrained hardware platforms, requiring tracking over a large area of operation at high accuracy. While earlier work on mobile AR uses backpack prototypes, e.g. [FMH*97] or [TDP*98], more recently there has been a trend towards smaller, discreet, lightweight handheld setups based on PDAs and cell phones. We have assembled a series of experimental platforms of varying form factor and capability for real-world testing of the trade-offs in wearable AR.

Our implementation of a classic backpack solution (Fig. 1) involved a frame equipped with a notebook computer running a standard operating system (specifically a Dell Precision 8100, 2GHz P4 CPU, NVidia Quadro4Go, Windows XP). This standard platform provides standard interfaces for communication (802.11 wireless LAN, GPRS) and peripherals. A differential GPS receiver (Trimble Pathfinder Pocket or Garmin GPSMouse) is used to determine the position of the system in outdoor applications. We use an optical-see-through stereoscopic color head mounted display (Sony Glasstron D100-BE) fixed to a helmet as an output device. The helmet also supports an inertial orientation tracker (InterSense InertiaCube2) and a camera (PointGrey Firefly) for indoor fiducial tracking and video see-through configurations [RS04].

While the backpack system uses very powerful hardware and allows development directly on the target platform, its weight and ergonomic properties are clearly unsatisfactory. We are therefore also experimenting with smaller handheld computer platforms, which allow a "magic lens" style of video see-through augmentation. Such a handheld AR platform is inexpensive and ergonomically superior to the backpack solution. Most potential users are already familiar with camcorders and consequently understand the handling (hand-eye coordination) of a handheld video-see through device. Informally we have observed that users prefer handheld AR over head mounted displays despite the lack of stereoscopic graphics and hands-free operation. The lower computational power of handhelds is partially compensated by the reduction in graphical complexity: monoscopic rather than stereoscopic; smaller screens, increased tolerance of lower resolutions and frame rates.

We have developed two handheld setups. The first setup (Fig. 2) is based on a mini tablet PC (Sony Vaio U70, 1GHz Pentium-M, Windows XP). This platform combines a regular PC compatible computer with several peripherals into a very compact form factor (footprint 15x20cm, 1400g including peripherals). The second setup (Fig. 3) is based on the Pocket PC standard for personal digital assistant (PDA) computers (ARM9 CPU currently attaining maximum speeds of 624MHz, Windows CE). While these devices weigh only around the 180g mark, they still feature a touch screen and a built-in camera. We have managed to implement real-time optical tracking and 3D graphics on the Pocket PC platform [WS03]. In terms of weight, size, and price these devices are almost ideally suited for our purposes, but software development for PDA operating systems is still not a straightforward task.

The software framework that allows rapid prototyping of AR applications with a high degree of 3D interaction is *Studierstube*, a versatile environment for developing virtual reality and AR applications [SFH*02]. It is based on an object-oriented scene graph (Coin), which allows the description of 3D scenes and 3D interactions through convenient declarative scripting.

2.2 User Interface

The main use of a mobile AR device is as an information appliance operated in browsing mode. The system should provide context-sensitive cues while the user is busy performing a task or navigating through the environment. Consequently, most input to the system should be automatically derived from situational context, without requiring explicit user attention. The main method for achieving this is by tracking the user's position in the environment, and the user's current viewing direction. Consequently, wide area tracking is of major importance for a mobile AR system (see next section).

However, applications will still require a certain amount of direct control. For example, a user may want to select a navigation target from a list of addresses or a map, or if the destination is within visible range more directly by using gaze direction. For such explicit control, we have investigated a number of interface alternatives.

Touch pad and touch screen: handheld AR devices are already equipped with a touch screen, which can be conveniently used to display on-screen menus operated by stylus or a finger (Fig. 1). The same touch screen can be used for selecting objects in the video-see through display by tapping on their position on the screen, effectively a form of raypicking interaction. For configurations using a head-mounted display, we have relied on either a handheld touchpad peripheral that is used to control a 2D cursor in the heads-up display, or by an additional PDA which can display menus directly on its screen. Both the touchpad and the PDA can be tracked using fiducial markers observed by the helmet-mounted camera, if 3D input is desired.

While the touch screen interaction clearly hints at its origins in desktop 2D and 3D user interfaces, the iOrb device (Fig. 4) was specifically designed for unified command and spatial input for mobile AR [RCK*05]. It consists of a single 3DOF inertial tracker (XSens MT9) embedded in a shell composed of two hemispheres of about 8cm diameter. By turning the sphere and then pressing the two hemispheres together, the user can issue application commands using variants of 1D and 2D pie menu techniques. Similarly, spatial selections can be made using a picking ray or cone. All interactions use only relative rotational measurements and are therefore mostly insensitive to measurement inaccuracies and drifting.

2.3 Tracking infrastructure

Wide area tracking cannot generally be done with a single sensor, because no single tracking technology can provide the range and accuracy required by a general mobile AR system. Therefore a significant body of work exists on hybrid tracking systems, combining multiple tracking technologies through sensor fusion techniques. However, most research focuses on building a single, improved tracking system through sensor fusion, rather than on alternating between different sources depending on availability, location, and context. Notable exceptions are the systems built by Hallaway et al. [HHF*04] and by Piekarski et al. [PAT*04], which are the only systems we are aware of that are capable of alternating between indoor and outdoor operation.

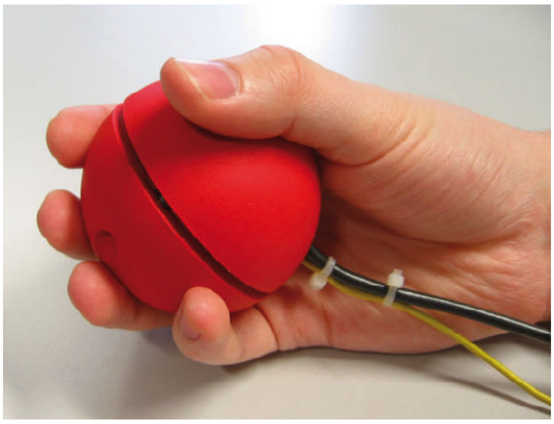


Fig. 4: The iOrb, an interaction device specifically designed for mobile AR users, unifies command input and 3D spatial selection at a distance through raypicking.

Several previous approaches combine multiple sensors popular for AR setups, such as fiducial tracking, inertial and GPS sensors. However, these approaches lack a general approach for management of arbitrary sensors. We have therefore developed a ubiquitous tracking framework [NWB*04], that addresses the problem of tracker integration and arbitrary sensor management. The most recent integrated solution that uses this approach executes on a handheld computer (U70), and combines five tracking systems: Inertial (XSens MT9), infrared vision (ARTTrack), magnetic (Flock of Birds), optical (ARToolKit), and GPS (Garmin GPS18 USB).

Each tracking technology has a dedicated working volume, with the exception of the inertial orientation tracker. The inertial tracker is used to assist other tracking systems with dead reckoning information, in particular the outdoor GPS system, which does not deliver any estimates of orientation.

As the core tracking software, we use OpenTracker (OT), which implements a pipes-and-filters network for connecting producers and consumers of tracking information [RS01]. The nodes of this network can execute on different hosts in a network. In particular, ARTTrack and Flock of Birds are stationary systems with a dedicated device server, each executing an instance of OT. The OT server will then communicate the tracking information to another instance of OT on the handheld computer over a wireless network.

Outdoor tracking: information is provided by a GPS receiver with the XSens inertial tracker providing complementary orientation estimates. Differential GPS corrections are obtained through a wireless internet connection from a local base station service or the new global correction service.

ARTTrack is a commercial multi-camera system capable of tracking target bodies composed of 4-5 small retro-reflective balls. These lightweight target bodies can easily be mounted on a helmet or handheld device, which can then be tracked in an outside-in mode while in view of the cameras. The mobile device itself is completely passive and does not require batteries or tethered cables for tracking. The pose data is transmitted from a stationary tracking server that performs the online pose estimation to the mobile system using wireless networking.

Flock of Birds: Since the Bird is wired, when the user with the handheld enters the effective envelope of the Bird, it is necessary to physically attach the Bird to the object of interest using velcro straps. Currently, the user triggers an event, by pressing a button, to acknowledge the presence of the Bird. Future versions will automatically determine Bird activity using correlated motion from an inertial tracker permanently mounted to the handheld device and the Bird, once it is attached to the handheld device. Similarly to the ARTTrack, the tracking data is transmitted wirelessly from a stationary server to the mobile device.

ARToolKit: A significantly modified version of the popular vision tracking library *ARToolKit* is used for tracking indoor regions beyond the reach of the magnetic and infrared technologies. Pose estimation of the mobile camera rigidly mounted on a helmet or handheld device is performed using the 2D location of the corners of one or several square markers visible in the camera image. The identity of the markers is then decoded directly from self-correcting 2D barcodes in the marker's interior area, which makes it possible to uniquely discriminate a large number of markers dispersed throughout the indoor environment. By looking up the geometric position of each observed marker in a previously surveyed model of the indoor area, the global pose of the mobile device can be computed from the camera pose estimation. The inertial tracker provides orientation dead reckoning if no markers are observed.

Tracker selection: The OT configuration in the client is responsible for making the tracking "ubiquitous", i.e., permitting online selection of the best available tracking technology. The selection mechanism is currently based on priorities: The stationary tracking technologies ARTTrack, Flock of Birds, and ARToolKit are selected in this order if data from the corresponding sensors is available. The systems attempts to fall back to GPS if none of these technologies is available, and finally reverts to a static map when there is no location data whatsoever. An improved version of the tracking framework is currently under development, which will permit fully automatic discovery of new tracking services based on a tracking service characterization.

2.4 Applications

Outdoor applications. The needs and requirements of a tourist are a suitable starting point for testing location-based applications. A tourist typically has little or no knowledge of the environment. However, tourists have a strong interest in their environment and

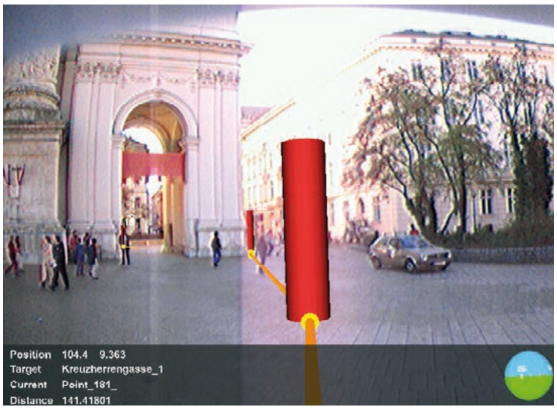


Fig. 5: An outdoor navigation guide for a pedestrian visualizes the selected route as a series of waypoints. Note the correct occlusion between the route and the archway .

Fig. 6: By gazing at a cultural artefact of interest, a user can instantly recall historic multimedia information.

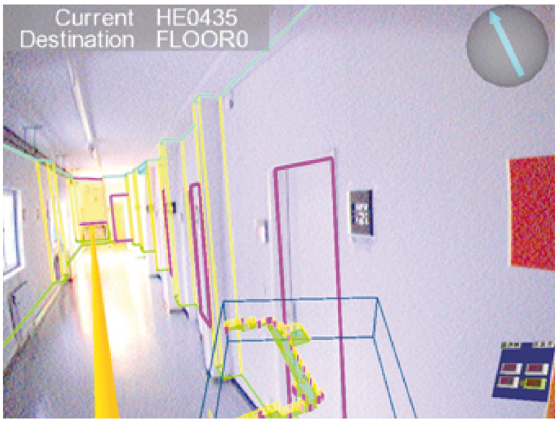


Fig. 7: Indoors, a combination of directional arrows, highlighting of exit, compass (upper right) and world-in-miniature (lower middle) is used to help a user navigate the environment.

Fig. 8: The "Augmented Library" allows a user to quickly locate the shelf on which a book of interest can be found, by emphasizing the relevant location.

also want to navigate through their surroundings to visit different locations. Guided tours are also popular for tourists. Consequently, we have chosen a tourist guide application for the City of Vienna as an example scenario for an AR application that integrates a large amount of data from different sources.

The system provides a navigational aid that directs the user to a target location. An information browser displays location-referenced information icons that can be selected to present more detailed information in a variety of formats. Both functions support collaboration between multiple mobile users.

In navigation mode the user selects a specific target address or a desired target location of a certain type such as a supermarket or a pharmacy. The system then computes the shortest path in a known network of possible routes. It is interactive and reacts to the user's movements. It continuously re-computes the shortest path to the target if the user goes astray or decides to take another route. The information is displayed as a series of waypoints that are visualized as cylinders standing in the environment (Fig. 5). These cylinders are connected by arrows indicating the direction the user should take between waypoints. Together they become a visible line through the environment that is easy to follow. The user can enable an additional arrow that points directly from her current position to the next waypoint. Buildings can clip the displayed geometry to enable additional depth perception cues between the virtual information and the real world. Finally, the system displays simple directional information, if the user is not able to perceive the next waypoint because she is looking in the wrong direction.

The information browsing mode presents the user with location-based information. Location-referenced information icons appear in view and are selected by looking at them (Fig. 6). They then present additional information associated with that location. The application conveys historical and cultural information about sights in the City of Vienna.

Indoor applications. Indoors, the mobile AR system guides a user on the way through the long and winding corridors of a university building with direction and map based contextual information [RS03]. The system continuously provides the user with two modes of visual feedback: a heads-up display with directional arrows and a world in miniature model of the environment. The heads-up display shows a wire frame model of the current room superimposed on top of the real scene. The application uses a shortest path search on an adjacency graph of the building to determine the next door/portal on the way to the destination, which is then visually highlighted. In addition, an arrow shows the direction to the next door or portal turn (Fig. 7). The application also presents

a world in miniature model of the building to the user in the lower area of the heads-up display. While the 3D overlay only shows the next exit, the miniature model shows a overview of the user's current environment including the complete path.
In the library, the mobile AR system may assist a user in locating and retrieving a book. Using a menu system, the user can select a book from a database. The corresponding bookshelf is highlighted in the heads-up display to aid the user in finding the book (Fig. 8). The system can also help in the return of a book. If a marked book is identified, the book's designated shelf is once again highlighted aiding the user to return the book to its correct position. This enables the user to simply look at the book in her hand and trigger the appropriate application behavior.

3 First experiences with large scale data models for AR

The indoor and outdoor applications presented in the last section require extensive 3D models and information presented to the user. Accurate and complete models of the buildings interiors and overall shape are required for rendering occlusions and highlights of buildings. Different navigation models for indoor or outdoor use were developed to fit the specific requirements.
Both applications are supported by a common world model based on an XML description of the geometry of world features. The XML tree is interpreted in the standard geometrical way, by defining a child's pose relative to its parent. However, the open XML-based format is not bound to any particular visualization tool or platform, and affords the definition of other than spatial relations by using relational techniques such as referring to object ids and annotations.
An outdoor AR system can be considered as a special case of a geographic information system (GIS). It presents geo-referenced information in real-time and in 3D, based on the physical location of the user, user preferences, and other context-dependent information. Large amounts of geo-referenced information, such as a 3D world model, require a database system for efficient storage and retrieval. The introduction of a GIS database also solves the problem of providing a consistent view of the 3D world model for a potentially large number of wirelessly connected clients.
Depending on location and context, only a small subset of the information contained in the GIS database is necessary for the client. Information is therefore retrieved dynamically by querying a database server. The response to such a GIS database query typically undergoes a series of transformation steps. Common operations are filtering according to geographic and logical constraints (e.g., return all coffee shops in a radius of 100m), and translation from a more generic format to a data structure that can be directly visualized [VZ04].
When we started with the implementation of our mobile AR framework, solutions for 3D GIS visualization were not sufficiently advanced for our purposes. Consequently, we developed our own XML based data format and processing pipeline using XSLT for data translation. Recently, the emergent Geographic Markup Language version 3 (GML3) standard together with the Web Feature Service (WFS) standard provide a standardized and extensible interface for accessing GIS information. CityGML [KG03], an application profile (extension) to GML3, is similar in spirit to our own custom XML dialect. Since it can be expected that these new standards will be widely supported in the near future, it is advisable to adopt them for AR applications as well.

4 Automating visualization generation

The complexity of interactive visualizations demands automated methods for generating engaging presentations. The fundamental idea of automated visualization generation for AR is quite old [FMS93], but few or no tools for this purpose exist, and GIS technology does not directly resolve this problem either.
Consider, for example, recent research which focuses on specialized visualization techniques for augmented reality, such as communicating the distance of occluded objects [FAD02], improving the readability of text overlays [LT04], providing automated layout of presentation items [HFH*01], filtering information [JLB*00], or adapting the visualization in the presence of tracking errors [CMJ04]. All these techniques could be made generally available to AR applications by an automated approach for visualization generation. However, a simple XML-based world model as presented in the last section is not flexible enough for this purpose.
GML's approach of an explicit representation of the geometric and other relations through so called features is better suited to provide the flexibility necessary for combining a large variety of applications and data sources. However, GML defines the syntactical aspects of geographic data exchange by fixing low-level data types and describing what information features contain and what relations exist. Any application using a specific GML data source therefore needs to know in advance how to interpret these features and relations. This means that these relations, feature names, and resultant structure are hard-wired into the application itself. Moreover, only traditional relational queries are supported. More complex queries, incorporating transitive closures of relations, require query iterations to implement. However, such requests are commonplace in graph search algorithms such as finding a path through a navigation network.
In order to further decouple applications from this inherent structure and to support a more expressive query language, we are investigating the use of another layer of information encapsulated in a semantic network on which applications operate. The semantic network layer includes the application's view of the world and the data sources' view and is able to integrate both. As a result, visualizations can be described independently of the structure of the underlying data source.
In the remainder of this section, it will be demonstrated with a set of examples how an integrated and semantic world model enables these methods. The semantic aspect of the world model entails that such visualizations can be developed independently from the underlying data model.

4.1 Example: Gas utility company

Professionals dealing with hidden and embedded structures can be supported in their field work with the integration of administrative information with detailed models of the physical environment. For example, a worker for a gas utility company has to find and repair a leak in a gas pipe in the field.
The worker will require accurate 3D information to locate access points to the pipe where he can measure various operational parameters of the pipe in order to locate the leak. The parameters are referenced to the points and can be queried by the system on the fly from the combined spatial-semantic database. A handheld visualization device will use the stored 3D model at the same time to display the layout and placement of the hidden pipe in the ground to facilitate planning of the repair. The worker can then proceed to carry out the maintenance.
However, the displayed information is not limited exclusively to the task at hand. Any other subsurface structure in close proximity to the site is also extracted from the model and its relevance is assessed. Obstructing structures are identified by analyzing the geometric relations they have with the pipe. For example, if another pipe is above the gas pipe of interest, the visualization will include it and show any possible areas of intersection with the work path. Similarly, other structures are checked for dangers to the planned work, such as electric fields that could trigger sparks in tools. Again the visualization will highlight such structures to inform the worker of possible risks.
After the task is completed the relevant administrative information including work time, material, client information and nature of the defect are entered by the worker and automatically related to the pipe and location by the system again. The collected information can then enter the business logic workflow of the company without further overhead. The relation to the 3D model enables automatic cross-referencing of administrative data and real-world locations and artefacts. Finally such a model can be reused for information visualization in report and analysis work.

4.2 Example: Pedestrian navigation

Navigation systems for cars have become standard equipment due to accurate and affordable tracking and high-quality road maps. Similarly, one can expect that pedestrian navigation covering outdoor city use but also indoor areas will become a generic feature of future mobile systems. Various systems have demonstrated partial results in this area. However universal navigation from room to room across two buildings, streets and even city districts remains out of reach. Besides the unavailability of ubiquitous tracking, a generic model covering all levels of details involved in such a task also does not exist.
Consider a user having an appointment with a customer in an office building across the city from her current location. Her PDA queries a web service ahead of the meeting time to compute a route from her own office to the customer's. Such a route will not only include accurate driving instructions but also information on possible parking spaces in the vicinity of the destination area, the path she has to walk to get to the office building and information on how to get to the customer's office.
A display included into her sunglasses conveys navigational information as she leaves her car and walks towards the office building. The entrance she has to use is highlighted and to give some impression of the location of the customer's office, the system highlights the windows facing out of the room on the building façade. Within the building, the system directs her to an elevator and displays, or automatically selects, the floor level she has to go to. Once on the right floor, the system points her in the right direction along the corridor.

4.3 Adaptive visualization engine

Within the scenarios described above, we identified several tasks that should be delegated to an automated adaptive visualization engine. Such an engine will operate on the given world model and its meta-data to derive which elements of the model are of interest and what the appropriate style of presentation should be.
Deriving styles and transformations. The adaptive visualization engine queries the world model for the structures directly relevant to the worker's task. From the given work area it also derives other structures that intersect the planned excavation volume. Based on the attributes associated with the structures it finds, it can assign appropriate visualization styles to them.
For example, structures that lie above the designated pipe are rendered in a bright color to draw attention to them. Nevertheless, they are rendered translucent enhancing the perception of the main structure. Structures within the volume but below the pipe are rendered with darker colors as they are not as important.
Similarly, a projection of the main structure and the excavation volume to the ground model is computed to throw a "shadow" on the real ground. Such a "shadow" maps the 3D location directly to the visible surface area and delineates the required excavation area.
Displaying dangerous areas. The worker's system should automatically identify dangerous areas or structures in the working area and notify the worker with appropriate signals. To do so it needs a model of the possible hazards related to the task at hand and a method of querying the world model to retrieve structures that fit the model.
To implement such functionality the application has a list of attributes that relate hazardous structures to the selected task. Then a query is formulated to search for structures intersecting the working area and being annotated with attributes matching the possible hazards. The query is translated into one or more WFS queries and is send to the server.
The results are converted into a scene graph suitable for rendering and interaction. Based on the returned attribute values, different levels of severity are assigned to the structures and presentation styles are set accordingly. The resulting scene graph is then added to the viewer's graph and becomes part of the presentation.

Deriving related objects of interest. For a mobile task like navigation, objects of interest are often occluded or not fully or directly visible. In such cases it is not simple for the user to interpret the visualization correctly, even if various techniques such as transparency or cut-away views are employed. Therefore the adaptive visualization engine can substitute currently visible structures for the actual target structures and use these in the presentation.

For example, as the user is coming close to the target building both the building entrance and a window associated with the target room are highlighted. The system emphasises the entrance in order to guide the user in the right direction, but also, it draws some attention to the window to provide some overview of the planned path. The user can therefore build a mental map of where she will go.

Within the building, doorways are again used as direct navigation aids, but an outline of the intersection of the room with the adjacent walls can provide more information about the location and size of the target room. Such subtle additions to the presentation could help users to gain a better understanding of the structure of their environment.

To implement these functions, the system will first compute a path from the current location of the user to the destination. Moreover, it queries the world model for potential occluding objects in the area between the user and the destination object. If such objects exist, it will further derive visible sub-structures of these objects and try to relate them to the destination room. Such relations can be topological such as windows connecting a room volume to the outside or geometrical such as proximity of walls. If such a related object is found, it can be used in the visualization instead of the destination object.

5 Semantic reasoning engine

More complex automation is achieved by incorporating knowledge-based query mechanisms into the application. Our aim is to provide a software component that reasons over the available world model to identify and select objects described by more complex propositions than simple query-based assertions.

The semantic reasoning engine maintains a representation of the world and application state as a semantic network which contains information on the individual objects in the scene, the tasks of the user and the selected visualization modes. The semantic network is based on an ontological description of the properties of objects.

It combines a set of formal descriptions of application knowledge:

- A basic ontology like OWL [HPH03] for defining the basic relationships between objects, such as membership of a class, subclasses, aggregation and attributes.
- An ontological description of the GML-based data in order to interpret and map the GML features to the semantic network representation.
- Application specific ontologies that further refine the basic ontology with the relations that hold in the application domain.
- A description of the possible user interface representations and their relations to domain specific object attributes.
- A set of mapping ontologies that translate between the GML relations and the application-specific or user interface concepts.

Finally, a knowledge base of facts about the objects is also maintained in the network. These facts are representations of the underlying GML feature data retrieved from the Web Feature Service back-end.

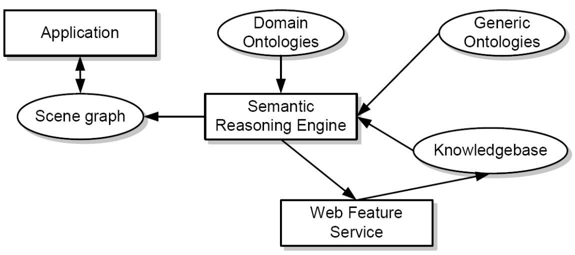
An inference engine such as Racer [HM03] or FaCT [Hor98] processes queries defined by the application and returns the results with respect to the semantic network. Relations that include geometric semantics such as distance or visibility are implemented as extensions to the inference engine that operate on the geometric data itself, rather than on the representations in the semantic network. If further facts are required, the engine also formulates queries to the WFS back-end to replenish the knowledge base with more information. For example, a prerequisite to certain queries could be that all objects within a certain distance of the user are kept in the knowledge base. As the user moves, the engine will update the knowledge base as required.

5.1 Building visualizations

The next step uses the knowledge encoded in the semantic network to derive convincing visualizations. Here we use the ontology describing the properties of types of visualization. For example, we could define that objects that are occluded but important for user orientation are of type *I* and are to be rendered with a bright yellow stippled outline, while objects that are occluded by any object of type *I* are themselves of type *O* and are rendered with a black translucent color to modify the luminance of occluded objects.

The inference engine can now deduce from assertions in the knowledge base whether a certain object meets the criteria to be classified as either type *I* or *O*. Similarly, we could also formulate a query that returns all objects of a certain type. Note that the decision of whether an object is of type *I* is not solely based on geometric calculations, because it must also be important to user orientation. A formalization of this concept is in fact encoded in the domain specific application ontology.

Fig. 9: The semantic reasoning engine relies on a knowledge base interpreted according to various ontologies.



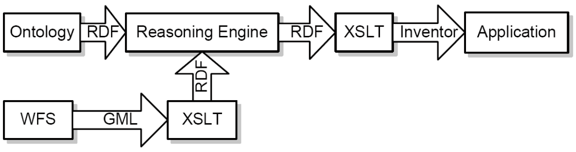


Fig. 10: XSLT is used as the general translation mechanism that interfaces the individual parts of the semantic reasoning system for AR. It can convert between geometric information (GML), semantic information (RDF) and graphical data for visualization, such as the scene graph standard Open Inventor.

The connection between the semantic reasoning engine and the user interface component is another crucial aspect of the system. The output of the engine – the results of queries to it – is transformed into scene graph representations for the rendering engine. However, due to the possible complex computations of query results, we cannot expect the reasoning engine to operate at real time in direct response to the user's interactions.
The output scene graph will rather describe the possible visualizations of all objects with respect to certain changes such as visibility or distance to the user or actions by the user such as selection. The visualization will be rendered with appropriate parameters driven by the sensor input and adapt at render time to such simple changes. Only larger movements exceeding certain thresholds or interactions with the application such as selecting a different mode or target will trigger a re-evaluation by the semantic reasoning engine.

5.2 System integration

The integration of the semantic reasoning engine into the overall system is supported by the extensive use of XML-based data exchange formats. Ontologies are expressed in RDF [MM03] and can therefore be served by web services. The knowledge base of facts in the reasoning engine is typically also expressed in RDF. Therefore XML-based transformation technologies such as XSLT can be applied to the GML query results of the Web Feature Service to extract and formulate the assertions in RDF and feed them to the reasoning engine.
The output to the application is mainly entailing the creation of scene graphs for 3D rendering. Here we have already successfully employed the same techniques to generate scene graph descriptions from XML data structures. As the output of the reasoning engine consists of facts expressed in RDF too, we can directly apply static transformations to it and create the corresponding graph structures.

5.3 Example: Tracking target objects for navigation

To demonstrate the use of the semantic reasoning engine we will describe its operation when applied to universal navigation. Here we always want to present the user with an object that is "semantically" related to the target object, even if the target is not directly visible.
Within our application specific rule base, we define a set of rules that always compute a visible place-holder for the target object. A first rule is that the best place-holder is the target object itself, if visible. Another rule states that an object belongs to the type class *IsInteresing*, if it is visible and stands in the relation *SubstituteFor* with the target object. The relation *SubstituteFor* is defined in terms of a set of logical disjunctions and conjunctions of assertions on properties of both the target and the candidate objects. Among the assertions is the topological relation *neighboursWith* meaning a spatial relation that objects are adjacent to each other. The concrete implementation in terms of testable attributes or relations depends on the world model. Therefore it is either defined in the world model itself or as a set of geometric relations *Touches* which is part of the query language for the Web Feature Service.
For example, in order to find windows that may act as substitutes for a target room, we define the relation *SubstituteFor* to include objects of a size not larger than the target, that stand in the relation *neighboursWith* to it and that are potentially visible, because the user is currently outside of the building. The semantic reasoning engine is able to map the relations to real underlying relations in the current GML data set without further interaction with the application. Therefore, the visualizations depend on high-level abstract descriptions of interesting objects rather than on the direct low-level expressions used to compute them.
The result of the reasoning step is the set of all objects belonging to the class *IsInteresting*. The result set creates a scene graph representation that includes the objects' geometry and appropriate rendering styles. Moreover, the scene graph also includes some logic to react to individual objects becoming visible or invisible as the user moves within a certain range, such that only one object is actually rendered at any point in time. When the user moves beyond this range or selects a different target, the application re-evaluates the set by updating the knowledge base accordingly and applying the reasoning again.

6 Conclusions and future work

Mobile AR has outgrown its infancy and is getting ready for early commercial deployment. We have presented a series of platforms and application prototypes developed to assess the feasibility of key technologies in mobile AR. One noteworthy aspect of our experiments is that they use probably the largest and most systematic AR model to date. From our experiences with this model and its creation process we have learned what today's 3D modeling technologies do not provide: truly flexible interpretation of the data, which makes applications independent of assumptions concerning model structure and the relations between model entities. Semantic web technology aims to overcome this problem in the domain of online information systems.
In this paper we explained why mobile AR, with its potentially large number of clients and location-based service providers, has essentially the same requirements as document-oriented semantic web applications, but in the domain of real-time 3D information. We derive a data model which allows a suitable degree of semantic reasoning for mobile AR, and describe how it can be used in practical examples. While we already have many tools in place for the implementation of such a model through our own work and

the resources available in the GIS and semantic web communities, the verification of the approach with real world scenarios will be the subject of future work.

7 Acknowledgements

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Applications of the mobile positioning data in space-time behaviour studies: Experiments in Estonia

Rein Ahas, Anto Aasa, Ülar Mark

1 Introduction

The objective of the paper is to introduce the potential of the mobile phone positioning data in geography and planning. Mobile phones are widespread and their positioning has achieved such accuracy that it can be used for social and geographical research (Mountain and Raper 2001; Spinney 2003; Raubal et al 2004). The social positioning method (SPM) applies the phone location coordinates and social attributes of the phone carrier for studying the space-time behaviour of society (Ahas and Mark 2005; Ahas 2005; Ahas et al 2004). SPM differs from earlier mobile phone based tracking experiments in the sense that it includes the social attributes and other relevant information of phone owners actively in the analysis. The acquired data allows the analysis of social flows, their mobility and space-time behaviour (Timmermanns et al 2002).
The key issue in using the social positioning method is guaranteeing the privacy of people, and data security (Froomkin 2000). As in any geographical survey, the people's consent is necessary for tracking and using the acquired data.

2 SPM data collection

Movements of sample of 117 individuals were recorded by positioning their personal mobile phones in February 2004. The size of the sample and the number of positioning events was limited by the budget allocated for the experiment. The sample is based on data of the gender and age groups distribution of Tallinn's population, based in turn on the data of the National Population Census in 2000. The experimental sample was proportionally divided into two groups: a) 91 residents of the central part of the city; b) 26 commuters eg. persons who are working every day within the city centre but living outside of Tallinn. To balance the sample the quotas of commuters were divided equally between he main commuting routes of the Tallinn region.
Collection and database options of the social positioning data were conducted by the Estonian company Positium Ltd, which is currently developing SPM applications. Locations of the selected phones were registered after every 30 minutes between 7 am and 11pm during the period of 18-22 February 2004. During 5 days the motion of 117 participants was observed and altogether more than 14 000 location coordinates were registered. The location coordinates were gathered by MPS, PinPoint Mgine determined the sector of possible locations of every particular mobile phone, and the actual location of the mobile phone was calculated as the geometrical centre of this positioning sector.
In addition to the mobile positioning data each individual completed a personal questionnaire registering data about their social characteristics and travel behaviour. For the positioning of the individuals, two preconditions were required: the personal consent of each participant and the required technical capability on the part of the mobile operator. In the current study the network of EMT, Estonia's biggest operator, was used. EMT has technical and organisational capabilities for location-based services. During the experiment period EMT was using the MPS system of ERICSSON Ltd for mobile positioning., enhanced by PinPoint Mgine software produced by the Estonian company ReachU Ltd. PinPoint software was also used for database options during the experiment.
One limiting factor of social positioning is accuracy of positioning data. Our experiments in Tallinn and Tartu conducted in 2004 revealed that SPM data allows successfully analysing the spatio-temporal behaviour of the society. The calculations of theoretical positioning error based on 180 000 positioning cases showed that the accuracy of 61 per cent of positioning remains within 1000 metres in urban areas and within 3000 metres for 53 per cent of positioning cases in rural areas in Estonia. Accuracy check conducted with the GPS indicated that the error is less than 1200 metres in 99 per cent of cases in urban areas. Today, some research findings are limited because of accuracy of positioning but many research areas are very promising.

2.1 Selecting time interval for mobile positioning

Important issue in SPM studies is the selection of the optimal positioning interval. Interval is dependent on research objectives and scale, transportation devices used by respondents, and available finances. We have used intervals of 4 h, 30 min, 5 min, and 1 min in experiments with different objectives. All normal end-users want to get positioning data with as short an interval as possible, but the interval is actually dependent on positioning costs. As mobile positioning is part of the services of mobile operators, the market price today is between 0,03-0,6 EUR per positioning event in networks of the Baltic Sea region. The costs of positioning

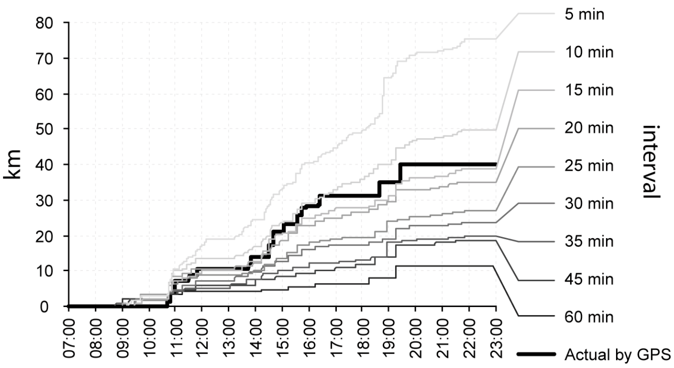


Fig. 1: Selecting best positioning intervals for tracing driving car in Tartu. Distances measured by different mobile positioning interval and actual route.

with 1 minute interval are 60 times higher than those with a 1 hour interval. This easy mathematics raises the question of determination of the optimal interval for positioning.

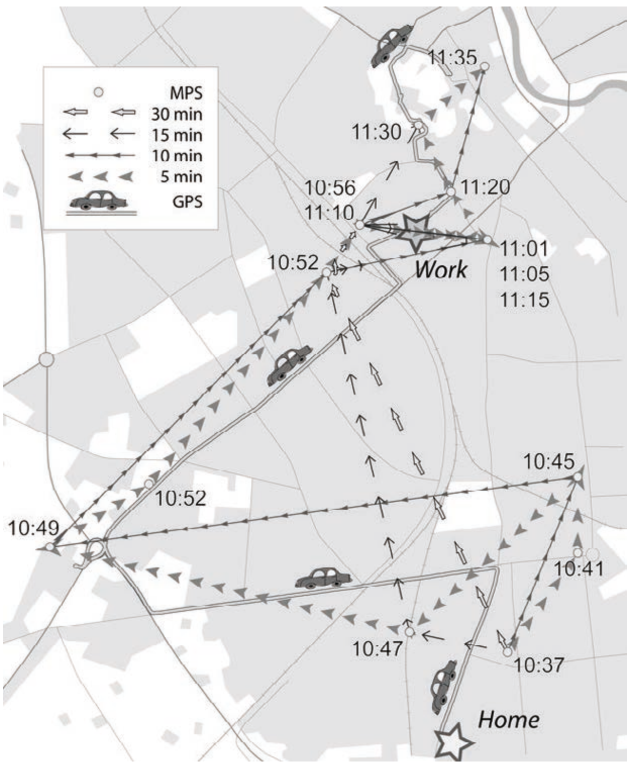
First we have to consider the objectives of the study and the transportation means used by respondents. This interval is different for walking and using car or bicycle. Figure 1 shows the analyses for selection of best positioning intervals for tracing a person with a car and walking a short distance in the city. This analysis is based on our one day positioning with a 5 min interval and GPS reference in Tartu. This shows that 15 min interval fits best for driving in a city like Tartu. Result was similar in Tallinn, but this optimal positioning sequence can be different for different cities and life speeds.

We also studied the spatial accuracy of this same 5 min interval experiment fragment in Tartu (Figure 2). The SPM modelled route for different (5, 10, 15, 30 min) positioning intervals in relation to actual route in Tartu are presented on figure 3. The 5 minutes interval fits best and 30 min interval loses most of the road points. The 5 minutes interval is relatively accurate for spatial movement and traffic studies. Visible is alos positioning biaz caused by antennae change during positioning (method of CGI+TA).

The good example that relevant planning of study project (objectives; respondents transportation device; positioning interval) can give us suitable results even with today's low accuracy and low "cost" intervals is shown in figure 3. This figure shows correlations between the automatic traffic counter on the Vabaduse-Sõbra crossing in Tallinn and the SPM database collected with a 30 min interval.

Correlations are especially high (r=0,81) if we eliminate local movements (walking or antennae change biaz) by using a minimum speed limit filter for SPM data to eliminate movements smaller than 500 m per 30 min intervals. The strong relation shows that the SPM data is relevant and can be used as a valuable supplementary tool comprehending the traffic flow. More importantly, the personalised SPM data enables one to add "a face to the traffic flow"- the social characteristics, which could so far only be guessed or indirectly assessed on the basis of conventional traffic counts and scanners.

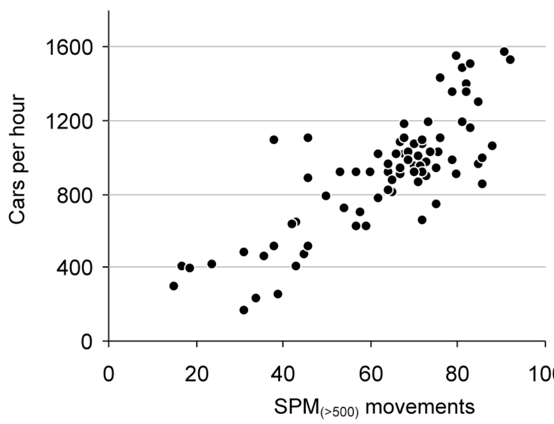
Fig. 2: Actual driving route and presentation on a map using 5 min, 10 min, 15 min and 30 min intervals in Tartu.



2.2 Temporal rhythm of spatial behaviour

The results demonstrate that mobile positioning is applicable in geographical studies; the best solutions can be exercised in studies of suburban commuting and in the space-time analysis of activity spaces. During work-days the residents of the city centre move less than the commuters (Figure 4). The differ-

Fig. 3: Correlations (r=0,81) between SPM database (movements over 500 m per 30 min) and the automatic traffic counter on the Vabaduse-Sõbra crossing in Tallinn during the 18.02-23.02 experiment.



ence (up to 10%) is the biggest in the morning between 8.30 am and 9.30 am and in the afternoon between 4.30 pm and 7.00 pm.
On weekend days the residents of the city centre are quite active in traffic between 9 am and 3 pm, when up to 75% of the sample is in motion. The commuters are more active on weekends in the afternoon between 3 pm and 6 pm.
According to the results of the positioning experiment the ratio of people who change their location during the day varies from 10-30% (mornings and evenings) to 70% (peaks of working days). In general, commuters are more active movers as could be expected and there is a general increase in movement on Friday afternoon and a decrease on Sunday morning.

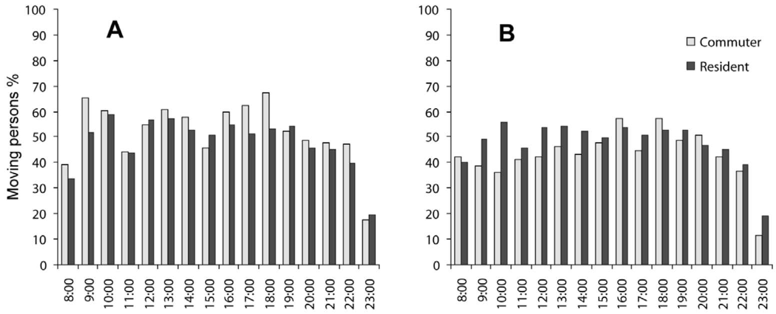


Fig. 4: Percentage of people changing their location during 30 min time positioning intervals within the sample of 117 participants. A-work days, B-weekends.

On working days the greatest activity of people can be observed between 9 am and 11 am and between 16 pm and 18 pm. The smallest activity during working days is between 11 am and 12 am and at 3 pm. The motion decreases as people start to arrive home, after 19.00. There are few movements before noon on weekends.

2.3 Spatial movement patterns

The space consumption in different regions of Tallinn is expressed on figure 2 and spatial coverage of positioned commuters on figure 3. By the late morning the population from all urban regions is concentrated in the city centre, by 10-11am the maximum number of people (75% of the sample) has reached the city centre. At the same time the proportion of the sample in the other parts of the city has increased up to 15%, which means that during the daytime less than 10% of the sample were outside the city. From 6 pm the number of people visiting the centre starts to decrease and the proportion of the sample outside the city starts to increase, reaching 20% by 9 pm. At the same time the number of people in the centre decreases to the minimum (58% of the sample) by 8-9 pm. By the late evening the number of people in the city centre has somewhat recovered – up to 65% of the sample. The diurnal rhythm of space consumption is relatively different on work days and weekends (Figure 4,5). The centre of the city is utilised more on working days (70% of the sample) and on weekends the area outside of city is more popular among the participants (30%). This result is logical and corresponds to the results of journey distances described earlier.
Despite the small sample (117 participants) and only 5 days of the experiment, it is still possible to draw conclusions on human time-space behaviour in Tallinn with using interpolation of different data sources. It is clear that the character of motion of the commuters and the residents of the city centre is quite different. The main differences between the commuters and the residents of the city centre are in the use of urban space. Compared to the average commuter who is covering 55 km during the experiment period day, the average resident covers only 31 km per day. The analysis of all the positioning events made during 5 days shows that during 30 min the resident is moving on average 2266 m, but the commuter, 4426 m. This shows differences in lifestyles and environmental footprints of the people working in the same area, even in the same office. Same time the commuters and residents of city centre have also different movement patterns in centre of Tallinn. Residents have more active in all city centre, they appear more likely in old town during lunch or evening hours (Figure 7). The commuters stay more in Tallinn "City" and they do not have free time to use old town as recreation of dining area. This creates clear division line between old town and "City" in central Tallinn which have different diurnal rhythm, visitors and functions.

Fig. 5: Space consumption of the studied 117 participants by one-hour interval positioning during different weekdays.

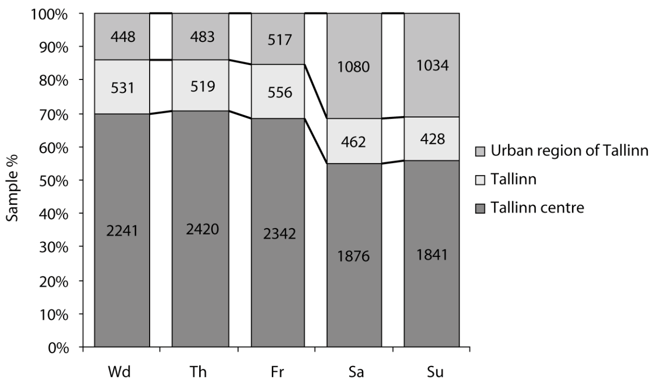
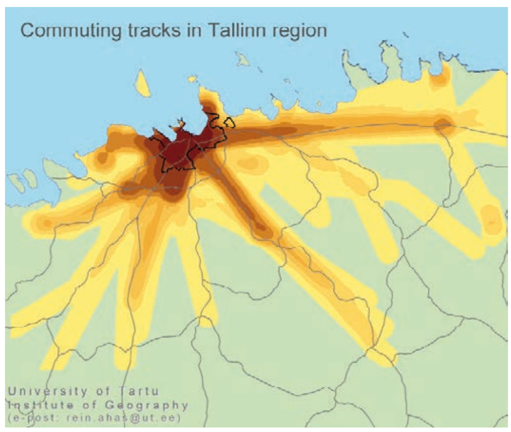


Fig. 6: Main movement tracks of positioned commuters.



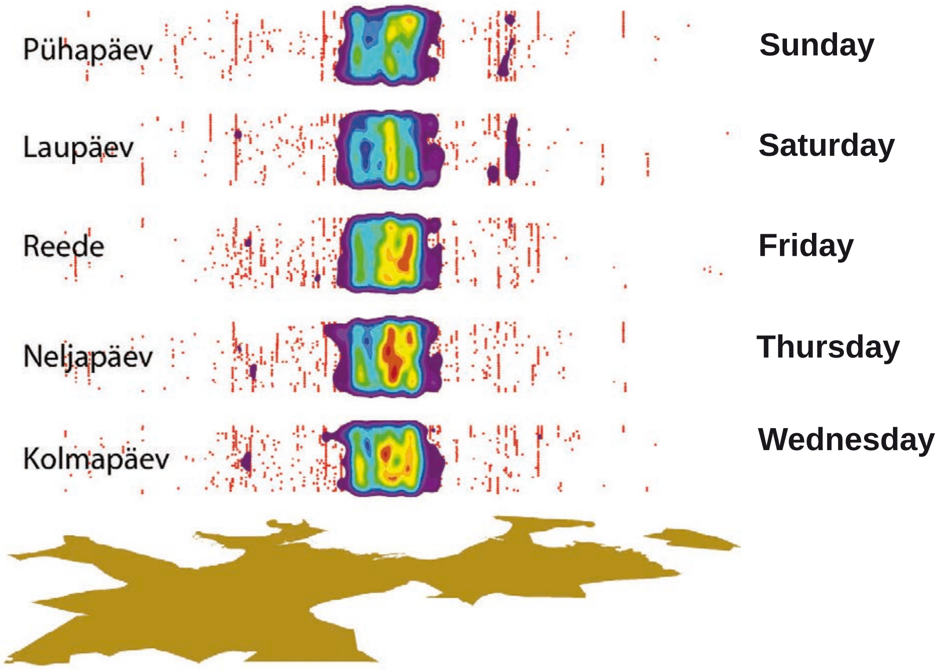


Fig. 7: Daily activity patterns in Tallinn recorded by positioning 117npersons with 30 min interval.

3 Conclusions

Mobile positioning data is useful and operational in mapping activity spaces and patterns in city. Some of the results of SPM analyses, such as space-time movement patterns of the city centre residents and the commuters, have great applicability. Some of the good results are unique and difficult to obtain by conventional methods, such as the rate and time of activity of commuters' journey distances during different days of the week, etc. This data could be obtained by travel diaries but with great methodological difficulties, as it is difficult to exactly monitor the activity between the starting point and the destination of the journey. A very important result of the current study is the finding very strong correlation between automatic traffic counters in Tallinn and corresponding SPM data (p=0.80), which demonstrates the credibility of the method.

Taking into account the large-scale distribution of mobile phones in the world, this would be a database with very high potential value. SPM data has three important aspects: 1) SPM data indicates the actual location and movement of people; 2) in comparison with earlier studies on space-time movement, both the quantity and the precision of this data is considerably higher; 3) the method makes it possible to work in real-time. With these great potential applications SPM will bring important changes in geography and the social sciences, planning and the way that planning can involve the general public. This will also hasten the development of real time methods and applications in geography and studies of activity spaces. Future development of the positioning sector will be determined by how positioning methods are implemented and how the public react to them.

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Suggestion for the bridging of the time gap

Brankica Malić

Abstract

The characteristics of the map - its exactness, its content completeness and the aesthetic design of the map - should be maintained regardless of the scale. These requirements have not yet been entirely fulfilled due to the use of digital technique in the production and the design of maps. In order to come up to the expectations there is the necessity to develop more efficient computers as well as screens with the smallest pixel size possible. However, one needs to find a mid-term solution for small screens, i. e. a consistent and suitable representation, under the present circumstances until the technology has evolved. Therefore it is indispensable to do research concerning the use of the rule based systems within LBS (Location Based Services). In this way the advantages of the digital map will be superior to the conventional map.

1 The present situation

Cartography has been and will always be transitional. There will always be new challenges in the technological development which cartography has to face.

Unfortunately, with the use of digital technology in the production of maps the content as well as the graphic and technical quality of the printed map on screens can not be preserved.

Due to the screen type, the screen size and the screen resolution the numerous parameters which have been developed for the conventional map for map representation have been altered, for instance, the minimal dimensions (Malić 1998).

However, dynamic updates, i. e. the change of the properties of the cartographic objects presented on the digital map, provide a straight-forward communication between the person and the computer.

2 The issue - TeleCartography or mobile cartography

Apart from digital technology the Internet as well as modern telecommunications devices have influenced cartography (Reichenbacher et al. 2002). By connecting computer networks with mobile computer the Internet offers a new art of map distribution and use (Gartner et al. 2003, Pammer et al. 2002). A continual positioning of mobile phones and other services of operators provide a platform for navigation and efficient usage for pedestrians and tourists with mobile city guides or national park guides as well as for car navigation systems (Retscher 2002).

With location based services the method of naming is still heterogeneous, i.e. the way of visualization and the way of positioning. At present there are several co-existing equivalent systems, some have been realized as prototypes.

2.1 The name of the method

Maps and map services are offered by Geo Services, which also provide positioning services, booking services, information services, settlement services, etc. Maps are indispensable for mobile services (Reichenbacher et al. 2003a). The various applications result in different names. Thus the label TeleCartography (Map based LBS) is used to put emphasis on the connection of computer networks, small computers and telephones (Pammer et al. 2002, Uhlirz 2002). The prefix „tele“ is applied in other fields such as, for instance, tele-academy, teleservices, telemedicine, etc.

Mobile geoinformation services are further terms for the so-called Location Based Services (LBS) (Buziek 2002, Reichenbacher et al. 2002).

The term mobile cartography aims at directing cartographic products to cartographic services. Here the focus is on the adaptation of mobile cartography, that is the dynamic adaptation of the mobile using situation (Reichenbacher et al. 2003a), rather than on the mobility of the (digital) map.

2.2 The procedure of visualization

When modeling the visualization shapes which are used with maps their scale and aspects of perception on (small) screens are taken into consideration (Kelnhofer 2002, Uhlirz 2002).

Under such conditions conventional map presentation for devices with small screen and for LBS is only suitable to some extent. For the screen resolution of 280 x 320 pixels a simplified graphic is required (Buziek 2002, Brunner et al. 2002).

Mobile computers such as pocket computers (handheld-PCs), mobile phones, smart- and feature phones (Gartner et al. 2003) with small screens of 80 x 60 mm^2 only allow for an enlarged and mostly simplified map graphic. Such a map graphic could consist of pictograms and cartograms using up only minimal space. For the representation of railway networks such as, for example, the local traffic, the train system and international flights, cartograms are used. Cartograms are simplified and schematic cartographic representation methods. At the same time they do not coincide with the scale although they are topologically correct. Lettering the map on the small screens can only be legible entirely by scrolling (Brunner 2002a and 2002b, Hake et al. 1994 and 2002, Meng 2002b). As the mobile map mainly serves navigation, the representation of traffic routes and landmarks are important. Here various orientation marks represent the landmarks (Elias et al. 2003, Zipf 2003).
An other suggestion for visualization is adaptive zooming. By altering the scale the content and the symbol selection of the map are adapted to the target scale (Galanda et al. 2003). The adaptation of mobile cartography, i.e. the implementation of the adaptive functions, is an advantage compared to web maps (Reichenbacher et al. 2002). The focus seems to be shifted from cartographic products to cartographic services (Dransch 2000, Reichenbacher et al. 2003a). There is the need to do research on the system, which is transparent for the mobile interaction between the user and device (person-to-machine) (Meng 2002a).
The project GiMoDig (Geospatial info-mobility service by real-time data integration and generalisation) has investigated and found online solutions for the availability of official geodata; there are supposed to be geodata for PDAs in the vector format.
These geodata have been produced with the scales 1:5000 to 1:10000 throughout Germany and also in the borderlands of Denmark, Finland and Sweden. Seventeen out of approximately 180 feature types were represented with support of national institutions. Everything is based on the FACC-Code (Feature Attribute Coding Catalogue), which has been developed as a military norm of NATO - DIGEST (Digital Geographic Information Exchange Standard) (Afflerbach 2004).
In Frech et al. (2004) an offline solution with raster data is presented as a base for the map. The ReGeo-Project has assumed maps of three different scales 1:500 000, 1:100 000, 1:50 000. Furthermore satellite images as well as aerial images are in use (resolution of 30 m and 1,5 m). Rappo *et al.* (2004) report on the application of logarithmic projection (anamorphous) that is the fish-eye view. Herman *et al.* (2003) consider the ergonomic design in accordance with the ISO-standard 9241-10 and 14915-1.

2.3 The procedure of positioning

Positioning is possible if a mobile computer is connected to a location system. GPS (Global Positioning System) could be employed. Another method of positioning is carried out by identification of „Cell-ID“ (mobile network cell). The time is measured between the sending of the signal until detected by the receiving station (Burghardt et al. 2003, Gartner et al. 2003). Besides the positioning of a mobile device is done via GPRS (General Pocket Radio Services) and UMTS (Universal Mobile Telecommunications System). An orientation procedure is supported by an electronic compass, which is installed in the mobile device (Lopau 2003).

3 The use of rule-based systems

As mentioned in the abstract there is the need to do research on the application of rule-based systems within LBS-systems. By the application of GPS-, GPRS- and UMTS-technology the location is determined. Then the location is shown on the screen, it is put in the centre, etc.
The application of rule-based systems should make it possible that the features of the digital map become sensitive. For each object the characteristic properties as well as the typical rules should be stored. After the initial information has been stored by means of client software dialogue, e.g. the client wants to visit galleries only in the closer surroundings, only these objects should be visualized. At the same time the selected object is supposed to recognize itself which galleries are closer to the location of the client. Such reactions of objects are controlled by programmed rules. The closer the object the more saturated the hue should be and the signature scale should be bigger. The focusing of the single selected items is the task of visualization.
The entire digital map should become sensitive to the needs suggested by the client. The dynamic properties of the digital map are to be stressed. Several dynamic properties have already been mentioned here such as the changing of the scale around the location, the so-called fish-eye view.

4 Conclusions

Reichenbacher *et al.* (2003b) discuss research issues of mobile cartography: How can effectiveness and mobility be combined best? Which expectations does the mobile user have for the map use (quality, functions, modalities of interaction, etc.)? Which function of the map is necessary for the mobile devices? How should the user interact with the map (clicking, speaking, pointing, etc.)? What are alternative representations apart from the map? How can perspective presentations and 3D-representations be used in mobile cartography? Are entirely abstract representations more suitable than (photo)realistic representations or pictures? When is what kind of option more appropriate?
There is also the need to do research in the field of design and representation of cartograms as well as cartographical symbols on the screen.

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Seasonal tourism spaces in Estonia: Case study with roaming data from operators network

Rein Ahas, Anto Aasa, Ular Mark

Abstract

We analysed tourists' space consumption in Estonia using anonymous mobile positioning datasets. The anonymous dataset allowed analysing the distribution of foreigners' country of origin in Estonia with the precision of network cells. If tourists with foreign mobile phone use phones in recreational areas, their country of origin can be recorded in cellular network and used for analysis. Mobile positioning data has great potential, as mobile phones are widespread in society, and this helps to describe the real movement patterns of tourists. This potential is used in different applications (Ahas and Mark 2005; Ohmori et al 2005).

We used anonymous foreigners' mobile phone roaming data from the biggest Estonian cellular network, EMT. This data allows one to analyse the distribution of foreigners' country of origin in Estonia down to the precision of network cells. The operator recorded for researchers the following data: country of origin, time and network cell of call events, for a total of 9.2 million entries. Because of the fragmentary availability of data, our study period was not standard: 1.04.2004-21.04.2005. We use the term tourist here in the meaning of all foreigners who visited Estonia and used a phone here. Tourists' country of origin is determined by registering the country of origin of the mobile phone he used in Estonia.

Our objective was also to evaluate the data and develop a method for how to use mobile positioning data in geographical research. This mobile positioning data has a very sensitive nature because of the fear of surveillance created by all electronic media and "good" scientists trying to use these data sources for research. We hope that our anonymous data set does not intrude on the privacy of tourists more than a regular street scanner in an intersection area or a census performed on the basis of tourist registration books in hotels. This, however, is a matter for future discussions concerning all electronic media.

We can conclude that seasonality produces very different and sometimes even opposite space consumption patterns in Estonia. Coastal areas are popular for summer tourism (Figure 1,2); more continental inland areas were used for winter tourism. Very popular summer tourism areas are dominated by one nationality: the Finnish in western Estonia, and the Russians in eastern Estonia. Latvians had higer percentage in Saaremaa and Pärnu during summer and in Otepää and Lake Peipsi in winter.

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Fig. 1: Results from factor analyses of the roaming dataset: Factor no. 1 describes tourist flows in the summer period.

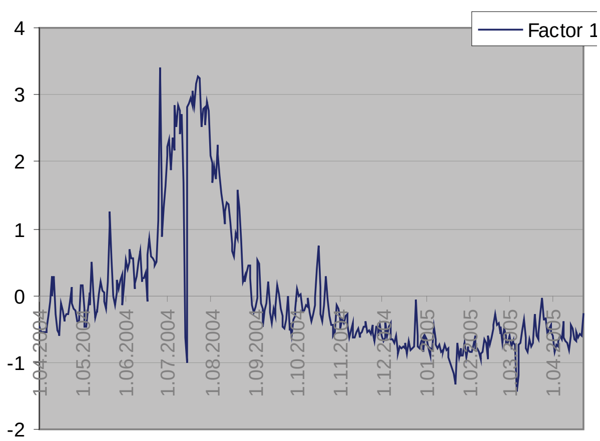
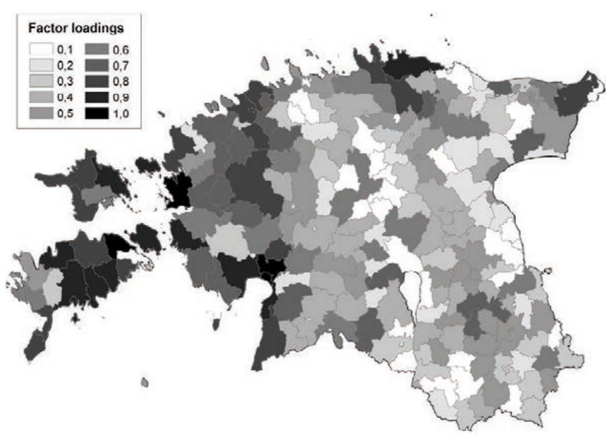


Fig. 2: Spatial correlations of the first factor - summer tourism areas In Estonia.



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