Small Group Interaction Methods on Location-Aware Mobile Audio Guides

by
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Martin Wermers

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Abstract

The use of audio guides in tourism is a widespread and popular way to convey additional information about exhibits in a museum. However, most audio guides in a museum isolate visitors from each other as they are not considering the social needs of a group. In this diploma thesis we describe our research on new interaction methods for small groups using audio guides in a museum. Inspired by the general goal to reduce individual isolation in the use of audio guides, we utilized the concept of interactive museum games to allow shared listening of audio content for small groups, being previously only available for groups of two.

Our first game design featured a quiz with multiple-choice questions which directed users through a museum. An analysis of this concept using an early paper prototype revealed that the associated limitations in players' individual freedom of movement were too severe.

Thus, we redesigned the game concept which resulted in the development of GroupAIXplorer, a quest game in the City Hall of Aachen. It supplies numerous opportunities for social interaction and collaboration. Most notable features are the preservation of visitors' freedom of movement, enriched with interactive and collaborative group activities which can only be achieved as a whole group. One type of these activities are discussion quests which encourage visitors to talk about questions without being limited in their answers by the system. As groups have to make decisions every now and then, the concept of a group leader was introduced.

We observed that communication among the users was encouraged and collaboration indisputable took place, due to the requirements of the quests. Visitors had a stronger group experience than with traditional audio guides. Our concept of a group leader needs further revision because many players considered the leader to be too powerful. Nevertheless, the presented quest game was highly appreciated among our users.

Überblick

Der Einsatz von Audioguides ist in der Tourismusbranche eine beliebte und weit verbreitete Möglichkeit zusätzliche Informationen über Ausstellungsstücke eines Museums den Besuchern zu vermitteln. Die meisten Audioguides isolieren allerdings Museumsbesucher voneinander, da sie nicht die sozialen Bedürfnisse einer Gruppe berücksichtigen. In dieser Diplomarbeit beschreiben wir unsere Forschung über neue Interaktionsmethoden für Kleingruppen, die Audioguides in einem Museum benutzen. Inspiriert von dem allgemeinen Ziel die individuelle Isolation bei der Benutzung von Audioguides zu reduzieren, machen wir uns das Konzept von interaktiven Museumsspielen zu Nutze, um gemeinsames Zuhören von Audioinhalten für Kleingruppen zu ermöglichen, was bislang nur für Gruppen von zwei Personen möglich war.

Unser erster Spielentwurf zeichnete sich durch ein Quiz mit Multiple-Choice-Fragen aus, welche die Benutzer durch das Museum führten. Eine Analyse dieses Konzepts anhand eines ersten Papierprototypen offenbarte, dass die damit einhergehenden Einschränkungen der individuellen Bewegungsfreiheit der Spieler zu massiv waren.

Wir entwarfen daher ein neues Spielkonzept, was zu der Entwicklung von GroupAIXplorer führte, einem Questspiel im Rathaus der Stadt Aachen. Dieses bietet zahlreiche Gelegenheiten für soziale Interaktion und Kollaboration. Die beachtenswertesten Eigenschaften sind die Wahrung der Bewegungsfreiheit der Besucher, angereichert durch interaktive und kollaborative Gruppenaktivitäten, welche sich nur als gesamte Gruppe vollenden lassen. Ein Typus dieser Aktivitäten sind Diskussionsquesten, die die Besucher dazu ermutigen offen gestellte Fragen miteinander zu diskutieren ohne dabei in ihren Antworten vom System eingeschränkt zu werden. Da Gruppen von Zeit zu Zeit Entscheidungen treffen müssen wurde das Konzept eines Gruppenführers vorgestellt.

Wir beobachteten dass Unterhaltungen der Benutzer untereinander angespornt wurden und dass Kollaboration zweifellos stattfand durch die Anforderungen der Questen. Besucher hatten ein stärkeres Gruppenerlebnis als mit gewöhnlichen Audioguides. Unser Konzept des Gruppenführers benötigt eine weitere Überarbeitung, da viele Spieler den Gruppenführer als zu mächtig empfunden haben. Dessen ungeachtet fand das präsentierte Questspiel hohen Anklang unter unseren Benutzern.

Acknowledgements

Several people have influenced me in this work. Others have helped me in numerous ways. I hereby would like to thank and remember all of them. I show gratitude to the members of the Media Computing Group who participated in an initial brainstorming and shared their ideas and knowledge on the scope of location-aware guide systems. Stephan Deininghaus, Torsten Palm, Ronny Seidel, and Jan-Peter Krämer gave invaluable feedback at an early stage of this project which was very insightful. I am also deeply grateful to my supervisor Gero Herkenrath for all his feedback, his thoughts on social interaction, and for always being willed to lend an ear. I furthermore would like to thank him and Prof. Dr. Jan Borchers for their encouragement to publish a case study on my project. I am looking forward to a new experience in life at CHI 2011.

I was blessed to find so many volunteers as participants in my user studies. I am thankful for their attendance and giving both positive and constructive feedback to evaluate my work. Special thanks go to Georg Helg for giving me the most comprehensive guided tour through Aachen City Hall I can conceive of. I would like to give thanks to the friendly museum staff of Aachen City Hall for their open-mindedness on my work and a great time in the museum.

I am very grateful to all my friends who helped me countless times by proofreading draft versions of this work and pointing out sections that require further improvement. I am deeply indebted to Torsten Palm, who gave me so much help in terms of language and in finding more suitable phrasing. In this regard I moreover show great appreciation to Stephan Deininghaus, Andreas Wortmann, Carsten Gester, Volker Schönefeld, Jan-Peter Krämer, and Seran Uysal.

Last but not least, I thank my parents and my sister Nicola for supporting me in life and in my course of studies over all these years.

Conventions

Throughout this thesis we use the following conventions.

Text conventions

Definitions of technical terms or short excursus are set off in coloured boxes.

> **EXCURSUS:**
> Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition:
Excursus

Source code and implementation symbols are written in typewriter-style text.

`GAIXQuestController`

The whole thesis is written in American English.

Download links are set off in colored boxes. For the case the online resources are not accessible, a CD-ROM enclosed with the print version of this thesis contains the linked files as well.

> File: Documentation of the brainstorming process[a]
> _____
> [a]http://hci.rwth-aachen.de/~wermers/thesis/downloads/Brainstorming-documentation.zip

Chapter 1

Introduction

Audio guides are a convenient way to provide tourists with rich information about visited sites, such as historical buildings of a city or exhibits in a museum. In recent years, more and more cultural institutions have started to offer audio tours, as they have many advantages over traditional media. Audio guides excel text panels and brochures in opening up another sensory channel which allows visitors to listen to explanations of exhibits on sight. Audio guides also liberate from reading dry texts and can create an immersive atmosphere by utilizing music, audio theater, and sound effects [Martin, 2000].

Furthermore, audio guides adopt many advantages of human guides while being more flexible, as users may decide on their own how much time they want to spend in the museum in total and on specific topics in particular. Depending on the implementation, audio guides may either direct visitors through the museum on a linear path just like a real guide would do, or otherwise serve as a random access playback device for spoken commentaries on exhibits of interest which provides visitors with an unrestricted freedom of movement. Moreover, audio guides are a good opportunity to provide spoken material in multiple languages [Martin, 2000] which all are available at any time. Due to the increasing processing power of mobile devices, nowadays it is possible to enrich the spoken commentaries with images and video.

For these reasons, audio guides have become a widespread and popular resource in tourism.

problems of audio guides

Today's audio guides, however, offer no possibility for groups to listen to content together synchronously. Additionally, most systems tend to isolate visitors from each other due to the use of headphones. This makes it hard for group members to communicate with each other, and thus social interaction among users may be inhibited, as stated also by [Martin, 2000]. This is a severe limitation because being at a museum usually is a highly social event. Only a small fraction of visitors are coming alone. [Petrelli et al., 1999], for example, found that only 5% of visitors of natural science museums in Italy were without escort.

AIXplorer

In 2009, the Media Computing Group of RWTH Aachen University developed the AIXplorer[1] , a mobile audio and multimedia tour guide for the city of Aachen (see Figure 1.1). In its current state, it serves day-to-day as an audio guide for the Aachen City Hall[2] and its vicinity, but it is planned to extend the system over the next years in order to help tourists explore the city and its rich cultural and historical heritage while offering location aware information. The audio guide features automatic room detection through wifi tracking combined with a very simple and intuitive interface. However, the system lacks features for groups as well, resulting in separated use in a group with low communication and interaction among members during the experience.

goals

The goal of this diploma thesis is to address the aforementioned limitations by developing a system that mediates audio content for multiple users synchronously. Furthermore, the system should encourage visitors to think deeply about the presented exhibits, while inviting them to discuss individual thoughts with other group members. Therefore, an interactive and collaborative audio-visual museum game for young adults was designed, to offer a rich group experience for groups of up to approximately five persons. As museum games may influence the behavior of visitors, one challenge was to preserve as much individual freedom

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[1] http://hci.rwth-aachen.de/aixplorer
[2] http://www.aachen.de/EN/ts/140_museums/140_70.html

Figure 1.1: AIXplorer audio guide in front of Aachen's City Hall.

of movement as possible while using the guide. Moreover, the concept for the planned group tasks in the game intends to foster social interaction and face-to-face communication.

The design of the game evolved into two iteration cycles consisting of a paper prototype for high level design decisions and a software prototype to evaluate the concept in a real museum setting. Regarding the latter, the software prototype builds up on the existing infrastructure of the AIXplorer. Thus, the developed software system was termed "GroupAIXplorer". In the following, this term will refer to the implementation of the second design iteration.

iterative design

1.1 Overview of the following chapters

2—"Related Work" presents various audio guide and game-like systems for small groups in a museum. We describe which common problems were addressed in which way by each project. As these systems influenced us in the design of our system and gave cause for thought, we explain why specific ideas were adopted, while others were deliberately solved in a different way.

3—"First Iteration" explains how our first ideas from an initial brainstorming session led to the design of a quiz game. The game idea was implemented via a paper prototype that was evaluated in a small-scale user test.

Based on the findings gained during the first iteration, we modified the initial idea of a quiz game to a quest game. The evolution of our second prototype and the design of the game is depicted in 4—"Design of the Second Iteration".

5—"GroupAIXplorer Implementation" describes how the quest game design was realized in software. The chapter begins with a technical explanation of the AIXplorer audio guide, as parts of that system were adopted for this work. Later sections present the GroupAIXplorer user interface in detail and discuss associated design decisions. In conclusion, we end up giving an overview of the software architecture.

6—"Evaluation" explains how the GroupAIXplorer prototype was tested in a real world situation in the Aachen City Hall. Observations from a user test as well as results drawn from observation, voice recordings, and questionnaire data are presented and interpreted.

Last but not least, 7—"Summary and Future Work" highlights the most significant results found in this work. This chapter presents also ideas for further research and lists remaining problems which should be addressed in the future.

Chapter 2

Related Work

In this chapter we focus on the existing related work leading to the development of this thesis. At first we present two studies that deal with the problems of audio guides when used in groups are presented at first. Afterwards we discuss publications in which interactive museum guides were developed that feature some kind of collaborative game. We finally compare these studies with our own ideas and discuss the particular assets and drawbacks of each system. Table 2.1—"Projects Comparison Table" provides an overview of the individual key features.

2.1 Systems for synchronized audio playback

2.1.1 Audio guide prototype by Bederson

In the mid-nineties Bederson was one of the first HCI (Human Computer Interaction) researchers who recognized that audio tours may isolate users and thus inhibit social interaction. The tour guides at that time allowed only linear playback due to the use of audio cassettes. Therefore it was hard for multiple users to stay in sync with each other, and spontaneous conversation during the tour was nearly impossible. The prototype he presented in [Beder-

son, 1995] introduced random-access digital audio and lo-
cation awareness through infrared rays. Infrared transmit-
ters were installed near exhibits and hence allowed auto-
mated audio playback when a user got close to an object
of interest. Companions could listen to audio contents syn-
chronously simply by approaching the exhibit at the same
time. Admittedly, the system did not pro-actively support
a group experience, but its technological innovations made
social interaction in small groups more likely to occur.

2.1.2   Sotto Voce

Aoki et al. [2002] present an audio guide system named
Sotto Voce which allows shared listening for pairs of visi-
tors in order to foster social interaction. The authors in-
troduce the *eavesdropping method* which enables each user
to automatically hear the content the companion is cur-
rently listening to whenever the user has not selected any
content himself. User tests of the system showed that in
this way mutual awareness of the companions' activity is
raised which led to an increase in communication and in-
teraction. Other findings implied that headsets with only
a single over-ear earphone reduce isolation and thus foster
ad hoc communication.

However, we believe the eavesdropping method is only ap-
plicable for groups of two. From a technological point of
view it would be easy to extend this method for more peo-
ple, but in that case the system would become rather com-
plicated in terms of usage. Considering that a single person
can focus only on one audio clip at a time, users would be
required to make a single selection or set priorities for cases
where multiple companions are available to eavesdrop on.

2.2   Interactive Museum Games

2.2.1   Mystery at the Museum

[Klopfer et al., 2005] developed a location-aware handheld

system to offer a learning experience for families in the Boston Museum of Science[1] . The design goals were to encourage collaboration between visitors to engage visitors more deeply in museum exhibits, and to show visitors relations between different exhibits. The latter aimed at visitors already familiar with the museum, in order to encourage them to explore parts they had not visited before. To achieve these goals the authors created *Mystery at the Museum*, a collaborative educational game. It mixes real objects from the museum with virtual characters and virtual items, and incorporates all these into an exciting detective story. Three pairs, each consisting of a child and an adult, take the role of either a technologist, a biologist or a detective in order to find the criminals that stole a priceless object from the museum. The game design adopts typical characteristics of classical adventure games, such as talking to virtual characters, gathering virtual items, and solving puzzles. The virtual characters and items are distributed throughout the rooms of the museum and become available for interaction when the visitor gets close to them. The items have a direct relation to real objects from the science museum wherever possible, e.g., a virtual electron microscope for item analysis is only accessible in a room of the museum which shows corresponding equipment. Children explore the museum and learn about the exhibits by this means. The character roles are intended to effect collaboration, as some items can only be picked up or analyzed by a specific character. Furthermore, the virtual characters act differently depending on the character talking to them. Thus, collaboration is enforced, as players are required to exchange items and give each other hints on what to do in order to solve the mystery.

The analysis of video recordings and survey data from a broad user test suggested that the game was engaging and encouraged players to think about the museum's exhibits. Due to the character roles with different skills, the participants felt that their individual actions made important contributions for the success of the whole group. The necessity of exchanging virtual items and sharing hints from virtual characters showed to promote more general collaborative problem solving. All in all, it appears that the design goals were met. However, the authors state themselves that it is

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[1]http://www.mos.org/

open to question in what way the concept is transferable to other museums, as technological exhibits play a major role in the course of the game. It is hard to imagine a similar game in a museum of art.

2.2.2   Kurio

Kurio [Wakkary et al., 2009] is an interactive museum guide specifically designed for families that follows a game-learning approach in order to motivate and structure the visits. This idea is close to the goals of *Mystery at the Museum* as presented in subsection 2.2.1. Historical information given at the exhibit gets mediated by completing missions and challenges which direct the group to different rooms of the building. The game's implementation is termed a *hybrid system* as it makes use of several different devices. For one thing a personal digital assistant (PDA) allows a dedicated user to monitor the progress of teammates, for another thing a tabletop provides the group with an overview of the game state. Furthermore, players use three tangible user interface (TUI) devices to explore the exhibits from the museum and to collect information needed to solve the associated missions. Each of the three tangibles resembles a tool from the real world, e.g., *the pointer* looks like a flashlight and is used to select museum artifacts by pointing on them. A device formed like a magnifying glass has the purpose to collect textual information, whereas a tangible which reminds of a telephone receiver is used to listen to audio files.

The qualitative feedback from a user study was very positive in general. Children especially liked the physical character of the game, due to the tangible devices. Those led to a more active experience based on the possibility to act rather than just takin note of the mediated contents.

2.2.3   Minpaku Navi

[Hope et al., 2009] examined how relations among family members affect the use of *Minpaku Navi*, an interactive

guide developed by the authors. One goal in the development of this system was to provide families with activities in the real world. The system consists of a footprint card and a portable terminal device. Users may use the card to virtually mark visited exhibits for later review, as well as to update their current location in an online portal. The terminal offers a quiz with multiple-choice questions about the shown exhibits. The quiz may be either used as a pure game to collect scores, or as a guide to explore other exhibits.

The most interesting results of the user study for this work are as follows: Based on results from conversational analysis, the authors argued that the quiz can enable collaboration, as parents and children helped each other to answer the questions. Another finding was that through the additional information the quiz was able to teach both adults and children. The authors also stated that their system could enhance conversation between family members.

However, a weakness of the system appears to be the footprint card, since the card did not update the information automatically. The players were hence required to remember performing the updates on their own. For another thing the current location of other family members could not be obtained by using the guide terminal. To make use of this feature, users had to use the desktop computers at the registration kiosk, as those provided the only way to access the associated online portal from within the museum.

2.3   Influences on this work

In the following, we describe how these systems took influence on this work. The system of [Bederson, 1995] is not included here, as his prototype focused on technological innovation. Furthermore, the features introduced by his system are conventional for all audio guides nowadays.

Sotto Voce showed that shared listening in a museum provides much opportunity to increase communication. This feature appeared to be a very promising way to increase

Adopted features

social interaction. However, it would be desirable to offer a similar feature for bigger group sizes. As the use of monaural headphones seemed to be mandatory to prevent isolation, we decided to follow this design recommendation.

Mystery at the Museum, *Kurio*, and *Minpaku Navi* gave evidence that museum games provide an opportunity for social interaction and an increased amount of collaboration. Our idea was thus to create an interactive game that serves as a springboard for synchronous audio playback.

Group size

We appreciated the flexibility of the group sizes in *Kurio*. Although family sizes in the user tests ranged from two to four, this had no limitations for the game. *Mystery at the Museum* on the other hand required a group of three parents and three children to cast all three characters of a game session. To realize groups of this size in the user tests of *Mystery at the Museum*, groups of single parents with their child joined forces with unknown families. Therefore, it is open to question how a typical family, e.g., two adults and two children, could play the game. Of course it is imaginable that a child plays one character without the aid of a parent, but this is not a good solution. During the game characters may split up from time to time to be more effective, and children might get lost without guidance. This especially holds for the Museum of Science in Boston which is a very spacious location.

We wanted to develop a game that is flexible regarding possible group sizes, as we did not want to exclude certain small-sized groups a priori. Both, small groups like couples and bigger groups of six or even eight players, should be allowed to play the game without major limitations. Although we would recommend group sizes of maximal five members, we did not want to enforce a limitation excluding players, as sharing a device with another player is unsuitable in an audio guide system with headphones.

The following table 2.1—"Projects Comparison Table" closes this chapter and provides an overview of the described systems.

	Sotto Voce	Mystery at the Museum	Kurio	Minpaku Navi	This work
Classification	Audio guide with shared listening	Collaborative museum game	Collaborative museum game	Quiz Guide	Museum game with synchronized audio content
Design Goals	Raise mutual awareness of companions activity; reduce isolation	Engage visitors deep in exhibits; show relations between exhibits	Motivate and structure museum visits of families	Provide families with real world activities	Provide opportunity for communication; preserve individual freedom of movement; dynamic group size
Key Features	Eavesdropping mechanism; monaural headphones	Mixes exhibits with virtual items and characters; 3 characters with different capabilities; exciting story	Missions & challenges around exhibits; a hybrid system incl. 3 tangible devices	Multiple-choice questions in quiz game; footprint card	Interactive game as springboard for synchronized audio
Target Audience	All kinds of museum visitors	Families	Families	Families	Small groups of young adults
Group Size	2	6 — consisting of 3 children & 3 adults	2–4	not specified. User test presented a family of four people.	2 – approx. 5

Table 2.1: Projects Comparison Table

Chapter 3

First Iteration

3.1 Brainstorming for research ideas

At the beginning of the project, an informal brainstorming was carried out with seven members of the Media Computing Group. The goal was to collect research ideas of new interaction methods for small groups using mobile audio or tour guides. We did not present our own ideas as we did not want to take influence or shift the focus on particular concepts. In the first quarter-hour each person was asked to sketch their ideas on DIN A6 record cards. Those were presented in turn in the second phase of the brainstorming. The participants discussed which ideas belonged together or were closely related, and thus spatially arranged the cards accordingly on the meeting table. All ideas were recorded without immediate judgement. Photo documentation of the whole process can be found at the following link. See Figure 3.1 for an example.

File: Documentation of the brainstorming process[a]

[a]http://hci.rwth-aachen.de/~wermers/thesis/downloads/Brainstorming-documentation.zip

Figure 3.1: Record cards from Brainstorming session.

3.1.1 Proposed ideas

The following listing summarizes and categorizes the proposed ideas:

- **Collaborative experience:** Allow audio-guide users to listen to the audio content together via synchronized playback. Maybe apply a _Master-Slave principle_, i.e., one group member is chosen as the group master, in order to decide which audio contents the group will listen to. The other group members with slave-devices could be able to save bookmarks of topics they are interested in and request the master to playback these topics later.

- **Collaborative gaming:** One game idea was similar to a scavenger hunt, in that a group has to locate a set of related exhibits in a museum, each coming with some kind of puzzle or task. Members could split up in their search, but be rewarded if they collaboratively solve the tasks. The reward could be some kind of content-unlock or achievement.

  In another idea, players would be asked to rate on a Likert scale how much they had liked a specific exhibit. Their teammates would then attempt to guess

their answers. Furthermore, a quiz game was proposed, in which the group would be asked a multiple-choice question that every player of the group has to answer.

All game ideas could include some kind of more or less elaborate scoring system.

- **Distribution of information:** Try to achieve distributed learning by giving each user only partial information and encourage the group to talk, discuss or explain about that information with each other. For example, tell visitors a story through a multi-screen comic, i.e., each member views another picture of a story. Since only a limited number of people can take a look at one device at the same time, it is anticipated that each group member will describe to others what he is seeing on his device. A similar idea was to distribute the information in a so-called tessellated screen space, meaning that the view of each device depends on the device's position in the real space. The device functions as a movable frame that reveals parts of a virtual screen space. Visitors would only get the bigger picture of an image if they work together by holding their devices close to each other, thus creating a kind of multi-display.

- **Day trip planning helper:** Assist tourists to organize their day in a foreign city. The proposed idea was that every person of a group could tell the system which sights they want to visit. The system could then compute a schedule for the day which is optimal in such way that common interests of group members are recognized and taken into account. Another feature idea was a progress bar that gives live feedback about the remaining number of sights and remaining time with respect to the schedule.

- **Location-awareness:** Many ideas made use of location tracking. For instance, in a mobile city tour guide it could be useful to display a city map that shows how crowded the city's sights are at the moment. Since groups may split up in a city, it would be helpful to display the location of all group members to aid the group in regathering. Regarding families, it could be useful to offer features for supervision of children.

Due to general privacy concerns regarding location-awareness, as well as the feeling that too strict supervision of children is not a good idea, it was suggested to offer children a feature to find their parents via a map instead.

- **Location-based games:** There were also some game ideas that relied on location tracking. A system could ask tourists to guess the size of a sight, e.g., the Katschhof square in Aachen. Afterwards the system could support the group in collaboratively measuring that size. To do so, group members simply need to spread out to the corners of the sight, so that the system would calculate the size by the GPS coordinates of each user. Another game would encourage users to recommend places that afford the opportunity to take great pictures. Descriptions at the corresponding places could contain hints regarding perspective or how to make the photo more interesting.

- **Communication:** Since it might well be that groups split up, different communication methods were proposed, including text chat, as well as audio- and video telephony.

From all these ideas, only a few were taken into account. The reason for this was in most cases that ideas seemed not to fit into our own thoughts and intentions, e.g., the day trip planning helper. The general idea to distribute information among group members to achieve social interactions appeared to be meaningful. The proposed applications of a multi-screen comic or a tessellated screen seemed to be very interesting ideas, but we had no idea how to embed them in a bigger concept. We felt each of them could only be one feature amongst others, but not offer a comprehensive group experience per se. Furthermore, the tessellated screen space would probably need a high precision 3D tracking system, e.g., VICON motion capturing[1], which could be used only in a single room of a museum due to physical setup and the costs of such systems.

On the other hand, there were also several ideas that we could make use of. The ideas on collaboration were re-

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[1]http://www.vicon.com/

ceived with high interest, especially the ideas on collaborative gaming. Our primary goal, however, was to offer a richer group experience via synchronized audio playback. Albeit, we did not want to empower one single member of a group to decide alone on the audio contents, since we believe it restricts the individual freedom of movement of the group members.

3.1.2   Target users and research goals

We wanted to address small groups of juveniles and young adults, but also families with children. Our research goals were to enable and encourage communication, interaction and collaboration in these groups. To achieve these goals we planned to develop an interactive game and use it as an opportunity to offer synchronized audio playback. The game could consist of questions around the exhibits of the museum, as well as collaborative assignments. So in principle the game should consist of certain group tasks. To incorporate synchronous audio playback, group members would listen together to audio clips at the beginning of a task as introduction, as well as at the end of each task, e.g., to learn about interesting stories and anecdotes associated with exhibits that appeared in a task.

3.2   Designing a Quiz game

As a game concept, a quiz game was designed which was inspired by the "Minpaku Navi" system of [Hope et al., 2009]. Other influences were video quiz games like "Buzz[2] " or "You don't know Jack[3] ".

The game should consist of several multiple-choice questions, with each question associated to one specific room of the museum. Questions should belong to different topics, which indicate what users might expect. It was intended

Description of the quiz game idea

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[2]http://www.buzzthegame.com/
[3]http://www.youdontknowjack.com/

to let groups select one out of three or four available topics after each question. The selection would then direct the group to the next room in the museum. Answering a question is considered as one round of the game that contains the following phases:

Procedure of one
quiz round

At the beginning, one player is chosen by the system to be the *active player*, i.e., to be in control to select the topic of the upcoming question. Since topics are bound to specific rooms, a room change may be necessary. In that case, a map tells the group where they find the corresponding room. When the whole group has reached that room, an introductory audio clip provides interesting information on one exhibit of the room related to the question. The audio is played back synchronously on each device. Thereafter, the actual quiz question is read out via audio and displayed on the display of each device. Next up, the multiple-choice answers appear on the screen as selectable buttons.

Players from now on have ten seconds to select one of four multiple-choice answers or abstain from answering. Correct answers are rewarded with a score of five, whereas the same amount of points is deducted for a wrong answer. The score of an abstaining player is not affected. Afterwards, the correct answer is revealed and additional information may be provided through a concluding audio clip, played back synchronously on all devices, too. The system then updates the players' scores, chooses a new active player, and presents again the topic selection screen. Since it is desired that choosing the new active player is considered fair, we propose algorithm 1. The algorithm uses the players score and the frequency players selected topics in past rounds as criteria for choosing the next player that is in control of topic selection.

In the simplest case, the algorithm returns the player with the lowest score. If there are multiple players with the same lowermost score, the player who selected less topics in the past is the next active player. If there are multiple players that have the same lowest score and the same lowest number of topic selections done, then one of these players is selected by random.

Algorithm 1 Algorithm to determine the next player that may select the next questions topic.

1: Let P be the set of players.
2: $S = \varnothing$
3: **for all** $x \in P$ **do**
4:    **if** $score(x) = minScore(P)$ **then**
5:       $S = S \cup \{x\}$
6:    **end if**
7: **end for**
8: **if** $|S| = 1$, with $S = \{y\}$ **then**
9:    **return** y
10: **end if**
11: $T = \varnothing$
12: **for all** $x \in S$ **do**
13:    **if** $selectionCounter(x) = minSelections(S)$ **then**
14:       $T = T \cup \{x\}$
15:    **end if**
16: **end for**
17: **if** $|T| = 1$, with $T = \{y\}$ **then**
18:    **return** y
19: **else**
20:    **return** $randomElement(T)$
21: **end if**

The following listing gives a summary of the quiz game design:

- Each question belongs to one topic and each topic is associated with exactly one room in the museum

- The topic is chosen by the so called *active player*, who is determined by the system in a fair way

- Questions begin with an introductory audio clip to provide information on one exhibit

- Players have to answer questions in a time limit of 10 seconds

- Wrong answers deduce as many points as a right answer would add

Basically, the design concept adopts the concept of "You don't know Jack" to bring it to the space of a museum.

Other designs in regard to time limit and scoring system might have be more suitable. However, at such an early state of the project we did not want to spend too much time on such details. The main interest was to find out if users would accept to be directed through a museum by the different questions. In order to receive feedback on the idea itself as soon as possible, a paper prototype of a quiz came was created.

3.3   Quiz game paper prototype

3.3.1   Paper prototyping techniques

Paper prototyping is a quick and cheap technique to create and evaluate first interface designs. A paper prototype consists of several rough, hand-drawn, pen and paper sketches, typically one sketch per interface screen.

There are various sorts of paper prototypes. In a storyboard-like prototype, several sketches of UI (User Interface) screens are laid out on one page. Labels and arrows visualize which actions in the UI lead to which screen. There's often only one interaction scenario shown at a time, to explain how to accomplish a specific task.

By contrast, a prototype in flip-book style depicts each interface snapshot on its own page. Since it's left unclear to test users which action leads to which screen, an instructor has to drive the flip-book whenever the user uses an interface element.

A third style is a post-it paper prototype, in which the instructor dynamically re-adjusts the UI by changing post-it labels that illustrate windows, dialogs and menus. The instructor may even draw new post-it notes on demand. For more information on Paper Prototyping refer to [Snyder, 2003].

3.3.2   Creation of the paper prototype

To evaluate if applying this game concept encourages group interaction and communication, a paper prototype of the quiz game was created for three players. Three spiral notebooks were used for the flip-book style. This prototyping technique was chosen because it allows test users to turn the pages by themselves. After each action they only needed to know the page number of the next screen. Thus it is easier for the instructor to tell all three users how to reach the next interface screen, according to the users action.

Besides verifying whether the concept was suitable at all, we wanted to figure out if the design decisions described in section 3.2, i.e., the time limit and scoring system are appropriate. It was also of interest if players would consider the algorithm for active player selection being fair. Before we had results on these issues, we did not want to spend time with the design of content, i.e., real questions suitable for a museum and appropriate audio clips before and after the questions. Thus, audio clips were only imagined to be played back, and the actual five quiz questions of the paper prototype were taken in written form from a german Trivial Pursuit[4] quiz game.

In a first step, generic versions of the interface screens were hand-drawn on record cards. Those included placeholders for player-dependent and dynamically changing elements, like player number, round number, and score. The generic interface cards were duplicated for each of the three players and then manually completed where different for each player. Almost 50 screens per player were cut out and glued on the pages of the spiral pads. About half of the screens deal with the interface for answering a question, because each of the four answers as well as the option to abstain became an own page. This was to ensure that users would get the right visual feedback and show the particular points they won or lost with that answer. Other screens included the scoring overview, a map of the alignment of the different rooms, as well as the screens for topic selection. Although the prototype may appear to be very elaborate, e.g., to present the right visual feedback, the interface

Crafting the paper prototype

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[4]http://www.trivialpursuit.com/
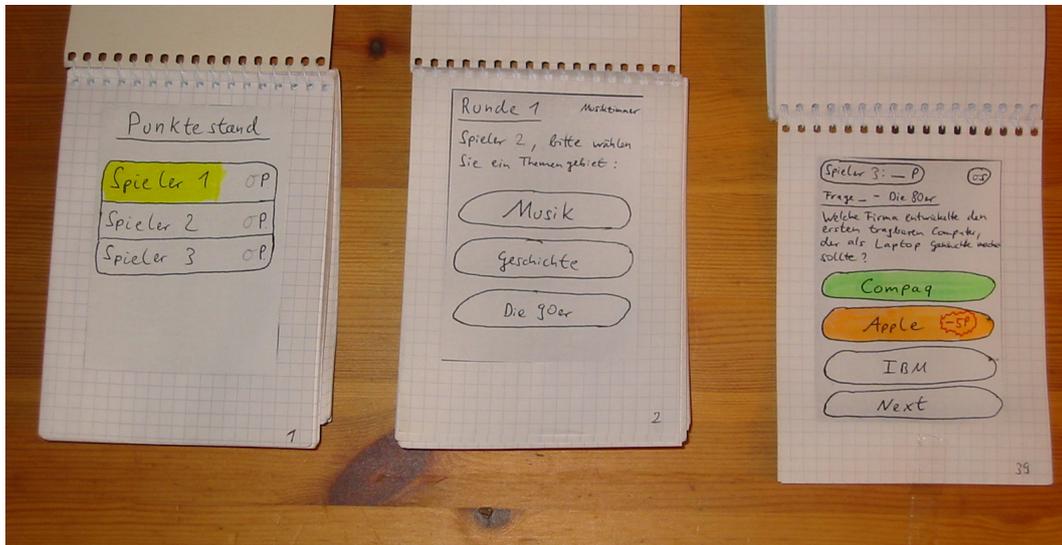
Figure 3.2: The three flip-book paper prototypes. The screens from left to right show a score overview, a topic selection screen and the visual feedback for one multiple-choice question.

itself was still kept very simple to allow high level design decisions. Figure 3.2 shows a photo of the crafted paper prototypes, presenting three different screens.

3.3.3   Evaluation of the prototype

The paper prototype was evaluated in two user test sessions at the Media Computing Group. Each test was conducted with a group of three male CS students, aged in the mid-twenties. To simulate the rooms of a museum with its different topics, adhesive tape was pasted on the floor of the test room in such way that a room-sized map appeared on the ground (Figure 3.3). The setting featured five rooms which were labeled each with a different topic name, e.g., 'The 90s', matching the topics of the different questions.

A test session started with a short introduction about the intention of the quiz game, including an explanation of the imagined museum setting through the use of the virtual rooms marked on the ground. Also, the game rules and the scoring system were clarified. Each player was given a

spiral pad paper prototype and a pencil with an eraser. The intention of the pencil was to let users update the scoring screen by themselves, but during the procedure it turned out to be easier to just tell the users the current player scores verbally.

Figure 3.3: Simulation of different rooms on the floor for the execution of the paper prototype user test.

Each group started the quiz game in the music room, which was told to be the first room of the imagined museum. The instructor randomly selected one player to be the first active player and directed the players to flip to the according pages of the prototype, showing the topic selection screen. There existed two versions of the topic selection screens, an active version for the current active player and an inactive version with grayed-out buttons for the other two players. The starting player then had the choice to select one of three topics. After a topic was selected, players were directed to the map screen to show them how to reach the corresponding room.

As soon as the whole group reached the appropriate box on the ground, the multiple-choice question was read out by the instructor. After completion, the users were told to turn to the next page to view the possible answers and decide on their selection. Meanwhile, the instructor counted

down the ten seconds time limit aloud. The players were requested to select an answer by laying down their finger on the appropriate button. The instructor then noted all answers and told each player the page for the visual feedback of his selection. He also kept track of the player's score. Next up, players were asked to flip to the score overview screen, where the instructor announced the updated scores. Finally, the instructor decided the new active player by simulating the algorithm described in section 3.2. The next round started then with the topic selection screen of the last room. As the prototype included only one question per room, players were asked to select only unvisited rooms. A real quiz game, however, could include several questions per room.

The whole quiz session including the short introduction lasted about 15-20 minutes. In the following, all test users were asked to fill out a questionnaire which featured various questions on the selection of the active player, time limit and the scoring system. Players needed about ten minutes to process the questionnaire. In conclusion an informal discussion of about 30 minutes took place, which gave insightful feedback in regards to eligibility of the game in a real museum setting.

3.3.4   Results

Criticism

The most important results originated from the group discussion of the concept at the end of each test session. The players liked the general idea to utilize a game to provide shared listening of audio contents in a museum. However, they did not believe the quiz game could offer an exciting group experience in a museum. The main criticism was that the social component of the quiz game was considered being too low. Players would merely listen together to audio, but the ensuing multiple-choice question would prevent communication, as players have to compete against each other and thus will not share their knowledge. Regarding social interaction, we anticipated that players would try to influence the active player in his topic selection. The user test showed that this was not the case. A few players also stated they did not like the quiz game as it made them feel

being tested for their knowledge. Visiting a museum on
the contrary should be entertaining. By observing the par-
ticipants in the user test we also realized how much the
quiz game constraints visitors in their individual freedom
of movement. We consider this as another undesired effect
of the game which should be avoided in the next iteration.

The results from the questionnaires were rather neutral.   Questionnaire results
The most significant ones are presented in what follows.
The algorithm for selecting the next active player (cf. page
19) was neither very well liked nor disliked, it received a
3.5 average on a 5 point Likert scale (0.84 STD). This may
be due to the fact that the test lasted for only five questions.
Thus, the method to select the next active player appeared
to choose one of the players with the lowermost score. The
test users, however, preferred either a fair consistent se-
quence or a completely random selection when asked to
state their priorities concerning different methods. The lat-
ter was unexpected and seems to contradict the former, but
may be explained by the participants affiliation with com-
puter science. The time limit was largely accepted. Only
one user considered it being too short. Four of six players
stated that deducing points is fair, whereas the remaining
two did not agree in this issue.

Fortunately, the participants provided many interesting   Ideas for a social
ideas for a more social game design. One user compared   game design
our goals with those of a science rally for children in a mu-
seum. He had recently visited the German Museum in Mu-
nich[5] where a school class was playing such a rally. Accord-
ing to his narration, each child had a sheet with instructions
to observe phenomenon's. The sheet further required every
child to find answers on related questions. Although chil-
dren were required to formulate answers on their own, they
teamed up to help each other and to discuss possible an-
swers. The most interesting part of this story was, however,
that the childrens' sheets were not evaluated or graded
with a score. At the end, children would just present their
answers to the whole class and the teacher would help in
case children did not find the correct solution. All in all
it was more important that children were encouraged to
think on their own but also to exchange their ideas with

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[5]http://www.deutsches–museum.de

other children, and not how good or precise they answered the questions. As answers were not graded, the children had no pressure to score best and no fear to perform poorly compared to classmates. As a conclusion from this story, the participant of the user test recommended to focus more on ways that allow visitors to come up with own ideas and share those with their companions.

Another player stated that the time limit is nonessential. He draw a comparison to one popular way to play the Trivial Pursuit game. In this variant questions are not directed to single players but instead to the whole group which sometimes results in a discussion on the precise answer of a question. Last but not least, one participant suggested to ask questions before providing the corresponding information so that players know for what kind of information they have to pay attention on. In his opinion this would allow people to better comprehend and memorize the given information.

Conclusion
Our conclusion from the user test was to come up with a new game design which avoids the encountered drawbacks and considers the given ideas to enhance the social component of the game. The results from the questionnaires, however, did not influence the further development as they focused on details of the quiz game design which were abolished due to the ideas just presented. Furthermore, as hypothesized in the related work section, we planned to enrich the game by synchronized audio contents to highlight the collaborative aspect.

Chapter 4

Design of the Second Iteration

As a consequence from the paper prototype evaluation, a more suitable game design needed to be developed. Based on the results from the user test, two important design aspects emerged:

The game should be designed in such a way that users do not feel being tested hard for their knowledge or feel tested how mindful they have been in the museum. Hence, the further use of multiple-choice questions appeared inappropriate.

Secondly, players should no longer compete against each other for the highest scores, because competition will ultimately hinder collaboration. If in-group-competition is still desired, the game should offer some kind of team mode at least. An alternative would be to reward points only to the whole group and therefore shift the competition between other museum groups, e.g., via an online system with categories like best group of a day, week or month.

4.1   Designing a Quest game

These aspects led to the idea of *quests*:

<div style="border:2px solid #c89b3c; background:#f5c04e; padding:1em;">

QUEST:
A quest is a group task that consists of the following phases:

1. *Introductory audio clip*

2. Object searching

3. *Task explanation audio clip*

4. Quest dependent group activity

5. *Solution audio clip*

The audio clips of phases 3 and 5 start synchronized on each device.

</div>

Definition:
Quest

Freedom of movement

The first change compared to the ideas from 3.2—"Designing a Quiz game" is that quests do not direct users to the associated exhibits, as it was in the quiz game after selecting a specific topic. Instead, the *introductory audio clip* encourages the group to keep an eye out for an exhibit with certain features—e.g., a portrait of an emperor, who has three hands—while each player may roam through the museum without any constraints. Thus, visitors are restricted less in their individual freedom of movement. Another design decision to support this is that groups are not forced to stick to a chronological order of solving quests. This means the group may also accept other quests in parallel, as they can finish quests in any desired sequence.

Fostering collaboration

Quitting to map out the route for the group may have yet another desired effect, namely that it may foster collaboration. We believe this is the case, as it is easier to find a specific exhibit when players work together as a group, e.g., by splitting up, searching individually for hints, and eventually rejoining with others, to discuss or show any discovered hints.

The second difference compared to the first game design is the *quest dependent group activity*, which replaces the multiple-choice questions. This activity may be either to solve an *interactive riddle* in collaboration, or to *discuss* possible answers of an openly asked question. Regarding the latter, this type of quests—so called *discussion quests*—do not require the group to enter any answer at all. Instead, the *task explanation* encourages the group to ponder about possible answers, and when feeling confident, to reveal the *solution audio clip*. Coming up with own ideas is considered more important than actually finding the right answer. This quest type was significantly influenced by the report on science rallies in the German Museum, described by one of the participants in our paper prototype user study (cf. subsection 3.3.4). The expectation of this replacement for multiple-choice questions was that collaboration will no longer be hindered, but instead is encouraged. It was also hoped that users will feel less tested, since questions without given answers allow more room for interpretation.

An issue of this second change is that discussions may greatly vary in their length. Enforcing a time limit by the game system, as it was the case in the quiz game, seemed inappropriate. This means that the group as a whole needs to make decisions from time to time. However, players may have different opinions how long the group should discuss on possible answers. This can be a big problem, for instance, when half the group wants to stop discussion and rather listen to the solution, but the other half wants to spend more time on the quest. We deliberately decided against a voting system to address this issue as we believe that outvoted members will rather accept such a circumstance when originated from a social discussion instead of imposed by a technological system.

Thus, we let groups choose one of their teammates as their *group leader* at the beginning of the game. His or her task is to make decisions in consultation with his team-mates. This includes accepting new quests as well as starting the associated task explanation once the group has gathered around the corresponding exhibit. Since people visiting a museum in a group are most often closely related to each other, e.g., friends or family members, we are not concerned that the leader will use his privileges in an egoistic manner. In-

Group activity instead of multiple-choice questions

Difficulties in making decisions

Group leader concept

stead, we imagine that non-leaders might try to influence the leader. We believe that this concept may also encourage social interaction between players, and thus further emphasize the whole group experience.

Supporting group dynamics

The quest game allows groups to dynamically split up and come together again, to promote each player's freedom of movement. Thus, there is a need to prevent that eager players hasten away and finish quests on their own without being considerate of teammates. Since we are interested in an experience for the whole group, quests may only be finished in case all players are together. Unaccompanied players that find the corresponding exhibit of a particular quest may call absent team members via the game system to come to their location in order to finish the quest together. We expect that groups will use this flexibility to find exhibits more efficiently.

Group score as reward for finishing a quest

After reunion, the group may progress, as the system will present the *task explanation* via audio synchronously running on all devices. As the group activity of a quest aims at fostering collaboration among players, we had to change the reward system of our game, too. Players will hence no longer receive individual scores. Finishing a quest instead results in a certain amount of group points. This score could be compared with the scoring of other visitor groups at the end of the game. However, we would like to mention that the design of the scoring mechanism was rather neglected compared to other parts of the game. Nevertheless, this does not belittle the importance of this general change.

Summary of changes

The following listing summarizes all design changes made:

- Users are no longer directed to exhibits but have to search them by themselves.

- Quests may be played in any order, and multiple quests may be accepted in parallel.

- Interactive riddles and questions for group discussions replace the multiple-choice questions from the quiz game.

- Discussion quests do not require groups to enter any answer at all into the game system.

- A group leader with certain privileges is elected at the beginning of the game.

- The players' individual freedom of movement is preserved by allowing groups to dynamically split up and come together again.

- No more in-group competition due to individual player scores. Instead, the whole group is rewarded with a group score at the end of a quest.

4.2   The Quests

As it was planned to create a software prototype based on the *AIXplorer* system in the Aachen City Hall, there was a need to create appropriate quests. In order to learn interesting anecdotes and stories about the exhibits of the city hall, a guided tour with Georg Helg—the representative chairman of the Aachen City Hall society—was arranged. The whole tour was audio recorded for later transcription and categorization of the gained knowledge.

Five appealing quests were created from those numerous stories. The stories were selected regarding their practicability, i.e., if they provided opportunity for an interactive puzzle or an interesting question to discuss on. Stories that allowed to draw connections between exhibits located in different rooms were also included. Last but not least, a critical factor was that the story itself appeared to be interesting or entertaining.

Several audio clips were recorded in the course of the quest creation. A detailed description of these quests and the associated group activities is presented in the following sections. The texts of the audio clips are printed in Appendix A.

4.2.1   Interactive Quests

These quests consist of a small riddle or puzzle build around specific exhibits of the museum which should be solved by the group in cooperation. These quests pick up some of the ideas on collaborative gaming originated in the brainstorming session described in section 3.1. For instance, a puzzle is divided in different parts which are then distributed among the players. The idea is to include every player in finding the solution of the puzzle as a whole. The following two quests are examples for an appliance of this principle.

The four virtues

Quest description   The quest begins in the White Room (cf. Figure 4.1 for a map of the Aachen City Hall), where the *introduction* directs the attention to one of the pillars located in the corners of the room. The audio clip points out that the depicted lion represents one of the four cardinal virtues according to Plato. Consequently, the group is encouraged to find a ceiling fresco in another room that illustrates all four virtues.
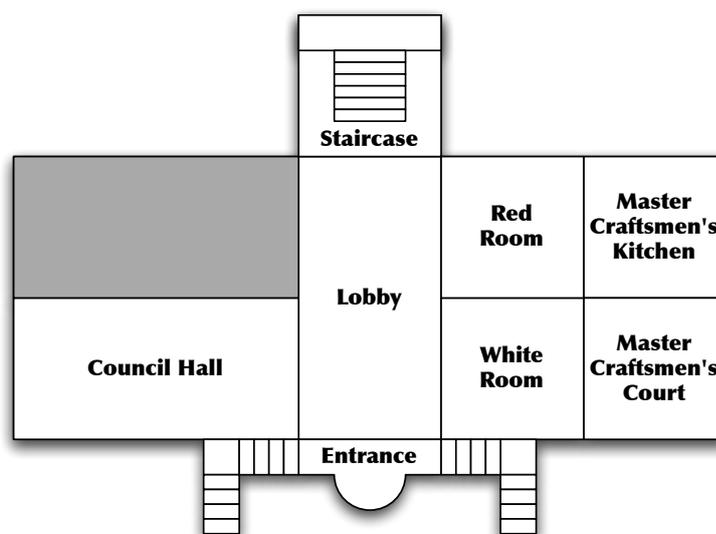
Figure 4.1: Map of Aachen City Hall (first floor).

This fresco is located in the Council Hall, where the group may proceed with the *task explanation* in case the group is complete. The explanation clip introduces the four cardinal virtues Prudence, Fortitude, Temperance, and Justice to the group. The task is hence to match each virtue with its associated symbol shown in the fresco. Therefore, the virtues are distributed among the players, so that every player has to solve one matching.

This quest provides much opportunity for collaboration and social interaction as the players may use their individual knowledge and imagination of symbols and virtues to assist each other. It may also encourage communication since it is expected that the group will discuss the four matchings altogether.

Baroque number puzzle

The quest introduces the visitors of the Aachen City Hall to *chronograms*. These are a kind of numeric puzzles which were popular among artists of the baroque period. To put it simply, a chronogram is a sentence with hidden numbers. Most of them are Latin inscriptions, e.g., on old houses, tombstones or paintings[1]. Letters which are also roman numerals (I, V, X, L, C, D and M) are highlighted to indicate that they are part of the numeric puzzle. To solve the puzzle, the value of *every single* numeral symbol is added up. The sum represents a year, which is often the year in which the work of art was crafted.

Chronograms

In *Baroque number puzzle*, the group has to find a portrait of Charlemagne in the Master Craftsmen's Court that contains a chronogram (cf. Figure 4.2). Since this chronogram is a *double chronogram*, i.e., two chronogram sentences that both have the same year as solution, the group is requested to split up, so that one half solves the upper chronogram and the other half takes care of the chronogram at the bottom. The solution of the chronograms is depicted in Table 4.1.

Task description

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[1]Source: www.mathematische-basteleien.de/chronograms.htm

Figure 4.2: Double chronogram contained in Charlemagne portrait by J.C. Bollenrath. Big red letters highlight the roman numerals. The two chronograms are separated halfway through by the word "et".

4.2.2 Discussion Quests

The following quests illustrate the concept of *discussion quests*. As stated before, the *task* in these is to contemplate and discuss about an openly asked question. Discussion quests will not give players any answers to select from, so it is hoped for that players let their imagination run wild and discuss about upcoming ideas. Communication and social interaction are considered more important than actually solving the question. Groups receive one point of group score for playing a discussion quest, no matter how much time they actually spent on discussion.

The three hands

The group learns that somewhere in the city hall there is an extraordinary painting showing a person with three hands. The painting the group has to find is a portrait of Holy Roman Emperor Francis II (Figure 4.3). The group's task is hence to contemplate on the cause of this oddity.

Chronogram	Sorted roman numerals	Sum
CaroLVs MagnVs hVIVs seDIs regaLIs et VrbIs granensIs	MDCLLVVVVVIIIII	1730
LaVDabILIs De pannIs IbI statVentIs IVDICII patronVs	DDDCLLVVVVIIIIIIIIII	1730

Table 4.1: Solution of the double chronogram

As soon as the group decides having spent enough time on discussion, they may reveal the *solution audio clip*. The reason for the third hand is that the painter reused the canvas of a painting of an old lady. Thus, Francis II was painted over the lady. This was figured out some years ago by a conservator during restoration. To keep the old lady in good memories, the conservator decided to extract one hand of her.

Discover the Habsburgs

This quest is closely related to the Peace Treaty of Aachen from 1748 which ended the War of the Austrian Succession. In the Red Room, the *introduction* tells the group that the war began because Maria Theresa of Austria was not accepted as sovereign successor of her father, Holy Roman Emperor Charles VI. For further information on the war and the peace treaty, the group is invited to take a look at the *Friedenstisch* in the middle of the room, which is an interactive table developed by the Media Computing Group in 2009[2].

Hence, the table serves as a springboard for this quest. Furthermore, the *introduction* encourages the players to keep a lookout for a portrait of Maria Theresa, as well as paintings of two other persons closely related to her, that are located

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[2]For more information on this exhibit refer to http://hci.rwth-aachen.de/aachenerfrieden

Figure 4.3: Painting of Holy Roman Emperor Francis II, part of the quest *The three hands*.

in another room. In case the group discovers these three paintings in the *Council Hall*, the subsequent task is to figure out the identities of the two men left and right to Maria Theresa and how they are related to her.

Contrary to the question from *The three hands*, the potential for discussion is here rather small in scope, as the questions have clear solutions. Clues regarding the names are found in the Council Hall, information of Maria Theresa's relatives are provided by the *Friedenstisch*. Nevertheless this quest is considered a *discussion quest*, as it focuses on communication, social interaction and collaboration.

May 15, 1865

The *introduction* tells about a huge festivity on the 15th of May 1865 in Aachen. The townspeople celebrated the 50th anniversary of the liberation from French occupation on this day and the integration of Aachen and the whole Rhineland into the Kingdom of Prussia. Furthermore the group learns that a prominent guest from Berlin visited the city on the occasion of this event, and that two paintings in the city hall remember this day.

Background story

Similar to *Discover the Habsburgs*, the players have to search these paintings and identify the portrayed persons. In this case, however, the paintings are located in two different rooms. Thus it is more difficult to establish the connection between the pictures. Nonetheless, this is possible due to a subtle shared detail: both paintings show the city hall in the background.

Difference to the other discussion quests

As it is quite challenging to recognize the similarity, it is very important for the group to collaborate in the search, as well as to discuss individual findings and to draw appropriate conclusions. Provided that the players find the first portrait in the Master Craftsmen's Court, they are rewarded with information about the former mayor Johann Contzen. Regarding the other portrait, located in the adjacent Master Craftsmen's Kitchen, showing William I, an audio clip narrates an anecdote about this famous German Emperor, his son Frederick and the genesis of RWTH Aachen University.

Importance of collaboration

Chapter 5

GroupAIXplorer Implementation

In the last chapter we presented a new game design which we believe allows more social interaction among its users. This chapter now presents in detail how this design was implemented in a software system.

The Media Computing Group already developed the *AIXplorer*, thus it seemed appropriate to implement the software system upon the existing hard- and software. A technical description of the AIXplorer and an overview of adopted parts is given in 5.1—"Adopting the AIXplorer system". The section thereafter (5.2) describes the user interface and how the quests were realized in the software system. Further design decisions in the course of the implementation are presented and explained. Section 5.3—"Software Architecture" then documents the software architecture.

5.1 Adopting the AIXplorer system

The main component of the *AIXplorer audio guide* (Figure 5.1) is an Apple iPhone[1]. The current AIXplorer version

AIXplorer hardware

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[1]http://www.apple.com/iphone/

uses the iPhone 3G[2], running on iOS 2.2.1. The iPhone is surrounded by a protective shell which covers all physical buttons. Thus, visitors can only access the capacitive touchscreen. The home button is deliberately hidden beneath the shell, so that users cannot quit the audio guide software. A lanyard may be attached to the shell to offer visitors a comfortable way to carry the AIXplorer. To attenuate ambient noise, closed stereo headphones are used, including in-line volume control.

Location-awareness

The AIXplorer is location-aware. This simplifies choosing audio commentaries, as only commentaries appropriate for the current room are offered for selection. This location-awareness is realized by measuring the signal strength of miscellaneous WiFi access points distributed throughout the building. A support vector machine [Hsu et al., 2003–2010] classifies the measured data—simply expressed—by comparing it to stored training examples.

Furthermore, a high precision location tracking system is installed in the upper floor of the building. Ubisense products[3] are applied to create an audio virtual reality experience in the Coronation Hall. Therefore, a Ubisense Series 7000 Tag Module is mounted on top of the headphones.

Adopted features

For the development of the GroupAIXplorer software, we merely adopted the room-accurate location tracking using the aforementioned wireless tracking framework. We did not use the Ubisense high precision tracking as the five designed quests focus on the exhibits in the first floor (c.f 4.2—"The Quests"). The software was implemented on the same hardware as described above. As a matter of fact, for our user test (cf. 6—"Evaluation") we installed the software on AIXplorer devices from the Aachen City Hall. Since the devices cannot be upgraded to a newer version[4] without upgrading the AIXplorer audio guide software as well, the GroupAIXplorer software needed to be developed for iOS 2.2.1, too. We also used the WiFi infrastructure installed in the Aachen City Hall to allow inter-device network communication.

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[2]http://en.wikipedia.org/wiki/IPhone_3G
[3]http://www.ubisense.net
[4]At the time of writing, the latest iOS version is 4.2.1.

Figure 5.1: AIXplorer audio guide device. The magnification shows the custom FireWire audio connector and the charging socket.

We did not use the same stereo headphones, as they hamper direct interpersonal communication. Instead, monaural headphones[5] were used to preserve ambience awareness and to foster communication in the game, similar to *Sotto Voce* [Aoki et al., 2002]. However, the AIXplorer has no standard audio jack on the outside of the protective shell (Figure 5.1). Instead, a FireWire 400 connector with a custom pinout—not following the official IEEE 1394 specification—is used for this purpose. So initially we had to decide if we want to keep the shell or not.

GroupAIXplorer headphones

We decided to keep the shell for different reasons. First of all, this would mean to reveal the home button of the iPhone, which would allow users to terminate the GroupAIXplorer software, either by mistake or on purpose. Less critical, but still a factor of concern, we did not want that test users easily recognize the iPhone, because some of them might try to play around with this fancy hardware and thus be distracted from the actual audio guide system. Last but not least, giving up the shell would also mean to

Reasons for keeping the shell

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[5]SENNHEISER GP 03-M, cf. http://www.sennheiser.com/guideport/

loose the lanyard and the associated wearing comfort. We wanted the devices to feel like real audio guides.

In conclusion, to connect the monaural headphones to the AIXplorer, we had to build a custom audio adapter—a 3.5mm TRS connector plug to a six-circuit FireWire 400 connector—following the pin assignment given by the AIXplorer design. Thus, five of these adapters were crafted for the user test.

5.2   Graphical User Interface

Now we present the development of the GUI for the quest game described in chapter 4. The implementation made further design decisions necessary. These are mentioned where appropriate and explained in detail as well.

GUI language

The GUI and all its contents, including the audio clips, were created in German. This decision was made as it was clear that test users of the system will be native German speakers. It was considered important that users have no difficulties in comprehension due to a foreign language. For this thesis, however, English translations of the interface screens were created.

5.2.1   Quest selection screen

When started, the GroupAIXplorer software presents its main screen, the *quest selection screen* (Figure 5.2). Its GUI shows available quests and quests that may be finished at the current room in the *quest selection table view*. The *top bar* displays the name of the room. In the *group leader information section* the name and the competencies of the group leader are presented.

Selecting an available quest

When a player selects an available quest, a modal pop-up box appears with a simple audio player that starts the *introduction audio clip*. In case the player is the leader, he or she may then decide to accept the quest for the group

Staircase [Group]	**Council Hall** [Group]
Paul, you are the leader of the group. You're the only member who may accept or finish quests.	Mary, please notice that Paul is your group leader. Only the group leader may accept or finish quests.
Available quests:	**Available quests:**
The Three Hands	Baroque Number Puzzle
	Quests to finish:
	The Four Virtues
Call Group Quest log	Call Group Quest log
(a)	(b)

Figure 5.2: Two examples of the quest selection screen. (a) shows the screen for group leader Paul, (b) for Mary, one of Paul's team-mates.

(Figure 5.3–a). Other players are not allowed to make such decisions, therefore, the UI offers a button to call over the leader (Figure 5.3–b). Provided that the group leader decides to accept the quest, it will disappear from the *available quests section* in the table view. On the other hand, rooms that contain quest related exhibits will then list the quest as a *quest to finish*, i.e., a quest the group may finalize by performing the associated group activity. As soon as the group leader accepts a new quest, the other group members are informed via a text message (Figure 5.3–c). This message provides instant access to the introduction audio clip.

The situation described above is not the only instance where the system offers a user to call over other players. In case that a non-leader tries to start the task explanation of a previously accepted quest, he will receive an informational message stating that he has not the appropriate powers (Figure 5.4–a). As a possible solution for this circumstance, the interface of the message box includes a button to call over the group leader. A similar situation arises when the leader wants to start the task explanation and

| (a) | (b) | (c) |
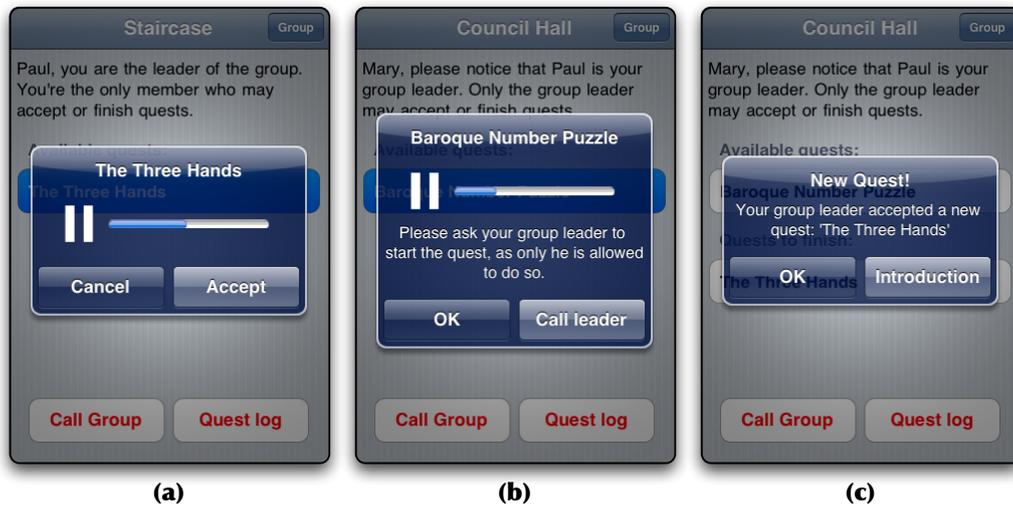
Figure 5.3: Different ways to access the introduction audio clip. Screen (a) shows the audio player of the group leader when selecting an available quest. Screen (b) is the result for other players when performing the same action. Screen (c) is an example of the message box non-leaders receive in case the group leader accepted a new quest.

the group is incomplete. As described in 4.1—"Designing a Quest game", the game design does not allow to finish a quest when only a part of the group resides in the associated room. Thus, the group leader receives an informational message (Figure 5.4–b), with the option to call over his group. Other ways to call over team-mates are the "Call Group" button on the bottom left of the screen, or to open the *Group information screen* via the appropriate button in the top bar (cf. subsection 5.2.3). The associated interface of call-over actions is described in 5.2.4—"Communication interface".

Quest log screen

As quests may be accepted and finished in any desired sequence, a *quest log screen* was implemented to provide an overview of the current game state. Players can access this view by selecting the button on the bottom right. Its GUI is described in the following subsection 5.2.2.

Given that the group found the exhibit related to an accepted quest and the whole group gathered around the exhibit, the leader may start the *task explanation* for the as-

(a)   **(b)**

Figure 5.4: Informational messages containing context-dependent call over buttons.

sociated group activity. Two quests feature an interactive riddle as group activity, whereas the other ones are discussion quests. Section 5.2.5—"Group activity user interface" presents the particular user interfaces of the two riddles, as well as a general description of the discussion quest interface.

5.2.2   Quest-log screen

The purpose of this screen is to give players visual feedback about the actual game state. The group score is presented textually. A table view lists all accepted and finished quests in corresponding sections (Figure 5.5–a). Undiscovered quests are deliberately hidden from the table view, as its part of the game to discover new quests while exploring the museum.

Visualizing the game state

Selecting an accepted quest gives players the opportunity to listen again to the introduction of that quest (Figure 5.5–b). This might be necessary when a player wants to refresh his memory regarding hints given at the start of the quest.
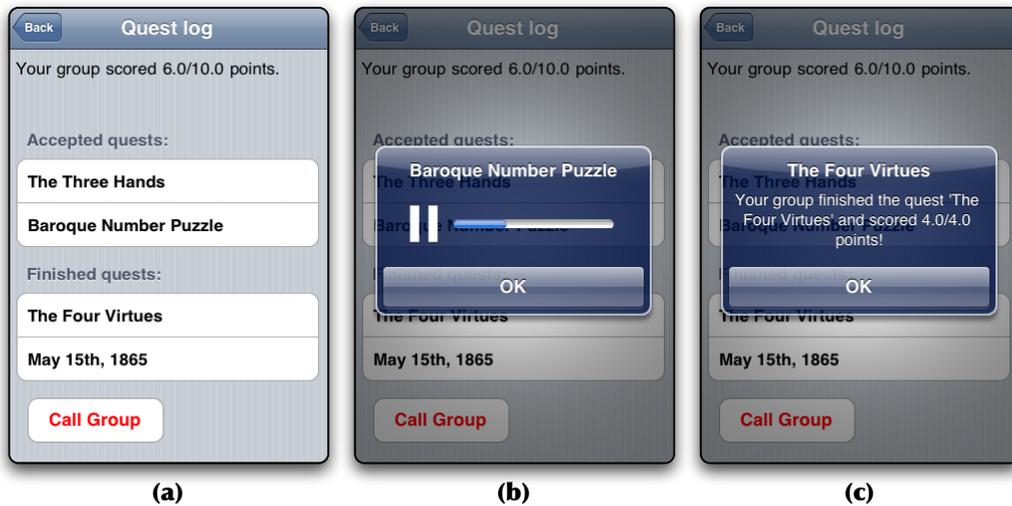
Figure 5.5: The Quest Log screen. (a) shows the general layout, (b) the feedback when selecting an accepted quest, (c) when selecting a finished quest from the table view.

Selecting a finished quest results in a pop-up box showing the reached score for this particular quest (Figure 5.5–c).

5.2.3   Group-information screen

This screen allows users to call over individual group members for talking. A table view shows all team-mates (Figure 5.6–a). Selecting an entry from the table view will send a predefined call over message to the selected player. Details on this are explained in subsection 5.2.4. Figure 5.6–b depicts the notification a sender receives from the system after the message was sent. Part (c) of the same Figure is an example for one possible reply of the called person.

Last but not least, a textfield at the top of the group-information screen allows players to enter their name.
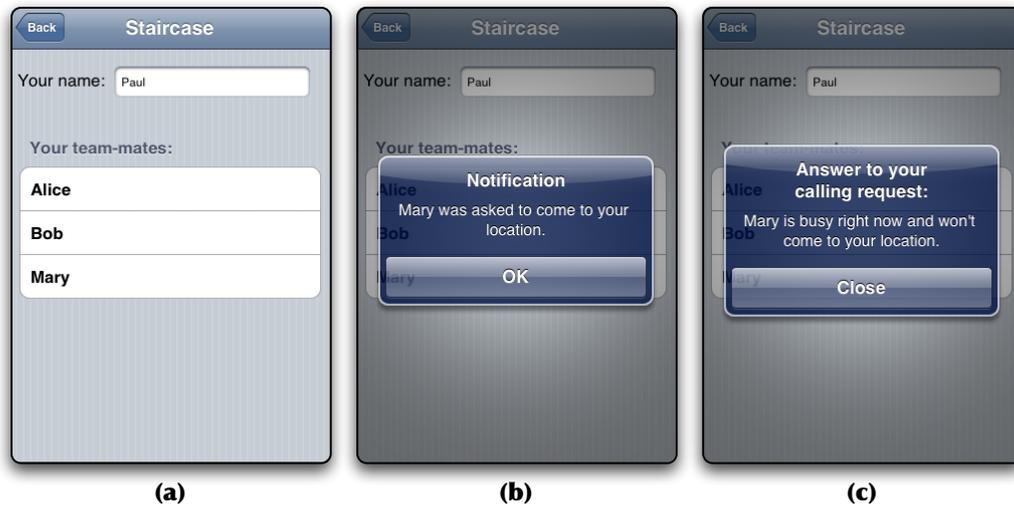
Figure 5.6: Group Information Screen. The screens demonstrate Paul sending a message to Mary.

5.2.4 Communication interface

One of the design objectives for the game was to allow groups to split up in their search for the introduced exhibits. The intention was to preserve the individual freedom of movement of each visitor (cf. listing of design changes on page 30). For this reason, the system does not force its users to stay together. But as the intention of the game is to provide a compelling group experience, there is also a continuous need to foster communication. When supporting individual freedom of movement in a group, it is important to prevent that members loose contact to their team-mates. Thus, a feature was needed to address this issue.

Freedom of movement and the need to reunite

We decided to implement a calling function for group reformation. This allows players to send predefined textual messages to other members, asking them to come over to their location. To describe the different features of the Communication UI in an adequate manner, we present in the following a possible scenario of the quest game in great detail. Assume the following situation:

Calling Function

Scenario:

Quest game scenario

A group of four friends—Paul, Mary, Alice and Bob—is playing the quest game in the Aachen City Hall. The group agreed at the beginning of the game that Paul takes on the role of the group leader. The group starts in the Red Room[6]. Bob suggests to select the quest *Discover the Habsburgs*, which is displayed as an available quest at this location. Paul and Alice follow him and subsequently listen to the introductory audio clip, whereas Mary misses Bobs suggestion. She is absent-minded and slowly walks around the room, as she is enthused by the splendid features and radiant colorfulness of the walls.

After the end of the introduction, Paul, Alice and Bob agree to accept the quest. Mary is still deep in thought, but gets aware of the situation when she suddenly realizes the others have already activated a quest, as her game device vibrated on acceptance. She reads the pop-up box on her screen and steps up to the group, to reduce the distance to her friends and to be aware of what is going on. Alice notices that Mary rejoins the group and wraps up the background story of the quest. She also tells Mary that Bob, Paul and herself are gathering information on Maria Theresa at the *Friedenstisch*[7] right now.

Splitting up

After having gained some knowledge about Maria Theresa and the War of the Austrian Succession, the group decides to split up to find the three portraits they have heard from in the introduction faster. Alice and Bob head east to the Master Craftmen's Kitchen, whereas Mary and Paul leave the room westwards, to enter the Lobby. Mary tells Paul that she first wants to listen to the introduction again, as she only got a summary from Alice. While Mary accesses the introduction via the *quest log* (Figure 5.5, pg. 46), Paul moves along north to the staircase. While listening to the introduction of the quest,

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[6]For a map of Aachen City Hall, see Figure 4.1 on page 32.

[7]For details on this interactive exhibit refer to 4.2.2—"Discover the Habsburgs" on page 35.

Mary examines the Lobby, unconsciously moving south. Meanwhile, Alice and Bob increased their distance, too, due to similar reasons. Alice wanted to examine some exhibits in the Master Craftmen's Court more closely, while Bob preferred to get an overview of the four rooms in the east wing of the City Hall. Bob ends up in the White Room, where he is fascinated by the gorgeous white and golden interior from the Rococo period.

At the staircase, Paul discovered that there is another quest to explore—*The three hands*. After listening to the introduction with interest, he is unsure if he should accept this quest, too, since the group is right now focused on *Discover the Habsburgs*. He uses the *group-information screen* (Figure 5.6, pg. 47) to ask Mary to come over to him[8], as Paul would like her to listen this quest's introduction, too, and to ask for her opinion. Mary recently entered the Council Hall in the west wing, where she believes to recognize the face of Maria Theresa that she saw previously at the *Friedenstisch*. She is distracted from the portrait because her device suddenly vibrates and displays Paul's message, depicted in Figure 5.7–a (pg. 50). As she is engaged in taking a closer look of the potential portrait of Maria Theresa, she does not want to leave the room right now. Thus, she quickly answers Paul request by selecting the button on the bottom right, labeled "I'm busy". Immediately, a message box pops-up on Paul's display, shown in Figure 5.8–a (pg. 51). Paul respects her decision and devotes his attention back on the search for the Habsburg portraits. As he feels to be on the wrong track, he returns to the Red Room to review the informations on the *Friedenstisch*.

Meanwhile, Mary figured out, that the person shown in the picture is indeed Maria Theresa. She further notices two other portraits to the left and the right of her. She checks her device and realizes, that *Discover the Habsburgs* is also listed

Examples for
sending messages

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[8]The call over example given in Figure 5.6 happens to fit this scenario.
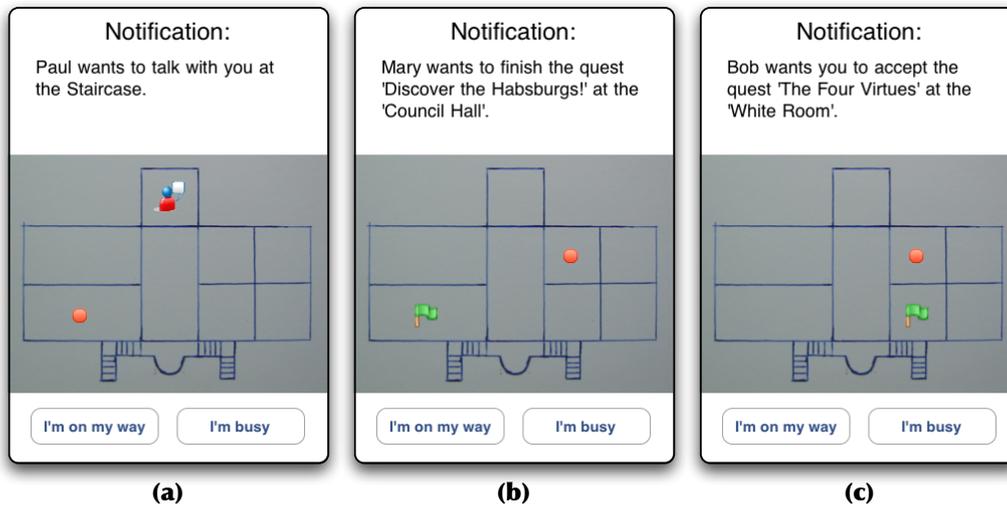
Figure 5.7: Call over screens of the communication UI. The text informs about the sender and the reason of the message. The map shows the receiver's own position as a red circle and the sender's location with a context dependent symbol. The receiver replies with predefined answers by selecting one of the two buttons on the bottom.

to be finished in this room. She selects the quest item to proceed with the quest. Figure 5.4–a (pg. 45) depicts the message she receives from the system, telling her that the leader is required to proceed. She uses the corresponding button to call group leader Paul. He receives the message shown in Figure 5.7–b (pg. 50) that asks him to come over to Mary to finish *Discover the Habsburgs*. He is glad that Mary found the portraits and thus confirms her request by selecting "I'm on my way". Mary receives his answer, shown in Figure 5.8–b (pg. 51).

Even before Paul sets out to walk over to the Council Hall, he receives another message. Bob just finished listening to the introduction of *The four virtues*. As he was not able to start the quest by himself, he called Paul to do so via the introduction interface for non-leaders (Figure 5.3–b, pg. 44). Paul's device hence displays Bob's message (Figure 5.7–c, pg. 50), which is similar to the one Paul received from Mary. However, he
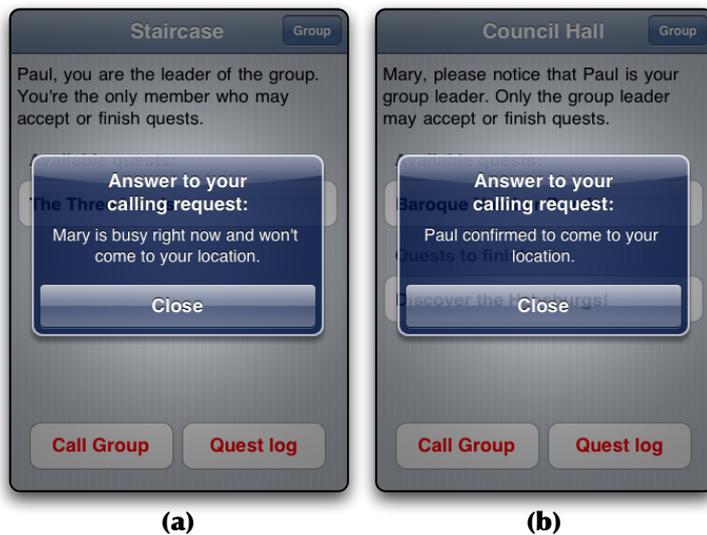
Figure 5.8: Call over replies. Screen (a) shows a negative answer, whereas (b) is an example of a confirmation.

notices that request and place of destination—depicted by a green flag—are different. As Paul was just on his way to the Council Hall, he *replies* with "I'm busy". Bob receives the corresponding message box. While Paul leaves the room in western direction, he realizes that Bob's message told him also Bob's location, the nearby White Room. He changes his mind, and decides to come over to Bob, although he just told him the opposite.

Once arrived there, he meets Bob, who reports from an interesting quest he just listened to the introduction audio clip. Paul on his part tells Bob that Mary found the portraits and suggests to come back to this quest later. Before coming over to Mary, the two guys ask themselves where Alice got to. They agree to search her in the outer rooms of this wing, as they both did not see her leaving this part of the building. This said, Alice enters the room from the adjacent Master Craftmen's Court, as she was also called by Mary to come over to the Council

Hall. Having reunited, the three walk together through the Lobby and into the Council Hall, where Mary welcomes them and tells about her recent progress.

As the group is complete, Paul can select *Discover the Habsburgs* from the table view of the quest selection screen, leading to the start of the *task explanation* on each device. In the following, we explain why the user interface for sending messages was designed in the way just described.

Reasons for predefined messages

We have chosen predefined messages over text or voice input for reasons of simplicity. Furthermore, the distances in the Aachen City Hall are rather short, so that users may quickly come together. We believe that talking in person leads to richer communication compared to text messages, phone calls or video chats. Also, text input methods might be cumbersome.

In conclusion, we sumarize the three different possibilities to call over other players:

- Using the context-dependent call buttons, when the group leader is required or the group is incomplete, previously shown in Figure 5.4.

- By opening the *group-information screen*, to call individual team-mates, depicted in Figure 5.6.

- Calling the whole group at a time, by using the *Call Group* button in the *quest selection* or *quest-log screen*.

5.2.5 Group activity user interface

Discussion Quests

We carry on with the game scenario previously described. The group found the three portraits belonging to *Discover the Habsburgs* in the Council Hall. Paul, the group leader, had just selected the corresponding entry from the quest selection table view. As a result, the game system will display

the screen shown in Figure 5.9–a on every device. Paul, Mary, Alice and Bob hence will hear the *task explanation* for the corresponding group activity synchronously, which is in this case to discuss who the two men to the left and right of Maria Theresa are (cf. 4.2.2—"Discover the Habsburgs"). A picture of the empress is visible in the background and appears uncovered after the audio player dialog is closed (Figure 5.9–b).

The group may take as much time as they want to *answer* this question. Whenever the group feels like revealing the solution, the leader may do so by selecting the appropriate button in the bottom right of the screen. A dialog box pops-up for confirmation, in order to prevent revealing the solution too early due to an accidental touch (Figure 5.10–a). Like other group decisions, non-leaders are not allowed to decide on this. Instead, they are encouraged to express their wish to the group leader verbally (Figure 5.10–b). The intent of this design decision is again to foster group communication and social interaction.

(a)   **(b)**
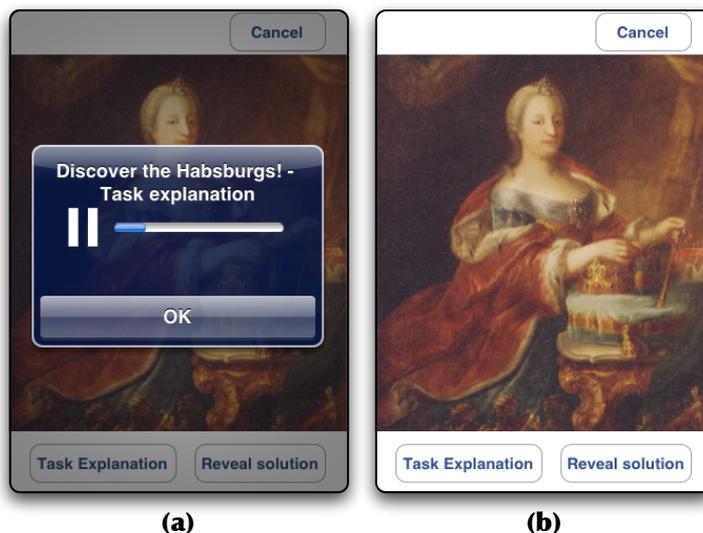
Figure 5.9: GUI of a discussion quest. (a) shows the task explanation audio player, (b) the portrait related to the quest.
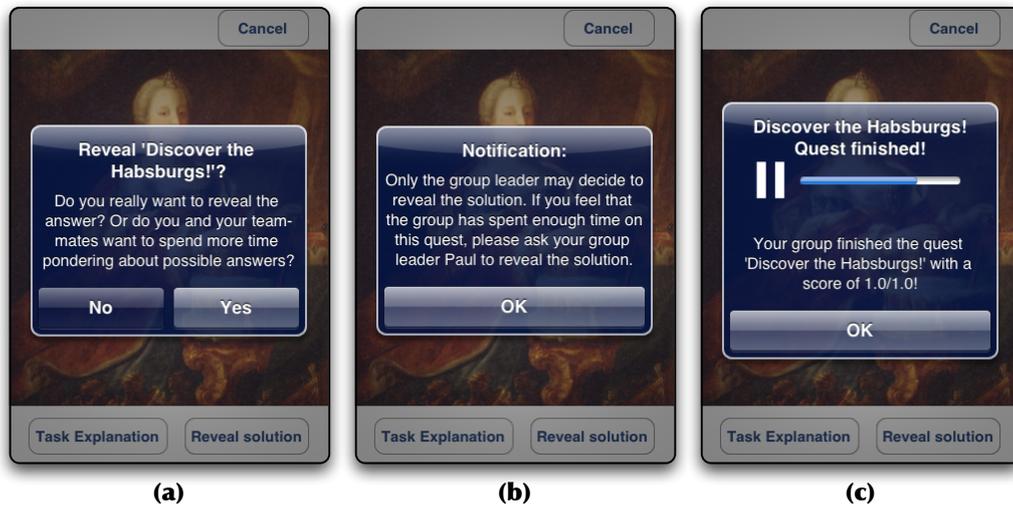
Figure 5.10: Revealing the solution of *Discover the Habsburgs*. The group leader will see a confirmation box when touching *Reveal solution* (a), whereas non-leaders see a notification (b). In the end, all players will see the solution audio player on their device (c).

As soon as the group leader decides positive, all players will hear the solution audio clip (Figure 5.10–c). This audio dialog also states that the group gained one point added to their group score for playing this quest.

Particularity of *May 15, 1865*

The interfaces of the other discussion quests, *The three hands* and *May 15, 1865* feature the same GUI, of course populated with other content. The latter quest, however, differs in so far as it is divided in two parts. This is due to the fact that the two associated paintings are located in two different rooms. We did not want to impose a fixed order, i.e., the group does not have to find one of the two images before the other one. Instead, the leader may start the task explanation in any of the two corresponding rooms. This is possible because the stories narrated at the end of each part happened at the same day but do not build on each other content-wise. The *solution audio* and the text in the corresponding dialog box tell the users that they have only finished a *quest part*. Furthermore, the players are asked to search next up for the other painting in respect of this date.
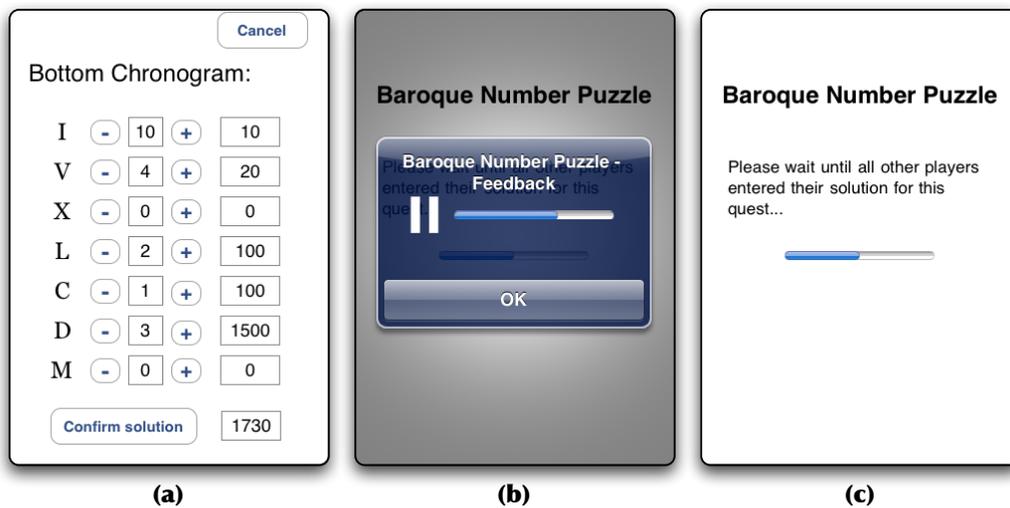
Figure 5.11: User Interface of *Baroque number puzzle*. (a) depicts a calculator to sum up roman numerals. (b) gives an example of the feedback audio dialog. (c) displays a waiting message for the team answering first.

Interactive Quests

The user interface of the two other quests, *Baroque number puzzle* and *The four virtues* differs considerably to the previous described ones. These two quests allow input from multiple players, not just from the group leader. In *Baroque number puzzle* for instance, the two chronograms contained in the painting (cf. Figure 4.2 on page 34) are distributed, i.e., the group is split into two, each having to solve one chronogram. Therefore, two random selected devices display a kind of *roman calculator* (Figure 5.11–a). All other players receive a message telling that this quest is played only on a few of the devices, i.e., not on their device. It further asks them to partner with group members and to enter the solution on the devices with the appropriate screens. The task explanation audio clip is still played back synchronously on all devices.

GUI of *Baroque number puzzle*

After the audio clip finished, the players can use the calculator to sum up the roman numerals from their chronogram part. When selecting the *Confirm solution* button, a dialog asks for input confirmation, again to prevent acceptance of accidental solution submissions. After this, a short
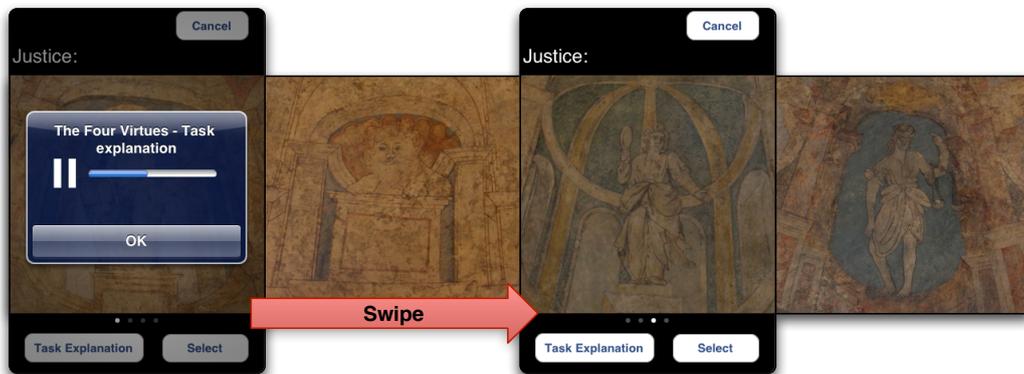
**Figure 5.12:** Group activity GUI of *The four virtues*. Each player has to select the picture showing the symbol corresponding to the textually displayed virtue.

audio feedback is given, telling each part of the group if their answer was correct (Figure 5.11–b). The team entering the solution first will see a waiting screen (Figure 5.11–c), indicating that the other team still needs to enter their solution to finish the quest. When both teams entered their solution, the quest is finished and the *solution audio clip* is played back on all devices in the same way as in a *discussion quest* (cf. Figure 5.10–c).

GUI of *The four virtues*

In *The four virtues*, the players may start the quest's group activity after they have found the ceiling fresco that depicts symbols of the four virtues *Prudence*, *Fortitude*, *Temperance* and *Justice*. Up to four devices will present the interface illustrated in Figure 5.12. The *task explanation* requires the players to figure out the appropriate matchings of the virtues and their symbols, e.g., that the lion represents *Fortitude*. Therefore, each device displays one virtue textually at the top of the screen. The different sections of the fresco are shown as photographs. Flicking through the four images is possible by performing a horizontal swipe gesture.

In groups larger than four, the game system randomly chooses four players to enter a selection. Remaining players are asked to team up with the other players in the same way as just described for *Baroque number puzzle*. In smaller groups, remaining virtues are not distributed, e.g., a group of three players only needs to match three randomly selected virtues. Similar to the GUI of *Baroque number puz-*

zle, a waiting screen is presented to the players that already entered their solution (cf. Figure 5.11–c). After all players made a selection, the *solution audio* reveals the correct matching, and its dialog presents the reached group score.

Shared interface elements

All group activity interfaces have one element in common, which was not discussed yet: the *Cancel button* in the top right corner. It is required as it may happen that the activity of a quest was started accidentally. Just like the other decisions, only the group leader is allowed to cancel a quest. He has to confirm his decision via a dialog box (Figure 5.13–a), whereas non-leaders are notified about their only option, i.e., to discuss this issue with their team-mates (part b of the figure). All players receive a notification if a quest was actually cancelled (Figure 5.13–c).

Figure 5.13: Cancelling a quest, (a) as group leader, (b) as non-leader. (c) shows the message non-leaders receive after the leader canceled a quest.

5.2.6   End of game

The game is over after all five quests have been completed. A final screen congratulates the group for their achieved group score. To simulate a scoring comparison with other groups, the message depends on the score of the group. We decided to set the comparison score to 7.5 points, so that it is challenging but still possible to beat the score. The congratulation message of the ending screen depends on the performance of the group compared to this score. In case the group performs poor, the congratulation message is neutral and does not mention the actual high score (Figure 5.14–a). However, if the group beats the score the system acknowledges this in the message (Figure 5.14–b).

This is another part of the scoring system which was just bluntly designed without too much consideration, as the scoring served mere as a very simple way to provide feedback how well the group performed (cf. section 4.1).


(a)   **(b)**
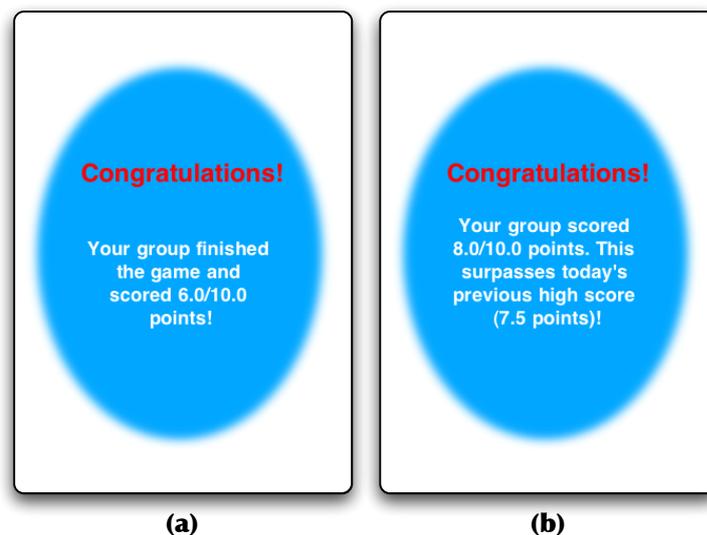
Figure 5.14: End of game congratulation. Shows the screens for a score below the simulated highscore of 7.5 points (a) and for a new highscore (b).

5.2.7 Discussion of design decisions

In the following, we describe decisions in the interface design that were not mentioned explicitly yet, but that observant readers might have already noticed.

First of all, there are several occasions in the quest game where confirmation dialogs were used to prevent accidental decisions by the group leader, namely before:

Confirmation dialogs

- Revealing the solution of a discussion quest (Figure 5.10–a).

- Submitting an answer in the interactive quests.

- Canceling the group activity of a quest for later playing (Figure 5.13–a).

As known from interface design classes and literature, e.g., [Nielsen, 1994], confirmation dialogs bear the risk that users start to ignore them after a time. Thus, an undo function is often considered to be more useful and user-friendly. In a game, however, it is essential that certain actions— like the selection of a virtue symbol—are not undoable, as it would allow score manipulation. Other actions in the game that do not affect the group score, like canceling a quest, are deliberately designed with a confirmation dialog, as the changed game state needs to be pushed immediately to all devices. For users that did not perform the triggering action, however, the associated effects might come unexpected, in case they have missed the discussion that lead to the decision. Thus the group leader is required to confirm his decisions. As museum visitors are one-time users in most instances, it is very unlikely that the confirmation dialogs are ignored.

5.3   Software Architecture

This section gives a brief overview on the software implementation. Only the most important classes and their usage is described. Appendix B provides a step-by-step instruction how to install the software on one of the AIXplorer devices. The GroupAIXplorer software was developed for iOS 2.2.1 and thus needs the according software development kit (SDK). The reader of this sections should be familiar with the concepts of the Objective-C programming language[9] and Apple's Foundation Framework[10] The source code of the GroupAIXplorer software prototype is available at the following URL:

File: GroupAIXplorer Source Code Archive[a]

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[a]http://hci.rwth-aachen.de/∼wermers/thesis/downloads/GroupAixplorerSource.zip

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5.3.1   Adopted Classes

As explained in section 5.1, we reused parts of the AIXplorer audio guide software. However, this included only the classes necessary for the location-awareness of the audio guide. We will refer to this part of the AIXplorer by the term *Wireless Tracking Framework*.

Class: Place

The use of this framework made it necessary to further adopt the `Place` model class which describes a room in the Aachen City Hall. The `Place` class consists of an `NSString` property *name*, and an `NSArray` property *topics*. The latter, however, is not used by our system. The different instances of the `Place` class are created from a resource file in property list format (PList format)[11] . This is an "Extensible Markup Language (XML) format with a pub-

PList format

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[9]http://developer.apple.com/library/mac/#documentation/Cocoa/Conceptual/ObjectiveC

[10]http://developer.apple.com/library/mac/#documentation/Cocoa/Reference/Foundation/ObjC_classic

[11]http://developer.apple.com/library/mac/#documentation/Darwin/Reference/ManPages/man5/plist.5.html

lic document type declaration defined by Apple"[12], used to
store serialized objects.

The `PListLoader` class is a Singleton class that allows to
create instances of model class from the aforementioned
PList files. The AIXplorer uses this helper class to allow
global access to different kind of arrays. Each array refer-
ences object instances from one of the following resource
files:

Class: PListLoader

- devices.plist
- macAddressMapping.plist
- places.plist

For the GroupAIXplorer software, we also adopted the
`PListLoader` class, but we altered it to our own liking,
namely to separate behavior corresponding to one specific
PList file into child classes. Thus, the `PListLoader` class
used in GroupAIXplorer only includes the parts used to
process generic PList files. To process the aforementioned
PList files, we created the child classes `DevicesHelper`,
`MacAddressHelper` and `PlacesHelper`.

PListLoader in
GroupAIXplorer

To distinguish classes originating from the AIXplorer audio
guide from our own classes, we added the prefix `GAIX` to
all GroupAIXplorer related classes.

GAIX prefix

The GroupAIXplorer software prototype furthermore uses
the ThoMoNetworking Framework[13] for inter-device net-
work communication. Provided the same protocol id string
is used, the ThoMoNetworking server and client classes au-
tomatically connect to other devices in the same local net-
work via Bonjour.

ThoMoNetworking
Framework

5.3.2   Class Overview

We start the description of the GroupAIXplorer software
prototype architecture by providing an overview on the

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[12]Source: http://en.wikipedia.org/wiki/Property_list
[13]http://hci.rwth-aachen.de/thomonet

Class:
GAIXAppDelegate

fundamental classes of the project. These classes and their connections are illustrated in Figure 5.15.

The application delegate of the software project is the starting point in regards of code execution. The `GAIXAppDelegate` class prepares the `GAIXNetworkController` and sets the shared instance of `GAIXQuestController` as its delegate. Furthermore, it creates an instance of the `GAIXPlaceViewController` class, which is the view controller of the quest selection screen described in subsection 5.2.1. This instance is then used as the root view controller of the `GAIXNavigationController`, which is a subclass of the iOS SDK's `UINavigationController`.

Class: GAIXNaviga-
tionController

Thus, it is possible to extend the usual navigation controller with a connection to the Wireless Tracking Framework. Therefore, the `GAIXNavigationController` creates an instance of the `WirelessLocator` class and registers itself as the delegate of the locator. The GAIXNavigationController further implements the methods of the `WirelessLocatorDelegate` to react on place changes. In the GroupAIXplorer software this is to update the title of the navigation bar, as it displays the name of the located room.

Class: GAIXNet-
workController

The `GAIXNetworkController` can be considered as a kind of wrapper class for extending the ThoMoNetworking Framework in an uncommon way. As all guide devices should be enabled to directly send network messages to every other device, the `GAIXNetworkController` contains an object of ThoMoNetworking server and client class each. Thus, every device serves as a server and furthermore may connect on its client side with any other device. The network controller serves as an abstraction layer to provide other classes with the possibility to send network messages to other devices by using other devices `GAIXDevice` instance as an identifier. Those classes thus do not have to care on which way the message is sent, from a client to a server instance or vice versa. The `GAIXNetworkDelegateProtocol` specifies the messages a delegate of the network controller has to implement to be notified about new device connections, lost connections and most notably to receive network mes-
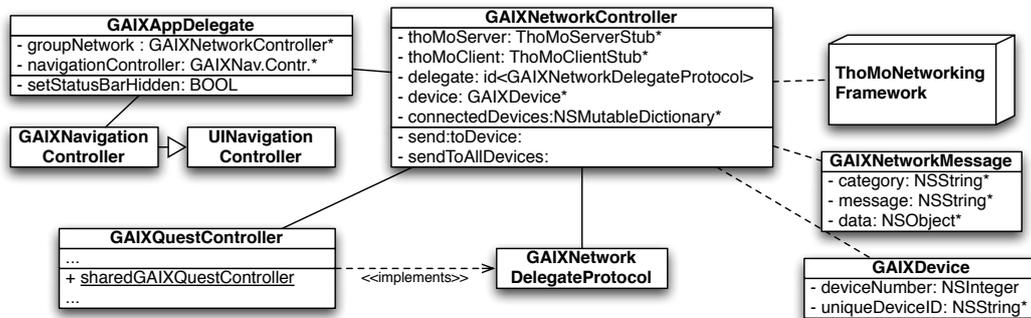
**Figure 5.15:** Main controllers of the GroupAIXplorer software.

sages sent from other devices. To be able to specify a kind of own network protocol of a distinct format, the `GAIXNetworkController` only allows to send and receive objects of the `GAIXNetworkMessage` class. These consist merely of two identifier strings and any *NSCoding* compliant object for attached data.

In our system, the `GAIXQuestController` instance created in the application delegate is set as delegate for the `GAIXNetworkController`. Thus, all network messages are redirected to the quest controller. This class is probably the most complex class of the software, as it deals with everything related to the manipulation of `GAIXQuest` objects, which is the model class for the quests of the game. As one can say the state of all quests renders the complete game state, it is conceivable to see the `GAIXQuestController` as the main controller of the quest game. Figure 5.16 illustrates the most important instance variables and methods.

Class:
GAIXQuestController

This controller sets the initial game state when the Singleton is instantiated due to the first call of
`[GAIXQuestController sharedGAIXQuestController]`
in the application delegate. In its init method, the quest controller utilizes the methods inherited from its parent class—the aforementioned `PListLoader`—to read in the data from the `GAIXQuests.plist` resource file. For each entry of this file, the quest controller creates one `GAIXQuest` instance, initialized with the values specified for each entry in the property list. References to all

instances are stored in an immutable array[14].
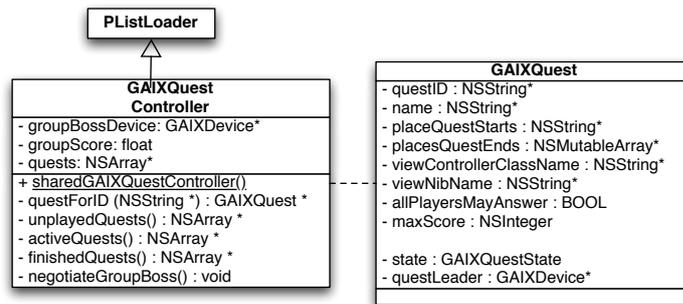
Figure 5.16: GAIXQuestController and GAIXQuest model class.

Class: GAIXQuest

The model class for quests features several properties, as shown in Figure 5.16. Among these, one has to separate between two sets of properties. The eight properties in the top of the class diagram are configured from the `GAIXQuests.plist` file, e.g., an identifier, the localized name of the quest and the ids of the places where the quest starts respectively ends. These values will stay the same over the whole game. Thus, they are readonly for other classes, as they are only accessible via their getter method. The other two properties of the `GAIXQuest` class are the quest's state and the quest's leader. The state of the quests is managed by the quest controller, depending on interface actions of the group leader and incoming network messages. Possible values are

- `kGAIXQuestUnplayed`

- `kGAIXQuestActive`

- `kGAIXQuestFinished`

The possibility of changing group leadership

The `questLeader` property of a `GAIXQuest` object might surprise, as the proposed quest game did not describe

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[14]Note: The references stored are immutable, not the referenced objects themselves.

the possibility to change the leader. Indeed, in the actual implementation this feature is deliberately left unused. Thus, the leader of each quest will always be that device which was preconfigured to serve as the device of the group leader. However, in principle it is possible to set different group leaders for each individual quest. Due to this idea—to possibly change leadership between players—the `GAIXQuestController` includes the `groupBossDevice` property. In the current software implementation this property will never change. However, we want to note that on the acceptance of a quest, the quest's `questLeader` property will be set to the current device instance referenced by the `groupBossDevice` property of the quest controller. Another detail on this has to be explained regarding the case a player selects an active quest in the quest selection screen to start the group activity of this quest. The quest controller will not simply allow this in case the player is the current group leader, but actually by checking if the current player is the leader of this particular quest.

As there are no means so far to change the `groupBossDevice` property in the course of the game, the group leader's device is directly set in the program code. This is done in the `negotiateGroupBoss` method of `GAIXQuestController`. Thus, changing the group leader device requires to recompile the whole software. We know this is bad programming style, but the use of these properties was initially a different.

Specifying the group leader device

The other classes of the GroupAIXplorer software prototype, e.g., the view controllers of the different screens of the quest game, are not interwoven in a complex way with other classes. They rather stand on their own and are simple in their usage. Thus, we will not give further explanation on these, as this is far beyond the scope of this work.

Chapter 6

Evaluation

So far this work described both the concept and the implementation of GroupAIXplorer, an interactive museum game with capabilities for a shared audio experience for small groups. The following chapter presents a user study which was conducted to find out whether the quest game concept indeed enhances group experiences in museums. It was of particular interest how users would deal with the concept of the group leader, as well as with the *discussion quests*. The outline of this chapter is as follows:

Section 6.1 describes the setup of the study, the hypothesis about the expected benefits of the game and the applied methods to gather data for later analysis. Observations from within the museum are then presented in section 6.2. Qualitative data from a questionnaire is evaluated in section 6.3. In conclusion, a final discussion on the results is presented in section 6.4.

6.1 Setup of the User Study

6.1.1 Task and Setup

Each user test session started with a short introduction on the quest game concept and a demonstration of the inter-

User test procedure

face. The users were then asked to fill out a consent form on the cover sheet of a questionnaire and to give statistical information about themselves (cf. Figure C.1 in Appendix C). Afterwards, the group was required to choose one player as the group leader. The software on one of the devices was preconfigured according to the group leaders capabilities, e.g., accepting quests, starting a quest's task explanation, and revealing the solution of a discussion quest (cf. section 5.2). This device was handed over to the elected player. The group was then requested to find and process all quests distributed in the different rooms of the museum. The group was told to be allowed to process the quests in any desired sequence. Processing a quest consisted of finding and accepting the quest, searching for the related exhibits, and master the quest dependent group activity. Furthermore, the instructor explained that the game solely took place in the first floor of the museum. The instructor then observed each group from a distance and helped users in case of technical problems. Solving all quests could take up to 90 minutes. Afterwards, the participants were requested to fill out the questionnaire. All in all, the study lasted at most two hours per group.

6.1.2   Hypotheses and Methodology

Five hypotheses were postulated which the user study would hopefully verify:

H1: The GroupAIXplorer quest game provides its users with a rich group experience.

H2: Visitors will not feel constrained in their freedom of movement.

H3: An elected group leader is an adequate way to deal with group decisions.

H4: The search of exhibits and the interactive quests enable collaboration and foster social interaction.

H5: The discussion quests enable communication among group members.

Furthermore, it was of particular interest whether the discussion quests would be accepted by the users. We were unsure if these kind of quests would be as appealing as the other quests because they barely offered any interaction with the game devices. Also, the system included by design no methods for semantical checks of answers from the group's discussion.

We deployed several means to acquire data for evaluation of these hypotheses:

The questionnaire handed out after completion of the game consisted of four pages (cf. Figures C.2 to C.5 in Appendix C). The first page presented six statements on the different quests and the quest game as a whole. Users were asked to rate these statements on a five point Likert scale in which the number 1 corresponded to "Don't agree at all" and 5 corresponded to "Total agreement". Furthermore, two free text forms asked for likes and dislikes of the game. The intention of these statements was to verify hypothesis *H1*. The second page included another seven Likert scale statements. These should provide data to evaluate hypotheses *H2* and *H3*. The second page also featured two questions on perceived device usage with default answers for users to check. Page three asked two questions on audio playback usage and two questions on collaboration during the game. The latter should support hypothesis *H4*. The fourth and last page of the questionnaire gave users a way to give general feedback in written form.

Another method to collect data on the quest game were audio recordings. The leader of each group received a voice recorder with an external microphone attached to the shoulder to record conversations over the whole game session. Of particular interest were the conversations occurring during the group activity phases of the quests. The analysis of these recordings should allow to verify hypotheses *H4* and *H5*.

Furthermore, software logging was deployed for usage analysis on each device. The following listing provides an overview of the different kinds of logged events:

- Interactions in the different user interface screens, e.g., quest selection screen, quest log screen and group information screen.

- Button selection in pop-up dialogs.

- Game state changes, i.e., accepting quests, start of a quest's group activity, and finishing quests.

- Interactions in the group activity screens, e.g., revealing solutions of discussion quest or answers in interactive quests.

- Usage of call over messages and their replies.

- Location-tracking, i.e., logging room names on change.

- Audio player usage.

The main intention of logging was to gather data on group dynamics, e.g., by logging call over messages and location changes. Also, they should help in later conversational analysis to provide contextual information regarding the corresponding game state. However, other interactions were also gathered, to possibly find further interesting aspects of usage. The device log files were later extracted from a database to plain CSV format, cleaned from duplicate entries and anonymized.

6.1.3   Participants

User description

The GroupAIXplorer system was tested with five groups of four to five people in the Aachen City Hall during business hours. 23 people were recruited to participate in the study. 21 users were between 21 and 34 years old. Two visitors were in the age group of 65 to 70. Four participants were affiliated with the Media Computing Group. The groups were arranged with respect to available times of individual users. Thus, users of a single group did not necessarily know each other. However, most users knew at least one other member in their group. Two groups consisted of two women and three men, two other groups were equally

composed of two men and woman. One group consisted exclusively of men. The average proportion of women was 35%.

The participants were asked for a self-assessment on their museum visiting frequency. Options to select from were *rarely* (defined as up to one time per year), *casually* (one to three times per year), and *frequently* (three times and more per year). 34.8% participants stated that they rarely go to a museum, 52.2% do so casually, and 13.0% considered themselves as frequent visitors of museums. Their self-assessed audio guide usage at museums was: 47.8% *never*, 39.1% *casually*, and 13.1% *always*. Figure 6.1 illustrates these values. For a detailed table of user statistics and group composition refer to Figure C.6 in Appendix C.

Self-assessed classification
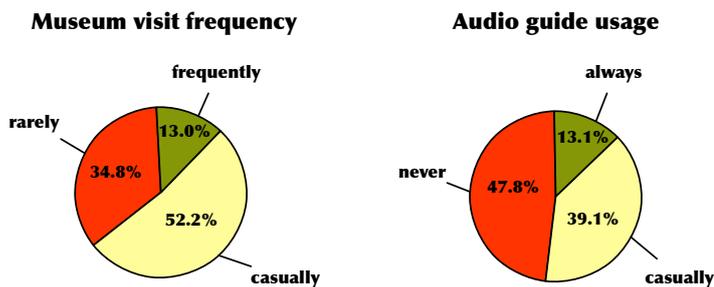
Figure 6.1: Museum visiting frequency and audio guide usage in museums of GroupAIXplorer participants.

Due to a network failure in the Aachen City Hall, the first two groups could not use the system in the intended way. These two groups hence played the quest game with only one device, which was carried by the group leader. The device's internal speaker was used for open air audio playback to allow non-leaders to listen to the quest's audio clips at all. Although the first two groups finished the game and filled out the questionnaire, their Likert scale rating was omitted from later analysis for the most part, as we felt that their results cannot be compared to those of the other three groups. Unless stated otherwise, the presented results originate from the questionnaires of groups 3 to 5, including 14 people.

Technical problems

6.2 Observations

All groups except one finished the quest game. Group four could only finish two quests, namely *The four virtues* and *Baroque Number Puzzle*, due to time constraints in the museum. An overview of the groups is provided by Table 6.1.

6.2.1 Group dynamics

Groups with a single device

The group dynamics observed during the study differed significantly between the groups with a single device and those with one device per player. The players' individual freedom of movement was mostly limited in groups with only one device. Players of these groups stayed together most of the time and kept a close distance to the group leader. This is no big surprise, as they had no other choice to stay up to date in terms of the quest status. Also, the lack of other means to stay in contact were a reason against increasing the distance to their team-mates. Members in these two groups showed different behavior: Some players stayed in the immediate vicinity of the leader and were active in finding solutions. Other members showed rather passive behavior in the search of exhibits and merely followed the others. The instructor was able to tell that two different participants—each in a different group—did not like the game due to these severe constraints. Those two participants made obviously a bored impression. This could be concluded afterwards by their responses in the questionnaire, too. One of those players stated the concept contradicted his way to visit a museum, as he was not able to solely decide on his path.

Groups with one device per player

Members of groups with multiple devices, however, had much freedom of movement. This allowed players to split up into smaller groups or even individuals, in order to look for quest related exhibits or to explore the museum. They rejoined every now and then to give each other feedback on their individual findings or to proceed with a quests' group activity. This matched our expectations on group dynamics when using the system in the intended way.

6.2.2   Quest processing behavior

Analysis of the device log files revealed an interesting difference regarding the way groups dealt with the five quests. Three groups showed a linear processing strategy. The players of these groups constantly focused on just one quest at a time and did not accept other quests in between. The other two groups seemed to accept every quest as soon as discovered and thus had multiple quests accepted in parallel. This difference in behavior does not relate to the different conditions of the five groups. Both the groups constrained to the use of one device and the groups with one device per player showed this behavior (cf. Table 6.1). Figures C.9–C.13 in Appendix C show excerpts from each group leader's log file. These excerpts illustrate the sequence on dealing with quests for each individual group.

Group No.	Size	No. of Devices	Quest Processing
1	4	only group leader	parallel
2	5	only group leader	linear
3	4	every player	parallel
4	5	every player	linear
5	5	every player	linear

Table 6.1: Information on the five groups of the GroupAIXplorer user study.

The instructor, however, did not notice this difference. This is due to the fact that he did not have insight into the game status while observing. Although these two groups accepted multiple quests in parallel, the group as a whole still focused on one quest at a time. Only in part players looked out for hints on the other quests to use them later or in case the group was stuck at a particular quest to continue on a different quest for the time being.

Nevertheless, the three groups that dealt only with one quest at a time did not have a disadvantage with this behavior. Their players still noticed other available quests and remembered their location without the use of the system. This behavior was actually observed by the instructor in group 5. When they discovered *The three hands* in the staircase the group deliberately did not accept this quest,

as they were busy with *Discover the Habsburgs* at that time. When they found the portraits of the Habsburgs in the Council Hall, they also discovered the portrait of Francis II, showing him with a third hand. So this group found the exhibit of the quest right before having the quest accepted in the game system. Later, when the group finished the discussion on the Habsburgs quest, they did not have to search the start of *The three hands*. They went straight to the staircase, accepted the quest and walked back to the Council Hall to start the group activity of that quest.

6.2.3   Call Over Usage

The reason for these two different behaviors on quest processing is unexplained, yet. However, we believe that personal preferences of the group leader are a critical factor on this, as he or she was the only player allowed to accept new quests. As described in 5.2.4—"Communication interface", other players had the opportunity to call the group leader over to accept a quest, but the instructor did not observe such behavior for groups 3-5. The Call over function in general, however, supported these groups when members were out of sight or at greater distance. The instructor observed that these groups split up and merged several times, also by use of the system. The log files from groups 3-5 also showed a regular use of this feature, illustrated in Figure 6.3. These files are also available for download:

Were leaders called to start a quest?

In regard to this issue, it was of particular interest if non-leaders called the group leader to start or to finish a quest. The instructor did not observe such behavior in any group. The log files revealed a similar picture. There is only one occurrence where this feature was actually used. Group 3 was dealing with the *Discover the Habsburgs* quest for some time. They had already found the Habsburgs portraits in the Council Hall but after listening to the task explanation, they decided to cancel the group activity as they felt not ready to answer the question. Thus, the group went back to the Red Room where they had accepted the quest. Two members of the group consulted the *Friedenstisch* to learn more on Maria Theresia and the persons involved in the War of the Austrian Succession. At that time, the group

User:	Times the user was called	user replied to come over	user replied busy	confirmation ratio
10	11	11	0	100 %
11	8	6	2	75 %
12	4	4	0	100 %
13	4	4	0	100 %
Average in group 3:	6,75	6,25	0,5	93,8 %

User:	Times the user was called	user replied to come over	user replied busy	confirmation ratio
14	16	10	6	62,5 %
15	6	5	1	83,3 %
16	14	11	3	78,6 %
17	15	14	1	93,3 %
18	8	7	1	87,5 %
Average in group 4:	10,75	9,25	1,5	85,7 %

User:	Times the user was called	user replied to come over	user replied busy	confirmation ratio
19	19	13	6	68,4 %
20	17	9	8	52,9 %
21	12	8	4	66,7 %
22	18	18	0	100,0 %
23	15	13	2	86,7 %
Average in group 5:	15,5	12	3,5	76,6 %

Figure 6.2: Call over function usage overview.

did not progress much regarding the question. So the other members explored the museum while the group leader and a female team-mate stayed at the table to read more on this topic. After a while another member discovered the quest *The three hands* in the staircase. He called the leader to come over to accept the quest. Figure 6.3 shows an excerpt from the group leaders log file that illustrates the successful use of the function.

> File: Log files used for Call Over usage analysis[a]
>
> ―――――――――――――――――
> [a]http://hci.rwth-aachen.de/~wermers/thesis/downloads/callOverUsage-Analysis.zip

6.2.4 Collaboration

The instructor observed that players gave each other feed-back on their findings when merging with other players.

Time	Type	Action	Details
15:22:21	UI	placeChangedTo	Lobby
15:22:34	UI	placeChangedTo	Red Room
15:28:38	UI	vcChangedTo	GAIXGroupInfoViewController
15:28:41	UI	vcChangedTo	GAIXPlaceViewController
15:30:21	UI	vcChangedTo	GAIXCallOverNotificationViewController
15:30:21	COVC	calledBy	User 12
15:30:21	COVC	toStartQuest	The three hands
15:30:21	COVC	atRoom	Staircase
15:30:39	COVC	sentConfirmationTo	User 12
15:30:39	UI	vcChangedTo	GAIXPlaceViewController
15:30:52	UI	placeChangedTo	Staircase
15:30:57	Interaction	selectedUnplayedQuest	1_Die_drei_Haende
15:30:57	audio	init	1_Die_drei_Haende_01_Einleitung.mp3
15:30:57	audio	play	0
15:31:01	audio	closed	0.2860771
15:31:01	Interaction	AlertView	kAudioPlayerStartQuest
15:31:01	Interaction	clickedButtonAtIndex	1
15:31:01	questState	active	1_Die_drei_Haende

Figure 6.3: Example for the use of the call over function to ask a group leader to start a new quest at another place.

This included for example exhibits that they assumed to be the searched ones. They also gave each other information on rooms they already checked for the searched exhibits. But also casual communication which was not directly related to the search of the exhibits was observed. For example, one player mentioned to his companions that Charlemagne probably had a lot of women. This information did not help the group in their search for the Charlemagne portrait, but it just belonged to the natural social interaction of the group.

By analyzing the voice recordings from the user study, we also found multiple occurrences of collaboration. The following *Excerpt I* (pg. 78) is only one example, but it is representative for groups 3 to 5. The transcription was created by following the instructions on conversational analysis by [Antaki, 2010]. Table 6.2 gives an overview of the notation used. We analyze in the following the social interaction and collaboration of group 4 when processing the group activity of *The four virtues*. As described in section 4.2, the group has to identify symbols on a ceiling fresco. The members of the group, Peter, Paul, Bob, Stephen, and group leader Jim know that these symbols represent the four cardinal virtues Prudence, Fortitude, Temperance, and Justice, but they do

Notation	Explanation
((...))	Action of a person or comment to describe the situation.
(*n*)	A conversational pause of *n* seconds.
my [talk [your talk	Alignment of overlapping speech or actions.
A: word= B: =words	The equal sign indicates that there is no pause between two speaker's turns.
\<word\>	Outward arrows show slower speech.

Table 6.2: Summary of transcription notation for conversational analysis.

not know the correct matching. The graphical user interface of this group activity was shown in Figure 5.12. The situation in this excerpt is as follows.

The group has previously identified the symbol for Justice. Hence, the members only have to deal with the three remaining virtues. They already described their guesses to each other regarding these other symbols. But as they do not know the correct correlations, they are stuck in their progress. In this scene, Peter has to find the symbol for Fortitude and Bob the symbol for Prudence.

Prologue of Excerpt I

Peter however does not want to guess any longer and suggests to select the symbol he previously presented as his guess for Fortitude (lines 1-4). However, Peter does not put his suggestion into practice as Paul starts laughing and Jim weakens the suggestion by sharing another suggestion on the symbol (lines 5-6). After a distinct pause, Peter deviates from his suggestion and asks the group for the virtue they already solved (line 7). Jim and Bob answer him. While Jim is the first one to answer, Bob's answer adds some additional information regarding the context ("Justice, the only one we recognized") which Jim immediately comments on (lines 8-12). Peter then guesses the meaning of another symbol, which shows an old man with a book. The other group members apparently have to think about

Explanation of the scene

this for a while, as the pause in speech is very long (line 13). Stephen, who had no chance to speak so far, takes this opportunity to provide the group with his thoughts on the old man (lines 14-16). Paul is not convinced by Stephen's elucidation and cut's in to support Peter's suggestion. Jim, however, is amused by Stephen's explanation (17-19).

Excerpt I.

1	Peter	I simply say this is Fortitude (.)
2		((shows Jim the symbol for Temperance))
3		even if what she holds in her hand looks
4		like a wooden spoon. (0.5)
5	Paul	[((laughs))
6	Jim	[I would guess it's a mirror... (2.6)
7	Peter	what was the fourth virtue? (.)
8	Bob	uhh [(1.6)
9	Jim	Justice.
10	Bob	Justice, the only one we recognized.
11	Jim	((said laughingly)) Justice is the only easy one (.)
12		yeah, right. (1.8)
13	Peter	then the one with the book is Prudence? (4.6)
14	Stephen	maybe the old man is for Temperance?
15		<Temperance of age> (0.2)
16		<calm[ness>...
17	Paul	it could also [be Prudence.
18	Jim	[((giggles))
19		(1.7)
20	Peter	if that's Prudence then could uhhh=
21	Jim	=is this a book at all? (0.9)
22	Stephen	it is a book, yes. (0.6)
23	Paul	then I would say that this is Prudence. (0.2)
24	Stephen	yes, I'd say so, too=
25	Bob	=should I just select that?
26	Several	yes! (0.2)
27	Jim	just give it a try. (1.1)
28	Bob	((selects the old man on his device))
29		((jokingly)) do you think reading books
30		brings Prudence?
31	Paul	((giggles))
32	Bob	[((listens to the audio feedback of his selection))
33	Jim	[which one's do remain? Temperance and
34		Fortitude? (0.2)
35	Bob	it was correct!

36	Stephen	yeah!
37	Bob	wonderful. (0.3)
38	Peter	well, I'll try now this strange wooden spoon. (0.4)
39	Jim	yeah, try it!
40	Peter	((Selects the symbol of Temperance for Fortitude))
41		((The group curiously waits for his feedback)) (5.3)
42	Bob	so? (1.5)
43	Peter	<yeeaahh...> it was wrong. (0.2)
44	Stephen	((short laugh))

After a notable pause, Peter further tries to make another suggestion, but stops, so that Jim questions if the group correctly perceived the symbol at all (lines 20-21). Jim's concerns are unmade by Stephen, who is sure that the old man is holding a book in his hands ("it is a book, yes.", line 22). Due to this insight, Paul draws the conclusion that this symbol has to be Prudence, and Stephen immediately agrees with him (lines 23-24). Now Bob steps in, as he is the player who is required by the GroupAIXplorer system to select the correct symbol for Prudence. Thus, he verifies if the other group members share Stephen's and Paul's opinion ("should I just select that?", line 25). Several teammates affirm his question, and Jim furthermore encourages Bob to select the old man ("just give it a try.", line 27). While Bob switches the picture on his device to the old man, he is joking on the implication of this mapping ("do you think reading books brings Prudence?", line 30), which amuses Paul. While Bob listens to the feedback audio, group leader Jim focuses already on the remaining virtues, but asks the group if he had remembered them right (lines 33-34). Before anyone can answer Jim's question, Bob tells the group about the outcome of his selection (line 35). Stephen acknowledges the positive result ("yeah!", line 36), maybe because he affirmed the question whether the symbol really features a book. Then, Peter steps in again, as he refrained from the previous discussion and as he still has to make a selection for Fortitude. Again, Peter states to choose his suggestion, but this time, he is encouraged by Jim ("yeah, try it!", line 39), who originally weakened Peter's opinion (cf. line 6). As Peter now affirms another selection, the group is silent as they are all curious if the selection was right. After a long pause, Bob checks back on

Peter ("so?", line 42). Peter then tells the group about his
wrong selection. Although his answer was wrong, Paul is
still amused by the situation (lines 43-44). Subsequently, the
group solved also the last virtue—Temperance. This made
no problems, as only one symbol remained.

This excerpt and the provided conversational analysis
demonstrates on numerous occasions that collaboration
and social interaction among the group members occurred.
Thus, we see hypothesis *H4* verified.

6.2.5   Communication

In this section, we analyze the communication which took
place in the discussion quest *The three hands*. In this quest
the groups had to contemplate on the question why Em-
peror Francis II is shown with three hands on a portrait (cf.
subsection 4.2.2). The reason was that the artist painted him
over the portrait of an old lady. Instead of providing a tran-
scription of one single excerpt like in the previous section,
we describe informally the discussions that took place in
the individual groups, perceived from the voice recordings.

In group one, the group leader immediately came up with
the correct answer. The other male player agreed with him,
while the two women in the group had another idea, "be-
cause he is standing behind (her)". However, the group did
not discuss further on this, as the male players were confi-
dent about their answer. The two woman did not try to
prevent the group leader from revealing the quest, maybe
because for the members of this group the experience was
rather unvaried, as they only had one device for the whole
group.

Group two first analyzed the picture and then drew con-
clusions for the discussion. They came up with the idea
that the person behind the Emperor strives for the power
of the emperor. They further ponder on the question which
famous person this could be. One player suggested that
the hand could be from Napoleon Bonaparte, because he
believes at that time Emperor Francis was merely a mari-
onette of Napoleon. The group agrees on this answer and

then reveals the solution audio clip. As the actual solution is rather simple, they are amused that they came up with a very sophisticated answer which still was wrong.

In group three, one user suggested that the hand belongs to the ex-wife of the Emperor. He further describes his idea, in that Francis charged an artist to overpaint her. The group leader is not convinced, so the other players . They also recognize that the hand definitely is female.

In group five, one woman immediately guessed the correct answer. However, she also found a reasoning for this oddity, which is similar to the one found by group three. The only difference is she believed the woman was the girlfriend, not the wife of the emperor. Moreover, she suggested that the woman originally stood behind him. Later, when the two broke up, the Francis would have charged an artist to remove her from the painting. Although other group members were skeptic on this invented story, the group discusses this possibility. One male member opposes, that the woman could have barely looked over his shoulder. He is not convinced at all of this story. The group leader suggests that he believes the hand is intentionally on the portrait, as he cannot see any traces of two different layers. The woman then adds jokingly that maybe the emperor just had three hands.

In the other two discussion quests, *May 15, 1865* and *Discover the Habsburgs* discussions could still be observed in some groups, but were shorter in length, as the questions were not as open as the one of *The three hands*. However, our observations still support hypothesis *H5*.

6.2.6 Other findings

We noticed that hardly any player volunteered right away when the group was asked to decide on their leader. Instead, players hesitated and waited for other players to do so. Finally, one player agreed being the group leader so that the game could start. We did not expect this behavior. To the contrary, we thought some players might even wrangle on this role. Maybe this is in part due to the constellation of

Group leader election

our groups as the participants did not now all other players of their group and thus were in an unfamiliar situation.

6.2.7   Problems

There were some minor issues in the design of the quests, due to ambiguities regarding the painting to find. During the quest *The Three Hands* one group discovered a portrait of Napoleon Bonaparte, on which he holds the Manus Iustitiae, the hand of Justice. As the group did not discover the portrait of Francis II yet, they thought this must be the painting mentioned in the *introduction*. Coincidentally, the two paintings were in the same room, thus it was possible to start the *task explanation* for this quest. Naturally, the group was confused to see a different portrait on their device and to hear that they successfully found the painting of Francis II.

A similar problem occurred during another quest that required the group to find a specific portrait of Charlemagne that depicts a puzzle with roman numbers. Regardless of the fact that the *introduction* explicitly mentioned that the portrait could be anywhere in the museum, the group thought it had to be the portrait of Charlemagne in the same room the quest was starting in. Though this painting did not show any roman numbers at all, the group tried to find some for several minutes. This demonstrates that quests not only need to be carefully designed, but also verified through user tests, before actually deployed in a real game.

6.3   Questionnaire Analysis

6.3.1   Likert Scale Results

The Likert scale ratings from the questionnaire approve the general impression of the instructor that groups liked the game concept and had an entertaining group experience. Figure 6.4 illustrates the ratings of statements on the quest

game[1]. A.1–A.4 asked for the liking of the different kinds of quests. Groups especially liked the interactions in the quest *The four virtues* (A.2). But also the group discussion quests were popular (A.3 and A.4). The avarage rating of *Baroque Number Buzzle* however is slightly lower compared to the other quests and tends to polarize players. Some of the commentaries from the questionnaires shed light on possible reasons. Users 11, 12, and 14 stated they did not like that only two group members were able to enter a solution. User 15 complained about a low awareness of other players' activity in this quest. On the whole, the quest game was liked very much and users considered the concept to be suitable for small groups visiting a museum (A.5 and A.6). Thus, we consider hypothesis *H1* being fulfilled.

We would like to mention that also most of the users from groups 1 and 2 liked the quest game. As a consequence of the missing device interactivity for most of the players, the interactive quests were rated on average slightly lower. The discussion quests on the other hand received a slightly better rating.
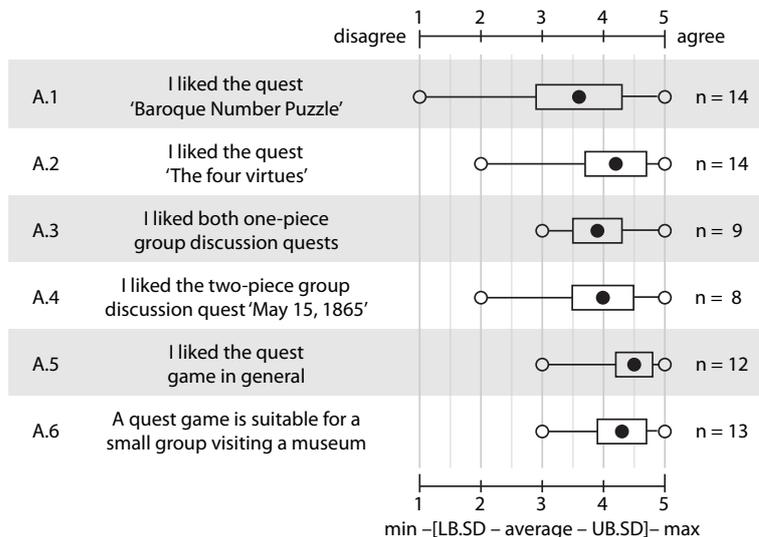
Figure 6.4: GroupAIXplorer questionnaire results from page 1, measured on a five-point Likert scale.

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[1]The Likert scale ratings are presented by Figures C.7 and C.8 in Appendix C.

The intention of the second part of the Likert scale statements was to receive ratings on design decisions made during the development of the game. Figure 6.5 provides insight on the results. The rating on statements B.1 underpins the instructors observations of a high freedom of movement as visitors did not feel constrained in their freedom of movement. Furthermore, the predefined messages to call distance players over were rated very high regarding their usefulness but only slightly above average when asked how well they worked out (B.2 and B.3). A reason for the latter can be found in the bad network performance in Aachen City Hall which could result in long delays until messages were received. However, we believe that the high level of freedom of movement was a critical factor for the success of the game. Our comparison of the observed group dynamics between groups with one single device and the groups with one device per player supports this statement. These findings hence support hypothesis *H2* .
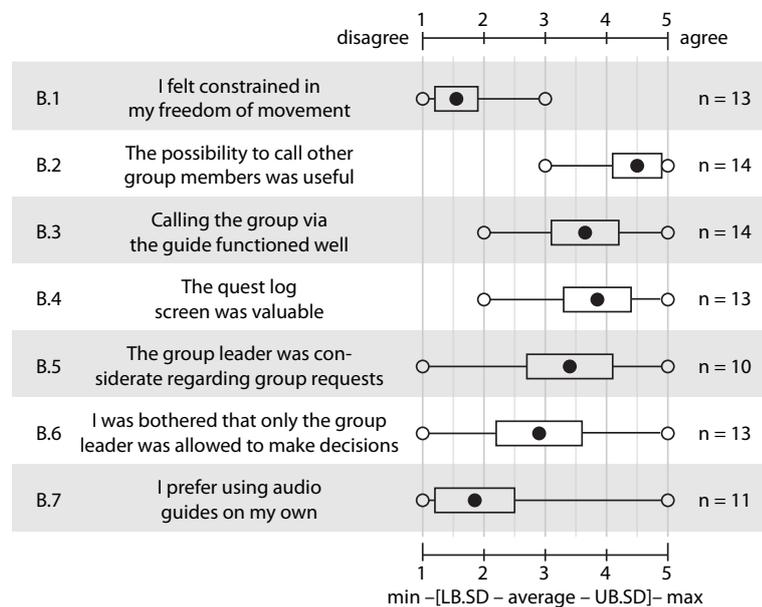

Figure 6.5: GroupAIXplorer questionnaire results from page 2, measured on a five-point Likert scale.

The concept of the group leader, however, was very polarizing (B.5 & B.6). About half of the participants had no problem at all with this concept. The other half stated the leader had too much power or was not considerate enough

regarding individual requests. We believe this is in part due to personal preferences concerning leadership and equality, but also due to the soft skills of the individual leader. Only few players provided written feedback on this issue. User 12 complained that the powers of the leader are exaggerated in terms of accepting quests. He suggested that every player should have the capability to accept new quests. Interestingly, this user was the only person who actually made use of the feature to call over the leader to accept a quest at his place. User 15 stated that the devices of non-leaders were very passive regarding the game. It is worth mentioning that also one group leader did not liked being the only player to make decisions.

As players had very different opinions on the group leader concept, we do not see hypothesis *H3* being verified.

Last but not least we found that the quest-log screen served its purpose to provide groups with an overview on their progress (B.4). We also found that the majority of participants do not prefer to use audio guides on their own (B.7). In what follows, we present some other interesting written statements from the questionnaires.

6.3.2   User Statements

In the following section, we present some interesting statements from the various free text forms included in the questionnaire.

One woman from group 5 mentioned that she was less attentive when listening to a usual audio guide, where "the information rushes past". In contrast to this, she listened more attentively to the GroupAIXplorer, since she knew that she would need that information to solve the quests. She stated she processed information from our guide easier than from conventional systems. A player of the first group described that visiting the city hall was more interesting and immersive with the system due to being in a group and thanks to the tasks. Another user compared revealing quests to a scavenger hunt and expressed that this was exciting and amusing. Also of interest, a male user from

group 4, which stated to rarely visit museums, told to have a higher motivation to look upon paintings and texts in the museum, due to the quest game.

Map of Aachen City Hall

Some players wished to have the possibility to see the map of the City Hall at any time, and not only when players called each other. Reasons for this were for navigating the rooms, but also to be aware of other players locations. In regard to the latter, we deliberately decided against group observation due to privacy reasons. Considering that users in a real world setting will most likely consist of friends or family, this decision might be exaggerated. However, at least a pure map of the museum showing the room names should be available for players of the game.

Almost all players stated in the questionnaire that they listened the introductory audio clip and the task explanation for multiple times. Thus, some users stated they would have liked to have a textual task summary of the tasks displayed on the device. It was hard for them to grasp every detail from audio only. This is not surprising because audio is a transient information channel.

One user recommended that some quests should start and end in the same room. He suggested to let *The four virtues* start in the Council Hall, so that users immediately discover the ceiling fresco. However, we consider the searching of the exhibits as an integral part of the game.

Other wishes that appeared repeatedly were related to the actual historical content provided through the quests. Several users would have liked to gain more information. However, one should never forget to consider that other players might be less interested in excessive history lessons. Interestingly, one user explicitly liked that the game did not include "boring, long recitations about the history of the city".

6.4 Discussion

We knew that the group leader concept was a very strong design decision. Although we had considered more sophisticated ideas that could balance the powers of the leader, we wanted to start with a relatively basic system and gain some ground data first. We further thought it might be the case that the social setting of the group balances possible downsides of such a system. However, we found no evidence for this. Yet, we want to highlight that not as many people refused the idea of a group leader completely.

Group leader concept

Only a few of the participants stated to visit museums frequently. Thus, it is left unclear if the presented results are valid for typical museum visitors. Even so, we found no statistical significance between the liking of the game and the frequency of museum visits. However, an interesting observation is that some of the infrequent museum visitors mentioned to have a higher motivation to look upon paintings and texts in the museum, due to the quest game. Thus, we believe that the quest game concept is a chance for museums to broaden their visitor audience.

Museum visiting frequency

The system log files revealed that non-leader players did not make successful use of the function to call over the group leader to accept a quest at their place. We believe this concept was either too complicated in its design or it could be that users considered it easier to search the leader by themselves and convince him on the spot to start a new found quest. It is possible that this part of the calling interface was simply unneeded as the Aachen City Hall is a small museum and because all quests were played in the first floor.

Call over to start a quest

An interesting result of our research was that the discussion quests were very popular. We feared that users might consider them less appealing compared to the other quests, e.g. *Baroque number puzzle*, as their activity provided hardly any interaction with the game system. Although the system provided no mechanism to validate the individual answers given in the discussion, users preferred them to the interactive quest *Baroque number puzzle*.

Discussion quests

Chapter 7

Summary and Future Work

This chapter provides an overview of the whole project. It summarizes the evolution of the presented system and recapitulates associated design decisions made in the course of it. Contributions in the field of interactive museum guides are pointed out, as well as concepts that were not successfully realized. Finally, ideas that could not be part of this thesis are given along with a recommendation for fields of further investigation for research.

7.1 Summary and contributions

In this thesis we dealt with the problems for small groups using audio guides in a museum. Stereo headphones and no means for awareness of companions' activities often result in a rather isolated experience and a lack of social interaction. Therefore, we developed GroupAIXplorer, an interactive, collaborative audio-visual multiplayer game and applied in the City Hall of Aachen.

In chapter 2—"Related Work" we described how we were influenced by several other systems. Some of them included methods for shared listening of audio content to raise awareness of companions' activities and thus fos-

ter social interaction. We also found that interactive museum games encourage collaboration and social interaction among group members. As the shared listening concept was only applicable for groups of two, we decided to develop a system that utilizes an interactive museum game to allow synchronous audio playback for multiple persons.

Starting at this idea we developed a quiz game with multiple-choice questions, presented in chapter 3. The developed paper prototype focused on the game concept which mapped the topics of questions to different rooms of a museum. Thus, the game directed users through the museum from question to question. In a small-scale user study we found that the limitations in players' individual freedom of movement associated with our concept were too severe. Furthermore, the multiple-choice questions offered no possibilities for collaboration and barely encouraged social interaction. Another important finding was that some users felt being tested for their knowledge. They found this an undesirable experience when visiting a museum.

Therefore, a new game concept was conceived as described in chapter chapter 4, which addressed the problems of the quiz game. The multiple-choice questions were replaced by quests. These quests no longer directed the group through the museum. Instead, players were encouraged to search for an exhibit with certain features. Freedom of movement was preserved by allowing players to split up in their search. The main part of a quest, however, was an activity which could only be processed as a whole group. We then also formulated a concept for shared listening to foster communication. It included to mediate audio information on the featured exhibits at the beginning of a quest, when the group found a related exhibit, and at the end of a quest. As we wanted to evaluate our game design in the Aachen City Hall, we arranged a guided tour with Georg Helg, the representative chairman of the Aachen City Hall society. We learned numerous stories about several exhibits, and created five appealing quests for our game. Two quests featured an interactive riddle in order to achieve collaboration and social interaction. Three other quests focused on telling a story about various persons found on portraits in the city hall. The group activity in these quests was to discuss an openly asked question about the depicted per-

sons. Resulting from the findings on multiple-choice questions, one particular design decision was not to require a group to enter or select an answer. Instead, the group as a whole could decide when to reveal the solution. The intention of this design was giving users more freedom for own thoughts and encouraging communication. Our hypothesis was that this kind of activity would still be a valuable group experience, although users might reveal the solution whenever they want. We introduced a group leader to resolve the problem of different opinions in a team. We gave the group leader much competencies in order to research in a user study how members of a small group will cope and react with this situation.

In chapter 5—"GroupAIXplorer Implementation" we describe how the quiz game was realized in a software prototype. We explained how the different phases of a quest can be accessed by the players. We also presented the implications of the group leader concept for the user interface. Most prominent for the success of the freedom of movement concept, we developed a method to call over players via the game system. We explained these concepts in a detailed usage szenario.

The results of chapter 6—"Evaluation" showed that the work presented in this thesis is a sensible approach to address problems of present audio guide usage in groups. The GroupAIXplorer quest game offered the participants of our user study a rich and entertaining group experience. The quests gave visitor groups multiple opportunities for social interaction and face-to-face communication. The users experienced together several stories about the featured exhibits by the use of synchronized audio clips during the progress of the game. Therefore, the problem of isolation was successfully addressed. Although the goal was to provide a group experience, individual interests and the freedom of movement of each visitor were preserved. We showed that users did not feel constrained, although the game made it necessary to merge with the whole group to finish quests. This freedom to explore the museum at will further enabled collaboration in the search of quest's exhibits. Groups split up spontaneously to find exhibits faster. Members continually rejoined again to exchange about their particular findings. The call over function of

our system supported them in the course of this. Collaboration was also achieved in the interactive puzzles of *The four virtues* and *Baroque number puzzle*. We provided evidence for collaboration in our observation in the museum as well as in the analysis of voice recordings. Last but not least, the presented quest game found high approval among our users. The questions from the *discussion quests* were very popular, although the game system did not include any means to verify answers given in the discussion. Thus, we believe our hypothesis was right, that activities without a check of the system may still lead to a valuable group experience. As most participants of our user study considered themselves as infrequent museum visitors, we believe that the concept our quest game can offer museums a chance to reach a broader audience.

Not surprisingly, however, were the results regarding the group leader. Users either did not like the concept or had no problems at all with it. As described in section 6.4, we deployed a simple concept for the first system in order to gather first results. Thus, this part of the system needs more elaborate research.

7.2   Future work

7.2.1   Group leader concept

As we found that the group leader concept needs further research, we formulate three different approaches in conclusion.

Social aspects

In our observations in the museum we found that players did not volunteer right away when a group had to select its leader. It would be interesting to determine if this behavior would change for groups that are very familiar with each other, e.g., family members or longtime friends. It is also of interest if the concept of one leader still is adequate for those kinds of groups. We further want to express the eventuality that due to this hesitation it were the more leader-like persons that finally volunteered for this

position. Maybe the system should hence start with a short psychological test to identify the players with the highest social competencies and propose them as the group leader. However, this approach bears the risk that users might feel patronized by a technological system, which is very undesirable. Regarding social aspects, we want to mention that possibly even the term *leader* itself was improperly chosen for this role which should more function as a group *mediator*.

Further research should also address alterations of the concept itself. For one thing, it would be of interest if the users perception of the group leader would change if non-leaders were allowed to accept quests and to start a quest's group activity once the group is gathered around the exhibit. These two limitations seemed to be the most severe ones for the non-leaders. We recapitulate that the reason for the group leader concept started with the design of the discussion quests. Those made it necessary to decide when to reveal the solution as we did not want to enforce a time limit. Thus, we propose to modify the system in such a way that one player is merely elected as the moderator of all discussions, but besides that all players have equal powers.

Equality to the greatest possible extent

Other ways to balance the power of the leader would be to change the concept from group leadership to a quest related leadership. That means, several players get the power of the group leader, but only for specific quests. Leadership could be given to the player who accepts a new quest. However, in this case one might need a sophisticated way to prevent single players to simply accept all quests. As we had this type of idea actually in mind as a possible later improvement, the GroupAIXplorer implementation already features the flexibility to associate leadership with individual quests, as described in 5.3—"Software Architecture". Thus, research in this direction would not take too much effort in means of software extension.

Distributed leadership

It would be interesting to perform a user study with a system modified in one of this ways and to compare its results with those presented in this work.

7.2.2 Further Research on Group Dynamics

Our findings on group dynamics were gathered from our observations from within the museum, from quest processing behavior and Call over usage analysis. However, the log files gathered would allow much more sophisticated analysis. Unfortunately, in group sizes of four or five, it is impossible to get an overview of group dynamics development and alterations throughout the game simply by viewing text files. The challenge is to connect the individual files and create a broader picture of the game for later analysis. Therefore, we propose to implement a visualization tool that displays the data of all logs of a group in a meaningful way. This tool should feature a map of the museum which displays the location of the individual players. It should further visualize the game status, quest related user activity—like listening to the introduction of a quest—and the use of the call over feature. The interface could include navigation buttons to pause/play and fast forward/backward the scene. Figure 7.1 presents a rough sketch of this idea.

7.2.3 Implementation extensions

In future versions of the GroupAIXplorer the following issues reported in our user study should be fixed. Those issues were:

- a map of the City Hall, accessible at any time;

- textual summaries of the introductory and task explanation audio clips;

- resolved ambiguities in the design of quests.

Last but not least, we present another interactive quest we had in mind we could not realize due to time constraints. The idea is to make use of the Ubisense high precision location tracking system installed in the Coronation Hall in the upper floor of the Aachen City Hall. The group activity of this quest is supposed to measure collaboratively the size
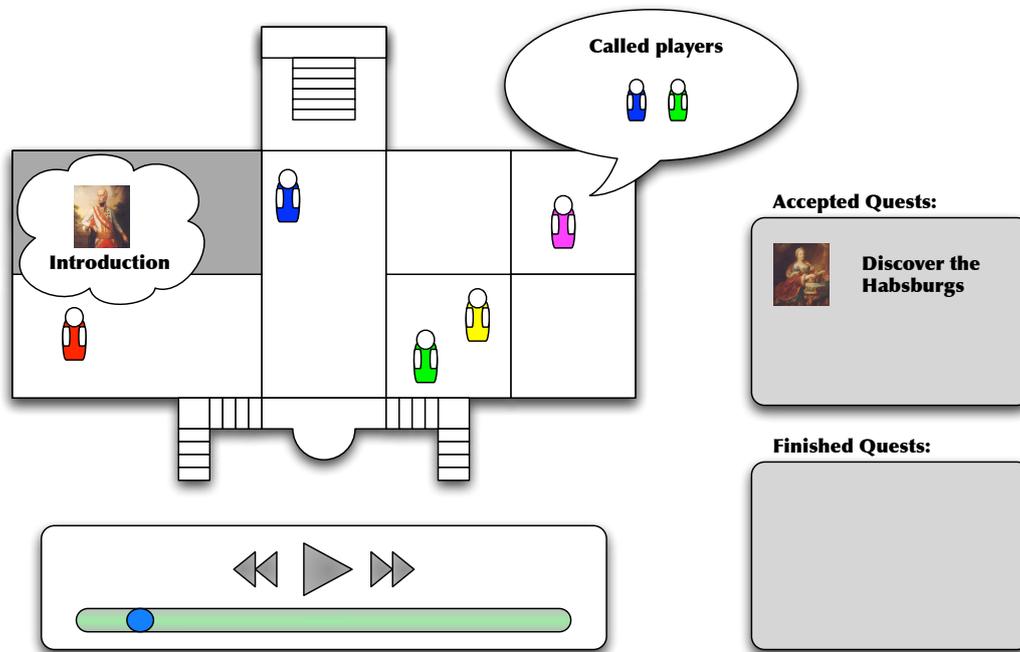
Figure 7.1: Sketch of the proposed group dynamics visualization tool.

of the Coronation Hall. Users will be required to fan out into all four corners of the room. The system would then calculate the size of the rectangle spanned by the users positions. Before users start fanning out, they are required to guess the actual size. This activity will be embedded in a story where the users that the Coronation Hall was accessed in the past from one of the narrow sides of the City Hall. Thus it appeared even more majestic as today.

Appendix A

German texts of audio clips

Die vier Tugenden	
Start: Weißer Saal	**Ziel:** Ratssaal
Einleitung:	Auf einer der vier Säulen im weißen Saal ist ein Löwe abgebildet. Dieser gehört zu den vier Grundtugenden nach Platon. In einem anderen Saal des Rathauses gibt es ein Deckengemälde aus der Renaissancezeit, welches alle vier Tugenden darstellt. Können Sie es finden?
Aufgabe:	Auf dem Deckengemälde werden die vier klassischen Grundtugenden Tapferkeit, Gerechtigkeit, Mäßigung und Weisheit dargestellt, auch bekannt als Platons Kardinaltugenden. Finden Sie zu der Ihnen angezeigten Tugend das passende Deckengemälde.
Feedback:	• Richtig, der Mann mit dem Buch steht für Weisheit. • Richtig, der Löwe steht für Tapferkeit • Richtig, die Dame mit dem Spiegel steht für's Maß halten. • Richtig, die Justitia mit der Waage steht für Gerechtigkeit. • Tut mir Leid, Ihre Antwort ist leider falsch.
Lösung:	Die Weisheit wird dargestellt von einem Mann mit einem Buch in der Hand. Der Löwe steht für Tapferkeit. Die Frau mit dem Spiegel ist ein Zeichen für's Maß halten, wohingegen die Gerechtigkeit von der Justitia mit der Waage dargestellt wird.

Figure A.1: German texts of *The four virtues* audio clips

Barocke Zahlenrätsel			
Start:	Ratssaal	**Ziel:**	Werkmeistergericht
Einleitung:	Ein Chronogramm ist ein Sinnspruch oder eine Inschrift, meist in lateinischer Sprache, bei der alle darin vorkommenden Buchstaben, die zugleich römische Zahlensymbole sind, für ein Zahlenrätsel verwendet werden. In der Barockzeit war es unter Malern sehr beliebt solche Zahlenrätsel in Ihre Bilder einzubauen. Hier im Rathaus befindet sich ein Gemälde aus dieser Zeit, das Karl den Großen darstellt, und ebenfalls ein Chronogramm enthält. Halten Sie Ausschau nach dem Gemälde, um das Chronogramm mit der ganzen Gruppe gemeinsam zu entschlüsseln.		
Aufgabe:	Um ein Chronogramm zu entschlüsseln, müssen alle hervorgehobenen römischen Zahlen aufaddiert werden. Das Ergebnis gibt dann das Entstehungsjahr des Kunstwerkes an. Auf dem Gemälde "Karl der Große" von Johann Chrysant Bollenrath befindet sich ein so genanntes Doppelchronogramm, d.h. es beinhaltet zwei Chronogramme direkt hintereinander, welche jeweils die gleiche Jahreszahl ergeben. Carolus Magnus huis sedis regalis et urbis granensis ist das erste Chronogramm, laudabilis de pannis ibi statuentis iudicii patronus das zweite. Beachten Sie, dass das Bindewort 'et' in der Mitte die Trennung der beiden Chronogramme kennzeichnet. Addieren Sie zusammen mit Ihren Gruppenmitgliedern die rot markierten römischen Zahlen des oberen / unteren Chronogramms.		
Feedback:	• Herzlichen Glückwunsch! Sie haben das obere / untere Chronogramm erfolgreich entschlüsselt. • Tut mir Leid. Ihre Antwort war leider nicht korrekt.		
Lösung:	Die Übersetzung der beiden Chronogramme lautet: "Karl der Große, Patron dieses königlichen Sitzes und der Stadt Aachen, sowie des löblichen hiesigen Werkmeistergerichts." Die Lösung beider Chronogramme ist 1730, und gibt das Jahr an, in dem das Gemälde entstanden ist.		

Figure A.2: German texts of *Baroque Number Puzzle* audio clips

Die drei Hände			
Start:	Treppenhaus	**Ziel:**	Ratssaal
Einleitung:	Im Rathaus gibt es manch eine Kuriosität zu entdecken. So existiert ein Gemälde, auf der eine Person drei Hände hat. Halten Sie die Augen danach auf...		
Aufgabe:	Sie haben das Gemälde von Kaiser Franz II gefunden. Können Sie sich erklären, wieso er auf dem Gemälde drei Hände hat? Überlegen Sie zuerst mit Ihrer Gruppe, was der Grund hierfür sein könnte, bevor Sie zum Abschluss der Quest die Auflösungsschaltfläche anwählen.		
Lösung:	Manche Leute behaupten, der Kaiser wird hier mit drei Händen gezeigt, da er die drei Aachener Stücke der Reichskleinodien klaute und nach Wien bringen lies. In Wahrheit wurde vom Maler des Gemäldes eine schon benutzte Leinwand wiederverwendet. Die darauf vormals abgebildete Dame wurde einfach von ihm übermalt. Dies wurde erst bei Restaurationsarbeiten entdeckt, und der Restaurator beschloss zur Erinnerung eine Hand der Dame herausschauen zu lassen.		

Figure A.3: German texts of *The three hands* audio clips

Finde die Habsburger!			
Start:	Roter Saal	**Ziel:**	Ratssaal
Einleitung:	Wie sie am Friedenstisch erfahren können, brach der österreichische Erbfolgekrieg aufgrund der Thronbesteigung Maria Theresias von Österreich aus. In einem anderen Saal des Rathauses befinden sich Gemälde von ihr, sowie von zwei weiteren ihr nahe stehenden Personen. Können Sie diese finden?		
Aufgabe:	Sie haben das Gemälde von Maria Theresia gefunden. Aber wer sind die beiden Herren links und rechts von ihr? Versuchen Sie dies zusammen mit Ihrer Gruppe herauszufinden. Wenn Sie meinen die Antwort zu wissen können Sie zum Abschluss der Quest die Auflösungsschaltfläche anwählen.		
Lösung:	Auf dem Gemälde links von Maria Theresia sehen wir ihren Vater Karl VI, der 1740 gestorben war. Rechts von ihr sehen wir ihren Ehemann Franz Stephan von Lothringen, der nach Beilegung des Erbfolgekriegs Kaiser des heiligen römischen Reiches dt. Nation wurde.		

Figure A.4: German texts of *Discover the Habsburgs* audio clips

Der 15. Mai 1865			
Start:	Foyer	**Ziel:**	Werkmeistergericht und Wekmeisterküche
Einleitung:	Am 15. Mai 1865 fand in Aachen ein großes Fest auf dem Marktplatz statt. Gefeiert wurde der 50. Jahrestag der Eingliederung in das Königreich Preußen und somit die Befreiung der französischen Besatzung. Zu diesem Anlass, kam auch hoher Besuch aus Berlin. Zwei Portraits hier im Rathaus beziehen sich auf dieses Datum. Können Sie diese finden?		
Aufgabe 1:	Sie haben das erste Portrait gefunden. Weiß jemand in Ihrer Gruppe, wen es zeigt?		
Feedback Aufgabe 1:	Um die Quest abzuschließen, halten Sie mit ihrer Gruppe Ausschau nach dem zweiten Portrait.		
Aufgabe 2:	Ihre Gruppe hat das zweite Portrait finden können. Wissen Sie auch, wer hier dargestellt wird?		
Lösung Werkmeistergericht:	Das Portrait zeigt den damaligen Bürgermeister Johann Contzen. Dieser wurde am 15. Mai 1865 von König Wilhelm I zum Oberbürgermeister befördert. Dabei bekam er eine Amtskette verliehen, die er hier stolz trägt. Dies war die erste nachgewiesene Amtskette, die ein Aachener Bürgermeister erhielt.		
Lösung Werkmeisterküche:	Das Portrait zeigt Wilhelm I, damaliger König von Preußen und späterer Kaiser des Deutschen Reichs. Dieser war am 15. Mai 1865 nicht nur aufgrund des Jahrestags zur Eingliederung der Rheinprovinz in Aachen. Nein, auch ein weiteres wichtiges Ereignis fand an diesem Tag statt: Zusammen mit seinem Sohn, dem Kronprinzen Friederich III, nahm er am Templergraben an der feierlichen Grundsteinlegung des heutigen Hauptgebäudes der technischen Hochschule teil.		

Figure A.5: German texts of *May 15, 1865* audio clips

Appendix B

Installing GroupAIXplorer on an AIXplorer device

The source code of the GroupAIXplorer software prototype is available at the following URL:

> File: GroupAIXplorer Source Code Archive[a]
>
> ───────────────
>
> [a]http://hci.rwth-aachen.de/∼wermers/thesis/downloads/GroupAixplorerSource.zip

We explain step-by-step how to install the software on one of the AIXplorer devices on what follows:

- Open the GroupAIXplorer project with Apple Xcode

- Configure the group leader device by providing the device number in the – `(void)negotiateGroupBoss;` method of the `GAIXQuestController` class

- Compile the software using the iOS 2.2.1 SDK. Select the debug version if you desired to change rooms via a button in the top bar of the software. For user tests always compile a release version.

- To install the software on an AIXplorer device via WiFi, first locate the application bundle. It is either

stored in the subfolder `build/Debug-iphoneos` or in `build/Release-iphoneos`, depending on the compiled version.

- Copy the `GroupAixplorer.app` file with a SSH capable FTP client to `/var/rwth/Applications` on the AIXplorer device.

- Connect via SSH to the AIXplorer device on the command line. Create a symbolic link into the Applications folder:

- `ln -s /var/rwth/Applications/GroupAixplorer.app/` `/Applications/GroupAixplorer.app`

- In case the AIXplorer audio guide software is still active on the device, stop the software by calling `/var/rwth/bin/aix-stop.sh`

- Restart the iOS springboard by calling `/var/rwth/bin/respring`

- The GroupAIXplorer program icon will then appear on the home screen.

Log files are stored in the folder `/User/Library` as SQLite files. The only way to access these is via SSH.

Appendix C

GroupAIXplorer User Study

Figures C.1 – C.5 show the German questionnaire handed out to the users. The Figures C.6 – C.8 present the questionnaire data, which were used in 6—"Evaluation", especially to create Figures 6.1, 6.4, and 6.5.

These tables and the complete raw data from the questionnaires are also available for download:

File: Excel version of user statistics[a]

[a]http://hci.rwth-aachen.de/~wermers/thesis/downloads/userStatistics.xls

File: Likert scale results of the questionnaire[a]

[a]http://hci.rwth-aachen.de/~wermers/thesis/downloads/likertScaleResults.zip

File: All results from the questionnaire[a]

[a]http://hci.rwth-aachen.de/~wermers/thesis/downloads/rawQuestionnaireData.zip

The Figures C.9 – C.9 present the quest processing behavior of all groups, created from the group leaders logfiles.

File: Anonymized logfiles of the group leaders[a]

[a]http://hci.rwth-aachen.de/~wermers/thesis/downloads/group-leader-log-files.zip

Einverständniserklärung für
GroupAixplorer Benutzerstudie

Bitte lesen Sie sich die nachfolgende Erklärung sorgfältig durch und füllen Sie bei Einverständnis den Teilnehmersteckbrief unten aus.

Diese Studie wird durchgeführt von Forschern der RWTH Aachen. Wir bitten Sie darum das audiovisuelle Gruppenspiel im Rathaus zu spielen. Dabei werden die von Ihnen getätigten Eingaben sowie die im Rathaus besuchten Räume auf dem Gerät protokolliert. Zudem bekommt der 'Gruppenanführer' ein Diktiergerät, so dass auch Teile der Gespräche in der Gruppe aufgezeichnet werden. Im Anschluß zum Spiel wird ein Fragebogen ausgegeben. Das Ausfüllen sollte ca. 10 Minuten dauern und geschieht auf freiwilliger Basis, d.h. Sie können selbst entscheiden welche Fragen Sie beantworten und welche nicht. Sollten wir Zitate aus dem Fragebogen oder der Audioaufzeichnung in Berichten oder Präsentationen verwenden, so geschieht dies ohne Angabe Ihres Namens. Jegliche persönlichen Daten werden entweder verändert oder weggelassen. Alle aufgezeichneten Daten bleiben anonym und werden vetraulich behandelt.

Vielen Dank!

Unterschrift des Teilnehmers

Steckbrief für Teilnehmer Nr. (wird vom Moderator eingetragen): _____

Geschlecht: ☐ männlich	☐ weiblich	
Alter: _____		
Beruf: _____		
Ich besuche Museen... ☐ selten (bis 1x pro Jahr)	☐ gelegentlich (1-3x pro Jahr)	☐ häufig (3x und mehr / Jahr)
Sofern Audioguides angeboten werden nutze ich diese... ☐ nie	☐ gelegentlich	☐ immer

Figure C.1: GroupAIXplorer Evaluation: Questionnaire cover sheet

ID: _____

Bitte füllen Sie die nachfolgenden Fragen entsprechend Ihrer gemachten Erfahrung aus.

	1 = stimme gar nicht zu			5 = stimme völlig zu		
Aussage	**1**	**2**	**3**	**4**	**5**	**Keine Angabe**
Die Quest 'Barocke Zahlenrätsel' (Entschlüsselung des Chronogramms) hat mir gefallen.						
Die Quest 'Die vier Tugenden' (Zuordnung der Kardinaltugenden zum Deckengemälde) hat mir gefallen.						
Die Quests, bei denen sich die Gruppe eigenständig Gedanken machen sollte ('Die drei Hände' und 'Finde die Habsburger') haben mir gefallen.						
Die zweiteilige Quest 'Der 15. Mai 1865' hat mir gefallen.						
Das Questspiel insgesamt hat mir gefallen.						
Ein Questspiel ist geeignet, um als Kleingruppe (bis 5 Personen) ein Museum zu besichtigen.						

Was hat Ihnen ansonsten gut gefallen? ➡

Was hat Ihnen nicht gefallen? ➡

Figure C.2: GroupAIXplorer Evaluation: Questionnaire page 1

	1 = stimme gar nicht zu			5 = stimme völlig zu		

Aussage	1	2	3	4	5	Keine Angabe
Ich habe mich durch das Questspiel in meiner Bewegungsfreiheit eingeschränkt gefühlt.						
Die Möglichkeit die Gruppe über den Audioguide zu rufen finde ich nützlich.						
Das Herrufen der Gruppe über den Audioguide hat gut funktioniert.						
Das Questlog war nützlich.						
Der Gruppenchef hat Rücksicht auf die Wünsche der Gruppe genommen.						
Es hat mich gestört, dass allein der Gruppenchef Entscheidungen für die Gruppe treffen konnte.						
Ich bevorzuge es Audioguides alleine zu benutzen.						

Frage
Was glauben Sie, wie häufig Sie während des Spiels auf das Gerät geschaut haben?
☐ bis zu 10x   ☐ 10 - 20x   ☐ 20 - 30x   ☐ 30x oder häufiger
Welche Ereignisse haben Sie dazu gebracht auf das Gerät zu schauen? (Mehrfachnennung möglich)
☐ Beginn eines Audiobeitrags   ☐ Vibration des Gerätes   ☐ Hinweis durch Gruppenmitglied
☐ Sonstiges:

Figure C.3: GroupAIXplorer Evaluation: Questionnaire page 2

Frage	(bitte markieren Sie eine Antwort)	Ja	Nein
Haben Sie sich die Einleitung einer Quest mehrfach angehört?			
Warum? ➡			
Haben Sie sich die Aufgabenbeschreibung einer Quest mehrfach angehört?			
Warum? ➡			
Haben andere Gruppenmitglieder Ihnen während des Spiels geholfen?			
Wenn ja: Wobei? Wie? ➡			
Haben Sie anderen Gruppenmitgliedern während des Spiels geholfen?			
Wenn ja: Wobei? Wie? ➡			

Figure C.4: GroupAIXplorer Evaluation: Questionnaire page 3

Platz für allgemeine Kommentare, Anregungen und Kritik

Figure C.5: GroupAIXplorer Evaluation: Questionnaire page 4

Gr.	Benutzernr.	Geschlecht: weiblich = 0 männlich = 1	Alter	Ich besuche Museen... ...selten	...gelegentlich	...häufig	Sofern Audioguides angeboten werden nutze ich diese... ...nie	...gelegentlich	...immer
1	1 (Chef)	1	21	0	0	1	1	0	0
	2	0	31	0	1	0	0	1	0
	3	1	28	0	1	0	0	1	0
	4	0	22	0	0	1	0	1	0
2	5 (Chef)	0	29	0	1	0	0	1	0
	6	1	26	1	0	0	1	0	0
	7	1	31	0	1	0	0	1	0
	8	1	65	0	1	0	0	0	1
	9	0	70	0	0	1	0	1	0
3	10 (Chef)	1	28	1	0	0	1	0	0
	11	0	28	0	1	0	0	0	1
	12	1	28	0	1	0	1	0	0
	13	0	27	0	1	0	0	1	0
4	14 (Chef)	1	26	0	1	0	1	0	0
	15	1	31	1	0	0	0	1	0
	16	1	25	1	0	0	1	0	0
	17	1	23	0	1	0	1	0	0
	18	1	28	1	0	0	0	0	1
5	19 (Chef)	1	34	1	0	0	1	0	0
	20	1	29	1	0	0	1	0	0
	21	1	28	1	0	0	1	0	0
	22	0	28	0	1	0	1	0	0
	23	0	23	0	1	0	0	1	0
	SUM	15		8	12	3	11	9	3
	AVG	65,2	30,8	34,8	52,2	13,0	47,83	39,13	13,04
	MEDIAN		28						

Figure C.6: GroupAIXplorer Evaluation: User Statistic

Gr.	Benutzernr.	'Barocke Zahlenrätsel' hat mir gefallen	'Die vier Tugenden' hat mir gefallen.	'Gruppennach denkquests' haben mir gefallen.	zweiteilige Quest 'Der 15. Mai 1865' hat mir gefallen	Das Questspiel insgesamt hat mir gefallen.	Ein **Questspiel ist geeignet**, um als Klein-gruppe (bis 5 Personen) ein Museum zu besichtigen.
3	10 (Chef)	4	5	4	n/a	n/a	5
	11	4	5	4	4	4	4
	12	1	2	5	4	4	4
	13	4	5	5	4	4	4
4	14 (Chef)	5	3	nicht gespielt	nicht gespielt	5	5
	15	3	4	nicht gespielt	nicht gespielt	3	3
	16	5	5	nicht gespielt	nicht gespielt	n/a	n/a
	17	4	5	nicht gespielt	nicht gespielt	5	5
	18	5	4	nicht gespielt	nicht gespielt	5	5
5	19 (Chef)	1	3	3	4	4	3
	20	4	3	4	4	5	5
	21	2	5	3	2	5	4
	22	5	5	3	5	5	5
	23	4	5	4	5	5	5
	n	14	14	9	8	12	13
	SUM	51	59	35	32	54	56
	AVG	3,64	4,21	3,89	4,00	4,50	4,31
	MEDIAN	4	5	4	4	5	4
	STD	1,393	1,051	0,782	0,926	0,674	0,751
	lower bound STD:	2,9	3,7	3,5	3,5	4,2	3,9
	upper bound STD:	4,3	4,7	4,3	4,5	4,8	4,7

Figure C.7: GroupAIXplorer Evaluation: Likert Scale results from page 1

Gr.	Benutzernr.	Ich habe mich durch das Questspiel in meiner Bewegungsfreiheit eingeschränkt gefühlt.	Die Möglichkeit die Gruppe über den Audioguide zu rufen finde ich nützlich.	Das Herrufen der Gruppe über den Audioguide hat gut funktioniert.	Das Questlog war nützlich.	Der Gruppenchef hat Rücksicht auf die Wünsche der Gruppe genommen.	Es hat mich gestört, dass allein der Gruppenchef Entscheidungen für die Gruppe treffen konnte.	Ich bevorzuge es Audioguides alleine zu benutzen.
3	**10 (Chef)**	n/a	5	5	5	n/a	4	n/a
	11	2	5	3	3	3	4	1
	12	2	5	3	4	5	4	n/a
	13	2	4	4	5	4	4	3
4	**14 (Chef)**	1	5	5	4	n/a	2	1
	15	2	5	5	3	n/a	4	3
	16	1	5	2	5	5	1	1
	17	1	5	5	n/a	2	2	1
	18	2	5	4	3	3	4	2
5	**19 (Chef)**	3	3	3	2	n/a	n/a	n/a
	20	1	5	3	5	3	2	1
	21	1	4	4	5	3	1	1
	22	1	3	2	2	1	5	5
	23	1	4	3	4	5	1	1
	n	13	14	14	13	10	13	11
	SUM	20	63	51	50	34	38	20
	AVG	1,54	4,50	3,64	3,85	3,40	2,92	1,82
	MEDIAN	1	5	3,5	4	3	4	1
	STD	0,660	0,760	1,082	1,144	1,350	1,441	1,328
	lower bound STD:	1,2	4,1	3,1	3,3	2,7	2,2	1,2
	upper bound STD:	1,9	4,9	4,2	4,4	4,1	3,6	2,5

Figure C.8: GroupAIXplorer Evaluation: Likert Scale results from page 2

Gr.	Time	Total playing time	The four virtues	Baroque Number Puzzle	The three hands	Discover the Habsburgs	May 15, 1865
	15:38:13	0m 0s					
	15:45:49	7m 36s		accepted			
	15:58:29	20m 16s			accepted		
	16:00:25	22m 12s					accepted
	16:01:03	22m 50s				accepted	
	16:01:20	23m 7s					groupActivity1
	16:02:23	24m 10s					partFinished
	16:04:10	25m 57s					groupActivity2
	16:04:30	26m 17s					finished
1	16:07:12	28m 59s	accepted				
	16:13:45	35m 32s			groupActivity		
	16:14:47	36m 34s			finished		
	16:16:30	38m 17s	groupActivity				
	16:17:06	38m 53s	finished				
	16:17:31	39m 18s				groupActivity	
	16:18:06	39m 53s				finished	
	16:20:56	42m 43s		groupActivity			
	16:22:41	44m 28s		finished			

Figure C.9: Sequence of quest processing in group 1

Gr.	Time	Duration	The four virtues	Baroque Number Puzzle	The three hands	Discover the Habsburgs	May 15, 1865
	16:45:11	0m 0s					
	17:05:06	19m 55s		accepted			
	17:13:48	28m 37s		groupActivity			
	17:16:40	31m 29s		finished			
	17:19:44	34m 33s				accepted	
	17:24:30	39m 19s				groupActivity	
	17:25:47	40m 36s				finished	
	17:27:39	42m 28s					accepted
2	17:32:15	47m 4s					groupActivity1
	17:32:35	47m 24s					partFinished
	17:33:35	48m 24s					groupActivity2
	17:34:29	49m 18s					finished
	17:38:18	53m 7s	accepted				
	17:40:12	55m 1s	groupActivity				
	17:40:53	55m 42s	finished				
	17:43:50	58m 39s			accepted		
	17:46:18	61m 7s			groupActivity		
	17:47:47	62m 36s			finished		

Figure C.10: Sequence of quest processing in group 2

Gr.	Time	Duration	The four virtues	Baroque Number Puzzle	The three hands	Discover the Habsburgs	May 15, 1865
	14:33:33	0m 0s					
	14:46:24	12m 51s		accepted			
	14:52:06	18m 33s					accepted
	14:55:46	22m 13s	accepted				
	15:02:01	28m 28s					groupActivity1
	15:03:50	30m 17s					partFinished
	15:12:21	38m 48s				accepted	
	15:16:41	43m 8s	groupActivity				
	15:18:33	45m 0s	finished				
3	15:31:01	57m 28s			accepted		
	15:40:01	66m 28s		groupActivity			
	15:46:46	73m 13s		finished			
	15:47:55	74m 22s					groupActivity2
	15:49:06	75m 33s					finished
	15:57:04	83m 31s			groupActivity		
	15:58:25	84m 52s			finished		
	15:58:59	85m 26s				groupActivity	
	16:00:45	87m 12s				finished	

Figure C.11: Sequence of quest processing in group 3

Gr.	Time	Duration	The four virtues	Baroque Number Puzzle	The three hands	Discover the Habsburgs	May 15, 1865
	17:08:42	0m 0s					
	17:19:48	11m 6s		accepted			
	17:23:17	14m 35s		groupActivity			
	17:27:32	18m 50s		finished			
	17:30:00	21m 18s				accepted	
4	17:34:04	25m 22s				groupActivity	
	17:34:34	25m 52s				activityCanceled	
	17:43:29	34m 47s					
	17:46:27	37m 45s	accepted				
	17:54:39	45m 57s	groupActivity				
	17:57:49	49m 7s	finished				

Figure C.12: Sequence of quest processing in group 4

Gr.	Time	Duration	The four virtues	Baroque Number Puzzle	The three hands	Discover the Habsburgs	May 15, 1865
	15:19:50	0m 0s					
	15:25:35	5m 45s		accepted			
	15:37:13	17m 23s		groupActivity			
	15:41:00	21m 10s		finished			
	15:45:21	25m 31s	accepted				
	15:49:56	30m 6s	groupActivity				
	15:52:23	32m 33s	finished				
	15:58:11	38m 21s					accepted
	15:58:53	39m 3s					groupActivity1
5	16:00:08	40m 18s					partFinished
	16:15:09	55m 19s					groupActivity2
	16:15:23	55m 33s					finished
	16:18:01	58m 11s				accepted	
	16:22:34	62m 44s				groupActivity	
	16:24:19	64m 29s				finished	
	16:27:13	67m 23s			accepted		
	16:28:48	68m 58s			groupActivity		
	16:30:16	70m 26s			finished		

Figure C.13: Sequence of quest processing in group 5

Glossary

AIXplorer

A location-aware mobile audio and multimedia tour guide for the city of Aachen, developed in 2009 by the Media Computing Group. At the time of writing, the guide covers the City Hall and its immediate vicinity. In the future, the AIXplorer will grow along different historical sites throughout the city.

Bonjour

A zero-configuration networking method, enabling automatic discovery of computers, devices, and services on IP networks using industry standard IP protocols. It is a key component of Apple applications, services and devices.

Chronogram

A numeric puzzle, consisting of a sentence with hidden numbers. Most Chronograms are Latin inscriptions with roman numerals. These are highlighted in font style or color to indicate their belonging to the numeric puzzle. The puzzle is solved by adding up the value of every single numeral symbol. The sum represents a year which is often the year the work of art including the inscription

was crafted. Double Chronograms consist of two different Chronograms that have the same year as result of each Chronograms puzzle.

Friedenstisch

An interactive table in the Red Room (also Friedenssaal) of Aachen City Hall. It features eight wooden blocks that let the table display information about information on the War of the Austrian Succession and the Peace of Aachen. The blocks are connected by a red line which gives the user a path he should follow when choosing the next block. This interactive exhibit was developed by the Media Computing Group in 2009.

Likert scale

Psychometric response scale often used in questionnaires. Instead of just agreeing or disagreeing, subjects formulate an answer to a statement according to their level of agreement. In this thesis users were presented five levels from 1 to 5, with 1 corresponding to "Don't agree at all" and 5 corresponding to "Total agreement".

PList format

A Property List format is an Extensible Markup Language format with a public document type declaration defined by Apple. It is used in Mac OS X and the iPhone SDK to store serialized objects.

Singleton

A Singleton is a software design pattern used to describe classes that can have at most a single instance, including global access to this single instance. The access is realized by a static class method, often called `sharedCLASSNAME` with "CLASSNAME" replaced by the name of the Singleton class.

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