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MagMAR. Collaborative, Mobile
Augmented Reality supported game with
player generated content.

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Submission date: June 2013

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Problem Description

The main objective of the task is to investigate the usage of mobile augmented reality (on tablets or mobile phones) for games and learning. The focus will be on serious games supporting collaborative learning in a museum setting.

A scenario shall be designed so that it can be used in the museum setting to engage the young visitors to explore the museum setting on a deeper level. In this context we envision a collaborative game to play on a mobile device, that allows the players to create their own in-game content and compete against the opposing team. The more effort is put into content creation part of the game, the more chances team gets to win.

The task will result in a state of the art on serious games and augmented reality in a museum setting, followed by analysis of a proposed prototype of such a system to be. The results will be evaluated using a field test in the real world setting(actual museum) with intended end users(high school students).

Abstract

Playing games in the museums enabled teachers to engage young museum visitors in the museum experience more deeply and made the place seem more fun. Aim of these games is to encourage the young visitors to investigate the museum on their own and learn some new information in more informal way. However these games usually have predefined content and are played using pen and paper, both becoming less appealing to the younger generation.

This work aims at investigating how today's technologies can make these games more appealing to the younger generation while still providing some level of educational content. In particular the main goal is to study if removing the predefined content from a collaborative game and allowing the players to create their own game content will provide sufficient levels of motivation and engagement for the intended end users. Secondary goal is to study if Mobile Augmented Reality is accepted and useful technology to create a link between real and digital worlds in a museum setting.

The outcome of this work is an analysis of a game that allows the players to create their own game content, connected to the particular museum the game is played in and an implementation of such a game that uses Augmented Reality as a link between digital and real world. Followed by analysis of a Web Interface that allows the supervisor of the game to control some of the content and monitor the players game progress in real time. A detailed implementation documentation of the prototype is provided that supports the provided storyboard. A usability study was performed to reveal limitations of the prototype and the design of the game itself. The game prototype as well as the prototype of the Web interface were used in a field experiment with intended end users at the Museo Del 900 in Milan. The results of the field experiment were the basis for the project evaluation.

A workshop paper based on the work done in this thesis has been submitted at the MasIE workshop in collaboration with my supervisor Monica Divitini, my co-advisor Ines Di Loreto and Micaela Mander.

The conclusions of the work might be of use to researchers working on a similar problems or might serve as a base for longitudinal research to assess academical gains of such an application.

Preface

This thesis is a result of a TDT4900 Computer and Information Science, Master Thesis course, taken at the NTNU(Norges teknisk-naturvitenskapelige universitet) in Trondheim, Norway. The work was completed by the author during the Spring semester of 2013 in collaboration with Department of Computer and Information Science(IDI). The work was supervised by Professor Monica Divitini and co-supervised by Dr. Ines Di Loreto. This work builds upon work done during the Autumn semester TDT4501 Computer Science, Specialization Project course.

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Chapter 1

Introduction

This thesis is a continuation of work that has been done during Autumn semester TDT4501 Computer Science, Specialization Project. Purpose of the project was to explore how Mobile Augmented reality(MAR) is used in museums. The main focus being on serious games that promote engagement and learning. Having discovered a lack of such games developed in recent years I explored the technological and creative challenges in designing such a game. This research included exploration into availability of tools that are required to create such a game for independent developers and the possibility of employing these tools in a meaningful way. During my research I developed a limited functionality prototype of a game supporting MAR, that I will use further in my master thesis.

Main objective of this master thesis is to conduct research to test out assumptions of the usefulness of MAR supported serious games in a museum setting where users generate their own game content. During this semester I will attempt to complete the prototype of the game created during Autumn semester and use it as a tool to try and assess the usefulness of MAR games. Since assessing academical gains these kind of game might provide requires longitudinal studies I will focus mostly on engagement level of the prototype. Using the game I will conduct a usability study to try and perfect the games graphical user interface(GUI), followed by a field test experiment, during which the game system prototype shall be tested in a real world setting(an actual museum) with intended end users of the system(high school students accompanied by their teacher).

1.1 Motivation

As part of the autumn semester Specialization Project I explored ways of using mobile Augmented Reality(MAR) to make museum experience more fun and engaging for the young museum visitors. The main goal of the project was to try and use the new technology in a meaningful way that might promote engagement and trigger deeper interest in museum items that might in turn trigger academical learning ensuring that the young visitors have fun as well as learn something new.

This research triggered a deeper interest in the MAR technology and its potential. Since the field is relatively young and rapidly changing due to technological advancements, it is hard to base any long standing hypothesis based on previous work of others. For example in their survey Specht, Ternier and Greller concluded that MAR has the potential to serve as a link between educational objective and contextual information, providing a very useful tool that might provide academical gains in collaborative learning.[18] Yet in an experiment

conducted Professor Christopher Dede showed that the MAR technology did not provide any substantial academical gains. [1] What the experiment did show was that participants found that using the MAR application on hand held device was "cool" and "engaging". Building on these contradictory statements I try to find what is the situation today, when smartphones are powerful enough to support even complex MAR applications and what are the quantifiable gains of using this technology in a museum setting. Furthermore I provide a unique game scenario in which the players of the games are the ones who define the game content.

The main concern of this thesis is to evaluate if the game scenario can engage the students to explore the museum on a deeper level and try to asses if MAR technology is useful in this context.

A personal interest in augmented reality is what motivated me to explore the theme of this thesis in the first place. It started recently after I read about the Google 'Project Glass' project. [3]. This project is focused on bringing mobile augmented reality(MAR) into our everyday lives by supplying users with very compact, non-intrusive device in shape of eyeglasses. It is extremely innovative, almost as if it was taken from a science fiction movie. This sparked an interest in AR and I discovered that it is a lot older than I thought. Augmented reality has been with us for a long time, it was constantly transforming, getting more powerful and smaller with each year. [7] Today handheld devices capable of visual reality augmentation are a common thing to have. Even a low range Android OS based phone with camera is capable of some levels of 3D visual augmentation. The technology developed for military and medical purposes is now available for education and entertainment.

The later created a lot of questions like "Why aren't there more augmented reality applications that we use every day?" and "Why existing augmented reality games are not well known?". With this project I try to find out what it takes to develop a MAR application that people could use and modify to their needs in their everyday natural environment. And what it takes to make the application useful in the educational context.

I chose the museum as the setting because i find museums interesting and it is be easier to design a game based on an old paper based game of 'Treasure Hunt' in a familiar setting.

1.2 Mobile augmented reality

Augmented reality is a relatively new field of computer science that recently gained a lot of interest in private sectors and by general population. Previously used mainly for military purposes this technology proved itself useful in other fields such as medicine, architecture and entertainment.[7]

The later field grew a lot in recent years due to rapid development in handheld devices technology, resulting in a new sub field of augmented reality called Mobile Augmented Reality(MAR) [19]. MAR's popularity today is tightly linked to the availability of smartphones that can exploit its capabilities and enhance user experience while still remaining relatively cheap.

Since entertainment and tourism is a big part of focus of MAR research and museums is a kind of entertainment, a lot of research is being conducted in usefulness of augmented reality to enhance visitor experience in the museum setting. MAR has the potential to give users more visual information about the items in the museums or even augment the items themselves.[10] At this time though the technology is mainly targeted at tourism, creating interactive guides and visual augmentation of exhibitions (i.e. to show how the exhibition item looked a long time ago or how it was used). Other fields such as medicine and military are focused on

training people by giving them extra information on environment that surrounds them. [12] By combining education and entertainment MAR has the potential to make the learning process for people a lot more interesting and fun.

There already are quite a few educational games that can be played in the museum setting to make the experience for the children a lot more interesting and create an environment where they can learn a lot more by introducing a level of interactivity. One such game is “Treasure hunt”, where participants are assigned items to find in the museum and answer a couple of questions about those items by filling in a paper form. Team who answers most questions fastest wins.

By going a step further this game can be taken to a mobile platform such as Android OS or iOS making the museum experience even more interactive and fun. And to make it even more interesting for the participants the supervisor and any automation of scenario generation can be excluded from the game generation process.

Given the availability of augmented reality frameworks and compatible smart-phones and the absence of any recent developments of these kind of games for museums it would be interesting to investigate how hard can it be to create a flexible game that can be adopted to any museum.

1.3 Objective

MAR research inspired a variety of games and game prototypes, but non of them went viral and became commercially available or popular amongst the general population. Due to time limitations of this project it is not possible to research the sociological and academical affect these games have and what would make them more attractive and useful in our everyday lives. Instead I focus on engagement level this type of game might provide in a museum setting.

The project is highly focused on cooperation technologies. The game is not predefined, but rather constructed while playing, giving all the control to the players. This aspect makes this project different from all other documented projects found at the time of writing.

This research can provide valuable information on what aspects of MAR supported game the players found to be engaging and exciting. This might provide a basis for further research in injecting educational context into MAR supported games that can be tested by longitudinal studies that this thesis does not cover.

1.4 Research questions

From the research objectives I can now define the research questions(RQ), each one of them can be further broken down into a set of subquestions(SQ), that might be measured in some way. It is important to note that these questions have to be answerable in given time for the project.

- RQ1: Does custom content creation of game content provide sufficient levels of engagement?

The first research questions aims to asses if the fact that users have to generate their own game content will trigger an engagement level enough to put a lot of effort into creating high quality content in turn motivating other players to do the same.

Player generated content is the basis of this game and answer to this question might provide some interesting data for analysis.

- RQ2: Does the social interaction between the players motivate them to create high quality game content?

The second research questions looks into social interaction between the players and what are the possible scenario solutions supported by the system to be that can motivate the players to create high quality game content.

- RQ3: Is the MAR technology useful in this type of game?

In its essence the game can be played using a pen and paper. The goal of taking this game to a mobile platform, particularly a modern smartphone is to try to appeal to the younger technologically tech-savvy generation. The MAR technology will be used in subtle way, so not to distract the young visitors from the museum itself.

1.5 Research Method

To conduct this research I plan first to find out if there are similar application to the one described in section 1.3. It is important to make sure that the research I am doing is unique and useful in some way. The review of similar project will let me identify difficulties that others have faced while conducting similar research and might provide some inspiration while designing the application.

To answer my research questions I plan to upgrade the prototype produced in Autumn semester to fully functional prototype that could be used for testing purposes with independent participants. This will allow me to conduct a usability study, assessing if this game is usable in a museum setting and if the participants think it might be useful application to make their museum experience more interesting, followed by a field test experiment with intended end users in the real world setting.

Data collected during these experiments will be transcribed and analyzed.

1.6 Results

The work completed during this project resulted in a semi-functional game prototype that was tested in two different contexts. First testing consists of a usability study with participants of different age and background, mainly to determine if the application is usable in attempt to detect integral faults in the application. The second test was conducted as a field test experiment in a real world setting with intended end users.

The usability test resulted in a high score and did not reveal any major failures. The results of the test were used as a basis to justify the experiment in a real world setting with intended end users.

The experiment in a real world setting revealed a major usability fault of the prototype and provided with a lot of data used to address the research questions of this thesis.

1.7 Report outline

This section contains of an overview of the chapters of this thesis:

- **Chapter 2 - State-of-the Art.** This chapter aims to explain what are the benefits of moving the game from its paper version to a MAR supported application, followed by a literature review of similar projects that explored similar ways of integrating MAR applications into museum setting.
- **Chapter 3 - Previous Work.** This thesis builds upon work completed during Autumn Semester Specialization Project. This chapter summarizes results of the work done previously.
- **Chapter 4 - Problem definition.** This chapter aims at clarifying the problem this work is trying to address. Challenges of the thesis are defined and requirement engineering results are presented.
- **Chapter 5 - Storyboard.** This chapter uses a storyboard of the scenario, to provide an overall overview of the system and to give a better understanding of how the game is played from the very beginning to the very end. Since the GUI of the game prototype was created during the Autumn Semester Specialization Project, actual screen shots of the application are used.
- **Chapter 6 - Solution Proposal and Implementation.** This chapter describes one of the possible solutions of the problem. First the result of the Autumn project are presented, followed by the changes made to design a whole new interaction module for the system to support the multiplayer activities.
- **Chapter 7 - Usability Study.** This chapter consists of the usability study. First the aim and design of the study is presented, followed by the results and discussion.
- **Chapter 8 - Evaluation and discussion.** This chapter describes how the system prototype was evaluated. The proposed prototype is evaluated using an experiment with intended end users in the intended real world setting.
- **Chapter 9 - Conclusions.** This chapter presents the conclusions of this work and proposes ideas for future work.

Chapter 2

State-of-the Art

2.1 Why Mobile Augmented Reality

In this section will explain possible benefits of introducing augmented reality technology to create a MAR museum game application. To do that, firstly it is important to understand what are the advantages of digitalizing this type of games in the first place and how this game would enhance the museum experience.

2.1.1 From paper to Virtual Reality

When people hear a term game, they form an image of the activity based on our childhood experiences. People who had their childhood since 1980, played video games their entire lives and have a very different view on them comparing to the previous generation.[21] Michael Zyda in his paper describes a video game as a "mental contest , played with a computer according to certain rules for amusement, recreation, or winning a stake". But in recent years video games became much more than that. Research shows that games can be beneficial not only in recreational perspective, but also in educational as a means to improve academic gains in a classroom setting.[16] The educational benefits of playing game are supported by previous and more modern experiences in creation and testing of these type of games.[11][17] Leading to emergence of a new type of games - serious games.

Serious games

The emergence of this type of games was a very important step in video game research. Firstly it broadened the research field of games and provided the new generation of students with innovative learning tools that are becoming more acceptable by general population.

In his article Michael Zyda defines serious game as a "mental contest played with a computer in accordance to specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives". This expands the previous definition adding a whole new dimension to the game: pedagogy. This addition is what makes the game serious. Figure 2.1 shows the integration of pedagogy into the standard video game model, consisting of story, art and software.[21] The main challenge of serious games is how to correctly incorporate pedagogical agenda into the game without making it boring and still provide academical benefits. This process involves balancing the entertainment component - story with pedagogy. In any case, to make the game appealing, the story has to

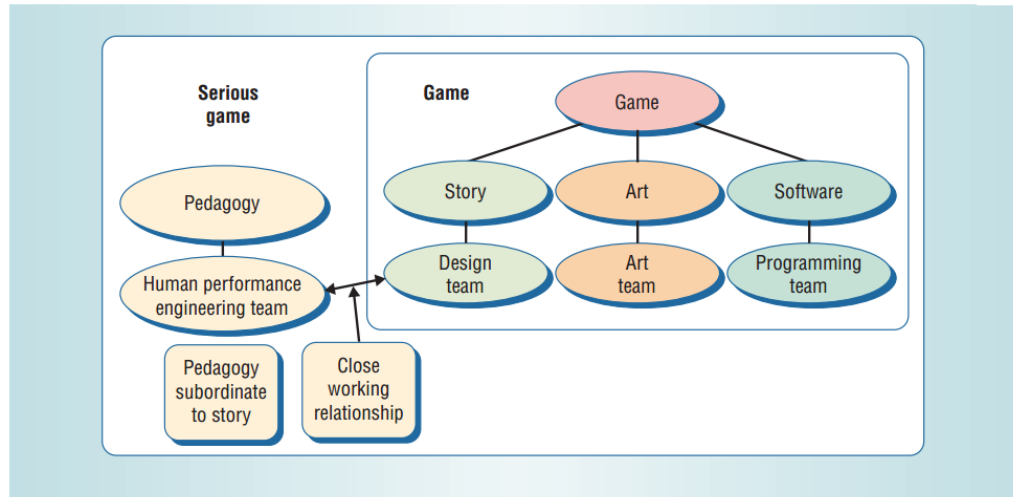


Figure 2.1: Serious game
 taken from: "From Visual Simulation to Virtual Reality to Games" [21]

come first.[21] The second challenge is the pedagogical approach itself. Software engineers have to work closely together with the matter experts of the field to be able to capture and evaluate academical impact the game has.

2.1.2 From Virtual Reality to Augmented Reality

Given the possibility that moving games to digital world might have substantial educational benefits, what are the advantages of Augmented Reality(AR) comparing to Virtual Reality(VR) used in the classical approach to computer supported education?

Virtual reality provides a 3D computer generated interactive environment. Since the 1990 it grew in complexity and quality and now can almost resemble real world. Some good examples can be provided by film making industry, where computer generated content looks and sounds as real as it gets. The other common examples is video games. Each year new video games are pushing the boundaries of what is possible, providing more physically and visually realistic game worlds that provide millions of gamers with new engaging and interactive experience. But there is one inherent flaw, all VR content is computer generated and no matter how close it gets to resemble real world we still know it is not real.[14]

Here is where AR comes into play. The main advantage of the technology is that it is created to supplement the real world with three dimensional virtual objects and/or audio content that appear to coexist in the real world. By providing more intuitive and natural means of interaction AR has the potential to further blur the line between computer generated content and the real world(see figure 2.2).

2.1.3 Mobile Augmented Reality in the Museum

The benefits that serious games might bring to education and entertainment enhanced by MAR seem like an interesting field to investigate further.

Due to time limitations of this project it is not possible to investigate academical benefits that these games provide in practice. Instead I will focus on engagement level that these games trigger in those who play them.

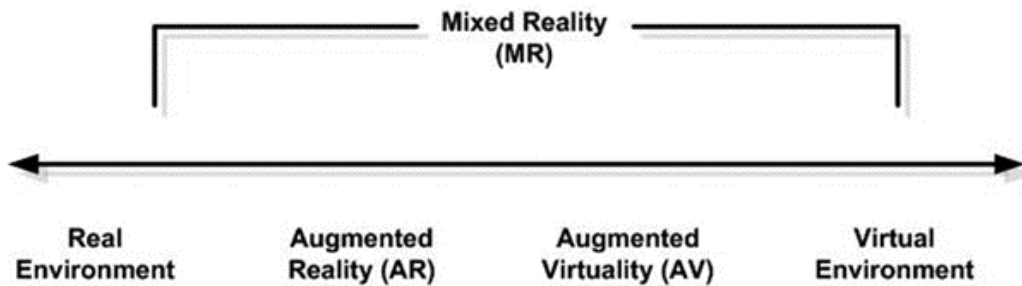


Figure 2.2: Augmented reality

taken from: A survey of augmented reality. Presence: Teleoperators and Virtual Environments 6 [7]

It would seem that serious games might have the ability to provide academical benefits to the ones who play it and given the technological advancement today it seems that MAR (see section 1.2) is an interesting tool to investigate in providing this engaging and educational experience.

The question to be answered is "Are MAR games useful in providing academical benefits?" In the section 2.2 I provide some examples of similar games that have been developed for museum setting. Most of them are based on the assumption that this computer supported learning is better than the standard approach of museum tours.

In this context a standard museum tour is when a supervisor or a guide walks with the museum visitors through the museum, telling them stories and facts about museum exhibits. In case of younger visitors this approach has many flaws. One of the biggest flaws is that young visitors probably have no need for the information acquired and unless they have some personal interest in the exhibit, they might forget all that has been told by the guide the next day.

Introduction of games though has the potential to help young visitors to use the information gained during the tour in a more meaningful way. [20] As in the young visitors collect the information and use it right away to complete some tasks or answer some questions.

The introduction of technology or a video game might provide multiple benefits to the setting described above. Young visitors are most likely used to play video games and are familiar with multiple platforms to play them on. Introduction of a video game to this setting might provide a natural environment in which the young visitors are used to play games. [21]

Going one step further and replacing the more common VR in the video game with AR might provide even more intuitive and realistic gameplay increasing the immersion of the players.

Even though it would seem that what I have here is a perfect recipe for a serious mobile augmented reality museum game, the tricky part is how to correctly incorporate pedagogical approaches into the game. In Chapter 5 I propose a game scenario and a storyboard describing my proposition for this kind of game.

Going back to the research question I think that research described in this section make a compelling argument that MAR museum game can be useful. To figure out to what extend the game might be useful and how much academical improvement it could provide comparing to the standard approach more extensive ethnological studies are required.

2.2 Museum adventure

2.2.1 Literature review

Preliminary literature review indicates that there were a few attempts at bringing a level of mobile augmentation into museum setting for educational purposes by means of designing a prototype application for PDA using flash technology. [13] The game itself is an implementation of a classical "Scavenger Hunt" game. In this game users played the game by answering the questions provided by the system. To find the correct answers, players had to explore the museum and find relevant information about one of the items found in the museum. The project was strongly influenced by the technological difficulties that the PDA's provided, as by that time handheld PDA's had almost no processing power and little to no memory. But despite the the slow hardware, participant interviews indicate that players enjoyed the experience and proved it to be not only entertaining but also educational. My project is closely related to the main theme, but uses MAR as means of interaction between museum items and the player, bringing the game to a whole new level.

Other studies indicate that the use of MAR has a lot advantages over using Virtual Reality simulations for educational purposes mainly due to human perception of our surroundings and ability to relate to the contents of the application. It is a lot easier to understand the augmented reality applications because they assist user by supplementing existing world instead of attempting to generate a new one. [10] This research supports the idea that by moving around the museum, trying to find the items using the mobile phone camera instead of just getting a list of questions might improve user engagement.

Kangdon Lee in his paper conducted a literature study of how augmented reality is used in education and training in the last few years and what future might brings us [7]. Even though there are some uncertainties of efficiency of augmented reality(due to costs of technology and software development) comparing it to conventional learning, this paper supports the validity of a need to do more research in this direction.

Another research in usefulness of educational games was conducted by Nikoleta Yiannoutsou Ioanna Papadimitriou, Vassilis Komis and Nikolaos Avouris. [20] By implementing interactive games in museum setting for PDA's and observing how people interacted with them, researchers concluded that when children can use the information gained in the museum immediately to play a game the museum experience can be both educational and entertaining. My paper introduces augmented reality into equation making the experience even more dynamic and interesting.

The most recent and relevant attempt was Mobile Augmented Reality Quest(MARQ). This is an electronic tour guide based on a custom cheap PDA, that brings 3D AR to a group of visitors. This game uses interactive visual and audio augmentation to make the visitors experience as rich as possible. This game supports multiple user interaction bu sharing the "collected items" between players and tracking the position of the players.

MARQ is a team-oriented game that is supposed to provide an AR museum tour. It is targeted at younger visitors(age 12-16), who have to explore the museum by solving interactive 3D AR puzzles to reveal parts of the story.

I used the last project as an inspiration, because it uses a lot of professional interactive 3D AR and is closely related to my research. The main difference of my research is that MARQ is specifically tailored for one museum and players have a predefined scenario. I want to explore the possibility of creating a game engine that helps set up and play the game as easily as

possible with minimal involvement of the museum.

Chapter 3

Previous work

In this chapter I will summarize the work completed during Autumn semester Specialization Project course. During this work I conducted a literature review of existing games with similar purpose that use MAR as the core technology to bring the real world and virtual world together. Since there was little work that could be found of using MAR in academical purposes in recent years I tried to apply the technology to construct a small prototype to explore technological difficulties in developing such a game.

The work revealed the limitations of MAR from technological point of view. There are a lot of MAR frameworks for modern smart phones, but very few of them are well documented and supported. Even though some application that can be used outdoors depend only on GPS coordinated of augmented content, applications that are to used indoors rely heavily on the quality of the anchor to the real world in form of physical markers or augmentation surfaces.

The work also revealed the benefits in cooperation of MAR comparing to VR technology. To play multiplayer MAR games all participants have to be at the play site. This requirement means that most of the communication between the players is live and some parts might be augmented by the technology.

3.1 MAR in museums

During the autumn project specialization course I explored how MAR is used in a museum setting today and how it was used in the past.

It turned out that there were few attempts to incorporate MAR into museum setting [10] [9] [20], but due to technological limitations they did not gain much popularity amongst the museum visitors.

Rapid technological development of mobile devices today, provided us with powerful and affordable mobile devices (smartphone's, tablet pc's) capable of complex visual and audio reality augmentation changed everything. Today a lot of museums have some sort of visual and/or audio augmentation to provide visitors with richer museum experience. Some museums use this technology as a digital guide (i.e. providing users with extra information about the item that they are interested in or showing visual augmentation of the item how it looked in the past) or for entertainment (i.e. mini games to make the visit more fun). The later interested me most and I wanted to explore how the MAR technology could provide more engaging museum experience while providing some sort of academical gain.

3.2 The prototype

To try and assert technological difficulties of creating MAR game in a museum setting I decided to design and implement a prototype of such a game. I assumed it could provide me with hands on experience in the field and help me answer my research questions not only by studying the work of others but also by using my own experience.

3.2.1 Designing museum MAR game

Creating a game from scratch would require the resources I did not have at the time, so I decided to base the game on a paper based game "Treasure hunt". In the original version of the game the players receive a list of questions on a sheet of paper and have to answer them by finding out information about the museum items by exploring the museum.

I chose to base my prototype on this paper based game mostly because the game was simple enough to implement and it had all the ingredients that I needed. The game required physical exploration of the museum to answer the questions and cooperation amongst the players.

As I kept the main ingredients(cooperation, exploration, answering questions) of the original game I decided to go a step further and added some originality to the game by removing pre-defined list of questions and splitting the game in two stages. This was a very important decision and I made a few assumptions on its engaging value that I am going to test in this master thesis. The removal of the questions essentially means that players have to create their own questions. Question creation might require a certain level knowledge and creativity that in turn might make the game more engaging for broader population.

Since the it would not make sense to create and answer your own questions I decided that the game should become team game, where two opposing teams compete against each other and/or time. Now each team had to create question linked to museum items that the other team should try to answer.

3.3 The technology

One of the most important decisions to make was choosing a platform to build upon. MAR is a popular technology and is available for a wide range of devices. It was important to keep the game as mobile as possible not to obstruct free movement of the players. This factor excluded ultra portable laptops and tablet pc's and I decided to implement a game for a smartphone.

The next choice was to choose between Android OS and iOS(Symbian and Windows was not considered at the time). I chose Android OS because it was more available and open-source platform that supports development for testing purposes and I personally had more experience with it comparing to iOS.

3.4 Mobile Augmented Reality Framework

After I chose the platform I had to find a well documented open source mobile augmented reality framework that the application would be based on. The framework can have a very big impact in the architecture of the application. As the components might assume architectural

patterns themselves, makes it difficult to select architecture prior to studying the components themselves.

After a brief review and testing of existing frameworks I decided to choose Qualcomm Vuforia SDK. Vuforia is a part of the Qualcomm AR Platform that also includes the Target management system. The framework uses markers to detect the augmentation surface. The user gets a lot of control with this framework as the images used as the augmentation surface can be custom defined by the user. [5] Comparison to other frameworks can be seen in table 3.1. Vuforia also had a step-by-step setup information and is very extensively documented and has a public forum where people can get help with practical problems. This last feature was the breaking point that led me to choosing Vuforia as the framework for my project.

| | Popcode | Vuforia SDK | AndAR |
|--------------------|---------|-------------|-------|
| Marker based | X | X | X |
| Well documented | - | X | X |
| Extended tutorials | - | X | X |
| Community forum | - | X | - |
| Open-source | - | X | X |
| Easy to understand | X | - | - |

Table 3.1: Framework features comparison

3.5 Choice of the device

There are a lot of devices based on Android OS to chose from. After I chose the framework I compiled and tested the example applications supplied by the framework on a few different HTC and Samsung smartphones ranging from budget to top of the range devices.

This provided me with some requirements fr the game. To make it user-friendly and usable by broader population the most important factor of the smartphone was resolution. Preliminary testing showed that resolution of 720 x 1280 pixels was optimal for the purpose of this testing. Keeping in mind the range of Android OS based smartphones it is not possible to insure the stability of the application on all existing devices. For purpose of this project I chose to support mainly HTC One X smartphone.

3.6 Development technologies

3.6.1 Android Software Development Kit

The Android software development kit (SDK) includes all the tools needed to develop applications for the Android OS. It has all the necessary libraries, debugger and even an emulator, that is not that useful, but still a nice feature. When I decided to develop application for Android there was no other alternatives that I was aware of. Moreover when I was researching MAR frameworks, installing Android SDK was the only suggestion in all the framework setup guides.

3.6.2 Eclipse Integrated Development Environment

I decided to use Eclipse Integrated Development Environment (IDE), because it has a very good support for the Android SDK and I had previous experience with it from earlier projects.

3.7 Cooperation

It is important to note that the game is to be played by two competing teams. This factor makes the application a multiplayer game. The first prototype of the application was a hotseat game, where players would play the game using one device in turns. But still the game is played by a team and not an individual.

When players create a question connected to a museum item only one of them can operate the device at any given moment, but all members of the team decide on the content of the question. This aspect provides a possibility (if not makes it mandatory) of live communication between team members to solve a common problem. The players are not pressured by time limits, so they can discuss the question until they reach a consensus.

MAR technology just might have the potential to bring back real communication to gaming and make people go outside and play.

Chapter 4

Problem definition

This chapter aims at clarifying the problem this work is trying to address and define the challenges and requirements one faces in designing and testing MAR educational game.

The main objective of this work is to find a way to incorporate a new and promising technology into museum setting to support collaboration and promote engagement to exploration to museum visitors. Mainly investigating if a MAR game can promote engagement that will trigger deeper exploration of museum items by the visitors of the museum and what are the advantages of this technology comparing to paper based games.

This objective can be broken down into two smaller objectives. First being designing a game that actually can promote engagement levels enough for the users to see the application as something they would use more than once. Second objective is to compare the engagement levels of a game that is using MAR to a more conventional paper based game.

This work focuses a lot on MAR as a tool for user interaction with museum items, but matters like collaboration and competitiveness between playing teams will also play as a factor in designing and testing the game.

To further illustrate the problem, a case scenario of a paper based game is provided in section [4.1](#).

4.1 Treasure Hunt

There is a number of games that can be played in a museum setting that require exploration of the museum. One of such games (and a focus of this work) is a game of treasure hunt that was chosen mainly because of personal experience with it in the past. The other factor that helped to make the decision is the low requirements of the game that made the transfer to smartphone much easier comparing to other board based games.

4.1.1 Scenario

Game participants enter the museum. They are greeted by the supervisor and are split into teams. Each team is given a paper and pen to play the game. The paper contains a list of questions that are related to specific items in the museum. Players are given specific amount of time to find answers to these questions.

When the game begins teams explore the museum finding relevant information on the labels that museums place near museum exhibits. This information is used to answer the questions by filling in the paper form.

4.2 Problem elaboration

The main problem with the classical approach is the game is not flexible and requires pre-defined list of questions. Each game requires new list of questions that has to be prepared by the supervisor. Second issue is that the questions have to be answerable using information that can be found in the museum at the time of game session.

All these limitations require a lot of effort from the museum trip supervisor or teacher. It also means that the game requires a game master; A person who would prepare the list of questions and answers in advance.

All this extra effort and limitations usually results in the fact that these games are rarely played and are usually substituted by a guided tour that can be rather boring and might be substituted by a pamphlet.

4.2.1 Information Collection

During the game session the players have to find answers to the questions found on the paper questionnaire based on the information provided by the museum in form of a small item description placed near the item itself or based on the information received from the teacher or supervisor beforehand as part of the curriculum.

This might help the visitors to revise the previously acquired information or acquire some new knowledge previously unknown to them. But the information is still strictly limited and even if the gameplay will trigger further interest in a particular museum item further exploration to gain more information is fairly limited.

This means that if the game is to be played at the same location more than once, museum visitors might not acquire any new information, making the game boring.

Most long-lasting games in the past have been competitive, because they lead to an endless supply of similar yet subtly varied puzzles. [2]

4.2.2 Score Keeping

In the classical approach teams of players submit the game sheets to the supervisor and are given the overall score. The game sheets are afterwards or immediately on the site are analyzed by the teacher or supervisor. The answers are corrected, final score and the winner is announced.

At this point the game is over and players might not even be interested in checking what answers they got right and what answers they answered incorrectly. Not to mention the extra time it takes for the supervisor to examine and evaluate the game sheets.

When designing such a game a score system plays a very important role as a direct way of motivating the players to progress throughout the game and contribute as much as possible. Assigning points for correct answer to the question provides the players a clear connection between the effort they make to find the right answer and the outcome of the game (team with

most points wins). [15] It also might be relevant for the players to receive a summary of the game at the end of each session as in the paper based game, to get an overview of all the questions and find out the answers to the questions they got wrong.

There are other various methods in motivating the players to play the games in form of challenges such as time, high score lists described by Malone [15] though effective, but not applicable in this domain.

4.3 Challenges

Designing a game that is supposed to be educational, engaging and fun at the same time provides a variety of difficulties that need to be addressed. It is important to provide the players a comfortable environment with puzzles that are constantly changing, are relevant to them at the time and can be solved with some effort. This requires a high flexibility rating of the game and ability to adapt to the needs of the players at any given time.

4.4 Flexibility

Since the game might be played in any museum by people of different age it is close to impossible to generate a list of questions that will suit everyone. To support high level of flexibility the system should leave the creation of the game content to the players themselves.

The system should provide players an interface of creation of the content that later in the game can be used by other players. This functionality eliminates the need to have a list of predefined questions as the questions are created by two competing teams at the first stage of the game. This factor creates the need for an information source more deep than an information pamphlet found at the museum, such as Internet. The players should be provided by a secondary device that they can use for information gathering that should in itself provide a ground for more interesting and relevant content to the players at given time and place.

4.5 MAR

During the Autumn Specialization Project I came to a conclusion that MAR technology has many benefits over VR technology in creating collaborative games for educational purposes. But it also has its drawbacks when used indoors. To identify museum items each of these items has to be marked with a small marker that can be placed anywhere in the vicinity of the museum item.

Even though physical markers provide some limitations to the game it also provides the supervisor or teacher the ability to select the items for the game session. This decision provides some trade off between the players ability to select any item they like and teachers ability to select items relevant for the course that he or she is teaching at the time.

To be able to control the markers without involvement from the museums side, the teacher or supervisor should have a separate interface to be able to set up the marker-item relationship and tack the game process.

4.6 Requirement Specification

This section describes the process of requirement engineering for both players client application and supervisors administrative Web interface. Both functional and non-functional requirements are presented to get a better overview of the system to be. Later a table of prioritized requirements is presented to help the process of implementation.

Most of the functional requirements presented in Table ?? are a result of requirements engineering process concluded during Autumn Specialization Project.

4.6.1 Prioritization

All requirements are prioritized as High, Medium or Low. This is done according to the IEEE 830 standard described in Recommended Practice for Software Requirements Specifications.

- Low(L) - low level requirements are optional and imply that they will contribute to the quality of the system, but will have no impact on the functionality.
- Medium(M) - medium level requirements are not essential to the functionality of the prototype, but might be implemented there will be extra time.
- High(H) - high level requirements are essential to the prototype and must be implemented.

4.6.2 Functional Requirements

The functional requirements describe what the system must be able to do. Functional requirements of the game application are described in Table 4.1. Functional requirements of the administrative Web interface are described in Table 4.2

Client Application

Requirements for the client application are presented in Table 4.1.

Supervisor Web Interface

Requirements for the supervisor Web interface are presented in Table 4.2

4.6.3 Non-Functional Requirements

Non-functional requirements or system quality attributes focus on desired qualities of how the system should perform tasks and not what tasks it should perform. Examples of non-functional requirements: security, performance, modifiability, usability. Since the application to be created is a prototype modifiability is the most important factor that must be addressed. Second most important quality of this system is usability, Since the prototype will be tested with possible end user audience, the application has to be of high usability.

| Requirement No. | Description | Priority |
|-----------------|---|----------|
| FR1 | Application should be able to display the startup menu view. | H |
| FR3 | It should be possible to connect to the game server | M |
| FR4 | It should be possible to start Stage 1 of the game | H |
| FR6 | It should be possible to select the museum items marker using augmented reality view | M/H |
| FR7 | When the item is selected it should be possible to create a question | H |
| FR8 | It should be possible to start Stage 2 of the game | H |
| FR9 | It should be possible to choose only the items that have questions created | M/L |
| FR10 | It should be possible to view and answer the question created by the opposite team in Stage 1 of the game | H |
| FR11 | When the Stage 2 of the game is finished it should be possible to enter results view | L |
| FR12 | It should be possible to use the application on two devices simultaneously | H |

Table 4.1: Functional requirements Application

| Requirement No. | Description | Priority |
|-----------------|---|----------|
| FR1 | User should be able to log in to the Web interface. | H |
| FR2 | User should be able to create a new game session. | H |
| FR3 | User should be able to create a desired amount of items and enter their description. Such as item title and item description. | M |
| FR4 | System should generate a unique marker for each item created by the user. | M |
| FR5 | System should provide the user with the ability to print out the list of questions with correlating markers. | M |
| FR5 | System should be able to save and keep previously created games. | H |
| FR5 | System should provide the user with the interface to track the game process in real time. This includes displaying the questions as they are created in real time and displaying the selected answers to these questions in the second stage of the game. | L |

Table 4.2: Functional requirements Web Interface

| Requirement No. | Description | Priority |
|------------------------|--|-----------------|
| NFR1 | The application should be user-friendly and intuitive | H |
| NFR2 | Since the application is developed for a phone GUI should be scaled accordingly | M/H |
| NFR3 | Since the application is a prototype it is important to keep in mind that it might be expanded in the future. Encapsulation and abstractions are important | M |

Table 4.3: Non-functional requirements

Chapter 5

Storyboards

This chapter is aimed at clarifying the game concept and the process of a game through a story. The story in detail shows the interaction between users and the system in a normal game session scenario. The end users of the system('Actors') are people of various age (16-35) with wide variety of backgrounds. To be played in a meaningful way the game requires at least 5 actors with different roles.

5.1 Actors

There are two main groups of users of this game.

- Supervisor - a person that sets up and supervises the game. The supervisor has a separate Web interface to set up the game and monitor the progress of the players. Usually the supervisor is a teacher, who takes the students on a trip to the museum.
- Players - a group of people who participate in playing the game. Usually it is the students on a field trip to the museum. The players are split into two teams.

5.2 Location

The game is not made for any specific museum. Instead it is focused on flexibility and its ability to be deployed and played at any location with vague resemblance to a museum(workshop, small gallery, local exhibition). But it does require for a sufficient space for the players. Players play the game simultaneously and if the teams stand too close to one another they might overhear the answers to the questions, what would lead to intentional or unintentional cheating.

For the purpose of illustrating the game in its intended location, the game scenario in Section 5.3 the museum is fictional and contains famous paintings from around the globe.

5.3 Scenario

5.3.1 Game background

The game application is a modern implementation of the classical game called "Treasure Hunt" based in a museum setting. In the classical approach players play the game using pen and paper. To start the game players are split into two teams and are given a list of questions that can be answered by finding the corresponding items and filling in the answers with a pen. To find answer to these questions players need to explore the museum on their own. The team that answers most questions correctly wins.

My approach replaces the pen and paper with an Android OS based device and Mobile Augmented Reality(MAR) based application.

5.3.2 Game scenario

The game is played in four stages:

- Setting up the game
- Starting the game
- Stage one
- Stage two

A scenario for each stage is provided in sections below.

Setting up the game

After familiarizing himself(or herself) with the museum, the supervisor decides to choose six items for his students to play with. The choice of the number of items can be influenced by the size of the museum or other limitations as time or item relevance. Now the information about the items has to be entered through games administration interface. The main page of the interface can be seen in Figure 5.1

To be able to do that the supervisor logs in to his account and selects 'Create new game' button from the main menu of the Web application(see Figure 5.2). Clicking this button opens a sub menu in lower part of the Web application where the supervisor inputs number '6' as that is his desired number of museum items(see Figure 5.3). This action creates six empty templates that contain:

- item title - the name of the item or a short description
- item description - a short description of an item that is sufficient enough to identify the item. This description might provide some generally known facts about the item (author, when it was created etc.), but should not contain extended information as to give players the opportunity to find that information themselves.
- marker - a unique marker that must be placed near museum item and ties the information entered to the museum item.

After entering all necessary information(see Figure 5.3) the supervisor clicks 'save' and 'print' buttons that save the game information and print out a sheet of paper with markers. The

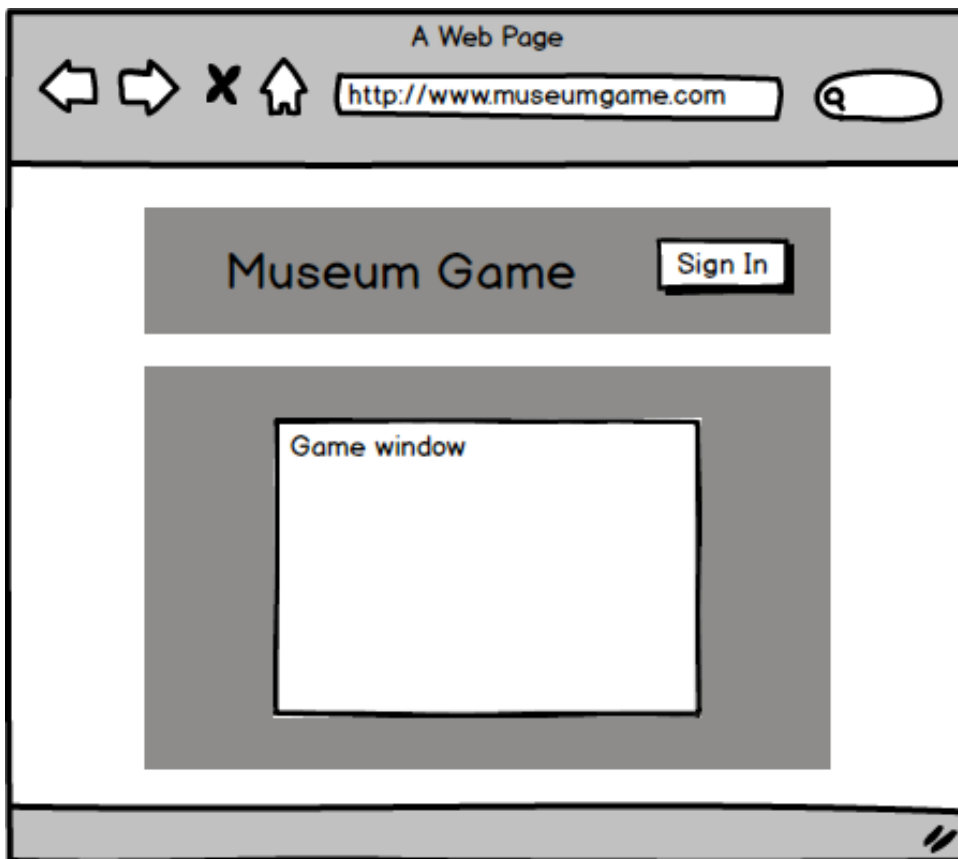


Figure 5.1: Administration interface: main view

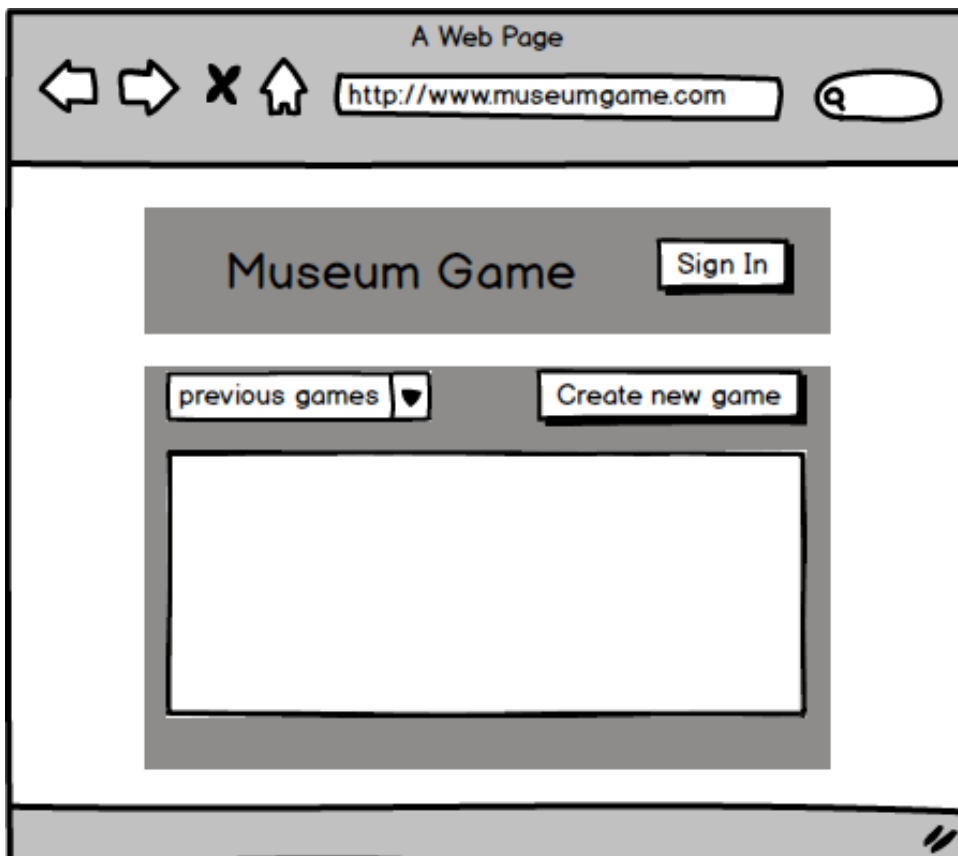


Figure 5.2: Administration interface: game administration view

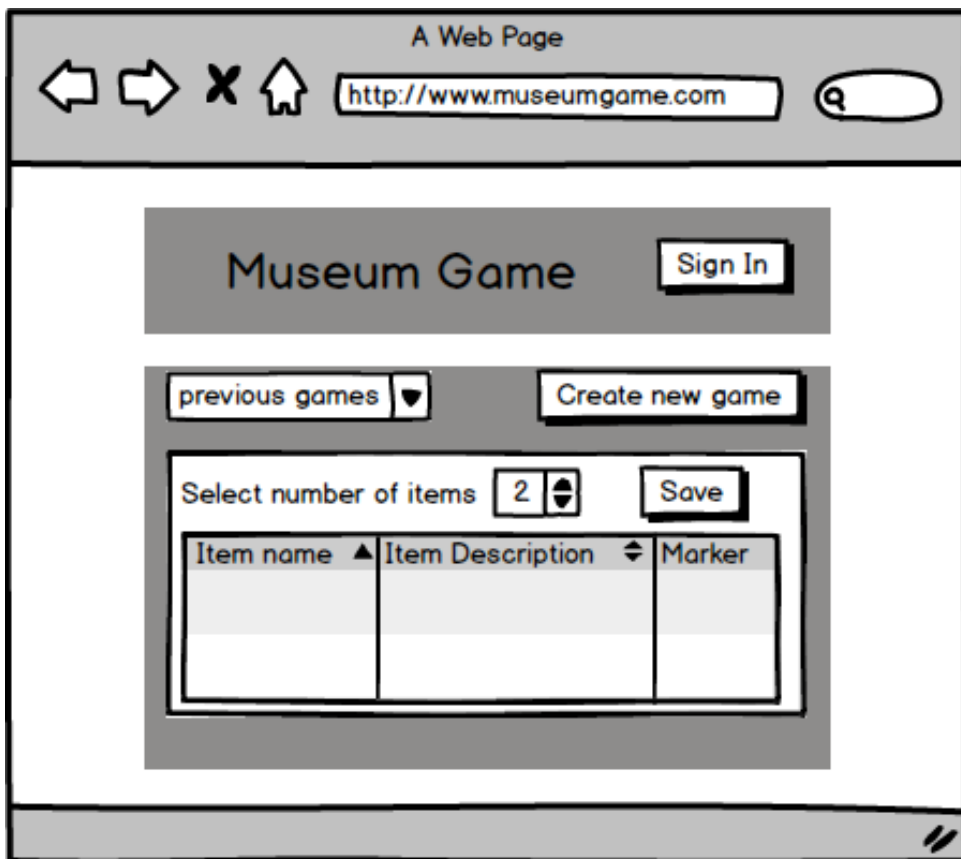


Figure 5.3: Administration interface: game creation view

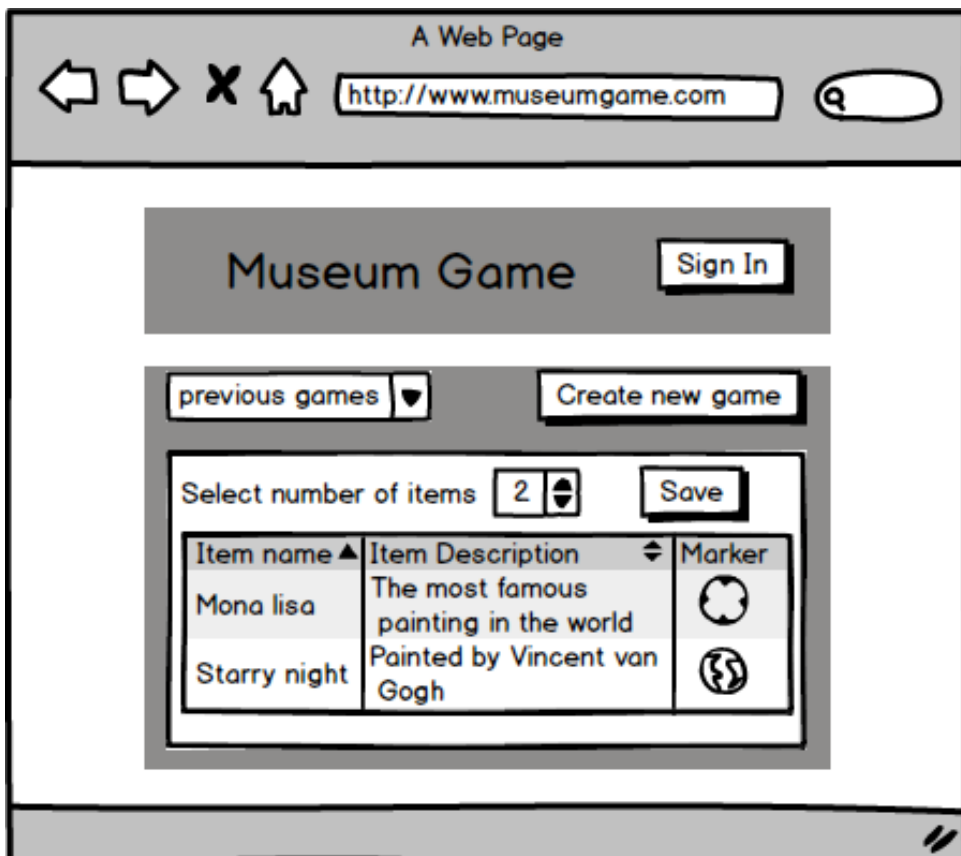


Figure 5.4: Administration interface: game selection view

markers on that sheet of paper will be used to mark the museum items. Now all is left to do is cut out the paper markers and head to the museum.

Before the actual game session the supervisor has to manually put all the markers(see Figure 5.5) in the vicinity of the corresponding museum item(see Figure 5.6).

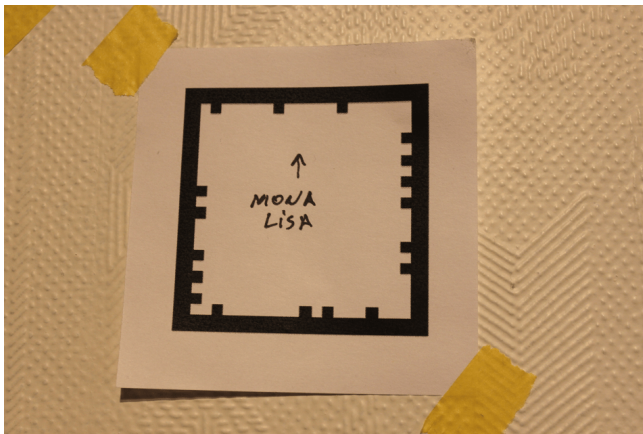


Figure 5.5: Marker

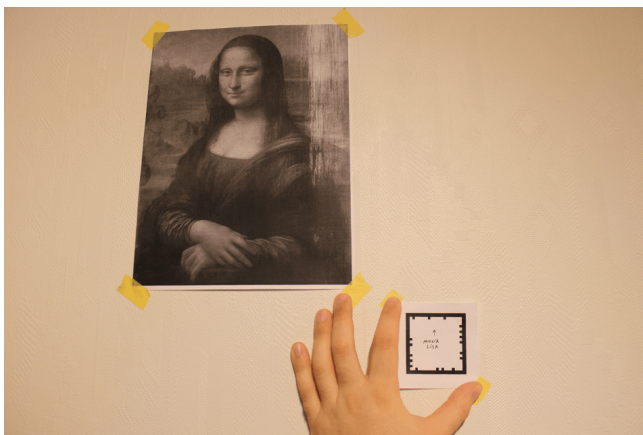


Figure 5.6: Marker placement near museum item

Now all the preparations are over and the game can start. To start the game the supervisor goes back to the administration interface and selects one of the previously created games from the drop down menu. All previously saved games are displayed using the date when the game was created. Upon selecting a game all the item information is showed once again and is available for printout.

After selecting the correct previously saved game and pressing the 'Start game' button the administration interface goes into listening mode and waits for the players to start the game.

Starting the game

After all the preparations are complete the supervisor invites the players to the museum. To be played in a meaningful way, the game requires at least four players, that can be split into two teams. The amount of players in each team is not limited, as long as the team is small enough to allow participation of each individual.

The supervisors gives the equipment required for the game session to the participants. To play the game it is required for each group to have an Android smartphone with the game application running. The smartphones might be provided by the supervisor or in some cases, if the players don't mind, players can use their own smartphones as long as they meet minimal requirements. To make the game more interesting the supervisor might also provide the players with a tablet pc through witch players can connect to the Internet to search for additional information about the item. Both the smartphone and the tablet pc can be seen in Figure (PICTURE). After

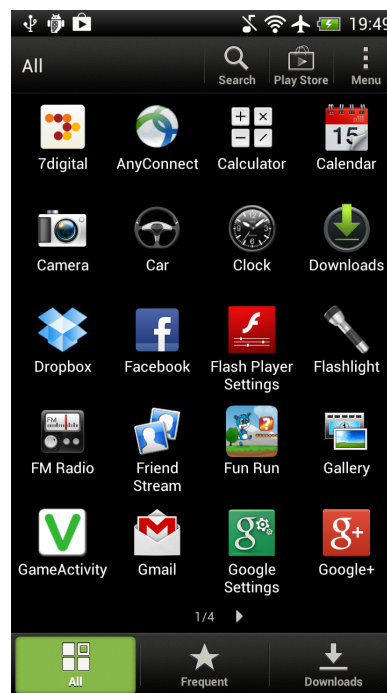


Figure 5.7: Game application icon

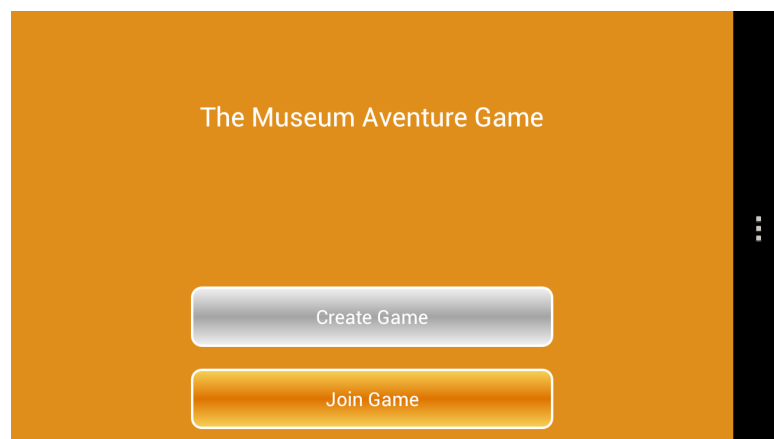


Figure 5.8: Startup view

the players have the equipment, they can start the application by clicking on its icon in the list of applications(see Figure 5.7). As soon as the players click on the application icon the game activity starts up and displays the startup view with two buttons (see Figure 5.8). Players click the 'Join Game' button and it takes them to the next view where they must enter unique game identification number. (see Figure 5.9) The supervisor tells the players that received the smartphone identification number(id) of the game server shat is was started through the Web application(see Section 5.3.2). The players can now enter the id number of the game and click 'Ok' button. If the entered id number of the game is incorrect the application will inform the

players of the incorrect action and ask to enter the game id again. The game id was correct and

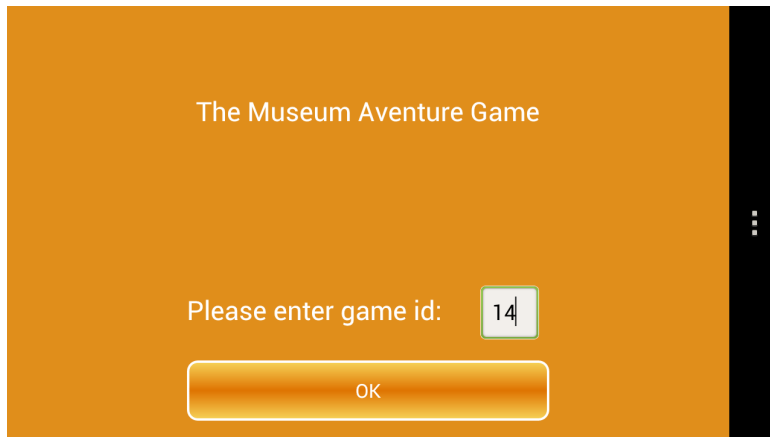


Figure 5.9: Join game view

both teams joined the game. At the time of joining the game the teams were assigned a color. Now the teams are named 'Team Red' and 'Team Blue'. As they play the game the teams do not interact with each other trying to keep the discussion volume as low as possible, so not be overheard by the opposing team.

Player from 'Team Red' approaches the first item and points the device so that the paper marker placed by the supervisor is visible on the devices screen. As soon as the device detects the marker it shows the players additional information about the item (such as item name and description) and overlays a 3D model of letter Q (short for question) on top of the marker (see Figure 5.10). This also makes the 'Create Question' button active. The all players from 'Team Red' read the augmented information and recognize the item. The player holding the device touches the 'Create Question' button. Now the team has to fill in a question form consisting of the body of the question and three answer alternatives, one of which has to be selected as the right one. Now the hard part begins, 'Team Red' has to come up with an interesting question that might be hard to answer. They turn to the player with the tablet pc and they search the 'wikipedia' pages in hopes to find some interesting information. The players find out that the painting was stolen on 21 of August 1911 and there are a few suspect names, that can be used as alternative answers. After some discussion players decide that it might be a good question so they enter it using the device (see Figure 5.11). After, they select Perugia as the correct answer and touch the 'OK' button to confirm the creation of the question. Now they are familiar with the question creation and create the questions for the rest of the museum items that were selected previously by the supervisor. Both teams are now finished with creating the questions and finish the first stage of the game by touching the 'end stage one' button (see Figure 5.12). As the players were creating the questions the supervisor can see all the questions created in real time. (see Figure 5.13) If the supervisor is not happy with the question created he/she might ask the players to try harder and create the question again. The game allows for multiple creation of questions, but only the last one is saved for the other team to answer.

Stage two

At the beginning of the second stage of the game all items that were marked by the supervisor now have questions created for them. The teams switch places and start looking for the museum items that were selected by the supervisor during setup of the game. The game is not aimed at finding hidden markers, so if players have trouble finding some of the markers they can always ask the supervisor to help them find that missing marker.

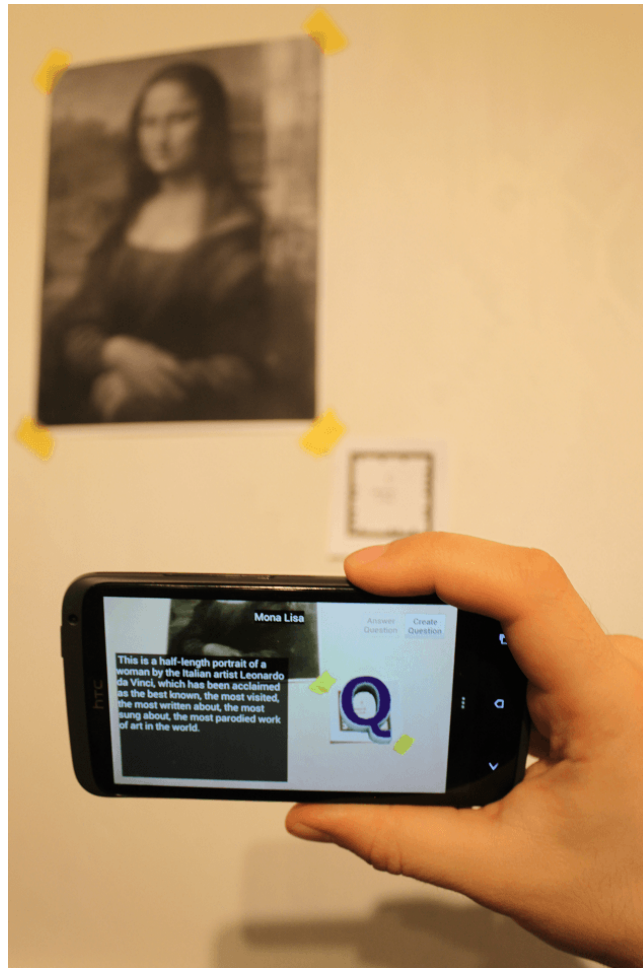


Figure 5.10: Mobile augmented reality at work

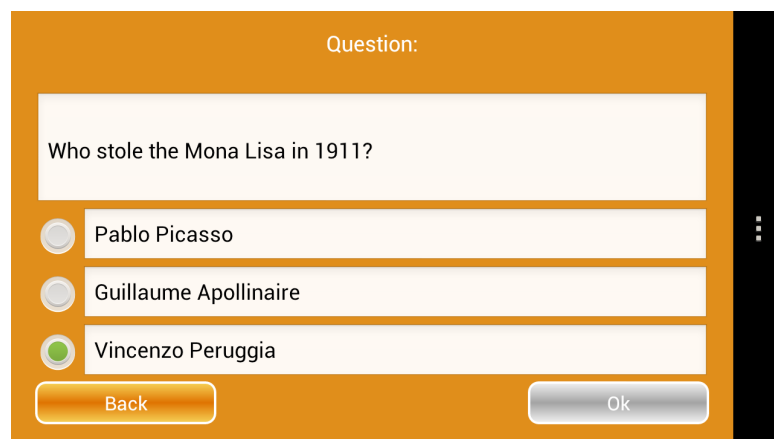


Figure 5.11: Visual augmentation when marker is detected

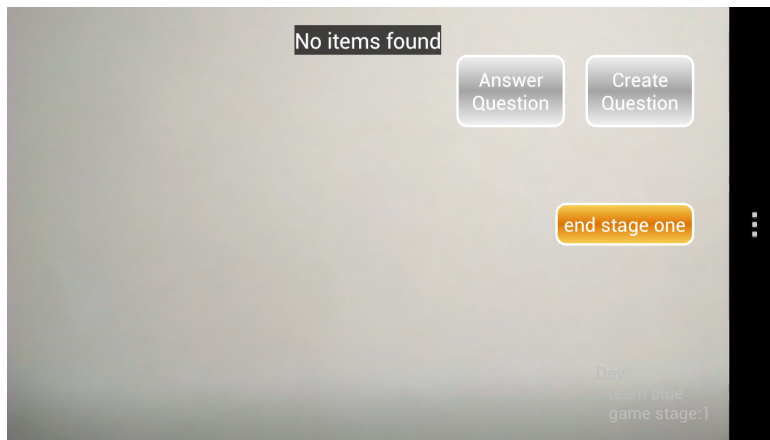


Figure 5.12: Question creation view

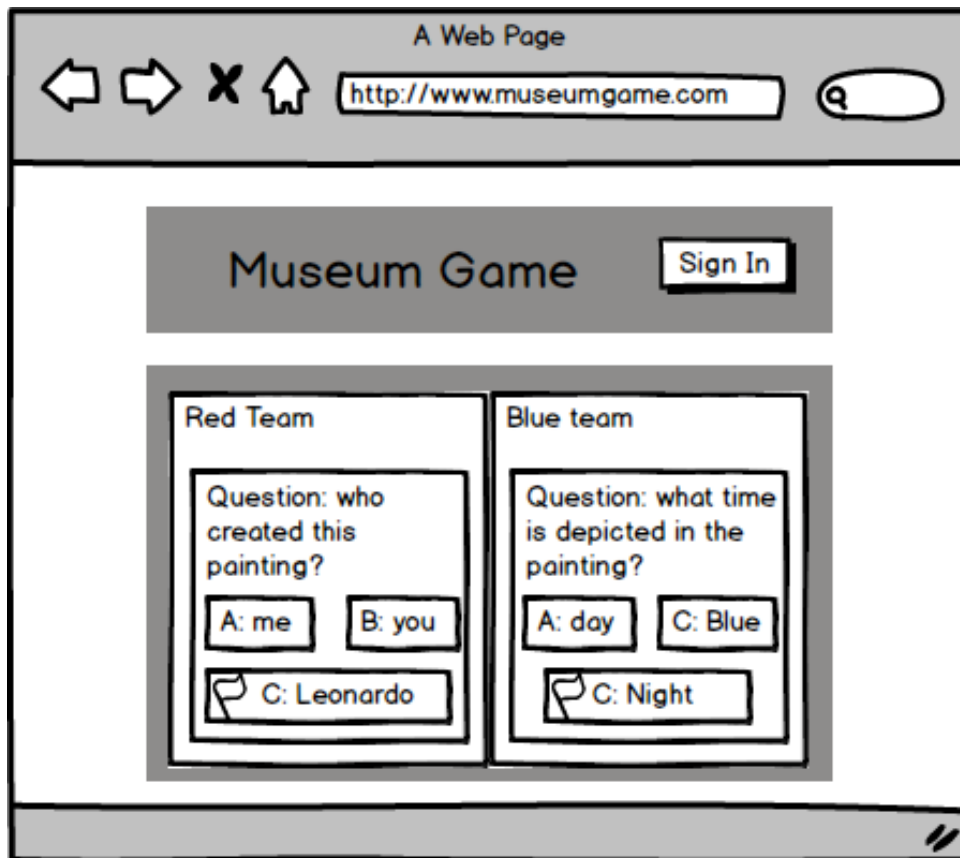


Figure 5.13: Game monitoring view

'Team Blue' enters the locale previously occupied by 'Team Red' and find their first item. Its a famous painting that they recognize even without the extra augmented information. They find the items marker using the device and touch the now active 'Answer Question' button. 'Create Question' button is active only on the first stage of the game and 'Answer Question' button is only active during the second stage of the game. As soon as the player touched the 'Answer Question' button a question answering view was loaded. Now 'Team Blue' has to read the question and choose the right answer. None of them know 'who stole the Mona Lisa', so they have to search for information on the Internet using the tablet pc provided by the supervisor. Since information gathering is not limited in any way, other players search for answer to the question using their own smartphones. Finally most of them find that it was Peruggia who stole the famous painting for patriotic reasons and they agree to select Peruggia as the answer.

The player from 'Team Blue' holding the game device submits the answer, and they move on to the next museum item. At the same time 'Team Red' selected a wrong answer to a question created by the players of 'Team Blue'. They are not informed immediately that the answer was incorrect, this information will only be available at the end of the game. Because 'Team Red' players failed to find the correct answer and submitted a wrong one, they get no points.

As soon as both teams finis the game, they are presented with the 'End game' screen that shows the final score.

Both teams answered all the questions and because 'Team Blue' answered all the questions correctly on their first attempt they get full 5 points and win against 'Team Red' with only 4 points.

Chapter 6

Solution Proposal and Implementation

This chapter describes one of the possible solutions to the problem described in Chapter 4. Since the solution is based on work done during the Autumn Specialization Project, this chapter starts with a short summary of the architectural solutions made during that work, followed by the changes made in designing the whole new system to support multiplayer activities.

6.1 Software architecture

The prototype developed during Autumn Specialization Course project resulted in a hot-seat multiplayer game that used a local database to store the information collected during the game session.

6.1.1 Architectural drivers

The architectural drivers of this application were the functional requirements FR4 and FR8, and non-functional requirement NFR1. The two functional requirements in essence meant that I had to use some kind of free off-the-shelf (OTS) components, such as an open source framework. The non-functional or quality requirement NFR 1 is concerned with quality of the graphical user interface(GUI).

The addition of a functional requirements FR10 and FR12 made a big impact on previous architecture of the system and in essence meant that the system can no longer be localized on one device and required a server through which multiple devices could communicate with each other.

Requirement F4 and F8

It should be possible to start Stage 1(2) of the game. Stage 1 and 2 are game modes when the user enters the augmented reality view. Through this view the user can locate item markers and view the visual augmentation on the screen of the device showing information about the item selected. The information should be shown automatically when the user gets one of the markers in the viewfinder.

This part can be accomplished by using appropriate OTS. Choosing what framework to base the system on can have a vary big impact on the overall architecture of the system.

Requirement F10 and F12

It should be possible to view and answer the question created by the opposite team in Stage 1 of the game(FR10). During the game session during Stage 2 of the game players have to detect the items with questions created by another team and answer them.

To do that the questions created by the opposite team during Stage 1 of the game should be accessible to the players Stage 2 of the game.

It should be possible to use the application on two devices simultaneously(12). When the game session starts both teams can start creating questions for the selected items simultaneously. The game requirement goes for the Stage 2 of the game when players need to answer the questions created by the opposing team, this action can also be done simultaneously.

Both requirements can be accomplished by using a remote database server through which the applications will communicate. In addition a PHP Web application might be used to create an extra layer of security and to make sure the requests will be handled safely on the server side instead of handling it in the application itself. The addition of the PHP Web application to handle database requests also allows for creation of a web interface as most of the database connectivity classes can be reused.

Requirement NRF1

This quality requirement is concerned with the GUI of the application. The main device the system will be used on is a phone with a relatively small screen. The systems GUI should be comfortable and intuitive enough for users to be able to use it without training. Keeping these factors in mind the GUI might change a lot during the project so it is important to separate GUI from the rest of the application to localize changes and make the system easier to change and maintain.

6.1.2 Architectural tactics

Usability

When developing a prototype for a phone it is important to keep in mind that the GUI might change a lot during the implementation. To separate the GUI from the rest of the application I will be using the model-view-controller(MVC) pattern.

Performance

There are a lot of different devices that this application can be used on. To limit the impact of the variety of devices I chose one model of android OS based phone. This choice limits the possible problems I might have with compatibility between the devices, but still 3D augmented reality is very demanding of the limited resources that the phone has.

To solve possible performance issues when using 3D augmented reality I chose to base it on Vuforia SDK. Vuforia has its own optimization techniques, possibly even solving the compatibility issues between different phone models.

6.1.3 Architectural patterns

Model-View-Controller

One of the applications architectural drivers is highly concerned with usability, creating the need to separate the GUI from the rest of the application. This can be achieved by using the

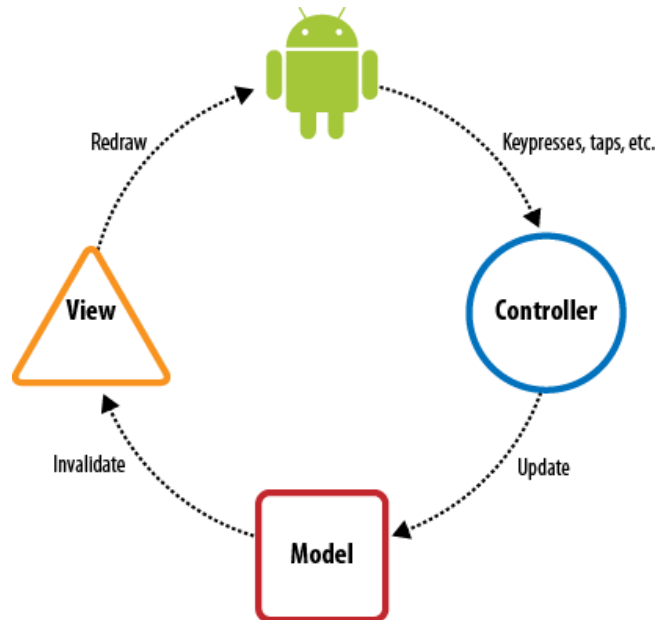


Figure 6.1: Model-view-controller android pattern

taken from <http://www.cs.ccsu.edu/~stan/classes/CS355/notes/03-AndroidUI.html>

model-view-controller(MVC) architectural pattern. In practice Android SDK partially take care of this, but MVC can be only achieved partially. This is shown in the figure 6.1. The GUI of the activity is described in an XML file, so it is important to keep the model of the game separately.

6.1.4 Logical view

Class diagram description

Class diagram can be seen in figure 6.2. Here is the short description of the packages and some of the relevant classes:

- ntnu.spec.game - contains main game class Game activity and the object of the ‘Game’ model.
 - GameActivity - the main game activity that is started when the users start the application. This activity is used to initiate the Stage 1 of the game or to enter administrative mode to create the game.
- ntnu.spec.FrameMarkers - this package contains all the classes responsible for 3D visual augmentation and communication with the native functions connecting the augmented reality view with java classes.
 - FrameMarkers - main activity of the augmented reality view that is started when the view is initialized from the GameActivity by the user. This activity is responsible

for the control over data needed to initiate rendering and communication with the native Android classes.

- FrameMarkersRender - this helper class is responsible for visual augmentation rendering in the frame
 - GUIManager - this helper class is responsible for initiating the GUI that is shown on the screen during the augmented view stage of the game. This class contains all button and textview declarations and defines the actions that need to happen when user interacts with these components.
 - Texture - this helper class defines what visual augmentation is shown on the screen when a marker is detected.
- ntnu.spec.Connector - connector package contains classes that are responsible for fetching the data about the items. This data might be kept in an XML format or MySQL database server. These classes return an array of data that creates a link between markers and items.
 - ntnu.spec.models - this package keeps model classes needed by the application. This class creates the separation of data models from view and controller conforming to the rules of MVC architectural pattern. This package keeps the models of the game. The game model implements the singleton pattern to make sure that only one instance is created. This is necessary as the main model of the game is accessed from different parts of the application.
 - ntnu.spec.views - keeping to the MVC architectural pattern different views are separated from the rest of the application logic and are kept in this package. Any other views that might be created during the implementation will be kept in this package as well.
 - CreateQuestionView - this view is shown when a user touches the button ‘Create question’ in the first stage of the game. This view is shown on top of the FrameMarkers activity, as soon as it is shown FrameMarkers goes into pause() mode. This view lets players create a question by filling in a template consisting of the body of a question and three possible answers. Users have to mark one of the answers as the correct answer.
 - ConfirmView - after the user creates the question and touches the ‘Save’ button, the user gets an a confirmation view that shows the summary of the question and answers and asks the user to confirm the creation of the question by pressing the ‘Ok’ button.
 - AnswerQuestionView - this view is shown when a user touches the button ‘Answer question’ in the second stage of the game. This view is shown on top of the FrameMarkers activity, as soon as it is shown the FrameMarkers goes into pause() mode. This view lets players answer the questions that the opposing team created in the first stage of the game. This view shows users the question and three possible answers, user chooses the correct answer by touching the corresponding TextView object on the screen.

6.1.5 Development view

The development view is shown as a package diagram shown in figure [6.3](#)

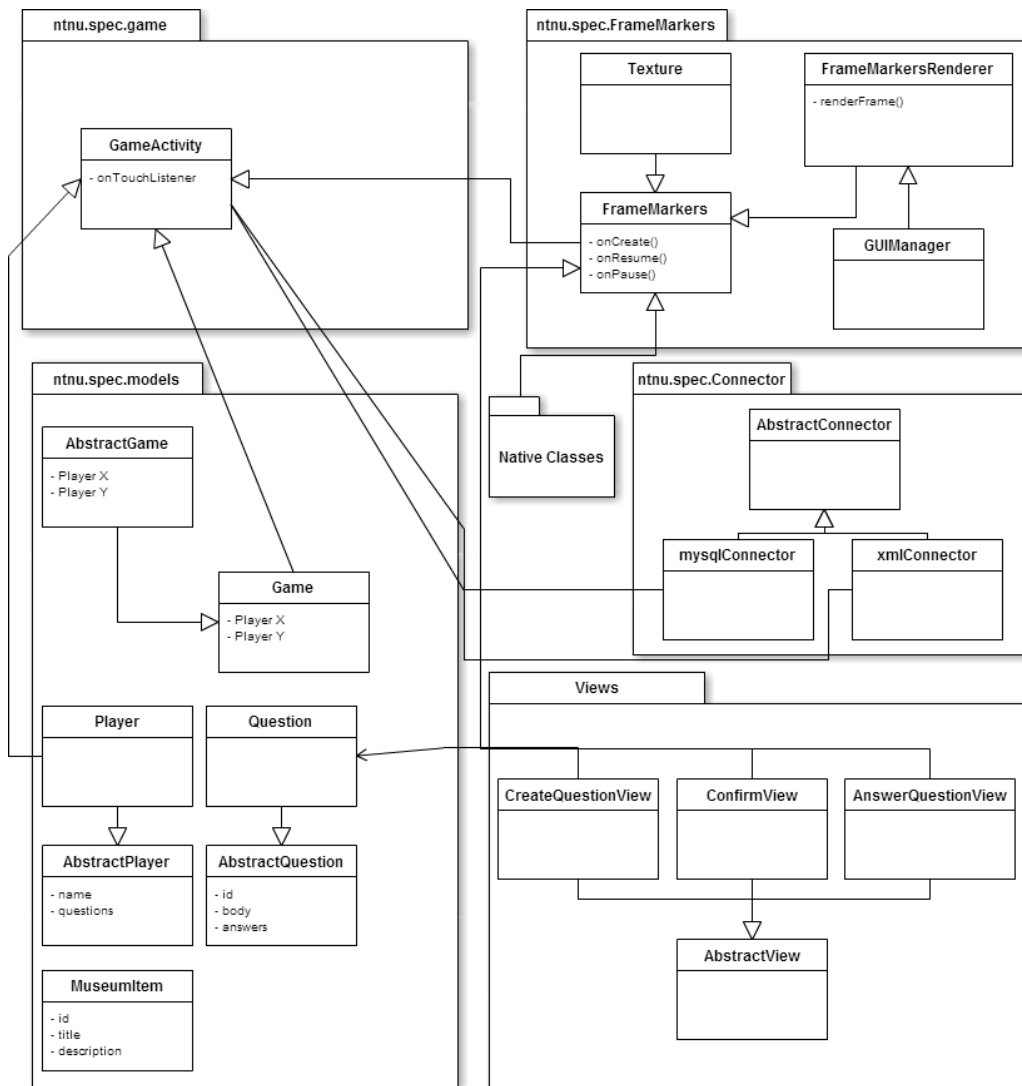


Figure 6.2: Class diagram

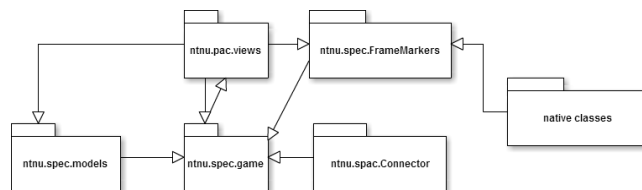


Figure 6.3: Package diagram

6.1.6 Physical view

The physical view is shown on figure 6.4 as a deployment diagram. Here is the description of the components:

- Player client - this component consists of the game application running on an Android OS based phone. This is the main part of the system. The game gets its information about the items from the database and displays it when the user finds one of the tags and views it in the viewfinder.
- Supervisor Web App - the supervisor Web application is used to set up the game. It consists of a web interface through which the supervisor can manage the item descriptions, create a print out of the markers and watch the game progress in real time.
- Database - MySQL database running on the remote server. This database will keep the information about the items, creating the connection between the tags and museum items. Questions created by the players are also kept in this database. To keep the first prototype simple, all this information might be kept in the XML form.
- Vuforia - Vuforia SDK is part of the Qualcomm AR Platform that takes care of managing the augmented reality part of the application. Figure 6.5 shows the diagram that explains what parts of the application it takes care of and what parts the developer has to do himself.

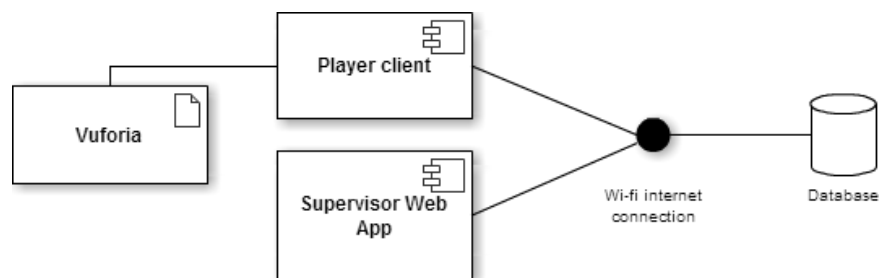


Figure 6.4: System deployment diagram

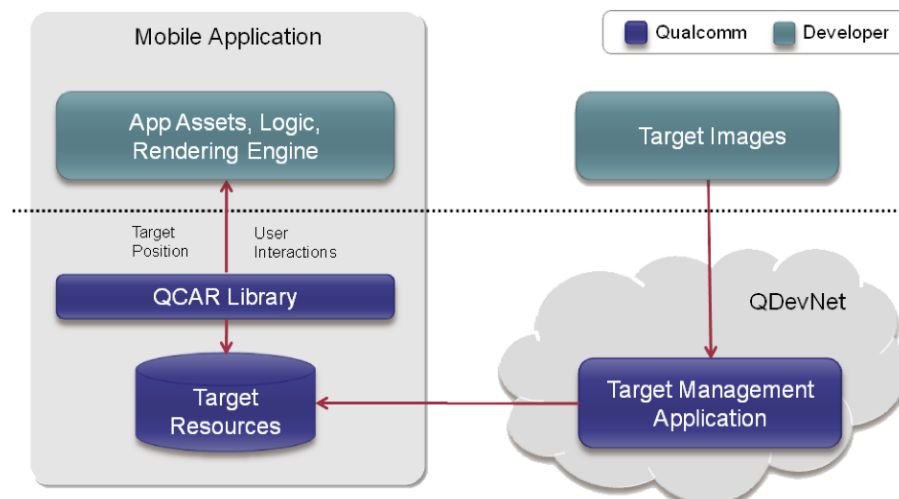


Figure 6.5: Vuforia SDK
taken from <http://developer.android.com/>

| Table name | Field name | Field description |
|--------------|----------------------|--|
| museum_users | user_id | identification number. Used for reference. |
| | user_name | Personalized user login name. Used as a login in Web interface. |
| | user_password | Personalized user password. Used as a means of authorization in the Web interface. |

Table 6.1: Description of ER diagram, museum_users table

6.1.7 Database

A MySQL database is used to keep various information used by the system. This information is shared between the Web interface and the application and is the main means of communication between two playing teams. An entity relationship diagram is shown in Figure 6.6

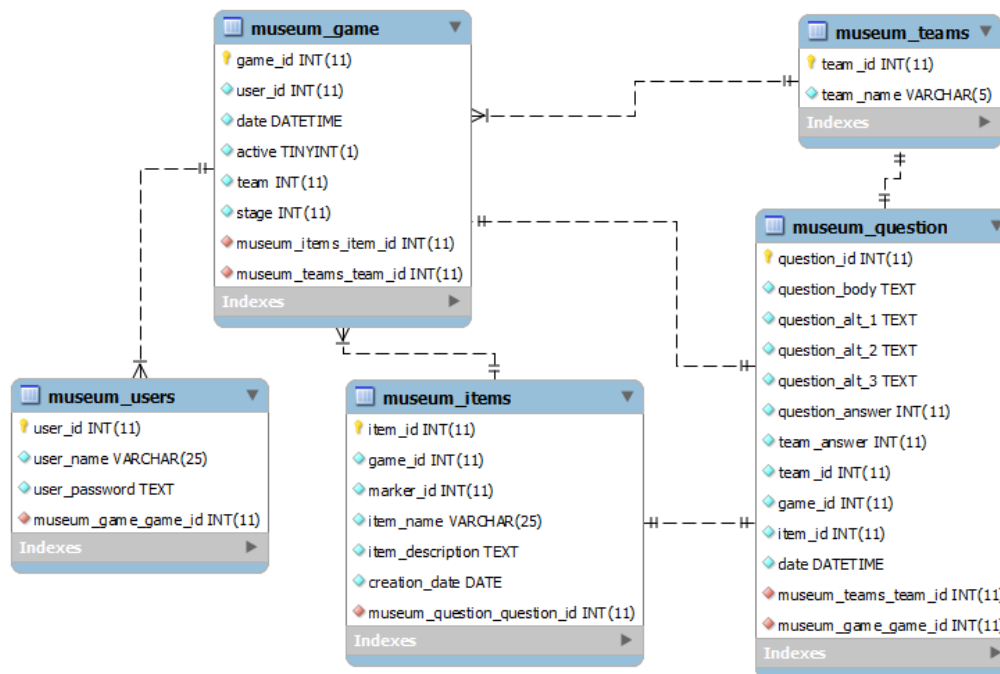


Figure 6.6: Entity-Relationship diagram

Only registered users can create/modify games. Table ‘museum_users’ (see Figure 6.6 and Table 6.1) contains user authentication information such as user names and passwords. The passwords are kept encoded using standard MD5 encoding.

The initial game content is created by the supervisor using the web interface. Through that interface, the supervisor is creating a game by filling in forms, after that the information is saved in the database. When a game is created table ‘museum_game’ (see Figure 6.6 and Table 6.2) is filled with the information that will be referenced to access other tables required to play the game. When a new game is created, supervisor must input how many items will be used to play the game and fill the required information required for each item (name and description). This information will be stored in the ‘museum_items’ table (see Figure 6.6 and Table 6.4) and will later in the game be accessed by the players through the game application views.

Once all initial content is created the supervisor can mark one of the created games as active, this will alter ‘active’ field in the ‘museum_game’ tables, making only one game that belongs

| Table name | Field name | Field description |
|-------------------|-------------------|--|
| museum_game | game_id | Game identification number. Used for reference. |
| | user_id | User identification number. Used as a reference. |
| | date | Date the database format. Used to identify when the game was created. Also used in the user interface as menu item to help the supervisor identify the game. |
| | active | Boolean that shows if the game is active or not. The game becomes active when the supervisor starts the game through the Web interface. Also used by the game application to identify if a user is connecting to an active game. If user tries to connect to a game that is not active, he or she gets a notification. |
| | team | Last logged in team id. Used to differentiate between teams in the game application. |
| | stage | Stage of the game. The game has 3 stages: 0 - not started, 1 - stage one of the game when players create the questions, 2 - stage of the game when users answer the questions. |

Table 6.2: Description of ER diagram, museum_game table

| Table name | Field name | Field description |
|-------------------|-------------------|---|
| museum_teams | team_id | Team identification number. Used for reference. |
| | team_name | Team name. The game is played by two competing teams. The players don't control the team names. The default team names are "Team Red" and "Team Blue". This is also reflected in the Web interface as when the game progresses question creation and answering views are colored accordingly. |

Table 6.3: Description of ER diagram, museum_teams table

| Table name | Field name | Field description |
|-------------------|-------------------------|--|
| museum_items | item_id | Item identification number. Used for reference. |
| | game_id | Game identification number. Used as a reference. |
| | marker_id | Marker identification number. Used as a reference in application and acts as an anchor between paper markers and augmented reality part of the application. Each marker identification number is linked to the physical paper marker that can be printed out from the Web interface. |
| | item_name | Title of the museum artifact. The title is part of the visual augmentation of the augmented reality part of the user application. Once the game locates the physical marker a text field is shown on top of the screen containing the name of the item. This is supposed to help the players identify the name of the item. |
| | item_description | Short description of the museum artifact. The description is part of the visual augmentation of the augmented reality part of the user application. Once the game locates the physical marker a text field is shown on the left side of the screen containing the short description of the item. This description is supposed to help the players identify the item without any doubt. This description complements the item name, and should only be used to help players identify the item, but should not be used to create questions as the description is visible in both stages of the game. |
| | creation_date | Date. Shows the exact time and date when the item was created. |

Table 6.4: Description of ER diagram, museum_items table

| Table name | Field name | Field description |
|-------------------|------------------------|---|
| museum_question | question_id | Question identification number. Used for reference. |
| | game_id | Game identification number. Used as a reference. |
| | team_id | Team identification number. Used as a reference. |
| | item_id | Item identification number. Used as a reference. |
| | question_body | The body of the question. Used to store the question body created by the players during stage 1 of the game. Also used in stage 2 of the game to show the question to the opposing team. The length of this field is not limited as to allow the players to create as sophisticated question as they will. |
| | question_alt_1 | Question answer alternative. Since the game is a kind of quiz, the users are required to create three alternatives, only one of which is correct. This is the first alternative and it shall be displayed first in the list when creating and answering the question. |
| | question_alt_2 | Question answer alternative. This is the second alternative and it shall be displayed second in the list when creating and answering the question. |
| | question_alt_3 | Question answer alternative. This is the third alternative and it shall be displayed third in the list when creating and answering the question. |
| | question_answer | Question answer alternative number. There are three alternative answer to one question; when creating a question player is required to mark one of the alternative answers as the correct one. This field is used to store this number of the correct alternative. |
| | team_answer | Question answer alternative number. There are three alternative answer to one question; when creating a question player is required to mark one of the alternative answers as the correct one. This field is used to store this number of the correct alternative. This field and question_answer are essential part of the system as they are used in the scoring system of the game to decide who was the winner. |
| | date | Date. This field stores the exact time and date when the question was created. This field is not used for application or Web, but deemed necessary for administrative purposes. |

Table 6.5: Description of ER diagram, museum_question table

to specific user as active, all others set to inactive. This prevents the players connecting to inactive games by accident.

Once all the initial content is created and game is set to active(game is started) players can use the game application to connect to the database and play the game. The game is played in two stages, first stage involves identifying items and creating questions. Once this stage starts all the information about the items is fetched from the database('museum_items' table). After the users successfully identified the item, they use the game application to create questions. The questions are stored in the 'museum_question' Table (see Figure 6.6 and Table 6.5).

6.2 Tools and Technologies

6.2.1 Android OS

Android is a Linux based operating system, that was designed for touch screen phones. The operating system gained a lot of popularity amongst smart phone users as it is open source and attracts a lot of developers in turn attracting a lot of users because of abundance of applications and Android capable device prices.

The Figure 6.7 shows a diagram of the overall Android Architecture. The Android OS is a stack of different layers, where each level consists of a group of components. Each level consists of interfaces that use the lower levels as services.

At the lowest level there is the Linux Kernel. This level acts as an abstraction layer between the hardware and other layers and is responsible for communication with the device at the hardware level. This level contains all the essential hardware drivers(software that can control and communicate with specific hardware components). This layer also provides tools for handling networking, virtual management and power management.

The Libraries level contains the Android native libraries. This level is responsible of handling different kinds of data. This level is responsible of providing interfaces to store and manipulate various data, some of the most important native libraries:

- **SQLite** - a local database engine solution used to store and manipulate data locally.
- **OpenGL** - 2D and 3D rendering engine, used to generate graphics shown on the screen
- **WebKit** - browser engine used to interpret and display Web content
- **Media framework** - a set of different solutions to decode digital stream, allowing playback of different types of media content

These libraries are written in C and C++ languages and usually are written for a specific device or group of similar devices.

The Application Framework level consist of the application building blocks that will be used directly when creating an application for Android OS. Components at this level are responsible for most basic functions of the phone, such as managing sharing data between applications, managing the activity life cycle of applications etc. This level also contains the Dalvik virtual machine. The Dalvik virtual machine is a type of Java Virtual Machine(JVM) that acts as a byte code interpreter. Dalvik virtual machine is highly optimized to be able to operate in an environment with low processing and memory resources, such as a smart phone. This level and the level above this level are written in Java.

The applications level is the top level of the Android Architecture. This is where all the standard phone applications live, where all new installed applications will live and this is the place my application fits in with the Android OS. Android OS is open source and provides unlimited flexibility allowing the developer to change any part of the architecture, opening limitless opportunities to create truly unique content. But it is also important to a developer to understand that even though we can access any part of the device using our application, users have to actually permit these actions while installing the application (thankfully not a lot of people read the warnings before installing a new application).

Android OS provides the developers with Android SDK that can be integrated with Eclipse SDK, providing the developer with a working open source solution that does not require any financial investment on the developer part. It is possible even to develop applications without having an Android OS capable smart phone as the SDK provides be it horrible but functional smart phone emulator.

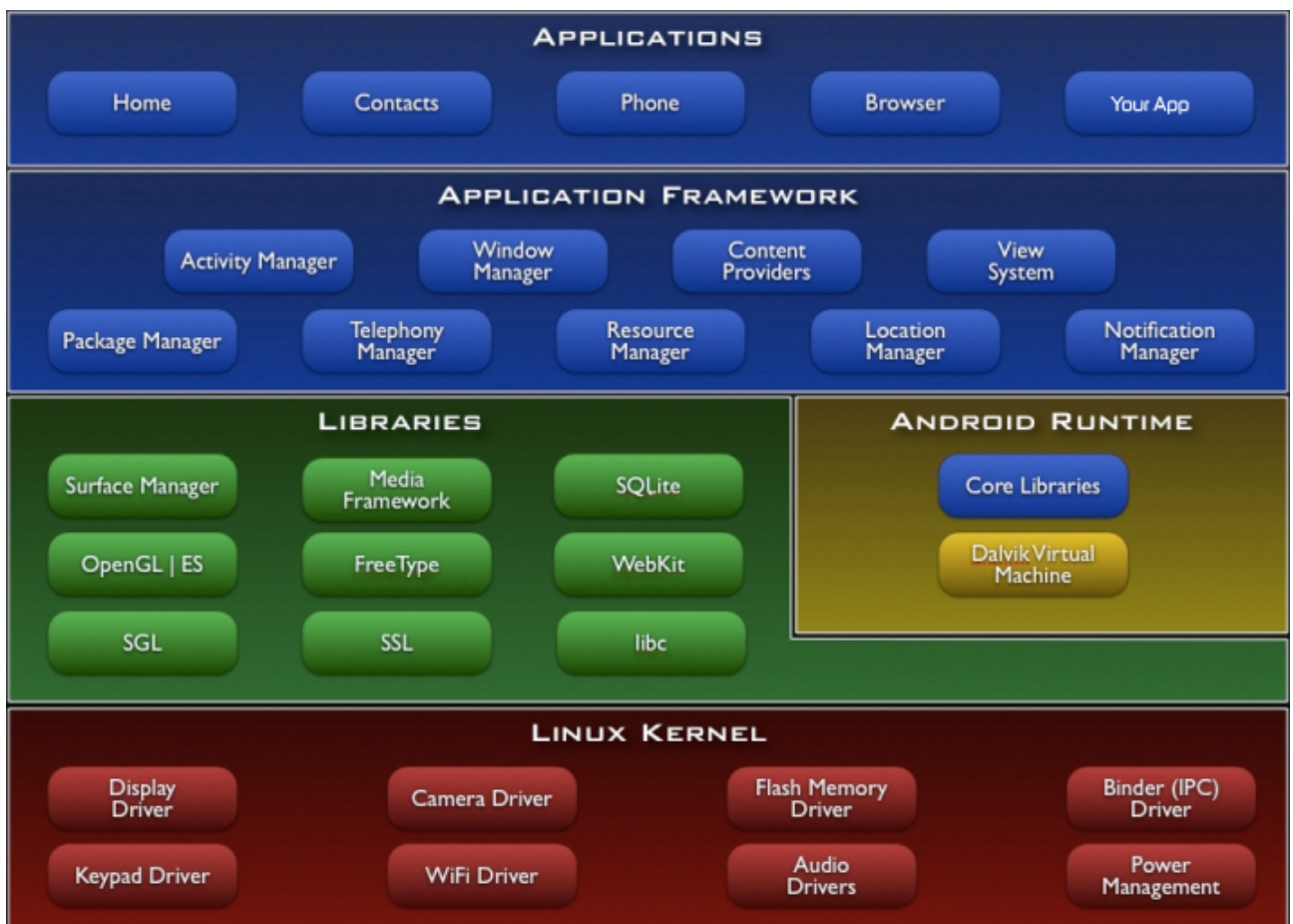


Figure 6.7: Android OS architecture
 taken from <http://www.qualcomm.com/solutions/augmented-reality>

6.2.2 Game application prototype overview

At the core of the application is a standard Android application (see application activity life cycle diagram shown in figure 6.8). At this level of the application all activities that control the GUI are implemented. The open source part of the Android OS technology means that there are a lot of open source OTS(off-the-shelf software) that help create application more quickly and professionally. When developing an MAR application I chose to use Vuforia SDK.

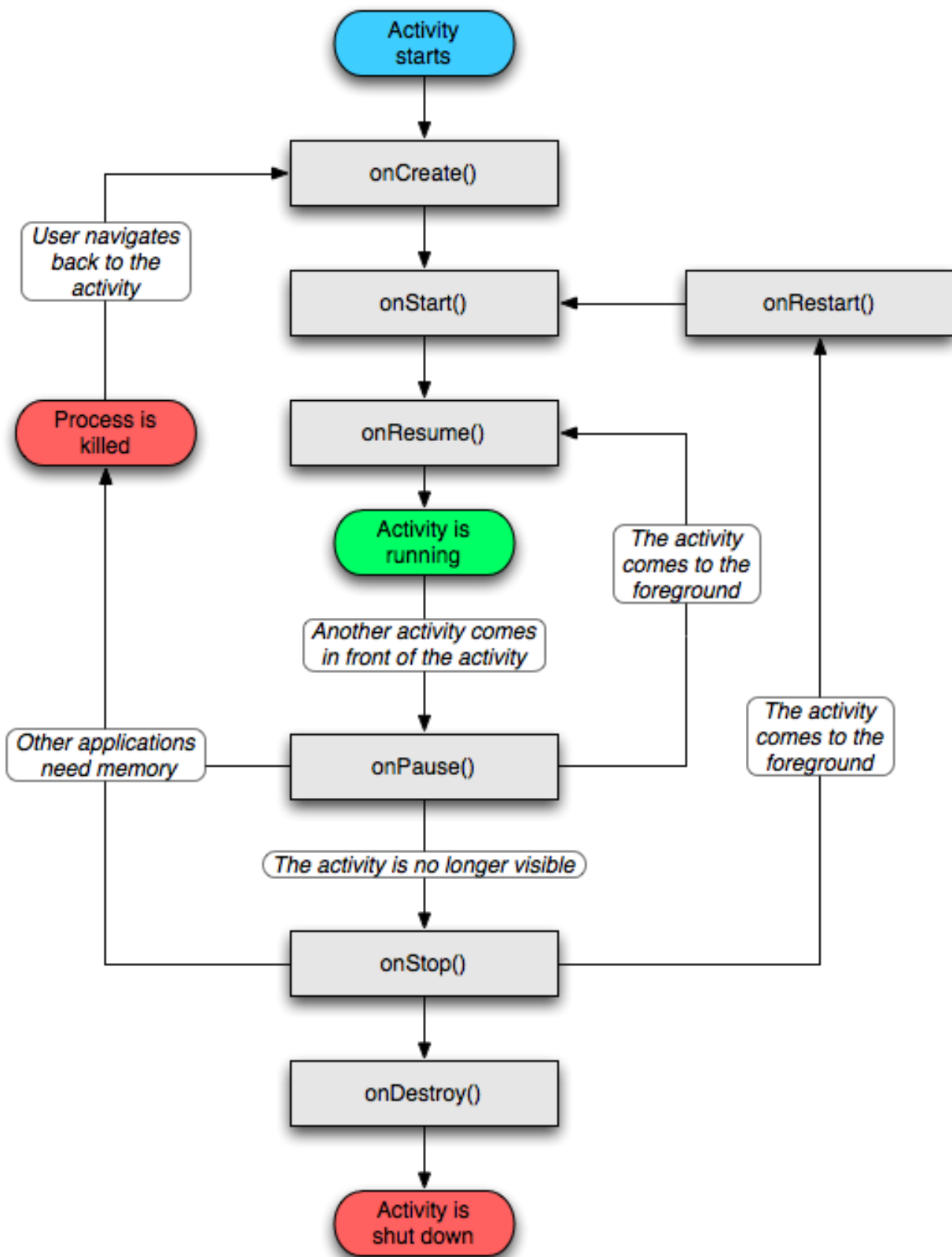


Figure 6.8: Android application activity life cycle taken from <http://www.linuxtopia.org/>

This platform was chosen because it supports a broad array of environments and devices, its high quality and support. Vuforia SDK has very few limitations, allowing the developers to level of freedom to design and create the solution they desire. The platform is very flexible and is capable of:

- recognizing multiple images at the same time
- advanced tracking and detection
- flexible image database

The game application solution was limited by the possibility of tracking players inside the museum. To create a link between visual the real museum items and the game application item augmentation, Vuforia SDK provides a solution Frame Markers. A frame marker is an image that is similar to a QR code, but allows to customize the image inside (see Figure 6.9). This is very comfortable as they can be adopted to almost any environment by changing their color or inserting an image appropriate to the location. One of the features of Vuforia SDK is the ability

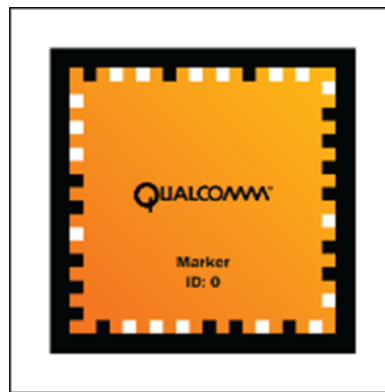


Figure 6.9: Vuforia SDK frame marker
taken from <http://developer.vuforia.com/>

to track such frame markers. The markers ID is unique and is encoded into a binary pattern along the border of the frame image, leaving the middle of the image fully customizable. This means that the markers are very subtle and might be integrated into museums by placing the binary pattern along the border of the nameplate of the museum item. This image recognition allows to precisely position and place virtual objects such as 3D models and other media, in the case of the prototype in question, additional textual information relevant to the players.

Although very unobtrusive, this approach has its limits and the possible ID range is from 0 to 511, meaning that there can be only 512 possible different markers and corresponding 3D models. This limitation creates the first application prototype limitation, limiting possibility to create and mark only 512 items.

The framework supports multiple Application Programming Interfaces(API) that allow the developer to get into development more quickly without constricting him or her to use framework specific language. To construct the image tracking and recognition part of the application Objective-C language was used and all the interfaces and textual augmentation was written in Java.

6.2.3 Supervisor Web interface overview

The supervisor Web interface is used to manage and control the information that is used as a link between the physical frame markers and the information about the museum item that

Vuforia AR SDK

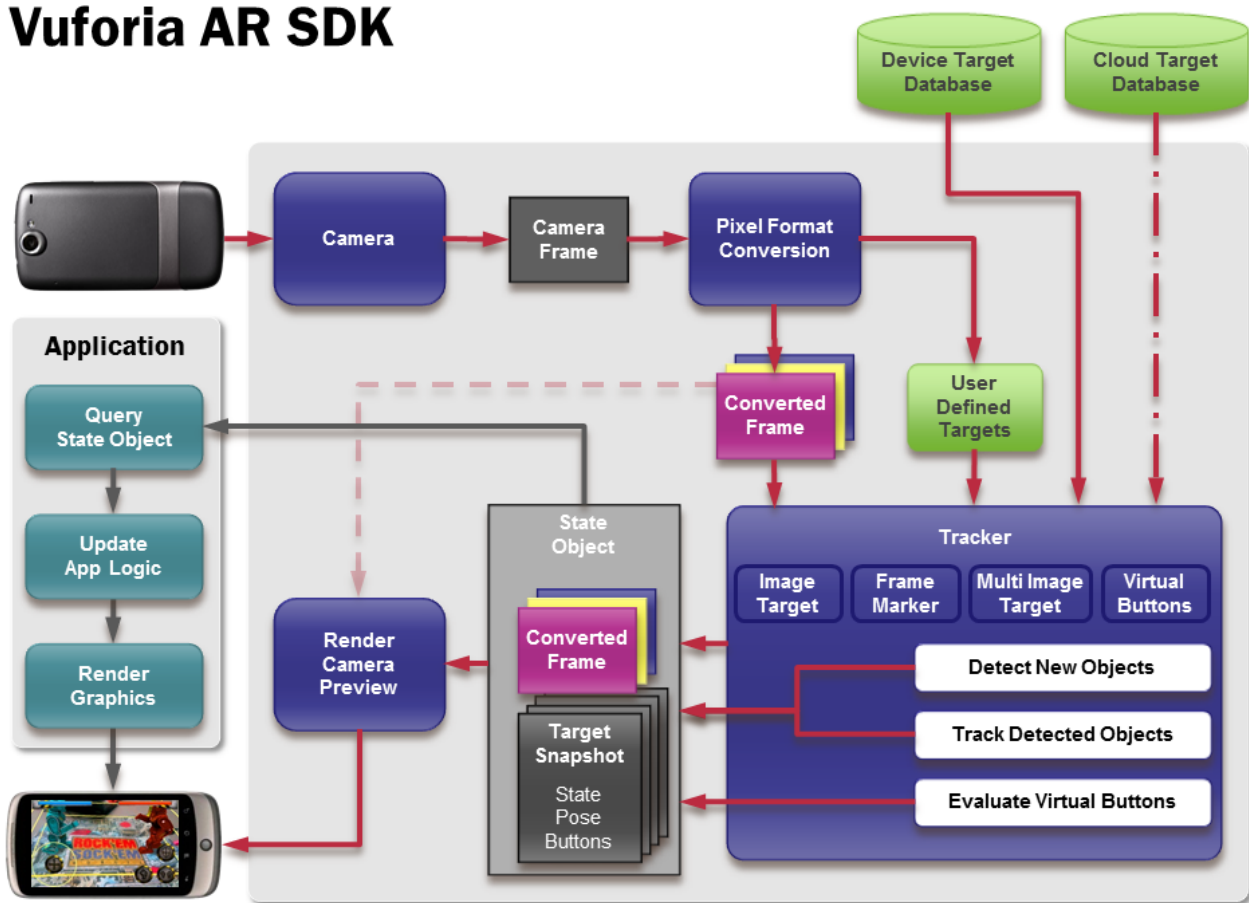


Figure 6.10: Data flow diagram of the Vuforia AR SDK in an application environment taken from <http://developer.vuforia.com/>

those frame markers represent.

The back end of the Web interface consists of a collection of communication classes that are used by both the web application and by the administrative interface users. Most of these classes consist of database table models that return specific data depending on posted parameters.

The front end of the application consists of user interfaces used to manage game content information and to monitor game in progress. These interfaces are written using HTML. The interfaces are controlled by using JavaScript language on the client side and Ajax technology to communicate with the back end of the Web application.

The Web interface has a very simple GUI, to make the use of it as simple as possible. In essence the GUI is a HTML5 driven web page. The main page of it can be seen in Figure 6.11. From this page, the only action user might take is to sign in into the system by pressing the ‘Sign in’ button in the top right corner. This action will trigger the sign in form(see Figure 6.12) to appear. If the user authentication is successful the user is taken to the Administration view.

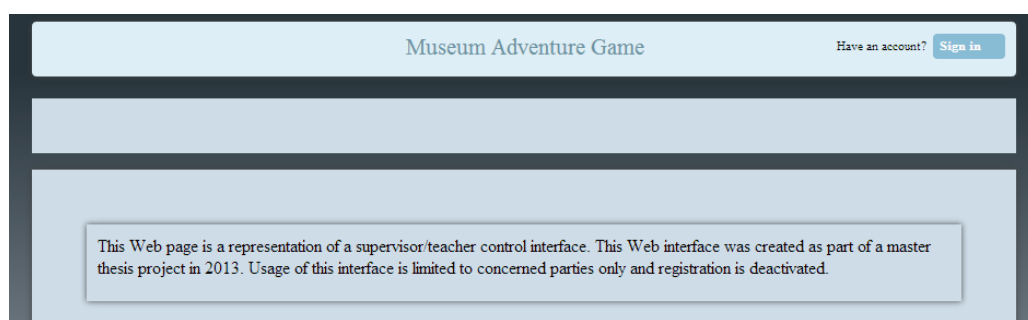


Figure 6.11: Web interface main view

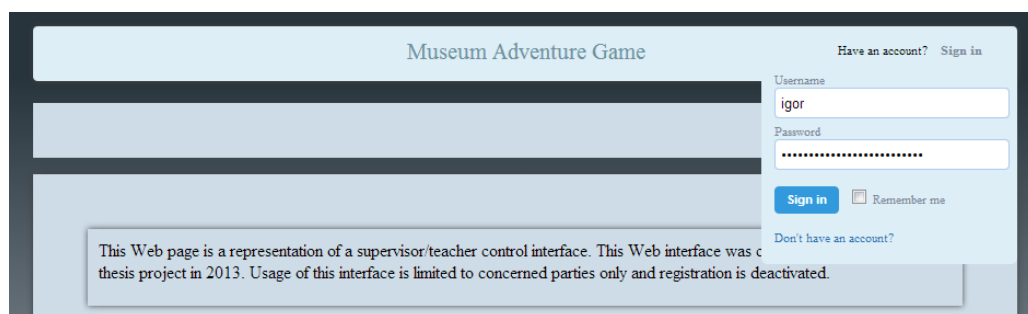


Figure 6.12: Web interface: sign in view

From the administration view the supervisor can either create a new game or to select one of the previously created games (see Figure 6.13). All the previously created games are kept in the database and only the supervisor himself(or herself) can remove them. The previously created games can be chosen by means of selecting one of the previously created games from the select box element on the left and the new game can be created by pushing the ‘Create new game’ button.

The rest of the Web interface can be split into two categories:

- **Game content management** - to start a game, the supervisor must first select the number of items that he or she wants to use in the game and input the information for each item that will be used to play the game (see Figure 6.14). This information consists of:
 - item title - the name of the item or a short description

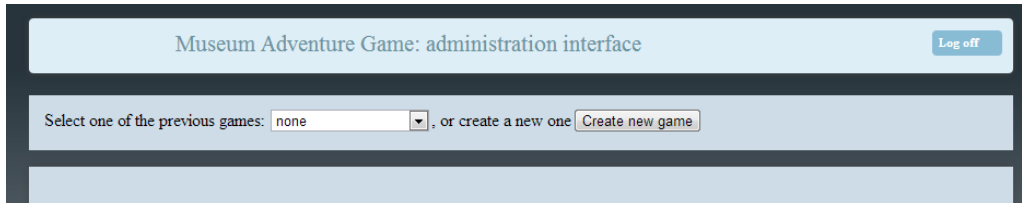


Figure 6.13: Web interface: administration main view

- item description - a short description of an item that is sufficient enough to identify the item. This description might provide some generally known facts about the item (author, when it was created etc.), but should not contain extended information as to give players the opportunity to find that information themselves.
- marker - a unique marker that must be placed near museum item and ties the information entered to the museum item. The marker is assigned to the item automatically and at this point is not customizable.
- **Game monitoring interface** - the game monitoring interface allows the supervisor to see the game actions as they are performed by the players in real time (see Figure 6.15). This interface has different functionality, depending on what stage of the game the players are in.
 - stage 1 - in the first stage of the game the supervisor can monitor the game progress and see the questions that the players are creating. The supervisor can see the whole question, all alternatives and the answer that the players marked as the right one.
 - stage 2 - in the second stage of the game the supervisor can already see all the questions that were created during the first stage. When players enter the second stage of the game, the supervisor can see the answers that players are choosing.

Even though the supervisor cannot alter the game data through this interface, the ability to monitor the game progress might be a powerful thing on its own as it means that players will be less motivated to post questions unrelated to the museum items.

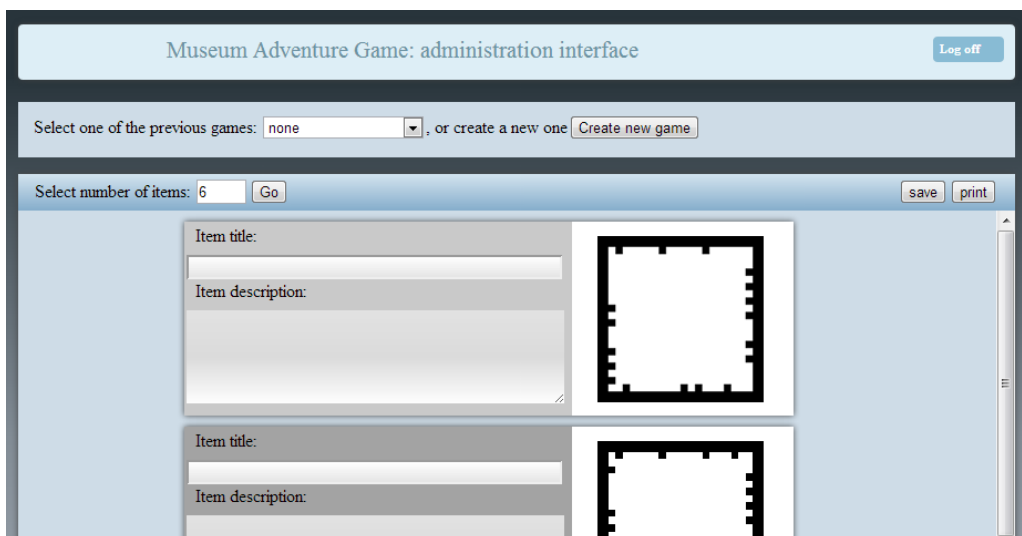


Figure 6.14: Web interface: item creation view

After the initial game content is ready (see Figure 6.16), the supervisor can start the game by pressing 'Start Game' button, this takes the supervisor to the game monitoring interface, where he or she will be able to see the game content created by the players (see Figure 6.17).

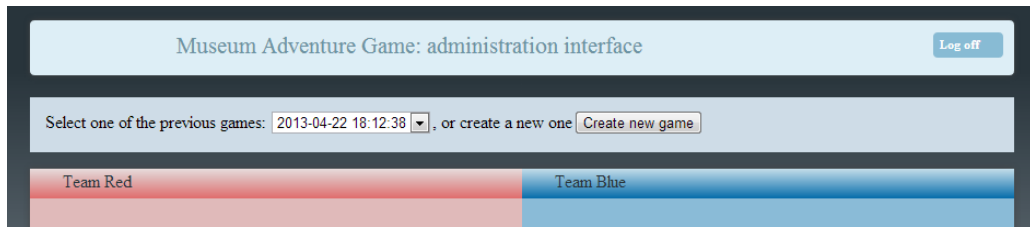


Figure 6.15: Web interface: game monitoring view



Figure 6.16: Web interface: filled game content management view

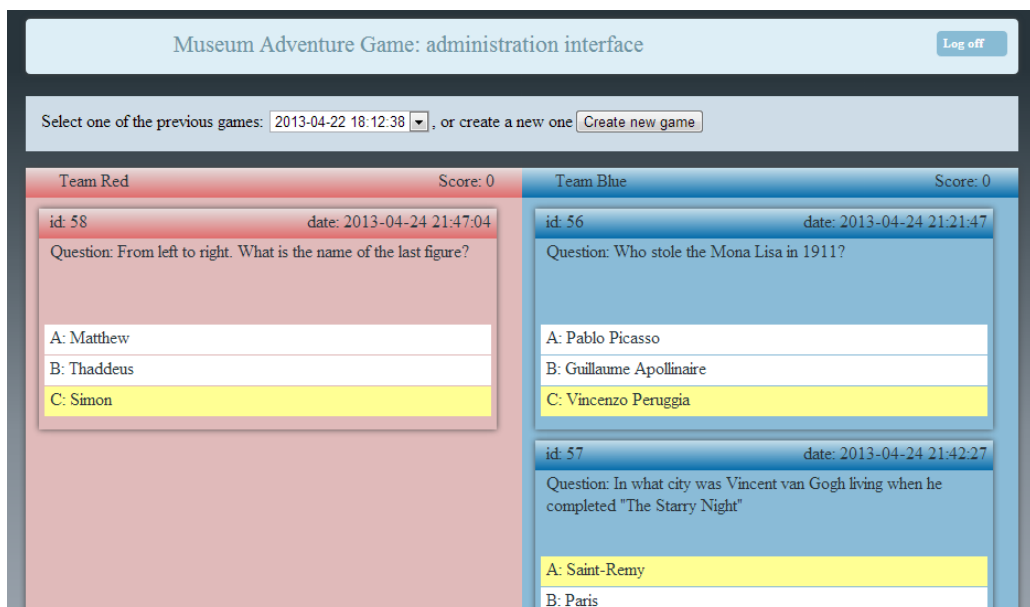


Figure 6.17: Web interface: filled game monitoring view

Chapter 7

Usability study

The game should be easy to learn and play and most importantly it should be useful for the end user. This chapter concentrates on the usability part of the game application comparing to industry standards.

To be able to judge if the game can be played by the intended end users it is important to conduct usability study. To do that I have developed the usability tests from two perspectives: supervisors perspective and players perspective.

During the testing I will assume supervisors role allowing test subject to be the players of the game. This will allow me to monitor the gameplay and will allow for more rapid testing.

7.1 Goals

The desired result of my implementation is a working usable prototype that can be used in further studies. After testing I will execute another sprint to improve the application based on the results of this usability study. So the main goal of this testing is to find the limitation of the game revealing future work that can be done in the last sprint, resulting in improved working prototype that will be used in further studies to assess games usefulness to the end user.

7.2 Approach

The usability of the game can be assessed from two perspectives:

- supervisors perspective
- players perspective

Since the focus of this study is on usefulness and academic gain from the game, supervisors perspective will not be a part of this usability study.

The most important focus of this study is to assess games usability from players perspective. It is important to find out if the GUI of the game supports quick understanding of the application and gives players the ability to use the game without further assistance after initial demonstration.

The usability study focuses on the end user experiences collected during testing.

7.3 System Usability Scale (SUS)

To be able to provide comprehensive evaluation of results collected during these studies I used the System Usability Scale. This provided me a reliable evaluation tool that is also considered as a industry standard [8]. In essence SUS provides a simple 1 to 10 scale that provides a broader view of subjective opinions of the usability of the application in question. This scale shows how easy it was for users to complete certain tasks and how satisfied were they in the process.

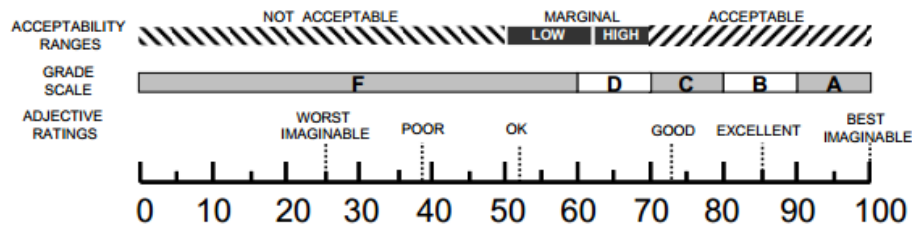


Figure 7.1: SUS scale

taken from: Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale [8]

7.4 List of terms

Throughout this section I will be using terms to describe entities involved in the testing procedure. Explanations for these terms are:

- The game - android application developed during these studies
- The device - android phone that runs the game
- The laptop - my personal laptop that is used for administration purposes
- The supervisor - in this context it is me and my laptop
- The players - test participants
- The tablet - android tablet used by the players to search for information on the Internet

7.5 Usability plan: players perspective

This section consists of usability plan for conducting usability study from players perspective. The plan is constructed using Usability Test Plan template [4].

7.5.1 Methodology

Participants

Since the game is developed mostly for school trips to the museum, the intended end-users are young people of age 12-15. Due to difficulties connected to the research involving minors the

usability study will be conducted using test subjects aged 18 and up. This usability studies main goals are to improve GUI and remove application bugs that might influence further research done with actual end users, so I believe it is not that important to involve the actual end-users at this point of research. Keeping in mind the reasons described above, test participant will be mostly random people with age range from 19 to 30.

There will be approximately 8 to 12 participants in my usability study. The participants will test the application in groups of 2 to 4 people experiencing partial of full game scenario.

Setting

One of the main goals of the application is its flexibility. The game can be deployed in almost any setting. For budget and time reasons the usability study will be mostly done in Gloschaugen campus. Some testing will take place at my personal home and homes of a few participants.

The game will be deployed at the available location by placing props (mostly printed out pictures of famous items that can be found in museums) on the walls and attaching markers to them.

Tools

The application supports a wide array of smartphones based on Android OS and many different phones were used during the testing. Some phones were supplied by me, some belong to the participants as they were curious if the game can be played on their personal phone. The list of phones used in the testing can be found in Table 7.1

| Make | Model | Android Version |
|---------|-------------|-----------------|
| Samsing | Galaxy Ace | 2.3.6 |
| Samsung | Galaxy S II | 4.0.4 |
| HTC | One X | 4.1.1 |
| HTC | Desire HD | 2.3.5 |
| HTC | One S | 4.0.0 |

Table 7.1: Android smartphones used in testing

In some test cases the users were also supplied with a tablet to help them find information relevant to the 'museum' items. In other cases users used their own personal smartphones to search the Internet for information.

For monitoring purposes I will be using a laptop that will help me log the actions taken by the players and control the gameplay.

Since both administrative interface and game server are located on a remote server both will be using WiFi technology to access Internet and connect to the server.

Questionnaire in paper form will be given to each participant at the end of the testing session.

7.5.2 Training

The players will be provided with some minimal training that will include the purpose of the application and general game rules. No training on how to use the GUI will be provided. This

will provide me with information of how user-friendly the GUI is and how easy it is to learn the game mechanics having zero prior knowledge of the application in question.

7.5.3 Procedure

Step-by-step procedure:

1. Participants arrive at the test location and are welcomed by the test facilitator.
2. Participants are given a brief explanation of this test purpose, procedure and duration of the test.
3. Participants are given an introduction to the purpose of the application and are informed of the general rules of the game and of the scenario that they will be playing through.
4. Participants are paired with a partner and given a device each. One receives the device with game application already running, the other one receives the tablet with browser window opened on Wikipedia [6] page.
5. Participants are allowed to play the game for as long as it takes to complete the scenario.
6. Participants are asked to fill out the paper questionnaire.
7. Participants are asked to reply to open questions concerning usability of the game and suggestions for improvement
8. Facilitator thanks the participants and the testing is officially over

7.5.4 Ethics

To adhere to the suggestions of the usability testing template all testing will be anonymous. No names will be used in the questionnaires nor will they be mentioned or referenced outside the testing session.

After each game session before the players fill in the questionnaires they are informed that the information will be used in academical purposes only and that their participation is anonymous.

7.5.5 Usability tasks

All possible actions that the test subject might carry out during the usability studies are shown in Table 7.5.5.

Tasks

Template

The description of each task will be done using a template shown in Table 7.5.5.

| Task Id | Description |
|---------|----------------------------------|
| 1 | Join the game |
| 2 | Start Stage 1 of the game |
| 3 | Create questions |
| 4 | Finish Stage 1 of the game |
| 5 | Start Stage 2 of the game |
| 6 | Answer questions |
| 7 | Finish Stage 2 of the game |
| 8 | View results of the game session |

Table 7.2: Task list

| | |
|-----------------|---|
| Task Id | Id number of the task |
| Name | Name of the task |
| Pre-conditions | Conditions that must be true before the task can be started |
| Task steps | Steps the user must perform in order to complete the task |
| Expected result | Expected results of the test |

Table 7.3: Task description template

| | |
|-----------------|---|
| Task Id | 1 |
| Name | Join the game |
| Pre-conditions | Application is started and running on the device |
| Task steps | <ol style="list-style-type: none"> 1. Receive the device from the test facilitator 2. Press the 'Join game' button 3. Enter server name provided by the supervisor |
| Expected result | Participant located the correct button and was able to press it and enter correct server name |

Table 7.4: The description of Task 1

| | |
|-----------------|---|
| Task Id | 2 |
| Name | Start Stage 1 of the game |
| Pre-conditions | <ol style="list-style-type: none"> 1. Database is filled with data linked to the markers 2. User completed Task 1 |
| Task steps | <ol style="list-style-type: none"> 1. Press the 'Start game' button |
| Expected result | Participant located the correct button and was able to press it |

Table 7.5: The description of Task 2

| | |
|-----------------|--|
| Task Id | 3 |
| Name | Create questions |
| Pre-conditions | <ol style="list-style-type: none"> 1. User located the marker near an item |
| Task steps | <ol style="list-style-type: none"> 1. View the items marker through the phones viewfinder 2. Select 'Create question' button on the screen 3. Fill out the question creation form filling in all the fields 4. Mark one of the answers as the 'correct' one 5. Confirm question creation dialog 6. Wait for the system to save the question on the remote database |
| Expected result | Participant was able to create questions for selected number of items |

Table 7.6: The description of Task 3

| | |
|-----------------|---|
| Task Id | 4 |
| Name | Finish Stage 1 of the game |
| Pre-conditions | <ol style="list-style-type: none"> 1. User created questions for required amount of items 2. 'Finish Stage 1' dialog appeared |
| Task steps | <ol style="list-style-type: none"> 1. Confirm the 'Finish Stage 1' dialog |
| Expected result | Participant located the correct button and was able to press it |

Table 7.7: The description of Task 4

| | |
|-----------------|--|
| Task Id | 5 |
| Name | Start Stage 2 of the game |
| Pre-conditions | <ol style="list-style-type: none"> 1. User completed Task 3 |
| Task steps | <ol style="list-style-type: none"> 1. Press the 'Start game' button |
| Expected result | Participant located the correct button and was able to press it |

Table 7.8: The description of Task 5

| | |
|-----------------|--|
| Task Id | 6 |
| Name | Answer questions |
| Pre-conditions | <ol style="list-style-type: none"> 1. User located the marker near an item |
| Task steps | <ol style="list-style-type: none"> 1. View the items marker through the phones viewfinder 2. Select 'Answer question' button on the screen 3. Mark one of the answers as the 'correct' one 4. Confirm question answering dialog 5. Wait for the system to save the score in the remote database |
| Expected result | Participant was able to answer questions for selected number of items |

Table 7.9: The description of Task 6

| | |
|-----------------|---|
| Task Id | 7 |
| Name | Finish Stage 2 of the game |
| Pre-conditions | <ol style="list-style-type: none"> 1. User created questions for required amount of items 2. 'Finish Stage 2' dialog appeared |
| Task steps | <ol style="list-style-type: none"> 1. Confirm the 'Finish Stage 2' dialog |
| Expected result | Participant located the correct button and was able to press it |

Table 7.10: The description of Task 7

| | |
|-----------------|--|
| Task Id | 8 |
| Name | View results of the game session |
| Pre-conditions | <ol style="list-style-type: none"> 1. User finished Task 7 |
| Task steps | <ol style="list-style-type: none"> 1. View the results |
| Expected result | Participant was able to view the results of the game session and understand the information provided |

Table 7.11: The description of Task 7

Descriptions of the tasks

7.5.6 Estimated time for the test

Time estimated for two pair of participants to complete one test session is about 15-20 minutes.

7.5.7 Usability Metrics

Usability metrics will allow me to evaluate the result of my usability study by comparing the actual results collected during the tests with my initial expectations. Since I am mostly interested in usability of the application I will be using the quantitative approach in collecting the data. To do that I used these metrics:

- Users rating of each task concerning ease of completion and comprehension
- SUS evaluation

Users rating of each task concerning ease of completion and comprehension

Test participants go through a game scenario completing various tasks. After the testing participants are asked to assess how difficult was it to complete each individual task and how easy was it to recognize what actions must be taken to complete it.

SUS evaluation

Test participants are asked to fill in the SUS questionnaire form (see Appendix A). The form consists of ten questions from the System Usability Scale. To be able to assess the usability of the system, the SUS score is calculated in two steps:

- calculate the score contributions from each item and sum them up (score contributions range from 0 to 4)
 - for items 1,3,5,7 and 9 the score contribution is the scale position minus 1
 - for items 2,4,6,7 and 10 the contribution is 5 minus the scale position
- multiply the sum of scores obtained in the previous step and multiply it by 2.5

7.5.8 Success criteria

Results from the questionnaires will provide me with data enough to be able to assess whether or not the desired level of usability was achieved. For the SUS the process is very straightforward as this is the industry standard with score ranging from 1 to 100.

For the difficulty assessment questionnaire I used a custom success criteria based on previous experience.

Success criteria for the questionnaires:

- the SUS score should be higher than 70

- more than 75% of the answers in the difficulty of the tasks assessment questionnaire should be ‘very easy’ or ‘easy’

7.5.9 Questionnaire

The questionnaire consists of two parts. The first part is used to assess difficulty of completing tasks and recognizing how to control the game. This part will consist of a 5 point scale that will correspond to the difficulty level of completing each task. The questionnaire can be found in the Appendix [B](#)

The second part consists of the standard System Usability Scale questions. The questionnaire can be found in Appendix [A](#).

7.6 Usability study results and evaluation

7.6.1 Difficulty assessment questionnaire

During gaming sessions users were asked to play the game in a normal scenario, throughout which they had to complete a list of tasks. After the gaming session participants were asked to assess difficulty of the tasks on a scale from 1 to 5:

1. Very easy
2. Easy
3. Normal
4. Hard
5. Very hard

The results accumulated from the questionnaire can be seen in Figure [7.2](#). The results are well over the minimal success criteria of 75% presented in Section [7.5.8](#).

7.6.2 SUS questionnaire

The results accumulated from the SUS questionnaire can be seen in Figure [7.3](#). According to the SUS score scale(see Figure [??](#)) the average result of almost 80 is between good and excellent score. Since the system was not tested by the intended end users but rather by people of various age and occupation, the resulted score is a lot higher than expected.

7.6.3 Summary of the results

This usability study showed that the application has good usability and is easy to learn. The result of the difficulty of the tasks show that almost all participants thought that it was either ‘very easy’ or ‘easy’ to complete various tasks in the game.

The SUS score of almost 80 is considered as between good and excellent. This shows that the application is usable and useful in some context. The testing was completed using participants of various age with very different background (some of them do not like museums at all) and the

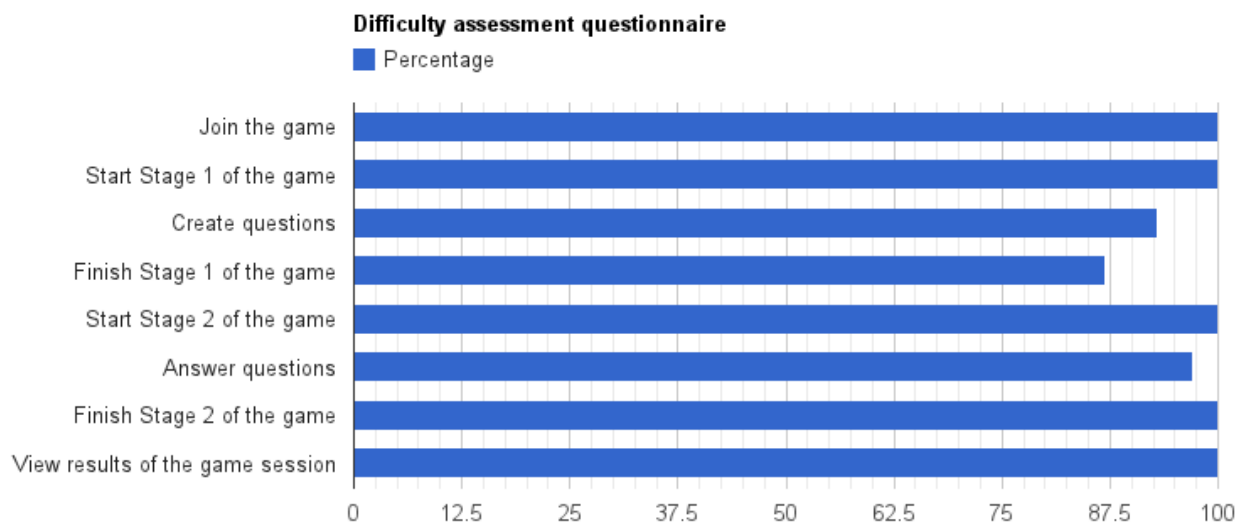


Figure 7.2: Difficulty level of tasks, as perceived by the participants

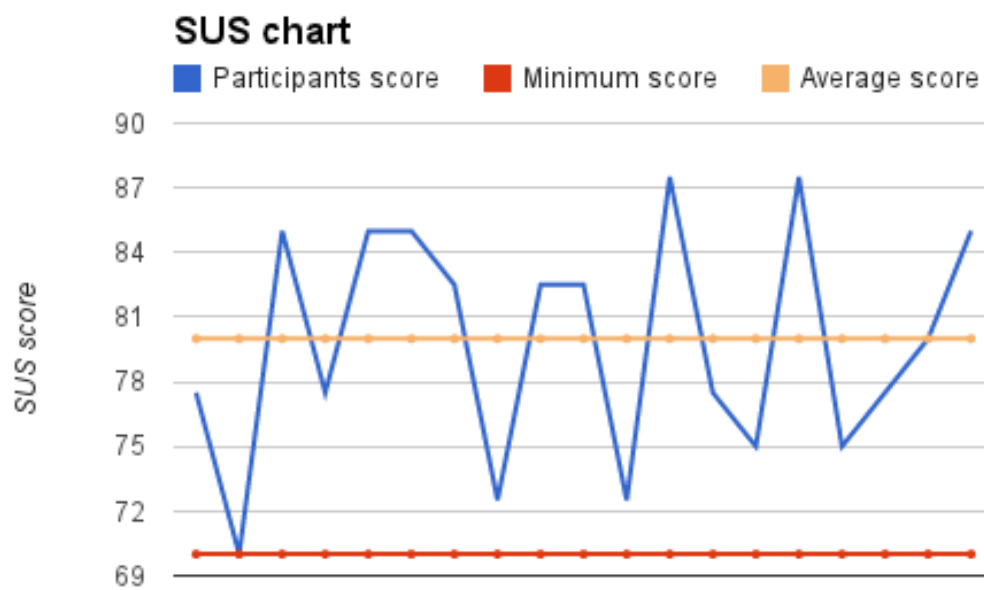


Figure 7.3: SUS evaluation

unexpectedly high score could mean that the game might be applicable by broader spectrum of users and not limited to school age young adults.

However, the testing of usability and difficulty of the tasks had only 19 participants. The low amount of participants cannot guaranty high accuracy of the results. Still the appeal of the game to broader population might require broader and more extensive testing of the application with more varied participant groups of different age and background.

Chapter 8

Evaluation and discussion

The purpose of this chapter is to evaluate the work done during this project. The evaluation is done in two phases. The first phase consists of a field test done with intended end users of the system in the intended location. The results of the case study are presented and followed by the second phase in which the feedback from the teacher is presented.

This chapter should give an evaluation of usability and usefulness of the system in the intended environment with the intended end users from the view of an teacher and the students that played the game.

8.1 The experiment

The experiment was arranged in collaboration with Dr. Ines Di Loreto (who was present during the experiment) and Scuola della Comunita Ebraica di Milano high school in Milan, Italy. The experiment was conducted on 9-th of May 2013 in the afternoon. The experiment was a part of a guided museum trip. The teacher and the students were asked to use the MagMar application for a part of the museum visit, before the guided tour. After the game session was over the teacher and the students resumed the classical guided museum visit for the rest of the trip.

8.1.1 Methodology

Participants

The application is aimed at young museum visitors. To play the game in a meaningful way the participants have to understand the context and be able to create meaningful complex questions that can challenge the opposing team and insure that all game sessions will not end in stalemate.

The experiment participants were high school students of approximate age of 18 years. Most of the students had personal interest in art and history of art and were familiar with the museum.

Setting

One of the main goals of this evaluation was to test if the application could be used in a real world setting that it was designed for. The museum setting was important to supply the

students with the context of the game essence and reveal the potential limitations raised by the museum.

The experiment took place in a contemporary art museum in Milan, Italy. The museum ‘Museo del 900’ was chosen by the teacher of the group of participants for a field trip and the applications was to be used as a part of that trip.

Tools

During the experiment two HTC Desire HD smart phones were used. The phones were supplied by the thesis supervisor and during the testing had the game application installed. The phones used 3G network for Internet connectivity.

The participants had no restrictions of using any other means of collecting the data required to play the game and were encouraged to use their personal phones and/or other materials that could be found in the museum.

For monitoring purposes the teacher was using an iPad, through which a Web interface could be viewed.

Questionnaire in paper form was given to each participant at the end of testing to collect the data.

Training

The participants were provided with some minimal training, that was comprised from the presentation of the purpose of the application and some general rules of the game.

Procedure

Step-by-step procedure:

1. Participants arrive at the museum and are welcomed by the experiment facilitator.
2. Participants are given a brief explanation of the purpose of the experiment, procedure and duration of the experiment.
3. Participants are given an introduction to the purpose of the application and are informed of the general rules of the game and of the scenario that they will be playing through.
4. Participants split into two teams and are given tools required to play the game (see Section [8.1.1](#)).
5. Participants are allowed to play the game for a strictly limited amount of time (the usual amount of time that is used for a museum trip).
6. Participants are asked to fill out the paper questionnaire.
7. Facilitator thanks the participants and the testing is officially over, the participant continue the guided museum tour.

Ethics

To adhere to the suggestions of the usability testing template all testing will be anonymous. No names will be used in the questionnaires nor will they be mentioned or referenced outside the testing session.

After each game session before the players fill in the questionnaires they are informed that the information will be used in academical purposes only and that their participation is anonymous.

Questionnaire

The questionnaire consists of 17 questions concerning different aspects of the game that this thesis is trying to assess:

- engagement questions - questions 1, 2, 6, 7, 11, 16. These questions are meant to assess the engagement level of the participants during the game session. With these questions I can assess if the game was fun and did the game scenario motivate the players enough to invest
- MAR technology questions - questions 3, 4, 5, 17. These questions are meant to assess the usefulness of the system. In its essence it is important to note that the game can be played with pen and paper and it is even more important to measure the benefits of introducing new technologies (smart phone with MAR application) into this field. At this point cost/benefit analysis
- social interaction questions - questions 12, 13, 14, 15. These questions are meant to assess if the multiplayer aspect of the game was a success. Participants are not only playing against each other, but are doing so in teams, increasing the level of collaboration required= to be able to win the game.
- learning questions - questions 8, 9. Even though assessing academical gains of this application is not part of this thesis it was interesting to get the participants point of view on the potential of the application in teaching purposes.
- information gathering survey - questions designed to find out what means of information gathering the participants used to create and answer questions.

Success criteria

The results gathered by means of the questionnaire should provide me with some information in ability to asses if my research goals were achieved.

In assessing these results, similar technique as in Usability study(see Section 7.5.8) was used with slight modifications. The questionnaire has answers that consists of 5 point scale. For positive questions(1, 2, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17) the score is contribution is scale position minus one, for negative questions(3, 4, 7) the score is equal to five minus the scale position, making these questions equal. To calculate the score for each group of questions their sum of scores obtained is multiplied by one hundred and divided by the maximum score of that group.

Success criteria for questionnaire parts:

- engagement - score of more than 70 was reached. Making the engagement level above average.

- MAR technology - score of more than 70 was reached. Making the usefulness of the introduction of the new technology above average.
- social interaction - score of more than 70 was reached. Making the collaboration part of the application an important part of the application.
- learning - score of more than 70 was reached. In the scope of this project this score has no meaning and was collected mainly for observation and no conclusions shall be drawn at this point.

8.1.2 Summary of the results and discussion

Due to some technical issues revealed by the experiment in the intended setting and time constraints of the museum visit, the experimentation had to be stopped after the players used only two items to play the game. Even though the experiment was cut short, it produced some very interesting feedback, both from the teacher and the students.

There were some deviations from the suggested plan of the experiment, as time limitations did not allow to fill the questionnaires right after the experiment. Instead the questionnaires were filled on Monday of the following week.

The results accumulated from the questionnaire can be seen in Figure 8.1. Most of the results scored higher or equal to expected minimal score of 70 out of 100.

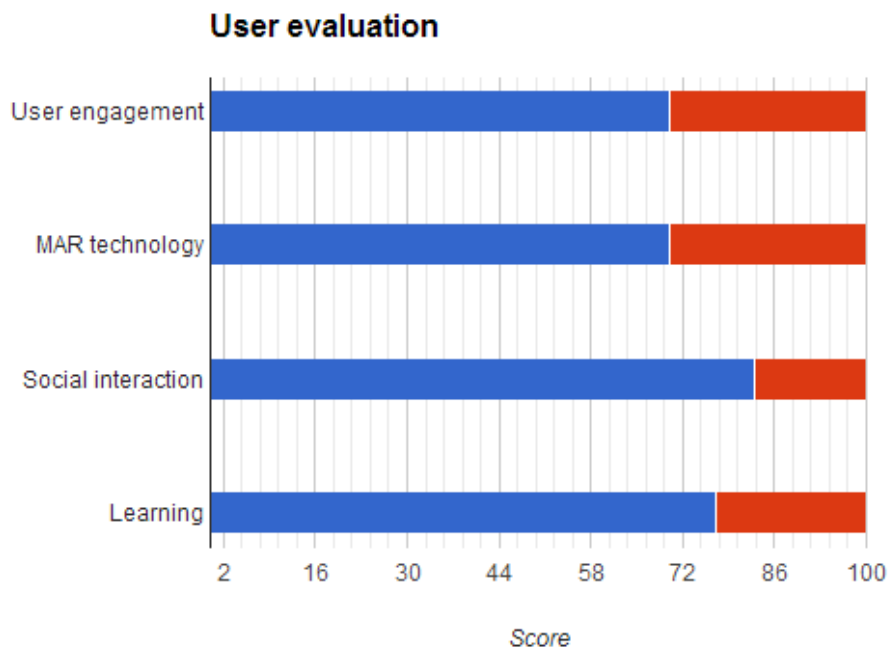


Figure 8.1: User evaluation of different parts of the application

User engagement

Judging from the answers collected through the questionnaire, most of the participants thought that it was fun to play the game, but less than half of the participant would like to use the system frequently during museum visits in the future.

During the game I lost the perception of time because it was a lot of fun.

It seems that question creation part provided high levels of motivation and most of the participants were proud of the questions they created and thought what it was not easy to create good meaningful questions. This is also supported by the way these participants rated the amount effort they put in trying to win the game as high.

This game made the visit more fun.

User generated content as questions created by the players is a very important part of this research. In the classical approach of this type of games the questions are pre-determined by the teacher and players have no control over them. The unique approach used in this game scenario is based on the assumption that users might enjoy the game better if they helped create parts of it.

Participants replies to open questions of the questionnaire suggest that the user generated content was the most interesting part of the game application application, supporting the idea that it might be more interesting to generate your own content as opposed to answering a predetermined list of questions compiled by the teacher or the museum. But some feedback from the teacher and the students suggest that there should be more control over the questions created.

The chart with scores given by participants can be seen in Figure 8.2.

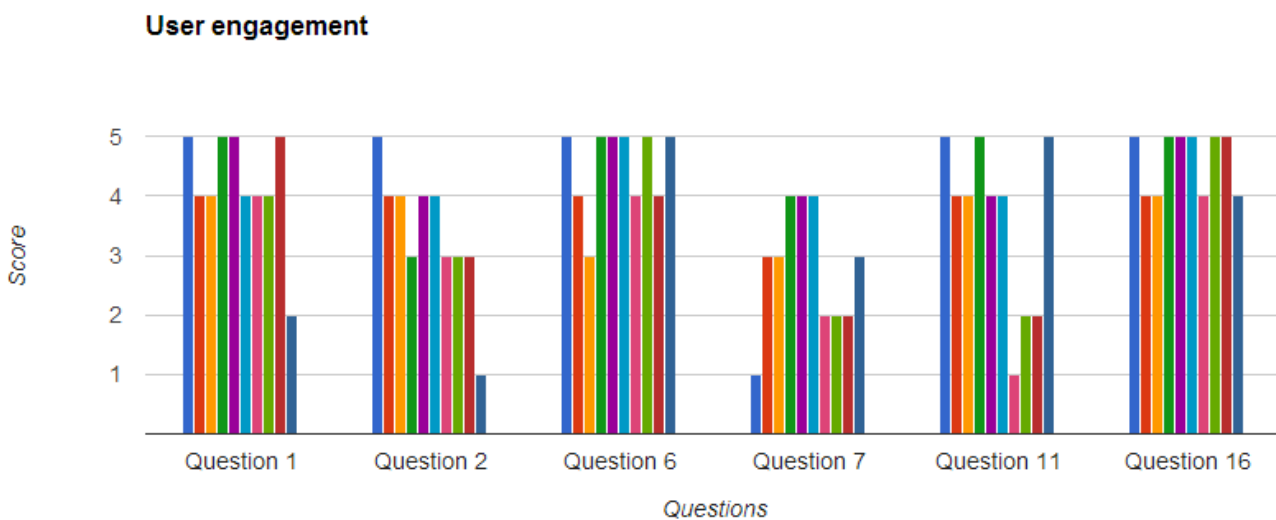


Figure 8.2: User evaluation of the engagement level of the application

MAR technology

The focus of the application and the thesis itself was on using MAR application in a museum setting and trying to asses if there are benefits in introducing this technology as a replacement for the paper based version of the same game.

The visual augmentation was used in a very subtle way mainly to create a link between the physical and electronic worlds and to provide the players with some additional information about museum items, so they would be easier to identify.

Judging by results accumulated through the questionnaire(see Figure 8.3) it seems like most

of the users were not distracted from a museum neither by the game, nor by the visual augmentation that was used in the game scenario.

There were quite a few comments regarding the functional issues of the prototype, limiting the freedom of the question creation part of the game. All these issues should be addressed in the next version of the game.

It also seemed that the choice of the device used for testing was not appropriate for the setting. There were many complaints about the difficulty of inputting text using the HTC Desire HD phone. It might be that participant prefer Apple solutions and rarely or never use Android bases smart phones. More research in form of a broad survey is required to be able to judge what is the most appropriate device to use for this type of game in the museum setting.

You should change from the HTC to an iPhone, because it is easier to use.

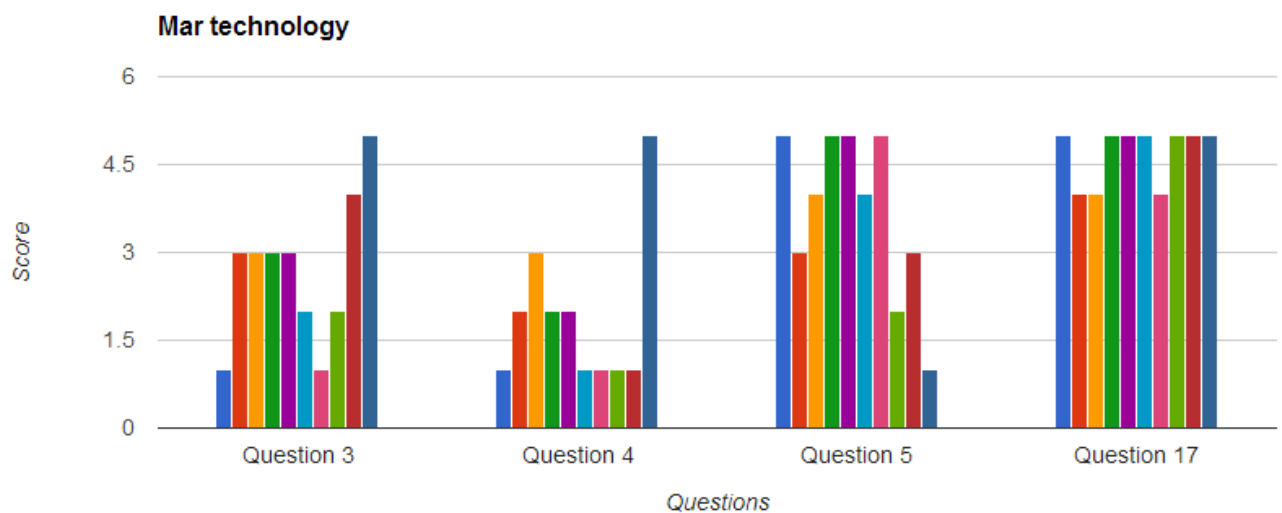


Figure 8.3: User evaluation of the MAR technology used in the application

Social interaction

One of the integral parts of the application was the social interaction amongst the players. Furthermore the players are not only trying to solve a common problem, but also have to cooperate in a team to win the game against another team of players. This part of the questionnaire helped to get some idea if participants enjoyed being in a team and if the presence of rival team motivated them enough to create more difficult questions in attempt to win the game.

The fact that we were two competing teams, motivated me very much.

This questionnaire part created some controversial results (see Figure 8.4), since the results were very different comparing them between teams. Almost all the players from the Blue team indicated that they thought that other teammates were not helpful, indicating that either team had issues with the group dynamics or the assumption that one device per group was wrong. This factor prompts some more research into game mechanics a game of this sort could support more diverse groups of players.

Other than the issue marked above, the players seemed to enjoy challenging the rival group of players it motivated them to create better, more difficult questions.

I was a little bit skeptical before arriving at the museum, but than the game made me competitive and I had a lot of fun.

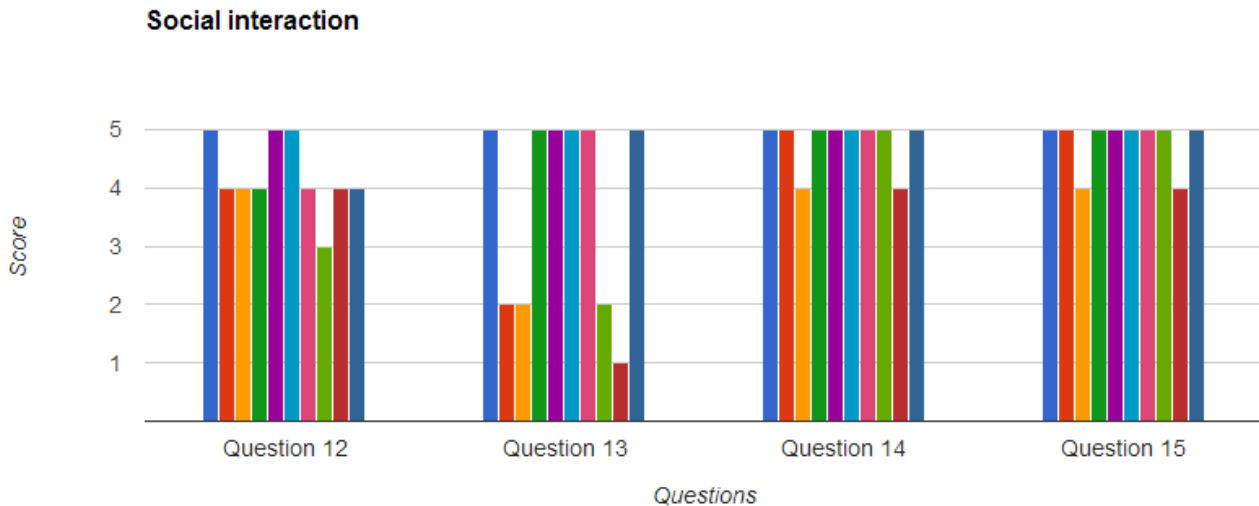


Figure 8.4: User evaluation of the social interaction between the players

The results of this part of the questionnaire suggest that it the most motivating part of the application was the fact that two teams competed against each other, but more research should be done into why one group was able to cooperate successfully, and the other deemed the other teammates as not helpful. More testing is required to determine the optimal size of the group and other social aspects that might have had an impact on the group dynamics during the experiment.

Learning by means of the application

The academical gains of MagMAR applications could not be assessed during this experiment. The feedback from the participants indicates that they think they learned something new in a way that was not proposed to them before. This might be an indicator that the game has the potential to motivate the students to gain knowledge by playing. But more longitudinal research is required to make any assumptions.

Some feedback from one of the student participants proposed an alternative use of the application. In the opinion of the participant the application might be used to motivate younger museum visitors, who are not interested in the museums. This is a very valid point and should be explored further, expanding the age group of the participants.

I think that this game is more useful for the children, because it will allow them to get into contact with art in an innovative and different way. Personally I prefer the classical approach.

Furthermore the freedom the students get when creating the questions might not be beneficial to the academic gain that the application might produce. As the students focused on the competitive part of the game, they were motivated to create questions that are very difficult to answer. This might produce very interesting questions, but than the students focus on rare facts and will not even read the general information about the work of art.

We were trying to create the most difficult questions, disregarding general information about the painting.

More research into finding ways to control the question in subtle but guiding ways should be done. Otherwise the game application might be used for entertainment as social activity, but

not as a teaching tool.

I think when ask to create the question you should give a frame for the question. I.e. create a historical question about the painting, create an artistic question about the painting.

8.1.3 Information gathering survey

The questionnaire contained a survey, to see what means did the students use to gather information used to create questions during the game session. As can be seen in Figure 8.5, the students used mostly Internet to search for information when trying to create a good difficult question and used mostly knowledge previously gained in school and Internet to answer the questions created by the opposing team(see Figure 8.6).

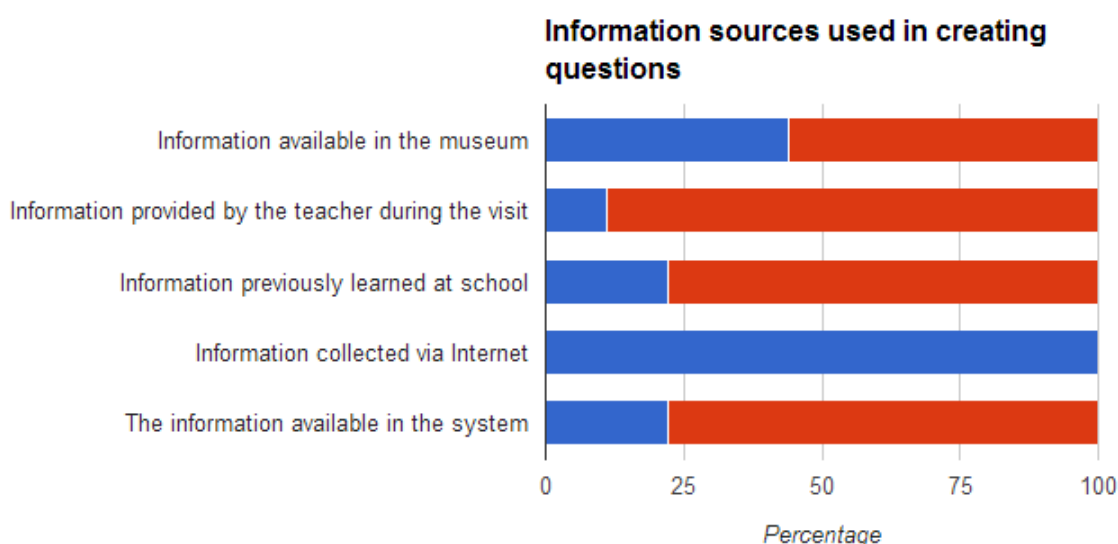


Figure 8.5: Information sources used for creating questions

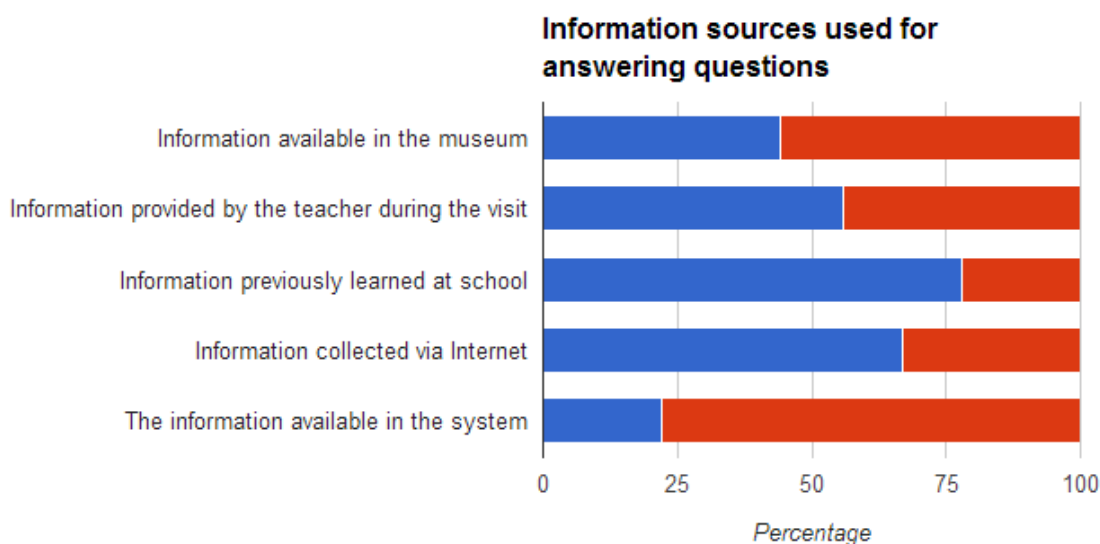


Figure 8.6: Information sources used for answering questions

An interesting fact to note that the textual information provided by the system as a description of an item was barely used to create or answer the questions.

This might indicate that the students understood the purpose of the description provided by the system as for what it intended by design - a means to recognize the museum item and be able to search the information about it on the Internet. Furthermore the description is visible during the creation and answering phases of the game and if used to create a question it would hardly be a difficult question to answer.

8.2 Teacher evaluation

Data for the teacher evaluation was collected during a Skype video conference. During this conference data was collected through a semi-structured interview with the teacher of the class of students that participated in the experiment.

The experiment participant is a high school teacher of art history and literature, that works with students.

The teachers opinion on the game was very important since the teacher available for live testing of the game application in a museum with 9 student participants. Since I could not attend the testing, it was important to get feedback on the way the students interacted with the system and the potential the system held for the teacher in a professional meaning.

The Skype audio conference consisted of a semi-formal interview with prepared open ended questions.

8.2.1 The Interview

The Plan

The plan was to conduct the interview as close to the end of the testing as possible, but due to unforeseen circumstances it was delayed until later time. Time of the meeting was previously discussed and due to personal preferences was set in the morning in the beginning of the week.

The teacher will be greeted and presented with the plan of the interview, explaining the procedure and will be informed of the duration of the interview. Subject agreed to be recorded in advance, so no further inquiries on this matter will be made. The interview itself will be recorded using CallNote application that can record Skype audio/video conversations with minimal hassle. Since I will be conducting the interview using a headset with microphone no external recorders will be used.

After the teacher is familiar with the interview procedure the interview will begin. The time for the interview is set to 15 minutes, but might be extended depending on the extend of the answers given by the expert. To keep the setting as informal as possible the time will not be measured in any obvious way, giving the teacher all the time in the world to get as much information as possible.

The teacher will be asked a predetermined set of questions. Depending on answers given to these questions the teacher might be asked a few follow up questions to clarify the given answer or just to get some examples to clarify the point of the answer. Questions are kept open to give the teacher a chance to expand on the answers producing larger quantities of possibly relevant data.

Data Collection Instrument

Interview questions:

1. How often do you visit museums with your class?
2. What kind of museums do you usually visit?
3. Do students get to choose the museum they are going to visit?
 - If 'no' who/how the museum is picked?
4. Would you say the trips are more recreational or educational?
5. Do you think the students enjoyed playing the game?
 - What part of the game did they enjoy the most/least ?
6. Was it difficult to set up the game?
 - Get permission from the museum to use the phones?
 - Place markers near the items?
7. Do you think that this game is something you could use during your trips to the museum on a regular basis?
 - If 'no' what would make the game more appealing to you, so you would use it on a regular basis?
 - If 'yes' what do you think makes the game appealing to you?
8. Do you think that this game has the potential to provide a level of academical gain the players?
9. How would you use the game to increase the academical gain of the museum trips?
10. What improvements to the game make you consider using it on regular basis?
 - improvements to the graphical user interface of the application
 - improvements the supervisors interface
 - improvements on the flow of the game
11. Do you have any comments about the interview or maybe can add something more on the topic?

Results

Conducting an interview with the teacher that was present during testing was very useful as a way to get an overview of the experiment from the teachers perspective.

It seems that the teacher supports the idea that students enjoyed playing the game and had fun while doing so. During normal visits the teacher usually gives the students a lecture in front of works of art, so they can visually study the picture and hear its history. From the teachers point of view the MagMAR game distracted the students from the surroundings of the museum. Furthermore students were so immersed in the game that they did not pay much attention to the paintings at all. It was also noted that even though students did not posses prior knowledge about the particular paintings used in the experiment, instead of creating questions directly

connected to the paintings, students searched for more hard to find information. This meant that they created good difficult questions, but not relevant nor for the history of the work of art, nor for the intended curriculum.

From the teachers point of view it seemed that the game motivated the students and kept them focused, but provided little to no academical gain comparing to the classical guided tour. Therefore it should be tested in different settings with students of different academical background.

The Web interface provided the teacher with museum item managing solution and live game monitoring solution. The game management solution was not that user-friendly and was regarded as hard to use.

It is interesting to note that the survey(see Section 8.1.3) showed that information entered to the system by the teacher was not used by students to create the questions, but only to identify the work of art. Yet the teacher perceived this information in a very different way. The teacher invested a considerable amount of time to formulate the information in a way that could trigger/motivate the students to create good(difficult, interesting and relevant to the curriculum) questions. This might indicate that with more defined rules(i.e. students have to use some information from the in-game item descriptions) it might be possible to steer the students to create questions that would be relevant for the curriculum, thus providing some level of academical gain.

The game monitoring solution, through which the teacher could observe the game live, due to time restrictions was used only after the game, but was regarded as a very useful tool that compliments the game application. It might also be used as a reflection tool, as the students only get the game results as a score, and have to come back to the teacher to get the right answers. More research into game end mechanics are required as at this point it is not clear whether students should get the complete summary of the results on the smartphone or come back and get inspect the summary with the teacher.

Chapter 9

Conclusions

9.1 Summary

The objective of this thesis was to investigate how modern technologies could be used to create a better, more engaging museum experience for the young museum visitors. In particular this work aims at bringing old paper based games to modern platforms to engage the young museum visitors with modern tools that they use in their everyday lives for entertainment. This work wants to show how modern technologies in conjunction with unique player generated content based multiplayer game, can encourage young museum visitors to explore the museum on deeper level. A literature review on previous attempts to create similar games was done, that showed the lack of recent projects in this particular field of research. To be able to answer the first research question(RQ1) and gain better understanding of the effects custom created content might have on the motivation of the players, a unique game scenario was developed to support user generated content in the game application. The scenario was the basis for the implementation and was evaluated by the end users during the real world experiment.

To be able to assess the advantages the Mobile Augmented Reality(RQ3) can bring to the game application, the game was built upon Vuforia Augmented Reality framework, that allowed to incorporate the Augmented reality into the application. An architecture of the application was proposed keeping in mind that it is built around the proposed framework. The visual augmentation was used to create a link between physical and virtual worlds and provide the players with additional information about the museum item that was created by the teacher. The use and usefulness of the technology was evaluated during the usability study and the real world experiment.

The implementation of the prototype was evaluated in two stages. In the first stage a usability study(Chapter 7) was conducted. The usability study aimed at measuring the overall usability of the application comparing to industry standards. In the second stage a field test experiment was conducted in the intended real world setting with intended end users. This evaluation was aimed at investigating usefulness of the system in a real world settings, to gain relevant feedback from the intended end users. During the evaluation the participants were asked to play the game and fill out a paper questionnaire. The experiment generated a lot of data that was used to support all the research questions, in particular it was useful to understand the social part of the gaming addressed by the second research question(RQ2) concerning social motivation in creation of high quality game content.

A workshop paper based on the work done in this thesis has been submitted at the MasIE workshop in collaboration with my supervisor Monica Divitini, my co-advisor Ines Di Loreto

and Micaela Mander.

9.2 Evaluation

The assignment of this thesis was to investigate the usage of mobile augmented reality (on tablets or mobile phones) for games and learning, focusing on serious games supporting collaborative learning in a museum setting. Due to the broadness of the task it was decided to focus on educational games that can be played in a museum setting. Incorporating Augmented Reality into a game application that could be played in any museum indoors proved to be very challenging. Due to constraints of the thesis it was not possible to evaluate educational gains of the game, the focus lay on the engagement part and ways to make young museum visitors interested in the game. Having only limited pedagogical knowledge made it even more difficult to address the design of the application.

The proposed solution implementation was tested using usability study with 19 participants. The results of the study suggest that the application might have high usability rating comparing to industry standards, but the small amount of participants cannot guarantee high accuracy of the results.

The whole system(game application and Web interface) was tested in Milan during a high school trip to a museum 'Museo del 900'. The experiment revealed some major flaws in the system, but provided very interesting research data. In particular that the class in question was more motivated by the custom content creation and social interaction parts of the game. Suggestions from the feedback received also showed that the system might have higher potential with different kind of target audience(young museum visitors that don't like museums).

After two different kinds of evaluation of the proposed solution, that prompted a lot of discussion I believe that this work achieved its goal. The proposed solution incorporated the Mobile Augmented Reality as means to connect the real world with digital word, evaluation showed that the main driver of the game was social interaction and the most engaging part was the creation of user generated content. Furthermore the supervisor Web interface provided and interesting monitoring solution that needs more research to be able to make some conclusions.

Overall the implementation of the solution is not perfect and needs a lot more work to fix the issues uncovered by the real world testing and more testing is required by end users with more diverse background.

9.3 Future Work

This chapter contains some future work ideas. The ideas were mainly taken from the feedback of the field test experiment and general observations.

9.3.1 Academical gain

The one thing this thesis does not address is the academical gain of this kind of game applications. This point was not addressed due to lack of pedagogical competence and time restraints of this master work. During the real world experiment the players almost unanimously agree that they think they learned something new because the game helped them focus on the museum items. This was contradicted by the supervising teacher stating that the game distracted

the students from the museum environment and information they used to create game content was not so relevant to the curriculum. This contradictory feedback requires more research to find out if there is actual academical gain and how to give direction to the content created by the players to be able to connect the game sessions with curriculum.

9.3.2 Portability

The application was developed for Android OS supported smart phones. The experimentation showed that users were not particularly happy with the supplied HTC Desire HD smart phone. Feedback from the participants showed that most of them would prefer an iPhone or a tablet PC. Applications ability to be deployed on different platforms, can be beneficial in supplying the users the best possible experience with the system.

9.3.3 Supervisor Web interface

The supervisor Web interface initially was designed as means to set up the initial game content and collect user data for further analysis. After initial testing the system was given a more user-friendly look and adapted to be used by the supervisor during the experiment. The feedback from the supervisor after the test suggests that the supervisor Web interface is a very useful tool to be able to track players actions in real time, but it also revealed some design flaws and proved to be hard to use without external help. In future the GUI of the Web interface should be redesigned to suit the needs of the potential end users(i.e. high school teachers).

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Appendix A

SUS questionnaire

| | Strongly disagree | | | | Strongly agree |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| 1. I think that I would like to use this system frequently | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. I found the system unnecessarily complex | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. I thought the system was easy to use | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. I think that I would need the support of a technical person to be able to use this system | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. I found the various functions in this system were well integrated | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. I thought there was too much inconsistency in this system | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. I would imagine that most people would learn to use this system very quickly | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. I found the system very cumbersome to use | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. I felt very confident using the system | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. I needed to learn a lot of things before I could get going with this system | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Appendix B

Questionnaire

Information: please assess the difficulty of completing each task during the game session.

| | Very easy | | | | Very hard |
|-------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| 1. Join the game | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Start Stage 1 of the game | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Create questions | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Finish Stage 1 of the game | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Start Stage 2 of the game | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Answer questions | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Finish Stage 2 of the game | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. View results of the game session | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Appendix C

Questionnaire

| | Strongly disagree | | | | Strongly agree |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| 1. I though the game was fun to play | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. I think I would like to use the system frequently when visiting museums | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Visual augmentation distracted me from the museum | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. The game distracted me from the museum | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. I found it easy to detect the items using the smartphone | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. I am proud of the questions that my group created | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. I thought it was easy to create meaningful questions | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. I think that creating the questions helped the me to learn something new about the museum items | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. I think that answering the questions helped the students to learn something new about the museum items | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

| | Strongly disagree | | | | Strongly agree |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| 10. I would like to share the questions we created with other museum visitors | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11. While playing I lost track of time while playing | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12. Collaborating with others helped the me to learn more about the museum items | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13. The other teammates were helpful | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14. Playing with others made the game more fun | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15. Challenging the other team made the experience more compelling | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16. I put a lot of effort in trying to win the game | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 17. The game encouraged the me to explore the museum in a new way | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

18. In creating the questions our group used (check one or more)
- ** information available in the museum
 - ** information provided by the teacher during the visit
 - ** information previously learned at school
 - ** information collected via Internet
 - ** the information available in the system
19. In answering the questions our group used (check one or more)
- ** information available in the museum
 - ** information provided by the teacher during the visit
 - ** information previously learned at school
 - ** information collected via Internet
 - ** the information available in the system

- In your opinion, which one of the questions you answered/created in the game is the best one? Why?

.....

.....

.....

.....

- Where there any difficulties playing the game?

.....

.....

.....

.....

- What improvements would you like to see in the next version of the game?

.....

.....

.....

.....

- Comments and general feedback

.....

.....

.....

.....

Appendix D

Questionnaire

| | Strongly disagree | | | | Strongly agree |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| 1. I though the game was fun for the students to play | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Visual augmentation distracted students from the museum | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. The game distracted students from the museum | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. I think that for the students it was easy to detect the items using the smartphone | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. I think that the students were pleased that others had to answer the questions that they created | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. I thought it was easy for the students to create meaningful questions | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. I think that creating the questions helped the students to learn something new about the museum items | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. I think that answering the questions helped the students to learn something new about the museum items | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

| | Strongly disagree | | | | Strongly agree |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| 9. I think that students would like to share the questions they created with other museum visitors | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. I think the students lost track of time while playing | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11. I think that collaborating with others helped the students to learn more about the museum items | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12. I think that students collaborated well in the same group | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13. I think that playing with others made the game more fun for the students | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14. I think that challenging the other team made the experience more compelling for the students | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15. I think the students put a lot of effort in trying to win the game | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16. I think the game encouraged the students to explore the museum in a new way | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Appendix E

Workshop paper

This chapter contains the workshop paper that was written and submitted for the MasIE workshop. The paper has been written in collaboration with my supervisor Monica Divitini, my co-advisor Ines Di Loreto and Micaela Mander.

Playing in museums by constructing your game

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Abstract. In this paper we present MagMAR, a system for supporting museums visits recognizing the different needs of educators and students. MagMAR combines a Mobile Augmented Reality game (targeted towards young visitors) and a Web interface (targeted towards educators). The Web interface lets educators shape and guide the learning process, while the game is intended to engage students during the visit. A first evaluation was performed asking 9 students and a teacher from a high school class to test a MagMAR in a contemporary art museum in Milan. Results show that the form game was very successful from the sociability and fun points of view, and also guided the students in the retrieval and usage of information for the quiz game. Further improvements are on the other hand due to make the game more integrated in the context and push the students to pay more attention to their surroundings.

Keywords. Serious Games, Augmented Reality, Young people

1. Introduction

Along the years, access to culture has changed forms. Starting from the '60ies in parallel with classic channels and institutions we have seen the emergence of youth culture channels (see e.g., [1] for a detailed analysis on the topic). These channels are dynamic and often informal, and many times do not enjoy official recognition (for example in the case of street art) [2]. In addition, the way young people accumulate, analyse, and disseminate information and knowledge today is strongly connected to new technologies [5]. Opportunities for young people to enlarge their cultural and creative expressions and development - in or outside of school - can thus pass through the usage of technologies.

Within the museum and culture research literature, there has been some emerging focus on how digital devices improve engagement to enhance the visitor's experience. For example, [6] tested a prototype handheld device that delivered descriptions of artefacts in a historic house to multiple users simultaneously, and found that conversations around exhibits increased. In another study, increased engagement and interest was also found with young students when they were given RFID sensors that could detect exhibit locations and unlock virtual information to extend their interactions [7]. Along similar engagement lines, other studies have examined how Augmented Reality (AR) can improve access to information and increase exhibit functionality. For example, [8] investigated the functionality of an AR-enabled mobile multimedia museum guide implemented in a fine arts museum in France. They found,

among other things, that using AR to enhance the museum experience could serve as a viable alternative to traditional text guides in retrieving information, which has potential to attract new audiences.

In this paper we present MagMAR, a system for supporting museums visits recognizing the different needs of educators (e.g., teachers and museums' guides) and students. MagMAR combines a Mobile Augmented Reality game (targeted towards young visitors) and a Web interface (targeted towards educators). The usage of MagMAR in museums and other cultural heritage settings is expected to enhance the fruition experience and reconnect young people to cultural heritage, letting nevertheless the educators able to monitor the learning cycle. The rest of this paper is structured as follow. Next Section and Section 3 describe respectively the motivations and the design principles that guided us towards the creation of MagMAR. Section 4 drafts a short state of the art while Section 5 and 6 describe the MagMAR design and a first evaluation we held with teenagers in a museum setting.

2. Motivations

In [4] the authors narrate an ancient anecdote. When the Spanish galleons arrived for the first time off the coast of the islands in Central America the Indians were not able to see them, as they were objects so far beyond their experience and their ability of understanding to make them in all respects "invisible". Only after a prolonged (and traumatic) contact with the new culture galleons finally became visible and could be integrated into patterns of behaviour, language, and in everyday experience. For many citizens local heritage (museums but also other structures) sometimes seems to enjoy features of invisibility comparable to those of the galleons of the story [4]. In line with [2] the authors of this paper believe that non-formal arts education approaches can be profitably used together with other types of formal approaches to reconnect people - and in particular young people - to culture, making cultural heritage visible to them. In addition, in a recent EU document[15]educators are asked to teach the students strategies and methods to be applied independently from school (the "know how"). This approach urges teachers to lead students outside the classroom, going to museums, on excavation and construction sites, investing time to put students "in situation" and enabling them to "learn by doing"[16]. Creating these possibilities takes time, tools, resources, interdisciplinary connections, and methodological experimentation. Among other things, this approach requires teachers to acquire skills that transcend the role assigned to them by the school until today. These skills, if already present, were acquired in most cases through "informal and non-formal" paths [16].

The two scenarios we described suggest the need to integrate informal learning in formal settings at two levels, the students' and the teacher's one. The approach we propose in this paper, MagMAR, is composed by an augmented reality game targeting young people and a web application targeting educators. These two elements are strictly linked together, enabling the usage of informal learning at both levels.

3. Design for Young People Access to Culture

In this section we describe some additional considerations which drove us in the creation of the MagMAR application.

3.1. *It's all about the form: the invisible museum and its non-public*

The youth population is, according to the cliché, a *non-public* for the cultural offer, or at least an audience motivationally weak and discontinuous. In study [8] the authors analysed the perceived image of museums targeting teenagers. What emerges is their generally negative connotation. The most used adjective in the conducted survey is *old-fashioned*, and the museum image is linked to the concepts of closure, normativity, distance. What is interesting in this study is that many of the factors that create this connotation are completely unrelated to the content but related to the *form* of the museum. Quality of the experience as a whole, rules of conduct and explicitly didactic value, but also lack of communication or inadequate equipment, are equally if not more important than the content of the collections in forming the judgment of young people towards the experience related to the museum.

3.2. *It's all about emotions 1: sense of belonging and sociability*

A second study targeted at teenagers [3], has clearly highlighted that young people perceive a great distance between the so-called “high” culture and the youth culture which is considered to be “popular”. The most successful initiatives at the level of youth culture proposed by traditional cultural institutions are those in which this distinction is not marked. Moreover, the most vivid, positive, and persistent memories of the museum are those attributable to strong emotions felt during a visit (the emotional dimension is predominant with respect to the cognitive in determining the value of the experience). More specifically what emerges is the deep need for comparison and relationship with others, a dominant socio-relational behaviour that informs the processes of choice, the formation of tastes, and the evaluation of the experience. While the typical adult visitor of museums gives the museum a value in itself (intrinsic dimension), is self-referential (in the sense that the visitor’s experience is individual)[9] and tends to have a reactive attitude towards the objects on display, for the interviewees seem to play a significant role the ensemble of environmental, socio-relational, and emotional factors more than the actual contents.

3.3. *It's all about emotions 2: ownership and content*

Recent technology, and especially the Web 2.0, offers people the possibility to become involved in activities that are called End-User Development (EUD), i.e. activities that range from simple parameter customization to modification and assembling of components, and even to the creation of new software artefacts [10],[11],[12]. Today, users are no longer passive consumers of computer tools, but they are more and more information and software producers. These new roles of end users blur the distinction between design time and use time in the life cycle of an interactive system. In addition, in [17] the authors highlight that the learning potential in the field of technology enhanced learning is not only linked to game play but also to game design and development (see also [13] [14]).

To summarize, form, ownership and sociability seem to be factors of engagement in exploring cultural heritage and in particular museums.

4. State of the Art: Games for Cultural Experience

Previous section clearly states that the form is an important factor for the engagement of the young population. In this section we describe why we opted for an augmented reality game as an alternative form of exploration in the museum setting.

Games, learning and cultural heritage

Recent studies have shown that the introduction of games has the potential to help young visitors to use the information gained during a cultural tour in a more meaningful way [21] as it obliges the young visitors to use the collected information right away to complete some tasks or answer some questions. In addition, young visitors are most likely used to play video games and are familiar with multiple platforms to play them on. Introduction of a video game in the cultural setting might thus provide a natural environment for the young visitors [22]. Indeed, game play is not a new practice for museums. Through the years a lot of (non-technological enhanced) educational games have been created for museum or other cultural settings. The main idea behind these games was to make the experience for the young visitors more interesting creating an environment where they could learn through interactivity. One typical example of these games is the “treasure hunt”, where participants are asked to find in the museum different items and answer a couple of questions about the same by filling in a paper form. The team who answers in the right way and fastest wins.

Augmented Reality

For the game described in this paper we decided to focus on the usage of *Mobile Augmented Reality (MAR)*. The main advantage of the AR technology is that it is created to supplement the real world with virtual objects that appear to coexist with the real world. By providing more intuitive and natural means of interaction AR has the potential to further blur the line between computer generated content (for example pc games) and the real world. In addition, the field of AR applications for culture has grown a lot in recent years due to rapid development in handheld devices technology, resulting in a new sub field of augmented reality called *Mobile Augmented Reality(MAR)* [18]. MAR's popularity today is tightly linked to the availability of smartphones that can exploit its capabilities and enhance user experience while remaining relatively cheap. Researches were conducted also about the usefulness of augmented reality to enhance visitor experience in the museum setting as MAR has the potential to give users more visual information about the items in the museums or even augment the items themselves [19]. However, current widespread applications are mainly targeted at tourism, creating interactive guides for the city or visual augmentation for exhibitions (i.e. to show how a site looked long time ago or how an item was used). Finally, from a learning point of view [20] findings suggest that the usage of AR in a cultural setting might have an impact on conceptual knowledge.

Augmented Reality and Games in Museum Settings

The introduction of digital technologies in cultural settings resulted in revisiting more in general the idea of game play/storytelling in museums (for a detailed presentation and overview see [23]). For this paper, however, we will focus only on the

attempts to bring mobile *augmentation* into the museum setting for educational purposes. In [24] the game itself is an implementation of a classical “Scavenger Hunt” game. A Scavenger Hunt is a game in which the organizers prepare a list defining specific items. The participants seek to gather all items on the list, or perform tasks, or take photographs of the items, as specified. The goal is usually to be the first to complete the list, although in a variation on the game players can also be challenged to complete the tasks on the list in the most creative manner. In [24] users played the game by answering the questions provided by the system. To find the correct answers, they had to explore the museum and find relevant information about one of the items found in the museum. The project was strongly influenced by the technological difficulties that the PDA’s provided (by that time handheld PDA’s had almost no processing power and little to no memory). However, despite the slow hardware, participant interviews indicate that players enjoyed the experience which proved to be not only entertaining but also educational.

Other studies indicate that the usage of MAR has various advantages over using Virtual Reality simulations for educational purposes mainly due to human perception of our surroundings and the ability to relate to the content of the application [19]. This research supports the idea that by moving around the museum, trying to find the items using the mobile phone camera instead of just getting a list of questions might improve user engagement. Another research on the usefulness of educational games was conducted by [21]. By implementing interactive games in museum setting for PDA’s and observing how people interacted with them, the researchers concluded that when children can use the information gained in the museum immediately to play a game the museum experience can be both educational and entertaining.

Finally, the most recent and relevant attempt we can describe is the Mobile Augmented Reality Quest [25]. MARQ is a team-oriented game to provide an AR museum tour. It is targeted at young visitors (age 12-16), who have to explore the museum by solving interactive 3D AR puzzles to reveal parts of the story. The game uses interactive visual and audio augmentation to make the visitors experience as rich as possible. This game supports multiple user interaction by sharing the collected items between players and tracking the position of the players.

5. The MagMar Design

MagMAR combines a mobile game (targeted towards young visitors) and a Web interface (targeted towards teachers). The Web interface lets teachers shape and guide the learning process, while the game is intended to engage students during the visit.

During the visit, students divide into teams to play the game, while teachers can monitor the progress. After the visit, the information is available to students and teachers to reflect about the museum experience. The actual game consists in a digital implementation of a Treasure Hunt game which replaces the pen and paper with an Android device and a Mobile Augmented Reality (MAR) application developed through the Qualcomm Vuforia framework.

One of the main elements which differentiates MagMAR from the games illustrated in the state of the art is the usage of user generated content not only before the beginning of the game for a set up phase, but also during the actual game session. In the first phase, the educator can decide which information will be available to

students as starting point, taking into account e.g., the learning objectives of the visit and the knowledge level of the students. In the second one, students will create contents in form of questions for the game. The main idea behind this design choice is to use the emotional element of ownership which is typically linked to hand-made objects [26] (the questions are valuable because they are created by the members of the team) also for engaging the students in the museum exploration.

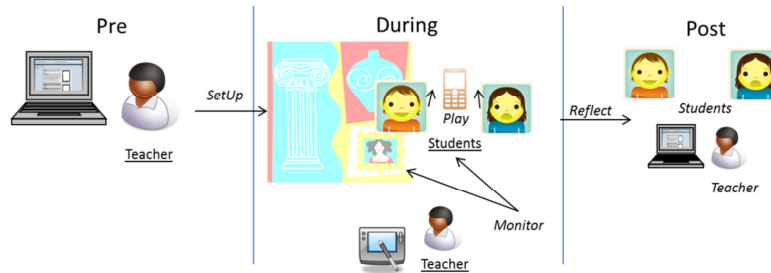


Figure 1. An overview of MagMAR intended usage

In the following we explain the three phases more in details, referring to the current implementation of the system.

Phase 1: The set up

The educators use a Web interface to specify the objects of the game on which they want to focus during the visit and provide related information (Fig. 2). The number of items to be used in each game is flexible as it can be influenced by the size of the museum or other limitations as time or item relevance. The teachers can not only decide which elements are relevant but also the given amount of information, which can vary from a short item description - only sufficient to identify the item - to a more complex description providing some generally known facts about the item (author, when it was created etc.).

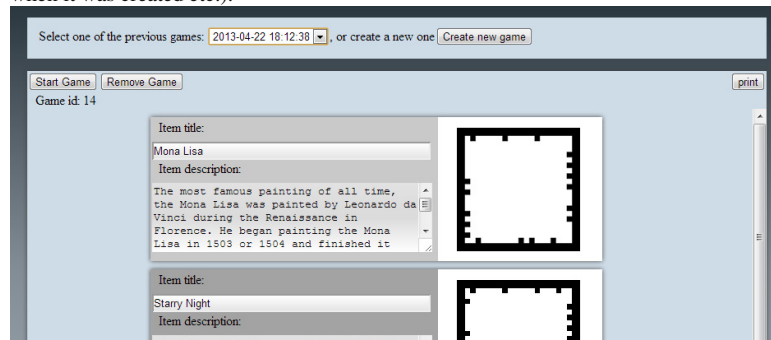


Figure 2. Web interface

For each item, the system generates a physical marker, a small unique pre-programmed picture that is used to identify an item in the physical world and access the related information. Once this phase is over the educator will print out the markers, cut

them out, and head with the class to the museum. Before the actual game session the educators have to manually put all the markers in the vicinity of the corresponding museum items (see Fig.3). In case this is not possible they can simply print out the images associated to the markers and use them while going around in the museum. The information entered by the educator in the Web interface is visible through the MAR application installed on the mobiles (see Fig.3). The visual augmentation is used to create an anchor between the physical item and the augmented dynamic information (firstly the one created by the supervisor, in a second moment the questions created by the students).

Phase 2-a: The game session: Supervising the visit

Once the preparation is over, the game can start. To start the game the educators open anew the Web interface on their personal device, select the previously created game, and start it. The system goes then into a listening mode and waits for the players to join the game. The Web interface allows also for real time game monitoring. This means that during the game session the educator can view in real time the questions created by the players, which provides an overview of the game progress. If the supervisors are not happy with the questions created they might ask the players e.g., to try harder and create the question again.

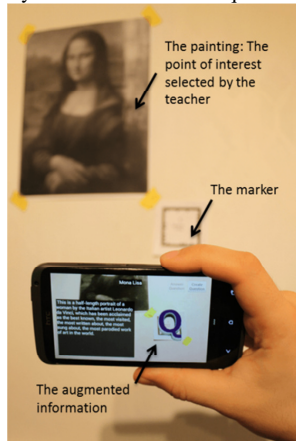


Figure 3. Interacting with markers

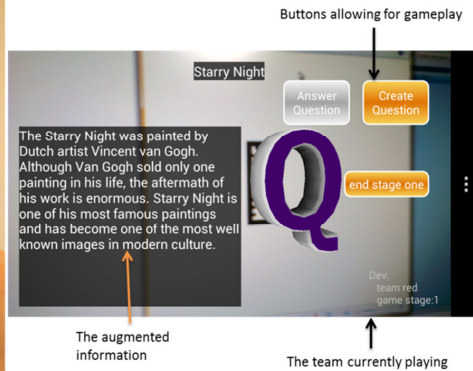


Figure 4. The question/answer process

Phase 2-b: The game session: Creating questions

The main goal of the game is to create difficult - but answerable questions - so that the opposing team will not be able to gain points. When joining the game the teams are assigned a colour (*Team Red* and *Team Blue* in our example). When a player from *Team Red* approaches the first item and points the device - so that the paper marker placed by the educator is visible on the device - the MAR application shows the additional information about the item. This action also makes the *Create Question* button active. Now each team has then to create a question, associated to a particular item, and provide three possible answers, only one of which is correct. The system creates no restrictions about information gathering. In order to create the questions the

players could for example browse the internet to find interesting facts linked to the items. If the teacher considers it more useful, the players can be “forced” to explore the museum exhibits and gain some new knowledge about its artefacts. And so on. This kind of game dynamic require also for good cooperation within the team.

Phase 2-c: The game session: Answering questions

When both teams have finished the questions creation, the answering phase starts (Fig. 4). All the items that were inserted in the game by the supervisor have now questions linked to them. The players from *Team Blue* are now in front of the same marker and are reading the question created by the *Team Red*. At the same time the *Team Red* is answering to the questions created by the *Team Blue*. Once all the teams have found all the items and answered all the questions, information on the supervisor screen gets updated (Fig.5). The supervisor is then able to see the list of the questions, the chosen answers for both teams, and their final score. These results can then be used for further briefing.

MagMAR is not conceived for a specific museum. Instead the design focuses on flexibility and on the possibility to deploy and play the game at any location (museums but also workshops, small galleries, and local exhibitions).

The setting up phase allows denoting any physical object the educators want the students to create questions for. The starting information is also provided by the teacher and it does not require any involvement of the museum, though it does not exclude it. Finally, associating information to the physical object with small markers and accessing it through augmented reality requires minimal impact on the physical area of the museum.

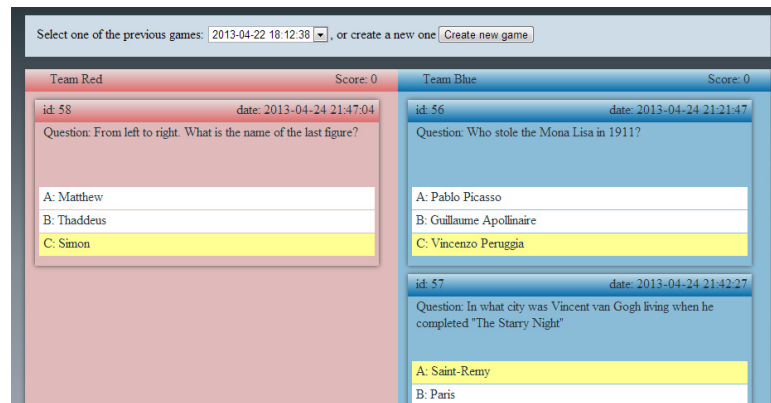


Figure 5. Game monitoring

Phase 3: Reflection after the game

In the current prototype this phase is not explicitly supported, for example through a specific web interface. However at the end of the game the educator can still see the questions created and the results of the teams. The educator can thus use them to (i)

discuss with the students about the game session; (ii) use them to identify e.g., knowledge gaps, interesting points for further discussion, and so on.

6. Testing MagMAR in a museum: initial results and future works

An initial experimentation of MagMar was conducted with 9 students (average age 18) from a high school class and their young, but experienced teacher. The experimentation was held in a contemporary art museum in Milan, Italy. We asked the students and the teacher to use MagMAR for a part of the museum visit, while using a classical guided visit for the rest of the time. Before the visit the teacher inserted in the system information on 11 artistic artefacts she planned to focus on during the visit. Due to time constraints and some technical problems with the prototype, students were asked to create questions only for the first two items, and the global visiting experience involved only 5 artistic artefacts. For the first item, the students created the questions while sitting on the floor in a room nearby the one where the painting of interest was located. For the second item, the students created and answered their questions while standing in the room where the painting was located, together with other works from the same period. While playing the game, the students were given not only a mobile phone with the MagMAR game, but also a museum guide, an Ipad with Internet connection, and they could use the content already displayed in the museum or ask the teacher in order to create and answer the questions.

Hereafter we briefly describe our findings summarizing the results from the observation held during the experimentation and the results of a survey we conducted after the visit. The survey was constructed around a set of quantitative questions - asking to rate from 1 to 5 some affirmations (1= strongly disagree; 5=strongly agree) - and other more qualitative questions to let the students and the teacher free to express more complex statements.

The evaluation of the game was very positive. Not only the students declared they had fun (4.2 average rate) but we observed they were strongly engaged during the game, discussing about the best strategy to use in creating the questions in order to win. Sociability was also important during the game. Students reported that collaborating with the others helped them to learn more about the museum items (average 4.1), even if collaborating was more fun (4.9) than helpful (3.8). Challenging the others was considered the factor that made the game experience more compelling (4.8). The game also worked as stimulus for information retrieval as the students used all the instruments at their disposal to create complicated questions. It is interesting to note that while for the first item they remained seated and only consulted the provided book and the Internet, for the second item they walked around trying to find content for possible answers also in the information exposed in the exhibit (in the specific case, the name of painters contemporary to the one of the focal painting). Though this is clearly not sufficient to draw any general conclusion, it was still interesting to see how the game could actually motivate an exploration of the museum and how a relatively small change of the playing conditions might have impacted on the type of questions that were formulated. Creating and answering questions was considered to help in learning something more about the museum items (3.9 and 4.2 respectively). In addition when asked what they remembered from the museum visit, the students answered with the content of the questions they created. From the observations we can add that one of the groups used the teacher as shortcut to answer the questions. As students were proud of

the questions they created (4.4) this could be an indicator that creating the questions was funnier than answering them. However this is a topic that needs to be investigated further.

On the overall, being involved in first person in the creation of the questions made the experience more interesting. For example, one of the students wrote that *“During the game I was much more interested in the paintings as I was directly involved in the researches about the paintings.”* Another one added that *“During the game, being involved in first person in the painting explanation,... I enjoyed it very much and I learned things that I still have in mind”*.

Another interesting point is linked to the museum exploration. From the teacher and observers point of view the game distracted the students from the interaction with the museum as their focus was directed towards the game and not the surroundings (the paintings). The situation seemed to reverse while doing the guided tour with the teacher. However students stated that the game encouraged them to explore the museum in a new way (4.6) while some of them (3) reported that they got somehow distracted after the game session. However, though the game on the overall was not perceived as a distraction, the use of augmented reality was more problematic. The current game is not able to exploit the full potential of augmented reality, it distracted the students and as a matter of fact none of them read the content previously inserted by the teacher.

In addition both the teacher and the students stated that a previous explanation of the paintings could have improved the experience.

Finally, a separate discussion should be done about the monitoring phase. The teacher gave the maximum rate (5) to the possibility to monitor the students while playing the game. This leads to think about the importance of this monitoring phase which should be further investigated. Given the positive results from the initial evaluation and because of the flexibility of the application (i.e., its possibility to be applied in different settings), during the next school year we will involve other classes in a more extensive trial.

Acknowledgements

The work is co-funded by NFR-VERDIKT 176841/SIO FABULA (<http://teseolab.org>). The authors want to thank the teachers and the students of the “Scuola della Comunità Ebraica di Milano” and the “Museo del ‘900” in Milan, Italy for their availability and kindness.

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Appendix F

Interview

This chapter contains the transcript of the semi-structured interview, that was conducted with the teacher that participated in the experiment in Milan.

F.1 Interview transcript

Interviewer: Thesis Author

Interviewee: The teacher

Interview setting: Interview conducted from the comfort personal homes or offices via Skype audio conference. The interview was conducted at 10 AM Monday.

Affiliation with the interviewee: a high school teacher that was available for the experimentation, suggested to be contacted by the co-supervisor of the project.

Start of the interview

Interviewer: How often do you visit museums with your class?

Interviewee: Often. I like to teach in the museum in front of the pictures. It is important for the students to see the actual work of art that we study in the classroom. The particular class involved in the experiment visited the museum 4 times during this school year.

Interviewer: What kind of museums do you usually visit?

Interviewee: It varies a lot and depends on the year the class is in. The museum is chosen depending on the curriculum.

Interviewer: Do students get to choose the museum they are going to visit?

Interviewee: No, I choose for them.

Interviewer: Would you say the trips are more recreational or educational?

Interviewee: Educational.

Interviewer: Do you think the students enjoyed playing the game?

Interviewee: Yes, they enjoyed it very much. Mainly they enjoyed the part of creating the questions, because they tried to create difficult questions for the team and had fun in searching for interesting information to on the Internet to do that. The students worked together and had a lot of fun, but I think the game distracted them from the actual works

of art. I would like for the students to focus more on the surroundings of the museum and not be so involved in the game.

Interviewer: Do you think that the game distracted the students from the actual museum visit?

Interviewee: Yes. Normally these students are very focused on the works of art and listen to my explanations about the particular painting. But during the experiment, students were more focused on the game, barely looking at the paintings.

Interviewer: Was it difficult to set up the game, like to set up the markers and get the permission of the museum to do this experimentation?

Interviewee: No, the museum was very cooperative. I personally know some of the people working there and it was easy to arrange. The only problem was with the prototype itself, as the game did not allow the student to create long questions. This created a lot of confusion from the students and we lost a lot of time in the beginning of the experiment. After we switched to creating shorter questions, we were able to play the game for some time.

Interviewer: Do you think that this game is something you could use during your trips to the museum on a regular basis?

Interviewee: I would be interested to test this game in a different kind of museum. I think this kind of game is very good for a technological or archaeological museum, because in these kind of museums the students can find very interesting information about the items. For example if one of the teams were to create question of what was the use of the selected artifact, both teams would learn it. Next year I would like to try it in the archaeological and science museums of Milan.

It is important to note that this class of students (that participated in the experiment) had a lot of interest in museums and art. Maybe with another type of class that has little or no interest in museums, the game would introduce them to the museum. The game might help them see the museum as not a boring place to be, but more fun place where you can play games and learn something while doing so.

I think that the class that participated in the experiment, might not have been ideal group of people to test on, because they like the museums and have a good cultural and family background. I think this test should be performed with another type of young people, who are not interested in art and museums.

Interviewer: Do you think that the game has more value for younger students?

Interviewee: Not necessarily younger, but maybe with students from different kind of schools. For example in schools that don't teach art history. So they can go to the museum, look at some paintings, play the game and have some fun. To show them that you can have fun at the museum.

Interviewer: Do you think that this game has the potential to provide a level of academical gain the players? Would they gain some knowledge?

Interviewee: Maybe, but during the experiment, the students were searching for information that is not that connected to the history of the work of art or the curriculum. It might be better to use the game after the guided tour, but not in the beginning. This way student will have so more background information about the paintings and might focus more.

Interviewer: Would you like some more control over the questions that the students create? Maybe as a rating system for each question?

Interviewee: The time in the museum is limited and making the game complicated might be worse. And during the game sessions I would not want to distract the students or be involved in the game as something more than observer.

Interviewer: Do you have some improvement suggestions to the graphical user interface of the application?

Interviewee: The biggest problem was the question length limitations. I think that the questions should not be limited.

Interviewer: Do you have some improvement suggestions to the graphical user interface of the application?

Interviewee: When creating the museum items, I would like to be able to input longer descriptions, as I think that the limited short description is not enough to be able to find some good information for creating difficult questions. It was annoying that after creating long descriptions I had to trim them down as I think longer descriptions allow will force the students to search for information that is not given.

Interviewer: Do you have some improvement suggestions on the flow of the game?

Interviewee: No, I think it was OK.

Interviewer: Do you have any comments about the interview or maybe can add something more on the topic?

Interviewee: No.

Interviewer: Thank very much for the interview and your participation in the experiment.

Interviewee: You are welcome, it's a pleasure to work with the Norwegian university. Good luck with your thesis.