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Faculty of Informatics

Visualization of Quality of Life on a Digital Urban Map

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Peter Benkö
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to the Faculty of Informatics
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Abstract

People who are looking for a new home within a city put emphasis on the infrastructure around a potential real estate. The structure of the neighbourhood with its different forms of facilities influences their perceived quality of life. With the rise of interest in the field of open data that led to the availability of rich data sets of geographical features within cities on governmental, industrial and open-source platforms, the concept of quality of life from the domain of Sociology was combined with the domain of Information Technology, to develop a prototype application that visualizes areas with good and bad quality of life on a digital map of Vienna.

The master thesis at hand will discuss the concept of quality of life and depict relevant aspects that deal with the geographical infrastructure in this respect. The research in this domain will yield specific items/facilities (such as parks and supermarkets) that affect the quality of life of people. Information about these items will be retrieved from the Open Government Data Vienna and OpenStreetMap platform and stored on a centralized server that was developed in the course of this thesis. It is able to accept user preferences that weigh these items according to their importance and applies a quality of life algorithm that assigns an index to areas over the city that expresses the goodness of quality of life based on the stated preferences.

The client application communicates with the server and visualizes quality of life areas in Vienna. It is a method of geovisualization that gives the users of the application an instantaneous overview over hotspots that fit best to them. The discussion part will conclude with interviews that evaluate the prototype application. A great acceptance was obtained during the evaluation phase as well as the willingness of people to utilize the application in the decision-making process of finding a new home in Vienna. Possible expansion stages are being discussed that would advance the prototype and make it ready to use on real estate platforms.

Keywords

Quality of Life, Open Data, Geovisualization.

Kurzfassung

Menschen, die ein neues Zuhause in einer Stadt suchen, legen großen Wert auf die Infrastruktur rund um ein potentielles Objekt. Die Struktur der Nachbarschaft mit nahegelegenen Einkaufsmöglichkeiten und anderen Einrichtungen beeinflusst die wahrgenommene Lebensqualität. Das steigende Interesse im Bereich von Open Data führt zur Verfügbarkeit von umfangreichen Datensätzen mit geographischen Standpunkten aller Art innerhalb von Städten, die von Unternehmen, Regierung oder offenen Quellen bereit gestellt werden. Im Rahmen der vorliegenden Diplomarbeit wird das Konzept von Lebensqualität aus der Domäne der Soziologie mit der Domäne der Informationstechnologie zusammengeführt, um einen Prototypen zu entwickeln, der je nach individuellen Vorstellungen Areale mit subjektiv hoher oder niedriger Lebensqualität auf einer digitalen Karte von Wien visualisiert.

Zunächst werden das Konzept der Lebensqualität, die entsprechende Literatur und der State-of-the-Art auf diesem Gebiet vorgestellt und relevante Aspekte mit geographischem Bezug ausgearbeitet. Aus dieser Recherche in der Domäne sollen spezifische Items/ Einrichtungen (wie zum Beispiel Parks und Supermärkte) abgeleitet werden, die die Lebensqualität beeinflussen. Standortdaten über diese Items werden von Open Government Data Wien und der OpenStreetMap Plattform bezogen und auf einem zentralisierten Server gespeichert, welcher im Zuge dieser Arbeit entwickelt wurde. Er empfängt Benutzerpräferenzen, die in die Berechnung von Lebensqualitätsindizes einfließen. Die Berechnung erfolgt auf Basis eines Algorithmus, der im Zuge dieser Masterarbeit erarbeitet wurde.

Das Ergebnis ist eine Client Applikation, die mit dem Server kommuniziert und die Areale mit dem jeweiligen Lebensqualitätsindex auf einer digitalen Karte über der Stadt Wien visualisiert. Es handelt sich um eine Form der Geovisualisation, die es den Benutzern ermöglicht, einen unmittelbaren Überblick über optimale und weniger geeignete Bereiche der Stadt zu gewinnen, je nach individuellen Anforderungen. Abschließend wird der entwickelte Prototyp im Rahmen von Interviews evaluiert, wobei sich eine ausgezeichnete Akzeptanz der Applikation und eine hohe Bereitschaft zeigte, sie beim Entscheidungsprozess, ein neues Zuhause zu finden, einzusetzen. Zukünftige Ausbaustufen werden diskutiert, die zu einem Realeinsatz im Rahmen von Immobilienplattformen führen könnten.

Schlüsselwörter

Quality of Life, Open Data, Geovisualization.

Contents

List of Figures

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List of Listings

List of Algorithms

List of Abbreviations

API Application Programming Interface. 7, 30, 38, 44, 45, 56, 58, 60, 68, 71, 72, 89

ARC Automatic Reference Counting. 30

CSV Comma-separated values. 24, 57, 58

EQLS European Quality of Life Survey. 15–17, 89

GIS Geographic Information System. xiii, 34–36, 40–43, 57

GML Geography Markup Language. 36

GPS Global Positioning System. 19, 25, 30

HTTP Hypertext Transfer Protocol. 27, 32, 36, 59, 60

JAXB Java Architecture for XML Binding. 32, 60, 61

JSON JavaScript Object Notation. 25, 32, 36, 57, 60–62, 69

MVC Model-View-Controller. 31, 59, 67

OGC Open Geospatial Consortium. 35, 36

OGD Open Government Data. xv, 7, 19, 20, 24, 34, 35, 47, 53, 57, 60, 67, 89

PSS Planning Support System. 43

RDF Resource Description Framework. 43

REST Representational State Transfer. 31–33, 59, 60

RSS Rich Site Summary. 24

SOAP Simple Object Access Protocol. 33

SQL Structured Query Language. 34, 60

SRID Spatial Reference System Identifier. 58

SWB subjective well-being. 13, 14, 16

URL Uniform Resource Locator. 33, 57, 59, 69

WFS Web Feature Service. xiii, 25, 35–37, 57

WMS Web Map Service. xiii, 25, 35–37

XML Extensible Markup Language. 24, 31, 32, 56, 60

Part I

Introduction

1 Motivation

> *Socrates, we have strong evidence that the city pleased you; for you would never have stayed if you had not been better pleased with it.*
>
> — Plato.

It is always beneficial when the field of Information Technology can be combined with one or more other disciplines to create added value. In the course of this master thesis the attempt was made to connect it with a concept from the world of Sociology, namely *quality of life*.

The rise of interest in the field of open data from the general public brought along initiatives of governmental institutions as well as open source projects. This implied the development of platforms that provide easy access to interfaces to various data sources. Retrieving and processing these data in combination with the personal preferences of persons that express their individual sentiment of quality of life should benefit from this fact.

The basic idea behind the topic of this master thesis was to develop a concept that could find quality of life hotspots in a city by asking the user of the implemented prototype application what kinds of facilities they find important and therefore easy to access from their home. The location and other properties of these facilities can be retrieved from various open data platforms. These circumstances lead to the question whether the quality of life for a certain area within a city could be determined based on geographical open data taking a personalized criteria catalog of a person into account and furthermore how to visualize the results in an intuitive and interactive explorable way.

The concept of quality of life is a frequently mentioned topic in the general public interest. Mercer's famous Quality of Living Rankings Report is published annually and was last conducted in February 2014 [57]. In this report, Vienna was yet again elected to be the city with the world's best quality of living. In general, cities in Europe, such as Zurich, Munich, Düsseldorf and Frankfurt provide very high levels of quality of living according to the report.

Mercer evaluates the quality of living conditions in different cities by assessing and comparing them in 10 different categories with 39 different criteria. Figure 1.1 shows these categories and criteria and gives a presentiment on relevant areas of life that will be discussed in the course of this master thesis and which will therefore influence the quality of life of people.

Mercer clearly distinguishes between the terms *quality of life* and what they refer to as *quality of living*. There are many aspects that influence the living quality within a city or a country, where some might be perceived individually different and therefore satisfying requirements might vary from person to person. On the other hand there are some aspects, objective criteria one might say, on which all people might agree that positively affect the living quality such as a low crime rate, clean air to breathe or the availability of consumer goods. The latter one is inspected by the Mercer quality of living reports where criteria can be measured and compared in a relatively easy way. The subjective perception of individuals is left out.

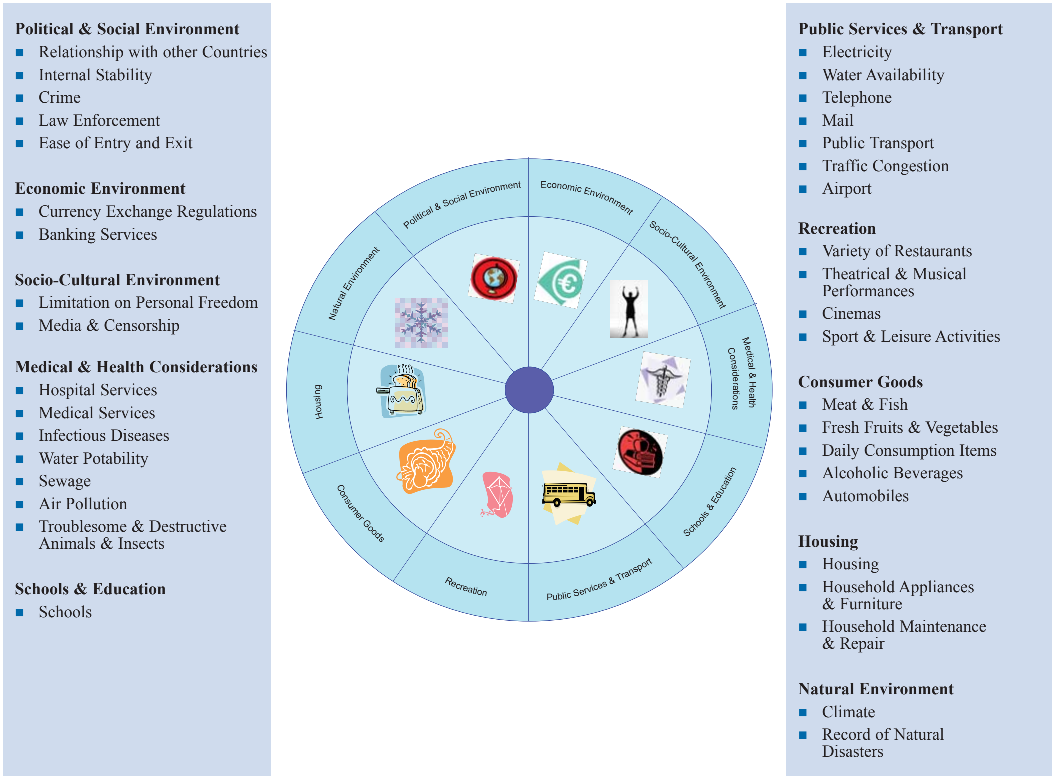

Figure 1.1: Mercer's Quality of Living Factors [58]

These approaches to measure quality of life will be discussed in detail in the following chapters and emphasis will be put on the novelty of the concept of this master thesis where the two worlds of subjective and objective parameters will be combined. That way comparable quality of life indices can be generated that are based on individual preferences (subjective) and at the same time underlie equal infrastructure conditions (objective). The reader will also recognize some of the criteria used by Mercer (see Figure 1.1) to appear in the quality of life prototype, since they are derived from a literature research in the field of quality of life with common studies.

2 Problem Description

The decision of a person or a family to find a place to live is of fundamental importance. A lot of factors play a role when it comes to decision-making. Apart from the fact whether or not the desired house/apartment is affordable, the future home should fulfill certain criteria that may diverge from individual to individual. In other words, people try to maximize their personal quality of life when settling down. Alongside indicators like the employment market or the political stability within a country or a city, other geographical factors will influence an informed decision-making process. A family with young children for example will put emphasis on accessible green areas, schools and bikeways near their home, whereas a single middle-aged worker might place value on parking lots, bars and sports facilities. Websites of real estate companies give great detail on housing conditions and financial aspects but a potential tenant or buyer does not get a detailed insight on how the geographical infrastructure around the property looks like. The core of this master thesis is to combine the concept of quality of life with the discipline of information technology in order to develop an application that is able to locate places within a city that match certain criteria and that were specified by the user such as

- green areas
- schools
- supermarkets
- public transport stations
- etc.

By stating what is important to someone, the application will visualize areas within the city that match the predefined criteria best. Within the scope of this thesis the city being considered will be Vienna, Austria.

To recap the problem that is addressed in this master thesis, a person is looking for an area within a city to live in that satisfies certain criteria. A big part of the decision making process is based on the geographical infrastructure that is prevailing in theses areas. So far, people have limited choices to get a picture on how the neighborhood of a certain spot looks like and the impression about one location and another is hardly comparable from looking at digital maps where some points of interest are annotated. It is furthermore not possible to get a quick overview over hotspots of the whole city and predetermine areas that can be concentrated on to find the new home.

The prototype application developed in the course of this master thesis should solve these problems by providing a method of visualization that instantly gives a feeling about areas with high quality of life. Furthermore a quality of life index is assigned to the areas to not only give the user a quick impression on how the infrastructure looks like but to also make it comparable to other parts of the city.

3 Methodological Approach

In order to define a set of reasonable items that influence living conditions, the discipline of Sociology and its concept of quality of life will be investigated. Existing studies about this concept on the international, national and urban level will be discussed and the different fields that make up the life in a country or a city will be outlined. Emphasis will be put on the infrastructure where the distance from a home to a respective facility is of crucial importance.

Out of this research, a criteria catalog will be derived containing geographical items from different fields that influence quality of life. Information about the location and other properties of these items will be extracted from the open data platforms OGD Vienna [85] and OpenStreetMap [68]. These two data sources will be combined and data will be stored on a server that will be developed within the course of this thesis.

The tool for this concept, to model open data and visualizing it, will be a digital street map. Items shall be annotated on this map and the visualization of areas with high quality of life should optically easily be distinguished from ones with lower quality of life. For that purpose an algorithm will be developed that calculates quality of life indices based on user preferences. It can be seen as a model with adjustable parameters.

These adjustable parameters are on the one hand the preferences that the user enters and are external. On the other hand there will be input parameters to the algorithm that can be defined internally and provide customization possibilities.

A possible criterion that can be configured by the user could for example be a supermarket. The relevance for the quality of life index will be based on the distance and the amount of supermarkets around a certain spot within the city as well as a weighting that expresses the importance of the item to the user.

The prototype application will be developed for a mobile platform [6], specifically for the iPad. The collected data from OGD Vienna and OpenStreetMap will be made accessible via a self-implemented Application Programming Interface (API) of the developed in-house server. Therefore, in the first step data will be retrieved from OGD Vienna as well as OpenStreetMap and stored on the server. Afterwards, a custom API will be implemented, in order to make the criteria catalog accessible for the client application in a unified manner. On the client, the user will enter his personal preferences, which will be sent to the server that runs the quality of life algorithm and responds with a set of quality of life indices for areas within the city that are going to be visualized on a digital map on the client.

4 Structure of the work

The upcoming chapter will give insight into the theoretical background of the concept of quality of life and examine its properties on a national and urban level. The domains of Sociology and Information Technology will be conflated and relevant items that influence quality of life will be depicted in a subsection. Furthermore the term *open data* will be introduced and the platforms that serve as data sources will be described.

Moreover the technologies that were used in the course of the development process for the client and the server will be depicted and relevant standards and file formats in the area of geographic data modeling will be introduced. The section about related work in the field of geovisualization will conclude the theoretical background part.

The implementation section will give insight into the actual development process of the quality of life prototype application and moreover illustrate the functional principle of the quality of life algorithm. The approach of migrating the data model of the different data sources to the server database and in further consequence map it to the client will be described.

Finally the discussion part will depict the results of the evaluation phase, introduce future prospects and possible expansion stages of the prototype application as well as closing remarks about the overall work of this master thesis.

Part II

Theoretical Background

5 Quality of Life

5.1 Introduction to Quality of Life

The prototype application, that is being developed in the course of this master thesis, aims to find quality of life indices for given locations within a city, based on individual preferences of certain criteria (i.e. parks, supermarkets, etc.). Therefore, the concept of quality of life has to be defined and discussed in order to construct a reasonable criteria catalog and measurement rules for it.

Brock defines in [17] three philosophical approaches to define quality of life. The first approach is based on the realization of normative ideals. For example, it is often important to people to being a self-determined and autonomous human being. People perceive their life of higher quality if they are able to fulfill their ideals. They might have religious views that dictate to help other people, so if they do, they also feel better about themselves. As one can see, this perspective takes personality factors and emotions into account, and will therefore not be of special interest for this thesis. The second approach deals with the satisfaction of people's desires or preferences. It is argued, that people will choose things that will have the most positive impact on their quality of life as they see it. The level of quality of life is therefore determined, by whether people are able to fulfill these needs by having access to such resources. This perspective is relevant when the user of the application chooses their personal set of criteria that in their opinion will influence their quality of life. For example one person might find a supermarket within walking distance of their apartment of value and therefore having a positive impact on their quality of life. The third approach considers the experience of an individual as paramount. Hence, the subjective perception of their own life is the indicator of quality of life. The overall satisfaction with life and the experienced happiness would be examples for such indicators.

Studying the concept of quality of life has drawn a lot of attention to researchers and became more and more important over the last years since. Diener and Suh describe two new approaches that evolved over the last decades [29]. On the one hand, there is the approach that measures quality of life based on objective or social indicators and on the other hand the measurement considers factors of the subjective well-being (SWB) of an individual.

Social indicators can measure the objective environment of an individual, considering the person resides in a certain geographic area or cultural circle. Therefore, circumstances are being measured which are the same for all people that belong to the same area or circle. No individual perception of the environment is being considered. Examples would be life expectancy at birth, divorce rate, unemployment rate or measurements that reflect the crime situation in a city or a country. These factors can be quantified, analyzed and compared.

The SWB approach does not deal with outside influences but rather assesses the individually perceived satisfaction with life in general. To be precise, it is divided into three parts - life satisfaction, pleasant and unpleasant affect. Life satisfaction tries to capture the overall experienced satisfaction with life. Affects influence an individual's life as positive or negative moods and emotions. The three components combined should give a subjective picture, whether a person sees their life of good quality or not. Figure 5.1 shows the different approaches to capture the concept of quality of life.

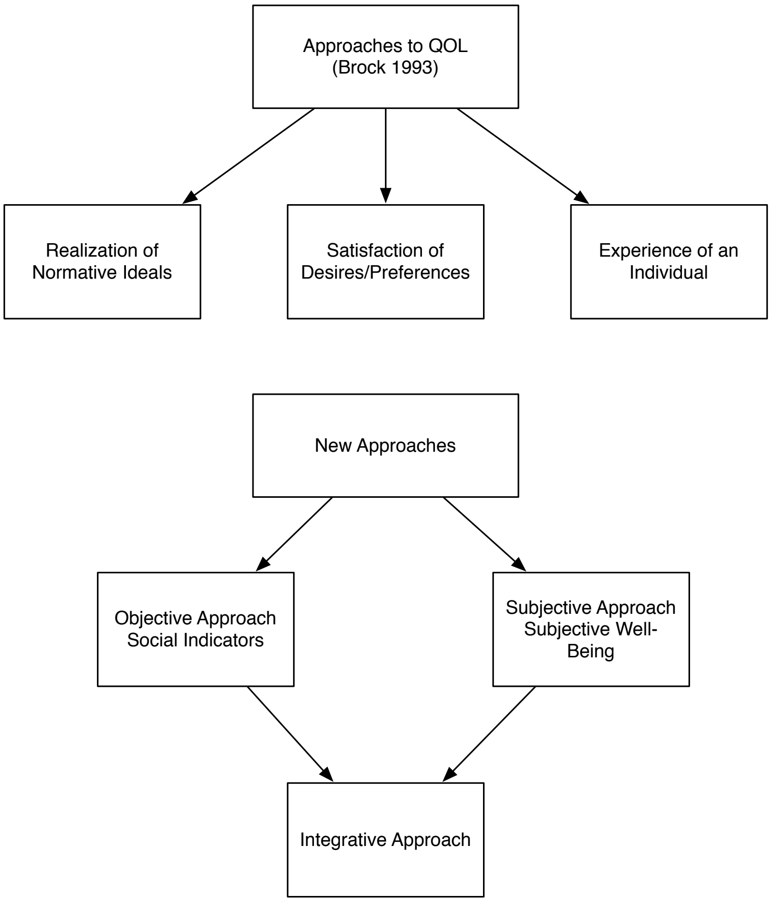

Figure 5.1: QOL Approaches

The social indicators approach will be of interest when defining quality of life that relates to geographical infrastructure. Locations of facilities, parks and other criteria can be measured in terms of distance and the environment remains the same for all people. The SWB approach will be relevant forasmuch since people who use the prototype application will select those items, that they personally think have a positive effect on their perceived quality of life.

Heretofore, the fundamental approaches of quality of life and how they relate to this master thesis have been laid out. The most recent and modern approach which is based on the social indicator and SWB approach was depicted by Costanza et al [23]. Costanza et. al justify that quality of life of geographical areas can best be measured on the basis of personally selected criteria. It is argued, that objective measuring is based on assuming the correct factors that influence the good life by authors or policy makers for the individuals. Those assumptions and suggestions might seem useful, but are not explicitly tested for applicability. It is rather crucial, how individuals actually perceive those objective indicators. The authors of the article therefore attempt an integrative approach that combines subjective and objective indicators:

> *Quality of Life is the extent to which objective human needs are fulfilled in relation to personal or group perceptions of subjective well-being.* [23]

Figure 5.2 visualizes the idea behind the integrative approach. Human needs have to be met in order to guarantee a good life – how individuals perceive this fulfillment of their needs is crucial for their personal level of quality of life. Factors in various domains like subsistence, reproduction, affection or leisure constitute to a fulfilled life. In the context of geographical infrastructure and therefore relevant for this master thesis are factors like accessibility of food, healthcare institutions, recreational facilities, green areas and more.

This approach is most applicable for the use case of measuring quality of life in this master thesis. The user gets a preselected set of objective indicators to choose from and can select the ones that are most valuable in their personal view by weighing them (for details see subsection 11.5.1).

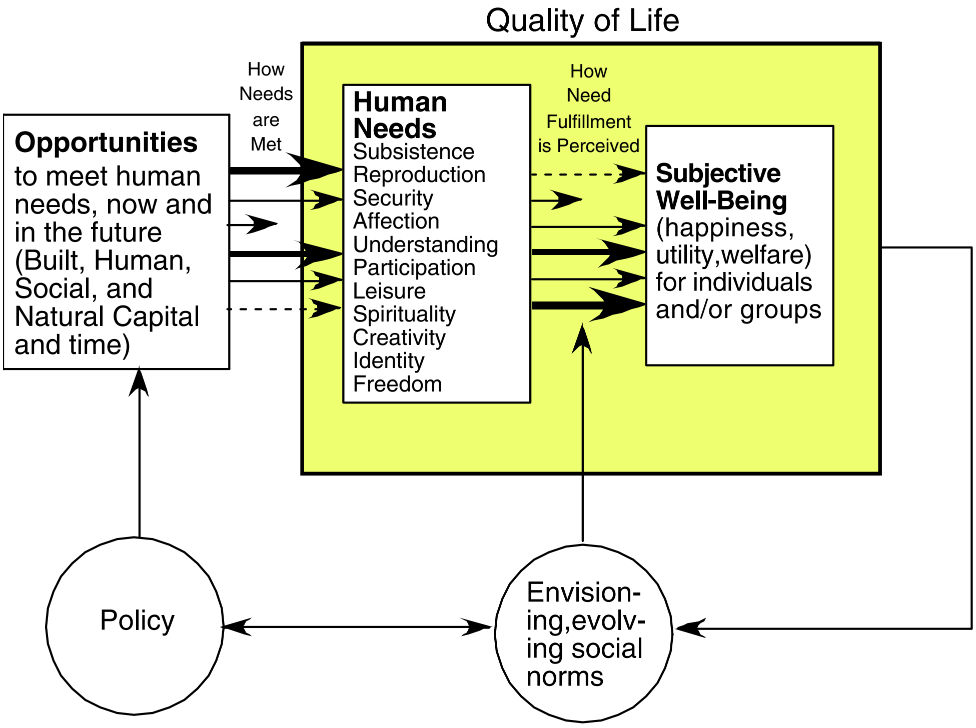

Figure 5.2: Integrative Approach to measure Quality of Life [23]

Scientists have been measuring quality of life on an international level in order to quantify the concept and eventually compare the results of different countries and show relationships between them, as well as on an urban/local level where cities are assessed and further factors have an influence on quality of life. The following chapters should give an overview and a basic idea over these two perspectives.

5.2 Quality of Life on the International Level

The European Quality of Life Survey (EQLS) is a tool, that tries to explore and document quality of life in European countries and has been carried out in 2003, 2007 and 2011 [15] [4] [5]. The analysis in these reports is based on a conceptual framework that gives a tailor-made structure for assessing quality of life in different aspects [31]. Emphasizing living conditions in different countries, the survey considers subjective (i.e. personal perception of life [29]) as well as objective (i.e. impersonal viewpoint that applies to all people [29]) approaches. It relates how quality of life is perceived by the people in contrast to what resources are available, or respectively how good the living conditions are within a country.

The following aspects have been investigated during the survey:

- Subjective well-being
- Living standards and deprivation
- Employment and work-life balance
- Family and social life
- Social exclusion and community involvement
- Home, housing and local environment
- Public services, health and health care
- Quality of society

The survey includes a big variety of categories that affect quality of life. The concept is considered to be multidimensional and many different factors play a role and therefore influence the so-called good life. With the importance of SWB already mentioned before, it is also a key factor in EQLS. Happiness and life satisfaction represent a fundamental basis of an individual's quality of life. Emotions and moods on the one hand and the cognitive perception of life in general contribute to the well being of individuals. Living standards, employment, economic aspects as well as social factors are important factors when measuring quality of life and are obviously assessed in detail throughout these surveys [15] [4] [5]. The chapter home, housing and local environment has the strongest connection to the purpose of this master thesis.

What can be derived from the above findings is, that when measuring quality of life, it is important to evaluate the local environment of people. Where a person lives and what possibilities and supply of resources are being provided, will affect the perceived level of quality of life. In the EQLS the accessibility of the following neighborhood services are taken into account:

- Postal services
- Banking services
- Recreational or green areas
- Cinema, theatre and cultural center

The report suggests that the accessibility of neighborhood services is important to positively affect the good life. They should not only be present somewhere in the city but also in reasonable distance and with appropriate opening hours. Recreation facilities such as cultural centers and green areas play a role in contributing to have a positive influence on the well-being of an individual. Other studies endorse the importance of green areas and their impact on quality of life [21]. It is argued, that green spaces contribute to a better environment, e.g. in terms of air quality, enhance the social and community life by offering a place for gathering, encourage people to physical exercise and promoting mental health. Figure 5.3 shows the fields to which green space relates to, including quality of life relevant domains as people and health.

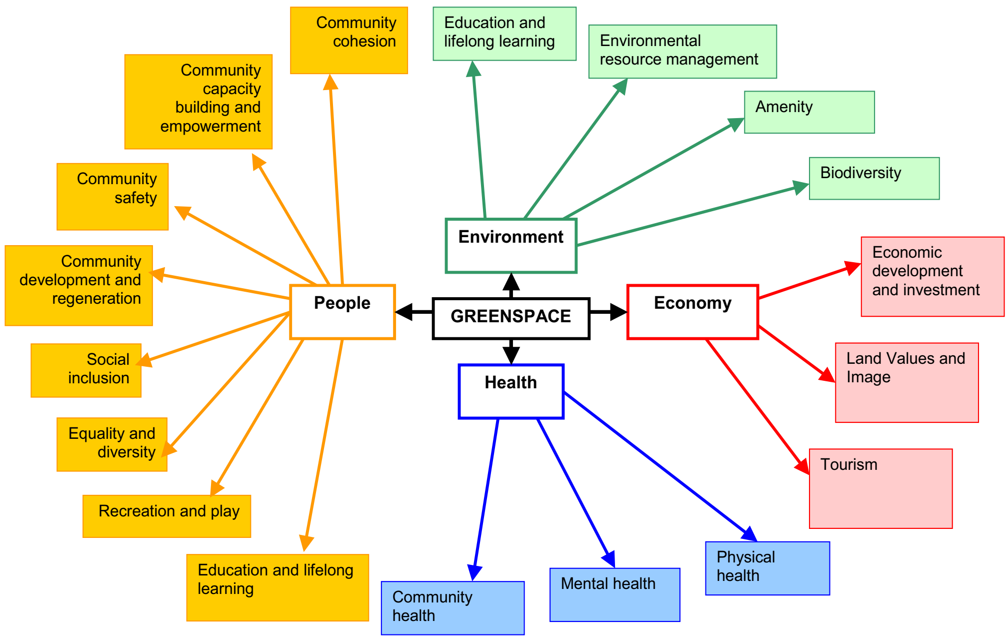

Figure 5.3: Greenspace and its implications [21]

Moreover, the chapter public services, health and health care of the EQLS reports that the accessibility to health care (e.g. doctors, hospitals) and public transport has an impact on the quality of life for people. Individuals depend on such basic services in case of sickness or have to rely on the public bus in order to get to work. For those instances and other use cases, these services play a part in contributing to a good life.

A study that was conducted in France in 2010 considered similar factors in terms of local environment [79]:

- Accessibility of banking services
- Accessibility of compulsory school
- Accessibility of grocery services
- Accessibility of postal services
- Accessibility of primary health care services
- Accessibility of public transport

These studies and its findings will, among others, be the basis and the inspiration for choosing the factors that are relevant for determining quality of life in the context of geographical aspects within this master thesis.

5.3 Quality of Life on the Urban Level

There are a number of scientific articles that deal with the concept of quality of life on an urban/ city level. Economic, political and living standard issues are still of great interest when measuring on this level, but the geographic and local environment perspective gets more important. Since this master thesis is investigating this section in particular, research on this field will be of great importance when it comes to choosing quality of life factors for the prototype application being developed.

As already mentioned in the previous chapter, defining and measuring quality of life is not unambiguous since the discipline considers a lot of domains and therefore is a multidimensional composition of different aspects. This master thesis is especially interested in the geographical and physical resources point of view, but to understand the concept of quality of life and factors that influence this concept, this chapter should give an overview over relevant items that are being investigated on the urban level.

Serag El Din et al. investigate how sustainable development and urban planning should be considered when talking about urban quality of life [73]. Designing a city in order to meet people's requirements and demands became important to urban planners to construct models that intelligently fulfill such needs. People want to have easy access to recreation facilities, health care institutions, grocery stores and facilities of basic needs as well as good transportation possibilities. The study narrows it down to 7 domains that influence the quality of life, which can be seen in Figure 5.4.

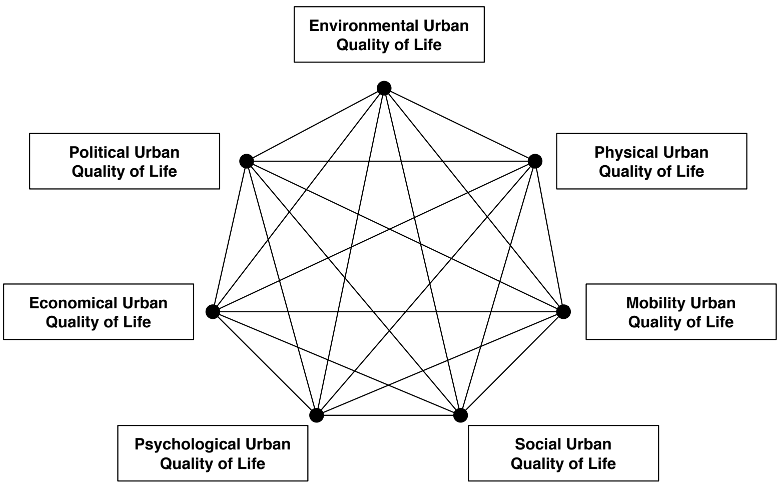

Figure 5.4: Urban quality of life dimensions [73]

A closer look shall be taken on the environmental, physical and mobility dimension, which are of special interest for the prototype of this master thesis. It is argued, that individuals benefit from access to green spaces, facilities that provide resources for basic needs, public services and that cities need to cope with accessibility and transportation issues. Those factors are crucial and have direct influence on how people perceive the quality of life in a city.

Of course, it depends on individual needs, but a person might appreciate a closely located bakery near their apartment on the way to the public bus station when going to work in the morning. A person might also enjoy a not too far away bar or pub which is easily accessible from home and a park, where they can enjoy the landscape while engaging in running activities. The physical environment is therefore of the utmost importance and plays a big role in today's quality of life conception.

By looking at studies in this domain relevant items shall be derived that will be used in the prototype application. Open data (see section 6.1) offers a wide range of geospatial data that contains coordinates of various facilities, schools, companies, etc. Based on existing studies, a preselection of reasonable items shall be created. Those studies are fundamental and are the inducement for the inclusion or exclusion of items from open data platforms. The prototype will contain a subset of the chosen items. Users of the application will have the chance to select factors, which are of special value for themselves and weigh their importance (see subsection 11.5.1).

Several other studies depict similar items when measuring quality of life. Das used a framework based on the objective and subjective approach to define quality of life in Guwahati, a city in India [25]. She examined the physical, economic and social environment and therefore also found aspects like the accessibility of shops, availability of parks and green areas as well as health facilities of high importance for the quality of life in the city.

A study that was conducted in Rome, Italy also considered factors like the availability of parking spaces, green areas, accessibility of schools, health services, sport facilities, cultural institutions, stores and public transportation issues [16].

Similar items were of interest in a study in Switzerland, where the accessibility of entertainment and shopping facilities, schools, social services, medical care and public transportation had an impact on the measured quality of life [88].

5.4 Conflating the Domains

This master thesis combines the domains of Sociology with its concept of quality of life and Information Technology with the field of open data. Creating an index with the mathematical algorithm and visualizing the results on a mobile device constitute the novel scientific aspect and the main generated value. Figure 5.5 visualizes this construct.

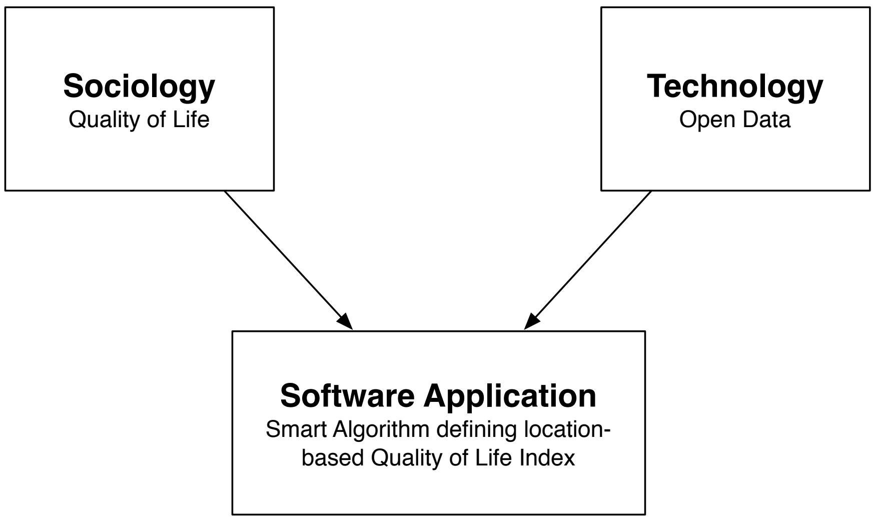

Figure 5.5: Involved Domains

Since the prototype application being developed will be working with geospatial data from OGD Vienna [85] and Openstreetmap [68], a subset of relevant items listed in the previous chapters will be considered. The local environment with its facilities and general infrastructure is the key aspect to define quality of life of an individual in the present context. Global Positioning System (GPS) coordinates precisely define the location of such items and provide the basis for an objective approach [29] of calculating a geospatial based quality of life index. To emphasize the nature of quality of life measurement within this master thesis, it is not a goal to consider factors like economy, social or political environment but it is purely an assessment of quality of life in terms of geographic features that are located in the neighborhood of an individual.

The prototype application has an additional distinctiveness. Users are able to choose and weigh items that they personally find relevant for themselves. George and Bearon concluded that people have different values among themselves and it is therefore not easy to define quality of life [38]. In the context of this master thesis, the users can individually define what is important to them, the preferences are only restricted to geographical items.

As mentioned in previous chapters, there are two new main approaches, an objective and a subjective one, to measure quality of life [29]. The distinctiveness or respectively specialty about using the prototype application of this master thesis is best described by a third integrative approach that was depicted by Costanza et al. [22]. The authors argue that while it is important to assess quality of life from both perspectives, there are limitations that arise when using one or the other separately. They come forward with an integrative approach that combines objective and subjective indicators. The present master thesis, although only considering a partial aspect of quality of life indicators (location-based infrastructure), uses objective factors (availability of infrastructure, i.e. schools, health care centers, etc.) and combines it with subjective factors (subjective perception of an individual's well-being, i.e. the individual's personal weighing of items that influence their quality of life) to generate a quality of life index within this context.

5.5 Derived Geographical Items

The previous chapters laid out the basis for defining relevant items that influence quality of life in the context of this master thesis. The items appear in the form of geodata and represent facilities or respectively resources of any kind that have a distinct location in the city of Vienna. The accessibility of these items will be crucial when measuring the quality of life in terms of infrastructure. The following items where chosen for the prototype:

1. Public Transport Stops - OGD Vienna [85]
2. Parks/Green Areas - OGD Vienna [85]
3. Schools - OGD Vienna [85]
4. Sports Facilities - OGD Vienna [85]
5. Doctors - check section 10.4 for details about the source
6. Post Offices - OpenStreetMap [68]
7. Supermarkets - OpenStreetMap [68]
8. Cinemas - OpenStreetMap [68]

As discussed in section 5.2 and section 5.3 certain items have a positive influence on quality of life. The first item that was chosen for the prototype application is public transport stops. A lot of people depend on good public transport infrastructure to get to work or different kinds of leisure facilities. It is therefore convenient to have prompt access to a nearby transport stop. Parks and green areas represent the second item. They have a positive influence on the social community life, physical exercise and mental health of a person [21]. Good access to schools, which represent the third item, is important to families. The fourth item are sports facilities that provide people with indoor and outdoor exercise possibilities, which in turn positively contributes to people's health. Since health care services are a highly important factor for quality of life, doctor's offices where chosen to be the fifth item and the representative of the field of health. Easy access to post offices is important to people who transact a lot of shipping activities. Also, if a package delivery was not successful, the person would have to pick up the package from the post office and they prefer not to carry the freight for too long. Supermarkets are facilities that are visited by people on a daily basis. They provide people with groceries and food, which is an elementary component of every person's life. The fact that supermarkets are close to people's homes make it therefore convenient to do the shopping and can save a lot of time. Cinemas, which represent the eighth item for the prototype application, give people the opportunity to engage in a form of cultural activity.

Overall, the most important areas that have an influence on the quality of life of individuals (from a location-based infrastructure point of view) are covered with one or more specific item(s) that are listed above. The user of the application will have the choice to select the most relevant items in their subjective opinion and weigh the importance of these items.

6 Open Data

6.1 Introduction to Open Data

> *A piece of data or content is open if anyone is free to use, reuse, and redistribute it - subject only, at most, to the requirement to attribute and/or share-alike.*
>
> — Open Definition [27].

Sociology constitutes the first important domain in the context of this master thesis with the field of quality of life. The second relevant field is open data from the Information Technology domain (see section 5.4). The basic concept behind open data is to make data available to the general public.

The importance and magnitude of open data can best be illustrated by the example of Wikipedia [90]. It is an online encyclopedia and provides free access to a knowledge database. It was the sixth most visited website on the Internet by the end of 2013, according to Alexa [2]. Taking the concept of Wikipedia one step further, DBpedia [26] evolved as a project that extracts structured information from Wikipedia and makes it accessible on the Web [9]. The datasets of Wikipedia are converted into an ontology, which makes it possible to query for sophisticated relationships and properties on these resources.

The topic gained special interest at the governmental level over the past years as well, which provides the basis for accessing the relevant datasets that are used in this master thesis. There was an initiative to provide different kinds of data in order to create more transparency and collaboration. Among others the government of Austria, and in particular the city of Vienna [85], assembled datasets that are machine-readable and accessible by everyone over the World Wide Web.

According to Open Definition the following criteria have to be matched in order to speak of open data [27]:

- *Access* – data should be in a modifiable form and easily accessible as a whole, preferably free of charge via the Internet
- *Redistribution* – data should not be restricted from redistribution or selling on its own or in form of a package from different sources
- *Reuse* – modifications and redistribution of the data must be allowed
- *Absence of Technological Restriction* – data should be able to be processed in an straight forward manner by using open data formats
- *Attribution* – redistribution and reuse may require attribution of the contributors and creators
- *Integrity* – in case of modification of the original data, this fact should be reflected in a different name or version number

- *No Discrimination Against Persons or Groups* – the license must not discriminate against any person or group of persons
- *No Discrimination Against Fields of Endeavor* – data may not be restricted from use in a specific field of endeavor
- *Distribution of License* – redistribution of the data must underlie the original license
- *License Must Not Be Specific to a Package* – license of the data should not depend on a specific package from where the data was extracted; parties who access the redistributed work should have the same rights as stated in the original license
- *License Must Not Restrict the Distribution of Other Works* – license of the open data does not restrict rights from work that is distributed along with the open data (e.g. it does not make other work automatically open)

The following sections will introduce the two sources of open data that were used for the prototype application – OGD Vienna [85] and OpenStreetMap [68].

6.2 OGD Vienna

The open data portal of the city of Vienna was introduced in May 2011 and encompasses datasets in various fields like population statistics, education, finance, health or economy. Data is continuously added to the web portal and existing datasets are maintained and kept up to date. By the end of December 2013, the data catalog comprised 223 data sources [85]. Table 6.1 shows the datasets used from OGD Vienna in the course of this master thesis along with the number of entries and the available formats for the set. The four items are just a fraction of more than 80 available location-based datasets on the portal, which could theoretically be taken into consideration in further expansion stages of the prototype.

Dataset	**Number of Entries**	**Formats**
Public Transport Stops	1807	GML, JSON, KML, RSS, CSV, SHP
Parks/Green Areas	984	GML, JSON, KML, GEORSS, CSV, SHP
Schools	629	GML, JSON, KML, RSS, CSV, SHP
Sports Facilities	1377	GML, JSON, KML, RSS, CSV, SHP

Table 6.1: Datasets from OGD Vienna. Retrieved on December 29th, 2013.

The motives behind the publication of these datasets were to achieve more transparency and provide a publicly accessible resource that would be used by people in order to create applications that generate additional value out of it. The data served its purpose and several applications have been developed since the launch of the portal [7]. The application being developed in the course of this master thesis conforms to the same principle. Geospatial data will be extracted out of the web interface and used in order to generate value out of it by applying an algorithm and provide the user with a visual presentation of the results.

Most of the data is provided in the Comma-separated values (CSV) and Rich Site Summary (RSS) [76] format. Geospatial datasets are furthermore provided in the Extensible Markup Language

(XML) and JavaScript Object Notation (JSON) [75] format conforming to WFS [77] and WMS [78] specifications (for details see subsection 7.5.1).

6.3 OpenStreetMap

The second source, from where relevant datasets are retrieved, is OpenStreetMap [68]. OpenStreetMap is a project in which map data is being collected in the form of crowdsourcing, i.e. all data is user-generated. The community saw a boost over the last years and had over 1.4 million registered users, contributing to the venture, at the end of 2013 [3] with an exponential growth rate. Table 6.2 shows quantitative information about users and entries of the OpenStreetMap database. *Nodes* represent a point specified by latitude and longitude (see subsection 7.5.2) somewhere on the earth. They can describe a point feature such as a church or an ATM or be part of a *way* which is an ordered list of at least two nodes. Whenever linear features like roads or rivers need to be represented, ways are being used to express these polylines or polygons.

Item	**Count**
Number of Members	1.473.444
Number of Nodes	2.142.217.041
Number of Ways	211.160.693

Table 6.2: OpenStreetMap Statistics. Retrieved on December 29th, 2013.

Haklay and Weber describe the origination process of OpenStreetMap being enabled by the removal of selective availability of the GPS signal, announced by US President Bill Clinton, which meant low-cost and more accurate GPS receivers for the end consumer [42]. With GPS devices of all kinds, e.g. receivers being implemented in ordinary smartphones, people do not need profound technical knowledge to gather geographical data and in this manner are provided with an easy way to contribute to the project. The authors furthermore elaborate on the background of OpenStreetMap by emphasizing its open source nature. Map data is free to use, editable, and licensed under new copyright schemes.

As with Wikipedia, people investigated the quality of the data of OpenStreetMap, since it is collected on a voluntary basis that follows a peer production model. Ather found the quality of the data in his analysis to be satisfying [8]. Different quality aspects can be examined in such an analysis, whereas the primary aim in his research was to investigate the positional accuracy of motorways in England. He found over 90% overlap for all roads tested.

Haklay investigated several quality aspects of OpenStreetMap such as positional accuracy, attribute accuracy and semantic accuracy [41]. He found the data of reasonable accuracy of about 6 meters, and a good overlap of up to 100% in digitized motorways.

The datasets used from OpenStreetMap to calculate the quality of life index with the prototype application are supermarkets, post offices and cinemas. To evaluate the quality of these specific datasets, the number of branches of the chain store Billa [13] in the OpenStreetMap database was compared to the number of branches that are listed on the official website of the company. Furthermore the number of post offices was compared, taking the data from Herold, the phone book administrator in Austria [43], as well as cinemas where counted and compared to the number of cinemas listed on the official cinema program website film.at [34]. Table 6.3 shows the comparison of OpenStreetMap and official numbers of the mentioned facilities.

QOL Item	**OpenStreetMap Count**	**Official Count**	**Coverage Rate**
Billa Branches	237	262	90.5 %
Post Offices	115	126	91.3 %
Cinemas	29	29	100 %

Table 6.3: Comparison of OpenStreetMap Items with official numbers. Retrieved on November 10th, 2013.

The use of OpenStreetMap as a data source in the context of this master thesis is therefore justified, since the map data is of very good quality. It is important to have a comprehensive database of the items that are used for calculating the quality of life index, since it makes the result more meaningful. For example, if only few supermarkets would be recorded in the OpenStreetMap database, a distorted index with a small value would be calculated, since many branches would not be taken into account.

Details about the technological infrastructure of OpenStreetMap are discussed in section 10.2.

7 Technologies

7.1 Overview

In order to implement the prototype application that calculates and visualizes the quality of life indices, hardware devices and current software technologies were used to realize the project. The users enter their preferences on the mobile device, which are then transferred to a server that does the actual index calculation. The results are sent back to the mobile device, are being interpreted and finally visualized in the form of a colored grid as an overlay of a digital map (see section 11.5).

The technologies being used for the prototype application shall be exhibited in the following chapters. The reader will be provided with fundamental knowledge about the architectural style and technology stacks. Details about specific implementation characteristics can be found in the corresponding section of Part III.

7.2 Client-Server Pattern

The prototype application was being developed by following the client-server pattern, which has been described by Berson [12]. As the named states, two main components are present in this architecture – a client and a server. The server manages data resources, usually in the form of a database and provides services, which can be called by the client. It is therefore a call-return style pattern where the components interact with each other by requests and replies. A common example of a client-server pattern is a web server that is accessed by a browser on a client via the Hypertext Transfer Protocol (HTTP) [32]. Figure 7.1 visualizes the client-server structure.

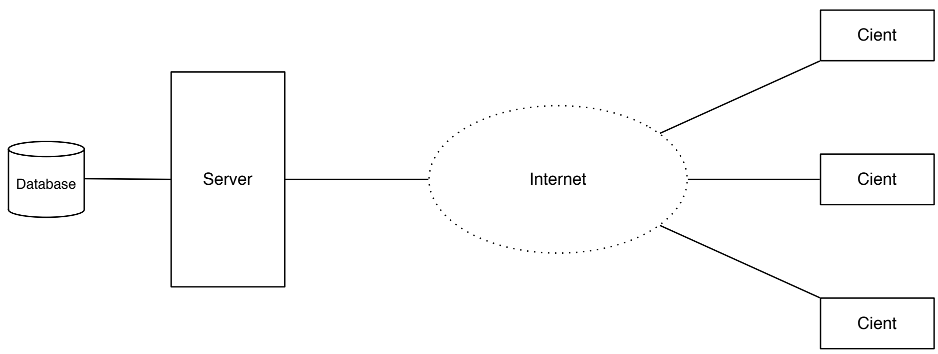

Figure 7.1: The Client-Server Pattern

As one can see in the figure above, the server organizes its database, which does not necessarily have to reside on the same physical machine but can be distributed on others. In some systems, clients directly retrieve data from the database on the server, run the application logic and visualize the result. In these systems, the clients are called thick, since they process all the relevant logic. The more common case is a thin client, where the client focuses on the presentation of the data and the server applies the business logic after accessing the database and sending back the finished calculations to the requestor. The big advantage in the latter system is, that the business logic is kept and maintained in one place and can be easily accessed from several clients. This makes the data and application logic easy to manage and information is always coherent. A disadvantage of the client-server pattern is, that servers may become bottlenecks in the case of errors or system overload, making it necessary to distribute and clone them.

The prototype application applies the client-server pattern in a conceived manner. The mobile device acts as a thin client, collecting user preferences and sending them to the server. The business logic, calculating the quality of life indices in this case, is performed entirely on the server machine. The indices with its geographic attributes are sent back to the client, which is only responsible for presenting and visualizing the output to the user. The second communication channel between the mobile device and the server is the interface from which the client gets geographical data for the items that can be weighed by the user such as supermarkets, parks, etc. Those items are indicated by annotations on the map, so that the user can see these locations and therefore interpret why a grid has a rather good or bad index (see section 11.5).

Table 7.1 gives a brief overview over the roles of the client and the server in the quality of life prototype application.

Role	Description
Client	Thin Client provides User Interface to the user. Collecting quality of life preferences, sending them to the server. Receiving quality of life indices with geographic assignment. Displaying colored grid to indicate low and high quality of life areas over Vienna.
Server	Managing the geospatial database. Handle requests from clients and provide data of the facilities on the one hand and calculating quality of life index requests on the other hand.

Table 7.1: Client and Server in the prototype application

Details about the data formats and client server communication can be found in Part III.

7.3 Client

As depicted in the previous chapter, the client in the prototype application is of a thin nature. It focuses on information collection and visualization of quality of life areas. The technological architecture was designed, so that business logic runs on the server, which makes it very easy to exchange the client instantaneously. In the course of this master thesis, the iPad [46] was chosen, established as a popular end user device.

7.3.1 The iOS Technology Stack

The application was developed to run on the latest version of the operating system of the iPad, which is named iOS 7 [6]. As of October 2013, the App Store as the distribution channel of third party applications for iOS devices, offered about one million applications with 475000 designed specifically as a tablet version. iOS in its core is related to the operating system OS X, and therefore shares the Darwin foundation [65], a POSIX-compliant operating system, with it.

iOS applications are built with the Objective-C programming language using Xcode as integrated development environment [54]. Objective-C is built on top of the programming language C and every C program can be compiled with an Objective-C compiler. Its features are continuously developed further by Apple Inc.

The iOS Architecture can be seen as a layered hierarchy, which can be abstracted in four different parts. Figure 7.2 shows the four basic layers of iOS, starting from the low-level layer Core OS, to the Core Services and Media layer up to the high level layer Cocoa Touch.

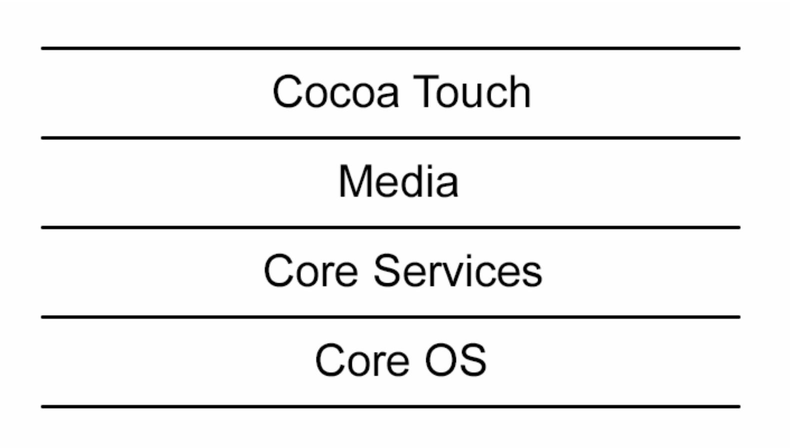

Figure 7.2: iOS Technology Layers [47]

In the following, the iOS technology stack will be briefly introduced and used frameworks in the prototype application will be pointed out.

7.3.2 The Cocoa Touch Layer

The topmost layer in the iOS stack is the Cocoa Touch Layer [47]. It contains frameworks that help to build the user interface, handle multitasking, touch-based input and other high-level services. Among others it provides the use of storyboards. Storyboards let the developer design the workflow and the user interface of the app in one place and help to separate the model and controllers from the view. The quality of life application makes extensive use of this technology. Gesture Recognizers are located on this layer as well and handle all kinds of touch events in app's views. The UIKit Framework provides the developer with graphical, event-driven elements such as labels, buttons and textfields and also handles the interaction with them. The core part of the prototype application makes use of the Map Kit Framework that enables the developer to integrate a scrollable map into the user interface. Map Kit provides possibilities to annotate maps to flag locations of geographical points, like e.g. a supermarket or post office, and furthermore you can use overlays to mark polygonal areas. With the use of overlays, the quality of life grid is colorfully visualized to the user in the application (see section 11.5).

7.3.3 The Media Layer

The Media Layer contains frameworks that let the developer interact with graphics, audio and video technologies. The Core Graphics framework for example enables one to render custom 2D vector- and image-based shapes. Some parts of the drawing code in the prototype application make use of this technology. The audio and video frameworks provide a rich set of API that help to create sophisticated multimedia apps, but will be neglected in this introduction, since the prototype application is not concerned with it.

7.3.4 The Core Services Layer

This layer of the iOS technology stack is of fundamental nature. It contains frameworks that define basic data types and provide among others technologies for location and networking services. The quality of life application draws on several of the features on this layer. A high level feature of the core services is Automatic Reference Counting (ARC) . Located at the compiler level, a reference counter takes care of managing the lifetime of objects and lightens the workload of the developer by automatically retaining and releasing those objects by calling the respective methods at compile time. Block objects are another feature used extensively in the project. Blocks are a construct on C-level and can be seen as anonymous functions linked with the data that is needed for executing these functions. They are especially used for callbacks, as in the prototype application, after network requests got answered by the server.

As already mentioned in the Client-Server chapter (see section 7.2), the client retrieves data about the location and other attributes of the different items, that people can put their weigh on. In order to save all those items in a persistent manner and therefore making them available without triggering a server request on every application start, the Core Data framework was used. After defining a schema on how your data model is built upon, object instances that represent rows in these data tables are created and managed through the framework. The backing storage in such a scenario is usually a SQLite database [66].

Furthermore relevant for the application of this master thesis is the Core Location framework. It provides GPS location based API that collaborates with Map Kit to process data of geospatial nature. Another fundamental part of this layer level is the Foundation framework that offers among others support for collection data types, string management and raw data block management.

7.3.5 The Core OS Layer

The Core OS Layer is located at the lowest level of the iOS technology stack. It contains services that handle among others the communication with Bluetooth devices, other external accessories as well as security and system related features.

The current chapter provided an overview over the structure and environment that was used to implement the client of the quality of life prototype application. The following section will introduce technologies that were used on the server.

7.4 Server

The server in the prototype application is responsible for answering requests from the client in two ways. On the one hand it provides geospatial data of the items and on the other hand it calculates quality of life indices over the city of Vienna.

7.4.1 Architecture

The Model-View-Controller (MVC) pattern [56] was adapted to first and foremost separate the data from the actual business logic part. The *view* component is not relevant for the server since it only answers to clients and does not support direct user interaction via an interface. The following sections should give a brief overview over the most important technologies and frameworks used in order to implement the server according to the MVC pattern.

Maven

The whole Java project on the server was set up by using the build automation tool Apache Maven [35]. It is used to manage dependencies on other libraries and for the build process. Maven projects are configured via an XML file, where project structure, dependencies, build and packaging related information is defined.

Java

The operating system running on the server is Ubuntu 12.10, a Debian-based Linux operating system [81]. The software platform for the implementation of the business logic is Java [39].

Apache Tomcat was chosen as an open source web server [19]. It complies with the Java specifications and facilitates an environment where Java code can be run in.

Hibernate

The Hibernate library for Java offers a framework that maintains the mapping of objects in Java to the tables in a relational database, as described by Bauer and King [10] and therefore logically belongs to the *model* component in the MVC pattern. It was chosen since it is able to abstract data access to any kind of database with high-level objects and its dedicated functions. This technology is used on the server in the prototype application for mapping data about the items like name, address and location coordinates out of the database into objects which are then processed further. Mapping is based on metadata that is configured via an XML file.

Jersey RESTful Web Services

The Jersey library logically belongs to the *controller* component in the MVC pattern. Inputs from the client are accepted and the quality of life algorithm is applied on this layer as well as results are sent back to the requestor. The web services provided by the quality of life server follow the Representational State Transfer (REST) architectural style, first described by Fielding in his dissertation [33], which is also the basic architecture of the World Wide Web. REST is not a communication protocol or a web services standard, but rather an architectural style for distributed systems. It has five main characteristics:

- Resource Orientation
  - Elements of a RESTful web service are resources that are accessed via the CRUD principle. Activities are not explicitly modeled
- Statelessness
  - No context is being stored, every request is self-contained.
- Uniform Interface
  - Resources are accessed via the same interface
- Naming
  - Resources are associated with an unique and descriptive name
- Layering
  - Intermediary servers can be inserted transparently along the way between client and end server in order to improve scalability, load-balancing or providing caches.

RESTful web services use the HTTP methods GET, PUT, POST and DELETE to manipulate resources. For example in the quality of life prototype application a GET method is sent to a specified URI to retrieve a school resource, expressed by the name of the school as well as location coordinates. Resources are usually represented in the XML or JSON format. The prototype application uses the lightweight JSON format since it has a smaller message size and namespace and schema support of XML would be an overabundance.

The Java specification for REST support is called JAX-RS and it uses annotations in classes to define REST behavior. The Jersey library implements this specification and offers a REST client and a server to manage the communication between them via web services. A Jersey servlet, that is defined in the *web.xml* configuration file, searches for classes that represent a RESTful resource. When an HTTP request comes in, the servlet looks for the appropriate class which is defined by annotations, and responds by calling the respective annotated method. JAX-RS provides XML and JSON creation via Java Architecture for XML Binding (JAXB) . Table 7.2 lists JAX-RS annotations that were used in the implementation of the prototype application on the server side.

Annotation	Description
@PATH(your_path)	Sets the path to base Uniform Resource Locator (URL) + /your_path. The base URL is based on your application name, the servlet and the URL pattern from the web.xml configuration file.
@POST	Indicates that the following method will answer to a HTTP POST request
@GET	Indicates that the following method will answer to a HTTP GET request
@PUT	Indicates that the following method will answer to a HTTP PUT request
@DELETE	Indicates that the following method will answer to a HTTP DELETE request
@Produces (MediaType.TEXT_PLAIN [, more-types])	@Produces defines which MIME type is delivered by a method annotated with @GET. In the example text ("text/plain") is produced. Other examples would be "application/xml" or "application/json".
@Consumes(type [, more-types])	@Consumes defines which MIME type is consumed by this method.
@PathParam	Used to inject values from the URL into a method parameter. This way you inject for example the ID of a resource into the method to get the correct object.

Table 7.2: Important JAX-RS annotations [86]

Since the REST architectural style is resource-based, the design decision for conforming this pattern was chosen over a more activity-based style like Simple Object Access Protocol (SOAP). The latter one would be more appropriate for applications like banking transactions. From a conceptual point of view, items such as schools, parks or cinemas can be seen as resources with various attributes and therefore qualify for a RESTful architecture. Figure 7.3 illustrates the different concepts behind the two approaches.

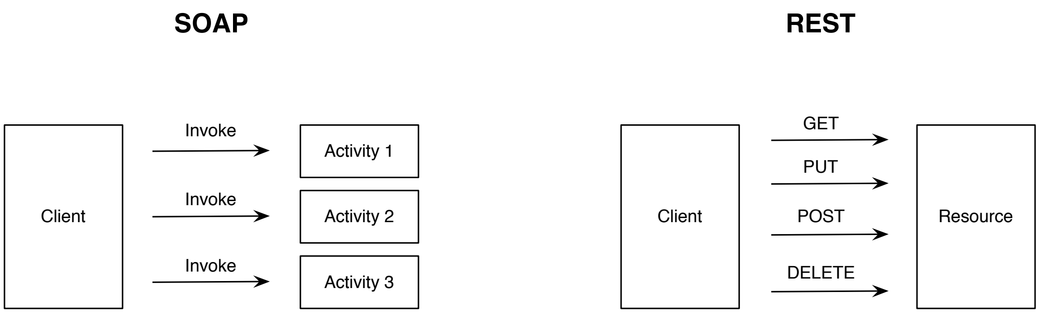

Figure 7.3: SOAP and REST comparison

PostgreSQL/PostGIS

Data about the quality of life items as name, description and location is extracted from OGD Vienna [85] and OpenStreetMap [68] and then stored on the server machine in a PostgreSQL database [40]. PostgreSQL is an open source project that features an object-relational database management system and is known for its ease of extensibility and standards compliance. The feature-rich, open source spatial database extender PostGIS [69] is the ideal plugin in order to allow storing geographic objects for the use case of the quality of life application. It provides features like querying locations and geospatial functions, e.g. to find items within a certain radius, to be run in Structured Query Language (SQL). Since analyzing this kind of structure of the data is a crucial point in the calculation of the quality of life indices, PostGIS is the logical supplement to the PostgreSQL database management system.

7.5 Geographic Information Systems

The core of the quality of life application prototype developed in the course of this master thesis is to analyze geographical data, processing it by running the quality of life algorithm and lastly visualizing the results on a screen. Tomlinson introduced the term GIS first in a paper in 1968 [82]. He described the structure of an information system used by Canada that helped to enforce the development of land, water and human resources. According to ESRI Inc., a leading supplier of GIS software, the term can be defined as:

> *A geographic information system integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. [49]*

A fundamental part of the prototype application is the nature of the data that is being processed. The application can be seen as a specialized GIS, since the basis on which quality of life indices are calculated is location data of the items taken into consideration. Querying longitude and latitude, looking at geographic distances, weighing those distances and displaying results on a digital map are core elements of the use case and represent the characteristics of a GIS. Figure 7.4 illustrates the nature of this concept on how it is applied in the prototype application.

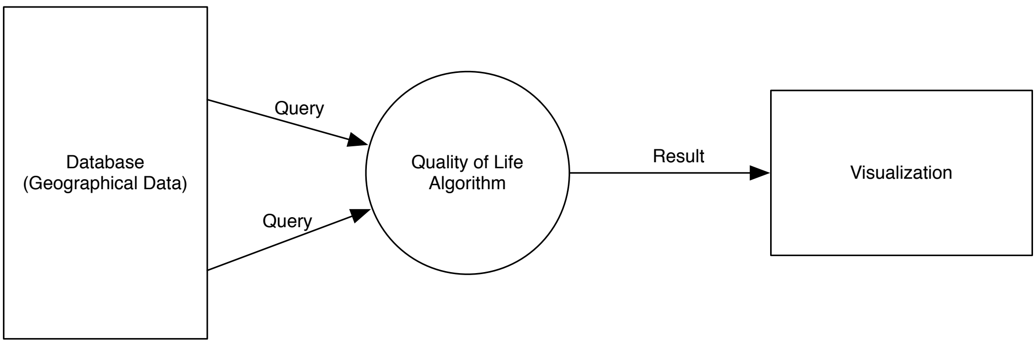

Figure 7.4: The GIS nature of the prototype application

GIS technology found its usage in more and more disciplines over the last decades. It plays an important role in flood hazard and risk assessment in combination with remote sensing techniques to predict natural disasters and work out strategies to cope with them [37] [14].

Moreover it helps to analyze utilization patterns of resources such as health services [44]. The role of GIS also extends to the level of public-sector decision making. Deitrick-Hirsch et al. state among others the problem for decision makers in arid regions with the uncertainty of water supply and the use of GIS technology to analyze, model and visualize scenarios to find the best solution in these cases [28].

Furthermore the technology is applied in fields related to the topic of this master thesis, namely in decision making for urban planning. Urban growth is a forthcoming paradigm that needs to be dealt with and GIS provide modeling techniques to run simulations for these scenarios [80]. As Coutinho-Rodrigues et al. depict in their study, the planning of urban infrastructure has effects on social, economic and environmental factors and they introduce a GIS-based decision support system that provides aid in urban infrastructure planning of multicriteria nature with visualization techniques of alternatives to find optimal solutions.

7.5.1 GIS File Formats

There are two fundamental ways on how geographical information can be encoded and stored into a file [55]:

1. Raster Format
2. Vector Format

Each of the two data structures has its advantages and disadvantages, depending on the use case, respectively what kind of geo data is being encoded. The vector format works with three types of geometries. A *point* feature is expressed by a single x,y coordinate and can be seen as a simple location. The prototype application solely processes point locations, like e.g. public transport stops. *Lines* can represent linear features such as roads and rivers and consist of a series of points. *Polygons* are used to express areas such as lakes or district boundaries and are built as a loop of coordinates. Discrete features like wells or trailheads can easily be described with the vector model, whereas continuously varying features such as soil types are harder to encode in this format. For the latter one the raster model is the better choice. In this format the data consists of a grid and its cells are considered as the smallest unit, usually called pixels. It can be interpreted very quickly by computers, but are less detailed than data in the vector model. The accuracy of raster data depends on the size of the individual cells - the smaller they are, the more detailed the data can be encoded. Figure 7.5 illustrates the difference between the two models and shows the approximation of the boundary in the raster model.

With a wide range of fields of application and several disciplines where GIS are becoming more and more important, it is crucial to define standards and specifications that unify the exchange and processing of geographic data. The Open Geospatial Consortium (OGC) comprised more than 470 members in November 2013 [67] and is a consortium of companies, government agencies and universities. It defines interfaces and protocols to enable the interoperability in information systems whenever geospatial information is shared over the web. The WMS and WFS protocols are two important parts of these standards which are both supported by the OGD Vienna portal, and the latter was used when extracting data for the server of the quality of life application.

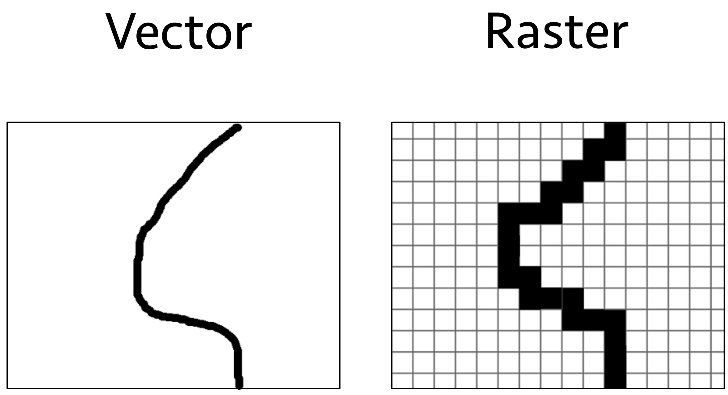

Figure 7.5: Vector vs. Raster model

The WFS defines an interface that allows to do requests on geographic vector data over HTTP and is therefore platform-independent [87]. The form of the response data is generally in the Geography Markup Language (GML) or sometimes in the JSON format. The GML grammar is also defined by the OGC and provides standards that are used as an interchange format for a rich set of geographical features.

The WMS on the other hand returns map images, that cannot be edited or analyzed by the requestor. Map layers are generated out of a GIS database and are formed to a response. An example of the service would be Google Maps [51]. Commonly used operations of the two services are

- GetCapabilities (WMS, WFS) - returns available options; lists feature types that are supported
- GetMap (WMS) - returns a map layer/image
- GetFeature (WFS) - actual geographic data is being requested; parameter could be a bounding box of the desired area

Figure 7.6 illustrates the functionality of the two services and underlines the difference between them.

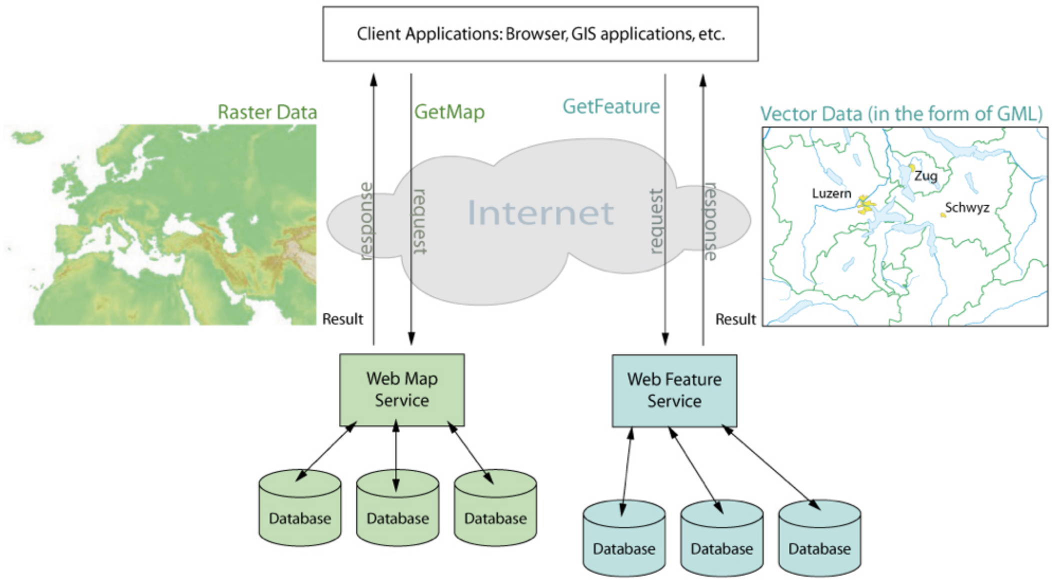

Figure 7.6: WMS vs. WFS [18]

7.5.2 Geographic Coordinate System

Parks, schools and other items that are taken into consideration when calculating the quality of life index have an accurately defined position on earth – the geographic data that was discussed in the last chapters. These locations are expressed in angles with *longitude* and *latitude* coordinates and represent a position on the surface of the earth [84]. The ellipsoidal shape of the earth is projected onto a rectangular flat map. This approach is illustrated in Figure 7.7. Angles of the longitude point are measured from the so-called Prime Meridian that goes from pole to pole and passes through Greenwich, a suburb of London in the United Kingdom. The longitudinal lines become parallel when mapped onto a rectangular surface, in contrast to the convergence on an ellipsoidal shape at the poles (Figure 7.7), which results in distortion the more you move away from the equator. The latitude coordinate of a point specifies the angle between the equator and the line that is parallel to the equator and goes through the specified point.

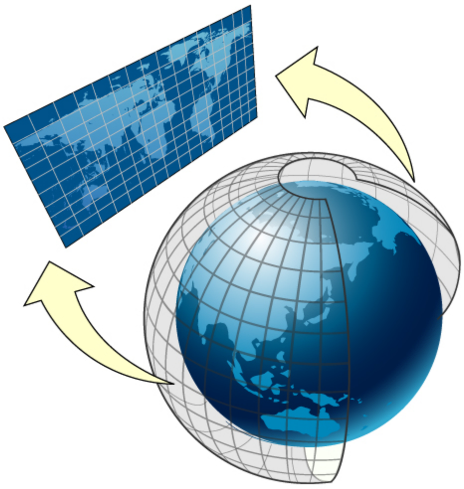

Figure 7.7: Map projection of the earth to a rectangular surface [48]

Geocoding

Since data records for doctors in Vienna were not sufficient from the OpenStreetMap database, a web crawler was used to extract the data from a website hosted by the medical association of Vienna [89] (for details see section 10.4). Name, address and phone number of doctors were retrieved and stored locally on the server. In order to persist them in the PostgreSQL database, the addresses had to be encoded to latitude and longitude coordinates in order to use the geometry types in the PostGIS extension and process the data for the quality of life index calculation. Converting addresses to geographic coordinates is called geocoding, while the opposite procedure, namely finding textual locations from geographic coordinates is called reverse geocoding. The geocoding API from Google was used to translate addresses of doctors to geographic coordinates [50].

8 Related Work

8.1 Introduction to Geovisualization

The key feature of the quality of life application is the visualization of the best-suited areas in Vienna for a particular user. Taking geographic locations of points of interest and combining them with the preferences of a user generate a digital map overlay over the city generated to illustrate hot spots that satisfy quality of life demands of that specific person. Therefore this visualization is of a dynamic nature and changes with a different set of preferences or respectively with a change in geographic infrastructure.

Fischer and Nijkamp describe the concept of geovisualization as tools and techniques that rely on visual representation and thereby support people in the exploration and analysis process of the data [63]. They depict the human visual system to be a key part of data analysis and emphasize the importance of cartography as visualization technique to scientists. MacEachren et al. define geovisualization in the following way:

> *Geographic visualization can be defined as the use of concrete visual representations - whether on paper or through computer displays or other media - to make spatial contexts and problems visible, so as to engage the most powerful human information-processing abilities, those associated with vision.* [60]

Furthermore MacEachren et al. formulate the term geovisualization as using techniques of the fields of scientific and information visualization as well as cartographic traditions to use the results for knowledge construction and decision support in various fields [61]. They propose four geovisualization functions, which are illustrated in Figure 8.1 as a revised version of 2004. The diagonal depicts the functions explore, analyze, synthesize and present whereas the space is defined by task types, user types, and interaction level enabled by the interface. The functions can be seen as use goals, where each one requires its own approach, indicated by the position in the cube with the implied characteristics from the three dimensions in the space.

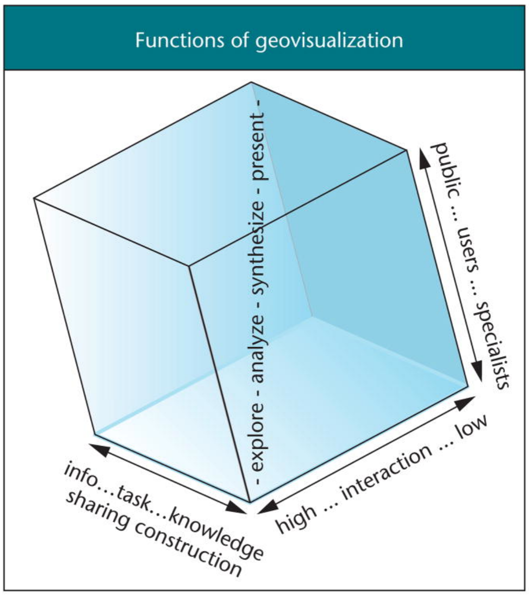

Figure 8.1: The four geovisualization functions according to MacEachren et al. [61]

MacEachren et al. emphasize the importance of geovisualization in the public health sector by explaining that the distribution of diseases can be examined by analyzing geospatial data about health outcomes and risk factors [61]. They argue that statistical analysis is often not enough and in order to reveal geographic aspects of such distributions, it is necessary to incorporate cartographic methods. They furthermore present applications in the field of environmental science where visualized maps can represent the vulnerability of people and places to environmental change as well as in the field of crisis management where GIS in combination with visualization techniques provide decision makers with up-to-date information about hazards and their impact.

The quality of life prototype application draws on the advantages of geovisualization and processes geospatial data in a way to eventually present the results in a human-readable way in order to give a person a quick overview over more and less suited areas in Vienna and thereby support a possible decision making process to find a home in the city.

As previously mentioned, geovisualization techniques are used in various disciplines such as public health, environmental science, crisis management, archaeology, wildland fire fighting and others. Bell et al. describe the use case of spatial analysis of cancer data for the purpose of informing policymakers and the public [11]. The program they introduce gives information about the mortality rate in certain areas, visualizes trends in the data and is able to illustrate coherences to possible associated patterns, e.g. lung cancer and smoking prevalence in a companion map. Danado et al. depict the use case of geovisualization in the field of environmental sciences, where environmental processes can be simulated and visualized in order to facilitate decision-making [24].

The following sections will give an overview over related work in the most important and relevant fields of geovisualization and their practical applications. Focus will be laid on applications, where primarily open data of some kind is used, in order to link the work to the context of this master thesis.

8.1.1 GeoVISTA

In 2002 Gahegan et al. introduced the GeoVISTA Studio project of the Penn State University that aims for easy development of complex data exploration as well as knowledge construction and geographic data analysis [36]. Since then, several adaptions of the software have been developed in order to fit specific use cases, of which some will be discussed in the following.

GeoVISTA CrimeViz

Roth et al. emphasize the importance of geography and spatial patterns in crime fighting in order to predict future incidents and provide statistical and visual techniques that support criminal activity analysis [70]. They introduce GeoVISTA CrimeViz, a user-centered web map application that should support police departments in exploring and sensemaking of crime incidents. A prototype has been developed that uses Google Maps API and crime datasets of the open data platform of the District of Columbia [20]. The revised prototype added a back-end spatially-enabled database in order to support more complex GIS operations and can be viewed on the web [1]. Figure 8.2 shows a screenshot of the current version of the application, retrieved in December 2013. Three different crime types are illustrated by location and sorted on a monthly timeline.

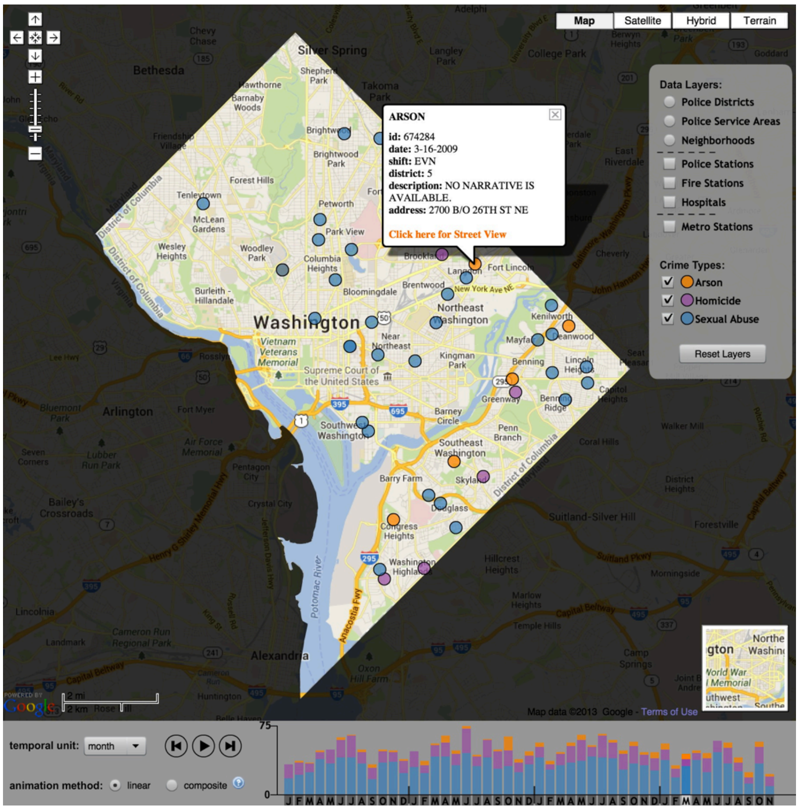

Figure 8.2: GeoVISTA CrimeViz web application

Similarly to the quality of life prototype, CrimeViz uses map overlays as a tool to visualize information and therefore provides a fast and easy way for human perceptivity to interpret the data.

[1] http://www.geovista.psu.edu/DCcrimeViz/app/

The same principle of retrieving datasets from an open data platform and storing and processing them via a GIS backend is applied.

SensePlace2

Also developed by the Penn State GeoVista Center is SensePlace2, a web-based geovisual analytics application introduced by MacEachren et al. in 2011 [62]. It gathers and analyzes information from Twitter in order to support situational awareness in crisis management. Twitter is only the first source of social media information that is considered in the application and it will be extended by other sources. Tweet contents are being analyzed with respect to geographic, temporal and thematic characteristics and visually represented on an overview and detail level. SensePlace2 leverages explicit geographic information from tweets, that is coordinate information that the user entered or the time zone information of a user's profile, as well as implicit geographic information, that is identification of place-related hashtags or automated entity extraction methods. Figure 8.3 shows a screenshot of the application with a specific query and a time constraint.

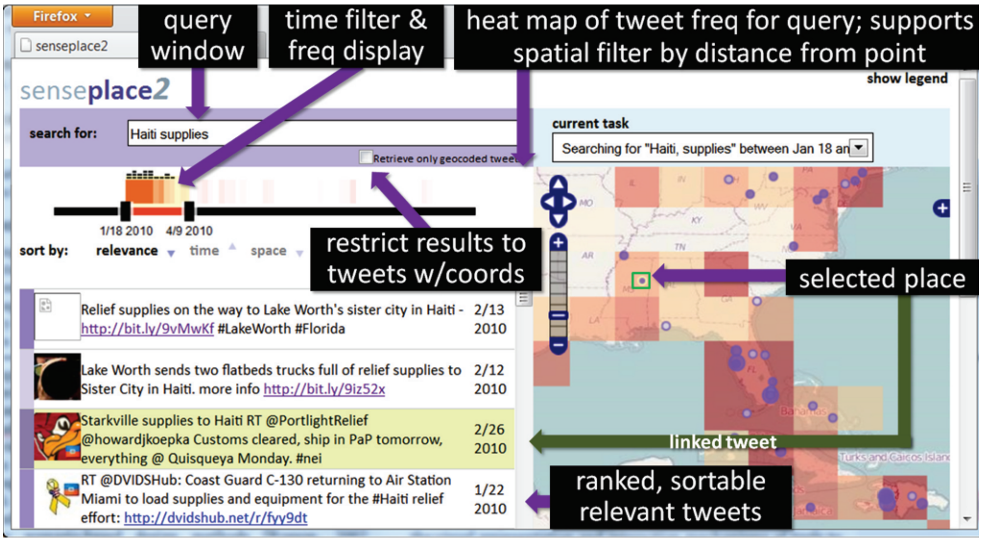

Figure 8.3: SensePlace2 interface: time constraint on query for 'Haiti supplies' plus spatial selection of relevant results. [62]

The authors argue that social media sources are becoming more and more useful in the domain of crisis management, which is underlined by its attention of major crisis management organizations, e.g. the Red Cross Emergency Social Data Summit held in August, 2010). SensePlace2 enables decision makers to take a visual analytics perspective of all the data gathered from Twitter in order to provide them with additional information for adopting better and well-founded countermeasures.

8.1.2 SemaPlorer

Schenk et al. introduced the tool SemaPlorer that enables users to acquaint themselves about a city or area [71]. It interactively visualizes semantically heterogeneous distributed datasets from sources such as DBpedia, GeoNames and WordNet using a map, media and context views. The user of the application gets in touch with four facets of data - location, time, people and tags.

The authors depict, that it is very hard or even impossible to gather specific information about a city, e.g. finding street arts in the city of Berlin. While searching for general information about a city can easily be done via Google, queries with semantic characteristics are a challenge that the authors are addressing. Interaction starts out with a simple text query and is pursued by clicking on more specific locations, persons or tags. Figure 8.4 shows the example of an initial query of 'berlin' and then clicking on the 'street art' tag.

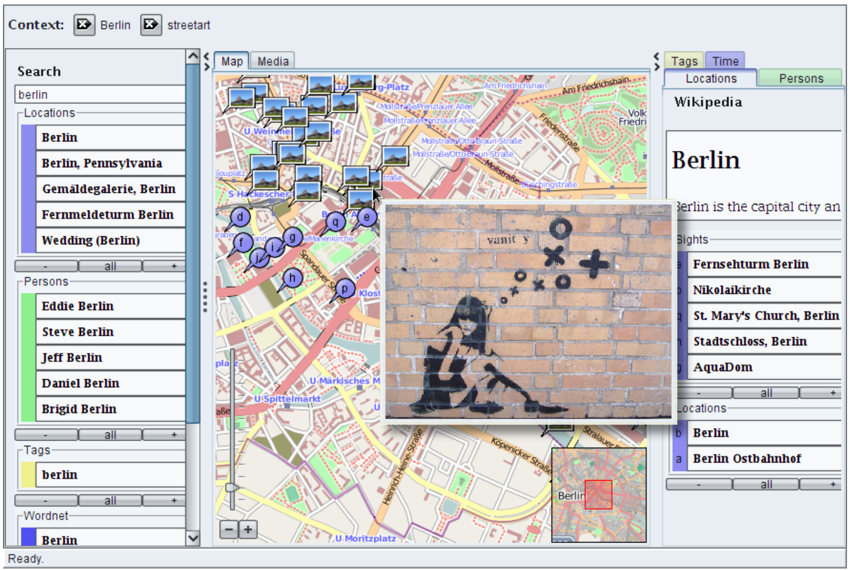

Figure 8.4: Screenshot of the SemaPlorer application showing street art in Berlin [71]

SemaPlorer interlinks different open data sources and uses Resource Description Framework (RDF) triples that are queried via SPARQL to allow for searching semantic coherences. Map Overlays and a user-centered design help the user to explore and engage with the data underneath in an easy and convenient way.

8.1.3 Geovisualization in Urban Planning

Geovisualization techniques can also be used in the field of urban planning, where different scenarios can be simulated and analyzed. Jiang et al. focus in their study on the geovisualization part of so called Planning Support System (PSS) which are mainly adopted in the public sector and are used for spatial decision making [53]. It is argued that visualization techniques on a geographic or cartographic basis facilitate the planning decision making process. Furthermore what-if modeling cannot only be carried out in order to explore data but with the possibilities that modern technology offers, decentralized geovisualization implementations can support collaborative decision-making. The collaboration occurs between people of different professions like planners, cartographers, environmentalists, politicians or investors within different stages of the process. Examples for visualization techniques are listed, such as 3D photorealistic representations that are being used to show urban redevelopment or possible pollution diffusion over a certain timespan.

The authors furthermore depict the fewer exploration capabilities of conventional maps in contrast to dynamic digital maps within a GIS environment, as digital geovisualization offers layer by layer display, clickable items and zoom and pan functionality. Within the context of this master thesis, the resulting map display is of interactive nature as well and not only offers the above mentioned features, but is also generated in a unique manner for the individual person with their set of preferences and therefore gives a distinct overview of suitable areas over the city of Vienna.

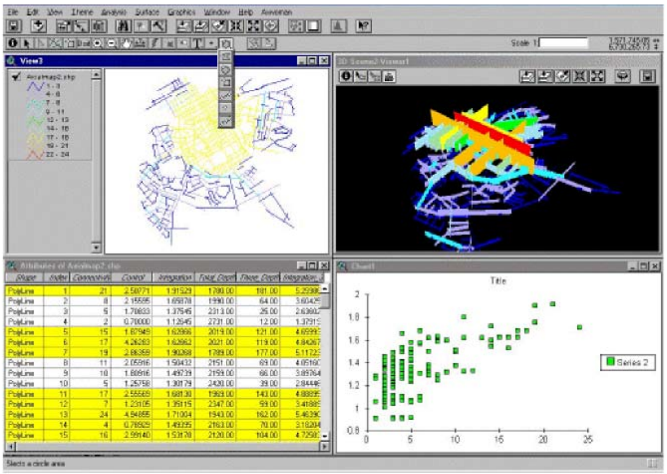

Figure 8.5: An example of exploratory analysis environments [53]

Jiang et al. point out possible use cases for exploring data in this way, such as street accessibility analysis [53]. Street segments are examined on how they link to all other segments and how changes affect vehicle flows in urban systems based on empirical studies. Figure 8.5 shows a screenshot of a prototype being developed in the course of this study and illustrates more accessible streets (red) and inaccessible streets (blue) and shows statistical results in the tables below.

8.1.4 Visualization of the London Underground Network

Another project where open data is visualized with overlays on a digital map is the *Live London Underground Map* from Matthew Somerville [74]. He illustrates the locations of all trains of the London underground network in approximately real time by retrieving open data from the TfL API [59] on an interactive map. Figure 8.6 shows a screenshot of the web application where the yellow dots represent the trains.

Figure 8.6: Live London Underground Map by Matthew Sommerville [74]

Bruno Imbrizi has taken the visualization of the underground network even one step further as he used not only longitude/latitude information of running trains but also station depth information and therefore created a 3D visualization of the London underground lines [45]. The data is also retrieved from the TfL API [59] but only represents a 30 minute prediction summary and is therefore not real time data. Figure 8.7 shows a screenshot of the web application where the spherical shapes indicate train stations and the cuboids represent trains. The different lines are distinguished by color.

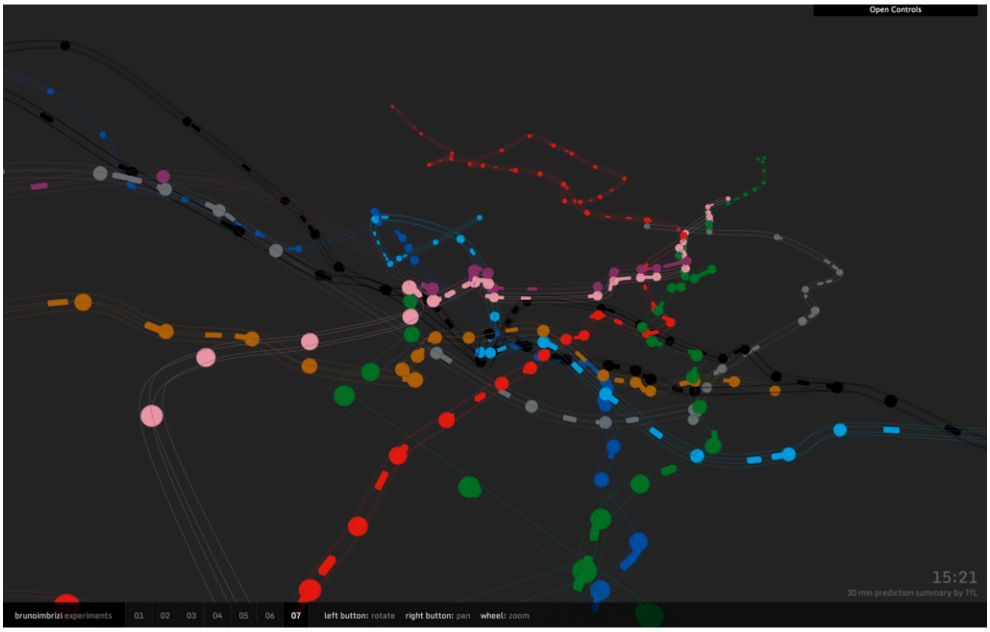

Figure 8.7: 3D Visualization of the London Underground Network by Bruno Imbrizi [45]

8.1.5 Visualization of the Austrian Rail Traffic

The ÖBB, provider of the national railway service in Austria, implemented an application for the iOS platform that visualizes real-time train traffic data on a digital map. The user can interact with the dots representing the trains and in addition to the current location get information about whether the train is on time or delayed and get the detailed transport plan within an additional overlay. Figure 8.8 shows a screenshot of the application with detailed information about a specific train.

At the time of writing this thesis, the ÖBB has not made their data available to the general public. However, they granted access to their data to Google for using it in Google Maps [51]. It is therefore not a visualization of open data in this sense, but still mentioned in this section because it features a geovisualization of data on a mobile device.

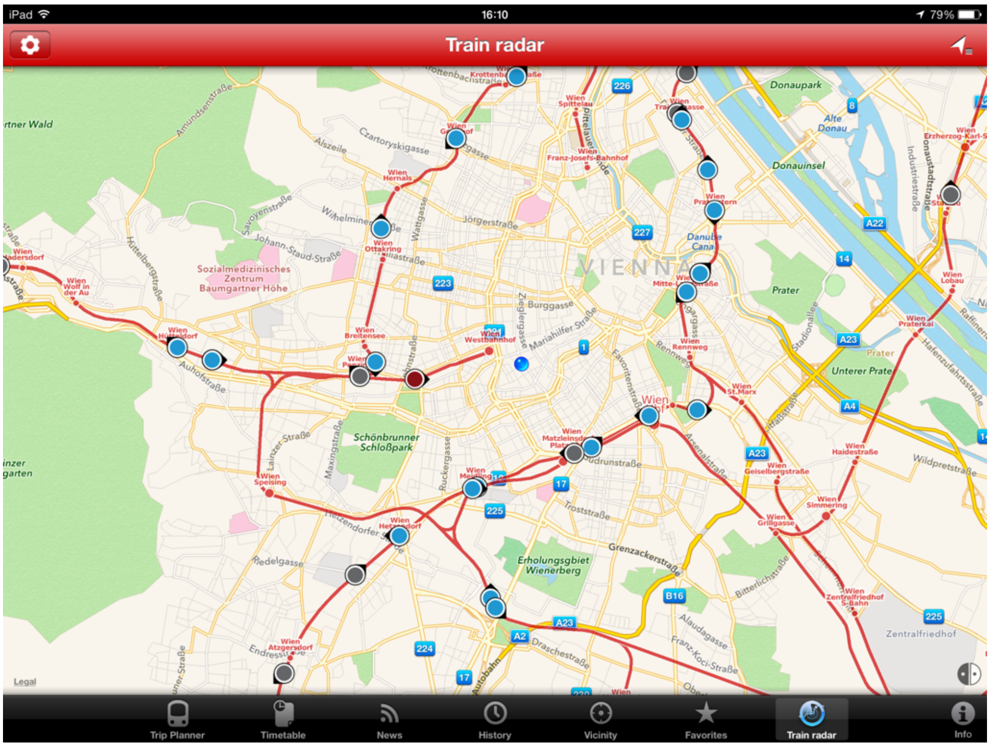

Figure 8.8: Visualization of the ÖBB Rail Traffic

8.1.6 Three-Dimensional Visualization of Geospatial Data

Metzler introduced a method of three-dimensional visualization of geospatial data on mobile devices in his bachelor thesis [64]. The OGD Vienna portal serves as data source for his application as well, as he accesses population data sets, among others, to implement the prototype. He points out that data that is visualized in software applications is of nominal, ordinal or quantitative kind. Furthermore he argues that when it comes to displaying quantitative data, color-coded visualizations are not the optimal solution. Considering for example the number of inhabitants of every single district in Vienna, coloring the districts from a range of green (few inhabitants) to red (many inhabitants) is neither intuitive nor comprehensible to the user. He points out the advantage of bar charts in such cases and proposes a three-dimensional visualization of the figures by introducing the dimension height for the multipolygons (districts in this case) to better distinguish between population numbers. Figure 8.9 shows a screenshot of the application where the three-dimensional multipolygons represents the districts of Vienna and express the number of inhabitants not only by a color but also by their height.

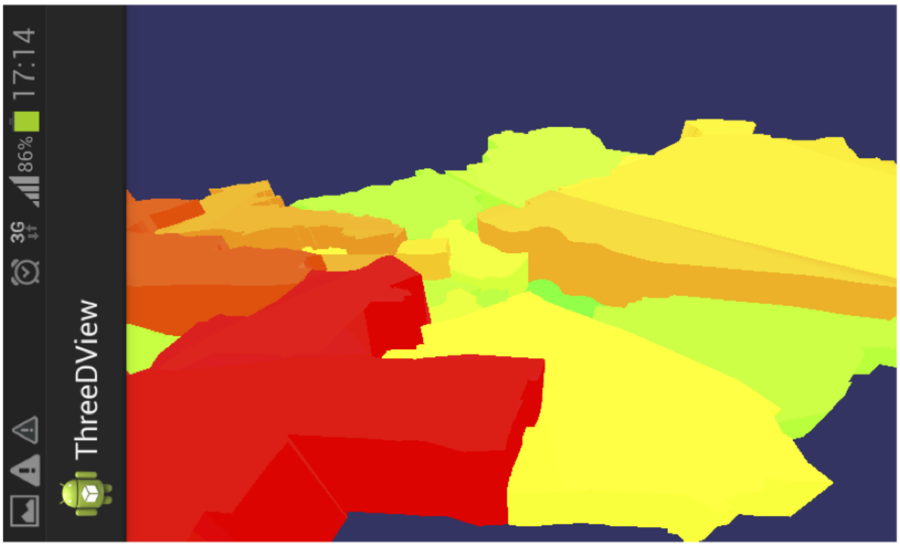

Figure 8.9: 3D-Visualization of the Number of Inhabitants of the Districts of Vienna

8.2 Related Work in the Field of Discovering Living Area Hotspots

Collaterally with the visualization of high living quality areas, the prototype application serves the purpose to decide where a person should live, i.e. where they should find a home. Two web platforms pursuing a similar goal as this use case are presented in the following.

8.2.1 Zoomsquare

Zoomsquare [91] is a web platform that offers real estate search where the user enters a set of preferences and is then provided with a list of objects that are indicated with a so called *zoomScore* that reflects the level of matching to these individual preferences. First, the user preselects areas within the city that come into question. In the second step the kind of real estate can be chosen (apartment, house, parcel of land). Then the user is able to give preferences about the size and the number of rooms. In the next step it must be stated whether to rent or buy a property and what budget is available. Finally the user can mark criteria as nice to have or very important such as parking, balcony, garden, etc. The user gets information about the neighborhood of a property such as nearby supermarkets, parks, public transport stops or kindergartens. This differentiates Zoomsquare from the quality of life application insofar as the user cannot put weigh on these items. Figure 8.10 shows a screenshot of the Zoomsquare web application with a list of proposed real property with its zoomScore on the left and details such as location and pricing information on the right.

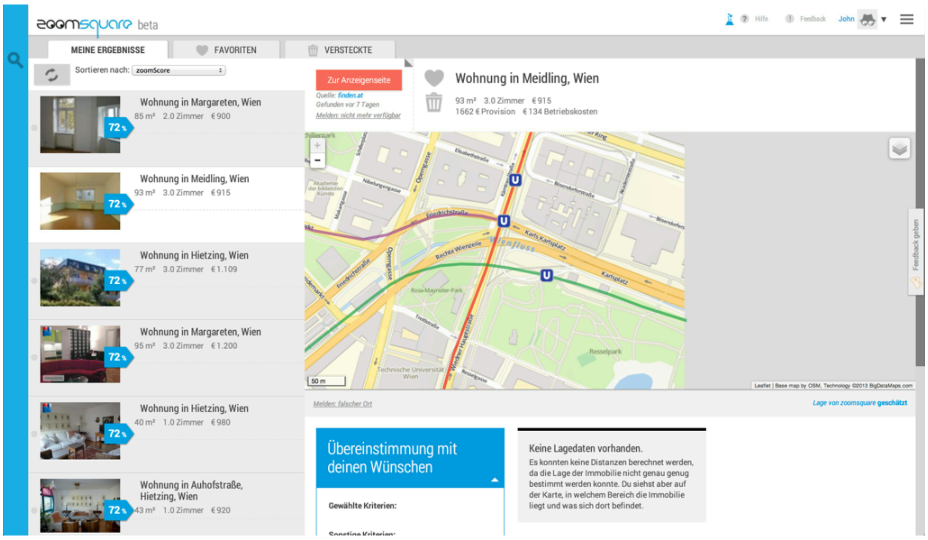

Figure 8.10: Screenshot of the Zoomsquare web application [91]

8.2.2 Walk Score

When using Walk Score the user can also search for real estate and with it will get a score that indicates the walkability of the neighborhood [72]. An address or city has to be entered and various information is listed to the user. A map of the area illustrates points of interests such as restaurants, supermarkets or public buildings. The walk score on a scale from 0 to 100 is indicated together with a marked area within the map that visualizes the reachable zone within 20 minutes of walking. A transit and bike score that indicates the level of public transportation and biking possibilities are provided as well together with a list of real estate properties that fall within the range of the search area. Figure 8.11 shows screenshots of the Walk Score web application with the example of entering Manhattan, New York as area, retrieved in December 2013.

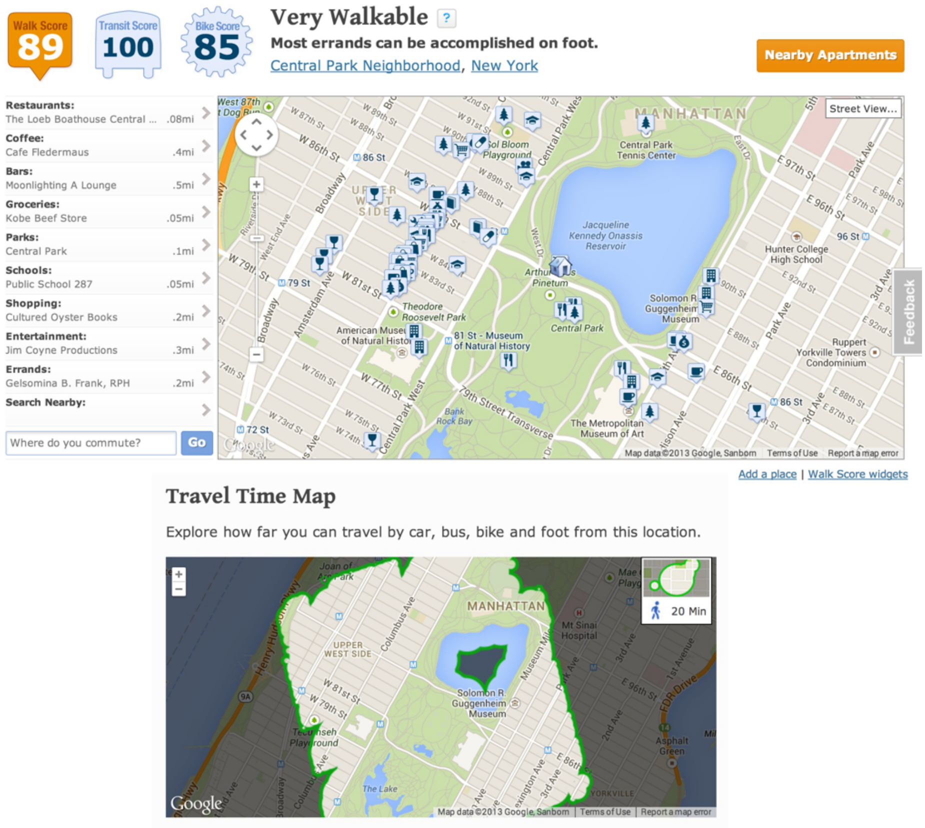

Figure 8.11: Screenshot of the Walk Score web application [72]

Both applications use the concept of numerical scores to indicate the matching of an area or real estate property. The same applies to the quality of life prototype application that provides an index that indicates the match of an area with respect to the user's preferences. It is a way of expressing the underlying geospatial infrastructure in combination with personal preferences and quickly gives the user a general point of reference whether a certain area is suitable or not. Together with a colored grid as map overlay the user immediately is able to assess the quality of a neighborhood and their decision-making process is therefore facilitated in a fundamental manner.

Part III

Implementation

9 Implementation Overview

The following chapters will give insight in the development process and its design decisions of the quality of life prototype application. The architecture will be discussed and a detailed look will be taken at the algorithm that determines the quality of life index. Furthermore, the server environment will be examined and its structure will be elucidated. The setup of the PostgreSQL database and the implementation of the Hibernate and REST interface will be discussed. Since the quality of life algorithm is applied on the server, its foundation and properties will be depicted in this chapter as well. The chapter about the client implementation will lay its focus on the communication with the server and the visualization of the quality of life areas over the city of Vienna.

9.1 Fundamental Design

The system architecture was designed by following the Client-Server Pattern (see section 7.2). Reasons for this decision are of technical and also juristic nature.

Location data of relevant items that are used for the quality of life calculation are retrieved from the OGD Vienna and OpenStreetMap platform and stored on a server. The data structures of the two sources are different from each other. From a technical point of view the goal was to develop an interface that provides these data in a unified manner. The server therefore consolidates the data from the two sources, hides their original structure and exposes it in a unified way to the clients. This brings along the advantage of maintaining the data in only one single place. Client developers would therefore not be affected if data structures change on the open data platforms.

Additionally, data sent from the server to a client can be minimized to the actual relevant information that is needed for the user interface on the client side.

As mentioned before the quality of life algorithm is applied on the server. This way the calculation of quality of life indices has to be implemented only once and can serve several clients for different platforms. Adaptions to the algorithm are applied at this single point, which reduces maintenance and guarantees unique and consistent results. Furthermore Postgis capabilities can be used on the server that provide a rich set of functions to process geospatial data such as finding items within a certain radius.

From a juristic point of view one has to reckon that access to the data on the platforms could be restricted. Since open data is cloned periodically from the sources to the quality of life server, full functionality can always be assured. Legislation amendments that for example would affect the accessibility of the OGD Vienna platform can be neglected and the data would still be available.

Figure 9.1 shows a sequence diagram of the interaction of a user with the prototype application. The input screen and the geovisualization are part of the client whereas the quality of life algorithm and open data are part of the server.

First, the user is able to update the map data, which triggers a request to the server that returns current location properties about the individual items such as supermarkets and parks. Furthermore the user is able to enter their weightings in the input screen, which triggers a request to the server that returns coordinates and quality of life indices for the areas that will be visualized – basically the quality of life grid. As soon as these data arrived the visualization is presented to the user.

Architectural diagrams of the server and the client can be found in section 10.5 and section 11.4.

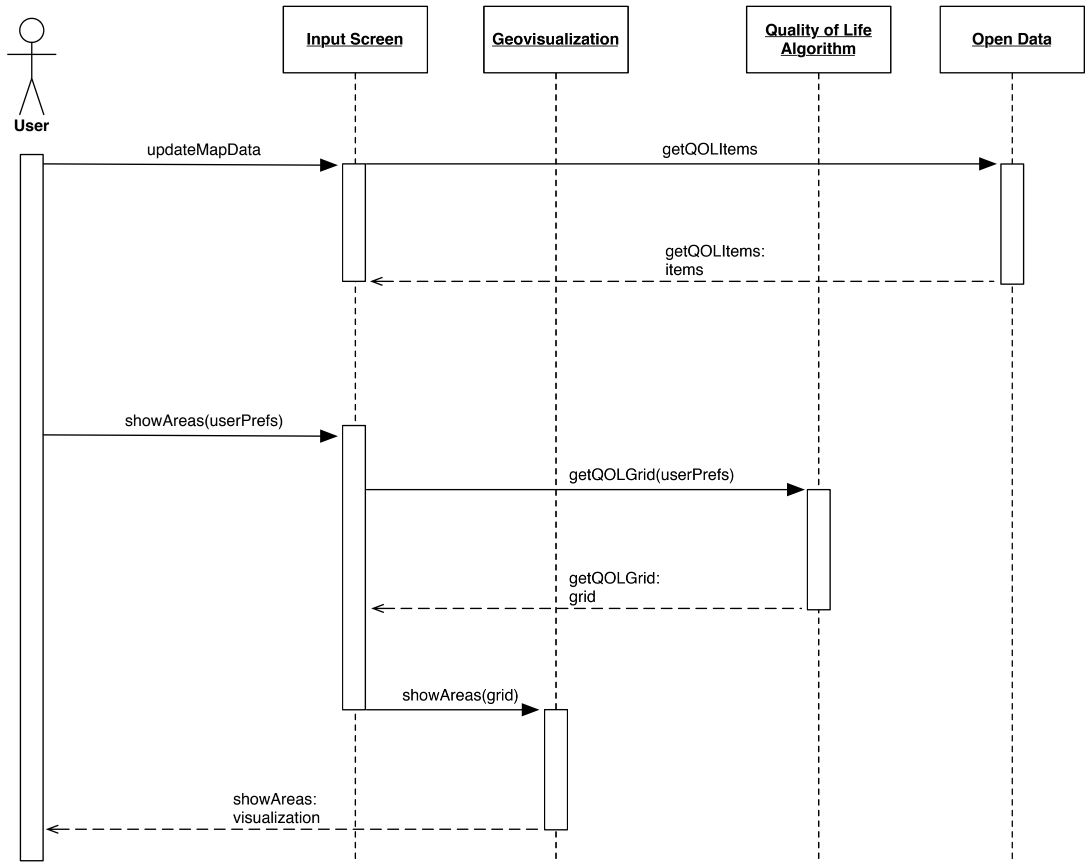

Figure 9.1: Interacting with the Quality of Life Prototype Application

10 The Quality of Life Server

10.1 Technical Environment

The server is running the Ubuntu 12.10 operating system, a free Debian-based Linux operating system [83]. The Eclipse IDE was used as Java development environment [30]. Required packages for the development process where installed via the APT package manager on Ubuntu, such as the Java JDK, Maven, Apache Tomcat web server, PostreSQL with its Postgis plugin as well as Osmosis, a command line Java application that can handle OpenStreetMap data. The whole development process was maintained and managed via Git, a distributed revision control system.

10.2 Migrating OpenStreetMap Data to the Server

As depicted in section 5.5 information about the items post offices, supermarkets and cinemas is derived from OpenStreetMap. The data model in OpenStreetMap consists of the following basic data primitives:

- Node
- Way
- Relation
- Tag

Nodes are single points on the earth's surface and are represented by latitude and longitude coordinates. They are comprised of an id number and a pair of coordinates and may include tags to describe the feature that the point represents, such as a phone box or a traffic signal. The tag is optional and usually omitted when the node is used as a point along a *way*. A way is used to define a polyline and consists of at least two nodes. They are used to represent linear features such as rivers or roads. Furthermore they may be used in a closed form where they represent polygons and mark areas such as the boundary of a building. *Relations* are used to describe relationships between two or more data elements and are therefore of a multi-purpose nature. A route relation for example contains all the roads that form a major highway, a turn restriction indicates that it is not allowed to turn from one way into another. *Tags* can be assigned to all of the previously mentioned data types. They are comprised of a key/value pair and provide detailed description of an item, such as the maximum speed of a road or the name of a supermarket.

The keys for the tags column in the datasets are predefined by OpenStreetMap in order to unify the data processing. Keys such as *addr:street* and *addr:housenumber* define properties of the address of an item whereas the tag with the key *name* simply provides a descriptive name for a feature. The following list shows one example row when querying for all items where the key *amenity* equals the string *post_office* which is the corresponding value for post offices in the OpenStreetMap database. Besides unique identifiers the row includes information about when the entry has been made or changed as well as a reference to the user who executed the change, detailed information about the actual item in the tags column as well as the geospatial location data.

- *id*: 15079901
- *version*: 7
- *user_id*: 1359
- *timestamp*: 2013–08–25 14:29:22
- *changeset_id*: 827750
- *tags*: ref=>1143, name=>Postamt 1143, amenity=>post_office, addr:city=>Wien, addr:street=>Baumgartenstraße, postal_code=>1143, addr:country=>AT, addr:postcode=>1140, addr:housenumber=>37
- *geom*: 011010

Data from OpenStreetMap can either be retrieved via the public API or via so called data dumps which can be downloaded as single files and contain data for a given geographical area. The latter option was used to bring data from OpenStreetMap to the server. The data dumps may come in different formats, where PBF and OSM XML are the most common. The Austrian dataset was downloaded in the OSM XML format from an official OpenStreetMap web server[1]. The developer community around the platform offers a command line Java application called Osmosis that can be used to process OpenStreetMap data in various forms. Among other things it provides functionality to read and write from and to a database or a file, apply change sets to data sources, sort data, etc. Osmosis was used to translate data from the data dump into the PostgreSQL database. Listing 10.1 shows the code that imports OpenStreetMap data into a previously created PostgreSQL database.

```
osmosis --read-xml file="extracted.osm" --write-pgsql
↪ host="127.0.0.1" database="opendatadb" user="postgres"
↪ password="opendata123"
```

Listing 10.1: Import OpenStreetMap Data to PostgreSQL database

Before executing the above command, it is crucial to set up and initialize the PostgreSQL database first. After creating the actual database, it is important to use hstore, a module that supports key/ value coding which is used for OpenStreetMap tags. Furthermore the Postgis plugin has to be activated in order to handle geospatial data types. Finally the OpenStreetMap schema, that is included with the Osmosis package, has to be applied on the database in order to support the data migration via the above command line.

The Osmosis application would provide more advanced features such as migrating only parts of a data dump file by stating box coordinates that define a specific area. The server for the prototype application stores data from the whole Austrian dump file to theoretically support a wider range of areas to apply the quality of life algorithm on.

[1] http://download.geofabrik.de/

10.3 Migrating Vienna Open Data to the Server

Information about public transport stops, parks, schools and sports facilities were retrieved from the OGD Vienna portal. The city is hosting a WFS web server (see subsection 7.5.1), where datasets can be downloaded in various formats (see section 6.2). The *GetCapabilities* call of the WFS specification was used to get a list of all available operations and a python script constructed all the necessary URLs and downloaded the datasets in the *shp* file (shapefile) format. The format is developed and regulated by Esri [49] and is a popular choice for storing geospatial vector data among GIS software. The datasets were finally imported into the PostgreSQL database via the *shp2pgsql* command line data loader that comes with the Postgis package.

Listing 10.2 shows one entry of the schools dataset. It contains an unique identifier, details about the geometry type, which in this case is a single point, a geometry name and descriptive properties about the specific school.

```
{
    type: "Feature",
    id: "SCHULEOGD.270138",
    geometry: {
        type: "Point",
        coordinates: [
            16.3563672807357,
            48.184068919651835
        ]
    },
    geometry_name: "SHAPE",
    properties: {
        NAME: "Volksschule Stolberggasse 53",
        ADRESSE: "5., Stolberggasse 53 "
    }
}
```

Listing 10.2: One entry of the schools dataset from OGD Vienna

The above listing shows the entry in the JSON structure, while geospatial datasets are available in various formats (see section 6.2). The shapefile format was chosen since the PostgreSQL data import could be easily achieved with the Postgis data loader. The whole import procedure could be encapsulated in one python script, from getting the WFS capabilities over constructing the correct URLs, downloading the shapefiles and migrating them into the database.

10.4 Retrieving the Doctors Dataset

Information about doctors in Vienna should originally be retrieved from OpenStreetMap. Looking into the available data revealed that only 240 entries of doctors in Vienna were present in the database. Research showed that there were more than 5000 doctors in Vienna by December 2013. In order to get more meaningful results for the quality of life indices, the data source for that item was changed and information was retrieved from an official website hosted by the medical association of Vienna [89]. Since data about the doctors was only retrievable via the website and not downloadable in a structured way, a web crawler was written that stores name and address of doctors in a CSV file.

In order to process the data, for example using Postgis functions that calculate distances, the actual latitude and longitude coordinates for the doctors were needed. Google provides a geocoding API that allows to convert addresses into geographic coordinates [50]. It was used to retrieve this necessary properties.

Listing 10.3 shows the creation of the doctors table and the import of the information from the CSV file and should serve as a specimen on how geospatial data is generally stored in the quality of life server.

```
CREATE TABLE doctors (
    gid serial NOT NULL,
    name character varying(254),
    address character varying(254),
    zip_code character varying(254),
    geom geometry,
    CONSTRAINT doctors_pkey PRIMARY KEY (gid),
    CONSTRAINT enforce_dims_the_geom CHECK (st_ndims(geom) = 2),
    CONSTRAINT enforce_geotype_geom CHECK (geometrytype(geom) = 'POINT'::text OR geom IS NULL),
    CONSTRAINT enforce_srid_the_geom CHECK (st_srid(geom) = 4326) );

CREATE INDEX doctors_geom_gist ON doctors USING gist (geom);

COPY doctors(name, address, zip_code) FROM '/home/opendata/crawl/doctors.csv' DELIMITERS ';' CSV HEADER;

UPDATE doctors
SET geom = ST_GeomFromText('POINT(' || longitude || ' ' || latitude || ')',4326);
```

Listing 10.3: Setup of the table Doctors with geospatial properties

Besides the primary key *gid* and descriptive properties of the doctors table, the column *geom* is used to store the geographical information and has the Postgis data type *geometry*. Furthermore every geometry column in a table in general must have at least the three following constraints:

- enforce_dims_the_geom – every geometry in the column has to have the same dimension (in this case 2 – latitude and longitude)
- enforce_geotype_the_geom – every geometry in the column has to have the same type
- enforce_srid_the_geom – every geometry in the column has to be in the same projection

The latter constraint sets the Spatial Reference System Identifier (SRID) of the geometry column which is used to define the coordinate system that the datasets are processed in. The rest of the code above creates an index on the geometry column to speed up searches and imports the doctors data from the CSV file into the database.

10.5 The Server Architecture

The Eclipse project was set up using Maven and configured to load dependencies such as Hibernate, Hibernate Spatial, Apache Tomcat, Jersey REST, PostgreSQL and Postgis libraries. The development process was designed to confirm with the MVC pattern. The *controller* component, responsible for communication between server and client and the actual business logic, was separated from the *model* component that handles data access to the PostgreSQL database and provides classes for the controller to work with it.

The *web.xml* file defines the Jersey servlet dispatcher that scans classes that are annotated as RESTful resources and defines the URL pattern where HTTP requests are accepted from. When a client asks for a resource, the dispatcher matches the request to the appropriate resource class that initiates the data processing. Basically a client can request two different types of information from the quality of life server – on the one hand it can ask for the model objects, i.e. the location data of schools, parks, etc. including descriptive information about these items and on the other hand a list of quality of life indices for squared regions that form a grid over the city of Vienna.

Figure 10.1 illustrates the server architecture and its layers.

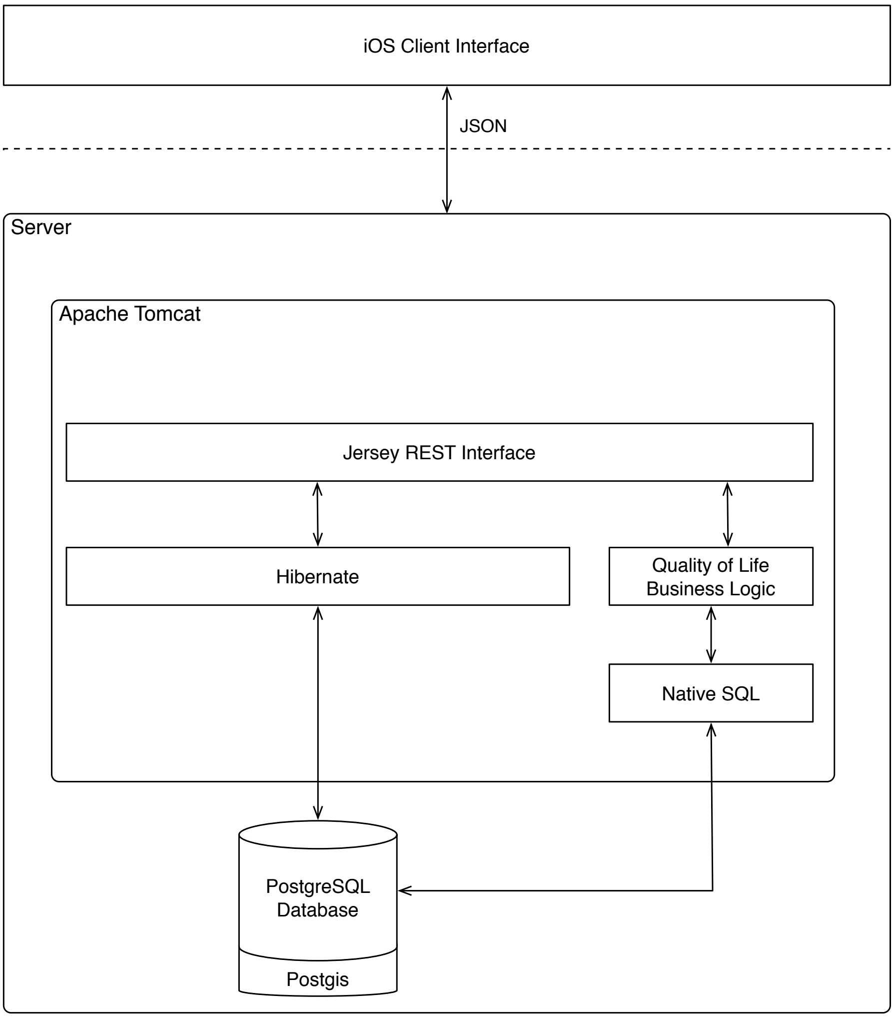

Figure 10.1: Quality of Life Server Architecture

10.5.1 Requesting Quality of Life Items

In the case of requesting items that were imported from the OGD Vienna portal, Hibernate directly maps the rows in the database to a list of objects of the corresponding class, e.g. name, address and point coordinates of a school, since every item has its own table. For post offices, supermarkets and cinemas that are stored in the OpenStreetMap schema named queries are used to map from PostgreSQL to Java objects. Listing 10.4 shows how data access and mapping is configured for OGD Vienna data and OpenStreetMap data via Hibernate.

```
<hibernate-mapping package="at.inso.livingquality.entities">
    <class name="Schule" table="schuleogd">
        <id name="id" column="gid">
            <generator class="increment"/>
        </id>
        <property name="name" not-null="true"/>
        <property name="adresse" not-null="true"/>
        <property name="point"
        ↪ type="org.hibernate.spatial.GeometryType"
        ↪ column="the_geom" not-null="true"/>
    </class>
    <sql-query name="getAllSupermarkets">
        <return-scalar column="name" type="string"/>
        <return-scalar column="geom"
        ↪ type="org.hibernate.spatial.GeometryType"/>
        select tags->'name' as name, geom as geom
        from nodes
        WHERE tags @> '"shop"=>"supermarket"'
    </sql-query>
</hibernate-mapping>
```

Listing 10.4: Mapping database tables to Java classes in hibernate

10.5.2 Requesting Quality of Life Indices

The second type of client-server interaction occurs when the quality of life indices are requested. The corresponding resource class accepts the preferences that the user entered on the client. The preferences consist of a weighting and the minimum amount of a specific item the user wants to have in their neighborhood (for details see section 10.6). Since the nature of the quality of life algorithm requires multiple queries that involve geographic calculations, database access with queries including Postgis functions is accomplished via native SQL statements. The intermediate Hibernate layer was omitted in this scenario since native SQL offers better performance.

10.5.3 Client-Server Communication

All HTTP requests are handled by the RESTful API of the server. The calls to retrieve data about the items do not require parameters whereas the call to get quality of life indices requires the user preferences to be sent along. The response of the server comes in the lightweight JSON format which is then processed by the client. The entity classes such as *School* or *Supermarket* are JAXB annotated which automates the XML or JSON format generation in this case on the server side.

One matter, that has to be dealt with when working with the geospatial types that come with the hibernate spatial package is, that the geometry type *Point* does not map naturally to JSON. An adapter was written for this custom marshalling. This is accomplished via the class *XMLAdapter<ValueType,BoundType>* that accepts two type parameters, one that JAXB knows how to handle out of the box (*ValueType*) and one that JAXB needs to be told how to marshal and unmarshal it to this known type (*BoundType*). Since this master thesis lays focus on the data modeling of open data, a detailed look shall be taken at the code sample that shows a part of the originalities that come with geospatial data processing. Listing 10.5 shows the adapter class that maps between the known *XmlRemappedPoint* and the unknown hibernate class *Point*.

```
public class PointAdapter extends XmlAdapter<XmlReMappedPoint, Point> {

    @Override
    public XmlReMappedPoint marshal(Point geom) throws Exception {
        if (geom != null) {
            XmlReMappedPoint point = new XmlReMappedPoint(geom.getCoordinate().y, geom.getCoordinate().x);
            return point;
        } else {
            throw new ParseException("Geometry obj is null.");
        }
    }

    @Override
    public Point unmarshal(XmlReMappedPoint point) throws Exception {
        WKTReader wktReader = new WKTReader();

        Geometry geom = wktReader.read("POINT("+point.getLongitude()+" "+point.getLatitude()+")");
        if (geom.getSRID() == 0) {
            geom.setSRID(4326);
        }

        try {
            return (Point) geom;
        } catch (ClassCastException e) {
            throw new ParseException("WKT val is a " + geom.getClass().getName());
        }
    }
}
```

Listing 10.5: Custom Marshalling for the geometry type Point

The two methods in the class of the listing above are responsible for marshalling and respectively unmarshalling from and to the geometry type *Point*. For the unmarshalling case the *WKTReader* class is used that reads a well-known text representation and returns a *Geometry* object.

The response of the server that contains quality of life indices contains the distance in meters between two consecutive points the indices were calculated for as well as a list of the bounding latitudes and longitudes and the actual index of that cell in the grid (for details about the grid system see section 10.6). Listing 10.6 shows a snippet of the JSON object that is sent back to the client.

```
{
    distance = "424.26407";
    list =      (
                  {
            bottomLatitude = "48.1580943855592";
            index = "0.85";
            leftLongitude = "16.26097512656408";
            rightLongitude = "16.26668866119971";
            topLatitude = "48.1619056144408";
        },
        {...});
}
```

Listing 10.6: JSON response of Quality of Life Indices

10.6 The Quality of Life Algorithm

As mentioned at the beginning of the implementation chapter, the quality of life indices are calculated centralized on the server and therefore consistently provided to clients on different platforms. This chapter should give insight on how the algorithm that calculates the indices was developed and how it was designed to be customized.

The core concept on how quality of life is defined lies in the geographic linear distance between an initial point and the items of interest such as schools or supermarkets. The closer a facility is to a point, the shorter is the amount of time that takes a person to get there and therefore the higher the quality of life – the further away a facility is to a point, the longer it takes a person to get there and the lower is the quality of life.

The basic design on how to visualize the quality of life indices was determined to be a grid in the form of an overlay on a digital map. Cells within this grid should on the one hand state the actual calculated quality of life index for that area in textual form as well as be filled with a transparent background color that ranges from green (Good – 100% quality of life) over yellow (Mediocre – 50% quality of life) to red (Bad – 0% quality of life) to provide the user with a quick impression on how area hotspots are distributed over the city of Vienna (for details see section 11.5).

That implies that an algorithm had to be constructed that calculates an index for a defined rectangular area and can be repeated any number of times to cover a whole city. Figure 10.2 illustrates a segment of a digital map with points of interest marked as annotation overlays on the map. It is shown how distances to the items are measured from a specified point in the center of the map.

From the concrete instance depicted in the figure above an abstract model was developed to generalize the distance problem and divide the area around an initial point with concentric circles. Figure 10.3 illustrates this abstract model and exemplifies the case of items being in different concentric circles.

The approach with the concentric circles allows to define geographic areas that can be weighted and allows to group items together that are within a certain radius. Items within the smallest circle have a greater effect on the overall indices calculation, items within the area between the two biggest circles are considered least important. The weighting of the importance of the respective

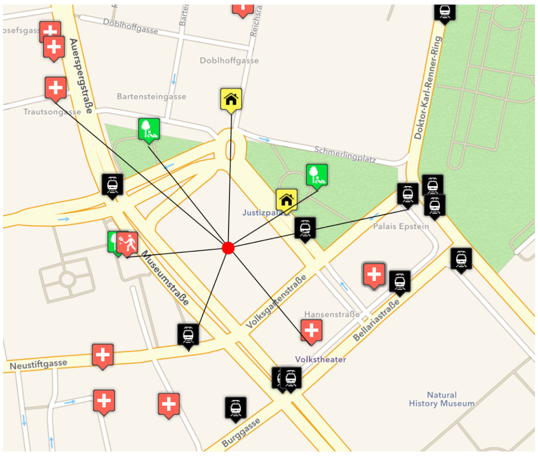

Figure 10.2: A map with a specified point and its distances to certain items

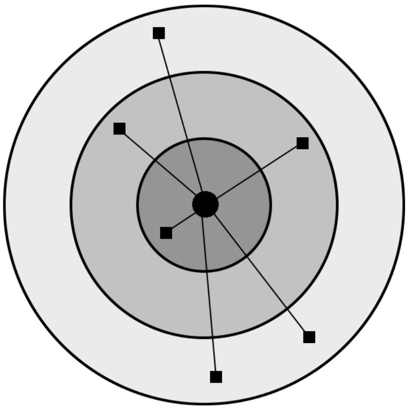

Figure 10.3: Model of the distance problem

area is achieved on the basis of a geometric progression. First the number of items within a concentric circle is considered and weighted based on the relevance of this segment. The following formula shows the calculation of a weighted index w based on the number of items a for a given segment i and a weighting factor q.

$$w_i = a_i * q^i$$

For instance, if the number of items a is 3 in every single segment and a weighting factor q of 0.8 was chosen, the innermost circle would get a weighted index w of $3 * 0.8^0 = 3$, the next segment would get $3 * 0.8^1 = 2.4$ and so on. This implies that the innermost circle is always weighted with 1 and considered to be fully relevant. Furthermore from this it follows that the smaller the value for the weighting factor is chosen, the less relevant the more outer segments get. The nature of the formula also implies, that a weighting factor smaller than 1 has to be chosen to get meaningful results.

Users have to indicate how many items they want to have in their neighborhood since this is an indispensable parameter to normalize against what is good and what is bad quality of living. If this number was initially set by the algorithm it would yield biased results. Thus every user sets their level of satisfactory quality of life for themselves.

The parameter *a* in the formula above represents the number of items within a given segment *i*. It is multiplied with the weighting for the segment and an overall index of all sub indices is summed up. This cumulated index is divided by the quantity that the user stated to be of good quality for them in order to normalize it against this value. If this index exceeds the value 1 it is set to 1 since a quality of life index of more than 100% makes no sense. In a final step the resulting index is multiplied with the weighting factor that the user entered and that states how important a specific item is to them.

This procedure yields a weighted index for a certain point considering one specific item. It is repeated for every item the user entered preferences for. These indices are summed up as well and normalized by dividing the cumulated value by the sum of all the weightings the user entered. This final result represents the quality of life index for a specific point considering all user preferences.

The algorithm is therefore influenced by two different parameter sets. The user specific parameter set contains the weighting and the minimum quantity for every item.

- Weighting – how important is an item for the user
- Quantity – how many of the items the user wants to have in their neighborhood

Weighting values are specified on a scale from 0–10 with 0 meaning not important and 10 meaning very important. The second parameter set is system specific and can be configured on the server side and comprises of the following variables:

- Radius – The radius around a specific point in which items are considered for the index calculation
- Distance – The distance between two consecutive geographic points
- Number of Concentric Circles – The number of the concentric circles allows to adapt the granularity of the area within the given radius
- Weighting Factor of the Circles – The weighting factor of the circles allows to adapt the importance of circle segments when moving away from the center

The separation of the radius and the distance allows to construct scenarios where the considered area around a point exceeds the consecutive point in the series, i.e. the distance between two points can be very short whereas the area considered around these points can still be large to yield reasonable results. Figure 10.4 illustrates the relationship between radius and distance in the algorithm. The distance for the evaluation phase was chosen to be

$$distance = \frac{2 * radius}{\sqrt{2}}$$

with *distance* being the length of the biggest square that fits into the outmost circle. It therefore represents one squared cell that is visualized in the grid on the client. At this point it should again be emphasized that all items within the biggest circle (within the given radius) are considered for the index calculation, not only the ones in the square.

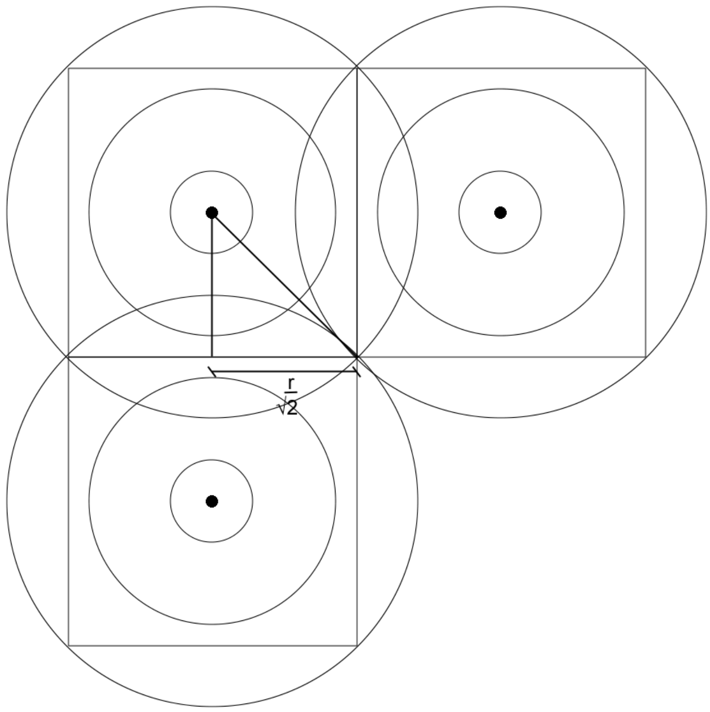

Figure 10.4: Radius and Distance in the Quality of Life Algorithm

Algorithm 10.1 shows the procedure of the quality of life index calculation in an abstract manner. First, the circular area around a point is divided into a specified number of concentric circles. The number of the respective item in every of the segments is counted afterwards. Then the number of items are weighted in every segment by multiplying it with the respective term of the geometric progression based on the weighting factor. After that the resulting index is divided by the desired number of items the user wants to have, if applicable set to 1 and then weighted with the factor that the user stated for this item. All these indices for different items are summed and finally normalized by dividing it by the sum of all user-weighting factors. This procedure is repeated for an arbitrary set of points within a geographic area. In the course of this master thesis all points at a certain distance interval are passed within the bounding box of the city of Vienna.

input : An Item Weighting Iw and the Item Quantity Iq.
system: A set of points P the indices should be calculated for, the number of concentric circles for a point NCC, a radius R, a concentric circle weighting factor Cwf, the number of items NoI.
output: A List of Quality of Life Indices

```
for each point p in the set P do
    cumulatedIndex ← 0;
    for i ← 1 to NoI do
        index ← 0;
        numberOfItemsInSegments ← FindItemsInSegments(p, R);
        for j ← 0 to NCC − 1 do
            index = index + numberOfItemsInSegments [j] * Cwf^j;
        end
        index = index/Iq;
        index = Min(index, 1);
        index = index *Iw;
        cumulatedIndex = cumulatedIndex + index;
    end
    qualityOfLifeIndex = cumulatedIndex/ sumOfAllUserWeightings;
end
```

Algorithm 10.1: Quality of Life Algorithm

11 The Quality of Life Client

11.1 Technical Environment

The quality of life client was implemented to be executed on an iPad device that runs iOS 7. The Xcode IDE was used as Objective-C development environment. As on the server side Git was used to maintain the development process.

The following chapters will give an overview over the development process from mapping the data model from the server to the client, handling client-server communication as well as the actual visualization of the quality of life indices grid as an overlay on a digital map. As on the server side, the MVC pattern was adapted and design decisions were made accordingly.

11.2 Mapping the Data Model to Core Data

As briefly mentioned in subsection 7.3.4 Core Data was used to store information about the items that are indicated on the map. For instance the public transport stops have to be annotated with meaningful icons and show details when tapping on it. This is a subset of the data retrieved from OGD Vienna and OpenStreetMap because not all associated information is needed on the client for visualization purposes to the user. Nevertheless the data has to be stored in a persistent manner in order to not issue a call on every launch of the client application. Core Data serves as an object graph and persistence framework on iOS and allows the serialization of the relational entity-attribute model to a SQLite store by default and to other formats as well. By using the framework the data can be accessed via Objective-C objects from code and the lifecycle, object graph management and persistence is managed by Core Data.

The information that is required from every item is latitude and longitude coordinates. All items share this basic structure and have additional properties that are specific to the respective item. The data model on the client was therefore set up to have an abstract entity called *PointEntity* with latitude and longitude coordinates and eight specific entities that inherit from the abstract one. Figure 11.1 shows the structure of the Core Data model on the quality of life client.

11.3 Drawing the Quality of Life Map View

The functionality of a scrollable map is provided by the *MKMapView* class of the MapKit framework. There are two ways to annotate a map. First the developer can use *annotations* which are objects that can be represented by a single geographic point. A custom image can be used to mark this point. On the other hand there is the possibility to display content that consists of several points and can form shapes of any kind by using *overlays*. In the course of developing the quality of life client both concepts where used – annotations represent the items that have a single coordinate and overlays were used to display the colored quality of life grid that is made up of squares (see section 11.5).

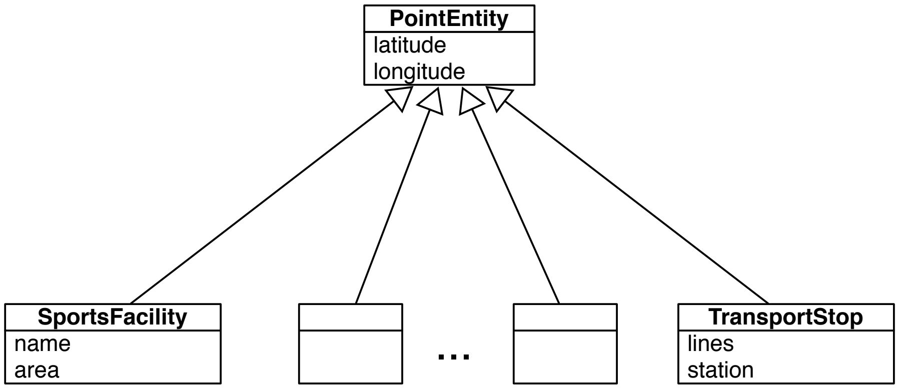

Figure 11.1: Core Data Model on the Quality of Life Client

In order to display annotations or overlays on a map two distinct objects are necessary in each case. One object that manages the data of the annotation or overlay (i.e. coordinates and optionally further information such as a description) and one view object that is used to draw the visual representation of an annotation or overlay onto the map.

When the map view appears in the quality of life application, data about the items is fetched from Core Data and quality of life indices are retrieved via an API call and annotations and overlays are added to the map. The map view manages these objects and uses the delegate pattern to ask its delegate, when necessary, for the respective annotation view or a renderer class that does the actual drawing of an overlay. The following two lines of code list the delegate functions that have to be implemented by the delegate, which in the quality of life application is done by the controller class that manages the map view.

```
- (MKAnnotationView *)mapView:(MKMapView *)mapView
↪ viewForAnnotation:(id<MKAnnotation>)annotation;
```

```
- (MKOverlayRenderer *)mapView:(MKMapView *)mapView
↪ rendererForOverlay:(id<MKOverlay>)overlay;
```

The map view is being told what annotations and overlays should be displayed. When a region that contains items or overlays is visible on screen, the map view asks its delegate for a view class or the renderer. The annotation view classes provide the respective icon for an item in the form of an image object. The renderer class contains custom drawing code for the overlay. It is a custom subclass of *MKOverlayRenderer* where the drawing code that uses Core Graphics is placed in the following method:

```
- (void)drawMapRect:(MKMapRect)mapRect
↪ zoomScale:(MKZoomScale)zoomScale inContext:(CGContextRef)context;
```

Its parameters are the respective map rectangle and its current zoom scale as well as the Core Graphics context, which can be seen as canvas on where to draw the overlay. Figure 11.2 illustrates the relationship between the map view and its delegate as well the data and view objects that are handed between them.

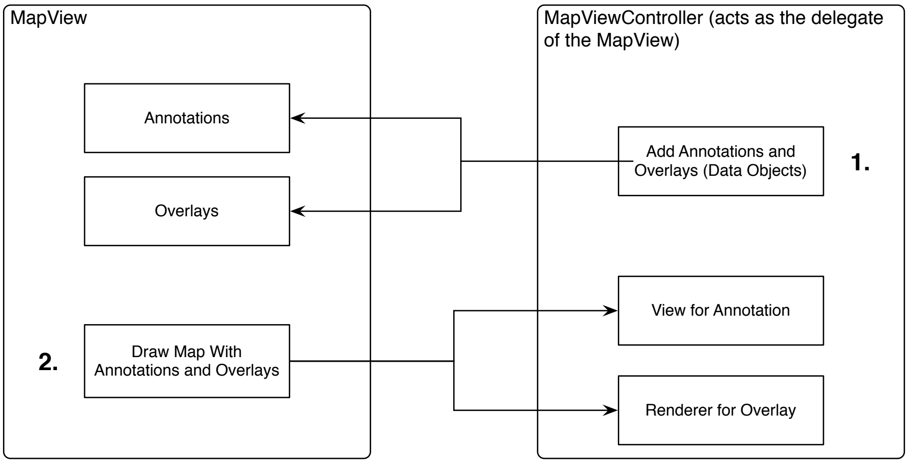

Figure 11.2: The Map View structure

11.4 The Client Architecture

The requests for the items are triggered by a controller class and carried out by a separate importer class. All networking code makes use of the AFNetworking library that extends the high-level networking abstractions in Cocoa with a modular architecture [1].

Following the singleton design pattern [52] one object is instantiated that inherits from the library class *AFHTTPClient* that is responsible for issuing the calls to the server. Properties such as a base URL to the communicating server and a global parameter encoding type (JSON) are set once at object creation and shared throughout the whole project. Calls are triggered via a method of the *AFHTTPClient* class where AFNetworking takes care of constructing the HTTP Request and its parameter encoding. Since requests are triggered in an asynchronous way, responses are processed with Objective-C blocks that serve as callbacks when data arrived.

The importer class creates these callback blocks, which contain code to create an instance of the respective model class (e.g. School, Park). Afterwards it saves the current context, which is the part of Core Data that can be seen as object space or scratch pad that manages a collection of the model objects.

The request for the quality of life indices is triggered by the view controller that displays the map with its grid. Responses to this request are not stored persistently but rather displayed instantly and the call is revoked when a new set of user preferences is entered. Figure 11.3 illustrates the client architecture and its networking and persistence layers. The controller components are depicted as well as the component that is responsible for the map visualization.

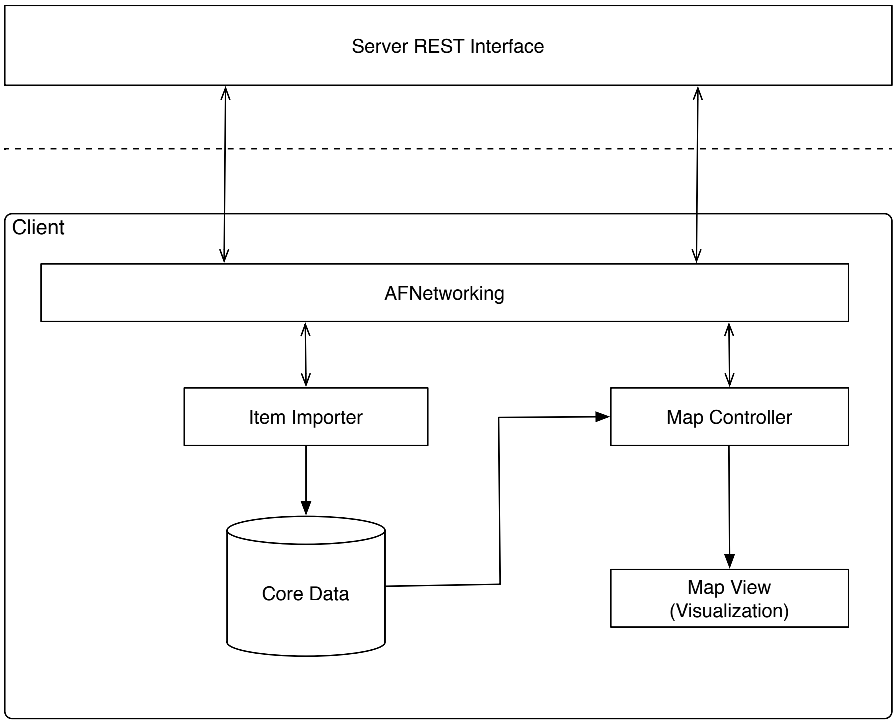

Figure 11.3: Quality of Life Client Architecture

11.5 Visualization

11.5.1 Items and User Preferences

When the client application launches, the entry screen allows the user to state their preferences about the items that influence the quality of life. For every item, the user can determine a weighting factor on a scale from 0 to 10 that expresses the importance of a particular item to them, 0 meaning not important and 10 meaning very important. Furthermore the user is able to state the minimum number of a specific item they perceive to positively influence their quality of life, e.g. a person wants to have at least two supermarkets in their neighborhood. Figure 11.4 shows a screenshot of the entry screen with the list of items that can be chosen from in the prototype application (for details about the choice of items see section 5.5).

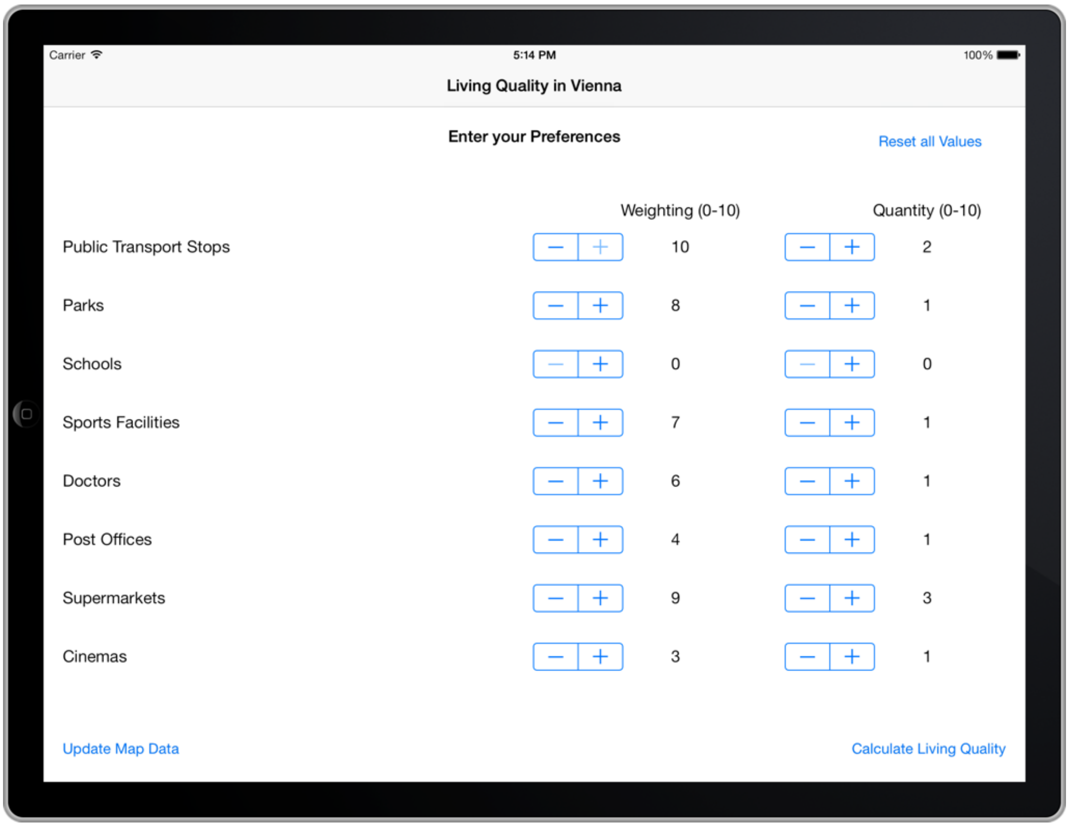

Figure 11.4: Weighing Items in the Quality of Life Prototype Application

In the lower left corner of the entry screen is a button to update the map data. Tapping on it triggers the API call to retrieve location data about the items. They are annotated on the map to give the user an instant impression about the infrastructure when they browse through the quality of life grid. The different facilities are indicated with different symbols. Table 11.1 shows the icons used for the respective item on the map.

Icon	**Description**
	Public Transport Stops
	Parks
	Schools
	Sports Facilities
	Doctors
	Post Offices
	Supermarkets
	Cinemas

Table 11.1: Icons for the Quality of Life Items.

In the lower right corner of the entry screen is the button for displaying the digital map with its quality of life grid. It triggers the API call that sends the user preferences to the server where the response is the data that defines the cells and the indices for the grid. The following section will outline the user interface and the functionality of the map with its annotations and overlays.

11.5.2 The Digital Map and the Quality of Life Grid

Via the tool of a digital map and its visualization capabilities the aim was to provide users with a quick impression on how areas with low and high quality of life indices are distributed over the city of Vienna. As already mentioned in section 10.6 this purpose could best be fulfilled via an overlay in the form of a grid where every cell is colorized in the range from red (Bad – 0%) to yellow (Mediocre – 50%) to green (Good – 100%). Related work in the field of geovisualization was introduced in section 8.1 and it was shown that interactive maps with overlay visualization techniques are very powerful and easily interpretable by human perception. Figure 11.5 shows a screenshot of the digital map with the quality of life grid of the user preferences stated in Figure 11.4.

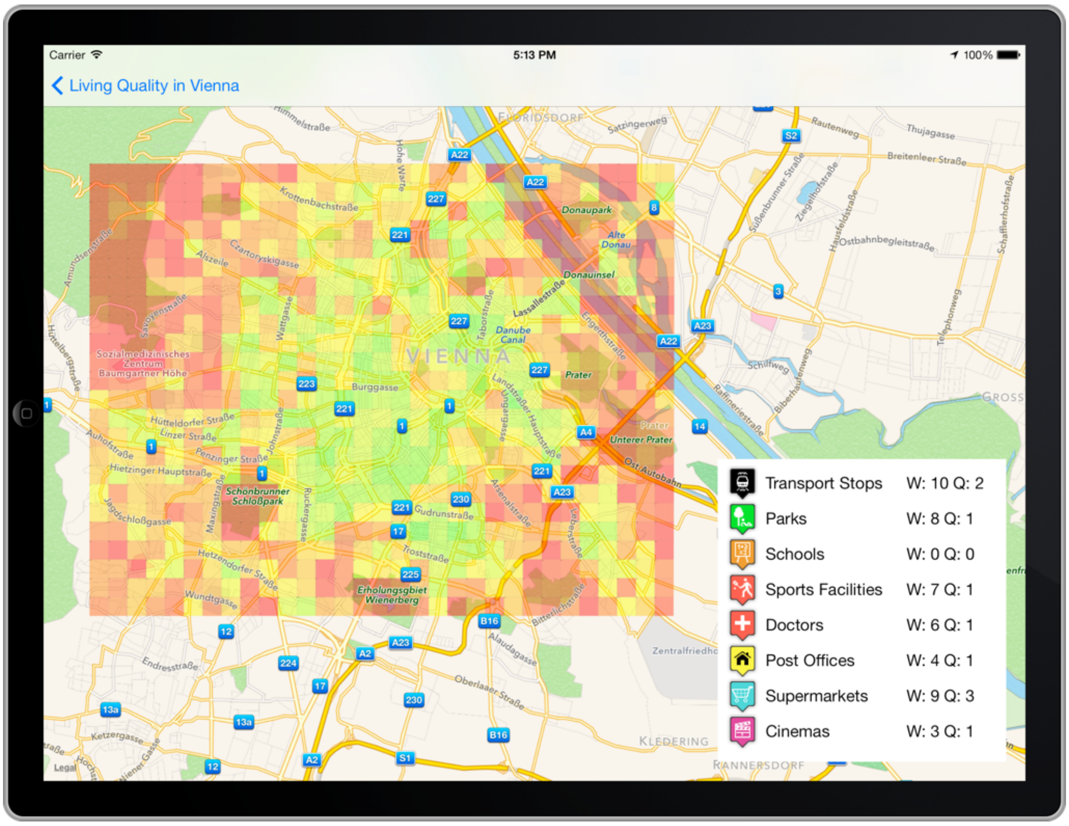

Figure 11.5: The Quality of Life Grid

The figure above illustrates the state of the application after tapping on the *Calculate Living Quality* button on the entry screen. The attention of the user is drawn on the colored grid that takes up most of the space in this map view. Preferences that were entered beforehand are listed in the lower right corner of the map view since users should be able to see what they entered in order to facilitate the assessment on whether assigned indices conform to their needs. The preferences window can easily be made transparent and therefore put in the background by tapping on it. This gives the user the possibility to concentrate on the actual grid even more by enlarging it and not loosing space for this listing.

By reference to Figure 11.5 one can derive that based on the preferences entered, the living area hotspots are distributed around the center with a few outliers in the surroundings. This can give the user an overall impression about where he would feel most comfortable.

The map view is interactive and can be zoomed in and out with the pinch gesture, i.e. moving two fingers together or away from each other. Figure 11.6 illustrates the pinch gesture and shows a screenshot of an extract of the map when already zoomed in further.

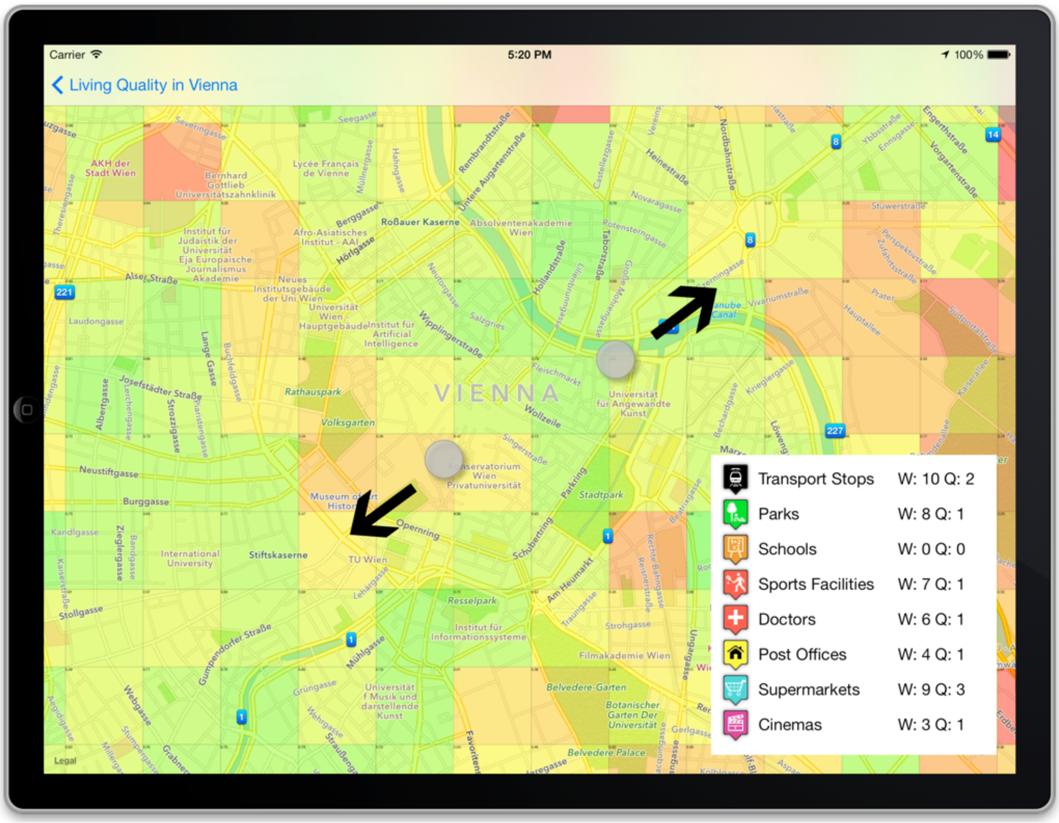

Figure 11.6: Zooming in the Map View

At a certain zoom level the annotations for the quality of life items appear on the map. They are hidden when the map is zoomed out, because the amount of annotations would overlap most of the grid and the user would not only be confused by all the icons but also lose the overview of how quality of life hotspots are distributed.

At the zoom level where cells can be inspected the user is presented with the quality of life index in the upper left corner of the rectangle and is able to get an idea of the infrastructure around a particular area. It is also possible to tap on the item annotations and retrieve further properties about them (e.g. the name of a doctor or the lines that cross a certain public transport stop). Figure 11.7 illustrates a screenshot of the map view at the zoom level of a cell and shows the additional overlay of a doctor containing the name and the address. The point from where the distances to the items are measured is exactly the midpoint of a squared cell. Items at the border of a cell therefore have a lower weighting because they are located in one of the outer concentric circles (for the concept of the concentric circles see section 10.6) and therefore play a smaller part in contributing to a higher quality of life index.

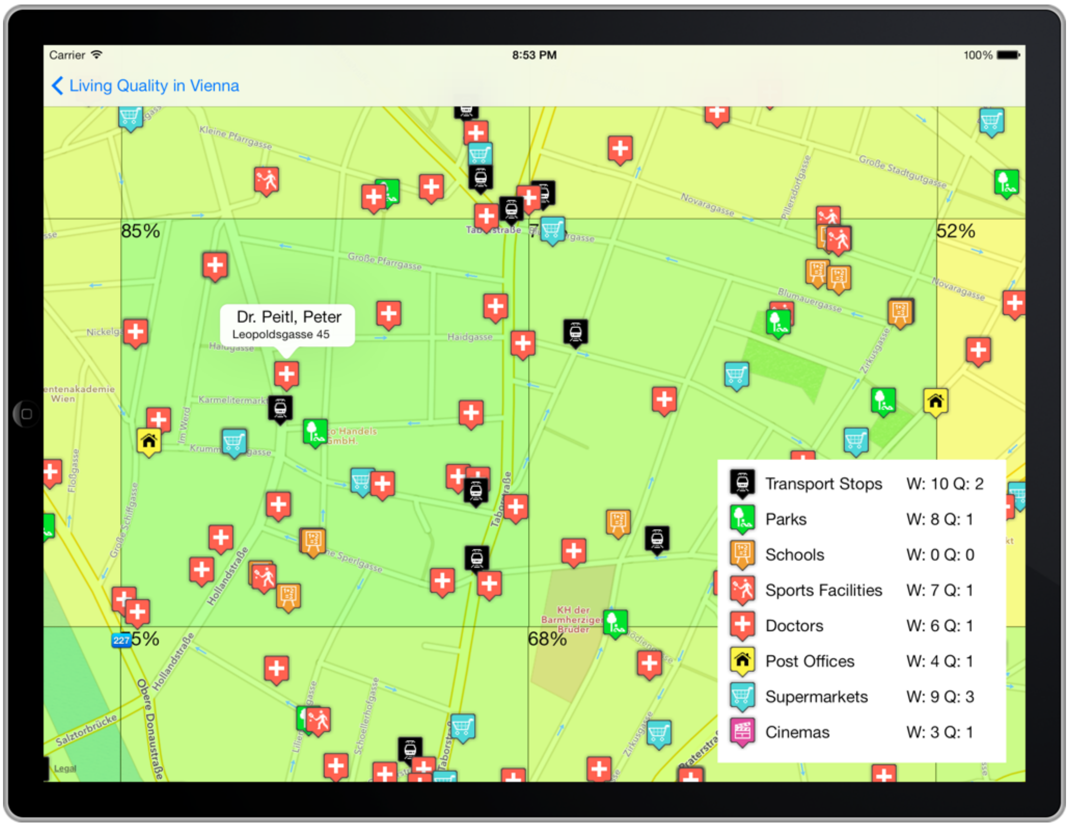

Figure 11.7: At the Cell Level of the Quality of Life Grid

The quality of life index of the focused cell of Figure 11.7 was calculated with 85%. There are several reasons that the maximum index of 100% was not reached. The requirement of two transport stops is clearly satisfied with one being in close proximity to the center of the cell. The same holds for the one park that was stated to have a weighting of eight. There is a sports facility, enough doctors and even a post office in the square, although the latter one is already at the border of the cell, which downgrades the score a bit. Since supermarkets are weighted as very important with the number nine and only two of them are present in the square, this also affects the score in a negative way. The one cinema that was requested, although with a low importance, is also not located in this particular neighborhood and worsens the score a bit.

Part IV

Discussion

12 Evaluation

12.1 Setup

The evaluation of the quality of life prototype application took both qualitative as well as quantitative aspects into account. From the qualitative point of view it was the goal to get feedback that could help to improve the application such as to check whether people found the selection of the eight selectable items reasonable and how they experienced the engagement of the visualization of quality of life areas. The quantitative part should reveal statistical key figures that give an impression on whether the users were satisfied with their experience overall and found the calculated indices reasonable. The evaluation was therefore divided into two parts. The focus with the first six persons that evaluated the application was laid on the qualitative aspect and whether the chosen categories and items seemed appropriate to the users and how intuitive and comprehensible they found the visualization. The second phase involved another 24 persons where focus was laid on quantitative aspects – for example to get an idea of how many people would actually consider such an application in their decision-making process of finding a new home within a city. Therefore a total of 30 persons – 15 women and 15 men – between the age of 20 and 37 were interviewed.

For the qualitative part of the evaluation six persons – two women and four men – between the age of 25 and 32 were chosen to use the client application and share their thoughts and experiences during their exploration of the digital map. As all 30 participants they filled out an evaluation sheet that is attached in appendix A. First they had to state their age, gender and family status to establish a connection between their personal properties and the preferences for what is important to their personal quality of life. In section 12.2 these six persons and their statements in the interviews will be discussed in detail and shall depict the qualitative aspects in the evaluation. Statistics about the quantitative results can be looked up in section 12.3.

Basically the survey itself was divided into two parts. Before inaugurating the persons into the concept and the functionality of the client application, they were asked two preliminary questions. The first one should reveal items or facilities they wanted to have in proximity of their home and that enhance their quality of life. This should give a sense on whether the eight preselected items were meaningfully chosen. The second question should give an idea on how the user imagined a good visualization of quality of life on a digital map. The second part included questions to answer after using the client application (see appendix A).

The internally defined parameters that were used for the evaluation phase of the quality of life algorithm can be seen in table 12.1.

Parameter	**Value**
Considered Radius	300 m
Distance between two calculated points	424 m
Number of Concentric Circles	3
Weighting Factor of the Circles	0.8

Table 12.1: Internal Paramter Settings for the Evaluation Phase

For details about the chosen values for the parameters see section 10.6. The predefined values for the evaluation phase and the fundamental form of visualization of quality of life areas with a colored overlay grid in general are the results of the master thesis at hand. Feedback of the users will be taken into account and integrated in the chapter Future Prospects (see chapter 13) of the discussion part.

12.2 Qualitative Evaluation

12.2.1 Evaluation Person 1

Person 1 was a 25-year-old woman and her family status was single. Her chosen set of preferences when using the client application can be seen in table 12.2.

	Weighting	**Quantity**
Public Transport Stops	10	5
Parks	5	2
Schools	0	0
Sports Facilities	8	2
Doctors	6	3
Post Offices	6	1
Supermarkets	10	3
Cinemas	2	1

Table 12.2: Evaluation - User Preferences Person 1.

As one can see, she placed great value on public transport stops and supermarkets whereas the item schools was not weighted at all, since she did not have any children. In the preliminary questions she stated that she wanted to have supermarkets, subways, parks, a police station and parking space in her proximity. That matched the preselected items very well, where subways fall into the category of public transport stops and only police stations and parking spaces were missing in the set. The question about how she imagined a good visualization she answered that she would visualize the quality of life with colors, ranging from red (bad) to green (good) which also matched very well with the actual visualization.

She stated the number of selectable items for a quality of life application as appropriate but wrote *security* as missing area in the survey and specified police station as concrete item. Furthermore she found the form of visualization rather appropriate and rather comprehensible. The color range and the size of the cells in the grid seemed appropriate to her. All of the calculated indices of the three chosen cells were reasonable to her and she stated that the quality of life index of an area would play a minor role in her decision-making process of finding a new home, especially if subway stops could be considered separately from bus and tram stops. Such a distinction would be a possible expansion stage of the application.

12.2.2 Evaluation Person 2

Person 2 was a 29-year-old man who was in a partnership. His chosen set of preferences when using the client application can be seen in table 12.3.

	Weighting	Quantity
Public Transport Stops	10	2
Parks	8	1
Schools	2	1
Sports Facilities	8	2
Doctors	6	1
Post Offices	9	1
Supermarkets	10	2
Cinemas	5	1

Table 12.3: Evaluation - User Preferences Person 2.

He weighted all available items and put emphasis on public transport stops, supermarkets and post offices. Since he was open to have children with his partner some day, he weighted schools to be of at least some importance. In the preliminary questions he stated that bars, restaurants, parks and sport facilities are of great value for him. The latter two matched the set of preselected items. He imagined the visualization to be circular shades, ranging from light (less quality) to dark (better quality). He found the number of selectable items to be appropriate but was missing the area of *food* during the exploration. Specifically he would be interested in nearby bars and restaurants – he also stated that a distinction by cuisine would be nice. He found the form of visualization, the color range and cell size appropriate and the overall visualization comprehensible. All the calculated quality of life indices of the specific cells seemed reasonable to him and he stated that the index would play an important role in his decision-making process of finding a new home.

12.2.3 Evaluation Person 3

Person 3 was a 30-year-old man and his family status was single. His chosen set of preferences when using the client application can be seen in table 12.4.

	Weighting	Quantity
Public Transport Stops	9	2
Parks	5	1
Schools	0	0
Sports Facilities	6	1
Doctors	7	3
Post Offices	5	1
Supermarkets	9	2
Cinemas	5	1

Table 12.4: Evaluation - User Preferences Person 3.

As the previous two persons, person 3 also put emphasis on public transport stops and supermarkets. As being a single and not having children, he did not put weight on the item schools. Before using the client application he stated that public transport, grocery shops and pubs are of importance to him when it comes to quality of life. This again is a good match with the preselected item set. He imagined a good visualization marked hot spot areas where hot or good areas are color-coded red and cold or bad areas are color-coded blue. He found the number of selectable items as appropriate but was missing the area of *nightlife* and specifically the item of bars. The form of visualization was rather appropriate to him but he suggested the form of isopleth maps, which are sometimes used to show data with continuous distribution on a map. The visualization was rather comprehensible to him and he found the color range and the size of the cells appropriate. All of the calculated quality of life indices were reasonable to him and he stated the index would play an important role in his decision-making process.

12.2.4 Evaluation Person 4

Person 4 was a 26-year-old man and his relationship status was single. His chosen set of preferences when using the client application can be seen in table 12.5.

	Weighting	**Quantity**
Public Transport Stops	8	5
Parks	6	2
Schools	0	0
Sports Facilities	7	2
Doctors	8	3
Post Offices	6	1
Supermarkets	8	4
Cinemas	0	0

Table 12.5: Evaluation - User Preferences Person 4.

Together with public transport stops and supermarkets the item doctor was most important to him. Since he is interested in sport activities as well, sports facilities and parks to go for a run were in the upper ranking hierarchy for him. In the preliminary questions he stated that supermarkets, a gym, doctors, public transport and parks were of great value for him. This overlaps with the previous persons and again matches the preselected item set very well. The form of visualization of quality of life areas on a digital map would consist of a two-colored hotspot zone overlay in his imagination. He found the number of selectable items in a quality of life application too few and stated that he would like to select approximately among 12 different items. Furthermore he stated that the areas of *nightlife*, *food* and *religion* should also be considered and that specific items such as parking, population density and noise exposure were missing in his opinion. He found the form of visualization appropriate and comprehensible. The selection of the color range seemed appropriate to him as well but the size of the cells in the grid were too large in his opinion. He found the index of a cell with a value of 80–100% reasonable and the ones with 40–60% and 0–20% rather reasonable. The index would play an important role in his decision-making process and he wished for a map scale to estimate distances more easily, a switch to turn items on and off, a variable grid size and finally the possibility to select quality of life items himself from a list.

12.2.5 Evaluation Person 5

Person 5 was a 32-year-old man who was in a partnership. His chosen set of preferences when using the client application can be seen in table 12.6.

	Weighting	Quantity
Public Transport Stops	9	2
Parks	7	1
Schools	3	1
Sports Facilities	8	1
Doctors	5	2
Post Offices	5	1
Supermarkets	10	2
Cinemas	3	1

Table 12.6: Evaluation - User Preferences Person 5.

The most important items were again supermarkets and public transport stops. Sports facilities and parks were also of great interest for him since he likes to engage in sports. In the preliminary questions he stated that parks, supermarkets, bikeways and a theatre would be nice in his proximity. He imagined a quality of life visualization as colored areas that can be distinguished from good to bad. The number of selectable items were appropriate to him but he was missing the area of *food* in the item set and stated a theatre and bikeways as specific items that he would want to choose from. The form of visualization, the color range and size of the cells were appropriate to him and he found the general appearance comprehensible. All the calculated quality of life indices in the specific cells were reasonable to him and the index would play an important role in his decision-making process although he also would like to choose his own items from a longer list of a preselected set of items.

12.2.6 Evaluation Person 6

Person 6 was 29-year-old woman who was in a partnership. Her chosen set of preferences when using the client application can be seen in table 12.7.

	Weighting	Quantity
Public Transport Stops	10	1
Parks	2	1
Schools	0	0
Sports Facilities	8	1
Doctors	1	1
Post Offices	0	0
Supermarkets	10	2
Cinemas	3	1

Table 12.7: Evaluation - User Preferences Person 6.

Supermarkets and public transport stops were rated of the utmost importance of this person as well. In the preliminary questions she stated that she wanted to have supermarkets, pubs, public transport stops and trees in the proximity of her neighborhood which is again a good match with the preselected item set. For the visualization she imagined a color based overlay, which is not very concrete but still seems to match the form of the actual visualization in the quality of life client application. The number of selectable items in a quality of life application were appropriate in her opinion but she was missing the area *fun* and specifically the item of pubs in the item set. The form of visualization, the color range and the size of the cells seemed appropriate to her and she stated the general appearance to be comprehensible. All the calculated quality of life indices of the specific cells seemed reasonable to her and such an application would play an important role in the decision-making process of finding a new home for her.

12.3 Quantitative Evaluation

The evaluation yielded very positive feedback and some important results shall be visualized in the following to give the reader an overview over the consenting responses.

12.3.1 How do you evaluate the number of selectable items?

People were asked if they wanted to parameterize more or less items – for example to have more detailed results – when using such a tool to discover quality of life hotspots. More than half of them found the number of eight items to be appropriate, six of them wanted to weigh more and 5 of them wanted to weigh less items. Figure 12.1 illustrates the distribution of answers.

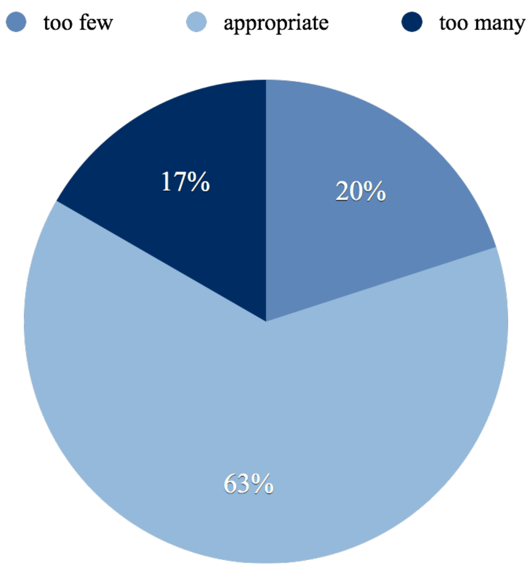

Figure 12.1: How do you evaluate the number of selectable items?

12.3.2 How do you evaluate the form of visualization?

The geovisualization of quality of life areas got very positive feedback. 28 of 30 people stated that they found the form of visualization either rather appropriate or appropriate. Figure 12.2 illustrates the distribution of answers.

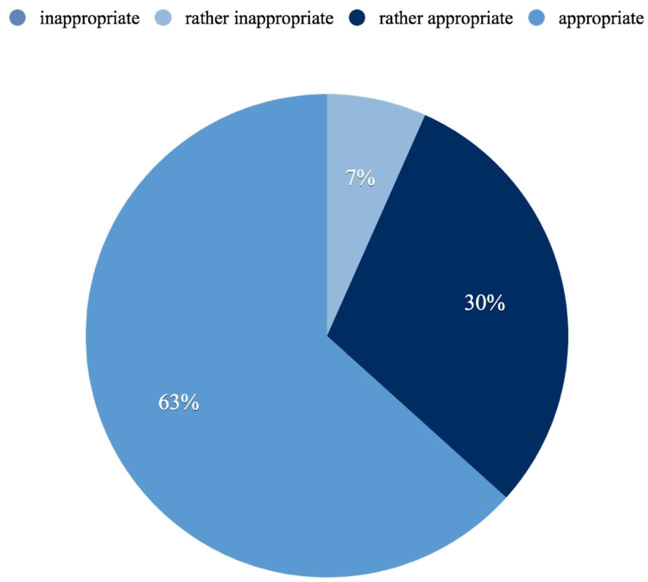

Figure 12.2: How do you evaluate the form of visualization?

12.3.3 How comprehensible do you evaluate the visualization in general?

As before, 28 of 30 people found the visualization to be either rather comprehensible or comprehensible. They stated that they intuitively knew how good and bad areas were marked and were hotspots of high quality of life over the city were to be found. Figure 12.3 illustrates the distribution of answers.

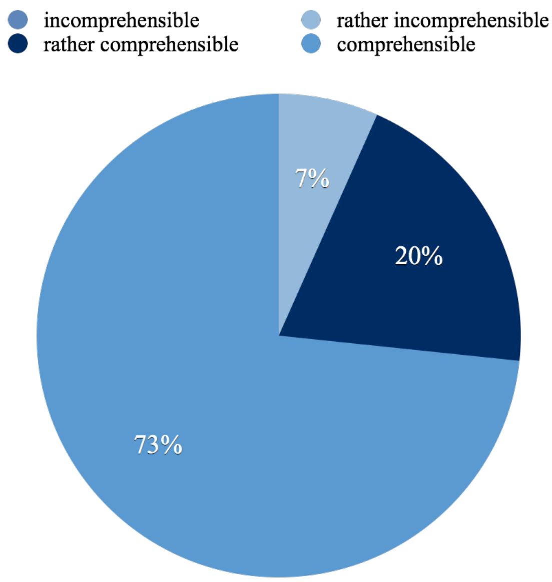

Figure 12.3: How comprehensible do you evaluate the visualization in general?

12.3.4 How do you evaluate the selection of the colors in the quality of life grid?

All of the persons answered this question with either rather appropriate or appropriate and obviously found the pattern to range from red over yellow to green to be very intuitive. Figure 12.4 illustrates the distribution of answers.

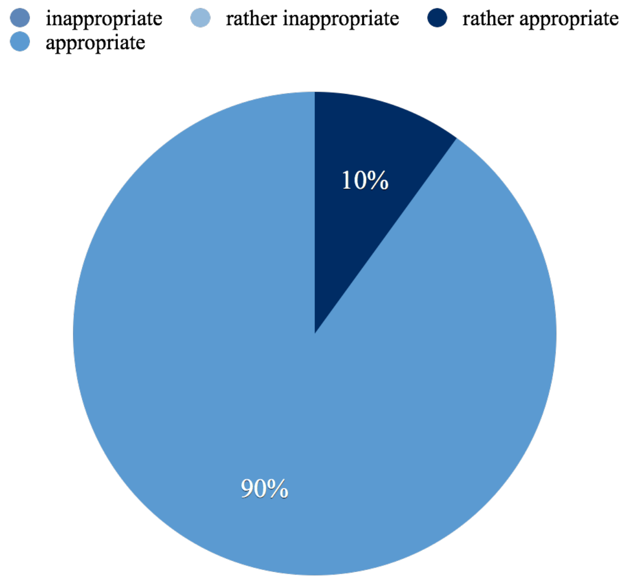

Figure 12.4: How do you evaluate the selection of the colors in the quality of life grid?

12.3.5 How do you evaluate the size of the individual cells in the quality of life grid?

Two of three people found the cell size to be of appropriate size. Four of the people said the cells were too small for them and six people wanted indeed smaller and more granular cells. Figure 12.5 illustrates the distribution of answers.

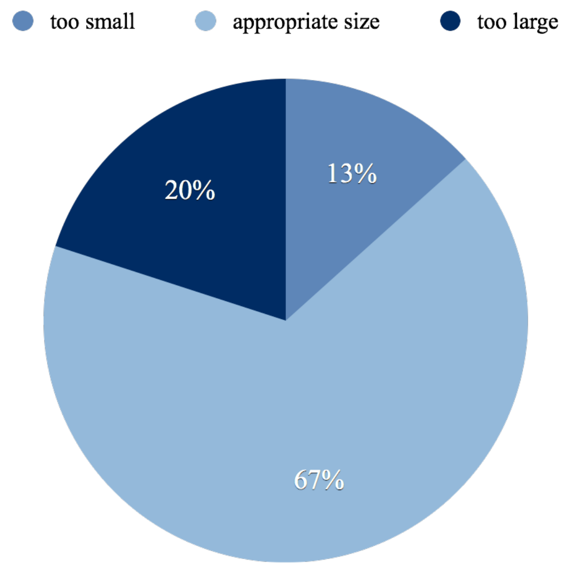

Figure 12.5: How do you evaluate the size of the individual cells in the quality of life grid?

12.3.6 Do you evaluate the quality of life index of a cell as reasonable based on your personal preferences and the prevailing neighborhood?

The persons were asked to choose three individual cells, one with low, one with mediocre and one with high quality of life and check whether they found the index to be reasonable. Figure 12.6 cumulates the answers of all the three cells and all persons and illustrates the distribution their distribution. 93% of all answers were either given as rather reasonable or reasonable. The quality of life algorithm therefore performed very well and gave the people a reasonable index that should give a quick impression on how good a neighborhood is weighted.

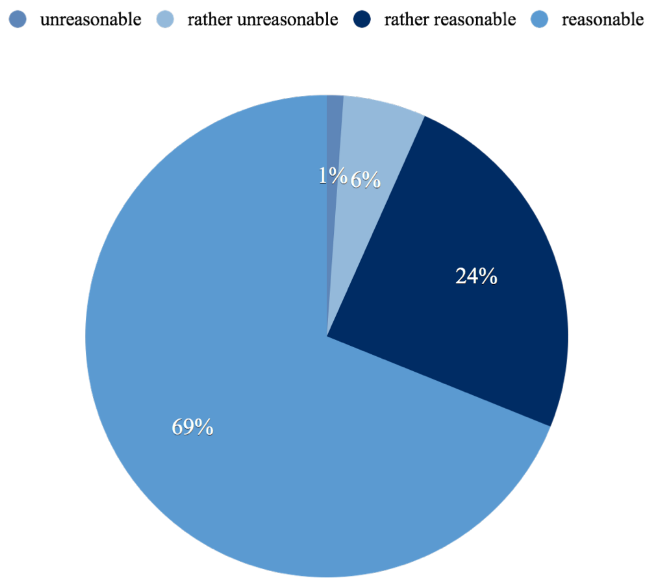

Figure 12.6: Do you evaluate the quality of life index of a cell as reasonable based on your personal preferences and the prevailing neighborhood?

12.3.7 Would you take the quality of life index into account for the decision-making process of finding a new home in Vienna?

The last question should give an impression on how reliable people found visualization with its calculated indices. 19 of 30 people stated that such a tool would play an important role in their decision making process, the other 11 people would consider it in a minor extent. Figure 12.7 illustrates the distribution of answers.

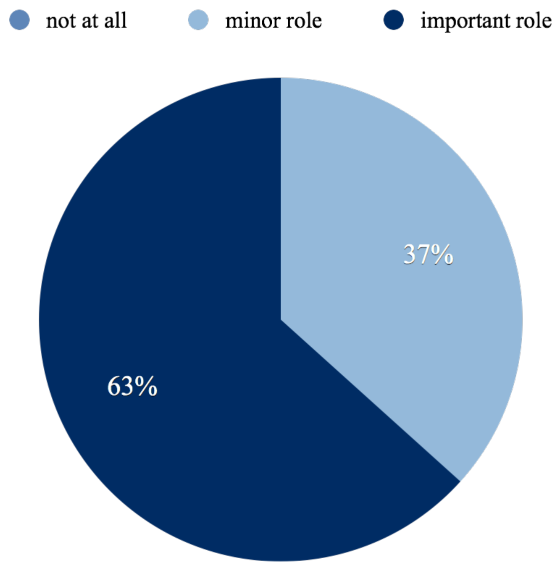

Figure 12.7: Would you take the quality of life index into account for the decision-making process of finding a new home in Vienna?

12.4 Summary

To summarize, all the persons who evaluated the quality of life client application had a good experience with it and the concept to visualize quality of life areas on a digital map would play a role in the decision-making process of finding a new home for all of them. The feedback was very positive and all the persons were able to intuitively use the application and interpret the results they saw on the screen, which is the crucial aspect of the visualization part of this master thesis. All of the persons took the survey very seriously and many of them asked whether the application will be made public so that they can use it on real estate websites. They were eager to contribute their ideas and suggestions to improve the prototype in order to become a sophisticated software tool.

Apart from a few areas that were missing for some persons, such as security and food related facilities (e.g. police stations, crime rates, restaurants), the preselected item set matched the requirements of the individuals very well. Further suggestions and wishes from the test persons constitute possible expansion stages of the application.

13 Future Prospects

The application that was developed in the course of this master thesis shall be seen as a prototype that conflates the domains of Sociology and Information Technology and that tries to visualize the concept of quality of life on a digital map. Eight relevant items were chosen during the research of current quality of life studies (see chapter 5) and presented to the user to put a weighting on them. The resulting application delivered very positive feedback in the evaluation phase (see chapter 12) provides a good basis for future expansion stages.

Currently the prototype application only supports discrete features, i.e. items that have one exact location on earth – one latitude and one longitude coordinate. Features such as parks could in the future be considered as areas which would allow a more accurate calculation of intersections – in opposite to the current calculation where distances are measured from the midpoint of a park. That way it would also be possible to consider the size of such continuous features which in reality also plays a role for individuals – e.g. people who are looking for big parks where they can go for a run.

An area that came up to be missing during the evaluation of the prototype was security. Therefore location data of police stations could for example be used in the application. At this point some thought can be put into the integration of data that is not solely based on locations. Crime rates and population density could for example be options for the user to put a weighting on.

Another improvement for a more accurate calculation of distances and therefore a more accurate value for the quality of life index would be to not calculate with the geographic linear distance between two points but to consider the actual walking distance that a person has to take. This kind of information would have to be extracted from an external routing service (e.g. Google Maps API.)

Since preferences for the personal quality of life experience vary significantly, the user should be presented with a larger set of categories that contain a larger set of individual items where the persons themselves can pick features that are relevant to them. OGD Vienna [85] and OpenStreetMap [68] provide a huge data source for such an expansion that would not only allow for a bigger number of options but also a more granular distinction of specific items, such as the cuisine of a restaurant or the kind of a public transport stop (subway, tram, bus, etc.).

As suggested in the EQLS surveys [15] [4] [5] the opening hours of items and facilities that contribute to a good quality of life should be considered because they determine the actual accessibility. The user should for example have the possibility to check for opening hours of restaurants, pubs or sports facilities.

For more experienced users it would be an advantage to set a few of the internally defined parameters for the quality of life algorithm themselves. For instance one of the persons who evaluated the prototype application asked whether it would be possible to set the size of the cells himself. This would allow for an even more individual visualization of quality of life zones. If the user would be made familiar with the nature of the algorithm with its concept of concentric circles it would also be worth to think about whether to let the user decide how many circles within a user-defined radius should be considered and how the weighting of these circles (weighting factor of concentric circles – see section 10.6) should look like.

When regulating the size of the cells it would possible to constitute a more granular distinction of quality of life areas. Small enough cells would result in a kind of an isopleth map where differences between two consecutive cells would be diminished and more coarse-grained zones over the city could be generated, which would also result in a more harmonious transition of colors between cells. Such a scenario would imply performance optimizations since a lot of individual points over a city are considered and require distance calculations to all the items. Caching results, loading items into the working memory would be possible approaches to address this problem.

Such a performance optimization would allow for a further expansion stage where the user could modify his weighting preferences with a slide control and get instantaneous updates of quality of life areas on the digital map.

The algorithm itself could be expanded by allowing a reverse weighting scenario, where the user could define items such as landfills that should be far away from their home.

Expansion stages are manyfold and the quality of life prototype application provides a fundamental basis to adapt use case scenarios of various kinds.

14 Closing Remarks

The goal of the master thesis at hand was to conflate the domains of Sociology and Information Technology to generate added value and provide the user of prototype application with an intuitive visualization of quality of life areas over the city of Vienna. The concept of quality of life and relevant aspects that deal with the geographical infrastructure in this respect was introduced. Special emphasis was put on modeling open data formats from different sources, combining them and store geospatial information on a central server. Furthermore a customizable quality of life algorithm was developed to measure and compare different areas within the city. Finally a form of geovisualization provides the user with a comprehensible overview over interesting hotspots given their personal set of preferences.

By integrating some of the suggestions from the previous chapter, the quality of life prototype application could evolve to a sophisticated addition to real estate platforms where people could use it as a tool that helps them in the decision-making process of finding a new home.

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A Appendix

Quality of Life Prototype Application Evaluation Sheet

Age: _____
Gender: ○ Male ○ Female
Family Status: ○ Single ○ Married ○ Divorced ○ Widowed ○ Partnership

Preliminary Questions

1) The proximity of which physical items/facilities influence your quality of life?

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2) How would you visualize areas with good and bad quality of life on a digital map?

Subsequent Questions

1) Preferences

1.1) How do you evaluate the number of selectable items?

○ too few ○ appropriate ○ too many

1.2) If too few, or too many, what would be an appropriate number?

1.3) In your opinion, does the quality of life prototype application consider all relevant areas of life?

○ Yes ○ No

1.4) If no, what areas are missing?

1.5) In your opinion, does the quality of life prototype application consider all relevant items/facilities?

○ Yes ○ No

1.6) If no, what items are missing?

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2) Visualization

2.1) How do you evaluate the form of visualization?

○ inappropriate ○ rather inappropriate ○ rather appropriate ○ appropriate

2.2) If (rather) inappropriate, what would be more appropriate?

2.3) How comprehensible do you evaluate the visualization in general?

○ incomprehensible ○ rather incomprehensible ○ rather comprehensible ○ comprehensible

2.4) How do you evaluate the selection of the colors in the quality of life grid?

○ inappropriate ○ rather inappropriate ○ rather appropriate ○ appropriate

2.5) How do you evaluate the size of the individual cells in the quality of life grid?

○ too small ○ appropriate size ○ too large

3) Assessment of the Quality of Life Index

3.1) Take a cell with an index between 80-100%. Do you evaluate the quality of life index of that cell as reasonable based on your personal preferences and the prevailing neighborhood?

○ unreasonable ○ rather unreasonable ○ rather reasonable ○ reasonable

3.2) Take a cell with an index between 40-60%. Do you evaluate the quality of life index of that cell as reasonable based on your personal preferences and the prevailing neighborhood?

○ unreasonable ○ rather unreasonable ○ rather reasonable ○ reasonable

3.3) Take a cell with an index between 0-20%. Do you evaluate the quality of life index of that cell as reasonable based on your personal preferences and the prevailing neighborhood?

○ unreasonable ○ rather unreasonable ○ rather reasonable ○ reasonable

4) Outlook

4.1) Would you take the quality of life index into account for the decision-making process of finding a new home in Vienna?

○ not at all ○ it would play a minor role ○ it would play an important role

4.2) Additional comments and suggestions for improvement.

____

User Preferences

	Weighting	Quantity
Public Transport Stops		
Parks		
Schools		
Sports Facilities		
Doctors		
Post Offices		
Supermarkets		
Cinemas		