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Erklärung zur Verfassung der Arbeit

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Abstract

This master thesis deals with the topic of knowledge transfer in the field of art history by means of a game. Special attention was given to mobile systems which are meanwhile numerously available in form of several smartphone platforms (Android, iPhone, etc.).

The first part of the work focuses on the definition and the history of playful learning. It is shown that this form of knowledge transfer has a long tradition and provides much more opportunities than simply having fun. Nowadays the term *Serious Games* concludes all types of games which provide additional value of any form besides entertainment, be it in form of learning games, or educational games but also critical games that intend to encourage a different way of looking at things. Games offer the advantage that their intrinsic motivational elements allow them to reach new audiences which otherwise maybe never could have been reached. Especially when dealing with topics of art history it is difficult to delight new target groups and motivate them for learning tasks.

Based on this background in the course of this work the mobile game *ARTournament* was created as prototype with the objective of transferring knowledge in different fields of art history. The game enters specifically the area of *Casual Games* which describes the growing domain of games being played in short bursts in between times.

The game was published in form of an application for Android smartphones and after a public test run the usage patterns have been analysed. In the final part of the work it is explained how the game was accepted and which learning success could be observed. Based on these experiences finally some suggestions for future improvements are made and a short outlook on the further development of Serious Games is given.

Kurzfassung

Die vorliegende Diplomarbeit beschäftigt sich mit dem Thema der Wissensvermittlung im Feld der Kunstgeschichte in Form eines Spiels. Besonderes Augenmerk wird dabei auf mobile Plattformen gelegt, wie sie in Form aktueller Smartphones (Android, iPhone, etc.) mittlerweile zahlreich zur Verfügung stehen.

Im ersten Teil der Arbeit wird die Definition und die Geschichte spielerischen Lernens näher beleuchtet. Dabei wird aufgezeigt, dass diese Form der Wissensvermittlung eine lange Tradition hat und Spiele die Möglichkeit bieten viel mehr als nur Spaß zu vermitteln. Unter dem Namen *Serious Games* fasst man heutzutage alle Spiele zusammen, die neben dem Spaß am Spiel einen Mehrwert jeglicher Art bieten, sei es in Form von Lernspielen, Erziehungsspielen, aber auch kritischen Spielen die zum Nachdenken anregen. Spiele haben dabei den Vorteil einen Motivationsfaktor zu schaffen, mit dem es möglich ist neue Zielgruppen anzusprechen, die ansonsten vielleicht nicht erreichbar wären. Besonders im Umgang mit kunstgeschichtlichem Wissen ist es bisweilen schwierig neue Personenkreise zu begeistern und für Lernaufgaben zu motivieren.

Vor diesem Hintergrund wurde im Rahmen dieser Arbeit das mobile Spiel *ARTournament* als Prototyp entwickelt, mit dem Ziel Wissen in verschiedenen Themengebieten der Kunstgeschichte zu vermitteln. Das Spiel betritt dabei gezielt das Feld der *Casual Games*, das den wachsenden Bereich der Spiele "für zwischendurch" beschreibt.

Das Spiel wurde der Öffentlichkeit in Form einer Applikation für Android Smartphones zugänglich gemacht und nach einem Testzeitraum die Nutzungsmuster ausgewertet. Im abschließenden Teil der Arbeit wird erläutert wie das Spiel aufgenommen wurde und welche Lernerfolge erkennbar waren. Basierend auf den gesammelten Erfahrungen werden abschließend Empfehlungen für zukünftige Weiterentwicklungen gegeben und ein möglicher Ausblick zur weiteren Entwicklung von Serious Games gezeigt.

Contents

CHAPTER 1

Introduction

Games are fun.

We already get encouraged at preschool and kindergarten to socialise with others and explore our environment by playing games. At this stage of life it seems to be the most natural thing in the world to treat everything like a game. This is also a phase in our life where we acquire an incredible amount of knowledge. Later on when we grow older games still accompany us through childhood and teenage years, but as time goes by we form the opinion that games are not as important as "serious" matters in life, like getting an education, learning, finding a job and earning money. The older we grow the more we experience that games drift into the background of our lives.

During the the last decades this attitude has begun to change. Already in the year 1992 Lepper and Cordova [LC92] presented the results of various studies that showed that learning is more effective if it includes an entertaining factor. The fact that games can be a powerful motivation factor became the impulse behind a new field of research. To combine the intrinsic fun of playing games with the benefits of acquiring knowledge became the main goal of a new area of game development: *Serious Games*.

Games have always been a part of our society but like everything else they also underwent changes throughout history. We are living in a time in which new technologies are presented at a higher rate than ever before in history of mankind. The last few decades brought us immense progress and change, especially in the field of information technology. Without a doubt these changes left remarkable traces in our society and of course also changed the way we play. Computer games became an important economic sector and found broad acceptance especially among the younger generation. Kids grow up equipped with modern computer technology and get used to playing computer games from one's earliest years. So it's hardly surprising that creating educational computer

games became an essential field of research and consequently these new opportunities are nowadays too important to be missed.

Like every part within the broad field of information technology also games were experiencing changes and innovations. The evolvement of the Internet influenced almost every aspect of modern technology. Instantly available information and global communication has changed processes in industry, science and the way how we interact with each other and of course also the way we play. Multiplayer and online games started a new era of game development. Moreover, in recent history the development of mobile networks, Internet on cell phones and last but not least the merger of computer and mobile phones in form of *smartphones* changed the game industry once again. Today we have possibilities in software development which would have been utopian only a decade ago. Incredible computing power within our palms, immersive connectivity to the world-spanning Internet and new ways of interaction with our computing devices raised the bar of expectations.

It's no longer the problem that the requested technology for realising ideas is not available, it has become more of a challenge to decide on the best technology as there are so many available. We are faced with the constant responsibility to keep up with current technological developments and their handling in order to stay competitive. This of course is important for businesses as well as for the educational sector. Nowadays schools, museums and other educational institutions are expected to monitor innovations on the market and adopt them if they provide added value. It's one of the greatest challenges to identify and select reasonable areas where new applications and technologies bring the best benefit.

Museums and other educational institutions focus on the transfer of information and knowledge. New services have to be analysed with regard to their ability to enhance this informational flow. Furthermore, advantages that may be available for both parties need to be detected. The aspired goal is to reach a win-win situation between the provider and consumer of information. This is the point where the advantages of games in general and possibilities of digital data processing merge together. Games give us a way to engage and motivate learners and using digital technologies enables us not only to provide information in a pleasant form but also allows us to draw lessons from the information how learners interact with a game. Observing the player allows us to improve serious games as the underlying learning process as well. Especially digital information processing in computer games allows us very well to study how users interact with the game and the presented information material.

To break it down in one sentence: the constant evolvement of information technology, computer games and *Serious Games* concepts provides us with a broad range of choices and it's the great challenge in present times to utilise these resource in order to make learning for the next generation more fun, fascinating and enlightening.

1.1 Motivation

The availability of powerful mobile computing devices combined with growing bandwidth in mobile networks enabled a whole bunch of new use case scenarios. The last years brought a lot of changes for consumers but also for researchers. The products and services which developed during the last years are only the tip of the iceberg of what can be done. Having these new tools and instruments available it's reasonable to carry on reflections on what is possible with these new resources. Especially the field of teaching and education which in many countries is under governmental control and therefore often inflexible and slow regarding the adoption of new technologies, still offers a broad field for new ideas. As the concept of educational games is no longer just of scientific interest, the idea of using new available technologies for creating these games is not so faraway anymore.

In the concrete context of art history there are already some projects using modern information technology on the Web like the recently presented *The Google Art Project*[1] where users can take visual tours through selected museums or the *Web Gallery of Art*[2] which contains a large publicly available online collection of artworks. While these projects focus on art representation there are others which encourage the users to interactively browse through artworks and also give feedback in form of tags and keywords, like the *explorARTorium*[3] and *ARTigo*[4] which provide valuable data for researches.

Art related applications on mobile devices are mostly found within or in the context of museums. Most of them focus on interaction or communication with their visitors and range from simple audio guides to applications running on modern smartphones like the application *TAP* of the *Indianapolis Museum of Art*[5]. These applications are used to enrich the value of the visit of the customer by providing additional information like pre-defined tours, details to the exhibits but also interactive content like tag clouds or exhibition-related polls. Creating games with educational content using mobile technology is just a further step. It's also a way to move a little bit outside museums and integrate the content into everyday life.

As in public mind art history still gets associated with the cliche of being boring and uninteresting it seemed an exciting challenge to find out whether it is possible to transfer art historical concepts by means of a game or not. Especially the new opportunities enabled by mobile devices allow games to be played more "casually", which means that they are used only in small time bursts, for example when having a few spare minutes during the day. This allows to address a new type of players, the *casual gamers* [KKNP07]. It seemed interesting to reach this new and growing audience which

[1] `http://www.googleartproject.com/`, Last accessed 4/11/2011
[2] `http://www.wga.hu/`, Last accessed 4/11/2011
[3] `http://www.explorARTorium.info/`, Last accessed 14/11/2011
[4] `http://www.artigo.org/`, Last accessed 14/11/2011
[5] `http://www.imamuseum.org/interact/tap`, Last accessed 15/11/2011

normally would not be counted among the group of typical gamers to bring them closer to the topic of art history.

The idea behind the prototype created in the course of this thesis was to learn from existing educational games and use this experience to create a game on a modern platform that provides the user with an enjoyable occupation and at the same time presents him or her art historic content in a way that the user will pick up some of the concepts while using it.

1.2 Goal

This work consists of two parts. In the first part of this thesis a theoretical overview on the development of the field *Serious Games* will be given as well an illustration of concepts behind learning. A critical view will be given on the backgrounds and reasons for using games as educational elements and why these may become an important factor in future educational systems as well as in the context of museums and other cultural organisations.

In the second part a game prototype will be described which has been designed, implemented and tested based on these observations. The resulting software is settled in the context of art historic paintings and will realise principles to transfer knowledge about the presented art epochs to players in an implicit way while using the game. The aim is to create a game targeted at mobile platforms to be able to reach a broad range of possible users and to explore features and possibilities of mobile platforms. Independently of the used educational concepts the architecture of the resulting software will be designed in a way so that it enables possible further reuse for other teaching areas (not only limited to art history). This means that the content will be logically separated from the game mechanics to enable further use of the resulting platform for other fields. Consequently, an important focus within the practical part of this work will be to carefully choose an architectural design that will meet the requirements and enables possible further evolvement.

The resulting application was made available to a broader group of testers in order to analyse how users interact with the game and if the implemented learning concepts seem to work. As an outcome it should be possible to evaluate the effectiveness and acceptance of the game and also to identify possible areas for improvement. In conclusion the determined results and learned lessons will be presented as well as possible outlooks for the future.

1.3 Question

This work deals with practical issues for creating an engaging game to transfer art historical knowledge. As the game does not aim at a specific user group and should reach a broad audience it should rely on general concepts for serious games and try to adopt best-practise ideas from existing games. The target for the developed software will be mobile platforms and therefore issues about advantages and disadvantages of mobile computing platforms will also be addressed and discussed. Finally some thoughts have to be spent on methods for assessing the outcome of the practical part of this work and how this relates to the used concepts.

To cover these topics throughout the course of this work the following main questions will be considered and will serve as guidance for literature research:

- *Which types of Serious Games are currently available?*
- *Which pedagogic models and ideas are used to reach the goal of transferring knowledge?*
- *Why does it seem that specific models work and others do not?*
- *Which limitations and advantages result from the use of mobile computing platforms and how can they be applied in the concrete context?*
- *How do users interact with the resulting game?*
- *How can the learning success be assessed?*
- *What can be learned from these experiences for future works?*

1.4 Overview

Chapter 2 gives an introduction to the topic followed by the presentation of other related and similar concepts. After this a short historical overview on the origins of serious games and their development until now is given for a better understanding of how this area evolved. Furthermore, current fields of serious games and their properties are presented. To conclude the pedagogic models behind such games are discussed as well as the reasons why this way of learning seems to be successful.

In Chapter 3 the situation of museums in the digital world is illustrated. Challenges but also resulting chances caused by the rapid development of communication technologies are discussed as well as the contemporary adoption of new technologies like

social networks or games within museums. Finally some thoughts are spent on the future development in this field.

Chapter 4 includes some historical background of the development of games and applications on mobile devices. Some economical developments are shown as well as the specifics which have to be kept in mind when developing for mobile use. Finally the subject focuses on the tiresome problem of platform fragmentation but also on proposals for solutions how this challenge can be faced.

Chapter 5 concentrates on the practical part of this thesis and presents the created prototypical game in detail. The game concept and the underlying impelling concepts are explained which led to the current result. Furthermore, the game and its administration Web-interface is described in detail.

In Chapter 6 the focus shifts to the technical background of the created prototype and the surrounding system topography and presents substantiations for the technical decisions made in the course of implementation. An overview on the resulting platform as well as details regarding the internal structure are shown.

Chapter 7 will give a report on the evaluation which was done by releasing the prototype into the public. The observed patterns of user interaction with the game will be discussed besides possible reasons for some of the resulting effects. Additionally, considerations for possible further evaluation are given as well as some ideas for potential future improvements.

Finally in Chapter 8 a summary will be presented together with conclusions derived from the results of the practical part of this work. They are accompanied by an outlook regarding the future development of serious games and the author's closing words on the topic.

CHAPTER 2

Serious Games

2.1 Topic Definition

What are *Serious Games*? Many people don't associate games with useful and productive activity. Games are still often seen as something for spare time, indeed enjoyable but only for leisure time when there is nothing important and productive to do. Playing is considered as relaxation and for enjoyment. According to [Zyd05] dictionaries tend to define games as "*a physical or mental contest with the goal of amusing or rewarding the participants*". The Oxford Paperback Dictionary [HM07] defines games also as "*an activity you take part in for amusement*". These definitions are often extended by the use of computers to define *Video* and *Computer Games*. They all have in common that games should be enjoyable and fun.

Serious games extend this definition of games by an additional pedagogic objective. Serious or educational games are games with the additional goal "*to further government or corporate training, education, health, public policy, and strategic communication objectives*" [Zyd05]. This does not necessarily mean that the educational goal has to be planted into the game by design. In one of the earliest definitions of serious games Clark C. Abt already stated that it is also possible to adopt existing games as educational tools by using them in a specific context [Abt70]. By thoughtful preparation a teacher can also use non-serious games as a tool to support his or her lessons.

Nevertheless, newer serious games are often designed for a specific educational purpose from the beginning. This introduces a new element into game development. Where before the task was to merge story, art and software development to create a result that hopefully is enjoyable and successful, a new pedagogic responsibility has to be taken into account. When designing a game with pedagogic content an important fact is that the entertainment component has to come first. A game has to be entertaining and enjoyable in the first place and instructive or educational only in the second place [Zyd05].

So building a serious game is a more complex task than just taking a regular game and putting educational content into it. This may be possible in some cases but often is not enough. The difficulty is to retain the power of motivation a game exposes and to use it secondarily as educational tool.

To sum up, a serious game does not necessarily have to be designed as an educational tool from the beginning. Also existing games have the potential of being used in a pedagogic environment. On the other side there are games designed with the specific purpose of education. The important point that distinguishes regular games from serious games is that the goal of using or playing these games is not simply entertainment or fun. There are further objectives, which may be learning or education, but also others like training or even advertising. Furthermore, it does not matter whether the game was designed with this goal in mind or is just used in this context.

2.2 Serious Games and Related Concepts

Aside from serious games there are a lot of other related and sometimes overlapping concepts and terms such as *e-learning*, *edutainment*, *game-based learning (GBL)* and *digital game-based learning (DGBL)*. For better understanding a short attempt of locating serious games in this context will follow.

The most comprehensive group probably is defined by the term *e-learning*. According to [HCS01] e-learning relates to aspects of computer-based learning, interactive technology and distance learning (cited from [LST09] and [SJB07]). So it is not limited to the kind of applications which are used but merely to the use of computers connected together over networks. This can include simple forums, via games through to audio or video conferences. The largest advantage of e-learning is that it enables learning over large ranges and in groups of geographically distributed learners [BB10]. People no longer need to coordinate their learning sessions in time or geographic location. Instead, they can connect with each other over the Internet and communicate and cooperate with teachers and each other using the computer as a tool, thus enabling non-parallel, flexible ways of learning. Moreover, this definition does not require that fun or entertainment has to be part of the learning process.
On the contrary, the term *edutainment* is defined as a mixture of education and entertainment and is not limited to games (or video games) but to any form of education that also entertains. It became a popular buzzword in the 1990s and was mostly used for marketing educational media in the era of a growing multi-media PC market [MC06, p.24]. According to [LST09] edutainment tends to focus on playful multimedia learning of themes in the context of schools, for example languages, maths, physics or chemistry. Serious games in principle have the same ambitions and could be seen as some special

form of edutainment. But Michael and Chen even go further and postulate that "*Serious games are more than just edutainment*" [MC06, p.XV]. They differentiate between the purpose of edutainment and serious games by determining that serious games extend the goal of classical edutainment media which mostly focuses on teaching facts and instead reach out to all forms of education, as they also incorporated into their book title: educating, training and informing. They also state that edutainment has a different target audience and mostly focuses on school children while serious games also target adult audiences.

Two other frequently used terms are Game-based Learning (GBL) and Digital Game-based Learning (DGBL). GBL and serious games are also used synonymously like in [Cor06], but Breuer and Bente in [BB10] state that GBL focuses on learning and education purposes while serious games also have application fields outside of teaching and learning (e.g. art, therapy, advertising etc.). While GBL can be done with any types of games (card games, board games, etc.) DGBL represents a further restriction of GBL to the usage of computers and therefore makes it a subgroup of e-learning. In [KRML$^+$08] the acronym Digital Educational Games (DEG) is introduced for games in this category. Prensky who coined the term DGBL in his book of the same name [Pre07] emphasises that in contrast to edutainment for DGBL the content and the learning context have to be coordinated in a way that the user always feels like a player and not like a learner.
Overall there are a lot of similar but still different names and terms for a broad field of overlapping concepts which Breuer and Bente nicely visualised in [BB10] in a graphic which is shown in Figure 2.1. It shows edutainment with its non-abbreviated name "Entertainment Education" as the most outer field which contains GBL and DGBL as the subsets of learning by playing and intersects with the broad field of learning using computers in the form of "e-learning". While e-learning is bound to the use of computers it does not necessarily include fun and entertainment. On the other side, in the centre of DGBL we see "*Classical Edutainment Games*" as the category of classical learning video games which first came up in the 1990s. While all learning games are considered as serious games, this group also goes beyond the learning and education sector and includes other fields like art, politics, advertising, etc. which is shown on the left in Figure 2.1 where the green area extends the entertainment education field. Finally it can be said that all of these terms still hold some fuzziness and are not used consistently within the literature. This may be explained by the fact that the whole field of research still is growing and defining itself.

2.3 History & Development

Games have been part of human society throughout history. Johan Huizinga, a researcher in the field of cultural history, stated in [Hui49]: "*Play is an essential component of all human culture*". He emphasises that play is one of the primary conditions

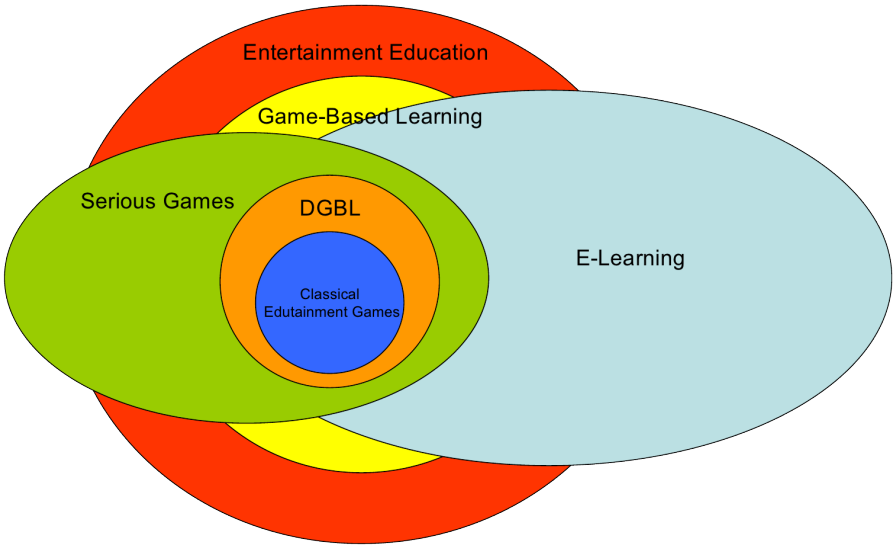

Figure 2.1: Serious games and related concepts *(source: Breuer and Bente [BB10])*

for the generation of culture. But games are not only an essential part of society they also have been used for teaching and learning for a long time. Already Plato established the connection between playing and education. He came up with the idea of thought experiments and hypothetical questions as a playful way to examine opposing philosophical viewpoints to train his students to see both sides of an issue [MC06, foreword]. Later on strategic games like *Chaturanga*, *Chess*, *Go* (*Wei Qui*, *Baduk*)or *Xiang Qi* were used over centuries by military officers to teach strategy [MC06, foreword]. Especially the military has a long history of using games for training, simulation and education. In the first half of the 19th century more complex war simulations were developed like *Kriegspiel* by Lieutenant George Heinrich Rudolph Johann von Reisswitz [MC06, p.51]. This simulation game was played on a physical board and based on drawn topographical maps, and tried to reproduce troop power and position in abstract form. It already had some complex game logic in form of an umpire so that to each participant only those troops were shown which they actually could have noticed in a real combat. In the following centuries military simulations became even more complex to reflect the possibilities of new weapon systems and different troop branches.

But also beyond the battlefield in the 1920s simulation as a training method began to arise in form of first flight simulators [Mar10, p.30]. The first simple prototype built by Edwin Link was motivated by economic reasons because he could not afford flight time to improve his own aviation skills and so he built a very simple prototype. Initially he was not taken seriously by the flight community and his first sales went to amusement parks where his “toy” got known as the “Link Trainer”. A few years later, when a few air force pilots got killed in an accident caused by reduced sight in fog, he could convince

the army that accidents like this could be avoided by training take-offs and landings in a secure environment like his simulator. From this time, simulation for flight training got widely approved and received a significant boom during World War II. Also besides flight simulation the military was a strong compulsive factor in the development of simulation games for training. With the rise of technology in the mid 80s a bunch of different simulations were developed for training and included areas from submarine skills to electrical theory [Ber06, p.2–4].

The second great activator behind the development of serious games was medicine. One reason for this was that medicine already had a tradition of biomedical simulation and modelling at this time and was target of significant governmental funding. The first applications created were Computer Aided Instruction (CAI) systems. Already in 1967 the first computer-aided program "*Tutorial Evaluation System*" for teaching medical students was presented by Oregan State University [Ber06, p.5]. But due to the fact that computer technology was still very expensive at that time, systems like this did not become widely spread. This changed in the 1980s with the upcoming of the IBM PC and the Apple II. The availability of computers rose and the presented solutions became more complex. In 1985 with "*HeartLab*" a first graphical patient simulation for doctors became available which intended to recreate the complete audio-visual experience of a real patient to teach the methodology of cardiac auscultation. Compared with today's simulations it was quite simple, but it was revolutionary for its time [Ber06, p.6].

The term *Serious Games* itself presumably got coined by C. C. Abt in 1970 in his same-titled book [Abt70]. Abt did not directly refer to digital games but described the strategy game "*Grand Strategy*" by Avalon Hill[1], which simulated some of the events in World War I. He observed that playing this game motivated students to start self-motivated research to be able to better play the game [MC06, p.112]. This was one of the first descriptions of using a game in classroom for educational purposes.

In the year 2002 the publication of the game *America's Army*[2] brought broader attention to the topic of educational games. First only meant as recruiting game it soon also found its way into soldier's combat training. In the same year the *Serious Games Initiative*[3] was founded by David Rejeski and Ben Sawyer in the Woodrow Wilson International Center in Washington [UW10] and contributed to the further propagation of the terms *Serious Games* and *DGBL*. In the following years research activity in the field began to increase and first conferences on the topic came up (Games for Health Conference[4], Serious Games Summit[5]) [LST09], [Pre07]. Also in the game industry serious

[1] `http://www.avalonhill.com/`, Last accessed 15/11/2011
[2] `http://www.americasarmy.com/`, Last accessed 12/11/2011
[3] `http://www.seriousgames.org/`, Last accessed 12/11/2011
[4] `http://www.gamesforhealth.org/`, Last accessed 15/11/2011
[5] `http://www.gdconf.com/conference/sgs.html`, Last accessed 15/11/2011

games became an increasingly important factor and already constitute a $20 million per year business [SJB07]. There is no indication that this development is going to change in the near future.

2.4 Fields of Serious Games

Serious games are not restricted to specific educational areas and can be found in a broad range of fields [LST09], [SJB07]. In literature the categorisation of serious games is not done by the type of games but mostly by their application areas. Zyda [Zyd05] states seven areas of serious games: Health, Public policy, Strategic communication, Human performance engineering, Training and simulation, Education and Game evaluation. The organiser of the Serious Games Award in Germany – nordmedia GmbH – defines the following nine categories of serious games: Bildung/Weiterbildung (education), Wirtschaft (economy), Medizin (medicine), Verteidigungssektor (military defence), Politische Kommunikation (political communication), Corporate Game, Educational Game, Health Game and Persuasive Game [Nor09]. Michael and Chen [MC06] identified the following areas for serious games: Military Games, Government Games, Educational Games, Corporate Games, Healthcare Games and Political, Religious and Art Games. A graphical overview on these fields is given in Figure 2.2.

Subsequently, the different categories will be shortly explained, following mainly the categorisation by Michael and Chen in [MC06].

Figure 2.2: Application fields of Serious Games

Military Games

Military has a long history of using games for training strategy and combat. One of the most well known games in this context is *Chess*. Chess is a highly abstracted representation of warfare in pre-gunpowder age. In a military context games have the advantage to be able to simulate complex battle situations by abstraction and simplifications in a safe environment and offer the possibility to explore and train new strategies. The Pentagon alone invests up to $4 billion per year into war-games and simulation equipment [MC06, p.55].

Military games are highly funded and the rise of new game technologies like modern 3D engines allow the creation of very realistic games which are no longer limited to incorporate abstract strategies but allow a realistic reproduction of real-world situations. This allows teaching and training of soldiers' abilities without the need to harm a single person.

Moreover, researchers at the University of Rochester have documented that the playing of video games which include fast-changing game elements improves the efficient processing of visual information. In addition to that, other skills resulting as side-effects of playing video games are highly valuable in a military context. This includes, but it is not limited to, improved multitasking behaviour, improved target differentiation and prioritisation skills, the ability to work in a team with minimal communication, desensitisation of shooting at human targets and an increased willingness to take aggressive actions when needed [MC06, p.58–59].

The publicly most well known game in this area became *America's Army*[6], which initially was used by the U.S. Army as recruitment tool but successfully found its way into soldiers' training and education programs [Zyd05].

Government Games

This branch contains all kind of games in national or regional governmental use excluding the military. These include educating and training games for police, fire-fighters, national agencies, space programs and many more. The idea is to train perilous situations in a safe environment so that in the case of emergency the procedures are routine and the action forces have their mind free of nervousness. One example for a game in this category is the game *Virtuelles Training für Polizeieinsatzkräfte* from Germany, which won the Serious Games Award in Silver in 2010[7]. The game allows the player to simulate realistic training situations where police officers have to act in teams to cope

[6] `http://www.americasarmy.com/`, Last accessed 12/11/2011

[7] `http://www.nordmedia.de/content/digitale_medien/digital_media_cluster/serious_games_award/award/subcontent/gewinner_des_serious_games_award_2010_ausgezeichnet/index.10667.html`, Last accessed 15/11/2011

with the events. All actions and communications are recorded and can be analysed at the end for assessment and future improvement in team work.

A similar concept is followed by *Angel Five*, a game used by the FBI to simulate terrorist attacks with weapons of mass destruction to optimise and train the cooperation with local agencies. The advantage of simulations like these is that they allow to practise the handling of events that would otherwise be expensive or impossible to practise in the real world. One resulting aspect of games in this area is that they often tend to be very specific. They also often go without extra visual enrichments (also called "eye candy") but instead focus on the core competences. For example, the game *3D Wild Land Fire Simulation*[8] only shows minimalistic representation of persons and vehicles but allows detailed configuration of environment settings like wind speed, wind orientation, terrain topology and fuel types to simulate fire propagation as realistically as possible. This example does not have any score calculation algorithm or anything similar neither. The goal of the game is to acquire intuitional experience how to react to different fire situations. This can only be achieved by experiencing as many different situations as possible. As this is already the goal of the game there is no need for other rewarding elements like highscore lists [MC06, p.84 et seq.].

Educational Games

As the educational sector represents the "classical" field where learning occurs, most serious games can be found in this area (see also Section 2.5). This makes it the most interesting field to look at to see how serious games are used and applied. It is also interesting to see if and how the classical approaches of learning are supplemented or replaced with games.

The educational sector includes schools but also higher education institutions like universities. The concept of using games in the classroom is still seen very critically. Although the first uses of serious games were in the context of classrooms, until today the game industry is still trying hard to get their products into the classroom. Already in the middle 1980s, Apple tried hard to sell their newly released *Apple II* computer and launched the *Classrooms of Tomorrow* program in 1985. Later on, as computers with multi-media capabilities began to spread into the average household, the market shifted to the home market accompanied by changes in the games. As pupils at home in contrast to school usually have the choice what they want to do, games had to become more appealing to motivate students to play them during leisure time. At the same time parents were eager to spend money on everything that claimed to be educational to justify the relatively high costs of PCs at that time. This development changed with the availability of the Internet and the new focus shifted to online games and the category of edutainment in general. Although a lot of games are available online now, in 2000 the

[8] `http://www.wildfirelessons.net/documents/3DSims_Overview.pdf`, Last accessed 10/11/2011

market for edutainment had grown to $1.6 billion per year. One reason why gaming in education seems to be so successful lies in the fact that it targets at a younger generation which grew up different from the generation before. Pupils have a rich experience of using computers and playing games and use the new medium more fluently. This is an advantage but also comprises the risk that educational games in comparison with other commercial games may be found dry or boring. On the other hand, teachers and parents generally tend to have concerns on new mass cultural media. This did not start with the rise of video games but is the repetition of similar reactions which were shown when movies, television, comic books or rock'n'roll music came up. Time will show that this new development will not be the end of western culture and modern education but instead should be seen as enrichment to the learning culture [MC06, p.111 et seq.].

Corporate Games

Corporations often have the demand to train and educate their employees for their designated work. Therefore, many companies have incorporated in-house training and education centres. Beginning in the early 1980s, computer-aided education came up as well as other forms of e-learning. This did not change the learning behaviour very much because more or less the same content which was presented before on VHS cassettes or manuals was made available via e-learning and simply was watched on the computer. Apart from that the learning process stayed the same.

This was changed by the introduction of simulation games for instruction. Michael and Chen state in [MC06, p.147] that some skills or complex work flows cannot be easily taught by simple multiple-choice tests or information sheets. So instead of reading and learning, the information games allow to directly involve the learners in realistic simulations with all the desired effects like that they are forced to come to decisions and take responsibility for their actions as they perform them. Another reason for using games in corporations which is also often mentioned by Marc Prensky, the founder and CEO of games2train.com[9], is that also in corporations the generations of employees are changing and a lot more workers come from the younger "*Video Game Generation*" and are more familiar using games. The companies hope that with the usage of serious games for training the motivation of these employees can be increased [MC06, p.147–148], [Mar10, p.63].

There is a broad range of themes for corporate games. It includes games for marketing and distribution personnel as well as games for learning technical procedures and even cultural training like games for making employees sensible to sexual harassment. Furthermore, there are also games for training of new workers like the German game *Das virtuelle Autohaus*[10] (The Virtual Car Dealer) which focuses on the introduction of trainees into the business of car dealers. Another area of corporate games are games

[9] `http://www.games2train.com/`, Last accessed 15/11/2011

[10] `http://www.vah-projekt.org/`, Last accessed 15/11/2011

for recruiting students and trainees to spark interest in fields which otherwise may only be difficult to advertise. One example for such a recruitment game is *TechForce*[11], a game which tries to motivate young people to start an education in the metal or electric industry.

Healthcare Games

Computer games are often associated with negative effects on health. Too long gaming sessions and repetitive movements during gaming can cause stress and injuries to the human body. Nonetheless games are also a valuable resource in the healthcare business.

One usage scenario is in the field of mental health. Games can be used as distraction to lessen pain. Also in case of phobias simulations can be utilised for confronting patients with the objects of their pain in a safe, simulated environment. Another use lies in diagnosing mental disorders like attention deficit and hyperactive disorders. Games can be used to identify strengths and weaknesses and help to better diagnose mental conditions.

But video games can also promote physical fitness. One of the first successful games in this sector was *Dance Dance Revolution*[12] released in 1991, in which the player has to perform dance movements on a special input controller that is placed on the floor like a door mat. Newer games make use of technologies of motion sensitive controllers or visual tracking to engage the user in physical movement. This type of game – also referred to as *Exergames* – nowadays overlaps with the home fitness market and is still increasing.

But also in training and education in the healthcare sector games are playing an important role. In 2004 an interesting study [RLH+04] was presented that showed that surgeons that played video games three or more hours a week showed significantly better results than their non-playing colleagues. They were tested with tasks from the "Top Gun course" – an established course to gain skill in the laparoscopic arena – and it turned out that the gaming surgeons had 37 percent fewer errors and were 27 percent faster at laparoscopic tasks. The authors emphasised the dexterity with the doctors' non-dominant hand, improved two-handed choreography, targeting and 2D depth perception skills [RLH+04]. Keeping this in mind new training games optimised for surgeons become imaginable.

Other games like *Pulse!!*[13] or *Dental Implant Training Simulation*[14] by BreakAway ltd. focus on training simulations of specific tasks with realistic patient simulations

[11] `http://www.techforce.de/`, Last accessed 15/11/2011

[12] `http://en.wikipedia.org/wiki/Dance_Dance_Revolution`, Last accessed 5/11/2011

[13] `http://www.breakawaygames.com/serious-games/solutions/healthcare/`, Last accessed 5/11/2011

[14] Idem.

using a modern 3D engine. The undeniable advantage of these games is that doctors can train difficult tasks and situations over and over again without harming a single patient [MC06, p.180 et seq.].

Political, Religious and Art Games

In contrast to the other groups these kind of games focus not on the traditional knowledge and skill transfer but instead on attitude transfer, so the goal lies more on changing the player's attitude, beliefs or behaviour. Game designers use games as a medium to present their own view on political or religious facts and use the power of expressiveness of the pictures and simulations in a game to make the consumer thoughtful and draw his or her attention to specific topics.

One representative of this class is the politically motivated strategy game *Peace-Maker*[15], which focuses on the Israelian-Palestinian conflict and tries to show the player in an unbiased way to understand both sides of the conflict, thus delivering the message that only compromises on both sides may lead to a stable result (in the game as well as in the real life) [MC06, p.203 et seq.]. But not only political topics can be mediated with games.

An example dealing with environmental problems is *Power Up*[16]. In this game the player has to save the planet "Helios" by using renewable energy forms. Another game that tries to bring attention to humanitarian problems is the game *Food Force*[17] released by the United Nations, which encourages the player to think about hunger in the world and shows up logistical challenges of delivering food during humanitarian crisis

An example for a religious game that tries to transport Christian ideology is *Catechumen*[18] by *N'Lightning Software*, where the player is exploring the world of the ancient Rome and has to fight Satan's minions and to rescue captured Christians [MC06, p.217]. Other games are spin-offs of existing religiously themed products, like the *Veggie Tales*[19], which are tales retelling popular bible stories where the central characters are represented by computer-animated vegetables. Based on these themes a number of small online games for children have been created.

In art games the artistic expression of the creator is the most important aspect of the game. Artists make use of games to express something from within theirselves like artists do also with other mediums. This makes art games by their nature to very personal projects [MC06, p.221]. One example for this kind of games is *Velvet-Strike*[20]

[15] `http://www.peacemakergame.com/`, Last accessed 4/11/2011

[16] `http://www.poweruptheGame.com/home.html`, Last accessed 15/11/2011

[17] `http://www.wfp.org/how-to-help/individuals/food-force`, Last accessed 15/11/2011

[18] `http://www.bmsoftware.com/catechumen.htm`, Last accessed 15/11/2011

[19] `http://www.veggietales.com/`, Last accessed 15/11/2011

[20] `http://www.opensorcery.net/velvet-strike/`, Last accessed 24/11/2011

which is a modification of the popular multiplayer first-person-shooter *Counter-Strike*[21]. Counter-Strike offers a feature that allows player to place temporary graffiti on the walls and floors within the game. Velvet-Strike modifies the game's repository of available graffiti images and adds pictures with subjects of anti-war protests and social and political commentary. Players of Velvet-Strike would log in to popular Counter-Strike servers, rush into the game and place their graffiti on the walls. However, they often get killed very soon by other unamused players [MC06, p.222].

Advertising and Marketing Games

Although not listed by Michael and Chen in their book, others, e.g. [SJB07], [SS08], [BB10], also mention advertising and marketing games as a separate application field of serious gaming. These games are often called *Marketing-* or *Advergames* [Rit08]. As games are a medium which consumers spend a lot of time with they represent an ideal instrument for transmitting messages or meanings on products and brands to a user during play. As serious games are defined as any game that has some additional purpose beyond being fun, this kind of games clearly matches with this definition.

Using games in this context also offers an additional advantage in contrast to traditional advertising. The information flow has not to be limited only to one direction. Marketing researchers can use the implicit feedback of game users to derive customers' opinions and preferences. For example, researchers may let users customise items or products within a game and monitor which colour or accessory is used the most. But according to Ritterfeld [Rit08] especially marketing games are often of ridiculous quality and there is much room for improvement.

2.5 Distribution of Serious Games in Different Areas

In 2007 Ritterfeld made a survey with 650 publicly available serious games in English and published how application fields were distributed in [Rit08]. It turned out that around 63% of games were used in educational context in schools, 14% were games aiming at society changes, which would match in the category of Political, Religious and Art Games above. Another 10% of games were used in corporations for employee training and qualification. 8% could be assigned to healthcare games, 5% were used in the military sector and only 1% were used for marketing and advertising. As there are no newer numbers for comparing yet, it cannot be said how this distribution is changing, but it shows that the traditional sector of schooling and education is one of the most important application areas for serious games.

[21] `http://www.valvesoftware.com/games/`, Last accessed 24/11/2011

2.6 Economic Considerations regarding Serious Games

Game developing is a big business. According to PricewaterhouseCoopers in the year 2008 the video gaming market will reach $55.6 billion [Ber06, p.293].

Nevertheless, developing serious games represents a relatively new field in the industry. For the big players in game development business the entertaining gaming industry is still mostly the only game market. On the one hand this means that there are still a lot of opportunities for game designers to explore, but on the other hand this fact also brings some economical risks due to the lack of experience in this young market [Ber06, p.289 et seq.].

The positive aspect is that, as this field in the market is relatively young, there are still lots of possible clients and application areas to be discovered. Also the willingness of customers in industry to spend bigger budgets in serious games is increasing, as shown by a survey from Michael and Chen in spring 2005. They asked educators, developers and researchers involved or interested in serious games how big the budget of their last serious game project had been, and 27.87 percent of the interviewees stated that it had been bigger than $500,000. 16.39 percent told them that it was larger than $1,000,000 and 1.64 percent answered that it was even more than $10,000,000 [MC06, p.247]. According to [SJB07] the serious games industry had already become a $20 million per year business. This clearly shows that this market is about to mature and becoming a serious sector in the business of game development.

Another positive aspect of developing serious games is that the projects are often tailor-made on a specific purpose for one unique customer in industry or education so there is less uncertainty regarding funding and sales on the open market. Also from the view of a customer a serious game offers good value for the money he or she spends on the game [Xin08]. On the other hand, there are also some barriers that hinder game developers from entering this market segment. Despite all the stated positive aspects and the fact that a lot of serious games have already been developed, from the point of a game manufacturer's view there is often still no proof of value of investing in serious games. It costs additional time and skills to work with educational content and often it is difficult to acquire the needed kind of information even from the customer. Moreover, such games are strongly dependent on cash flow from the customer and especially smaller software developing companies could not handle an unexpected stop of funding. And as a last but common reason the fear of failure has to be listed. As with every new field of business there is an increased risk when entering a new territory, which may present an additional barrier for entering the serious gaming market [Xin08].

2.7 Pedagogic Models and Serious Games

Every game involves learning, even if it is only to learn how the game is played or which strategies are the best to win. This is also true for every digital game where the player not only has to learn how to use the technology (how to turn on the device, how to launch the game) but also the basic game interface (which button to press for starting a new round) and the game logic itself. When talking about a serious game there is a difference between learning the game itself (how to use the game) and learning what the game is intended to teach. Additionally, simply adding educational content into a game does not guarantee that the resulting game will still be an enjoyable and motivating experience. It also makes a difference how the content to be learned is integrated into a play.

According to the underlying pedagogies in [UW10] three different categories are identified:

The first one is based on behaviourism where the user is rewarded for the correct response to the presented input. Examples for this are games like "MathBlaster!"[22], where the player gets rewarded by shooting balloons when he or she gets a sum correctly. Brain training games also fall into this category. These games often have in common that the rewards (score points, new levels, etc.) are typically separated from the learned content (like in "MathBlaster" where the math problem to be solved is separated from the balloons which the user is allowed to shoot afterwards). The concept behind this type of games is that the user learns by conditioning and gets rewarded if he or she responds to the presented situations with the correct input. The game elements itself can also be used as the gratification elements to keep the player interested. This type of games is often called *edutainment* [UW10] although this term also is interpreted in different or more specific ways. In [SJB07, p.2] serious games are defined with the same goals as edutainment but including "all aspect of education – teaching, training, and informing – and at all ages", and edutainment is characterised as "education through entertainment" which includes any form of education that is fun and not only games [UW10, p.28].

The second group of games is based on cognitivism where the user has to acquire knowledge by combining inputs in different forms like text, pictures or sounds. The user himself or herself is responsible for putting these inputs together, interpreting them and use the achieved abilities to identify and solve problems in the game environment. Exploring virtual games or simulations tend to fall into this category. Also related to this class of games are the ones based on constructivism which means learning by making. Simulations or virtual environments that enable a player to integrate social behaviour as well as feelings or emotions when interacting with other players for example can be

[22] `http://www.mathblaster.com/`, Last accessed 15/11/2011

used for acquiring social skills and also situation-related knowledge (e.g. military simulations to develop convoy driving in a team of colleagues) [UW10, p.29].

Serious games incorporating multiple models for learning can be seen as the third group and newest group. This includes games using constructionism as underlying learning principle where learning is strengthened by having users to explain the learned content. An example would be a physics game containing a realistic physics engine modelling correct behaviour of gravity. The user then could make experiments on his or her own in this modelled environment, for example by throwing objects around, and then has to express the derived coherences in his or her own words. Also games constructed on Kolb's learning cycle based on *experiential learning* [Kol84], which consists of "concrete learning, reflective observation, abstract conceptualisation (forming a theory-based experience) and active experimentation – the decision and problem solving stage" [UW10, p.29] fall into this category. In this category the goal is to place the player in settings close to reality to train and teach the participants by experiences within the simulations to optimise their knowledge and skills in real life situations.

Different pedagogic strategies allow the implementation of different goals. The presented concepts behind serious games are not necessarily distinct. They may overlap and merge one into another and still are in the process of evolvement.

2.8 Changes in Learning Behaviour

Learning by playing offers a completely different access to knowledge. But has it been like this before or are we experiencing some changes? James Paul Gee, the founder of *Games2Train*[23], emphasises in his publications [Pre01], [Pre03] that the learners' behaviour is fundamentally changing. The new generations are growing up completely differently from their parents, grandparents or any generation before. Nowadays an average college student has spent less than 5,000 hours reading in his or her life but over 10,000 hours playing video games, not to mention other technologies of everyday life like Internet, e-mail, cell phones and instant messaging. Prensky postulates that "*today's students think and process information fundamentally different from their predecessors*" [Pre01]. He also quotes Dr. Bruce D. Berry of Baylor College of Medicine, who says that "*Different kinds of experiences lead to different brain structures*" which makes it even likely that students' brains physically may have changed. Whether this is true or not, it seems undeniable that the new generation has adopted completely new thinking patterns. Also according to James Paul Gee in [Gee04] the presence of computers and video games changed the principle of learning. Younger generations develop

[23] `http://www.games2train.com/`, Last accessed 15/11/2011

a different way of acquiring information. As stated by William Winn, head of Learning Center at the University of Washington's Human interface Technology Laboratory in [BW04, p.35], kids who grew up gaming process information in new ways: "*They develop hypertext minds. They leap around. It's as though their cognitive structures were parallel not sequential.*".

Prensky [Pre01] introduces the term *Digital Natives* (in contrast to *Digital Immigrants*). He uses this term to describe the young generations which grew up with personal computers, video games, Internet and see these elements as an integral part of their lives. These new media encourage a non-linear way of working. The structure of the World Wide Web with its hyperlinks makes it possible to explore and consume information in breadth instead of a strictly linear way.

While teachers are claiming that pupils have reduced attention, at the same time students spend hours on playing video games. According to Prensky [Pre01] this is largely because of the old way of learning in schools. Digital Natives are used to get immediate feedback to their action, they are desperate for *interactivity* all of which is not fulfilled by traditional school systems. Regarding to the often claimed short attention spans of students today he says: "*So it generally isn't that Digital Natives can't pay attention, it's that they choose not to*" [Pre01].

This brings up one of the most important issues with learning: *Motivation*.

2.9 Motivation and Flow

One of the key factors to learning is motivation. Especially in learning situations where students learn on their own without direct supervision of a teacher (for example when using e-learning tools) an engaging factor has to be created to encourage students to work with the presented material. Traditionally games are associated with being fun and therefore can act as a strong motivational component. Indeed several studies have shown that for example in mathematics and physics the use of games may improve the learning effect [MSWA07].

However, the fun-factor may not always be sufficient as motivation element in educational game design. According to Kiili [Kii05] games should provide more than just fun. They should support the reflection of possibilities, exploration and experimentation. He states that games are most successful and generate the most positive effect when facilitating the *Flow* experience.

Already in 1975 Csikszentmihalyi discovered that under some circumstances people continue performing activities without noticeable extrinsic motivational factors. They seem to forget the world around them and dive into their activity in complete concentration. He further describes this condition as full immersion in an activity without self-reflection allowing even difficult tasks to be performed without feeling overchallenged or stressed.

He called this state "*Flow*" and described flow as completely focused motivation without the need for extrinsic motivational elements. When experienced under optimal circumstances a person gets involved so deeply in the currently performed activity that nothing else in the environment around seems to matter. Examples for this effect are doctors during surgery, chess players, dancers, computer gamers, rock climbers etc. These activities are all capable of engaging people so deeply that nothing in the world around them seems to be noticed anymore ([Csi75] cited in [Rhe06] and [Kii05]).

Research has shown that the experience of flow also has a positive impact on the effectiveness of learning ([WTR93] in [Kii05]). To let the flow experience happen some conditions have to be fulfilled. According to Chen, Wigand & Nilan cited in [Kii05] flow is divided into three stages:

- Flow antecedents
- Flow experience
- Flow consequences

The antecedents of flow include the following factors: focused attention, a clear set of goals, appropriate feedback, potential control, a perception of challenges that are matched to the person's skills, playfulness, speed and ease of use. The flow experience itself is accompanied by concentration, a sense of control over the activity, time distortion and telepresence and induces increased learning effects and increased exploratory behaviour (flow consequences) [Kii05].

Especially the effects of concentration and increased learning success are highly desirable when designing an educational video game. To enable the effect of flow as many as possible of the identified flow antecedents should be supported by a game's design.

Playfulness and ease of use should be regarded when designing the game's user interface and mechanics and are considered as related to the game's usability. Giving a clear set of goals and appropriate feedback also correlates with the game concept and its specific representation. But one of the most important tasks is to scale the challenges within the game so that the user does neither feel unchallenged nor overchallenged. If the player's skill level is significantly higher than the challenge he or she may become feeling bored. On the other side if the player's skill level is too low he or she may feel anxiety. In both situations the flow experience will not happen and the user may abandon the game.

To ensure that a user can stay within the flow state the game's difficulty should increase with the player's skill level. Csikszentmihalyi visualised this area of optimal proportion between skill and challenge in a diagram which was adopted by Kiili in [Kii05] (shown in Figure 2.3). He states that the channel of flow can be extended at the

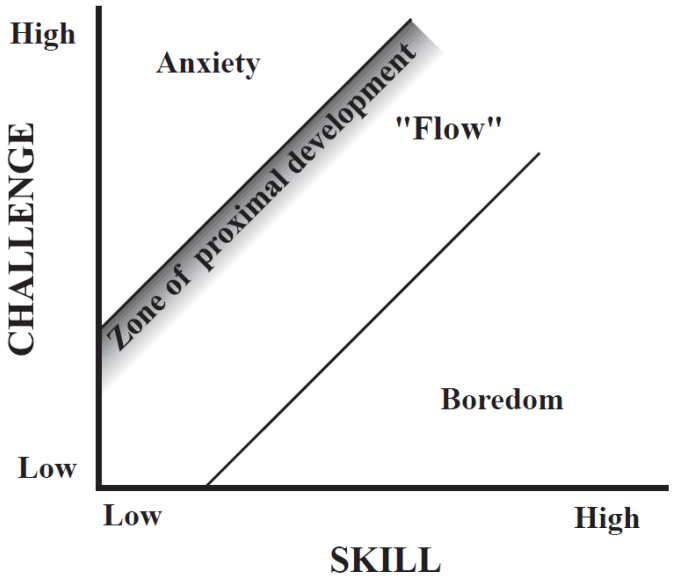

Figure 2.3: Channel Model of Flow *(source: Kiili [Kii05])*

upper end when a player has the possibility to get help by other players. He added a new zone to the flow channel and named this area “Zone of proximal development”.

In conclusion it can be said that a game’s intrinsic motivation by providing fun can be utilised for engaging learners. In an optimal setting beyond just providing fun a game should also lead the player to reach the state of flow. This can be supported by following some basic principles in game design like providing clear goals and feedback and offering the player appropriate challenges based on his or her abilities.

2.10 Advantages of Game-based Learning

In classical teacher-centred learning the focus lies on the content to be taught. The teacher’s work is to preprocess and present the material to the learners. It is not about the “why” or “how”, it simply is stripped down to the “what”. Not the learner but the material to be learned is important.

Nowadays much more learning material is available online or on digital media, but often simply the same content has just been put into a new frame. It has not been adapted to use the possibilities of digital media and often consists of long texts and lacks interactivity. The training in these products is done with a presentation-and-test model which Prensky refers to as a “tell-test” version of the same curriculum as used before in classical media [Pre00]). First the content is presented to the learner (in its old and non-interactive form) and each teaching unit is followed by some kind of test before the learner can continue with the next session. Prensky refers to such products

as "*click and fall asleep-ware*" because these materials do not use the potentials offered by the new media [Pre00].

Computer games as well as self-reflected sustaining learning have in common that they both are active and self-regulated activities. Another commonality is the viability of their content. Viability means that information is relevant for an individual and useful for reaching his or her goals. Especially games tend to offer information that turns out to be useful later on in the game, in other words: it is *viable*. Games also let the user experience immediate feedback and inform the player this way directly of the success of his or her activities and the related learning success. Both points are important for effectiveness of learning [Wec09].

The didactic potential of games lies in their ability to motivate users to become active and acquire abilities of their own. Another positive aspect is that a player can perform actions without pressure or consequences in the real world and therefore gets encouraged to act freely and light-heartedly. This easiness of acting combined with the impulse of self-motivation unlocks the great power of learning by gaming. Despite all these positive sides of game-based learning it is important to be aware of the fact that there is no *Holy Grail* of learning, as different types of knowledge acquire different approaches for learning. Prenksy puts this in a nutshell very nicely when he says:

"*While we hear a great deal of 'this is how people learn,' and, more recently, 'this is how this style of person learns' we rarely, if ever hear 'these are ways that people learn facts. And these are ways that people learn skills. And these are ways that people learn theory. And these are the ways people learn judgement. And these are ways that people learn to reason. And these are ways that people learn to create new things. And these are ways that people learn to change their minds.*"' [Pre00, p.14]

It is important to keep in mind what goals have to be reached within a specific learning context. When designing a game for teaching it should be considered if the intended learning goal is suitable for being covered with a game. However, if nothing contradicts using a playful approach great opportunities lie in the use of a game and new prosperous ways of involving learners in a mature, self-motivated process of acquiring knowledge can be achieved.

As can be seen by the broad area where serious games are applied to playing is a powerful element for motivation and learning and can be used to raise interest in many different topics which otherwise may have been difficult to promote. The next chapter will show by the example of museums that it is not always easy to attract new audiences or to keep them interested. In this context games can provide a valuable additional resource for achieving these goals.

CHAPTER 3

Museums and their Digital Challenge

Constantly evolving information and communication technologies have a great influence on our everyday life in private as well as in business. The availability of the Internet as a global and pervasive communication network opens new possibilities, but the high speed of development also demands a lot of flexibility in analysing and adapting existing work-flows in order to integrate new technologies and use them for the greatest benefit. Also museums and other educational institutions are faced with the challenge to evaluate new technologies for their usefulness while keeping an eye on costs and profitability.

According to the International Council of Museums (ICOM) Code of Ethics for Museums [Mus04] the main responsibilities of a museum are to "*preserve, interpret and promote the natural and cultural inheritance of humanity*".

Especially the first and the third point are the ones most people associate with the main tasks of a museum. Preservation includes physically storing, protecting and restaurating objects of cultural heritage, while promoting involves their presentation to the public. Traditionally this is done by preparing permanent or temporary exhibitions in a physically accessible place like the museum building. One of the main objectives in presenting the exhibits is to attract possible visitors and encourage them to get in contact with the preserved cultural heritage and thus fulfilling the educational mandate by transferring some of the knowledge to the public.

This is not a simple task, as museums are confronted with decreasing public interest, falling visitor numbers and tight financial funding [Sch01]. In this situation the use of new technology may help to find new ways to attract possible visitors or even new ways to present and promote the objects of cultural heritage.

Several studies showed that using multimedia technologies in exhibitions can posi-

tively influence the duration of visitors' stay within a museum: A study at the Japanese Gallery of the Minneapolis Institute of Arts came to the result that the duration of stay in specific areas of the museum increased almost by 400% after multimedia elements had been installed [Sch01, p.95]. In the exhibition "The Art of Persuasion", which showed art from the 17th century, the average duration of stay almost doubled [Sch01, p.95]. These examples show how the work of a museum can benefit from using modern technology.

But this development does not end at the museums' doors.

3.1 Museums on the Web

Apart from the physical location of the museum, the Internet has been discovered as a new virtual and geographically independent room for representing the museum and its content. According to [Sch01] in the year 1998 27 percent out of 3,350 surveyed museums answered that they were providing a Web page. Based on some prominent art museums Arends et al. [AGMW11] found that their Web presence reaches back to 1996 at least. Today a website is not only an essential part of most museums' publication work, also the usage pattern has changed dramatically over time.

Initially Web presences were used for providing organisational information like opening hours, maps of the buildings and the announcement of upcoming exhibitions, thus providing a one-way communication between the visitor and the institution. Later on with the rise of the so-called *Web 2.0*, user participation became a major issue. New social features on the Web have been adopted in different forms by museums. While one group is using existing and established social platforms on the Internet like Facebook[1], Twitter[2], Flickr[3], YouTube[4], etc. to provide additional information to the visitor, others provide own platforms where users can explore artifacts or give feedback in the form of tags or ratings. Such an approach brings the benefit that artifacts get enriched by descriptions in the visitors' language thus making them findable more easily for other visitors. Moreover, in the context of research some projects are emerging which focus on the online presentation of art combined with collecting user feedback like the *explorARTorium*[5] [WAF+11] or *ARTigo*[6] thus also working on the creation of a user-generated folksonomy. Some museums follow a different approach to intensify the contact with visitors by means of Web-based solutions and build 3D-based replicas of their facilities allowing the user to virtually explore the museum or some of the artifacts. A spe-

[1] `http://www.facebook.com/`, Last accessed 15/11/2011
[2] `http://www.twitter.com/`, Last accessed 15/11/2011
[3] `http://www.flickr.com/`, Last accessed 15/11/2011
[4] `http://www.youtube.com/`, Last accessed 15/11/2011
[5] `http://www.explorartorium.info/`, Last accessed 14/11/2011
[6] `http://www.artigo.org/`, Last accessed 15/11/2011

cial type of these environments represents Multi User Virtual Environments (MUVE)s where multiple users simultaneously can interact with the virtual environment or each other [AGMW11].

In a survey in [AGMW09] the websites of 69 museums were analysed on how they were using their Web presence and for their usage of Web 2.0 platforms like Facebook, Twitter, YouTube and similar. The results showed that slightly more than two thirds had some form of "Web-gallery" available which ranged from simple object lists to complex 3D panorama views of exhibition rooms. Taking Twitter as an example for the usage of external Web 2.0 platforms, it was shown that over 31 percent used Twitter as communication instrument to propagate information and stay in contact with their visitors.

3.2 Mobile Applications in Museum Context

Furthermore, besides the classical Web usage a new field of communication is widening in the form of mobile Web devices. More and more museums are discovering the mobile Web as well as applications on smartphone platforms like Apple's iPhone or Google's Android as a new communication channel to their customers. As an example the number of applications for the iOS platform matching the search-term "museum" increased from less than 10 hits in June 2009 up to 130 as of January 6th 2010 according to [AGMW11].

New technological possibilities allow to reach new audiences beyond the physical visitor. While mobile devices already have a history of being used in museums in the form of audio- or tour-guides, the current generation of smartphones allows a lot more usage scenarios. While in previous times visitors had to pay to rent a mobile device like audio guides for the duration of their visit, now it is possible to bring content on the visitors' own platforms, thus reducing the maintenance costs for museums and being able to present new content on mobile devices to visitors for free [AGMW11].

As with websites, there is also a broad field of different application types. Some focus on the on-spot collection of tags or user-feedback like the so-called "*like-o-meter*" [RS06] or provide mobile guidance for physical tours trough the museum like the mobile guide developed by the PEACH project [RS06]. Others like "*The Urban Art Guide Berlin*"[7] are not even focused on tours inside a museum's building but provide guidance to (Graffiti) artworks spread over the whole city of Berlin. Two examples of mobile solutions providing additional information on artifacts within museums are the application "*Love Lace*"[8] of the Powerhouse Museum in Sydney, Australia[9], which shows

[7] `http://www.urbanartguide.com/`, Last accessed 21/11/2011

[8] `http://itunes.apple.com/us/app/love-lace/id447292338?mt=8`, Last accessed 10/11/2011

[9] `http://www.powerhousemuseum.com/`, Last accessed 10/11/2011

additional information on exhibits, creators and background information to the currently running exhibition, as well as the application "*Royal Academy of Arts Summer Exhibition 2011*"[10] of the museum with the same name[11], which focuses on the current exhibition in a similar way.

3.3 Games in Museum Context

Another form of interaction with visitors shown in [AGMW09] is the usage of games. When examining different websites Arends et al. also detected that some museums are using games to introduce visitors into art-historical background.

For example, the Museum of Modern Art and P.S.1 Contemporary Art Center in New York created the online game "*Destination: Modern Art*"[12] addressing young children at the age of 5–8. While this game is focused on getting familiar with the museum itself other projects like "*The Art Zone*"[13] by The National Gallery Of Arts offer several tools to create own artwork mirroring paintings of old masters, giving the user an understanding about details and forms in paintings in a playful way.

These projects have in common that they use games as a medium to reach new audiences and give a good example how otherwise maybe hard to teach information can be conveyed in a playful and enlightening way.

3.4 Future Development

The Web as geographically independent space has become an important factor for museums in reaching visitors and other interested groups. Beginning with unidirectional communication in the era of Web 1.0 the development went to a direction of active user-participation. This is realised by the use of established external social media platforms or museums' own systems providing opportunities for user participation in form of tagging and rating systems or 3D based virtual environments.

Furthermore, games on the Web and within museums are being used to provide fun and entertainment as an engaging element to draw additional attention to art and art history especially among groups of people who otherwise could not have been reached that easily. Moreover, the development of mobile networks and smartphone technology introduced a broad ecosystem of mobile applications including applications in museums' context. At the same time the mobile game market is shifting from dedicated gaming platforms to smartphone systems.

[10] `http://itunes.apple.com/us/app/royal-academy-arts-summer/id440701122?mt=8`,Last accessed 10/11/20 11

[11] `http://www.royalacademy.org.uk/`, Last accessed 10/11/2011

[12] `http://www.moma.org/interactives/destination/`, Last accessed 10/11/2011

[13] `http://www.nga.gov/kids/zone/zone.htm`, Last accessed 10/11/2011

Combining the advantages of games and the mobility and pervasiveness of mobile smartphone platforms, new scenarios for teaching and engaging users in the fascinating field of art history can be realised.

CHAPTER 4

Developing Mobile Games

4.1 Overview

The area of mobile games has experienced an interesting history until it became the field we are looking at today. Although not directly related to gaming, a very first breakthrough in personal mobile entertainment in general was done with the invention of the Sony Walkman in 1979, which was the first mobile device for entertainment. In 1980 Nintendo followed with its "Game & Watch"[1] mobile games series. These games were simple electronic devices consisting of a small LCD screen and some buttons for input. Each device was limited to exactly one game, so for playing another game it was necessary to buy another device. Later on in 1989 Nintendo released the "Gameboy"[2], which allowed to play different games on a single device by simply exchanging cartridges. At the end of the 1990s the focus in mobile gaming shifted to mobile phones and nowadays the term "mobile game" usually refers to digital games played on mobile phone devices [PS06].

Gaming on mobile phones has a distinguished history. It all started back at the end of the 1990s, when most mobile phones had limited features and were equipped with tiny black and white displays. The first game ever published on a mobile phone was "Snake" (see Figure 4.1), embedded first in the Nokia 6110 in 1997 and rolled out later to a lot of subsequent generations of Nokia phones [Bus06].

In these days, the gaming experience was very limited due to the hardware restrictions of the devices at that time. Most phones' displays had no capability of displaying colours and were limited to monochrome and low resolution graphics. The screen size was very small compared with today's devices and had a very low pixel density which

[1] `http://en.wikipedia.org/wiki/Game_%26_Watch`, Last accessed 14/11/2011
[2] `http://en.wikipedia.org/wiki/Gameboy`, Last accessed 14/11/2011

Figure 4.1: Snake – the very first game on a mobile phone *(source: [Xti11])*

resulted in images being displayed in a coarse-grained and pixelated way. Furthermore, compared with today's smartphones, the devices back then offered far less technological features like sensor inputs or networking. Nevertheless, games used the possibilities that were available as well as they could and actually already early versions of Snake offered a multiplayer mode by using the infrared port to communicate with the other player's phone [Bus06].

However, one of the most severe restrictions of this very first generation of mobile games was that they were hard-wired into the devices' operating system and there was no possibility to install additional software or games. This lack of extensibility soon was discovered as a shortage, and subsequent generations of phones were equipped with software development environments which provided an Application Programming Interface (API) for programmers to create and install their own software on these mobile phones. On the one hand native APIs for mobile operating systems like Symbian[3] were released, while on the other hand environments for targeting multiple device types were presented like Java 2 Platform, Micro Edition (J2ME)[4] from Sun Microsystems (now Oracle) and Binary Runtime Environment for Wireless (BREW)[5] by Qualcomm.

While this development opened a broad new field for software developers, it also had its catches. Already in the year 2006 there were an estimated 2 billion cell phone users worldwide, thus theoretically providing a huge userbase for software products targeting mobile phones. But the reality looked different. The large varieties in the devices' hard- and software made it difficult to reach this large audience [Bus06].

At the same time other mobile gaming platforms besides mobile phones were released. In 2004 Sony's PlayStation Portable (PSP)[6] and the Nintendo DS [7] caught the customers' attention by providing processing power and graphic capabilities completely

[3] `http://symbian.nokia.com/`, Last accessed 14/11/2011
[4] `http://www.oracle.com/technetwork/java/javame/`, Last accessed 14/11/2011
[5] `http://www.brewmp.com/`, Last accessed 14/11/2011
[6] `http://at.playstation.com/psp/`, Last accessed 14/11/2011
[7] `http://www.nintendo.com/ds`, Last accessed 14/11/2011

outdoing their mobile phone counterparts at this time. While mobile games until then mostly were played casually, these new platforms also targeted the group of "*true*" gamers, who do not just play casually in between other actions, but perform gaming with deeper involvement and engagement [Bus06]. This group is also referred to as *hardcore-* or *core-gamers* in [KKNP07].

The situation again changed drastically in the last few years with the continuous development of smartphone technologies. Modern smartphones' processing power is in no way inferior to that of dedicated gaming devices and nowadays they are often equipped with efficient graphic processors. Combined with the fact that these new devices tend to become the new digital centre of everyday life, they continuously dig off market shares from devices like the PlayStation Portable or the Nintendo DS [Ana11]. While these two devices have ruled the mobile gaming market for over two decades, they lost almost half of their market share over the last two years. Their stakes fell from 81 percent to 42 percent from 2009 to 2011. Figure 4.2 visualises this development.

The clear winners in this situation are the smartphone platforms Android and iOS from Google respectively Apple, which together now (2011) comprise 58 percent in the market of portable games [Ana11].

Compared to the earlier days when "Snake" was presented, those platforms offer

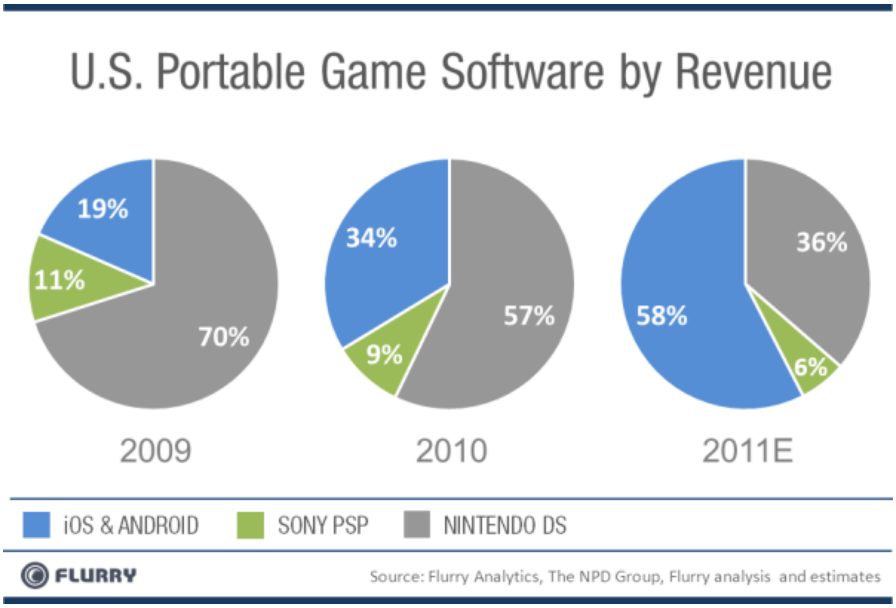

Figure 4.2: Development of mobile gaming market shares *(source: Flurry Analytics [Ana11])*

an incredible number of new technological opportunities for developing games. Not only that their processing power exceeds that of previous devices by multiple times and immersive networking capabilities ensure connectivity at any time and everywhere, numerous additional hardware sensors also allow the creation of "context-aware" applications. These applications enable a new form of user-interaction and understanding by taking into account many external conditions like the user's location, the device orientation, noise or light levels and many more [ADB+99].

Although technological opportunities increased drastically, some of the fundamental problems stayed the same. Platform fragmentation still is the developers' biggest burden. The mobile application market is divided among several major smartphone platforms which are incompatible to each other and again burden the developers with the necessity to develop for multiple different systems. When it was the decision to write software based either on J2ME or on BREW a few years ago (see also Chapter 4.3), it is now the decision between *Android*, *BlackBerry OS*[8] and *iOS*, which were the three top-most used systems in the beginning of 2011 according to [Com11].

In conclusion, mobile game development has undergone a long history of changes and got a huge technological boost in the last few years. It started with dedicated gaming devices in the 1980s, made a short side trip to mobile phones in the years around 2000, just to be overtaken again by the gaming platforms PlayStation Portable and Nintendo DS, and finally seems to move definitely to the new generation of smartphones. While technology evolved, the old problem of platform fragmentation stayed the same and still challenges today's game producers.

4.2 Specifics of Developing for Mobile Devices

Developing software for a mobile device can be a fascinating task. The fact that a device is available everywhere and can be carried around opens new fields of ideas for applications to think about. Especially modern smartphone platforms which offer a rich field of technical capabilities like connectivity to the Internet, GPS-based location data, acceleration and gyroscope sensors, compass, cameras and many more inspire a whole new branch in the software industry.

New sensors open unimagined possibilities for user-interface and user-interaction. For example, the application "*Hoccer*"[9] on the Android and iOS platform uses sensor-based motion detection to allow users to initialise a data transfer between two smartphones by literally "throwing" the data from one device to another. Other applications

[8] Operating system of Research In Motion devices (`http://www.rim.com/`, Last accessed 14/11/2011)

[9] `https://market.android.com/details?id=com.artcom.hoccer`, Last accessed 15/11/2011

like "*Google Sky Map*"[10], which shows a map of the night sky, use the device's orientation to determine which part of the map should be shown on the display, thus providing the user the feeling of looking through a window to the map of stars.

However, mobile computing is also accompanied by some disadvantages and limitations which may embody development barriers and have to be considered when developing applications. At first the performance of mobile devices is limited compared to regular PCs. Another point to be considered is the latency of wireless networks. While in classical development environments developers mostly can rely on a working and reliable network connection, on mobile devices the network connection often provides higher latency and may even be unavailable [Xin09]. Moreover, the smaller size of screens puts additional responsibility on the developer to consider this limitation when designing a user-interface. Content has to be carefully formatted to match the screen's limited capabilities. User interface guidelines like presenting most important content first or considering alternate forms for navigation that are optimised for using less space (like transparent widgets or navigation layers) can help in finding a viable design [KL02].

Another point to consider is the different context and situation of users of mobile games and applications compared to traditional software on a personal computer or games on a console at home. On mobile devices users often do not have as much time or patience to concentrate on long gaming sessions as compared to fixed-location computer devices. However, users tend to play more short playing sessions instead of a few long ones [Koi06]. Taking this into account it seems advisable to design mobile games and applications in general in a way that they support usage over several short time slices instead of a single big one. Additionally, on mobile phones externally triggered events like incoming calls or short messages may interrupt an application's life cycle.

Regarding the propagation of mobile games Koivisto mentions in his paper in [Koi06] the possibility of *cross-platform* and *cross-media* games. While cross-platform games are applications distributed on several different (mobile) platforms, cross-media games are applications that are not only limited to the mobile platform, but may also have a counterpart on other platforms like personal computer, gaming consoles or in the form of Web games. For instance, in a game applying this distribution concept a player may acquire some points or skills in a virtual world on his or her phone and later on use these items when continuing the game in the Web-browser.

Another hindrance to be considered is the quickly fluctuating hardware of mobile devices. While being more of an issue before major smartphone operating systems like Android and iOS absorbed the market, the rapidly changing and quickly outdated hardware presents an essential burden for developing mobile applications as stated in [Xin08].

[10] `https://market.android.com/details?id=com.google.android.stardroid`, Last accessed 15/11/2011

4.3 Cross-Platform Solutions on Feature Phones

According to Wikipedia[11] *feature phones* is a course-defined term for low-end phones that also offer some organiser capabilities like calendars or clocks and alarms but have none of the typical smartphone features like WiFi and mobile broadband access, touch-screen displays, GPS navigation, etc. available. These devices focus on the core features of a mobile phone namely being able to place calls and sending short text messages (SMS). They were the predominant type of phones in the pre-smartphone era.

At the end of the 1990s the first programmable mobile phones (feature phones) with an API came up which allowed third-party applications to be developed. As different platforms offered different APIs, soon first efforts were made to create environments or toolkits to develop once and deploy on multiple devices.

Java Platform 2, Micro Edition

One very widespread development platform was Java 2 Platform, Micro Edition (J2ME). In 1999 J2ME was released by Sun Microsystems with the aim to bring their Java programming language to the new segment of mobile and embedded devices. To abstract the large variety of target devices and their different capabilities every target system declares "profiles" it supports. From a programmer's point of view one has to declare profiles which the application wants to use and this way narrows down the list of possible target devices. Until today one limitation of J2ME is that it is still restricted to the features of Java Runtime Environment (JRE) 1.3, thus excluding a lot of important new features of the modern Java language like for example "Generics" [Wik11b].

Technically the platform is structured similarly to the classical Java 2 platform. The written code gets compiled into a special format, known as "bytecode" which is readable and runnable on the Java Virtual Machine (JVM). Implementations for the JVM are available for different platforms and devices, thus enabling J2ME-code to be run on many different hardware platforms [Wik11b].

Binary Runtime Environment for Wireless

Binary Runtime Environment for Wireless (BREW) is a Software Development Kit (SDK) targeting phone platform in the non-smartphone segment. In contrast to J2ME, BREW is not providing a virtual machine but instead is running native code. To achieve this the BREW runtime library has to be shipped as part of the target operating system, thus making BREW a part of the target system. Because of this fact BREW sometimes also is called a "pseudo-operating system". In fact the API BREW offers is similar to system level APIs on other operating systems. The programming language used is

[11] `http://en.wikipedia.org/wiki/Feature_phone`, Last accessed 15/11/2011

C and C++. BREW focuses on non-smartphone mobile phones which sometimes are also called “feature-phones”. The clear distinction to smartphones can also be seen in a current case study[12] on the BREW homepage, where a clear differentiation is made between “Smartphones”, “Brew Phones” and “Non-Brew Feature Phones” [Wik11a], [Bre11].

4.4 Overview on Cross-Platform Solutions for Smartphones

As BREW and J2ME are not primarily targeting smartphone platforms like Android or iOS, other solutions have been developed to address the demand for multiplatform programming on smartphones. As a result, a lot of different frameworks emerged in the ecosystem surrounding Google’s Android and Apple’s iPhone platform. The diversity of available solutions is reflected in the variability of targeted applications as well as in the concepts used behind.

For example, J2ME uses the concept of a virtual machine. This runtime has to be implemented for all target environments and represents an abstraction layer where application developers can base their code on. BREW does this in a different way by enhancing low-level system APIs which implicates the need for modification of all target systems by means of including the BREW library.

Smartphone platforms offer a richer software stack than feature phones, including powerful engines for rendering Web pages according to modern standards. This enabled a new approach for targeting multiple platforms by moving applications on the Web. Web applications which are optimised for use on mobile phones have the advantage that they do not have to be installed on target devices. By the use of new emerging Web technologies like the upcoming standard HTML5[13], applications with a broad range of functions can be built. From a developer’s point of view HTML5 and related technologies offer new APIs for additional features like the user’s geo-location or data storage on the device for offline use and allow to come closer to the richness of features of native applications. As stated before the biggest advantage of this kind of application is their availability. In principle they should be accessible with any device supporting the corresponding Web standards like HTML5.

This is an important point to consider. As emphasised by Tim Berners-Lee, the inventor of the World Wide Web (WWW) [BL10], the Web only became so successful because of its openness and universality. If information is only available by use of proprietary devices or protocols the risk of segmentation comes up. This inequality in the

[12] `http://www.brewmp.com/sites/default/files/press/pdf/comScore_brew_whitepaper.pdf`, Last accessed 14/11/2011

[13] `http://dev.w3.org/html5/spec/introduction.html`, Last accessed 24/11/2011

ability to access information – also known as *digital divide*[14] – should be avoided in the sense of an open and universal Web.

While keeping this in mind Web applications will always lack possible features compared to native applications, as they are limited to the API offered by the Web-browser, which on principle is located at a higher level of abstraction than the API offered by the platform itself. Therefore they cannot access additional functionality such as different hardware resources like acceleration or light sensors, or other capabilities of mobile platforms like sending text messages or placing calls.

This gap between native applications installed on a smartphone and completely Web-based solutions has been filled by frameworks like "*PhoneGap*"[15], which provides an application environment similar to a browser to developers but with additional interfaces for accessing hardware-related features (like GPS, vibration, light-sensor, etc.). One noticeable peculiarity of this type of applications is that their look and feeling clearly reminds of Web pages as they are rendered by the same engine as used for normal Web-browsing on the device.

To avoid this shortcoming other solutions like "*Titanium Mobile*"[16] use a different approach. They provide a runtime environment which offers a familiar (but nevertheless proprietary) API for application development as used for native development. When a program finally gets packed for distribution, an interpreter engine will be included into the application package. On the target system the interpreter reads the program's code and dynamically calls corresponding native APIs on the target system. From the user's point of view this approach offers the advantage that the resulting applications cannot be distinguished from programs written in the native language of the target platform. As a downside developers have to learn a new API to be able to use the framework.

Of course, as all of these solutions introduce additional software layers between the developer's code and the target system they come with the cost of possible performance loss compared to native applications. While the amount of overhead may differ widely between the usage of a full Web-browser engine or a slim interpreter this fact should be considered when choosing a framework.

To overcome this shortage products like "*XMLVM*"[17] aim to provide a real cross-platform compiler toolchain which produces native code as an outcome. The developer can write in one or several source languages and the compiler transforms this code into the target platform's native language. As this is the most complex approach, this field is still under development and may not be matured enough for all usage scenarios.

[14] `http://en.wikipedia.org/wiki/Digital_divide`, Last accessed 24/11/2011

[15] `http://phonegap.com/`, Last accessed 22/11/2011

[16] `http://www.appcelerator.com/products/titanium-mobile-application-development/`, Last accessed 11/11/2011

[17] `http://xmlvm.org/`, Last accessed 20/11/2011

In general, every multiplatform solution aiming at different target systems is facing the challenge how differences regarding available features or underlying structures are masked or otherwise handled. While Web applications simply provide only a subset of possible functionalities and keep out the rest, the other presented concepts differ whether they offer only the overlapping group of core-features common to all target platforms or provide ways to access extra functionality, for example by means of an additional platform-specific API.

Overall the field of cross-platform development is gaining strong attention as long as there is no single smartphone platform dominating the market. While there are some shortcomings that have to be accepted, the advantage of reaching a broader base of possible users may compensate this drawback.

Having these possibilities at hand considerations have been made how these can be used in the practical part of this work. As stated in Chapter 3 especially museums and other institutions mediating cultural heritage are searching for new ways and technologies to enthuse new audiences with art and art history. As the field of art history still inheres the cliche of being boring or uninteresting this seemed an exciting challenge of trying to encourage new target groups by means of a serious game using mobile smartphone platforms.

CHAPTER 5

Practical part: Creating the Game "ARTournament"

In the following chapter the creation of the prototype of the game "*ARTournament*" will be characterised and its determining factors will be described. The target audience as well as the concept of the created game will be identified and explained. Furthermore, a detailed overview on the progress of the game will be presented followed by the presentation of its graphical features.

5.1 Target Audience

The game is not directed at a special group, neither with regard to the age nor the educational level. As it requires reading introductory information and understanding basic game mechanics the minimum age of players can be determined around 8–10 years. The game does not explicitly require any prior knowledge of art history, therefore, no expertise of the player is necessary in this area. Regarding the educational level the game will not make any presumptions on the user's background and is therefore aimed at a variety of different educational levels.

However, the fact that the game will be distributed on a modern smartphone platform limits the group of possible users to owners of suitable mobile phones who are willing and capable of installing third-party-software on their device. As a consequence the resulting group of players will probably not be equally distributed among different demographic groups.

Regarding the usage type of games ARTournament will be associated with the group of *casual games* for *casual playing* (as defined in [KKNP07]). This categorisation refers to the style of playing and not to the type of players. This means that the game generally

addresses all types of gamers including hardcore- as well as casual gamers but focuses on a casual usage pattern meaning that the game can be played during short time periods for example when having a few minutes of spare time during the day like on the bus or the underground.

5.2 Learning Goals

The game enables the transfer of concepts of art history. The contents of the specific levels can be managed and extended online through a Web-based content management system which allows the extension of the learning matters in the future.

In the initial version the game content is chosen to communicate knowledge with regard to the following aspects of art history:

- The ability to associate artworks with different art historic categories:

  The user should learn to name the specific theme of the piece of art presented to him/her. He or she should also be able to confirm or deny the belonging of a given artwork to a specific theme.

- The ability to identify artworks of different epochs:

  When presented artworks of different epochs, a user should learn to identify the one which was created in the epoch of question. Furthermore, it's a goal that the player learns to identify the specific epoch in which an artwork was created by becoming familiar with the unique features of the various eras. As the game focuses on specific themes the resulting learning effects may be limited to these particular categories.

- The ability to distinguish artworks from different regions:

  The user should acquire abilities to differentiate between artworks from the same epoch, which were, however, painted in different regions and therefore influenced by different art schools.

- The ability to identify artworks painted by specific artists:

  The most difficult skill the game is intended to teach is the ability to identify artworks of a specific artist in a group of similar pieces. In the initial version the game focuses on masterpieces by the following artists: *Botticelli*, *Caravaggio*, *Dürer*, *El Greco* and *Velazquez*.

The realisation of these goals is of course directly related to their concrete manifestation in the according levels. Although the individual levels are the result of an

intensive development process, the evaluation showed that some of them may need further adaptations or require redesign. The goal of this initial work was to test and evaluate how instructional and appealing levels based on given data from the database could be designed to match the user's learning abilities (see also Figure 2.3).

The selection of artworks and artists presented to the players and hence the implied learning content were influenced by the availability in the Web Gallery of Art (WGA)[1] database that was used as a source in this context. The WGA is an open accessible database containing over 27.000 reproductions of artworks covering the time-frame from 1000–1900 (for further details on the WGA see Section 5.11). As it is going to be discussed in the course of the evaluation the design of the levels might be improved by using additional metadata during the process of selecting the artworks to use, thereby focusing on the specific needs of the learners.

However, these further enhancements should be part of potential future improvements as the realisation would require additional research that goes beyond the scope of this work.

5.3 Computing Platform

One aim of the practical work was to create the prototype of a game aimed at mobile computing platforms. It's also a fact that smartphones have gained an incredible growth of market shares in recent years. According to a study by ComScore in January 2011 [Com11] overall 65.8 million out of a total of 234 million subscribers in the United States owned a smartphone in January 2011 compared to "only" 42.7 million in January 2010[2]). As a consequence the prototype of the current game should be made available on a widely known smartphone platform thus providing a large market of possible users.

ComScore's study [Com11] also shows that Google's Android platform has reached the top place with regard to market shares with 23.5 percent of all smartphones in the United States. Due to the fact that the author of this thesis is also mainly experienced in programming for the Android platform and has a long job-related history of programming with the Java programming language (which is also used on Android) the initial decision was made that the game should be made available on the Android platform. It was also considered to aim at multiple platforms if this goal was achievable with a reasonable amount of work, especially focusing on Apple's iOS platform (including the popular iPhone and iPad products).

[1] `http://www.wga.hu/`, Last accessed 4/11/2011

[2] `http://www.comscore.com/Press_Events/Press_Releases/2010/3/comScore_Reports_January_2010_U.S._Mobile_Subscriber_Market_Share`, Last accessed 14/11/2011

This way the focus shifted to multi-platform development frameworks as discussed in Chapter 4.4. If a framework fulfilling all the requirements for the prototype could be identified it should be used for realising the game ARTournament.

5.4 Game Description

The game is called *ARTournament* and represents a classic guessing game. The idea was to assign the player a specific goal while showing him or her multiple artworks that provide the possibility to guess which of the presented images matches the given task. Based on a short initial briefing and immediate visual feedback on his or her guesses the player should soon learn to distinguish between artworks that belong to the given context and those that do not. Immediate and clear feedback should support the player's experience with regard to the flow of play and is supposed to be beneficial to his or her learning process [Wec09], [Kii05].

For the visual representation of the artworks different implementations have been discussed. In a first practical study a representation in form of a flow of floating artworks were considered. The images on the screen floated from the right to the left side in a constant movement. The user still had the ability to either stop or move back and fourth in the stream by tap-and-move gestures to the left or the right (see Figure 5.1) but the stream continued its movement as soon as the player released his or her finger. With a single tap on an artwork a user could select and mark the artwork as a corresponding image to the level's criteria.

Figure 5.1: Screenshot of an initial design study using floating artworks

After discussing this first approach the idea was dismissed because the user interface tended to be overloaded confronting the user with too much information. Additionally it put temporal pressure on the player because the images would constantly move out of sight. Furthermore, this concept did not allow a detailed representation of the artworks in full-screen size.

As a consequence the decision was made to create a user interface which does not put temporal constraints on the gameplay meaning that the player has sufficient time to study and enjoy the artworks in detail. Additionally the possibility to view the artworks in full-size should be included enabling the user to inspect details and zoom into the piece of art if he or she wants to. Experienced power users should, however, still be able to navigate through the game in their preferred speed. As a result of these considerations a grid-structured user interface was chosen that presents four illustrations of masterpieces at once (see Figure 5.2) and offers the possibility of opening a detailed view by double-tapping on an item. This design adaptations also influenced the game mechanic as they now changed from a continuous flow of items to discrete bundles of four artworks. Each of these quadruplets contains one "correct" item that the player has to identify. In order to do that the player simply has to tap on an artwork once thereby be marking it with a blue star-shaped icon. It is possible to undo or change the selection until the player presses the "Ok" button in the lower section of the screen which confirms the decision and causes the display of the feedback. Feedback on the user's choice is displayed immediately and in form of a transparent overlay and a prominent

Figure 5.2: Screenshot of the final game design, showing 4 pictures at once

icon covering most of the display. For additional visual feedback the icons are kept in the signal colours red and green. After confirming the results by tapping the "OK" button again, the next round of four images is displayed.

5.5 Player Motivation and Score Mechanism

As stated by von Ahn and Dabbish in [vAD08]a game should provide the following features to increase the player's enjoyment:

- *score keeping*
- *high score lists*
- *timed response*
- *player skill levels*
- *randomness*

One of the most efficient ways of motivating players is to assign points for each successfully solved task, thus providing a stimulus for playing the game. Therefore, a simple scoring mechanism is implemented in the current version of ARTournament. The scoring system rewards correctly identified artworks by adding a fixed amount of points to the user's score depot depending on the level. In order to avoid player's frustration there is no penalisation for wrong answers.

To keep the user motivated the score values are kept continuously and outlive restarts of the game, even user relocations to a different device thus fulfilling the suggestion from [vAD08] to keep score values. As the game mechanism itself is already designed to use a client-server model the decision was made to additionally submit the score values to a centralised webservice and use this service to synchronise scores across device borders.

In fact the same webservice is used to provide a global device-spanning high score list which also corresponds with the "player enjoyment criterion" stated in [vAD08]. Hence, an all time global highscore list, which takes all game sessions that have ever been played into account, is provided in the first version. To avoid demotivational effects for new players only the three users in the list above and below the player's own score value are shown instead of the entire list. Feedback from players, however, indicates that there is a demand for other score-related rewarding systems. As a potential enhancement of the game additional highscore lists limited to a specific time period could be included. A possible solution in this context might be weekly or monthly lists that complement the all-time global hall of fame. While this types of highscore lists

have not been implemented in the current version of the game it should be considered for future improvements (see Chapter 7.6). Von Ahn and Dabbish also mention this type of score rewarding in [vAD08] by stating that providing different types of lists provides additional multi-level goals to the game, thus resulting in additional motivation for an extended gameplay.

One of the initially stated factors – providing timed response, which includes putting some temporal limit on the gameplay – was intentionally left out of the game design. As mentioned in the previous chapter one of the goals was to give the user temporal freedom to explore and enjoy the pieces of art, which resulted in the fact that a time limit for solving assigned tasks was omitted. While it is mentioned in [vAD08] that a time limit may provide additional challenge factor, providing the ability to explore artworks without pressure was considered more important.

To provide challenges and train different skills an approach of interdependent level stages with increasing degrees of difficulty has been chosen. At the beginning the player is confronted with a limited range of simple levels which serve as starting points into the game's thematic field. As time goes on and the player's ability constantly increases more levels with increasing degrees of difficulty get unlocked. The selection of currently available levels roughly represent the player's acquired skills.

As additional motivational element randomness with regard to the artwork selection process is included in the game mechanics. To avoid that the user gets tired of playing the same levels over and over again the selection process for artworks is not based on particular items but focuses on the query for specific metadata criteria instead. This way a level – even if it is played a number of times – never looks exactly the same even though the same goal and degree of difficulty is provided.

5.6 Level Progression and Dependency

As mentioned in the previous section, the game provides different interdependent levels in order to ensure a gaming experience with increasing degrees of difficulty that match the player's learning process.

The goal of the game design was to provide interdependent relationships between different levels so that specific tasks have to be solved before others. On the other hand, some degree of freedom of choice should be offered to the user. Therefore enforcing a concrete order of playing levels was avoided. The aim was to allow the players to choose levels related to their personal interests within the framework of the levels offered. Additionally, it should be avoided that a user has to quit the game just because he or she fails to solve one specific level.

To achieve this goal levels have been categorised in groups of the same difficulty which is indicated with the term *stages* in the management interface of ARTournament. Each concrete level is assigned to a particular stage and has assigned zero or one stage as

Display name	Description	Score for correct answer	Stage	Required stage	Goal Total	Goal In_a_row	Actions
1: Genre	Lerne das Genre von anderen Bildgattung zu unterscheiden. Es werden immer 4 Bilder angezeigt, wobei eines zur Bildgattung Genre gehört. Hinweis: In Genre Bildern werden Szenen aus dem Alltagsleben gezeigt. Versuche immer das **Genre** zu entdecken! ;-)	1	1	*--none--*	0	5	Edit Delete
1: Portraits	Lerne Portraits von anderen Bildthemen zu unterscheiden. Dir werden immer 4 Bilder angezeigt, wobei eines ein Portrait darstellt. Versuche immer **das Portrait** zu entdecken! :-)	1	1	*--none--*	0	5	Edit Delete

Figure 5.3: Screenshot of the management interface showing level details

precondition to be played as can be seen in Figure 5.3. Thus a specific level is unlocked for the user as soon he or she has solved any of the levels associated with the stage which is considered as a precondition for the particular level.

As a result of this design a player does not necessarily have to solve all level in lower stages to reach the higher counterparts. Hence, the freedom of choice when selecting levels and room for personal interests and dislikes are guaranteed without losing all forms of dependency between different levels of difficulty.

Figure 5.4 shows a visualisation of the resulting level graph. Each circle represents one specific level. The grey-coloured nodes on the left side represent the entry-point levels which do not have any stages as preconditions. Hence, these points are visible on the game device from the very beginning before a single round needs to be played. When a first-time user starts playing the game he or she can only choose between these initial levels. After he or she has solved any of the levels in the first stage all levels from stage two become available.

5.7 Level Goals

In the last section the term of “solving levels” has been used. It needs to be clarified how “the solving” of a level is defined. Due to the fact that the levels and their content can be managed dynamically by means of a management Web-interface the goals that need to be achieved for unlocking the levels of subsequent stages are also supposed to be defined dynamically. In the current implementation of the game two relevant factors have been specified for declaring a level as “solved”: The number of correct user inputs in the current round altogether and the number of correct answers in a row.

In the course of configuring the levels, the game administrator can choose if the first, the latter or both conditions have to be fulfilled in order to declare a level as solved. Also

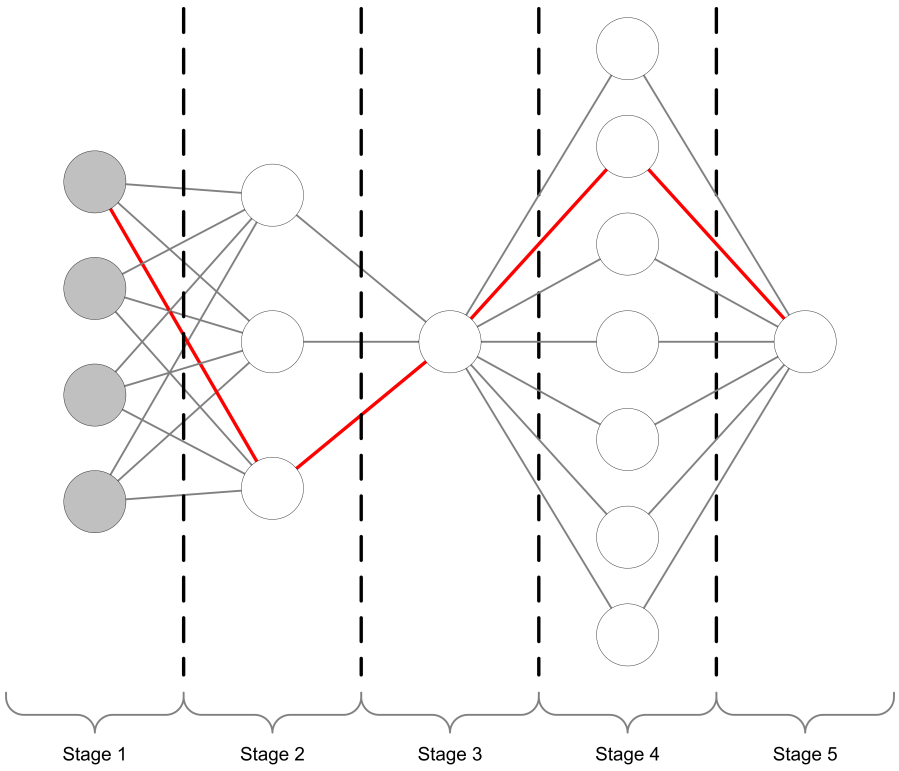

Figure 5.4: Visualisation of all possible paths through the level graph, highlighting one exemplary path in red

the concrete number of correct answers can be determined dynamically thus allowing to adapt the degree of difficulty that is necessary to "solve" the level.

5.8 Interaction Pattern

As a consequence of the described game mechanics a regular pattern of interaction between the user and the system is possible. In the course of gameplay each interaction represents a point where some kind of information is transferred between the two parties (player and game).

The initial action comes from the player when he or she selects a level to play. The information which is transferred from the player to the game is the level which should be started. At the beginning of a level information from the system to the user is transmitted in the form of the initial presentation of the level's goals and in form of a short introductory text helping the user to achieve the level's task. The content of this information can be edited freely by the game administrator via the management Web-interface.

After a game's round has started a recurrent interaction pattern is emerging. It starts with a system action by presenting information in form of four different artworks to the user. The player then gives input to the system by selecting one of the four presented options which is immediately followed by the system's feedback on the correctness of the given input. This information is accompanied by additional hints with regard to the current state as well as the requirements that still need to be fulfilled in order to complete the level. (i.e. telling the user how many correct guesses he or she is still missing for level completion).

The resulting interleaved pattern consisting of alternating actions performed by the user or the system is visualised in Figure 5.5.

5.9 Information Flow

In the course of analysing the interaction different streams of information between the game and the user can be identified. On the one hand, there is a stream of explicit information from the system to the user due to the level introduction. This text contains details on the level's goals and hints how to detect the appropriate artworks. Also the system's feedback on the user's input is information flowing from the game to the user.

These two streams to the user form the input from which he or she is might acquire

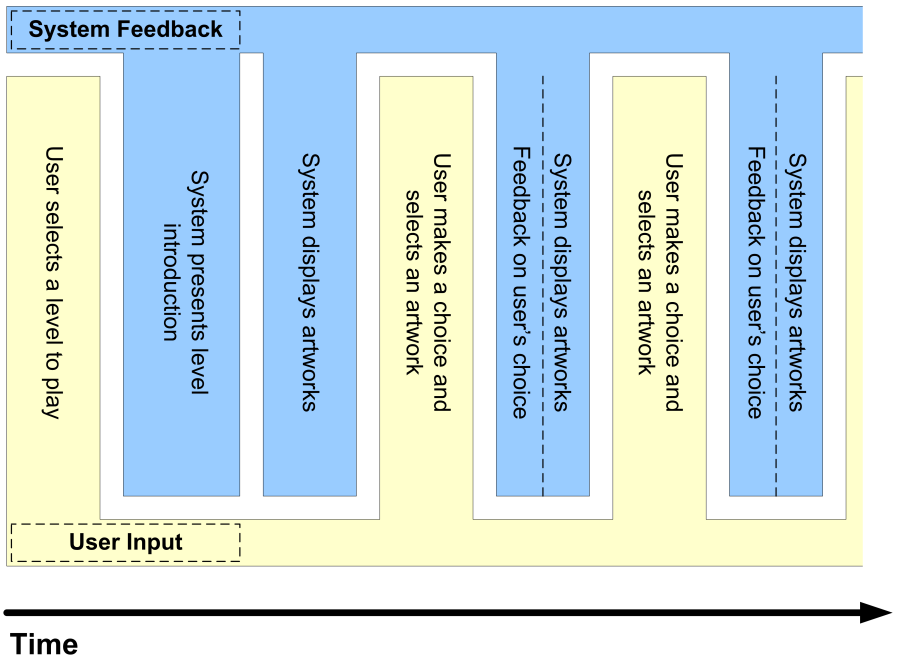

Figure 5.5: Visualisation of interaction pattern between user and game

new knowledge during the game. According to the classification of different pedagogic models in Chapter 2.7 the game may be associated with the second group where the player acquires knowledge by combining and interpreting different inputs based on the concept of cognitivism. The user gets feedback whether a specific artwork was identified correctly according to the level's goals but he or she has to gain the essential information implied in the current level for him- or herself. In other words, it is expected that after having made a few mismatches the player will become familiar with the features the current level seeks to convey thereby acquiring knowledge about this specific area of art history.

Another important aspect that needs to be taken into consideration is the data the user of the game implicitly provides for the game's operator. By analysing the user response patterns with regard to specific levels or even single pictures new insights may be exposed. One example in this context might be related to the typical response patterns within a specific level, which may expose information related to the question whether the task of a specific level seems to be too difficult or too easy for the majority of users. Based on the assumptions derived from the learning model, an improvement in the player's answers should be recognisable in the course of time. If that is not the case the level may need redesign.

Moreover, the result information with regard to concrete artworks may provide additional knowledge in this context. The fact that one concrete item of a particular level is remarkably often erroneously identified as the correct answer may indicate that this artwork might inhere some of the principles that are taught in the level's context. In combination with data-sources from other applications (for example art tagging tools such as the explorARTorium[3] or similar ones) this back-flowing information stream may provide valuable information for further research.

As a future enhancement this information backflow could be enriched by means of additional feedback features within the game, such as the possibility for users to rate the individual images or provide custom tags for specific art objects.

5.10 Content Management Features

As it has already been stated before, the game was not designed to simply convey static content in the individual levels but to provide a range of randomly selected images matching the specific level's criteria instead. In order to achieve this goal the selection of the chosen artworks representing the various levels was based on a given set of query criteria provided by the metadata of the artwork database that was used as the main source in this context. This means that the levels are not created by specifying the individual artworks shown but by defining a set of query criteria on the metadata used to

[3] `http://www.explorARTorium.info/`, Last accessed 14/11/2011

select the items. Additionally, some information on the level itself needs to be provided to complete its definition (i.e. its name, the stage level and required stage as well as the introductory text). The range of possible query criteria for the image selection process is limited by the available metadata provided by the artwork database used in this context (see Section 5.11 for details).

As the games uses a server-based design the user interface for the level administration was made available online in form of a Web application. Secured through a password protection this administration interface allows the management of existing levels and the creation of new ones. The available query criteria are presented in form of check-boxes and drop-down menus so that a game administrator is provided with an easily usable interface. In order to get a visual feedback whether a set of chosen criteria is suitable for creating a level, a preview function is provided. Based on the current selections, artworks will be queried from the database in the same form as the game engine would do it thus allowing the game administrator to assess the outcome of his or her selection.

As for some topics only a small set of artworks is available in the database in addition to the preview images, the number of total results based on the given query are therefore displayed, in order to avoid that levels with a small amount of available artworks will be created as this might result in the fact that certain objects would be repeated too frequently. The number of items sufficient for providing a level with appropriate content is related to the administrator's opinion but to ensure at least a minimum of variability and randomness 50–100 artworks should be available.

In Figure 5.6 a screenshot of the management interface is shown. The area with the blue background contains the user interface elements for defining the query selection criterions in the database. Thereby a level is defined by two sets of selection criterions: one for defining the "correct" artwork (in the following called *reference artwork*) representing the level's topic which the player has to identify and a second set for querying the other artworks which function as "wrong" choices for this specific level (in the following called *contrasting artworks*).

The perceived difficulty of a level strongly depends on how much the "correct" artwork differs from the contrasting pieces. Consequently, the difference between the two sets of query criteria should be chosen thoughtfully. The query constraints for the reference artwork are defined explicitly by providing specific inputs for the various metadata categories. This is done by choosing options in the drop-down boxes in the left-most box (with the green border) shown in Figure 5.6. The selection criteria for the contrasting artworks can either be defined by providing explicit values as well or by providing constraints *relative* in relation to the reference artwork. As the reference artwork is selected randomly within the given frame of query constraints, a certain degree of variability with regard to the result of this query is likely. The relative constraints allow to define different criteria based on the concrete randomly chosen reference artwork.

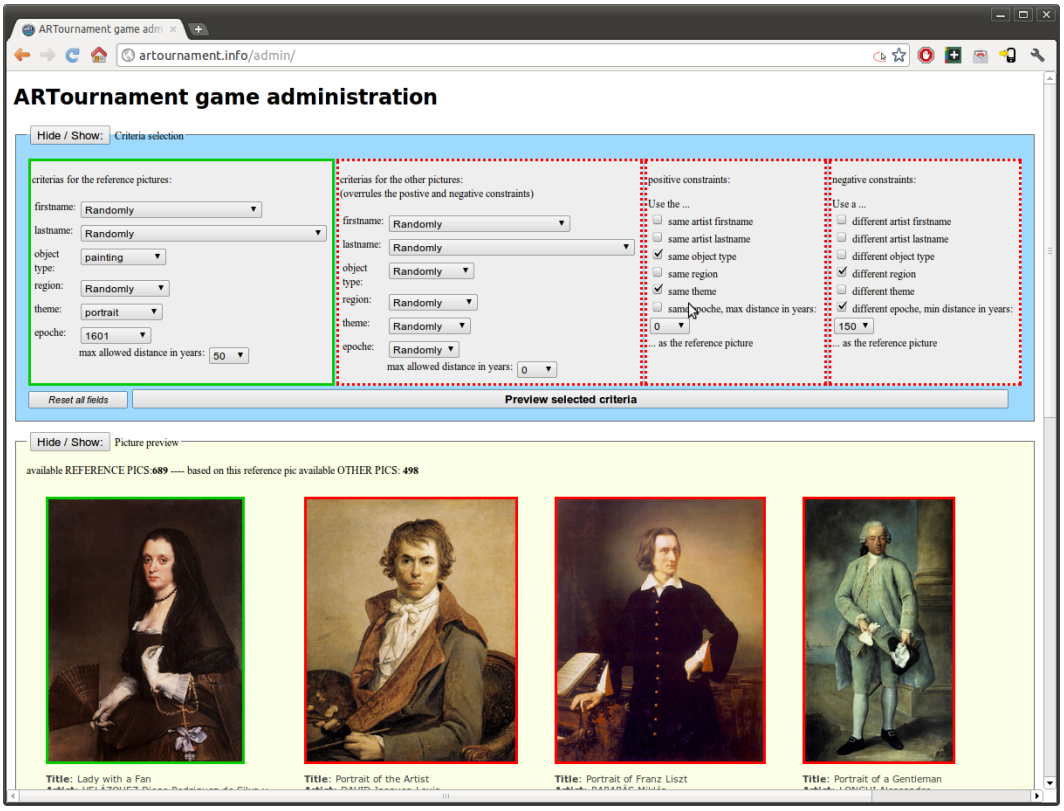

Figure 5.6: Screenshot of the Web-based management interface of *ARTournament*

These constraints are expressed by several assertions of the form: "*must have/must not have the same artist/theme/.. as the reference artwork*".

The user interface elements for defining the criteria of the contrasting artworks are shown in Figure 5.6 with a red-dotted border (the left-most box allows defining the explicit criteria while the other two are used to enter the relative query criteria).

Once a suitable set of criteria is found and verified by checking the preview images they can be saved as a new level. To complete a level's definition it has to be assigned a name, an explaining introductory text as well as a score value (how much points will the user get for a correct answer) and the goals that need to be achieved in order to be able to declare this level as "solved" (see also Section 5.7). Finally, the stage of the level and an optional prerequisite stage has to be added. After the meta-information is saved the level is immediately made available to all gaming devices and may be found the next time a query for the list of levels is done, which happens every time the user starts a new game.

5.11 Artworks Database

Displaying actual artworks to the user is a relevant part of the gameplay. To be able to provide a rich and differentiated range of artworks the Web Gallery of Art (WGA)[4] was chosen to serve as source for digital images. The WGA collection currently contains digital reproductions and metadata of over 27.684 artworks and more than 3.277 artists covering a timespan of almost 900 years from approximately 1000 to 1900 [Wga11].

The WGA database provides a large variety of artworks and therefore represents an optimal data source for the current purposes. The provided metadata covers information on the artist (like the name as well as the date and place of birth and death) as well as on the artwork itself. Further useful information may be found with regard to the time period when the object was created, the school of the artwork as well as the region and the theme of the item.

The full list of data fields contains:

- the artist's full name
- the date of artist's birth
- the place of artist's birth
- the date of artist's death
- the place of artist's death
- the title of the artwork (in English)
- the epoch of object creation
- the museum or collection where the artwork is located
- the town of the museum
- the type of the object (painting, etc.)
- the object's form
- the school of the artwork (region)
- the artwork's measurements
- the information if the image is representing only a detail section or the full size artwork

[4] `http://www.wga.hu/`, Last accessed 4/11/2011

Not all data fields are filled for all artworks, however. Based on the available data considerations were made with regard to the question which pieces of art are suitable for the current purpose of creating reasonable and meaningful challenges for the game.

As the game requires the player to visually identify corresponding artworks only metadata fields could be taken into account which also relate to the visual appearance of resulting artwork in some way. While it is likely that the epoch of the creation of the artwork influences its features considerably, it is rather unrealistic to assume that the place of exhibition can be identified by simply looking at it. Other fields may have an indirect influence such as the artist's birth place as this may indicate the region where his or her work emerged. It needs to be emphasised, however, that a sharp distinction between useful and "unrelated" information appears to be problematic as the two fields blur into each other and leave room for subjective interpretation. Thus, before creating the game a selection of relevant metadata had to be made that will be used for defining query criteria to describe the artworks.

In the course of this process those types of data were chosen that influence the artworks' outcome most significantly. As a result, the following list of metadata records was included in the game logic:

- the artist's name
- the type of the object (e.g. painting, mosaic, etc.)
- the region where the artwork was created (e.g. Greek, Flemish, Italian, etc.)
- the theme (or category) of the artwork (religious, portrait, still-life, etc.)
- the epoch when the object was created (grouped in time spans of 50 years and additionally allowing to define a radius for the allowed distance in years)

This group of selection criterions is reflected in the controls in the user interface on the management Web application (see also Figure 5.6).

5.12 List of Levels

In the course of this subcategory, an overview on the defined levels in the current version of the game will be given as well as the defining criteria and the intended learning goals. As a convention the leading digit in the level name represents the stage in which the level is located. The dependency between stages is defined ascendingly, meaning that the completion of stage 1 is required in order to be able to play stage 2 and so forth.

As the WGA database also contains other art objects apart from paintings a query constraint for all levels with regard to the object type "painting" has been set in management interface. This constraint will not be explicitly mentioned in the list below.

- **1: Genre**
  Goal: The goal is to teach how artworks of the theme *genre* look like. The player should be able to identify genre images when compared to paintings of other themes.
  Reference artwork: Paintings from the time span 1601–1650 allowing a tolerance rate of 50 years showing the theme *genre*
  Contrasting artworks: Paintings showing a different theme (relative constraint)

- **1: Portraits**
  Goal: In this level the user should learn to identify portraits when compared to paintings of other categories.
  Reference artwork: Any painting showing a portrait (metadata field "theme" containing "portrait")
  Contrasting artworks: Any painting showing a theme different to portrait

- **1: Religion**
  Goal: In this level it's the goal to sensitise the user to artworks with religious content (theme: "religious"). He or she should learn how religious themes differ from others. *Reference artwork:* Artworks showing a religious theme
  Contrasting artworks: Any artwork showing a different theme

- **1: Stillleben**
  Goal: This rather simple level intends to show the player how a still life looks like.
  Reference artwork: Items from the epoch 1601-1650 including a tolerance rate of 50 years showing a *still life*
  Contrasting artworks: Any painting showing something else than a still life

- **2: Portraits aus dem 15. Jhdt.**
  Goal: This level in stage two is already intended to be more difficult. Thematically it presents a follow up level to "1: Portraits" the player should deepen his or her experience in recognising portraits and should particularly learn to identify portraits from the 15th century. Since this level is a lot more difficult than its predecessor an additional help is provided by using contrasting pictures that are not only from a different century but also from a different region.
  Reference artwork: Paintings from the epoch 1401–1450 allowing a tolerance rate of 50 years, including artworks from any region
  Contrasting artworks: Items also showing a portrait but created with a different

region than the reference artwork and created in an epoch at least 150 years distant from the reference item

- **2: Portraits aus dem 16. Jhdt.**
  Goal: This task follows similar goals than the level before but addresses portraits of the 16th century.
  Reference artwork: Objects created in the epoch from 1501–1550 allowing a tolerance rate of 50 years, again including artworks from every region
  Contrasting artworks: Artworks also showing a portrait but with a temporal distance of at least 150 years to the reference piece. Additionally, the region must differ.

- **2: Portraits aus dem 17. Jhdt.**
  Goal: This is the third level in the series of identifying portraits of a specific century. This one focuses on items of the 17th century.
  Reference artwork: Paintings originated in the epoch from 1601 to 1650, again allowing a tolerance rate of 50 years, showing a portrait
  Contrasting artworks: As in the two levels before any artwork from a different region and at least with a distance of 150 years to the reference object

- **3: Holländische Portraits**
  Goal: This is currently the only level located at stage three and represents the third degree of difficulty with regard to identifying specific portraits. This time the task is to identify the correct portrait not only based on its creation epoch but also depending on the region of its creation. The goal is to find all Dutch portraits from the 16th century. The idea behind this level was that the player should already have learned how portraits of the 16th century look like in the course of the previous stage and can now enhance this knowledge by learning the difference between individual regions with particular focus on Dutch painters.
  Reference artwork: Paintings showing a portrait from the region 1601–1651, again with a tolerance rate of 50 years and "Dutch" origins
  Contrasting artworks: Artworks showing the same theme (also portrait) and created at the same epoch (allowing a maximum distance of 50 years to the reference item) but from a different region

- **4: Botticelli**
  Goal: This level features paintings of the Italian painter *Sandro Boticelli*. This is the first of several levels that try to transfer knowledge about the characteristics of

paintings created by particular artists. The level's goal is to identify all paintings by Boticelli. In order to provide a little help the contrasting artworks are not only from a different painter but also from a different region.
Reference artwork: Artworks created by Sandro Boticelli, without any further constraints
Contrasting artworks: Paintings from any artist different from Boticelli originated in a different region than the reference object

- **4: Caravaggio**
  Goal: This challenge is constructed similarly to the one before but focuses on the Italian painter *Caravaggio*. The player should learn to identify his paintings when compared to others from different painters.
  Reference artwork: Any artwork that was created by Caravaggio
  Contrasting artworks: Any item which was not painted by Caravaggio and in a temporal distance of not more than 100 years to the reference artwork

- **4: Dürer**
  Goal: This level also focuses on a specific artist, in this case *Albrecht Dürer*. Dürer's work is shown in contrast to other painters and the player is supposed to learn to identify them.
  Reference artwork: Artworks from Albrecht Dürer
  Contrasting artworks: Any object which was not created by Dürer and originated in a different region than the reference image

- **4: El Greco**
  Goal: Like the ones before this level tries to teach characteristics of the painter *El Greco*. In order to provide a reasonable challenge his works are compared to those of different painters all of them showing the same theme.
  Reference artwork: Paintings by the Spanish painter El Greco
  Contrasting artworks: Any other work not by El Greco but showing the same theme as the reference item

- **4: Hieronymus Bosch**
  Goal: Also the pictures of *Hieronymus Bosch* have got a level of their own. The goal is to learn more about Bosch's way of working as well as about the characteristics of his pictures
  Reference artwork: Works from Hieronymus Bosch
  Contrasting artworks: Any other paintings that were created by different artists

but also show the same theme and were created during the same epoch (allowing 50 years tolerance rate) as the reference artwork

- **4: Jan van Eyck**
  Goal: This level is devoted to *Jan van Eyck* and should emphasise his work. Once again the contrasting images will show the same theme and originate from the same epoch.
  Reference artwork: Any art object made by Jan van Eyck
  Contrasting artworks: Objects from different painters showing the same theme as the reference artwork and also originated in the same epoch with a maximum of an allowed temporal distance of 100 years

- **4: Velazquez**
  Goal: This is currently the last artist-centred level and specialises in the painter *Diego Rodriguez de Silva y Velazquez*. Once again the player will have to recognise paintings by Velazquez and should learn to distinguish them from other artworks showing the same theme but were painted by different artists.
  Reference artwork: All artworks from the database created by Velazquez
  Contrasting artworks: Any object not created by Velazquez but showing the same theme as the reference painting

- **5: Expert Caravaggio**
  Goal: This level was designed as a follow up activity to "4: Caravaggio". Once again it's the goal to identify all paintings by Caravaggio but this time the challenge is made harder by reducing the differences between the reference object and the contrasting artworks. Assuming that the player is already familiar with the topics and the characteristics of Caravaggio's artworks after having completed"4: Caravaggio" he or she has to identify his work among others from the same region, showing the same theme and created in the same epoch. When mastering this level the players should have internalised Caravaggio's work and be able too identify it even among those from similar artists.
  Reference artwork: Once again any painting created by Caravaggio
  Contrasting artworks: Other paintings originated by different artists but showing the same theme, being created in the same region and a temporal distance of not more than 50 years to the reference artwork

5.13 Copyright Considerations

Art historic masterpieces underly the same protective regulations for intellectual property like any other intellectual work. In most countries of the world the copyright of intellectual property ends 70 years or less after the death of the creator [Wik11c]. After the expiration of this period the work looses its legal protection state and falls under public domain. Works in the public domain are publicly available and free to use by anyone.

This means that copyright concerns in general are an issue for masterpieces of art as well as for any other intellectual work. In the case at hand the copyrights for the works in the WGA have already expired thus allowing the artworks and representations of them free of use. Nevertheless, this does not necessarily exclude the possibility that the operators of the WGA hold further intellectual rights on their database. Especially the metadata also represents intellectual work and may be protected by further copyright claims. According to the WGA legal statements[5] their content is copyrighted as a database allowing use for educational and personal purpose thus making it possible to be used in the current work.

[5] `http://www.wga.hu/frames-e.html?/legal.html`, Last accessed 18/11/2011

CHAPTER 6

System Description

While the previous chapter focused on the description of ARTournament with regard to its content, this chapter is primarily concerned with a short technical description of the created system.

The architecture is based on a client-server model. In the course of this thesis a practical implementation of both parts has been realised. In the following chapter an overview of both components will be given as well as details about the communication protocol used between the server and the client.

6.1 Motivation for a Server based Platform

The game is intended to represent graphical representations of artworks to the user. In the course of the initial phase of the project, considerations on the storage location of these digital reproductions were already made. The pictures in the used WGA database are stored as JPEG image files with sizes ranging from about 50 to 300 kilobytes. In order to enable a diverse gameplay pictures should not be repeated too often. As the number of pictures needed to design a level should at least consist of 50 pictures, storing the entire content within a self-contained application package did not seem to be the optimal solution.

As a result it was decided that the application should be able to load the pictures from the Web. Consequently, an unlimited number of pictures were available for the design of the individual levels which positively influenced the range of variety and thus enabled a diversified approach to the project.

As a consequence of this decision the application got the additional requirement of having an online connection available which heavily influenced the question of possible

use-case scenarios. On the other hand, smartphones of both target platforms (Android and iOS) offer networking capabilities via wireless mobile and WiFi networks. As the author also expects mobile broadband connections to expand further over the next few years, the constraint of needing a network connection seemed acceptable.

Despite this decision the game logic itself as well as the metadata for the levels could have been included in a self-containing application package. Due to the fact that a network connection was already considered an essential component of the design, it appeared to be a rational and an equally advantageous consequence to include the possibilities of locating the level-defining logic away from the mobile device to an online server. Having the logic of selecting game content outsourced to a centralised server instance not only increases the flexibility with regard to creating, modifying or extending the levels even after the roll-out of the game but also allows the additional gathering of feedback by analysing the usage behaviour and the given user input during the gameplay.

As an additional benefit a server-based concept also allows the centralisation of the the highscore list probably resulting in an additional motivation as the players are able to compete with each other.

6.2 Technological Decisions

In the course of the project several technological decisions had to be made. In the course of this chapter the reasons for these decisions are going to be outlined.

Game Client

As stated in Chapter 5.3 the goal was to support multiple target operating system platforms. Due to time considerations it was not an option to develop the software on multiple platforms. An environment for cross-platform development was chosen in order to be able to work on a single code-base and having the possibility to deploy on multiple target platforms. As it has already been shown in Chapter 4.4 a lot of approaches for the use in different contexts are available. As they all offer different advantages and disadvantages and have the one or other shortcomings, a catalogue of criteria was identified that can serve as a basis for reasonable decisions.

Decision Criteria

Several possible platforms for cross-platform development on mobile devices were identified. In this context a list of features was compiled that was necessary for realising the project.

In order to simplify this task the criteria were separated in mandatory (*Must-Haves*) and optional ones (*Nice-To-Haves*) thus creating a priority-related list of features.

Consequently, the platform which fulfilled all "Must-Have" points and most of the "Nice-To-Have" points was chosen for realising the project.

In the following the chosen list of features as well as its properties will be discussed in detail:

Must-Haves:

- **Open-Source Licensed**

  Two very important criteria for the software were related to aspects of availability and openness. Given the fact that the budget of a university project like this is generally rather modest, an open-source software represents a convenient way of keeping the costs low. Furthermore, it enables and encourages further development if limitations or new ideas should come up in the course of the project. In this context, however, it has to be considered that the use of an open-source software also involves the risk that support or documentation may only be available in a limited form.

- **Support for at least iOS and Android**

  As it has already been stated before Android was identified as the main deployment target. Therefore, the support for the Android platform was one of the basic mandatory criteria. As second very important platform iOS from Apple was identified. Although it was only the platform with the third-most market share [Com11] it was the mostly wanted platform in the author's personal environment. Moreover, iOS in combination with Android still covers 48.1 percent of the overall smartphone market [Com11]. Furthermore, it has to be emphasised that at the time of this decision the presentation of the next generation of iPhone products was believed to be imminent which lead to the expectation that this market would receive further customer attention in the future.

- **Broad Userbase – Support**

  When using an open source software it can not be taken for granted that support and good documentation will be available. Especially for products that are not developed by a company but by independent developers it is advisable to look for indications on how much attention the project receives.

  Useful indicators for the progress of a project are the release cycles or update cycles in the source repository on the one hand and the communication activity

in project related forums or support and discussion groups on the other hand. Especially when learning to use new forms of technology appropriately, good support channels are an important factor.

- **Performance Comparable with Native Applications**

  The advantage of being able to create software for multiple platforms should not come at the cost of application performance. The guideline for this project was that the resulting software should not run with noticeably lower speed than software developed while using the native platforms API. As described in Chapter 4.4 it will be inevitable that there is at least some small kind of performance overhead. For the current project the goal was to ensure that a typical player should not be able to notice a remarkable difference in application performance compared to a similar application. Moreover, the focus was placed on performance during the game's runtime. If the framework required longer startup times it weighed less.

- **Native Look & Feel on the Target Platform (Acceptance)**

  As seen in Chapter 4.4 cross-platform solutions differ with regard to the way the user interface elements such as buttons, text fields, etc. are presented. Some frameworks rely on a browser rendering engine and therefore use Hypertext Markup Language (HTML) widgets as user interface elements. As a consequence the resulting interface differs from the familiar features the player is used to on his or her specific device. One claimed advantage of vendors of platforms using Web-based user interfaces is that the application will present itself in a consistent look and view over different platforms.

  Nevertheless, from the point of view of the user of a single device all applications use the same design elements and the same behaviour (based on the platforms native user interface API) except the one that is based on a HTML based interface. Another point is that rendering a complete HTML interpreting environment usually requires excessively more resources and is generally not considered an ideal solution. Thus for the realisation of this project it was considered an important constraint to be able to use native user interface widgets on each target platform.

- **Support for the Linux Operating System**

  The last reason was rather related to practical than technical aspects. As the author of this work mainly worked with a Linux workstation it would be highly preferable to be able to develop and run the software on these existing machines without having to invest in other platforms.

Apart from the obligatory constraints a few other optional factors were identified. While these are not essential for the realisation of the project the fulfilment of one of these requirements gave a platform a higher rating in the decision taking process.

The following optional requirements were identified:

Nice-To-Have:

- **Programming Language**

  While not necessarily being a show-stopper the programming language of a framework will indeed influence the decision in some way. Like every programmer the author of the current project also has some preferences and strengths when it comes to choosing a programming language. As the personal experience of the author and his job-related history concentrated on writing in the Java programming language and Web-based technologies like CSS and JavaScript frameworks, using these languages was preferred if a choice between equally rated platforms had to be made.

- **Easy to Use Networking API and Multi-Threading Features**

  As an important part of the game mechanic includes fetching contents from online sources, the networking features of the platform play a considerable role during the implementation of the game. Practically every content within the game including level information, score lists, picture data and the pictures itself are loaded dynamically through a network connection. These includes synchronous downloads as well as asynchronous transfers, for example during the game rounds when the data for the next round is loaded silently in background. The complexity of the resulting code handling asynchronous transfers and appropriate error handling is largely influenced by the features and possibilities of the framework's provided networking and multi-threading API. For this reason a framework offering a high level API for networking features was highly appreciated.

- **Support for Web-Services or Similar Communication Protocols**

  A highly relevant aspect is the communication technology used to transfer data between the game server and client. The server platform was intended to be built using a Java enterprise edition (Java EE[1]) without any further limitation regarding the communication protocol. As with Java server technology different kind of Web-services can be built relatively easily it was considered optimal if the used framework on the client's side also came with support for Web-services or similar technologies. The final decision how the data transfer between the server and the

[1] `http://download.oracle.com/javaee/`, Last accessed 10/11/2011

client would be implemented was highly influenced by the features offered by the chosen framework.

- **Support for Other Mobile Platforms**

  As stated before one requirement for the framework was to support building applications at least for the iOS and Android operating systems. Nevertheless, any additionally supported target platform would provide an obvious advantage with regard to the possible user base. Therefore, solutions supporting more target environments should be rated higher in the decision taking process than solutions with equal features.

- **Good Tooling and Debugging Support**

  As a last point the surrounding software landscape of the framework will be taken into account. Having good tools for authoring, debugging and deploying software can make a significant difference regarding the time needed for developing and testing. As the Android platform itself comes with very powerful debugging features like stack traces, heap and stack dumps, breakpoints, live-on-device debugging, ability for tracing method calls, logging of radio data, support for inspecting the hierarchical structure of user interfaces layouts, etc. (see [2]) these features were taken as reference for comparison.

  While having all these features available for debugging would have represented the ideal case it was expected that any framework would only be able to support a subset of these features as it has to abstract the complexity of multiple target platforms that may not support all the functions.

Platform Decision

Based on the listed criteria above finally the platform *Titanium Mobile*[3] from Appcelerator Inc. was chosen.

Titanium Mobile is an actively developed open-source project firstly presented by Appcelerator Inc. in 2008. Titanium Mobile aims at promoting the development of mobile applications for the iOS and Android platform by the use of Web technologies. It offers a platform-independent API for accessing native mobile functionality of the target devices based on the programming language *JavaScript*. This interface allows the use of features common to both target platforms. Furthermore, it's possible to access additional platform-specific functionalities like Apples *iAd*, Android's background services

[2] `http://developer.android.com/guide/developing/debugging/index.html`, Last accessed 9/11/2011

[3] `http://www.appcelerator.com/products/titanium-mobile-application-development/`, Last accessed 11/11/2011

or inter-app communication in the form of *Intents*. This platform-specific functionality is provided by additional elements in the API.

The core components of Titanium Mobile are published under the Apache License 2.0 on the open-source collaboration platform Github[4]. This core framework provides APIs primarily needed basic features in mobile application development such as networking, device sensors, camera, accessing the clipboard, vibration, geo-location, file system access, device contact access, streaming, recording and playback of audio, Google Maps, Push-notifications, SQL databases, native Graphical User Interface (GUI) widgets, sending SMS or e-mails, initiating calls and many more. These functionalities are being accessed by the use of the Titanium-specific JavaScript APIs thus requiring an initial learning phase even for experienced JavaScript developers.

The platform can be extended with modules. At the time of the development of this project the business model of Appcelerator Inc. includes the selling of additional commercial modules (Titanium+Plus[5]) providing extra functionality such as enhanced commerce features (barcode reader, PayPal in-app purchase support), enhanced media capabilities (TV out) and analytic modules (allowing to analyse the usage behaviour within applications). In addition they also offer a all-in-one commerce solution (Titanium+Commerce[6]) providing modules for billing and in-app shop support as well as a complete Web-based framework for shop- and customer-management.

For the needs of the prototype developed in the course of this work the features of the open-source licensed core framework were sufficient to achieve all the planned goals. Titanium Mobile provides a comprehensive multi-platform Integrated Development Environment (IDE) allowing development on Windows, Linux and Mac OS X operating systems. It supports developing applications for both the Android and the iOS mobile platform even though restrictions of Apple Computer Inc. (manufacturer of iOS products[7]) require the use of a computer running the Mac OS X operating system when deploying or testing applications for the iOS platform[8].

Presumed that none of the Android-specific API elements have been used, applications developed on Windows or Linux can still be tested and deployed later on for iOS but as long as working with Linux or Windows developing is restricted to the Android platform only. During the course of this thesis the development was done using a Linux-based workstation. Hence all testing was done on the Android emulator and several concrete Android devices. Nevertheless, it was taken care that no Android-specific

[4] `https://github.com/appcelerator/titanium_mobile`, Last accessed 18/11/2011

[5] `http://www.appcelerator.com/products/titaniumplus/`, Last accessed 18/11/2011

[6] `http://www.appcelerator.com/products/titaniumcommerce/`, Last accessed 18/11/2011

[7] `http://developer.apple.com/devcenter/ios/`, Last accessed 18/11/2011

[8] `http://developer.appcelerator.com/get_started`, Last accessed 18/11/2011

features were used thereby making it possible to deploy the application to iOS devices in a future enhancement easily.

Web Application Framework

As stated before a server-client based architecture was chosen thus implicating the need for a server component. As also indicated in Figure 6.1 this component has to perform several tasks:

- Delivering Game Content (Artworks)
- Providing Game Metadata
- Maintaining Score Database
- Providing a Web-based Management User Interface

As can be seen several different forms of communications occur between server and the mobile device (client). One essential part of the game is the artwork referred to. The masterpieces are available from the WGA in form of digital images organised in a file-system based directory structure, ordered by artists. To deliver these files to the game clients the directory was simply made available via Hypertext Transport Protocol (HTTP) by placing it on a Web-server. To enable clients to locate the pictures they need to know the Uniform Resource Locator (URL) of the images to display as well as other necessary metadata about levels in general. For delivering this kind of information an additional server-component besides the web-server is necessary. For this purpose a Web application was created. Supported by the author's experience with the Java programming language and its established use among server-side programming languages [Wte11] the decision was made to create this element using a Java-based framework.

The interfaces for delivering game-metadata and maintaining the centralised score database as well as the HTML-based management user interface were created in the form of several Java *servlets*. Java servlets are a special kind of Java classes using a standardised API in order to supply the possibility to create dynamic output in a Web-server environment thus allowing to deliver dynamic content over HTTP. The Java servlets are running on an instance of Apache Tomcat[9] which is available for free licensed under an open source concession.

Database

The database serves as back-end physically storing game levels' metadata, information on the available artworks from the WGA and the centralised highscore list. As well as

[9] `http://tomcat.apache.org/`, Last accessed 20/11/2011

with other parts in the system an important decision criterion was the availability of the used product in the form of free and open software. In the current market landscape two popular open-source based database solutions are available [Ser11]: MySQL[10] and PostgreSQL[11] which both offer features of a modern Relational Database Management System (RDBMS) including support for the set of Atomicity, Consistency, Isolation, Durability (ACID) features and transactions. The decision between those two systems was influenced in favour of PostgreSQL by the fact that at the Electronic Commerce Group located at the Institute of Software Technology and Interactive Systems[12] there was already an PostgreSQL-based import of the WGA metadata available and used in other projects like the explorARTorium[13]. By the kindly support of the members of the explorARTorium project group it was possible to use this database dump and as a consequence the other needed database entities (for maintaining score and level information) also have been realised using PostgreSQL.

6.3 Platform Overview

The main part of ARTournament platform is structured in a three-tier-architecture. The topmost level of the application is a client running on mobile devices representing the game to the user. While this tier is not strictly limited to presentation and also contains application logic it still only implements general game mechanics and principles (e.g. the user interface for displaying the quadruplet of images, or the highscore list view). The client software on the mobile device only realises static principles which will not change in the course of all levels. The game's content and deeper logic which, for example decides which artwork should be shown or how many score points a correct answer is worth is implemented in the second tier, placed on the server side in form of a Web-server based Java application. The third tier maintains the system's data and is represented by a PostgreSQL database server respectively the filesystem containing the images of artworks. The administration interface for managing the game content represents a separate presentation layer, using a browser-based approach thus allowing the usage from any Web-browser.

Figure 6.1 gives an overview on the involved components that form the ARTournament platform. In the first tier the client appliances are shown. As already stated before these are the software clients that are currently running on mobile phones as well as the management interface restricted for administrator access. The administration interface consists of a dynamic Web page and communicates with the server application via HTTP. The game clients in general also communicate with the server using HTTP as

[10] `http://www.mysql.com/`, last accessed 20/11/2011
[11] `http://www.postgresql.org/`, last accessed 20/11/2011
[12] `http://www.ec.tuwien.ac.at/`, Last accessed 19/11/2011
[13] `http://www.explorARTorium.info/`, Last accessed 14/11/2011

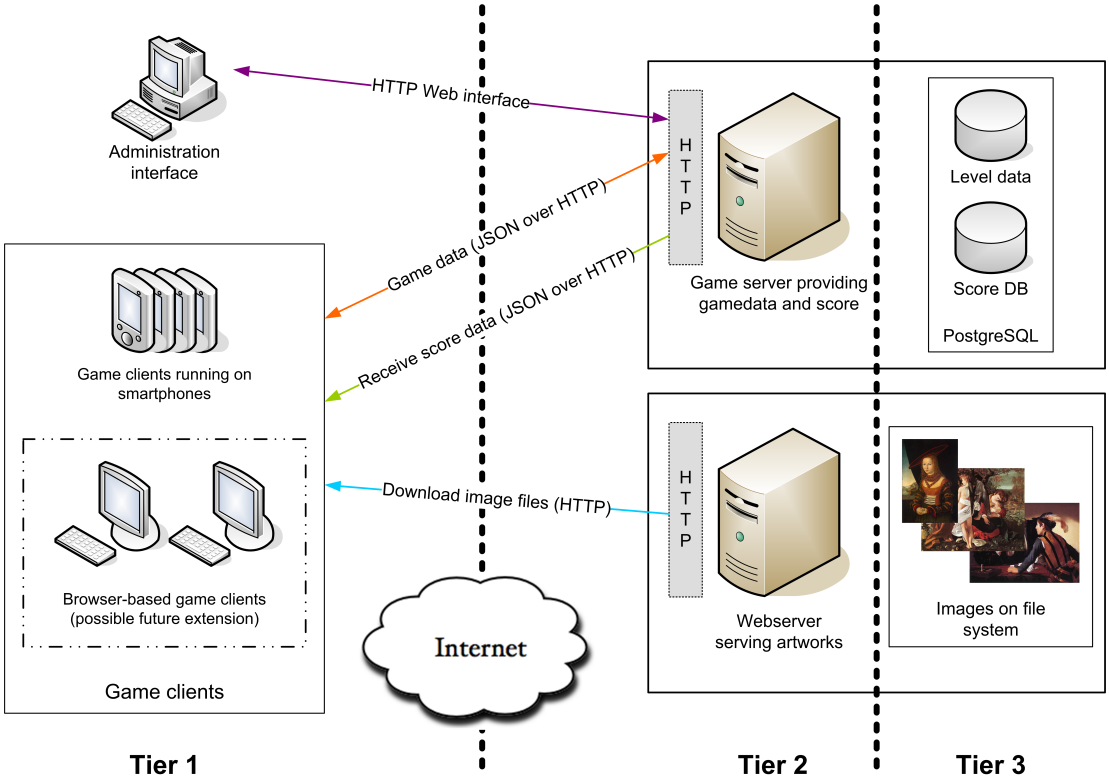

Figure 6.1: Overview on the ARTournament platform

transport protocol. However, as several types of information are transferred between the server and client different protocols are in use. The image files are simply downloaded using the capabilities of HTTP. The game's metadata as well as the submission of user input and score information is done by transferring JavaScript Object Notation (JSON) formatted documents. As the applied framework (see Section 6.2) on the client devices is using JavaScript as programming language the handling of JSON documents is well-supported and provides a lightweight standard for encoding information for transport over the network. As illustrated in Figure 6.1 a future extension could incorporate additional clients for presenting the content of ARTournament. Since JSON and HTTP are widely-used protocols it should be possible to implement additional game clients for ARTournament. For instance versions for other platforms, that are currently not supported, or a Web-browser-based version could be created.

Tier two represents the application logic on the server side. The game logic is responsible for interpreting the game information in the database and provides reasonable data for the game clients based on this information. It consists of a connector to the database system as well as a library for reading and parsing JSON-notated objects and serves HTTP requests from the game clients by using Java servlets. Furthermore the

Web-server serving the requests for artworks is also logically assigned to tier two. Back in tier three the data is maintained. A PostgreSQL database server provides access to all game-, artwork- and highscore-data and communicates with the Java application by means of a Java Database Connectivity (JDBC) connector. JDBC represents a vendor-independent standardised API for accessing different types of RDBMS from within the Java programming language. On the Web-server the representations of artworks reside in form of digital image files on the server's file system.

6.4 Typical Request-Response Sequence

In Figure 6.2 a typical request-response sequence between the client an the server is shown. In the following the steps are explained in detail:

1. the user is about to select a new game, the client requests a list of available levels
2. the server returns a list with available games
3. based on the user's choice the client requests one specific game for play
4. the server returns metadata for the requested level as well as the 4 URLs for the artworks to be shown in the first round
5. the client fetches the 4 images from the Web-server
6. the client displays the artworks to the user and requests the next set of URLs from the server
7. the server returns the URLs of the next 4 artworks
8. the client fetches the next 4 images in the background while presenting the current round to the user
9. the client sends the user's response to the server and presents the user feedback on his or her choice; consequently the sequence continues at step 6
10. at the end of the game, when the user navigates to the highscore list, the client requests highscore data from the server
11. the server returns a highscore list prepared for the specific user

During the play of a single level the steps 6–9 are repeated constantly until the player decides to quit or start another level.

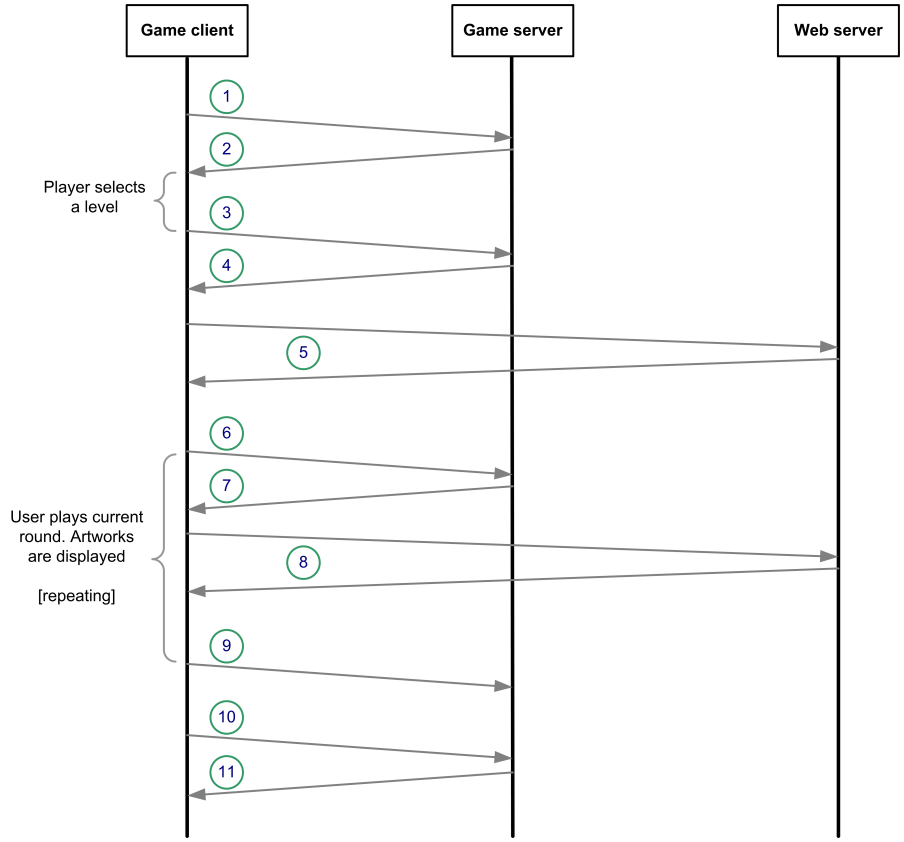

Figure 6.2: Sequence diagram visualising a typical request-response sequence

6.5 Web Application

The Web application consists of two major components: the management Web-interface and several interfaces serving requests from game clients.

Management Web Interface

The Web application was built using Java Enterprise Edition hosted on a Apache Tomcat Servlet container. The administration interface for managing the game's content was designed for simplicity. Thus a simple HTML page layout was chosen. For enabling an interruption-free work cycle without the need for reloading the whole page for each user interaction Asynchronous JavaScript and XML (AJAX) based functionality was included for re-rendering parts of the page asynchronously. This was realised by including the popular JavaScript library *jQuery*[14]. jQuery offers an easy to use interface

[14] `http://jquery.com/`, Last accessed 19/11/2011

for manipulating specific parts of a HTML page dynamically and fetching data from the server asynchronously in the background.

The resulting Web page was created with one simple JSP page containing the main skeleton of the page and several Java servlets for delivering dynamic data used to fill the content regions of the page with the assistance of jQuery (e.g. the area with the picture previews or the table containing all game data).

Game Data Interfaces

The interface for serving the game clients includes three elements: one component for delivering the list and metadata of all levels, a second one for serving data for concrete levels during gameplay and a third interface for processing all score-related requests, like updating the user's score or queries for the highscore list. These three interfaces have been realised by creating three Java servlets `GetGameList`, `GetGameData` and `ScoreServlet` and are available under three different URL patterns. Each of these components is designed to receive parameters via HTTP POST requests and delivers responses (including exceptional error states) in form of JSON formatted documents. The game clients are designed to interpret the data accordingly and consequently imposing tight coupling between these two tiers.

Class Overview

Figure 6.3 presents an overview on the classes implemented for realisation of the Web application. All created classes in the project have been name-spaced below the package name *at.zweng.ARTournament*. Underneath this package several sub-packages have been defined for further organisation of the resulting classes according to their field of use. As the overall structure is not very complex most names are speak for themselves. Nevertheless, in the following a short description will be given.

The package `clientservlets` contains the three classes for serving the different types of game client requests as mentioned in Section 6.5. These classes represent the main entry points into the application. At this place requests from clients arrive and get served by calling according methods in the other packages and sending back the calculated data. The other packages include the `config` package which only contains some helper classes enabling the application to be configured by means of Extensible Markup Language (XML) configuration files. As the name suggests the package `db` encapsulates all database-related activities thus providing a clean interface to the rest of the application. `util` simply contains some helper classes for the JSP generation as well as utilities for logging and performance measurements. The package `webservlets` hosts all the servlets serving all the different type of requests coming from the management Web-interface, like deleting and creating games (levels), fetching the list of

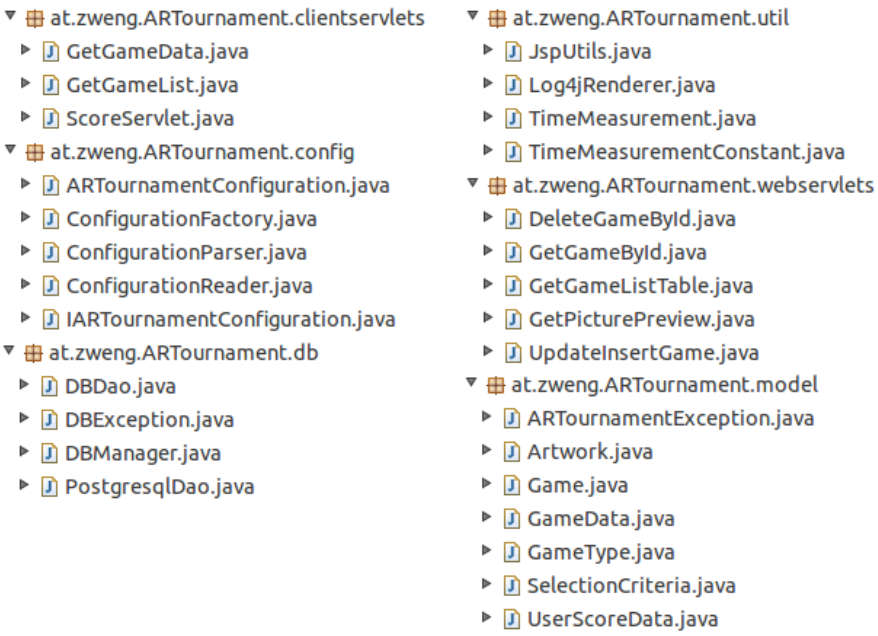

Figure 6.3: Overview on Java classes of the server component

games and displaying the preview pictures. Another interesting package is `model` as it includes all the object representations of the game's entities.

The class `Artwork` provides the representation of a single artwork holding all artwork's metadata information from the underlying database. The `Game` class identifies the configuration of exactly one level and provides all the information that defines a level as entered in the management interface. On the other hand `GameData` encapsulates all metadata and information needed to deliver the game-data for a single round to the client. This class gets serialised into the JSON format for being delivered to the client. `SelectionCriteria` include the information which query criteria have to be used for selecting artworks from the database as described in Chapter 5.10. For each game there are selection criterions defined for the reference and for the contrasting artwork which both get represented by an instance of this class within the system. The last class `UserScoreData` encapsulates the score information for one single user. When requesting the highscore list an appropriate query is done on the score database table which returns a list of instances of this class. The data transferred to the client simply consists of a JSON-serialised representation of this list.

Database Structure

The database serves as back-end for persistence in tier three of the architecture. The application data structure is organised simply and consists of three database tables. Fig-

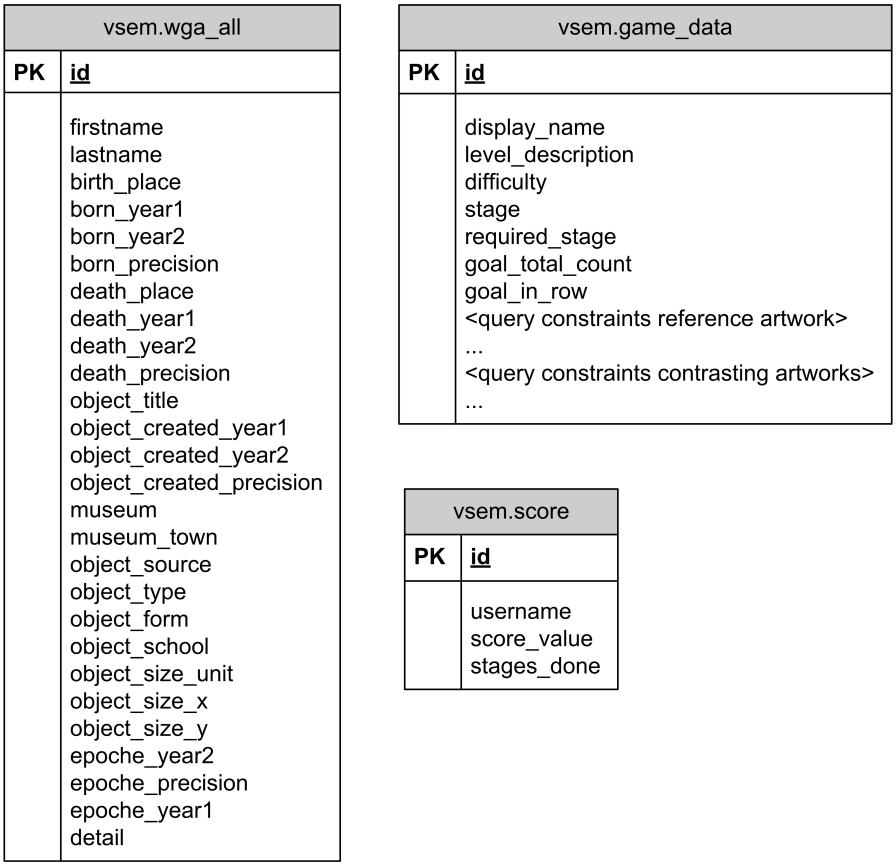

Figure 6.4: Entities in the database model

ure 6.4 displays a graphical visualisation of the entities in the database model.

The table `vsem.wga_all` was already given from the WGA project containing all metadata information of the artworks for use in the game. Its structure and data had been adopted unchanged in this project. The table `vsem.game_data` stores all data which is defining the concrete levels and contains one entry per level of the game. The management Web-interface for creating and editing game levels causes data in this table to be processed. The last entity in the database (`vsem.score`) is a simple model for persisting score data values. This table holds information on the current score value of each player as well as the unlocked stages.

6.6 Titanium Game Client

The game client was implemented using the Titanium Mobile platform[15]. This environment is using JavaScript as programming language. JavaScript is weakly typed and supports only function scope, meaning that every variable declared outside a function is created under the *global namespace*. On the other hand JavaScript handles functions as first-class objects (allowing functions to be stored into variables or passed as arguments) which allows a very flexible and powerful style of programming. As a drawback of this freedom and because of the single global namespace errors (for example by accidentally global defined variables) may be introduced easily and may be hard to track down thus making it important to adhere to a clean style of coding and keeping an organised program structure.

The structure of the current project was leaned at the Model-View-Controller (MVC) pattern[16]. This ensures separation of the code for creating the user interface from the application logic. As the complexity of the game system seemed manageable and for the sake of simplicity in the current version the functions for data manipulation (e.g. `Game.loadGame()` have been included into the data objects itself thus diluting the MVC pattern a little bit but still keeping separated game functionality from GUI logic.

Although JavaScript has no concept of packages like Java a similar directory structure was chosen to keep the project well-organised. To avoid that the global namespace gets polluted and to ensure that different aspects of the application stay isolated from each other every module was encapsulated into an anonymous function body thus limiting the scope of all declared variables to the function body as seen in the example below:

```
( function() {
    art.model.Game = function(..) {
        /* module code ... */
    }
}());
```

All functions and variables to be used outside the module have been assigned names in a custom namespace which has been prefixed with the term "`art`". As a convention the second part of the name represents the directory containing the module like `art.model.Game` in the example above. Figure 6.5 gives an overview on all modules created within the client application. The folders `model` and `ui` reflect the separation of GUI functionality and application logic. Most modules' names speak for themselves. Beneath the namespace `art.app` some globally used features have been located as for

[15] `http://www.appcelerator.com/products/titanium-mobile-application-development/`, Last accessed 11/11/2011

[16] `http://en.wikipedia.org/wiki/Model%E2%80%93view%E2%80%93controller`, Last accessed 19/11/2011

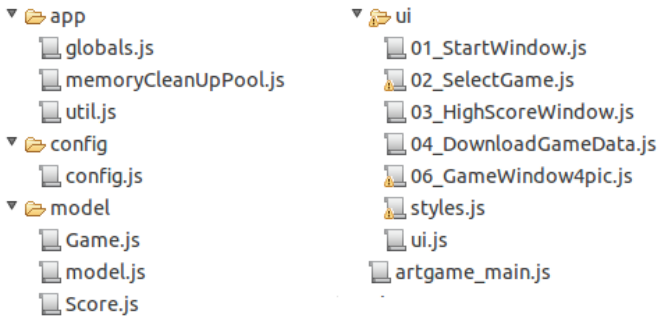

Figure 6.5: Overview on JavaScript modules of the client application

example a few global variables (e.g. a reference to the currently displayed window) as well as some helping functions which are intended to ease general tasks like the merging of objects or similar general functionality. The module directory `art.config` only contains one single file encapsulating all configurable values (e.g. the URL of the game server component while `art.model` hosts functionality for data representation within the local system and functions for loading and sending the encapsulated data. The module `art.ui` contains JavaScript files for creating the different type of windows and views used throughout the game. It has been taken care of that commonly used configuration parameters for manifestation of specific GUI elements like buttons or text views are outsourced and collected in a separate file named `styles.js`. While this is neither required by the Titanium framework or JavaScript it seemed like a feasible way to configure the overall application appearance from a single place.

6.7 JSON Data Structures

As already stated in the sections 6.3 and 6.5 JSON-formatted objects have been chosen as means of transportation for the data between the server and the client of the game. As JSON documents can be easily parsed into objects within JavaScript and powerful JSON libraries (like Google-GSON[17]) for Java are available this seemed an optimal trade-off between functionality and complexity. As a consequence for the realisation of this project no special data format has been created. The content of the transferred JSON documents corresponds to the object's structure. As a result a similar anatomy of objects on client and server side has been implemented. While this is not desirable in general it was accepted as an admissible condition for the current project as the transferred objects are of minor complexity and could be easily used in other projects. It should be possible to use the same data structure for the creation of further game clients. In particular a Web-based game could even benefit from this design as JavaScript is the

[17] `http://code.google.com/p/google-gson/`, Last accessed 20/11/2011

most widespread language in the context of Web-browsers allowing JSON-data to be included easily.

6.8 Security Considerations

For the first prototype no special considerations regarding security have been made. In the current version any communication between the game server and the clients is done unencrypted via plain HTTP. For future expansions switching to the encrypted Hypertext Transport Protocol Secure (HTTPS) may be considered. The same is true for the administration Web-interface. Currently the Web page is accessed over an unencrypted HTTP connection. An additional enhancement for future work would be the implementation of a more fine-grained user-management. In the course of the current work a very simple access management was implemented by means of a single hard-coded user account secured by password protection. While this was sufficient for the work on the prototype a better access control system may be desirable for future versions.

Another risk to be considered is the possibility of data being manipulated or faked when transmitted back to the server. As the protocol was designed for simplicity for the prototype it is not secured against tampering or replay attacks. As the only data transmitted from the client to the server are the user's responses during gameplay this affects the score database as well as underlying user response evaluation systems. For the course of development of this prototype this risk was recognised and accepted.

It is difficult to prevent an attacker from modifying client software to send incorrect data. As a consequence it is hard to completely prevent this kind of attack. However, it would still make sense to raise the bar in a future productive version by the use of cryptographic signatures to ensure data integrity. As the application needs to be deployed on the user's device this still would leave the possibility to extract the signing keys out of the application package but this would make attacks at least a lot more difficult.

CHAPTER 7

Evaluation

One of the most interesting parts in the course of this work was to see how users react to and interact with the created game. To aggregate some user-data the final game was packaged for distribution on Android devices and made available to the public on a dedicated website[1] and on the weblog of The Virtual 3D Social Experience Museum (VŠEM) project website[2] at the Institute of Software Technology and Interactive Systems at Vienna University of Technology to gain further attention from potential players.

7.1 Data Sources

To gain some insight in the users' behaviour after an initial test run the system has been modified for the evaluation phase to log interaction data between game clients and the server so that the following information can be extracted:

- date and time of user action
- username of the player
- the currently played level
- the database ID of the artwork which the user has to identify
- the system's feedback on the user's answer (correct/incorrect)

Based on this information it was possible to analyse usage data drilled-down to levels, players and single answers.

[1] `http://ARTournament.info/`, Last accessed 20/11/2011
[2] `http://vsem.ec.tuwien.ac.at/`, Last accessed 20/11/2011

7.2 Method and Expectations

Working on the single round centred dataset information has been aggregated on a level and user base to gain statistical information about different users and game levels. The intended effect was to see if a learning process has taken place and how the difficulty of different levels has been perceived. Also general usage data should be extracted to get an overview on the number of players that could be reached and how intense they used the offer of playing the game. Apart from general information it was also expected to detect some changes in the answer pattern (*correct/incorrect*) of individual players.

Hypothesis:
If the user is able to acquire knowledge on a specific level the percentage of positive answers per time period will increase over the time of gameplay.

7.3 First Impressions

The evaluation phase lasted from October 19th 2011 until November 16th 2011. A first analysis showed that in this time a total number of 24 users played 4235 rounds distributed over all 16 levels of the game. An analysis of temporal distribution has shown that almost half of the game sessions (47.2%) took place within the first 10 days. Figure 7.1 shows the detailed distribution of total rounds played per day. It also was very interesting to see that over 80% of total sessions have been played by the top five players. Figure 7.2 shows a diagram visualising this fact in detail. Another finding was that most of the sessions have been played within a single level. As illustrated in Figure 7.3 almost half of all played rounds have been spent in level *"5: Expert Caravaggio"* (2066 out of 4235) which is the only level in the highest stage.

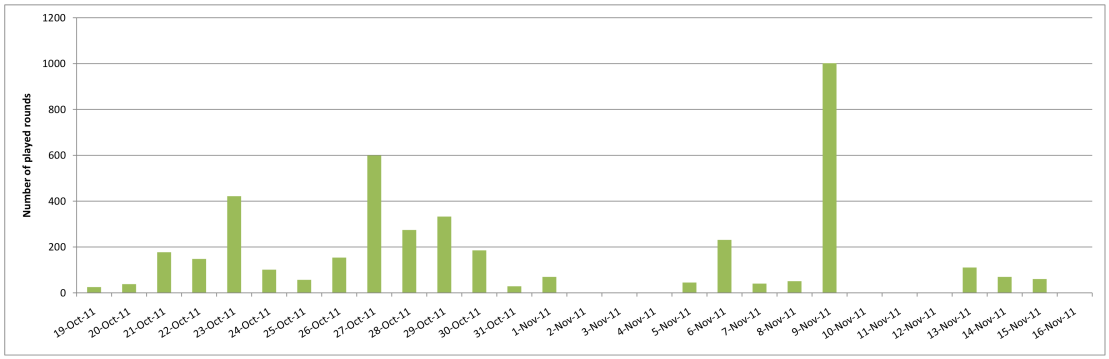

Figure 7.1: Distribution of played rounds per day

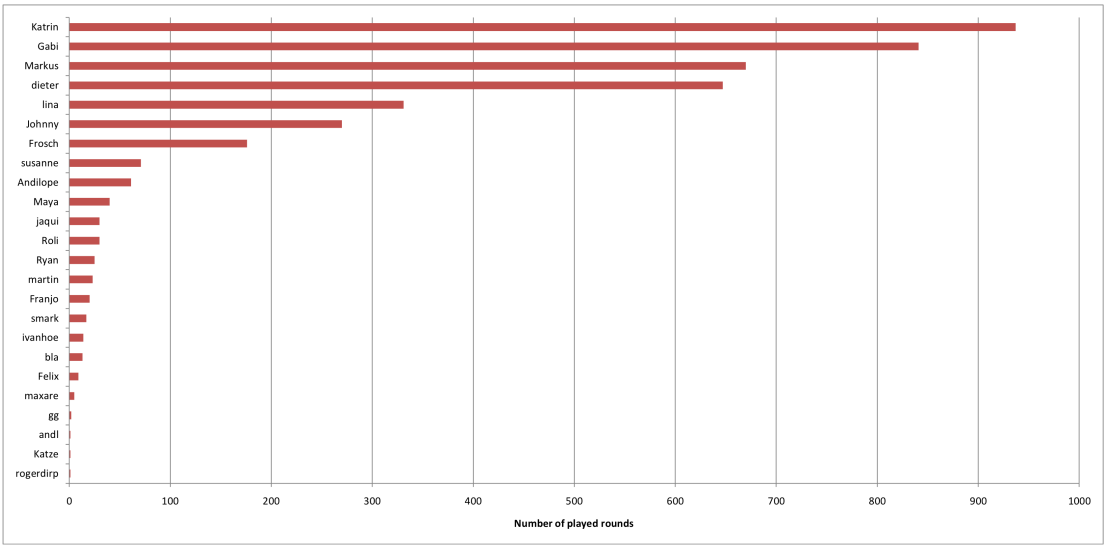

Figure 7.2: Distribution of played rounds per user

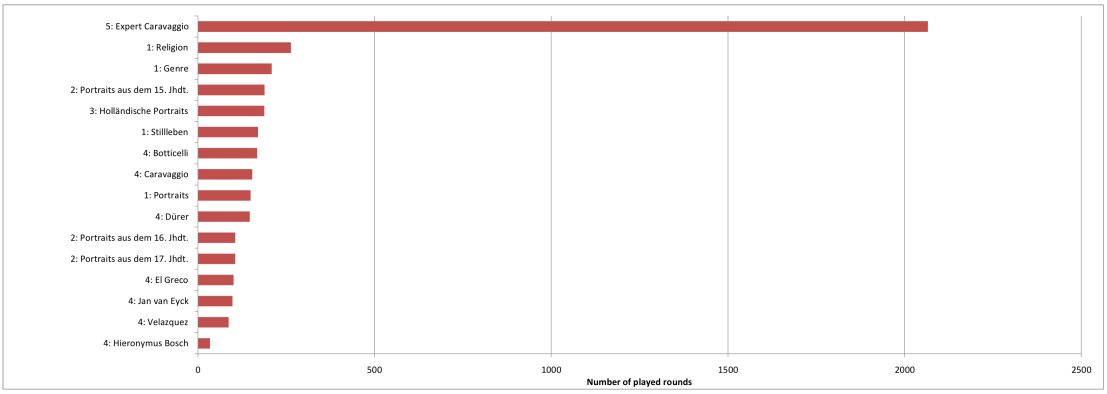

Figure 7.3: Distribution of played rounds per level

7.4 Analysing Player Performance

After having these basic facts by hand the performance of players regarding the correctness of their answers has been analysed. It was an interesting question how the difficulty of particular levels was perceived by the users and influenced their behaviour. In a first breakdown the overall achievements have been analysed and the percentage of total correct answers calculated on a per-level base. It should be remembered that the chance for guessing the correct answer only by accident is 1 to 4 which would result in a 25% success rate. When looking at the data some of the results were expected (e.g. being *"1: Stillleben"* and *"1: Portraits"* on top places) while others were quite interesting. For

example, level *"5: Expert Caravaggio"* – which was supposed to be one of the most difficult ones and thus being located in stage five – was placed on the third rank with a total of 81.2% correct answers.

For further understanding this result was compared to the number of played rounds. A visual representation of this data is given in Figure 7.4. This result suggests that the increased number of played rounds also led to an improvement of players' performance. Therefore, Figure 7.4 could be interpreted in this manner that levels are placed on top ranks (regarding the percentage of correct answers) either because they are easy to play per se (like the first both levels where portraits and still-lifes have to be distinguished from other art categories) or because the users mastered them by playing a high number of rounds.

Another important point not to be left out is the number of players using one particular level. Abnormality in data could be caused if only a low number of persons or a single player with special knowledge about the level in question were producing the majority of data. For this reason the number of unique players per level has been visualised. As can be seen in Figure 7.5 level *"5: Expert Caravaggio"* has indeed been played by seven gamers. Another interesting point is that level *"4: Hieronymus Bosch"* has only been played by two players. Combined with the low number of 34 played rounds this may explain why this level got on rank four in Figure 7.4, as it would be easily possible that a single highly skilled or lucky user influenced the result positively on this low amount of data. To check how the rounds within level *"5: Expert Caravaggio"* were spread among players their distribution had been inspected in Figure 7.6 which showed that at least four players were playing over 300 rounds and thus making it implausible that one single player was responsible for the success rate of the level.

As it was also an interesting question whether the players producing most rounds

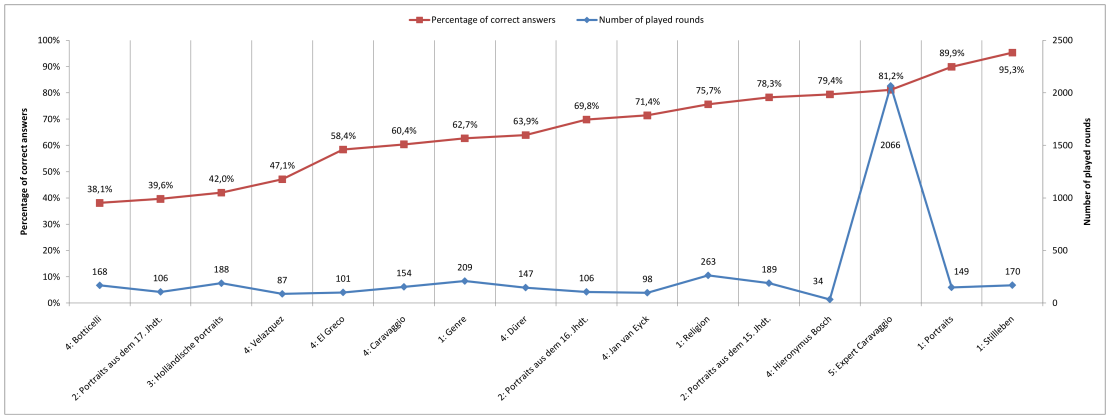

Figure 7.4: Percentage of correct answers opposed to played rounds per level

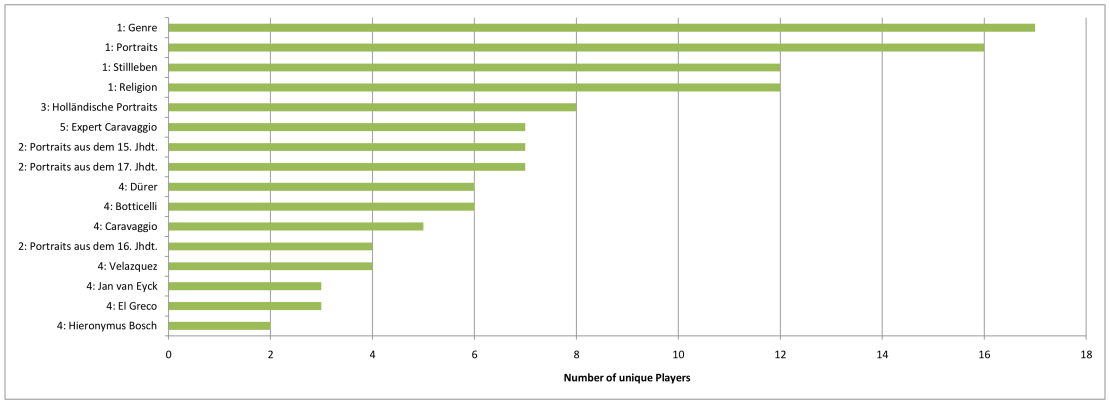

Figure 7.5: Number of unique players per level

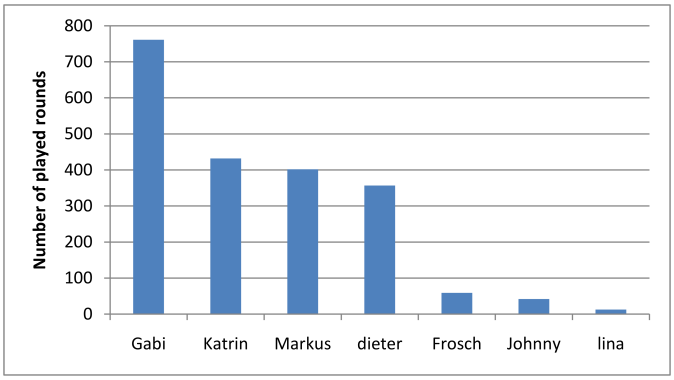

Figure 7.6: Rounds per player in level "5: Expert Caravaggio"

are also responsible for the success rate or not the relationship between played rounds and the highscore value has been evaluated in Figure 7.7. This figure shows that there are indeed differences between players' abilities. This is illustrated through the fact that the player with most completed rounds only ranks in the 3rd place according to the score value.

However, the most interesting question is still how the users' knowledge developed over the course of time while using the game. The author's hypothesis suggests that there should be a visible improvement in the rate of correct answered rounds. To examine further if this assumption may be correct the data records have been separated per user and level. The resulting data has been visualised exemplarily for level *"5: Expert Caravaggio"* in Figure 7.8. For visualising the success rate over the course of gameplay the result data has been partitioned in groups of ten rounds. For each of these groups the percentage of correct given answers has been calculated and illustrated. The result

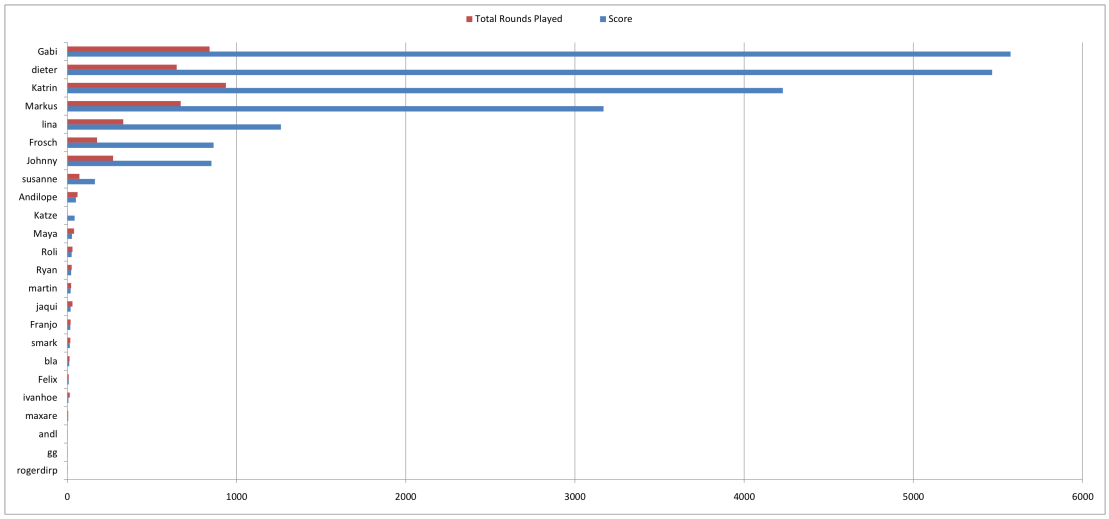

Figure 7.7: Number of played rounds opposed to score values

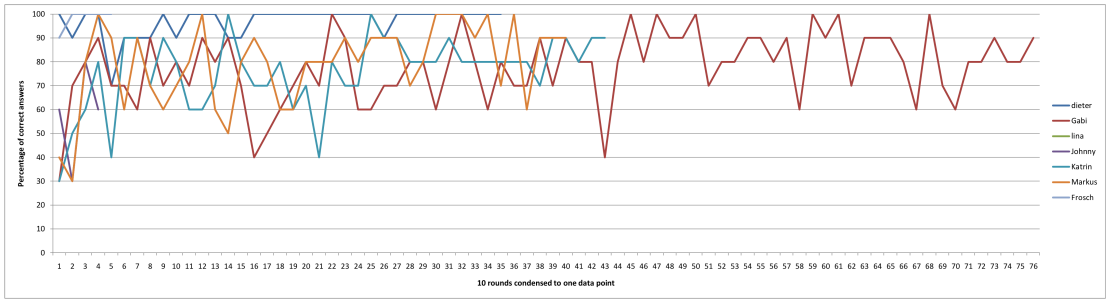

Figure 7.8: Progression of success rate in level “5: Expert Caravaggio” grouped per 10 rounds

leads to the suggestion that most players start in the region of approximately 30% which indicates that they are guessing at the beginning but improve their abilities quickly and then stay constantly on the higher level of success rate.

For a better visualisation a different approach was chosen. In Figure 7.9 the overall number of rounds that each player spent with the game was divided into 5 equally-sized partitions and the success rate for each of them was calculated. To clean out data caused by “short-attempters” who test a level for just a few rounds and quit immediately only data from players, who have played at least 20 rounds in one particular level, has been included. The resulting figure now shows more clearly that the players’ results are improving over time. Except for the user with the nickname *Johnny*, who had a falling curve at first lasting until the third part of his or her playing time but then increased his or her success rate to almost 90% in the fourth section, only to fall down again

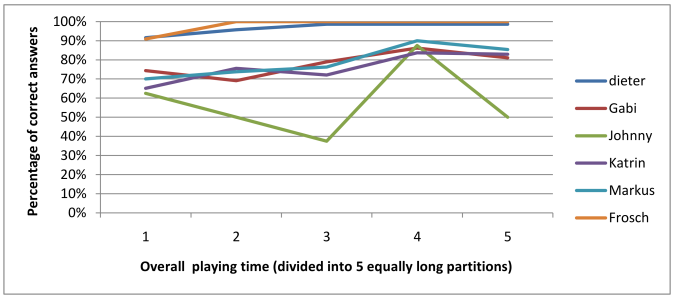

Figure 7.9: Progression of success rate in level "5: Expert Caravaggio" dynamically grouped in 5 equally long time periods

to around 50% in the last fifth. Such varying results may be either explained by the fact that the player was not playing continuously in a row but with large temporal gaps between playing session and thus forgetting again some of the learned concepts or based on the low number of rounds played. Because of the randomness of artwork selection there could have been an accidentally produced series of exceptional difficult tasks to be solved.

When analysing the usage data for *Johnny* in detail it turned out that in fact he or she was one of the players using this level almost fewest of all (see Figure 7.6) and was playing only on two days which lie almost 20 days apart from each other:

- 5 rounds on 20/10/2011 and
- 37 rounds on 09/11/2011

An explanation for a decreasing result at the end of playing time could be a declining interest, which led to the result that the player quits.

When analysing the data of other levels in the same way similar patterns of progression can be observed. It seems that after an initial learning curve the players acquired the knowledge needed for the current game and continues playing on this higher niveau of answer correctness. It is noticeable that the resulting skill-level can be different from user to user, reflecting different background skills in art history but the pattern of the curve still stays similar. This is illustrated in Figure 7.10 where four diagrams give an overview on the progression of success rate over time in four different levels.

While these are examples where the players tended to adopt the content there are also levels where the learning results seemed to be doubtful. As already presented in Figure 7.4 the game-levels *"4: Botticelli"* and *"3: Holländische Portraits"* are among the three levels with the worst success rate. When looking at the user progression in these levels in Figure 7.11 it can be seen that the users' success rate is generally located in lower areas and is not increasing at all or even decreasing over time. This indicates

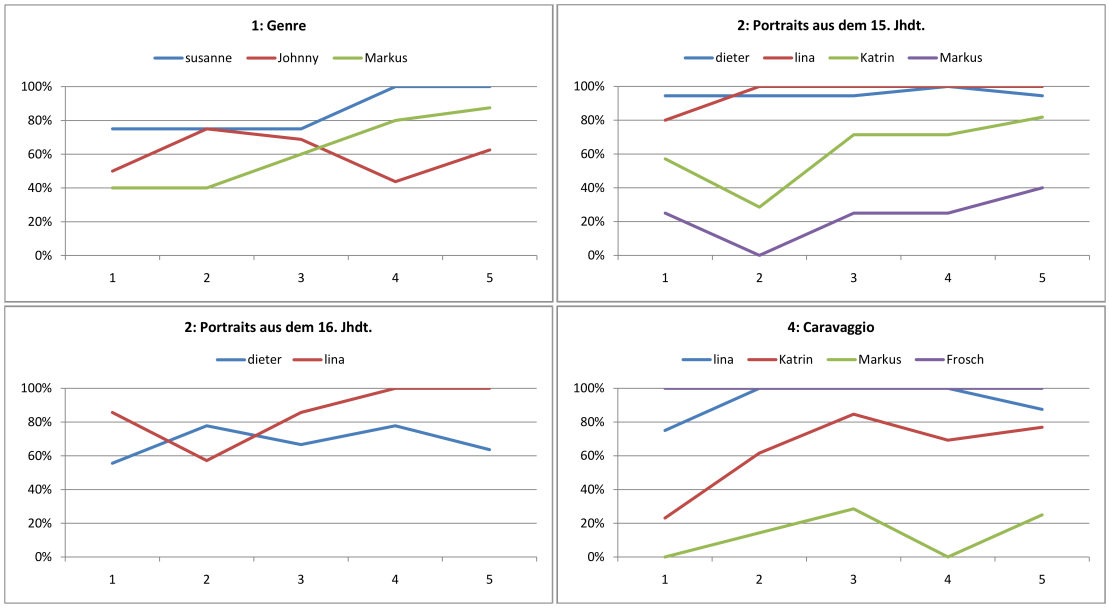

Figure 7.10: Progression of success rate in 4 levels dynamically grouped in 5 equal long time periods

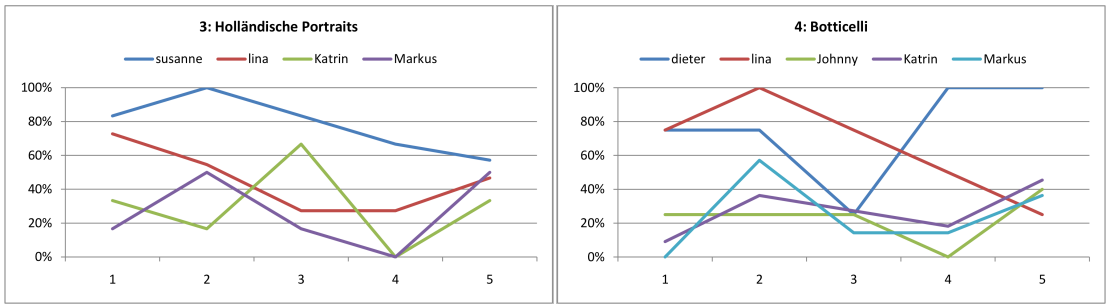

Figure 7.11: Progression of success rate in 2 levels dynamically grouped in 5 equal long time periods indicating bad level design

that the level goals are not clearly communicated or cannot be derived by the users during gameplay. Obviously no learning effect has taken place with regard to these levels.

In conclusion, there is some evidence that in general the users were able to acquire knowledge during gameplay. The overall result shows clearly that the average success rate lies far beyond 25%, a number that would have been expected for blindly guessing the answers. The learning curve increases steep at the beginning and then mostly seems to stabilise over gameplay. Furthermore, a decrease of success rate may also be observed after some time of gameplay which may be interpreted as a loosing of players' interest

and slipping into boredom. Overall the players seemed to have learned from the levels' content. Regarding the initial goal of getting new users in contact with art history the game can be considered as successful.

7.5 User Responses and Feedback

When advertising the game prototype users were also encouraged to give feedback and make suggestions for possible future improvements. While some of the participants stayed anonymous and therefore couldn't be contacted or were not interested in giving feedback the responses may not be representative for the whole group of users. However, some players brought interesting insights and ideas for future improvements.

In random talks with some of the best players according to the highscore list they concordantly reported that one very strong motivational factor to play for such a long time was to overtake the others at leading places in the highscore list. So after they had unlocked all available levels they focused on those levels which allowed to earn the highest score points per correct answer (i.e. the most difficult ones). This phenomenon was also confirmed by the results of an analysis of the data on the game server as presented in the previous Chapter (7.4). Hence, the interviewed persons mastered a single level at the highest stage (*"5: Expert Caravaggio"*) until they reached perfection in answering the questions and used this level for score harvesting. As a consequence, they left out completely the other levels as they seemed to be useless with regard to the purpose of winning. The effect was that the players acquired impressive knowledge in this one specific area (recognising artworks by the painter Caravaggio when compared with other Italian artists of the era), but neglected other fields. This can be seen very clearly in Figure 7.3 which shows that the level dedicated to Caravaggio's work has been played exorbitantly often compared to all the others. This fact indicates one weakness of the game namely the lack of more motivational stimuli for playing except the score value. Then players would be encouraged to turn back to other levels as well.

Another interesting fact was that some of the players started to gather information based on the background of the played levels, for example by using the Internet. The purpose of searching for further information with reference to the contents of ARTournament was to improve their skills and therefore be able to earn higher score values. In fact, this observation reminds of C. C. Abt who already described in [Abt70] (cited in [MC06, p.112]) a similar behaviour with regard to his students, who began to research the events of World War I unrequested after he had introduced an educational game to them. The students were eager to improve their knowledge and for that reason they tried to acquire more information. This was an interesting effect, even if not primarily expected and considered when designing the game.

7.6 Suggested Improvements and Future Work

Reward by Means of Badges or Awards

Based on user inputs considerations have been made for further expanding of the score system. Possibilities include the definition of a different weighting for score points, which could motivate the gamers to switch between various levels instead of focusing on one single level. Furthermore, additional motivational elements could be created as part of the game's reward system, like special awards or so called "badges" for the achievement of extraordinary goals. This could be for example an award for playing more than a specified number of levels on a single day or being the first one to have more than a specific number of correct answers in a row in one particular level. This could encourage players to focus also on less popular levels where prizes like this still could be earned easier as the number of contestants may still be lower.

Another idea would be to allocate rewards for increasing the own performance in particular levels. If a player had, for example, a low success rate in one level and then accomplishes the task to increase his or her performance by a specific amount he or she could be rewarded by earning extra points or a badge. This could provide an appealing way of guiding users also to less played levels.

Furthermore, the classical score system could be extended to also cover fine-grained results based on single levels. Additional to the existing all-time highscore list this could be accomplished by the introduction of temporal limited highscore lists, for instance a list of the best players per week or even per day.

Better Error Feedback and Dynamic Help

Other feedback from the protagonists regarded the design and representation of the game contents. A few players noted that the feedback given on user input by the system should be improved, especially displaying in more detail why a specific answer was wrong. Another element criticised by some players was the frustrating experience when they got stuck in a level and did not see any improvements in their success rate. As stated before in Section 7.4 this may indicate a too difficult level design, thus making the learning curve to steep to cause a learning effect at players' side. This could be solved by trying to modify the level parameters and to redefine the selection criteria for the contrasting artworks in order to ensure easier identification.

However, a different approach would be the introduction of a dynamic helping system, which interferes the gameplay whenever the user is endangered of being overchallenged and that is indicated by the success rate of his or her inputs. Such a system could prevent users from leaving the state of flow and slipping of into the zone of anxiety as shown in Figure 2.3. The interventions could be done in form of additional prepared helping texts tailored to the level's goals, giving additional hints about the specificities

of the art historic topic in question and thus lowering the barrier for new users and preventing them from quitting the level because of frustration. In addition, the value of the initial introductory text representing a user's entry point into the context of a new level featuring new art historic challenges could be enhanced by enriching it with visual examples of related artwork.

Using Folksonomies as Additional Source of Metadata

As seen in Chapter 7.4 there are particular levels which receive bad success rates by the majority of players. While in some cases this may be solvable by simply changing the query parameters for artworks in the level this is not always possible because of limited expressiveness of the available metadata. For example level *"3: Holländische Portraits"* seems to be quite difficult (as seen in Figure 7.4 and 7.11). The goal is to spot artworks from a specific region compared to objects from other regions. While it may be very difficult for many people to differentiate between regions which are spawning similar schools of art for others the differences may be obvious. However, based on the available metadata it's not always possible to further restrict query parameters.

This could be overcome by enriching the present data by information from other sources. For example user generated folksonomies compiled by tags like described in [WAF+11] could present a valuable source of additional information for creating a more fine-grained sequence of levels, avoiding too large gaps between the level of difficulty of two sequential game levels.

Allowing User Feedback on Artworks

Another possible extension of the game mechanics could be to allow the users themselves adding tags or ratings to particular artworks thus allowing flow-back user data to influence future game sessions. As mentioned already in Section 5.9 this also could provide valuable data for use besides the game. Of course if this suggestion is realised it has to be taken care of how this interaction step will be included into gameplay to avoid that it presents a hindrance of the user's game flow.

Expanding by a Web-based Game Version

Apart from the already presented proposals the expansion of the game to different devices could be considered. As already mentioned in Section 6.3 and 6.7 the platform's architecture would allow an expansion of the game to the medium of Web-based games played in a browser. Beside attracting new fields for possible users it would also allow existing players to intensify their immersion by continuing their gaming sessions even when changing to a different media and therefore making ARTournament a cross-media experience.

7.7 Considerations for Further Evaluation

The current evaluation is based on the observation of users' interaction with the game system and how the usage and response patterns have changed over time. As seen in Section 7.3 the base data was limited to 24 players. For future evaluation a larger test run could be arranged in order to provide a broader base of data on usage behaviour. This would allow to derive more accurate information on the game's effectiveness.

Furthermore, when a broader user base was reached, an evaluation of the learning success by means of comparing it with traditional forms of teaching could be done. To achieve this goal two groups have to be formed: one control group being taught art historic knowledge by means of traditional methods, for example like discussion of representative artworks and a testing group which is told to play ARTournament. Based on questionnaires done before and after the test runs a better assumption could be made on the effectiveness of learning with the game.

CHAPTER 8

Conclusions and Outlook

Playing is an interesting phenomenon. From childhood on each and every one of us was occupied with nothing else but playing games all day long. From a young child's point of view the whole world is big and new and so many things out there still need to be learned for later life. By playing games we successfully reduce all the complexity and dangerousness of the world to simplified and enlightening abstractions. In the course of this thesis a lot of information has been presented on the advantages of playing games and how they encourage people to interact with new situations more freely and fearlessly by levering the pressure of risks and consequences in the real world. With all these positive words spoken games still adhere the atmosphere of being an occupation for children or teenagers wasting their time in front of computer displays and game consoles. Moreover, media discussions in the recent years addressed the question if playing computer games not only may be lost time but also endangers children's characters by encouraging violence and brutality. Singular events like pupils attacking their teachers or colleagues in the course of a killing spree raised the media attention and draw an disproportional picture to the youth's situation in general and the influence of simulation games on their lives.

Fortunately the topic of gaming also is addressed in different ways. As shown in Chapter 2.3 games have been used for various purposes since centuries and especially they year 2002 marks a turning point in the field of *Serious Games* as it experienced a substantive boost. Not only that games are no longer being reduced to a peripheral section of software development – they conquered this field years ago – but now they are also recognised again as a valuable educational resource. The market for serious games is increasing and has left the field of school education behind and is now spreading out to all areas of training and education. Games are about to being accepted as a valuable form of expression in education and hopefully their use will not have to be justified anymore in future. Eric Zimmerman – an artist and game designer at the game centre of

New York University[1] and the MIT[2] – expresses this wish in his words when he writes on Twitter: "*We don't have to justify music or stories or images by demonstrating that they improve people. We shouldn't have to justify games.*"[3]

At the same time we are facing extensive technological changes interweaving broad layers of society. Mobile devices are advancing and offer increasing computing capabilities with every new generation. The market of mobile games has been exploding during the last years and it seems a reasonable step for creators of serious game to follow this path of development and also move to mobile devices. While there are still a lot of pitfalls ahead and the intense fight for market shares brought developers the chaos of platform fragmentation there are still solutions out there that promise facilitation. In the course of this thesis this challenge was accepted and the attempt was made to create an enjoyable and beneficial game for casual moments now and then to not only kill some time but also earn the gratification of increasing one's knowledge about the exciting field of art history. Museums and other institutions in the context of art history are facing the problem of decreasing interest of visitors and are eager for finding innovative ways of reaching possible new target groups.

With this background the creation of *ARTournament* attempted to evaluate how users of mobile smartphones can be encouraged to engage themselves with art historic contents and how the playing of a game would affect their learning success. The results showed that even with a quite simple prototype it was able to attract users quickly although no commercial distribution channels have been used. The analysis of game data showed further that even with an incomplex game concept impressive results can be achieved as the majority of the users accomplished far better results than from what would have been expected if supposed that they had just been guessing the answers. Furthermore, it was interesting to see how intense the game's intrinsic motivation worked as users were encouraged to play thousands of rounds competing for top places in the highscore list. Based on the experiences made a lot of possibilities for improvement have been identified for future development and some of the weaknesses in the current game have been spotted.

In conclusion, many positive experiences have been made during the work on the prototype. Based on the results the assumption can be made that further developments in the field of serious games with regard to a cultural heritage contextualisation will probably be successful. Due to the distribution and acceptance of serious games in other topical areas there is no reason to assume that this trend will come to an end. Having this in mind serious games will hopefully await a joyful future not only limited to educational surroundings, for instance schools, but also occupy a broad field of various thematic spheres, including also the section of cultural heritage.

[1] `http://gamecenter.nyu.edu/`, Last accessed 21/11/2011

[2] `http://cms.mit.edu/`, Last accessed 21/11/2011

[3] `https://twitter.com/#!/zimmermaneric/status/133662057047396354`, Last accessed 17/11/2011

Acronyms

ACID Atomicity, Consistency, Isolation, Durability 68
AJAX Asynchronous JavaScript and XML 71
API Application Programming Interface 32
CAI Computer Aided Instruction 11
BREW Binary Runtime Environment for Wireless 32
DEG Digital Educational Games 9
DGBL Digital Game-based Learning 9
GBL Game-based Learning 9
GUI Graphical User Interface 66
HTML Hypertext Markup Language 63
HTTP Hypertext Transport Protocol 67
HTTPS Hypertext Transport Protocol Secure 77
ICOM International Council of Museums 26
IDE Integrated Development Environment 66
J2ME Java 2 Platform, Micro Edition 32
JDBC Java Database Connectivity 70
JRE Java Runtime Environment 36
JSON JavaScript Object Notation 69
JVM Java Virtual Machine 36
MUVE Multi User Virtual Environments 28
MVC Model-View-Controller 75
PSP PlayStation Portable 32
RDBMS Relational Database Management System 68
SDK Software Development Kit 36

URL Uniform Resource Locator 67
VŠEM The Virtual 3D Social Experience Museum 78
WGA Web Gallery of Art 42
WWW World Wide Web 37
XML Extensible Markup Language 72

List of Figures

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