Institute for Visualization and Interactive Systems

University of Stuttgart
Universitätsstraße 38
D–70569 Stuttgart

Diploma Thesis Nr. 3558

Parallel Exhibitions: Empowering Users to Virtually and Physically Design Customized Museum Exhibits

Lars Lischke

Course of Study:	Informatik
Examiner:	Prof. Dr. Albrecht Schmidt
Supervisor:	Tilman Dingler, Stefan Schneegaß, Paweł Woźniak
Commenced:	27.08.2013
Completed:	26.02.2014
CR-Classification:	H.5.m

Abstract

Digital content is ubiquitous in all parts of life today. In particular Web 2.0 technology changed the way of communication. It allows everybody to contribute to digital content and to reach a large audience. The possibility to contribute also has an effect on the desire to contribute to "real world" matters. At the same time an incredible amount of information is online accessible without any effort. In many cases this enables us to find specific information fast and without leaving our current location.

This forces public knowledge places, like libraries or museums, to re-think their role as knowledge providers. These institutions have to become places of social interaction which provide meaningful collections of objects and information as well as space for creativity.

Visiting a museum is a great experience. Seeing objects, which have texture and physical characteristics combined with the history and the story of the exhibit, is an adventure and beneficial for engagement with a certain topic. Museums store much more objects, than they can present. These exhibits are not accessible for the public and sometimes not even for research purposes. It is a challenging task for curators and museum professionals to select objects for a meaningful and appealing arrangement. Re-creating and re-arranging exhibits in museums is mostly prohibited for visitors, because shown exhibits are often one of a kind, expensive, or damageable.

During the last decade museums build large databases to index their objects. In *Parallel Exhibitions* we make use of these databases to invite visitors to become co-curators in museums. We design and implemented an application, which allows museum visitors to contribute to the exhibition design. Curators can additionally include physical exhibition in the virtual interaction space to create a close relationship to other exhibits in the museum.

To evaluate our concept and our application we conducted a field test in a museum as well as an online study. In addition we interviewed possible users and museums professionals. We observed a rich social interaction around our application in the field study and the studies confirm that visitors have an interest to contribute to exhibitions they are visiting, both locally and on social media.

Kurzfassung

Digitale Inhalte sind heute allgegenwärtig. Im Besonderen Technologien des Web 2.0 haben die Art der Kommunikation verändert. Diese Technologien erlauben es digitale Inhalte beizusteuern und einer breiten Öffentlichkeit zugänglich zu machen. Die Möglichkeit eigene digitale Inhalte weiterzuverbreiten hat auch einen Einfluss auf das Bedürfnis nach Mitbestimmung in der realen Welt. Gleichzeitig ist eine enorme Menge an Informationen online, von überall ohne Aufwand verfügbar.

Dies zwingt öffentliche Einrichtungen wie Bibliotheken und Museen ihre Rolle als Informationsanbieter zu überdenken. Diese Einrichtungen müssen sich zu Orten der sozialen Interaktion weiterentwickeln, die sowohl wichtige Objekte und Informationen vorhalten also auch Raum für Kreativität bieten.

Ein Museumsbesuch ist ein Erlebnis. Ausstellungsstücke, die eine Vergangenheit haben, zu sehen und die Beschaffenheit des Materials wahrzunehmen ist faszinierend. Diese Faszination fördert eine intensive Auseinandersetzung mit dem Thema. Dennoch ist ein Großteil der Ausstellungsobjekte in Archiven gelagert. Diese Ausstellungsstücke sind für die Öffentlichkeit nicht zugänglich, manchmal sogar für Forschungszwecke nur schwer zu erhalten. Durch die große Zahl der Ausstellungsobjekte ist es selbst für Kuratoren eine herausfordernde Aufgabe, Objekte für bedeutungsvolle und ansprechende Ausstellungen auszusuchen. Für Besucher ist es im Allgemeinen nicht möglich Ausstellungsstücke neu zu gestalten oder neu anzuordnen, da die meisten Ausstellungsobjekte Unikate, sehr wertvoll oder zu empfindlich sind.

Während der letzten zehn Jahre haben Museen große Datenbanken erstellt um ihre Objekte zu katalogisieren. In dieser Arbeit nutzen wir die Datenbanken um Besucher einzuladen die Ausstellung mit virtuellen Ausstellungsstücken mitzugestalten. In einem iterativen Prozess haben wir eine Anwendung entworfen und implementiert, die es Besuchern erlaubt zur Gestaltung der Ausstellung bei zu tragen. Zusätzlich können Kuratoren reale Ausstellungsobjekte in den virtuellen Interaktionsraum der Besucher integrieren, um für eine enge Verbindung zwischen realen und virtuellen Ausstellungsteilen zu sorgen.

Um unser Konzept und die Anwendung zu evaluieren, führten wir eine Feldstudie und eine Onlinestudie durch. Zusätzlich interviewten wir mögliche Museumsbesucher und Museumsmitarbeiter. Dabei fanden wir heraus, dass Besucher ein Interesse haben, Ausstellungen vor Ort und online mitzugestalten und dies zu einer lebhaften Kommunikation im Museum führt.

Contents

List of Figures

1. Introduction

Museums are public knowledge places with the purpose to collect, perpetuate, and to present artifacts concerning a defined topic to the public. Besides showing objects, museums contribute to research on these artifacts and educate visitors [40]. This purpose raises different challenges for the future. The large collections of objects archived in museums are still growing. To keep the objects accessible to the public and for researchers, these collections have to be indexed meticulously. Matassa describes the situation as follows [38]:

> "...the single greatest barrier to the better use of collections is insufficient knowledge of what they [the museums] have."

Objects which are unknown by museum staff and curators are useless, because they cannot be shown or used for research purposes. However, even if all exhibits are inventoried they are not always easily accessible to the public. According to the study *Collections for People* published by the University College London, only 13% of the collections stored in Museums in England and Wales are strongly promoted for being accessed by the public[32]. Even in future the limited space and the demand on sustainability will also not allow showing all objects in showrooms. Hence the storerooms have to be accessible to the public and research in an online or offline way.

As well the challenge to keep overview over the collection as providing access to stored objects can take advantage of modern computer and web technology. Online repositories can index nearly every object without causing high costs. Digital repositories can be easily browsed and specific objects can be found fast by searching for certain keywords. At the same time the number of users is nearly unlimited.

Online repositories can either store objects owned by one institution or focus on a wide range of categories e.g. Europeana[1], Albertina Sammlungen Online[2], Google Cultural Institute,[3] or Wikimedia Commons[4]. Most of these online tools use concepts of Web 2.0 technology. For example, Wikimedia Commons is a community based platform and invites everybody to support the project by providing content. Thus way Wikimedia Commons creates a large online collection of multimedia content related to cultural heritage and important social events.

In contrast to Wikimedia Commons, Europeana provides access to digital cultural heritage from different European institutions. Europeana is founded by the European

[1] `http://europeana.eu/`
[2] `http://sammlungenonline.albertina.at/`
[3] `http://www.google.com/culturalinstitute/`
[4] `https://commons.wikimedia.org/`

Union mainly by the eContentplus Program. According to the strategic plan [2], the goal of Europeana is to build an open platform for European cultural heritage content. This shall support stakeholders through knowledge transfer and advice. Furthermore the goal is to make cultural heritage content easily accessible for everybody and establish new possibilities for uses to participate in creating cultural heritage. After the great success of the project " The First World War Poetry Digital Archive"[5] in the UK, which called for submitting privately owned pictures and text from the time of the First World War, the project was transformed into the Europeana 1914-1918 project[6] [23].

The Web 2.0 as a set of technologies allows users to create easily new content. Thereby the communication is changing from a few-to-many communication to a many-to-many communication. Wikimedia Commons as well as the Europeana 1914-1918 project are classical examples of Web 2.0 projects. Web services like Wikis, blogs, and social networks illustrate the success and the great influence of Web 2.0 applications on western societies in all parts of life. The ideas of Web 2.0, especially participation and co-creation inspired the term Museum 2.0 [52, 56]. To be attractive today museums have to provide possibilities for visitors to take an active role and have to be a room for communication. On the one hand, many museums use social media channels, like YouTube, or Facebook to communicate with the public. On the other hand, there is still a need to design technology for the Museum 2.0 to bring the Web 2.0 into the museum. Two initial successful examples of Web 2.0 projects closely related to exhibitions are: the GO exhibition, a community-curated open studio project at the Brooklyn Museum[7], where visitors were invited to vote for different art studios and the LIKE-IT exhibition at the Essl museum[8]. The Essl museums presented a set of art works to the Facebook-community of the museum and invited them to vote. Only the objects with the highest rating were presented in the exhibition.

However even if there are some very successful examples of interactive exhibitions and the use of digital cultural heritage, the i2010 Digital libraries flagship initiative indicates the need to digitalize and to inventories cultural heritage [18]. At the same time applications have to be designed to use the digital cultural heritage for social discourse and to develop cultural heritage further. Otherwise the effort to digitize and to provide access to digital cultural heritage seems to be useless. The importance of applications that work with cultural heritage is shown by the CloudMedia Platform project[9]. In this project, different stakeholders aim to build a platform to interact with additional content related to museum exhibitions.

It is obvious that the amount on data and information which is accessible will be still rise over the next decades. Also the quality of images, 3D models and videos will increase. Furthermore nearly everything will be printable as 3D model. The experience of "virtual worlds" will be much more immersive than today. This calls the way of education and the role of museums and libraries fundamental into question. The challenge for the future

[5] http://www.oucs.ox.ac.uk/ww1lit/gwa/
[6] http://www.europeana1914-1918.eu/
[7] http://www.gobrooklynart.org/
[8] http://www.essl.museum/
[9] http://www.cloud-media-projekt.de/

will be to create meaningful connections between facts and not to know something by hard. The museum of the future will be a place where curators provide high quality exhibits and information to a certain topic. The museum will not provide this that visitors can look at it. Instead curators and engaged visitors will create in cooperation new connections between existing artifacts and build new objects be re-combine others. The motivation to visit a museum will be the experience and the social interaction with others who are interested in the same topic. Naturally in a ubiquitous connected world, the engagement with topics of interest and the community of the museum will not end at the museum's exit. So "visitors" can contribute to the exhibition even they are physical not in the museum with mobile devices.

In this thesis, we propose and analyze different approaches (1) make archived objects accessible for a large audience (2) invite visitors to become co-curators while visiting an exhibition (3) enhance the communication in the museum and communication between the museum and the community and (4) include objects in exhibitions which are physical unavailable at a given time, because they are shown somewhere else or the risk of transporting them would be too high. Because of the importance of the "aura" of original cultural heritage [42], we aim to enrich museums instead of replacing them by web applications.

2. Related work

In this chapter, we classify this work into relation to other relevant research. We divide this chapter in work concerning museums and social media, technology which are suitable in museums setting, like smartphones or interactive tables, techniques to motivate visitors to participate and concepts which support the collaboration between visitors. Finally we class the methodology we use in this thesis.

2.1. Web 2.0 - Museum 2.0

Museums are changing from places which collect cultural heritage to places of interaction, communication and participation [56, 14, 38]. This calls for connecting museums to social media. Thereby the communication and participation can be continued after the visit and also other people can contribute. Different projects focus on this connection already.

In *Confronting the Challenges of Participatory Culture*, Jenkins et al. describe "the participatory culture" as a culture with "1) [...] civic engagement, 2) strong support for creating and sharing creations with others, [...] 4) members who believe that their contributions matter, and 5) [...] members care what other people think about what they have created" [30]. To build a participatory culture Russo [49] argues to focus on large ceremonies. Important events or ceremonies, like the 100th anniversary of the first world war, spark the interest of many people. This motivates people to engage with a certain topic. In the following the author compares the use of social media in museums with design related crowed-sourcing projects. By using that knowledge, a community projects can be much more successful and develop economical power. These aspects are fundamental for all projects which are designing interactive technology to call for co-creation, in particular in museums or any other public institution.

Weilenmann et al. [62] examine instagram photos taken at the Gothenburg Natural History Museum. They identify different reasons for taking and sharing pictures in the museum. The main reason for visitors to share images is to show that they visit the museum or the town. Others focus more on the experience of the visit and tell a story about the visit with images. They looked for aesthetic pictures or special captions. Weilemann et al. also identify an influence of social online media while taking pictures. Some instagrammers react to twitter posts and adjusted their stories. The authors argue that instagrammers act as "virtual curator" while telling a story with instagram pictures. This also extends the dialogue between the museum and the community. This paper indicates that visitors are interested in sharing their impressions of a museum with others in a digital way. Thereby, they are willing to use own commonplace devices. The open question for this research project is now how the shared impressions can be used by the museum's community or in the museum. In *Parallel Exhibitions* we want to

make use of the interest in sharing experience online. At first this can visitors motivate to become active and at second the museum gets feedback also from people who are not visiting the museum.

Stuedahl and Smørdal [54] investigate how museums can be designed to be more appealing for young visitors. Thereby, they focus on the use of social media and mobile phones in the museum. The mobile phones are used to provide additional hyper-media content, like videos and images. They connect physical exhibits, in this case a reconstructed wiking boat with digital content. They also define three design concepts to trigger visitors to use their mobile phones and social media: (1) "Collecting": The exhibition provided additional materials which can be downloaded by the visitors to their mobile phone; (2) "Reflecting": Questions were presented to the visitors. To solve the tasks the visitors also have to use the digital content placed in the museum; (3) "Sharing": The visitors were invited to share their answers, opinions and thoughts in form of text messages, images and small videos on a "collective screen" in the center of the exhibition. Like in the setting described in work by Weilemann et al. Stuedahl and Smørdal use visitor-owned devices. This has the advantage of the possibility to "provide something to take home". To motivate visitors to become active Stuedahl and Smørdal confront visitors with doubts and questions. This is described as one powerful concept to call for social interaction by Simon [52]. Simon describes four design techniques to create "social platforms". (1) "Providing live interpretations [...] to help visitors make a personal connection to artifacts."; (2) "Designing [...] provocative presentation[s ...] that display objects in juxtaposition, conflict, or conversation with each other"; (3)"Giving visitors clear instructions on how to engage ..."; (4) "Offering visitors ways to share objects either physically or virtually by sending them to friends and family". From these design concepts we will especially focus on sharing objects virtually with others. Sharing content locally in the museum has the advantage of forcing visitors to communicate with each other. This enhance the engagement with the exhibition and can indicate which exhibits are interesting for the visitors.

Russo et al. [51] argue for a shift in the museums' communication from a one-to-many communication to a many-to-many-communication. This can be fulfilled by using web 2.0 technology, like blogs, social networks etc. On one hand this facilitates visitors taking an active role in the museum. On the other hand, the curators get support from the community. This can help shape the collecting policy of the museum. The stake of social media in public knowledge places, like museums or libraries, enhances the possibilities for new learning practice. Sharing opinions and knowledge in such a setting enhance the engagement with the exposed objects and the communication about the exhibits. Thereby the visitors as well as the museum can get acknowledgment. As good example Russo et al. describe a service which allows creating and uploading own podcasts of the visit of the Museum of Modern Art (MOMA), New York. After uploading a podcast other visitors can download the podcast and use it as an unofficial audio guide [50]. The invitations to create audio tours trigger the visitors to engage deeply with the exhibition. Later on, the creator of an audio guide can get commendation for his ideas. In contrast, we aim to invite visitors to share their thoughts about exhibitions in a visual way. We provide a virtual space to show others opinions about single exhibits, even if they are

displayed in the exhibition or not.

Another example of sharing museum content is presented by the Brooklyn Museum. The museum provides a Facebook application, called ArtShare, which allows adding exhibits to the personal profile of the user. Thereby, the users can show which objects they like. It is also possible to add own content to ArtShare [6, 7]. This creates identification with the exhibits which are presented on the personal Facebook profile. At the same time it inspires discussion in the community about art and exhibitions. Pierroux et al. faced the low interests of young people to visit art museums. To "reach young people where they live" they proposed a platform for sharing multimedia content during a school field trip to an art museum. The students can communicate about art by using their mobile phones. This is particularly interesting, because interpretations and describing art is a central part of the class. The students get motivated to participate by using technology which they like [43]. Presenting or sharing content with friends or a community seems to be a strong motivator for visitors to become active. In *Parallel Exhibitions* we aim to motivate visitors to share their ideas. If this can get students interested in a certain topic, it is an even greater success.

Not only is the role of visitors in the museum changing. Also, the work of curators is changing. According to Dicker curators perceive the work with social media as time-consuming and not always considered by the museum. More than the half of the interviewed curators stated that they not use social media at work, because of time issues. More than one third do not see a benefit in using social media [17]. This indicates a need for powerful tools for curators to share cultural heritage with an online community. These tools should not enable curators to do the work of the marketing department. Instead, they should invite curators to communicate with the community and to review the museum's collection.

2.2. Technology in public knowledge places

Interactive technology has special requirements in public settings, in particular in museums. In this section we review technology which is suitable for visitor interaction in museums.

There is a noticeable number of tabletop applications used in museum settings. Tables have been tools for communicating and exchanging ideas since thousands of years. Correia et al. see an interactive table as perfect tool to enhance participation in museums. They build an interactive table for a museum setting. This requires a large interaction space which allow, input from multiple visitors at the same time and over a long period of time. Additionally, the hardware has to be robust enough to be used by many users. The authors claim the interactive table as a device which motivates visitors to engage with the exhibition in a virtual way [13]. Hsieh et al. designed an interactive tabletop with tangible objects for a historical museum in Taiwan. They see a particular potential in tangibles for learning and social interaction in the museum. They describe hepatic feedback as very beneficial for understanding and engaging. Especially the sensory information enhances learning [29]. Interactive tabletop installations in the museum need

maintenance tools for the museum staff. Facing this issue Sprengart et al. presents a tool called Curator which allows creating rich multimedia exhibitions for tabletops [53]. In general, we can conclude interactive tables allow face-to-face interaction while working with digital objects from different angles. This creates a homey atmosphere for collaboration [20]. However the use of interactive tables also raise challenges. As a result of a field study in the Museum für Naturkunde Berlin, Hornecker sees the difficulty to connect the interactive table strongly to exhibits. So it is possible that the visitors do not recognize the table as part of the exhibition or that visitors get distracted by the technology. Furthermore she observed that 50 % of the visitors passed by without a glance at the table [27]. In contrast, interactive tables were successfully used in an art exhibition in UK. Thereby the interactive screens were placed between other exhibits, comparable in attract attention [60]. The findings of Hornecker and Lehn et al. could be an actual challenge for us, because we aim to provide additional exhibits which are not shown as physical objects. It might be challenging to include such an installation.

As soon as the interaction becomes more ubiquitous and the user is carrying the interaction device around, we will face the issue of indoor positioning. Kuflik et al. present different technologies to provide indoor positioning. They focus on technology which does not distract visitors from the exhibition and which has a low demand on maintenance. They discuss, amongst other technology, the use of Infra Red (IR) positioning systems, Radio Frequency (RF), Wi-Fi and cellular based system [33]. RF respectively near field communication (NFC) based positioning seems to be most promising. Blöckner et al. present a museums guide based on mobile devices. In comparison to regular mobile museum guides the devices allow to control public displays by using NFC-technology. This invites to interact with virtual content in an exhibition [8]. Hardy et al. analyze interaction with static posters and with dynamic displays by using mobile phones which support NFC in a tourist information setting. Static content like maps can be downloaded to the smartphone. The dynamic displays allows manipulations of the public shown content. They compared the usability of both systems in a user study. According to Hardy et al. both systems provide the potential to enrich installations with interactive information [22]. Following Hardy's argumentation NFC technology is well suitable to build interaction systems which combine digital interaction with physical exhibits. Under the assumption that the number of smartphones which support NFC would be increasing, this technology is interesting as it enables us to include visitors' devices in the interaction, e.g. to provide content "for take away". Also some of our low fidelity concepts allow visitors to interact with their smartphone with the exhibition and other visitors. To implement such a concept we would need communication between the exhibition and smartphones as well as we would need indoor localization to provide the right content on the right position.

Combining virtual with physical exhibits calls for augmented reality (AR). According to Woods et al. AR enriches the possibilities to explore exhibits. Overlaying information or using metaphors like books to display multimedia content enhances learning possibilities in museums. Virtual objects also have the advantage of being easily modifiable and cheap to reproduce in comparison to original exhibits [64]. The argument of "indestructibly" of virtual exhibits in comparison to rare and fragile originals is reasonable for any

interaction with virtual exhibits. It is not only possible to use well-known patterns from the ”real world“ in the virtual one. It is also possible to copy concepts known from the virtual world, e. g. it looks reasonable to show ”others who like this exhibits, like also...“ as virtual presentation of exhibits.

2.3. Visitor collaboration

Museums visits are social events. Normally multiple people visit a museum together: As a school trip, for a scientific reason or in their leisure time. The role of museums is changing from collectors to places for interaction [56]. This interaction means not only interacting with technology, but social interaction. Social interaction calls for creating new ideas, art or any other project together. This social interaction can be supported by new technology included in exhibition design.

Designing tools to foster social interaction in exhibitions raises different challenges. First, these tools have to be appealing as well as there are only a few visitors around as the exhibition is very crowded. Furthermore, tools which enhance the social interaction have to be scalable in terms of visitors' expectation and knowledge, because museums will be visited by enthusiastic experts and sparsely interested people at the same time. There are also differences in how single visitors, groups of companions, or pairs interact with their social environment. According to Hindmarsh et al., tools which successful foster social interaction distinguish between action points and viewpoints. Thereby visitors can observe the interaction of others. At the action point visitors have the chance to take on an active role. On one hand, the view points is showing the ”honey pot“. On the other hand, not all visitors have the same desire to become active [24]. Clarke et al. present an interactive multimodal exhibit at the Riverside Transport Museum in Glasgow. The installation invites groups of visitors, mainly families, to explore the functionality of a steam locomotive. In this case, the visitors have to keep the virtual steam engine running by performing tasks on two separate interactive terminals. The need to perform the right task at the right moment, visitors at the two terminals have to communicate without virtual support over a physical distance. The solving of the common task seems to be beneficial to visitor engagement [12].

Like we see in chapter 2.2 interactive tables seem to be fruitful to use for collaboration and social interaction in the physical world. By analyzing peoples behavior Marshall et al. conclude that decision-making or any other collaboration is more satisfactory if all members stand in a (semi) circle [37]. Tables allow standing or sitting around while having a good view of the interface. Zancanaro divides tabletop applications in two categories. On one side shared interfaces can be used to solve a defined common task [65]. A well known example of a tabletop which is used to solve a defined task is the reacTable. The reacTable allows multiple users to explore music electronically [31]. Following Zancanaro the other category of applications supports social interaction implicitly and is not goal oriented [65]. As an example Zancanaro et al. build a cafe table which directs group conversation to a museum topic. Therefore, the table analyzes the audibility of the conversation and the attention to the table of each group member.

The table presents related images and text message to draw attention to museum topics [66].

A special focus of collaborative interaction in museums concerns groups of young visitors and families. Work related to social interaction with young visitors aims mostly to enhance learning in museums. Cabrere et al. build an interactive museum guide which provides small games and tasks for students. The games and tasks are related to certain exhibits. In a field study they faced typical problems. The focus of some students switched from the displayed exhibits to the handheld computers. While other students lost interest in the interactive guide because of the complexity of the tasks [10]. Hope et al. designed a comparable guide by using mobile game-terminals. In addition visitors can leave their footprint by "check-in" with a rented "footprint card". This allows "friends" to follow by using the guide. Besides showing personal routes through the museum, the game terminal provides quizzes which can be solved by the family. As a result of a field test in a Japanese museum the authors conclude a positive effect for engagement and family fun. As future challenge they see more personal content to address different visitors [26]. Kurio is a museums guide for families which consists of interactive tangibles, PDAs and tabletop displays. While a family explores the exhibition they do "journey through time". To travel back in time they have to complete different tasks in the museum [61]. The narrative and playful guide motivates families to discover the exhibition more carefully.

Another approach to use mobile technology for social interaction is to combine user owned smartphones to share ideas with others in "an offline break". Lucero et al. use multiple smartphones show larger images. They also assume spatial awareness to exchange information between smartphones [36]. This idea could be interesting to use in a museums setting. Visitors could collect virtual exhibits and exchange ideas in special areas with other visitors.

2.4. Motivating visitors - call for interaction

Designing technology for museums which motivates visitors to participate is a challenging task. One issue is to indicate interaction and then to spark interest in the interaction. Another issue is to design technology which does not attract users' interest by itself.

According to BJ Fogg, there are three parameters to persuade visitor to interact with a system. Either we can increase the motivation to perform a certain action or we can lower the complexity of the task. In general it is important to trigger the visitor at the right moment to interact with the system [19]. In this section we will focus mainly on users' motivation and on the triggers we could use in a museums setting.

To understand users' motivation in participating we take a look on the motivation to become active in social media and web 2.0 services. Vassileva presents two theories of motivation. The first one is an economic view of motivation. The core assumption is "that people are rational agents who act to maximize their utility (payoff)" [57]. A basic concept is to build a marketplace where users can offer ideas or support and others can get these ideas or support by spending virtual money. The second theory is developed

in psychology. There it is divided into extrinsic motivation and intrinsic motivation. Intrinsic motivation triggered without influence from the outside. One important aspects of extrinsic motivation is social comparison. Status, reputation and attention provide a strong motivation for the most of users of social media. Both theories see gamification as a good tool to motivate people to participate [57].

Ideas like handing out badges, providing goals, levels and rankings or high scores to motivate people to perform a certain action are much older than web 2.0 technology. Since 2003 Wikipedia's Barnstars[1] are used to reward good users who wrote meaningful articles. Even if gamification concepts have a strong power to motivate, the gamification elements have to be well integrated with the setting. Otherwise, they can disturb and demotivate users [15, 16].

Rashid et al. try analyze the participation in online communities. They analyze if it is beneficial to show participants the value of their work for others in the community. In the case of a movie database this had a very small positive effect [45]. Both Verhagen et at. and Lin et al. claimed extrinsic motivation as the main motivation to use social networks like Facebook and virtual worlds like Second Life[35, 59]. Lin et al. argue that the main motivation to use social networks is enjoyment. Sharing text messages and multimedia content gives as well sharers as readers the feeling of interest. In addition, social networks become interesting by providing small games for leisure time with a social component [35].

As well the aspect of social acknowledgment as the idea to provide an exchange value seems to be interesting to motivate museums visitors to participate. For example visitors could get a discount in the museum's shop for contributing ideas or they could print their shared ideas as post cards (for free). Visitors who become active could also get attention from others. Depending on the concrete concept shared ideas could be presented and ranked in the museum. By including existing social media networks in applications for interaction in museums, users could get acknowledgment by a larger and probably more important group of people.

Another way to motivate user to engage with an exhibition is to personalize the interaction. Personalization allows presenting single visitors or groups of visitor content which is relevant for them. Ardissono et al. divide technology for personalization into stationary and mobile technology [5]. Rocchi et al. presented related video clips on handheld devices to young visitors. Additionally background information is provided on large screens in the museum. The personalized videos guided young visitors through the exhibitions. The content of the videos is adapted in relation the interests and the position of the user. With the digital personal guide, Rocchi et al. aimed to enhance the engagement of young visitors with the exhibition [47]. In the CHESS (Cultural Heritage Experiences through Socio-personal interactions and Storytelling) project a museums guide is build, which guided visitors through the exhibition by telling stories about the exhibits. To analyze visitors' interest, they ask to take part in a survey. The answers are analyzed by an algorithm to provide most interesting content for visitors [44, 58]. These algorithms can be trained by community recommendations. Recommendations

[1] `https://en.wikipedia.org/wiki/Wikipedia:Barnstars`

and personal bookmarks are the strength of community-based personalization [58]. Museums tours as well as the recommendations can be used on-side in a museum as online form home.

Alt et al. [3] investigate the impacted of interactivity of public displays. Thereby the authors confirm that the interactivity of public displays have a positive effect on recall and recognition. These results should be assignable to interaction on larger display in museums. The positive effect on recall and recognition could motivate curators to include interactivity in exhibitions, because it enhances learning in the museum. This is a common goal of many museums [40].

Even if the visitors are motivated to participate and to use the system, they have to be reminded to become active at the right point of time. Kules et al. present four principles for interactive systems: (1) "Immediate Attraction" possible users should be attracted by presenting the most interesting content, (2) "Immediate Learning" the system should be easy to use. Users should be able to use the system after observing others for some seconds while they interact, (3) "Immediate Engagement" the system should allow to start immediately with solving a certain task without any distraction (4) "Immediate Disengagement" when a user stops interacting the system should be immediately ready for input from the next user [34]. All these principles seem to be important for an interactive system in a museum setting. If the system does not spark the visitors' interest, nobody will use it. The most people will not be willing to learn how to interact with an interactive installation in a museum. If visitors cannot interact with the system at the same moment they see it, they will lose interest and believe the system does not work.

A challenging task is to indicate interactivity. Müller et al. analyzed in a field study how interactivity can be noticed on public displays. Besides observing other people interacting with the system (honey-pot-effect), it is highly useful to display a mirrored user image. It can be also beneficial to show an avatar or shadow of bypassing users [39]. To indicate interaction with shadows of visitors seems to be interesting in a museums context, because it is less disturbing from the museum's content proportion to real visitor images. Even so, it seems to be challenging to include moving elements in an installation to call for interaction without destroying the content and the museums atmosphere.

2.5. Methodology

To evaluate concepts and implementations there are three common types of collecting data in human computer interaction (HCI) [55]. An overview of evaluation methods in public spaces can be found in [4] which also should be considered in the museum context. To get an idea how a certain group of people perform meaningful actions ethnography studies are very beneficial. By observing members of the focus group relevant insights can be collected to design tools to support members of the focus group to fulfill a certain task [55]. Already existing concepts or applications can be analyzed in laboratory studies (lab studies) or in field studies, also called in-situ studies. According to Brush there are three mainly types of field studies. In "Studies of current behavior" researchers observe

people how they are acting on certain situations. This type of study can be also seen as an ethnographical study. "Proof-of-concept studies" analyze how a new technology or prototype works in the real world. The last type of field study is called "Experience using a prototype". Here will be analyzed how people behavior will be changed by using the prototype [9].

Field studies are more expensive and difficult to conduct than lab studies. Lab studies provide maximal controlled environment for interacting with a prototype. Nevertheless Rogers et al. claim that "it's worth the hassle" to conduct a field study for research in ubiquitous computing. They argue that field studies allow analyzing how people use technology under real world conditions. Thereby not only the usability can be analyzed, also the influence of the behavior of the user and the environment [48]. These assumptions are confirmed by Hornecker and Nicol. The authors analyze interactive museum games in a lab study and in an open-end field test. Because the games focus on children and their parents as players, families are invited to the lab test at the closed Robert Burns Birthplace museum in Alloway, Scotland. After the reopening of the museum the authors observed families playing with the same interactive games as analyze in the lab study by captured video material. Concluding, they identify in the lab study and in the field study the most usability issues. However in the field study they also identify issues concerning social interaction between groups of visitors and distraction by other visitors and exhibits [28]. If not only the usability of a system should be tested, but also the influence on the social interaction in a museum it seems to be necessary to conduct a field test. An example of a field study in a museum is presented by Graziola et al. They analyzed visitor's attitudes while using different types of mobile guides. They asked to visitors to use as well adaptive guides as no adaptive. All invited visitors tested both systems. In addition to observing all participants are asked to answer questionnaires concerning the guide [21].

2.6. Submitted Paper based on this work

On base of the findings of this work a work in progress paper is published at the 8th International Conference on Tangible, Embedded and Embodied Interaction:

Lischke, L., Dingler, T., Schneegaß, S., Schmidt, A.:
User Defined Exhibitions – Exploring Possibilities to Involve Visitors in the Design of Museum Exhibitions
8th International Conference on Tangible, Embedded and Embodied Interaction, (TEI 2014)

3. Design

Parallel Exhibitions aims to include virtual exhibits in exhibitions and to allow visitors to become co-curator of the exhibition. The process of arranging own exhibitions shall enhance the social interactivity in the museum. In an iterative design process we created different concepts. We discussed the concepts within our working group and with our project partners.

3.1. Design requirements

The aim of this project is to design and implement technology to bring digital archived cultural heritage and classical museum exhibitions together. This setting creates some special needs concerning hardware and software design.

On one hand, the number of visitors can vary greatly. If plenty of people visit the exhibition, long queue time to interact with the digital content has to be avoided to prevent frustration. On the other hand, if only a few people attend the exhibition, not used systems might look inactive or expected interaction between visitors might not work. To avoid queue time at interactive installations, it would also be possible to use a scalable number of mobile devices. The mobile devices could be owned by the museum as a digital guides or a bring-your-own-device (BYOD) concept would be possible. By following the BYOD concept the visitor are invited to install a museum app on their smartphone or tablet before they enter the exhibition. The advantage for the museum is the low demand on museum owned hardware. This lowers the costs for equipment acquisition and maintains. On the other hand the museum has to provide the museums app for multiple hard- and software platforms. Nevertheless the museum will not reach all visitors. Some visitors will not have a supported device or a smartphone at all others do not want to install new software for a museum visit. A suitable solution could be to combine fixed interaction terminals with mobile respectively visitor owned devices. This would allow all visitors to play with interactive installations and provide interaction without queue time for visitors with own devices.

Not only the number of visitors varies, also the expectations of the visitors can be different. Some visitors might have expert knowledge others might be new to the topic of the exhibition. Also personal attributes will differ. Some people might like to become co-curator and to be an active part of the exhibition others might just “consume“ the exhibition.

At last the objects may have different attributes. Many physical exhibits are stored in large museum storerooms. Not always they are indexed or even scanned or photographed. At the same time large online achieves store thousands of objects. This creates a confusing situation and selecting fitting and interesting objects becomes a challenge as well for

curators as even more for visitors which interact with a subset of digital objects. This clarifies the special responsibility of the curators.

3.2. Discussion of prototypes

All prototypes aim to enhance the museum to show more objects. The selection of objects shall fit optimal to the visitor's interests and the system shall enrich the visitor experience in the museum. The museum stuff and the visitors benefit from more communication about interests and objects.

In the following, we describe different low fidelity prototypes we designed and discussed within our working group.

3.2.1. Voting Tablet

As an extension of a classical exhibition virtual objects can be placed between regular exhibits. The virtual objects can be projected by a regular data projector or displayed on large screens. To collect feedback and to get to know the interest of the visitors, the curator presents a collection of virtual exhibits, which could fit to the design of the showroom. While the visitors are passing by, they can rate the objects in the collection. Therefore, a tablet computer is mounted in front of the virtual exposed object.

Which exhibit is shown depends on the rating function. To display the last selected exhibit might be problematic. Visitors might press on an object just to try it out and see if something is happening. This would not allow concluding, which exhibits most are interesting for visitors. More suitable might be a sum-function over all rates: $MAX^I(\sum^n \frac{1}{t})$ thereby are I all objects, N all ratings for object i, and t the time since this rating was done. This rating function has the benefit of respecting all ratings form visitors. By giving newer ratings a bigger impact, older ones will "fading" out.

In addition to positive ratings also negative ratings could be used. By knowing not only which objects visitors like mostly but also which exhibits are disliked, the curator can identify objects which provoke visitors mostly. Both user interfaces are shown in 3.1. The advantage of this concept is a very short interaction time. The visitors can interact "on-the-fly" during the museum visit. Furthermore the use of everyday technology lowers the inhibition threshold for the visitors to interact. The technology is also beneficial for the museums. Regular tablet computer and projectors or screens are inexpensive and lightweight. So the concept can easily rearrange or placed in multiple rooms of the exhibition.

On the other hand the small and fast interaction is disadvantageous for the interaction between visitors and between visitors and the museum's staff. Furthermore the visitors do not get inspired to think deeply about the presented topic.

This interaction does not need to be performed on a tablet computer. It would also be possible to place any other device, which can display html5 content or to provide access for visitor owned devices.

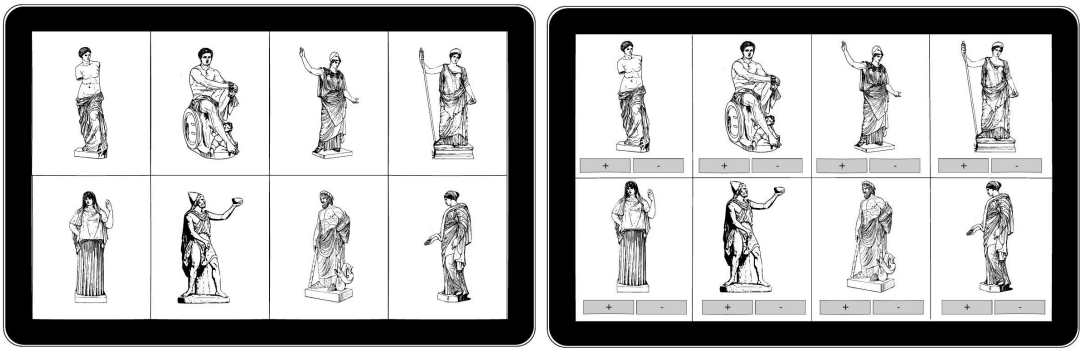

Figure 3.1.: Tablet computer user interface: Visitors can choose an exhibit out of a set, which they would like to see. Left: The interface allows making a fast and easy choosing. Right: In addition to the interface on the left side, visitors can choose which exhibits they like or dislike

3.2.2. A Tabletop application to design a room

Instead of using one interface for one virtual exhibit like in section 3.2.1 this concept uses only one interactive tabletop application to place multiple virtual objects in a room. The table can be placed anywhere in the exhibition. An ideal place would for example be the center of the room in which the virtual objects can be placed. The application shows a footprint of the room. In this plan the areas where virtual objects can be placed are marked. In the middle of the screen a “sandbox” shown. In this “sandbox” all exhibits which can arranged in this room are shown. The objects in the “sandbox” are randomization. The virtual exhibits can be moved from the sandbox to a free spot by wiping the object to the spot. To exchange two exhibits the object from the spot can be moved back to the “sandbox”. If a 3D-model of the object is available, it is also possible to rotate the exhibit freely.

In addition tangibles could be used on the table to arrange the virtual objects. Therefore small 3D-prints of the virtual exhibits would be needed. The possibility to see and touch the presented virtual exhibits can spark visitor’s interest in the interactive system.

The large user interface of an interactive tabletop invites several visitors at the same time to arrange objects. In general tables are important tools in many civilizations. Humans are used to work and collaborate around tables [41]. The work around the table creates an atmosphere of community and enhances the interaction between visitors. The central interaction area allows placing it in a distance to the spots where the virtual objects can be placed. Thereby visitors can easily look at the current arrangement, while others replace exhibits.

For this scenario the museum needs only one device and several projectors. The size of the table and demand on space in the museum let this concept appears as more self-containing as the concept in section 3.2.1.

3.2.3. Hidden Objects placed by visitors

On the entrance of the museum visitors can grasp digital exhibits from "rummage tables" with their digital guide or their smartphone. Either visitors select digital objects, which are fascinating for them or they can load a random collect of objects to the guide. While the visitor is walking through the exhibition, she or he can leave digital exhibits where he thinks this object would fit here. Additionally he or she can argument the left object with a comment or explanation. Other visitors can explore these hidden objects by using the digital guide. Different ways to detect a hidden exhibit are thinkable. One possibility would be to detect the examined object by the digital guide and to show all hidden objects placed by visitors around this exhibit. Another way to detect hidden objects could be to notify the visitor by an acoustical signal, while he or she is walking "over" a hidden object. In large exhibitions with many visitors the number of hidden objects could be too high to inform the visitor about every digital object. To reduce the number of detectable objects, the visitor could notify only about objects which fits to his interests. The interest could be measured by the collection of digital objects on the digital guide of the visitor. Also the collections of the visitor which has placed the hidden object and the visitor which detects the object could be compared to compute the importance of the hidden object.

As motivation to place objects, the visitor gets points for leaving an exhibit. Also he gets point if somebody detects the object again. The points could be used to give a discount in the museum's shop or to show a ranking and to name the visitor-curator of the day.

Another approach to motivate visitors to take an active part in the exhibition is inspired by the augmented reality game Ingress[1]. Visitors are divided into several teams. By adding virtual content to a physical exhibit they can conquer the exhibit. The teams can be building automatically by chance or by certain criteria to enhance the social interaction between the visitors in the museum.

3.2.4. Spark interest by pieces of exhibits

In the whole exhibition images of parts of exhibits are presented in frames or boxes. By showing not the full object visitors start to think about the images and the object behind. This can lead to a creative engagement with it. Visitors can collect images which fascinate them with a guide or smartphone. On one or multiple tabletops, called "exploration point", in the museum visitors can explore the object in its entirety. Thereto the visitor places his or her smartphone on the table and selects an object to discover it on the large screen. On the "exploration point" visitors can have a look on the object from different perspectives and see background information about it presented as multimedia content. Also visitors can create new "bits" of the object and place them in the museum to inspire other visitors. By providing only a few exploration points, visitors will meet each other here by chance. This can be used to provide a room for exchange of ideas.

[1] `http://www.ingress.com/`

3.3. Concepts for the night of museums Amsterdam

The following concept are based on the preliminary concepts in sections 3.2.1, 3.2.2, 3.2.3 and 3.2.4. The following concepts are designed for a multimedia installation during the night of museums *"Museumnacht Amsterdam"* at the Allard Pierson Museum[2] in Amsterdam. Therefore we created three different concepts. One is focusing on the interaction between visitors, one includes social media networks and the last one is as simple as possible.

3.3.1. Enhanced visitors' interaction

According to Clarke and Hornecker visitors need a common task to interact more with each other [12]. In this concept visitors use their own smartphone to "collect" digital copies of objects shown in the museum. Every exhibit is furnished with a QR-code. By scanning the QR-code of an object with a smartphone (see figure 3.2) the visitor loads the exhibit in his collection.

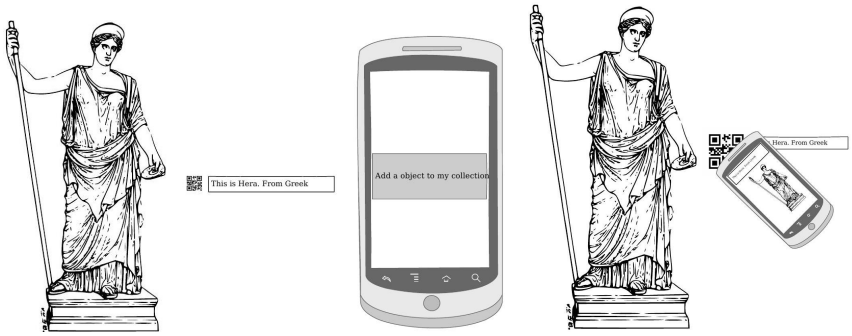

Figure 3.2.: *Left:* An exposed statue, with the QR-code, to get a digital copy. *Middle:* A smartphone is ready for scanning a QR-code.*Right:* A smartphone is scanning the QR-code.

Soon as the visitor has collected one object she or he can show the object to other visitors in the museum and explain why she or he is fascinated by the object. Only the image of the exhibit is transferred to the smartphone of the other visitor. The explanation has to be given without any technical support. For the exchange of virtual objects both users get "museumPoints" (see figure 3.3) and acknowledgement of the museum's community rises. The number of current owned "museumPoints" are also recorded in a high score. There the visitor can compare his or her success with all other visitors and with the visitors, who are currently in the museum.

At some areas in the exhibition visitors an invited to design virtual parts of the exhibition. For that purpose are tablet computers and projectors installed in at these areas. To be able to change the digital content of the virtual exhibition the user needs more "museumPoints" than visitor which has modified the current digital content at

[2] `http://www.allardpiersonmuseum.nl/`

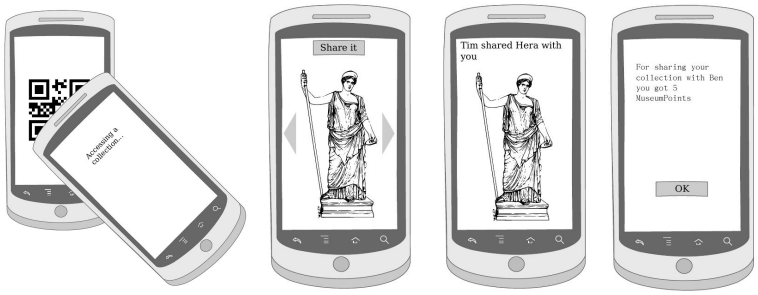

Figure 3.3.: *Left:* A visitor is connecting to a digital collection of another user. *Middle:* Sharing virtual exhibits. One visitor is sharing his collection with the other one. *Right:* The visitors get museumPoints for sharing.

last. To check the number of "museumPoints" the visitors has to login on the tablet computer. A proposed way to authenticate is using QR-Codes. Therefore the visitors got a private QR-Code at the entrance or the smartphone application generates one, if needed (see figure 3.4). Instead of using QR-codes it would be possible to use Bluetooth or NFC-technology for communication.

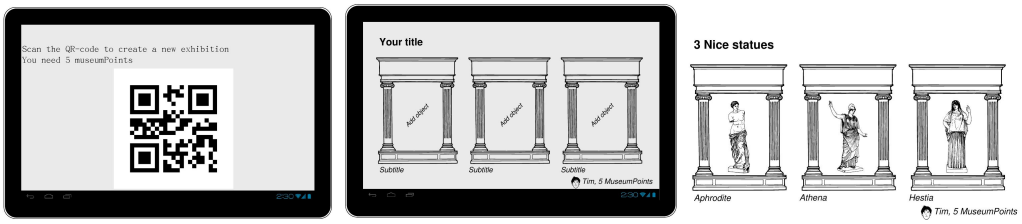

Figure 3.4.: *Left:* Tablet computer login screen to design digital content for the exhibition. *Middle:* Design screen for adding content. *Right:* Presentation of the content on the projection screen.

The use of visitor owned devices has the advantage of the possibility to enable personalized interaction. The personalization allows integrating gamification concepts to motivate visitors to participate. In practice we use points and high scores as classical elements of gamification [46]. Furthermore visitor owned devices allow to provide *"take-home"* content. The collected exhibits on the mobile device cannot only used to exchange them with other visitors, but also as digital souvenir. On one hand this is a nice memorization of the museum's visit. On the other hand if the visitor shows his "collection" around, it is personal promotion for the museum.

A lively communication between visitors can only occur, if a critical mass visits the exhibition and if the visitors are willing to take part. This also requires the ownership of smartphone in the group of visitors.

3.3.2. Connect exhibitions to social networks

Like in section 3.3.1 one or multiple terminals to become co-curator and be placed in the exhibition. On these terminals visitors can create virtual arrangements of samples, which they like, fascinate or they miss in the museum. The set of objects, which can be presented by the users, is categorized. So that users can find relevant objects for their arrangement. Additionally the user can append a comment to the arrangement to explain the idea behind it. The use tablets or interactive tables as input devices is most suitable. Regular PCs or user owned devices are also eligible.

In contrast to the concept in section 3.3.1 the challenge is not to get access to the exhibition design tool by collecting points. Every visitor can just start to design a virtual exhibition (see figure 3.5), but not every proposal will be presented to a larger audience in the museum. Here is the challenge of this concept.

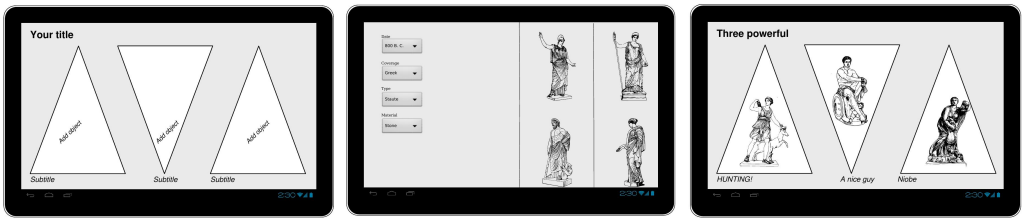

Figure 3.5.: *Left:* Empty arrangement on the visitors interface. *Middle:* Selectable collection. *Right:* Complete arrangement.

The proposal has to convince other visitors and followers on twitter to be great. Therefore, the design will be posted on twitter. Additionally all proposals will be presented as thumbnails at a terminal in the exhibition. Both visitors in the museum and twitter users are invited to rate the proposals. Either on twitter by clicking ”Favorite“ or in the museum without an own device by tapping on the thumbnail (see figure 3.6).

In this concept the idea is to motivate visitors by attention from other visitors and mainly form an online community. Parts of online community are the community of the museum people how focus on the topic of the exhibition and personal followers of the user. By showing the arrangement to friends the visitors the visitor expect attention and tells ”look I am in the museum and doing cool stuff“. Every post form visitors is also promotion for the museum.

Challenging is the login on twitter. Most natural would be to present own arrangements in the personal news thread. This would require entering twitter name and password on a public device. Many visitors might not be willing to enter personal data on a public device, because of security doubts or easily because they do not know the needed login data. Hence we propose to share all arrangements on one twitter account owned by the museum. If the user wants to, he can mention his own twitter name in the comment. The use of one museums account has also the benefit to allow visitors without a twitter account to share their ideas and motivate them to get in touch with the social network. To avoid the login on a public device the user could also use a private device. But a

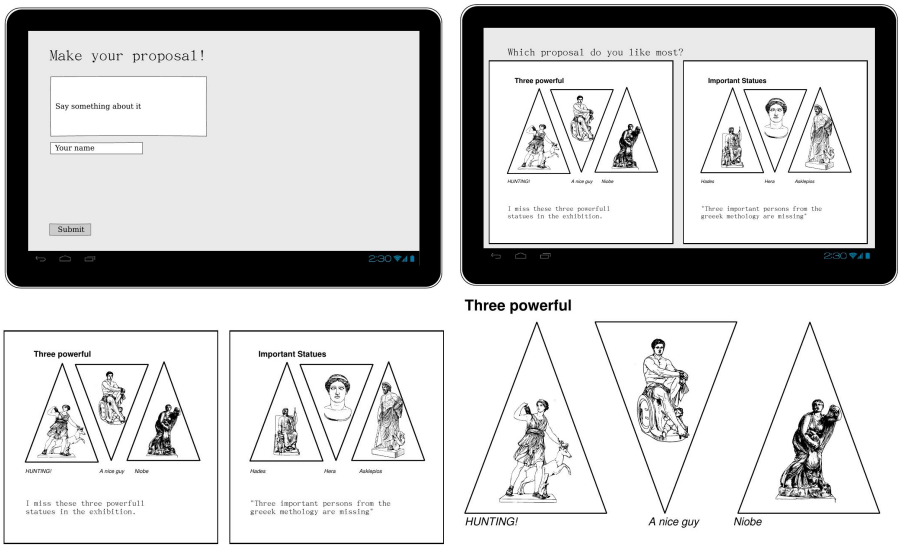

Figure 3.6.: *Top left:* Screen to describe the proposal. *Top right:* Another tablet is showing all submitted proposals. *Down left:* Projection screen with all proposals. *Down right:* A projection screen is showing the best rated proposal.

smartphone might be too small to arrange multiple objects comfortable and the number of visitor, who carry a tablet in an exhibition around might not be very high.

3.3.3. On-the-fly co-curator

In the showroom an interaction terminal and a presentation stage is integrated. The interaction terminal is featured with a tablet computer or any other computer with touch input. On this touch screen visitors can leave and share thoughts, impressions and wishes about the exhibition. For that propose they can write text, combine it with provided virtual exhibits and include own images. To group content visitors are also invited to use frames. These frames create a more valuable impression. In contrast to the other concepts, users add and manipulate content at the stage rather than creating new own arrangements. So it is not possible to remove everything. This concept aims to offer a platform to share and discuss the exhibition and does not call for a challenge between visitors. At the same time as the visitors create the content it is presented in the museum on a projection wall (see figure 3.7). This projection inspires other visitors to think about the view of other visitors and motivate them to contribute also to the arrangement.

To direct visitors' attention to the system a possibility would be to display the interface on a Microsoft Pixelsense 2 instead of a tablet computer. The MS Pixelsense 2 has the advantage of the bigger size than a tablet computer. This would allow interaction in groups of visitors. This could be relevant in particular in a museum environment and would enhance the interaction between the visitors.

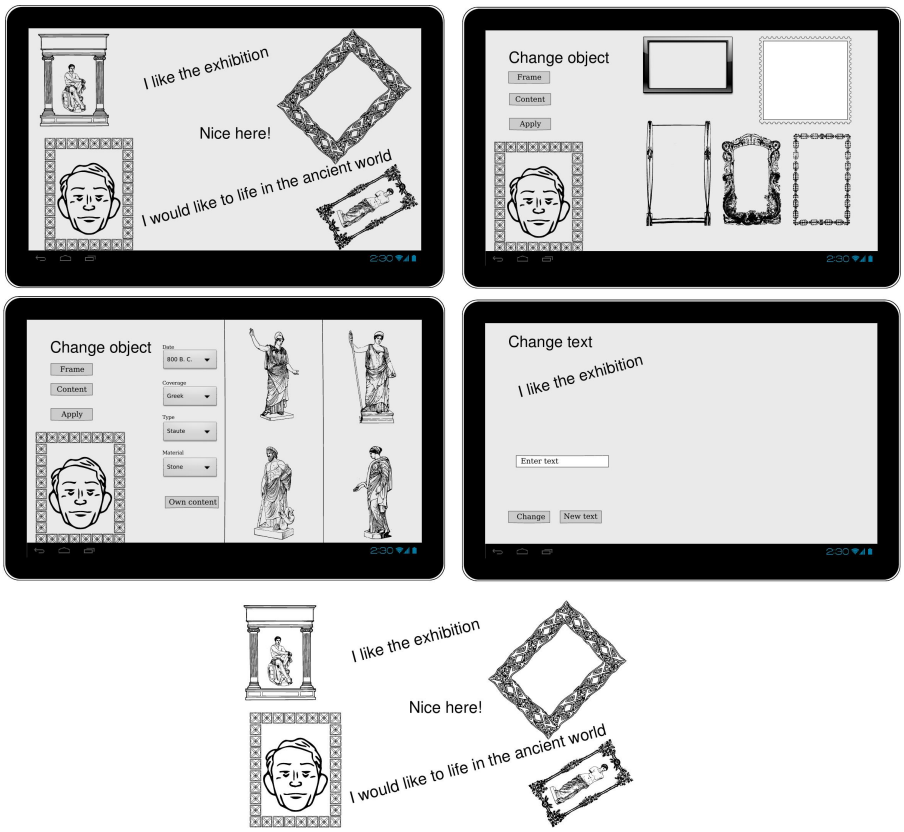

Figure 3.7.: On the tablet screen are the current presented objects shown *(top left)*. By clicking on an object visitors can change it. They can change the frames *(top right)*, they can change the content *(middle left)*, and they can change or add text *(middle right)*. The creation is presented on a projection wall *(down)*.

Another interesting setting is to use multiple input terminals for one presentation stage. Ether visitors could use own devices or multiple museum owned terminals could be placed in different locations. Including visitor own devices would allow in an easy and fast way to inform the user about changes or relations to his content. Than the user could react on this without walking back to the terminal and an exchange of opinions could take place.

Another challenging scenario would be to create a room for interaction which includes multiple exhibitions with a related topic. Thereby visitors of both museums could get an impression of the emphasis of the other exhibition. Depending on the location of the museum, shared virtual exhibitions would not only present different views of a common topic, it could be also a cultural experience for the visitor. This could be interest especially for exhibitions with and cultural or social aspect.

We decide to implement this concept in the first version with some adjustments for the

field study at the Allard Pierson Museum. In contrast to the in section 3.3.1 we do not need to equip the whole exhibition with QR-Codes and we do not have to ask the visitor to install an application on their private smartphone. Additionally an organizational issue would be to get images of all exhibits in the exhibition to share them with the visitors.

The other concept in section 3.3.2 has a restricted access in terms of presented arrangement. We assume that it would not be possible to reach enough visitors and twitter users during one night to get an active interaction. Furthermore, both other concepts spark probably mainly the interest of smartphone owners and twitter users. This concept has no expectations about the daily use of smartphones or social networks of the visitors.

We assume that this basic concept as well suited for a first field test, because the interaction do not take much time and is possible without any precognition. By not including too many possible elements, we do not influence the user to explain their ideas how the application should be designed.

In contrast to the basic concept "On-the-fly co-curator", we change the interface to one screen. On the left side we place the stage, where visitors can arrange exhibits. The stage has one global title, which can be ether given or freely entered by users. On the right side we placed an overview over all selectable virtual exhibits. Every exhibit on stage can be commented by text. We exchange the frames by fix plinths, because the museum provided physical one for the field test. The function to include own data we removed from this concept, because of technical reasons.

4. Implementation

In this chapter we describe the iterative design and implementation of our concept. The implemented prototypes are based on the design requirements and low fidelity prototypes presented in section 3.3.3.

4.1. Technology

We implement the application as html5, web application to be independent from any device specific language or platform. The implementation as a web application allows also the use for the largest diversity of different use cases. An implementation in C# and WPF for the Microsoft PixelSense or in Java for Android could serve the same purpose. However to switch the platform or including the application in a website would become difficult.

For the client we use JavaScript, because JavaScript is well suitable for dynamic web pages, which allow users to manipulate displayed content. In contrast to php, JavaScript allows to load content dynamically. This enables to load single objects when they are needed without reloading the whole application.

At first we used an Apache web server to serve the application, because the Apache server is already used for other projects. Soon as we need full-duplex communication, we change to a *node.js*[1]. After testing php based solutions to implement a WebSocket, we see much more benefits in using *node.js*. In contrast to php based WebSockets, the *node.js* works reliable and fast. Also the communication between the application and the database works without any problem. The use of *node.js* as only one drawback in our case. To share our concept with others, the application has to be accessible over the internet. Because on our project server Apache already uses Port 80, we have to use another port. The port we use is blocked by some company or university networks. The only possibility to overcome this issue, is to use port redirectoring.

4.2. First Working Prototype

To accomplish a high portability and an easy access for user owned devices in future prototypes we implemented the application as web-based application. The application consists of three parts: the user interface, the presentation to a large audience, and the communication in the backend. The objects which are included in the first working prototype are selected manually from Europeana[2] for the Egypt-exhibition at the Allard

[1] `http://nodejs.org/`
[2] `http://www.europeana.eu/`

Pierson Museum in Amsterdam[3]. It would be easily possible to access other databases. By accessing a standard protocols like, Open Archives Initiative Protocol for Metadata Harvesting[4] (OAI) the application can be used with different databases without any effort. Connecting the application to exhibit databases would allow to build a "curators' view", where the curator team of the museum can import objects in the application and prepare them to be arranged by visitors.

4.2.1. Visitor view

The main part, the user interface, is realized in JavaScript. The interface is divided into two canvas objects. One of them is located on the left side. There users can arrange content. Therefore we call this canvas stage. Additional curators can add non editable elements, like physical exhibits which are included in the presentation. On the other canvas all available virtual exhibits are displayed images. Both canvas objects uses the *KineticJS* framework[5]. The framework allows to handle graphical objects and user triggered events comfortable as well on desktop devices as on touch devices. This gives the opportunity to provide gestures for mouse-based and touch-based interaction. To enable the use of the interface on desktop computer and mobile devices, like tablets and smartphones, the size of interface is scalable. Even if the size scales up or down, the aspect ratio is constant. The constant aspect ratio assured that stage is equal to the canvas, which is presented in the exhibition.

The virtual exhibits, which can be selected, are displayed in a cluster on the right side of the screen. By tapping on the image the object will be added to the stage. If a device without touch interaction is used the image can be selected by a regular click. On stage the images can arrange freely by dragging them. To change attributes of the object the user has to tap or click on the image. A menu with two icons appears to resize the image and to add a comment. The button to add a comment can also be used to change the text. We use a menu here, even if other gestures for example for zooming on touch sensitive interface are well known[25, 63], because multi-touch events do not work properly on all devices at the moment. While the image is moved by the user a garbage can is displayed in the upper left corner. If the object is moved to the garbage can, it will be deleted. The text, zoom and the garbage can icon are part of "Gentleface Wireframe Toolbar Icons for GUI designers"[6].

4.2.2. Exhibition view

The current arrangement of artifacts on the virtual stage shall be presented visible for all by-passing museum visitors. Therefore, the stage is mirrored and displayed on a second web page. By using a second independent web page the mirrored stage can be presented

[3] http://www.allardpiersonmuseum.nl/
[4] http://www.openarchives.org/
[5] http://www.kineticjs.com/
[6] http://gentleface.com/free_icon_set.html

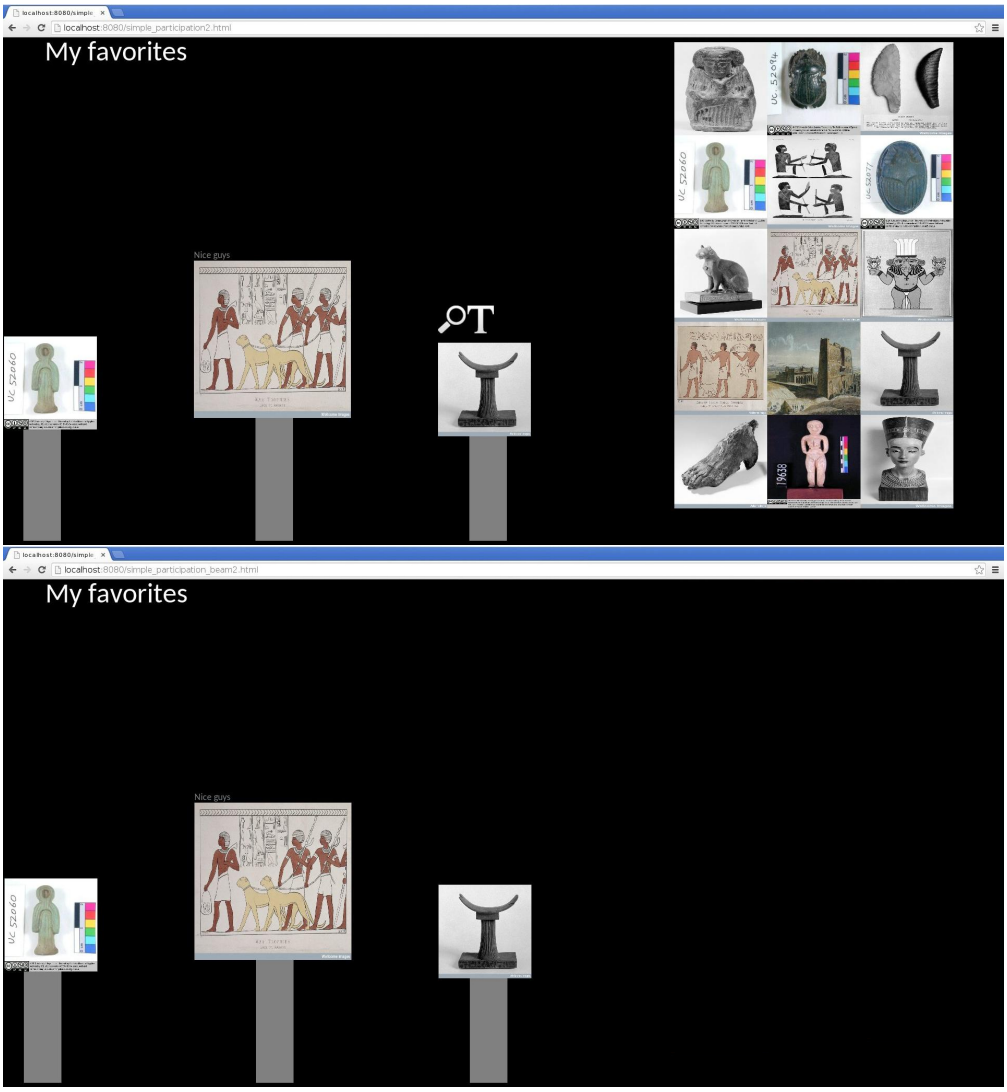

Figure 4.1.: *Top:* Interface for visitors with arrangement. Above the exhibit on the right plinth is the edit menu shown. *Bottom:* The same arrangement on the web page to present the arrangement. The edit menu is not visible here.

in every web browser (see figure 4.1). To connect the stage with the mirror of the stage, we use a WebSocket based on *node.js* and *socket.IO*[7].

The exhibition view is updated after every change done by a user. Thus the stage appears more ordered and without any editing icons.

[7] `http://socket.io/`

4.2.3. Backend

All html-views of the application are served by a node.js server. Furthermore, the server provides the communication between the two views and between the visitor view and the MySQL-Database. Every time the exhibition view is updated, the arrangement will be also stored in the database, to analyze users' arrangements. For this purpose every database entry contains also a timestamp. To enable ratings of different arrangements in later versions, it is also possible to store a current voting value.

To implement the communication between the node.js server and the MySQL database we use *felixge/node-mysql*[8] package.

4.3. Second Working Prototype

The field study at the Allard Pierson Museum revealed different challenges. At first, users want to use only objects which they know. At this point the application lacked of information about the exhibits, which can be presented. At second the interactivity of the system has to be communicated active to the visitors. Otherwise visitors will just look at the system without touching respectively interacting with the system.

As well visitors as museum staff and curators ask for sharing arrangement on social media or on the museums homepage. Other visitors were interested in taking their exhibition home as a printed version.

To improve the application the visitors view and the backend had to be adjusted.

4.3.1. Visitors view

To call for interaction without annoying users we have to detect inactivity. Therefore we measure the inactive time. Is the interface longer than a given threshold not used, a hand tapping on the screen appears at random positions and in random orientations on the stage. The hand symbol is also part of the "Gentleface Wireframe Toolbar Icons for GUI designers". Soon as users perform any action the hand will disappear. The threshold time before the hand is shown is easily adjustable. At the moment we call for interaction after 12 minutes. The optimal value should investigate in a practical test.

The information about the object should be provided in an obvious but not abstracting way. At first we extended the "edit menu" above the added image on the stage with an "info button". If the button is pressed, an overlay will appeared and display information about the exhibit. In an iterative process we decided to show the additional information about the exhibit before the user can add the object to the stage. Now the information together with a larger image of the object is displayed in an overlay when the user clicks on an object in the collection. This overlay also includes a button to add the exhibit to the stage.

[8] `https://github.com/felixge/node-mysql`

4.3.2. Backend

The changes in the visitors view create also the need for adjustments in the backend. To store the information about the exhibits, we create another database table called `TBImages`. In this table we store the path of the image, a name and a description. This has the advantage of separating the content from the implementation of the application. When a user loads the visitors view, the node.js server queries the image data from the database and sends all information over a WebSocket to the client.

4.4. Third Working Prototype

After the improvements based on the findings from our field study, we discussed the implementation with a curator and colleges. As result we decided 1) to increase the number of objects distinctly 2) to build relations between images 3) to give users the possibility to share the arrangement on a museums owned twitter account. Figure 4.2 provides an overview over all components of the applications after the adjustments.

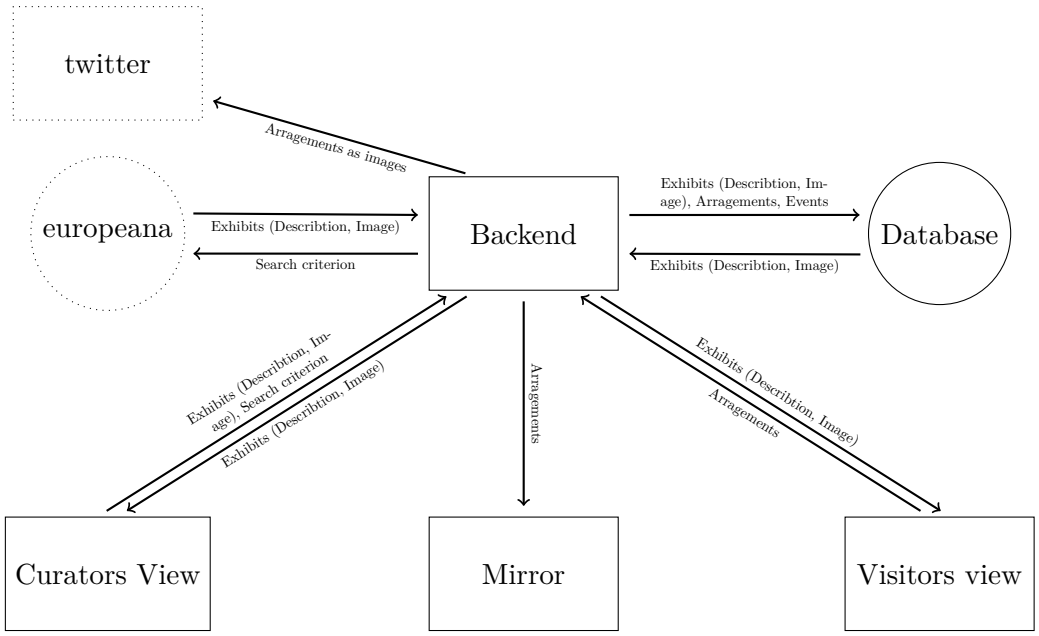

Figure 4.2.: Model of communication between all parts of the application. The Backend communicates with twitter and Europeana over REST. The database queries are MySQL statements. A WebSocket provides a communication channel for the interfaces.

4.4.1. Visitors view

The new functionality requires additional control elements. If the number of objects increases, not all exhibits can be shown in the collection at ones. Hence we divided the collection in multiple pages and implemented a scroll lower and a scroll higher button. With these buttons the whole collection can be browsed and instead of a rearrangement when the application is reloaded, all exhibits will keep their order.

A collection with too many objects to get easy an overview needs methods to divide the collection in currently interesting objects and objects which do not fit to visitors' ideas. In a pull down menu the visitor can select a keyword, which interests the visitor. If a keyword is selected, in the collection only exhibits with the selected keyword are displayed.

When an exhibit is moved to stage, only objects with the same keyword, so called recommended objects, will be shown in the collection. To control which object are recommended, all objects stored together with their keywords in a dictionary. Every time an exhibit is added to stage, the array of keywords which controls the displayed collection is updated. Thereby the collection gets updated. In the following reducing the viewed collection seems to be random and unpredictable. Hence we did not change the collection viewed on the right side automatically. Instead we show up to nine related exhibits radial around the added element on stage. To give the user the possibility to view more related exhibits, we include a symbol in the circle around the added exhibit to show only related exhibits in the collection. Nevertheless the user still has the possibility to select one category out of a dropdown menu (see figure 4.3).

To be able to share the arrangement or to export it we create a jpg image in form of a Data-Url by using the *KineticJS* function `toDataURL`. To export user's arrangement we open the Data-URL in a new browser window. When the arrangement should be shared on twitter we open an overlay, using simple modal, and ask the user to enter a text message. In this text message the visitor has the chance to explain the arrangement and mention the own twitter name to be shown as creator. The text message and the data-url of the arrangement will be transmitted by a WebSocket to the server. The server handles the twitter update on the twitter account *parallel exhibition*. It is beneficial to use an exhibition or museum owned twitter account, because this allows user to share their ideas independently of an own twitter account. Furthermore users have not to enter their own twitter account data.

In this version we use *KineticJS'* `toDataURL` function also to offer also printing. Thereby the data-url of the arrangement will be open in a new window and the printing dialog of the browser will be open. After closing the dialog also the window will be closed.

It is only possible to use *KineticJS'* `toDataURL` function, if all elements shown on the stage are hosted on the same server, like the application website. If other content from arbitrary server is included, it is not possible to export the arrangement, because of security policies. Hence it is not possible to export or to share arrangements with exhibits from Europeana, because the application does not work with local stored copies of the exhibit, but with the direct image path of the exhibit on Europeana. Thus we

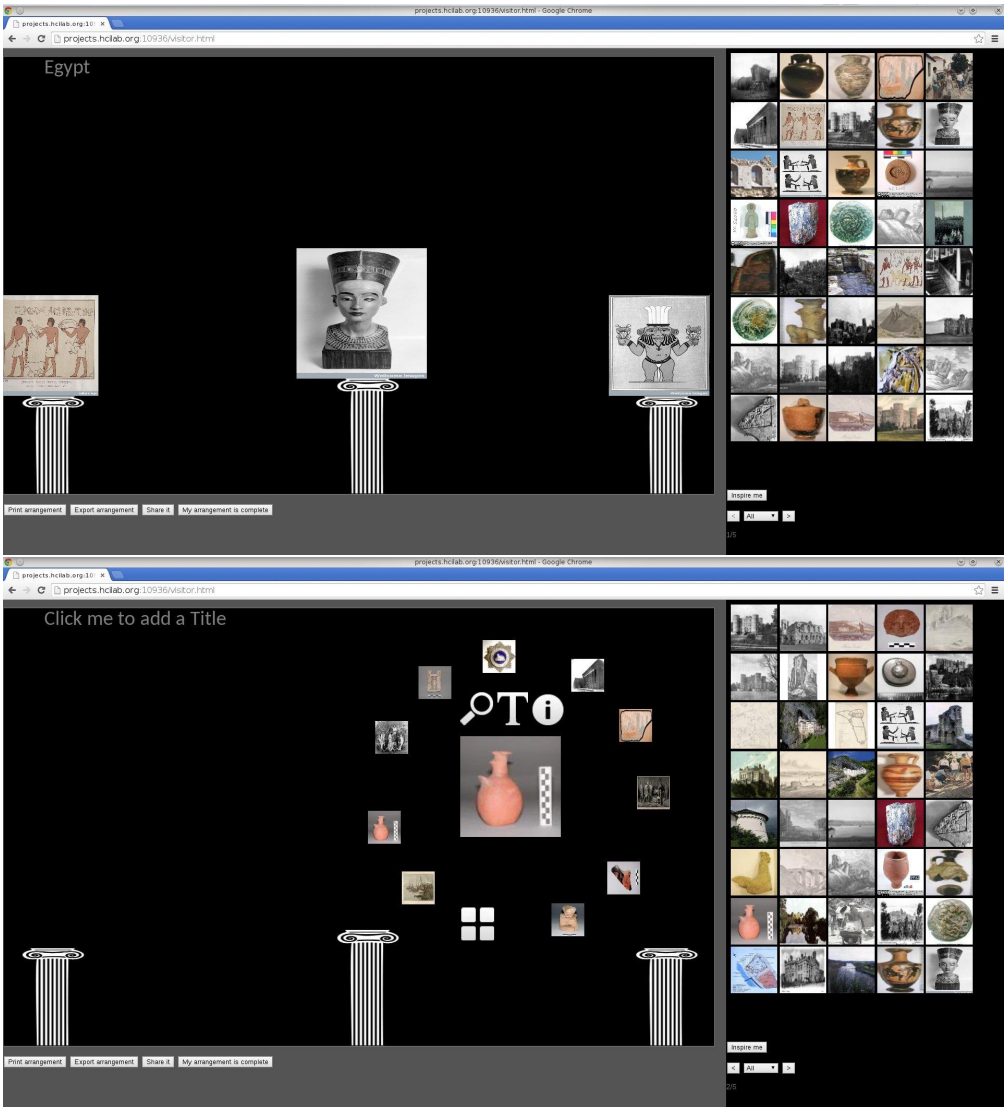

Figure 4.3.: Top: Visitors view with an arrangement. Buttom: The edit menu of one exhibit is open and related objects are shown.

implemented a proxy running as a part of the server application. The visitors view has to distinguish between images which are hosted locally on the project server and images which are hosted on any other web server.

4.4.2. Curators view

The curators view contains functions to maintain the content of the visitors view. Currently it consists out of two web pages: one for adding objects to the collection and one to maintenance the objects in the collection.

There are plenty of sources of exhibits. May be the museum has an own database with owned exhibits or a common database like Europeana shall be accessed. Here we implemented a small prototype to collect objects from Europeana. The user can enter a search criterion. The first 100 image results from Europeana will be added to the collection on the database. To assist the user the properties of the objects will be predefined by information from Europeana (see 4.4.3). After all elements are added to the database the page to maintenance the collection will be viewed. The adding functionality is in a very early state. It is mainly implemented to show the possibility to access other data sources and to extent the collection for testing and studies. For a final implementation it should be possible to enter different keywords, like creator, date of creation, places etc. At this point museum staff's feedback would be useful to ask for the correct keyword. Also the user should get feedback while the data from Europeana is collected and processed to the database.

To maintain a large collection the curator needs a tool to edit the properties, like name, description, or keywords, of the objects. Also undesired exhibits have to be erasable. The quality of a large set of elements depends amongst others on the efficiency of the maintenance tool. Hence, it is possible with our curator view to edit or to delete multiple exhibits at once. It is questionable if it is reasonable to allow changing the name or the description of multiple objects to the same at once.

The curator view is like all other views implemented as an html5-web page. The page is mainly optimized for a full HD[9] screen, but resizing of the single elements allows also using the curators view on nearly every other screen. On the left side of the page is the properties editing menu. There the name, description and tagged keywords can be editing. Also a button to delete elements is placed there. By selecting a checkbox it is possible to switch in the multiple elements mode. To keep overview over used tags and to avoid misspellings the text field proposes all tags which are already stored in the database.

On the right the collection is viewed in a *KineticJS* stage object. On a full HD screen every single exhibit is displayed as 200x200 pixels large image. If the collection is too large to be shown at once the arrow-buttons on the left side can be used to browse the collection. Below the buttons the page number is displayed to indicate the currently viewed subset of the collection (see figure 4.4. In difference to the visitors view, the single exhibit in the collection is always in the same order. Even if there is a need to review collection by the museum staff (see Section 1), the order of elements is kept because the main purpose of this view is to provide an overview and not to inspire museum staff. To get new ideas how to use the own digital and physical collection museum staff can use a not open to the public visitors view. To make modifications at one ore multiple exhibits the user select the element by clicking or tapping on it. The selected exhibits will be highlighted to indicate which elements are selected. To provide a faster access to single elements in future a search function should be implemented.

[9] 1920x1080 pixels

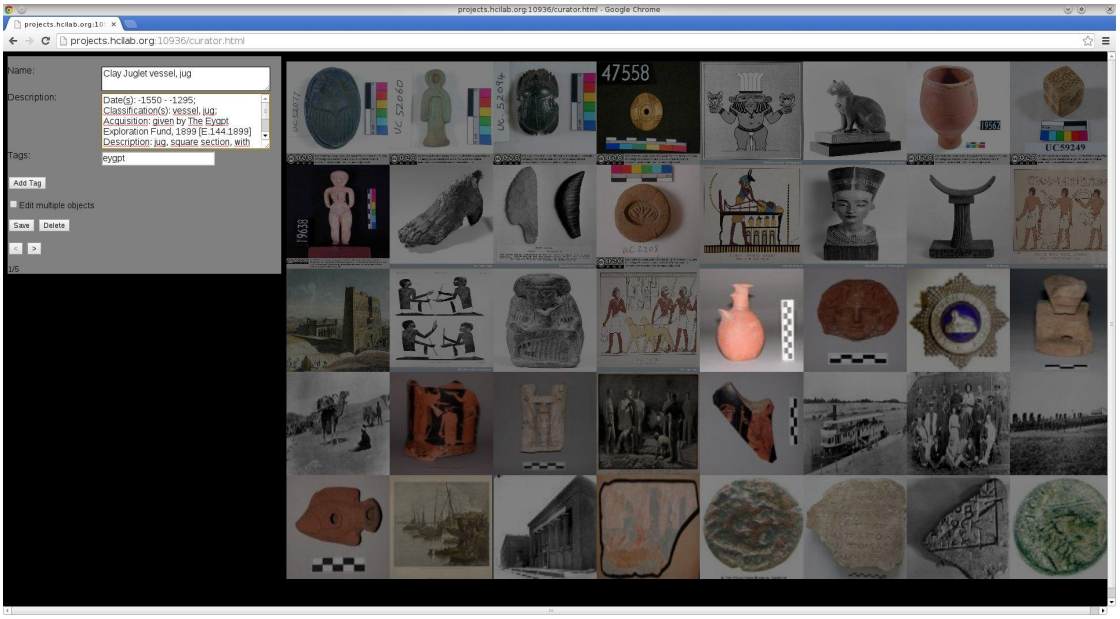

Figure 4.4.: Curators view: On the left side the properties can be set. On the right side the collection is shown. The selected exhibit is highlighted.

4.4.3. Backend

To build relations between different exhibits, elements can be tagged with keywords. To map this structure in our database we create two new tables. One called `TBCriteria` to store the name of the keyword together with a unique id. In the second table, called `TBImageCriteria`, we store the relation between criterion and image. The criterion As well as the image is represented by their unique id. This allows an n-m-relation, to connect multiple images with multiple criteria.

To insert new objects from Europeana to the database the curators view sends the entered search creation over a WebSocket to the server. The server requests the first 100 images related with the search criterion by using the Europeana REST API[10]. To be able to use request data over the REST API the server needs a private Europeana API-Key. As a result the server gets a JSON-Object with all related objects hosted on Europeana. This JSON-Object contains an object for every single exhibit. In this object amongst others the title respectively the name and the image path are stored. Europeana does not know an explicit description of the elements. Thus we use information about the creator, about the publisher and the date of creation to build a description. The for the description need information is contain in the requested JSON-Object. Only a web link to request the information is part of the JSON-Object. So we need to request the information about the exhibit one by one. To benefit from the asynchrony concept of node.js at first we request the JSON-Object with all related elements from Europeana.

[10] `www.europeana.eu/portal/api-introduction.html`

Soon as the JSON-Object with the data about all exhibits is returned we insert the search criterion as keyword to `TBCriteria`. The insert query returns amongst others the unique id of the keyword. Is the id existent, we query first the information to create the description text and add then all exhibits with path, name, and description to `TBImages` and create a connection between exhibit and keyword in `TBImageCriteria`. The process of query the description and adding the exhibit to the database will be done in parallel for every founded exhibit.

To export or to share the arrangement on twitter we use the *KineticJS* function `toDataURL`. The function `toDataURL` expects that all content on stage is hosted on the same server then the web page. To guarantee this the server application provides a proxy to redirect images from Europeana. To implement the proxy functionality we use express[11]. Thereby the server application requests the queried http-content and pipes the content back to the client, which has sent the request.

To post the arrangement on twitter we use one twitter account. The application and the twitter account *@ParallelExhibit* is registered to use the twitter REST API. The server application gets the image data and the status text from the visitors view as a JSON-object. The server application removes the MIME-type and character set information of the data-url and writes the remaining image data into a binary buffer. The buffered image and the status text will be posted by using twitter's `POST statuses/update_with_media`.

4.5. Online Study prototype

Finally we prepared the prototype for an online study. The online study aims to analyze how users will arrange objects and what they think about combining virtual exhibits with physical exhibits. Therefore we extended the automatic user tracking and adjusted the interface to be more self-explanatory.

4.5.1. Visitors view

We identified the need for assistance while the user is using the application for the first time. Hence we placed two notifications in the application. One is fading in a second after loading the application over the collection. On this notification the user gets called to click on an exhibit to add it to the stage. The notification disappears soon as the user has clicked on one of the elements. The second advice opens up when the first exhibit is added to stage. The advice is placed on the stage and explains how to move or to edit the exhibit. The notification should not disturb the user while he is arranging content. On the other hand the user should be able to read the instructions carefully. Therefore the advice on the stage disappears after 10 seconds.

To be able analyze users behavior in the online-study the visitors view sends every action, like adding an element, clicking on a button, to the server application to store the information in the database. To assign the arrangement to the answers of the

[11] `http://expressjs.com/`

survey the visitors view requests a unique id form the database. This id is stored in the session storage to be also available on the survey pages. The visitors view sends also information about the used system, like window width and height, operation system, system language, used web-browser and platform to the backend.

4.5.2. Backend

To store all data to analyze users' behavior we create different new tables in the database. One table, called `TBAction`, is used to store all information about the actions the user is performing. Every action associated with current arrangement on stage. This allows conclusions about what the user saw while he was performing a certain action. In the table is also the name of the action and up to two related attributes stored. For example if the user adds an exhibit from the related objects around another added exhibit, in the `TBAction` will be the id of the drawing, "added from related" and the path of both images as attributes stored.

In four additional tables we store all information which is related to the participant in the online study. In `TBUser` we store all information, which can be automatically collected by the visitors view, like the system properties. In `TBSurveyPersonal` is the personal information from every participant, like age, profession, and frequency of museums visits stored. Because we use different surveys for people who are working in a museum and for people who are only visitors of museums, we use two different tables in the database, `TBSurveyMuseum` and `TBSurveyVisitor`.

5. Study

To evaluate our concept and the implementation we conducted one field test in a museums and an online-study. In addition we interviewed museums professionals to get an understanding of their work. This is needed to design an application which convince all stakeholders.

5.1. Field-Study

In a first study we analyze how our first working prototype sparks interest of the visitors. We investigate how the curators see co-creation by visitors. An important aspect is the social interaction around the system. The best way to observe users' motivation and social interaction is to conduct a field study in a real world setting [28]. Hence, we decided to conduct a field study.

5.1.1. Setting

To evaluate our concept the Allard Pierson Museum[1] invited us to conduct a field test in the Egypt-exhibition during the Museum's night of Amsterdam. The Allard Pierson Museum is collecting artifacts of ancient civilizations, like Egypt, Near East, Greek, or the Roman Empire. The purpose of the museum is to provide access to ancient artifacts for research and for a large public audience with a special focus of young visitors. The museum aims to be a "relaxing place, and a stimulating and inspiring surrounding for visitors and staff"[1]. The Egypt collection contains objects from all periods of time between 3000 and 332 B.C. The exhibition focuses on funerary rites and mummification.

The provided room for the field study was approximately four meters wide and five meters long and open on two sides. In the middle of the room we placed an interactive table, namely a Microsoft Pixelsense 2.0[2]. On this interactive table we run two Firefox windows in full-screen-mode. One window was displayed on the surface of the table with the user interface of our prototype. The other Firefox window was used for projecting the mirrored stage.

The usage of the Microsoft PixelSense has multiple advantages. The size of the table attracts attention by itself and looks more impressive than a tablet computer. On the other hand the table is bulky. So it is difficult to integrate a PixelSense in an exhibition and it is unlikely to place several tables in different rooms in one museum. The touch input on the PixelSense is working with infrared light (IR). The IR part of the ambient

[1] http://www.allardpiersonmuseum.nl/
[2] http://www.microsoft.com/en-us/pixelsense/default.aspx

light can have a critical influence on the touch input technology. By a high IR part of the ambient light, the touch input is less accurate. To achieve the best input quality we shade the room.

The arrangements were displayed the mirrored stage on a projection space in front of the interactive table. This setting allowed users to see directly their arrangement presented. At the same time other visitors of the museum had enough space to stay around and watch. In addition, we placed three physical plinths in front of the projection space (see figure 5.1). To indicate the possibility to place objects on these plinths we represented them on the stage virtually. A drawback of the setup was that the room was not part of the main route through the exhibition.

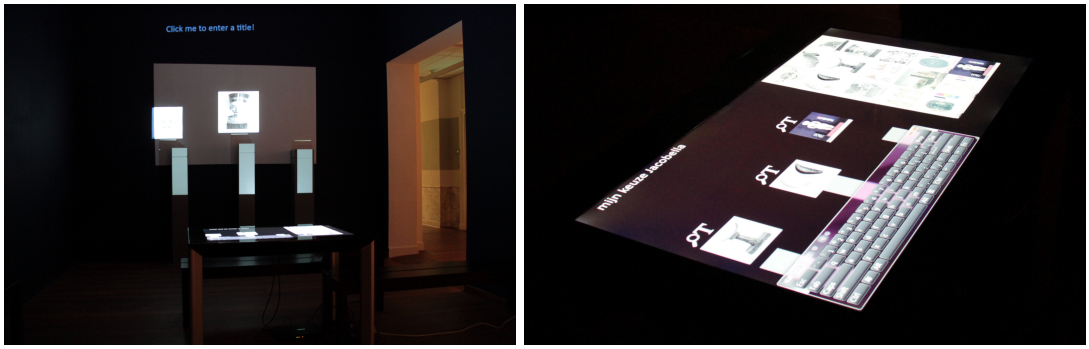

Figure 5.1.: *Left:* In front the interactive table and in the background the presentation of an arrangement. *Right:* User interface

We decided to capture data by observing the visitors and classical note taking. In addition our application logged every interaction in a database. We dispensed with video recording, because it could prevent visitors to act naturally. In addition we conduct semi-structured interviews with users and museums staff.

5.1.2. Observations and Findings

During five hours of study time we observed 35 visitors interacting with the system. Further 30 visitors passed-by without interacting with the system. Approximately 20 visitors who just passed-by looked at the system.

In general the visitors were very open to try out our system and to play around. The openness of the museum to include new interaction technology in exhibition might be a supporting factor. Most of the users were roughly between 20 and 35 years old. However we also observed older people interacting with the system. The lack of younger users is caused by the setting of the Museum's night of Amsterdam. Children and teenagers are not the main focus group the night of museums in Amsterdam. The distribution of female and male users was nearly uniformly. Most users discovered our application in small groups up to five people or in pairs. Only two single visitors interacted with the application. This is justified by the distribution of the visitors. Most people visited the museum in such groups.

Communication and feedback

Most of the visitors liked the idea to explore additional exhibits, creating arrangements of objects and present them to the public. We observed many discussions about certain exhibits (see figure 5.2). The application motivated visitors to engage deeply with the virtual exhibits. So multiple users asked for background information related to the objects. We observed uncertainty of the visitors which objects are well suited to present to the museums audience. As soon as a curator was around to provide more knowledge, visitors arranged exhibitions more self-confident. Also the conversations about the exhibits were livelier when a curator provided stories around the objects. Visitors also mentioned that they would like to get feedback from curators.

Figure 5.2.: Visitors discussing with an researcher

In contrast visitors used only very rarely the possibility to argument single exhibits or the whole arrangement with text. Also users did not continue on creating an arrangement started by other visitors. If the stage was not empty when the visitors arrived, they started by removing all objects. To invite visitors to interact we arranged single exhibits and added questions like "Do you like cats?" as title. This did not show much effect on visitors. So for example two women passed by, one of them read the title out, but without any interest to answer the question.

Multiple users asked for a possibility to print their arrangement to take it home. Surprisingly in particular younger visitors around 25 years old asked for printed versions. In interviews they mentioned that they would also accept a possibility to share it online, but a printed post card would be much nicer. Only one elderly visitor took pictures of the own arrangement with a smartphone to show it to friends. The fact that only one visitor took an image, is in particular surprisingly, because the organizer of the Museum's night of Amsterdam provide an app[3] which allows to capture impressions by taking pictures.

One curator asked if the arrangement is live on the internet. He would like to include a live view on the museums homepage. He sees this as a great opportunity to present the museum as a place of active communication.

[3] `http://museumnachtamsterdam.nl/`

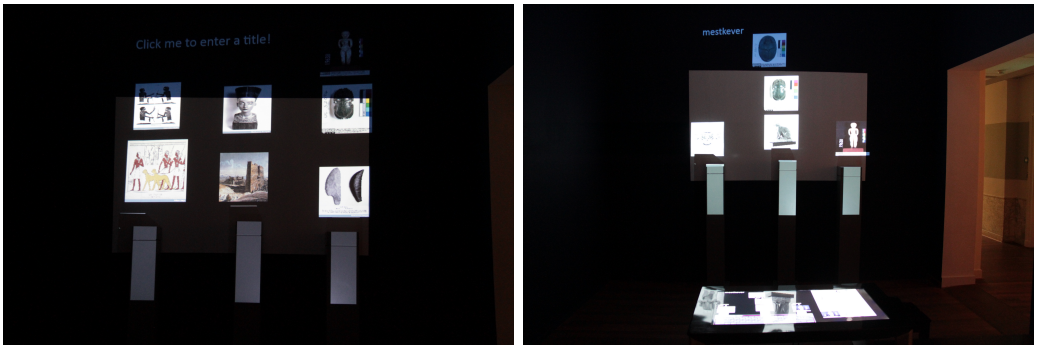

Figure 5.3.: Arrangements of virtual exhibits

Shifting attention

Even if, the projected area was directly in front of the interactive table, multiple visitors needed some time to discover that they are manipulating the presentation. When a lively discussion around the table took place, many groups of visitors lost the attention to the projection screen totally and used the table only to support the discussion by enlarging exhibits and removing them afterward. Other users, which were not involved in debating exhibits, discovered the three plinths and used them to place objects on them. If the arrangement contained more than three objects, the exhibits were arranged in a stack above the plinths (see figure 5.3). Users who identified the plinths complained about the missing of a "physical correct behavior" of the objects in the application. Other visitors did not expect any movement, besides dragging, of the objects.

Usability

Besides the already mentioned missing physics engine we discovered some usability issues. The most users observed others while interacting with the application before they start to interact with the table. Many of them need additionally a personal invention to give the application a trail. Soon as the visitors started to interact with the application, the users were immediately able to add exhibits to the stage either by dragging the element to the stage or tapping on the object. However some users had difficulties to recognize the garbage can in the upper left corner. They tried to remove exhibits by dragging them out of the frame in any direction.

To enter text we placed the virtual keyboard over the application, at a not for interaction used area at the button of the screen. Because most visitors come from the area around Amsterdam we provided the Dutch keyboard layout. The minimal text input could be caused by the curiosity of a touch keyboard on a Microsoft PixelSense. Typing on the virtual windows keyboard is quiet different to tablet or smartphone keyboards.

We run the application in the newest version of Firefox. To avoid distraction and to provide a good user experience we run the application in full screen mode. By the overlaid keyboard it would be easily possible to quit the full screen mode and to try to

use the web browser for other purposes. However we were very happy that no visitors tried to use the interface for browse in the internet.

Gamification

Some visitors assumed a game behind the interaction. In particular if we placed a question like “What do you think about Egypt? as title, people looked for a quiz. The users who were looking for a quiz, tried to arrange the ”right“ elements on the stage. Because there was no feedback given by the application if an exhibit is right or wrong they got confused. In the interview they mentioned that they would like to play some kind of game. The game should assist to collect objects with a meaningful relationship. Also one of the curators developed the idea to ”combine a physical exhibit with a virtual game“. Thereby visitors could overlay the physical exhibit with additional images. The images should be placed on positions where the shown objects belong to. As an example the curator could image to exhibit a mummy. The visitors could select different pieces of grave furniture, like scarabs and drag them virtually on the mummy. By moving pieces of grave furniture to the right place users could collect points.

Content representation

The desire for more stories around the presented exhibit was already mentioned. Visitors mostly said that they would like to read related information about the exhibits before they decide to add them to the stage. Some visitors would like to include in addition to images also videos in the application. The interest in including videos can be also seen as the wish to enhance the story-telling aspect of the application.

Some images were obviously distorted. However no user described this as annoying or complained about it. We also could not observe users who explicit ignored blurred images.

5.1.3. Discussion and Future Work

Over all the feedback of visitors and museum staff was very positive. We observed lively social interaction between visitors and discovered different improvements for future developments. We see possibilities to design the application more playful and to enhance visitors' engagement with the application. We discussed different possible solutions within our working group. We discussed the use of different interfaces for visitors' interaction. Furthermore we rethink alternatives enhance social interaction and the relations between exhibits.

Interface devices

There are multiple benefits in utilization of an interactive tabletop. At first the table is large enough to be noticed by visitors. The size of the display allows groups of visitors to stand around and discuss lively about virtual exhibits. The bulkiness of the Microsoft

PixelSense protects the table to get rearranged in a physical way by unauthorized persons.

Beside the possibility to place the table between other exhibits, like we did it in the field test, it could be interesting to place the table at the entrance or somewhere around the exhibition. This could be on the exit of the museum or in the museums café. According to Simon[52] presenting questions to visitors, provoke them to reflect on the topic of the exhibition. By facing visitors with questions like "What do you expect to see?", "What do you miss in the exhibition?", or "What would you arrange around this statue?", visitors get motivated to share their thoughts.

The size of an interactive table can be also a drawback. The issue of shifting attention from exhibits to technology is well described e.g. by Hornecker [27]. So physical exhibits around could appear smaller and less interesting than they are. The required space and the high market price of interactive tabletops could prohibit the installation of many well integrated interaction terminals in one exhibition.

The advantages and drawbacks of an interactive table let us rethink the interface devices we use.

Tablet-version During the last years tablet computers have become commonplace. They are inexpensive and available in many form factors. Because our application is implemented as web-application and we provide dynamic resize of the user interface, it would possible to run the application immediately on any commercially available tablet computer. Furthermore many people use tablet computers for daily purposes. We assume this could lower the barrier to interact with the installation.

The small size of tablet computers would allow placing an arbitrary number of interactive terminals between regular physical objects. Thereby the tablet could be mounted on a tablet floor stand. In this scenario we would use tablet computers with a screen diagonal of approximately 10 inches, like the iPad form Apple or Google's Nexus 10. Tablet computers with a smaller screen size might provide too little interaction space for the most settings. One use case for smaller tablet computers could be to add and arrange small virtual exhibits, like coins, small tools, or jewelry, in a showcase.

We observed many visitors who interacted only a few minutes with the application and went on. It could be interesting to provide a smaller interaction space respectively less space for arranging objects. This could allow creating a stronger relationship to surrounding physical exhibits. By placing multiple areas which can be arranged in the exhibition, visitors could be more motivated to arrange some objects from time to time while walking through the exhibition.

An adverse aspect of the utilization of tablet computers appears if a group of visitors join to the interface. The tiny screen of a tablet computer does not allow all members of the group to have a good glance on the arrangement. This would prohibit lively discussion. During our field study we observed the discussions as one of the greatest benefits of our application. So it would be a large damage to prevent them. To overcome this issue it could be a solution to provide a "conversation area" with an interactive tabletop and multiple scattered tablets in the museum.

Private device Arranging virtual exhibits by a personal owned device might have different strength in comparison to public devices. So users could easily create personal accounts without entering personal data on a public device. This can create a much more personal experience for the visitors. The utilization of gamification is expected and wanted by visitors. By using user owned mobile devices interaction on multiple positions can be easily implemented. Furthermore elements like rankings are much impressive if users can easily observe their success over a longer period of time. Also sharing own arrangements online becomes much simple. However the desired possibility to print arrangements gets more complicated, because visitors have to connect to the museums' printer.

Even if there are ways to enhance social interaction by using mobile devices [11], they are not easily to adapt on our concept. Social offline interaction in a group of visitor around one smartphone is a complicated issue, because only one or two visitors can look on the screen at the same moment.

Presentation of content

One of the main findings of our field study was the need for information about the virtual exhibits and the desire for stories around them. One obviously improvement is to add information as text to exhibits. We discussed different way to show users the information. We conclude to provide two ways to access the information. One way is to present the information before the exhibit can be added to stage by clicking or tapping on the element. Then an overlay opens and after reading the user can decide to add the object or not. If the exhibit is already on stage the visitor can click or tap on the exhibit. Thereby a small menu above the exhibit opens. In the menu is a button to show the overlay with the information again.

We discussed different approaches to guide the user while selecting objects to exhibit them. A basic part of our concept is to place physical exhibits in the presented arrangement and to provide given topics for the arrangement. For example is would be possible to place a statue on one of the plinths. Providing headlines for the arrangement did not motivate visitors for interacting as we assumed. According to Simon [52] it is suitable to use provocative questions. Another approach is to suggest exhibits after one object has been added to stage. Therefore we decided to add keywords to the exhibits. Exhibits which have a common keyword are related and can be proposed by each other.

Users desire to print own arrangements seems to be interesting, because printing post cards on demand is not very challenging and should be easy to include. This offers visitor the unique chance to compose a post card with their favorite exhibits. Additionally we decided to have a closer look to integrate social media in the application to spark the interest of the museums marketing and visitors.

5.2. Feedback from Curators

We conduct four interviews with museum professionals working at museums in the Netherlands and in Italy. We interviewed one curator twice. One time before our online

study and one time afterwards.

In the interviews after the online study we focused on the general use of virtual exhibits in combination in museums settings and how technology can be designed to invite visitors to communicate their ideas.

All interviewees confirm our basic assumptions that nearly every museum has more exhibits in storerooms than space to show them to the public. In addition online repositories provide large amount on cultural heritage objects which could be used. They also agree that it is beneficial to enhance the communication between the museum and external persons. In general they see the museum as place for interaction and communication. The endeavors to create digital databases of all objects stored in achieves were successful. All interviewees reported that their own museum has a digital database of owned objects. The databases provide information as text and also images of the objects. They also do not know any museum without such a database. Even so there is still a need to improve the knowledge about the objects. One of the museum professionals mentioned that they can easily see what the museum owns, but it is still difficult to build meaningful connections between the objects. So the issue described by Matassa [38], that it is a challenge to keep an overview over the owned objects.

All museum professionals are interested to get feedback from non professionals. However they are focusing on different groups. One professional is not sure if visitors are interested in contributing to the design of an exhibition. The interviewee does not see a way to create meaningful conversation areas in a regular exhibition, but tools to collaborate with communities are interesting for the professional. In contrast another curator sees collaboration with visitors as time consuming but meaningful and important. Hence the curator asks if it is possible to store the arrangement in a database connected to objects catalogue, to use it later for analyzing which exhibits are combined by visitors. This can also be used to present multiple arrangements in the museum or on the homepage of the museum. In addition saved arrangements, produced in a traveling exhibition, can also be shown in the next museum where the exhibition is displayed. In context of displaying multiple arrangements the curator proposed to improve the possibilities to present text. Thereby as well the presentation of text in the arrangement can be improved as the function to comment the whole arrangement should be implemented. Furthermore the curator proposed possibilities “to stay in touch with the own arrangement” after the visit by leaving the email address or something similar.

We also discussed different user groups and settings in which our application could be meaningful. Together with the museum professionals we discovered five different scenarios. The main scenario is to invite visitors to arrange virtual exhibitions in the museum. Therefore curators would use virtual exhibits which are owned by the museum. One interviewee says:

> I like the concept of combining virtual with physical exhibits. It is a great way to show what we have in the storage.

Overall the curators have a strong interest to use our application to present objects which are owned by the museum. As a web-application published on a webpage they can also image to integrate other virtual exhibits, for example from Europeana, in the

used dataset. The interviewees assume it as suitable to provide the application for the museums community or for school kids to prepare museum visits. Furthermore they mention to be interested in using the application for their own work. They would like to sketch ideas for upcoming exhibitions fast and easily to get an impression of the new exhibition. Even we focus on visitors' interaction in this work, this indicates an interesting need to develop tools to assist museum professionals and curators. This indicates that another approach to enhance visitors' participation is to build tools for museum staff which also provides functions to invite visitors to give feedback. This would give the curators the feeling of control. As well in the interviews as in the online survey the curators seems to be afraid of lowering the quality of the exhibition by providing space for visitor arrangements. In connection with the desire to use the tool to create exhibitions the curators bring up the idea to provide a top view of the showroom to arrange exhibits. We discussed an application with top view as low fidelity prototype. We decided to implement another concept, because the view angle does not change in the implemented concept. We assumed that it is more intuitive to see the exhibits in the presented angle.

The museum professionals see also possibilities to improve the representation of virtual exhibits and design of the application. They ask for 3D presentation of the virtual objects. Here is the challenge to provide 3D data models of the exhibits. It is a great idea to show virtual 3D exhibits, but 3D models of cultural heritage objects are prevalent yet. They also admit that at least the databases of their museums do not contain 3D models. Besides our proposed setting to show plinths to place virtual exhibits one curator proposes to place an empty showcase in the exhibition. With our application visitors are invited to fill the showcase. The empty showcase creates an uncertainty about the sense which motivates visitors to explore it. Furthermore one curator sees no need to include gamification in the application because the experience to be a curator would be enough. To create a stronger curator experience and to motivate visitors to visit the museum a second time they would be willing to change exhibits by the proposals of the visitors.

Two curators work for a museum which focusing on the politic and military conflicts in the 20th century. They describe their interest in our application as follow:

> Many visitors like to contribute to the exhibition, because they like to tell personal stories or stories of their families in the time of the first or Second World War. At the moment we are looking for a possibility to provide space to include personal stories.

This supports the assumption that visitors want to make the experience to be a curator and that they have an intrinsic motivation to share their ideas and stories. This might strongly depend on the topic of the exhibition. Topics which are related to personal experience outside the museum, like contemporary history, motivate visitors more to contribute than exhibitions which focusing on ancient life.

5.3. Online Study

Beside installations in museums we discussed to use our concept to enhance community support and provide visitors the possibility to engage with the topic of the exhibition before the visit.

To evaluate our concept as an online tool for interacting with digital cultural heritage, we published the application on our project server. We included approximately 200 images form Europeana as content for virtual exhibits. The objects are related to ancient Egypt, ancient Greek and medieval castles. In addition to the application we published a survey to get feedback about our application and interaction with virtual exhibits in general.

We shared the link of the online-study in our social network and to get feedback from museum professionals in the meSch project.

5.3.1. Study Structure

We divided the online study in four parts. In the beginning we introduce the application and explain the idea of this thesis very roughly. A very short description is reasonable because it does not influence the participant to much but gives an idea about the setting.

In the second step the participant was invited to create an own exhibition freely. We did not include any recommendations. Soon as the arrangement was completed, the participant was guided to the survey by pressing the button “my arrangement is complete”.

The survey consists out of two parts. At first we ask to answer some general personal questions, like age, profession, and gender. Additionally, we asked frequency of museums visits. In the second part of the survey, we asked people who work in a museum and people who only visit museums different questions.

5.3.2. Data collection

We captured data while the participant created own exhibition. Soon as the application opens, it sends information which is contained in the HTTP-User-Agent-Headers to the server. This information covers name of the operation system, browser name and system language. In addition the application sends the window width and height. The database adds the current timestamp to every entry. While the participant is arranging exhibits, every action is recorded and will be transmitted to the database. Thereby we store the type of action and up to two related objects. For example if the participant added an exhibit from the collection of related objects around the first one, we store the name of both exhibits together with the action time and a timestamp. If the action affects the presentation stage, we also store the new arrangement as a JSON-Object in the database. It would be more storage sufficient to store only the changes combined with the timestamp, but the full copy allows a faster reconstruction. The answers on the survey are also stored in three database tables. Every participant has a unique ID

during the whole study. Thereby it is possible to group participants according to special attributes.

5.3.3. Results and discussion

In this section, we first present and discuss the data we captured while the participants interacted with the application. In a second, step we analyze the answers of the survey.

Application analysis

During the 18 days we run the study, 40 people participate in the study and used the application. These participants used the application on average 226.23 seconds, the median absolute deviation is 135.5 second (see figure 5.4). However the time they spend with arranging exhibits varies greatly, so the standard deviation is 220.69 seconds. As interaction time we measured the time between the application opens and the click on the button "My arrangement is complete". Meanwhile the participants used on average 5.65 (SD = 4.25) exhibits for their arrangements (see figure 5.4). In figure 5.5 we replaced all exhibits in final state by semi-transparent rectangles to shows all positions of exhibits. We did not remove the comments related to single exhibits, to indicate also the text input. Comparable to our observation in the field test (see 5.1.2), we see minimal text input. The semi-transparent rectangles display the hot-spots of exhibits. There are three eye-catching areas with a high denseness of exhibits. The three dark blue areas in the horizontal middle are the top of the plinths. This allows the conclusion that it is fruitful to provide some fixed elements. This could even more explicit if these elements would be physical objects.

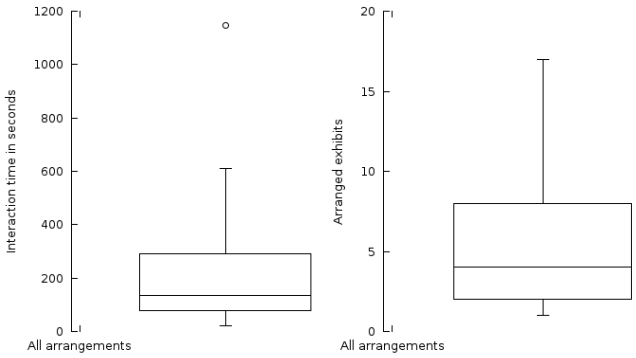

Figure 5.4.: Interaction time and number of arranged exhibits

Unfortunately the number of participants who work for a museum is too small to draw conclusions. However the image of the areas where exhibits are placed, shows attentively arranged virtual exhibitions (see figure 5.5). Also every other analysis allows only vague assumptions, because of the small number of participants.

Figure 5.5.: *Left:* Positions of all exhibits on all arrangements. *Right:* Positions of all exhibits arranged by museum professionals

To analysis the results more detailed we divide the participants in different groups. We aim to develop an understanding which visitors show interested in using our application. Because female and male participants are comparable in terms of profession and age, we compared the number of arranged elements and the interaction time. In our study 46% of our participants are female and 54% male. On average female participants used the application 72 seconds longer and arranged 3.75 elements more than male participants. Due to the student's t-test there is no significant difference in the interaction time, but the difference between the number of arranged elements is significant, given that the p-value is lower than the level of significance $\alpha = 0.05$. Even more interesting is to compare the groups of visitors who visit a museum multiple times a year, and participants who visit museums maximal once a year. Participants who visit museums rarely arranged on average 5.67 exhibits (SD = 4.16), while participants who are more interested in museum visits arranged 6.0 objects on average (SD = 4.57). For this hypothesis, that there is a difference between these groups in respect to their number of arranged object, the student's t-test calculates a p-value of 0.82. Thereby we have to reject the hypothesis. Also the hypothesis that there is a significant difference in the interaction time of this group, the participants who visit museums seldom interacted 117 seconds longer, cannot be confirmed.

The analysis of the performed action does not show unexpected abnormality. Overall we recorded 931 performed actions by 40 users. On average every participant performed 23.28 actions (see figure 5.6). The most performed action is adding exhibits from the collection to the stage (see figure 5.7). The possibility to add exhibits which are proposed by already inserted objects used 28 participants (70 %). Participants who added proposed exhibits, added on average 3.25 proposed objects and 5.0 exhibits from the collection. This shows the attractiveness to get proposals and support the observation in the field study, that users looking for more guidance. Four participants added only one exhibit from the collection and added on average 1.5 proposed object (SD = 0.58). Only 40 % of the participants removed objects by using the garbage can. One fifth removed more than one exhibit. Nearly every participant (93.75 %) who used the garbage can also added exhibits which are proposed. Thereby we can assume that participants who liked to use the stage to edit content and those participants who add proposed exhibits

experiment more with different arrangements. In general the number of added exhibits and the interaction time have a linear relation. The number of removed objects and the interaction time have also a linear relation. Figure 5.8 shows the interaction time in relation the number of exhibits. We determine linear regression curves as well for the relation between interaction time and added exhibits (gradient = 0.022; SD = 0.004) as for the relation between interaction time and removed exhibits (gradient = 0.006; SD = 0.001). To calculate the regression curves we removed one pair of data (interaction time = 1148; added exhibits = 11, removed exhibits = 2), because the interaction time is several times larger than the average and the standard deviation (M = 226.23; SD = 220.69). If we would not remove this point, the influence of the point would be unacceptable large. The f-test indicates that there is a significant linear relation between the interaction time and the number of elements. Also the student's t-test confirms that the gradient is suitable to approximate the variants. We use a level of significance of 0.05.

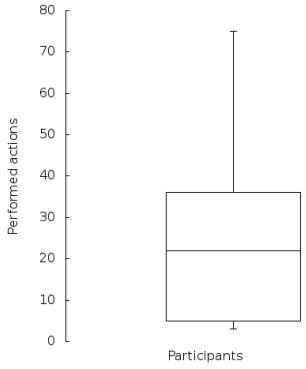

Figure 5.6.: Number of actions per participant

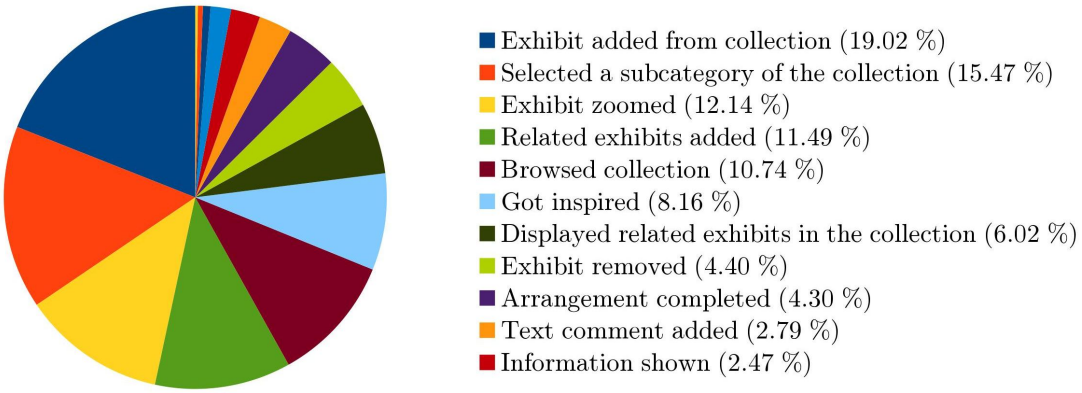

Figure 5.7.: Performed actions

The domain of definition is restricted by several constrains. Trivially opening and closing the application take time and less than zero elements cannot be added. Hence

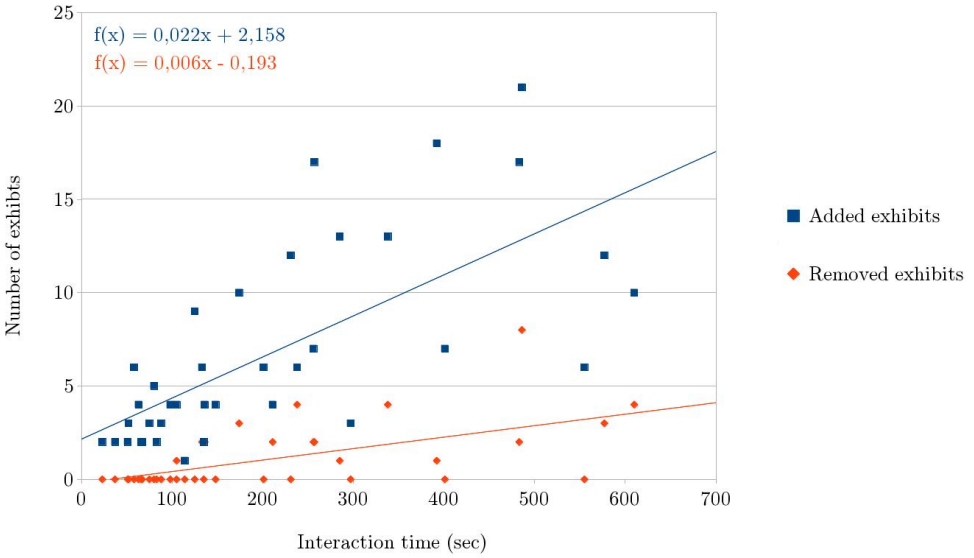

Figure 5.8.: Number of added and removed virtual exhibits with regression curves

the interaction time and the number of objects have a limit of 0. On the other side the number of elements is limited by the elements in the collection and the provided space to arrange them. Theoretical the time has no upper limit, but depending on the number of objects in the collection, users will not discover new exhibits after a while.

Both regression curves are linear functions. So if users interact longer with the application they add and remove more exhibits. There are no evidence that users who take more time, select images more carefully. Instead the regression curves indicate that participants use the time to experiment and to arrange different objects together. In figure 5.9 we present some typical arrangements, done by participants in the study.

The function to select subcategories of the collection seem to be attractive, 55 % of all participants used the function. From these participants 95.45 % used the function at least twice. This confirms the assumption that a large amount on virtual exhibit is needed to inspire visitors. A large amount on objects creates the need of functions to keep overview.

In contrast to the comments related to single exhibits, the titles of the arrangements and the twitter comments are created more carefully. Participants entered titles like “Women of Egypt”, “Women of Egypt”, “My museum“ or ”cultural footprints“. As twitter post participants wrote for example ”ancient bins and a random foot“ or ”extremely cool ;)“ (see figure 5.10).

The participants selected 119 of 196 different exhibits (60.71 %). Four of five most selected exhibits are part of the Egypt-collection, we collected for the field test manually. This might have some reasons. At first the collection is one of the smallest. If one exhibit of the collection is chosen, all related objects in this collection will be shown. All other

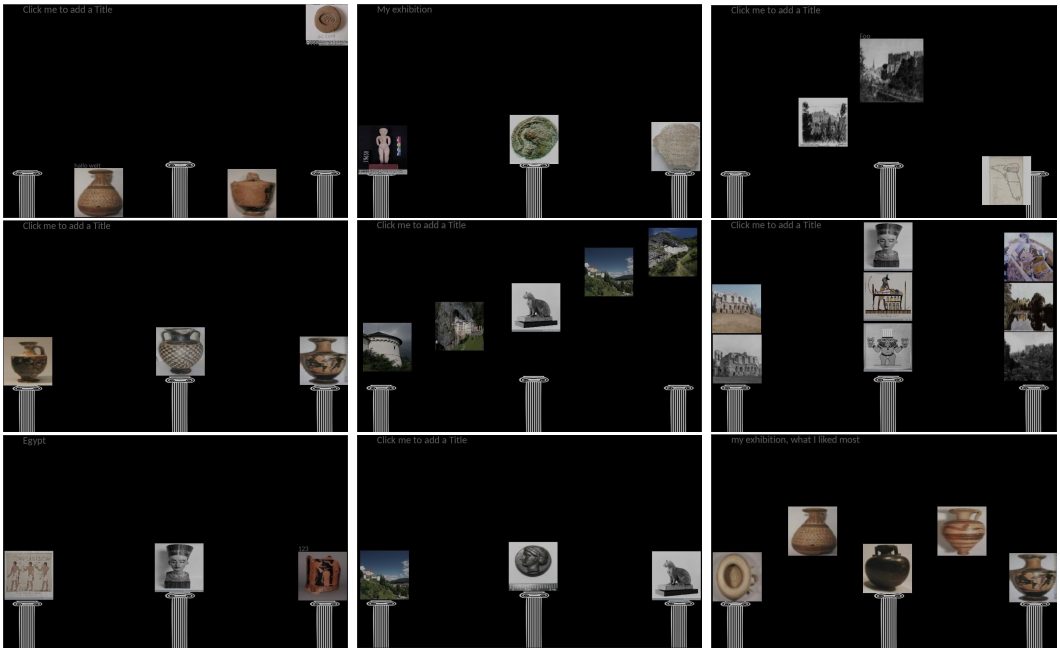

Figure 5.9.: Different typical arrangements

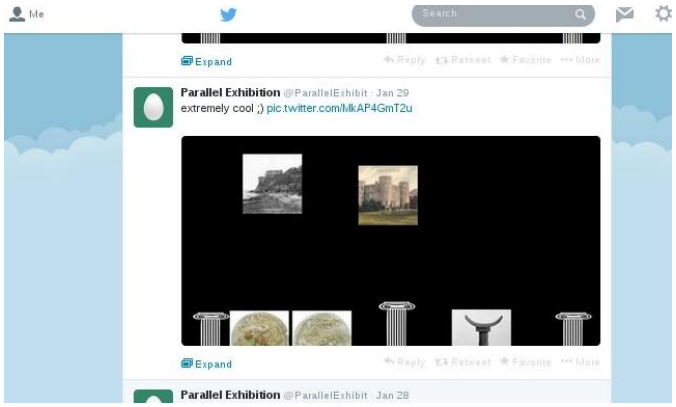

Figure 5.10.: Example of shared arrangements on twitter

collections are much larger. In proportion to the most selected images, images which are part of other collections, have only a small probability to be shown as related object. At the same time the quality of the elements are much better than the element which are automatically included from Europeana.

5.3.4. Survey findings

To get an understanding of the needs of visitors and museum professionals we provided to different surveys. We ask both groups about their interest in visitors' participation

in the museum. So we ask the museum visitors about their motivation to become a co-curator while the visit a museum and some concrete questions to our application. We ask the museum professional as well how they would like to include visitors in their work. Furthermore, we are interested in their assumptions what visitors motivate to become active.

Visitors view

In the survey we ask the participants who are not working as museum professionals about their motivation to explore virtual exhibits in a museum. The number of female and male who work not in a museum participants were nearly equal, 47.37 % female participants and 52.63 % male participants (N = 38). Most participants are higher educated (see appendix chapter 6). The participants visit mostly museums by chance. 60.53 % of the participants visit museums at least once per year. Nearly a quarter (23.68 %) visit museums less than one time per year. The group of frequent museum visitors contains 7 participants (18.42 %). They visit museums at least once a month.

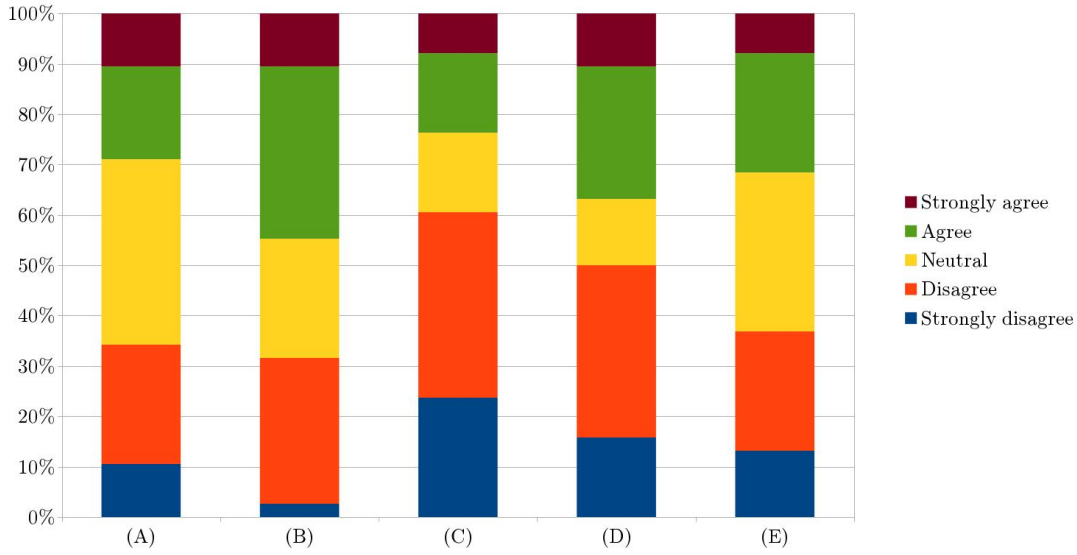

Figure 5.11.: Agreement to the statements: (A) "I would like to influence the design of the exhibition which I visit."; (B) "I would like to share my opinions about the exhibition with other visitors in an exhibition."; (C) "I would prefer to arrange exhibits on such an application before I visit the museum."; (D) "I would prefer to arrange exhibits on such an application while I am visiting the museum."; (E) "I would prefer to arrange exhibits on such an application after I visited the museum."

We ask the participants five times how much they agree to certain statements in form

of a likert scale. We used a scale from 1 - "I totally disagree“ to 5 "I totally agree“. The answers to the question "I would like to share my opinions about the exhibition with other visitors in an exhibition.“ is on median 3 (MAD = 3) (see figure 5.11). As follow up question we asked if and how the participants would like to share their ideas and opinions. As multiple choose answers we provided:

- "Yes, with my friends on Facebook“ (31.58 %)
- "Yes, with my followers on twitter“ (18.42 %)
- "Yes, on other social networks“ (2.63 %)
- "Yes, on the museum's homepage“ (26.31 %)
- "Yes, I would like to take home a printed post card“ (44.74 %)
- "Yes, ...“ (13.16 %)
- "No“ (31.58 %)

Five participants used the free text field. All of them mentioned that they would like to share their experience with their families and friends in an offline way. If we combine the answers which are indicating an interest in sharing the experience in social networks 36.84 % of all participants would share their ideas on Facebook, twitter, etc. In contrast 21.05 % of the participants is interested in taking a printed post card home, but they would not share their experience in social networks. This confirms the assumption from the field study that there is a larger interest in taking something physical home than sharing museum experience with online "friends“.

To get a better understanding what museum visitors motivate to contribute we asked how much they agree to the statement "I would like to influence the design of the exhibition which I visit. “. On average the participants answers with 2.94 (SD = 1.14). We also provide a multiple choose question what they would motivate to arrange a virtual exhibition. We provided the following answers:

- "Because it's fun" (39.47 %)
- “Because I like to share my thoughts with others” (21.05 %)
- “Because I miss something in the museum/ I have a idea to make the exhibition more interesting” (55.26 %)
- “Other ...” (21.05 %)

Participants who answer “other” furthermore stated:

1. “None, I would rather look at the exhibits“
2. "To plan ahead for my visit“

Even if multiple participants mentioned to be interested in using our application for planning museum trips, the three statements if and at which point of time the participants would like to use the application indicate something different:

- ”I would prefer to arrange exhibits on such an application before I visit the museum.“ (M = 2; MAD = 1)
- ”I would prefer to arrange exhibits on such an application while I am visiting the museum.“ (M = 2.5; MAD = 1.5)
- ”I would prefer to arrange exhibits on such an application after I visited the museum.“ (M = 3; MAD = 1)

The results might have a bias, because in the study the application has no direct connection to an exhibition. Hence the presented objects might be influenced the answer of the participants. Furthermore without a real exhibition it might be difficult for the participants to image the experience of a visit.

If we divide participants who are visiting less than once per year a museum and participants who visit museums, the overall the motivation to engage with the application is a bit lower in the group of participants who are not visiting museums. In contrast over all the motivation in the group of visitors who visit museums is a higher. We also had a look on the group of visitors who would like to share arrangements online in social networks. The results in this case are comparable to the group of participants who visit museums from time to time.

As addition comments the participants mentioned different ideas for future developments. The proposal “Show me only the exhibits I actually visited” is contrary to the main idea of this work to include virtual exhibits in a classical museum setting. However the idea to print personal arrangements of the greatest exhibits which are shown in the museum seems to be attractive for visitors. It could be enhance the interest to arrange exhibit, if also physical shown exhibits would be virtual available.

Other participants proposed to include more information about the exhibit and also user generated information, like rankings. The need for more information is obvious. Because for the study we collected the information about the exhibits automatically from Europeana. To use the application the support of the museum staff would be needed.

Professional view

In general museum staff seems to be open for new ways of interacting with visitors and communities. So one participant wrote

> It [including visitors in the design process of an exhibition] has the potential to introduce new angles, stories and perspectives to the exhibition, resulting in a richer experience and an exhibition that a more diverse audience can relate to.

Also there is an interest in enhancing the communication between visitors and professionals. So the benefit of more communication could help to get a better understanding of visitors' needs. But on the other hand the participants mentioned some uncertainties:

> Involvement is of utmost importance, and I doubt whether the average visitor will be interested in the co-creation of an exhibition from scratch [...] Involving users in the development of an exhibition is time consuming.

This interest in discovering new "angles" of the collection and a enhanced communication fits to the visitors' interest to be influence the design of exhibitions and the motivation to arrange virtual exhibitions. Together with the openness to provide space for digital interaction and the willingness to rearrange exhibits by the feedback of visitors. It is a good starting point. Concerning the application the participants proposed to provide more structured tasks for the visitors to support them by creating an exhibition. Also they mentioned the quality of the images.

At the moment we use directly the images from Europeana. The quality of the images can be easily increased by using other images with a higher quality. It would be also possible to use images with a transparent background to create a more impressive virtual exhibit.

5.4. Discussion and Future Work

Both studies and the interviews with museum professional have shown an interest in combining virtual and physical exhibits in a museum. Visitors and museums professional would like to exchange ideas and to improve exhibitions. This is a great starting point to continue the development of our application. As a next step the presented content have to be improved. Also the user interface can be design in more appealing way. This step should be done in close cooperation with a museum, which provides an exhibition for a longer field test with more participants.

We assume that there are three possible directions to develop the application. The first one is focusing on visitors, who are visiting museums from time to time. To analyze the benefit of gamification it would be interesting to implement an improved version of the concept in chapter 3.3.1 and compare it to our application. To develop an improved version of a game based application the concept presented by Caon et al. [11] should be taken into account.

Also interesting would be to focus on the community of the museum. Thereby tools for engaging over a longer period of time would be needed. Hence our application could be adjusted to an online tool for community management. This tool could contain complex query functions to search objects, functions to comment exhibits and arrangements as well as live views of the museum.

One curator mentioned the need for tool to plan upcoming exhibitions. It would also be interesting to design tools to support the work of museum professionals. This would include tools to visualize arrangements of objects, to cooperate on the design of certain arrangement, and search through the database with complex queries.

6. Conclusion

Parallel Exhibitions is motivated by four basic assumptions: (1) Museums have much more interesting objects in the storerooms than they can show to the public. (2) Digital catalogs of stored cultural heritage provide an easy way to get access to digital copies of objects. (3) There is a strong need to design applications to make a use of these data for professionals as well as for museum visitors. (4) The role of museums is changing in western societies from places that show cultural heritage to interactive places that contribute to the understanding of cultural heritage by providing space and knowledge to discuss.

In Parallel Exhibitions we do not aim to build a "virtual museum", because it is a unique experience to see and may be to touch physical exhibits. Furthermore, we see museums as a great meeting place to reflect together with others about art, history, or science. Our goal is to make a use of exhibits which cannot be shown as physical objects for some reasons and to invite as well visitors as professionals to discuss the presentation of objects together. Additionally it is time include online databases, like Europana or Wikimedia Commons in museums and present them to larger public.

To reach our goal we started an iterative design process. At first we created different concepts as mock-ups and paper-prototypes and discussed them within our working group. Thereby we focused as well on mobile applications which use smartphones or tablets as interaction device as on applications for interactive tabletops. Both device classes have different benefits. The reviewed research let us conclude that mobile applications have much more potential to present personalized content than applications which are running on one only a few large displays [5, 33, 47]. On the other hand interactive tabletops have great physical qualities to enhance the cooperation between users [41]. We decided to implement sand-box application which allows curators to place physical objects and invite visitors to enrich the arrangement by adding virtual exhibit next to the physical exhibits. To avoid limitations in the use of different devices we implemented the application as html5/ JavaScript application with a node.js server-script in the backend. We did not include any restrictions which could limit the interaction of visitors, to get an open and creative feedback from museum visitors and museum staff. Even so we had concepts to include gamification or a more guided approach in mind. We discussed these concepts with visitors and museum staff during a field study, in multiple interviews, and in an online study.

In the field study we invited visitors of an ancient exhibition to arrange virtual exhibits. We observed around 35 visitors interacting with our application and discussing about the presented exhibits. Thereby the large display of the interactive table was very beneficial to enhance the interaction between visitors. The discussions were even livelier when a curator was around to provide more information about the virtual exhibits. Also some

visitors mentioned that they would like learn more about the exhibits, or that they do not know enough to create a proper arrangement. We take the wish for more stories and information about the virtual exhibits very seriously and included relations between exhibits and information boxes in the next version of our prototype. In general visitors need some time to discover the interactivity by them self. To make the interactivity more obvious we included design constrains for public displays [39].

However not only the perspective of the visitors is important. Also the museum staffs have to feel confident to provide such an application for the visitors. Hence we conducted several interviews with curators and museum professionals. All of them confirm our assumption that museums have much more exhibits than space to arrange them. To keep track of all exhibits the museums have databases with descriptions of all exhibits. The museums professionals can mostly imagine using the database to present also virtual exhibits.

They are open for more communication with communities or visitors. Nevertheless some museums professionals are afraid that communication with visitors are too time consuming. Thereby, we conclude that an application which aims to enhance the participation of the visitors in museums have to be time efficient manageable by the museum staff. Also tools for planning upcoming exhibition virtually are needed by the curators. By providing the possibility to access databases our application is a good starting point to develop applications to support the work of the museums professionals and to enhance the participation of visitors.

In the online-study approximately 40 people participated. The study confirms two assumptions of the field test. Again participants were more interested in printing their arrangements than in sharing it in social online networks. Also the participants liked to use the plinths to arrange objects. This support the hypothesis that arranging virtual exhibits with physical constrains and real objects is appealing for museum visitors.

The study results show different possible way to continue the iterative design process. Hence the focus group of the application has to be specified. Is the focus on museum visitors who are in the museum, then the next step would be to compare multiple smaller interaction terminals with the setup we used now. If the community shall be motivated to contribute to the exhibition design, our setup should be compared with an online web interface to support the museum. Assuming that the museum professionals have to be convinced, it would be also possible to focus on a tool to assist exhibition planning by using virtual objects. Nevertheless none of these possible focuses exclude the other.

Bibliography

[1] Allard pierson museum. http://www.allardpiersonmuseum.nl/. Visited on 06.12.2013 10:20.

[2] Europeana strategic plan 2011-2015. http://pro.europeana.eu/c/document_library/get_file?uuid=c4f19464-7504-44db-ac1e-3ddb78c922d7&groupId=10602. Visited on 08.02.2014 14:20.

[3] F. Alt, S. Schneegass, M. Girgis, and A. Schmidt. Cognitive effects of interactive public display applications. In *Proceedings of the 2Nd ACM International Symposium on Pervasive Displays*, PerDis '13, pages 13–18, New York, NY, USA, 2013. ACM.

[4] F. Alt, S. Schneegaß, A. Schmidt, J. Müller, and N. Memarovic. How to evaluate public displays. In *Proceedings of the 2012 International Symposium on Pervasive Displays*, PerDis '12, pages 17:1–17:6, New York, NY, USA, 2012. ACM.

[5] L. Ardissono, T. Kuflik, and D. Petrelli. Personalization in cultural heritage: the road travelled and the one ahead. *User Modeling and User-Adapted Interaction*, 22(1-2):73–99, 2012.

[6] S. Bernstein. Artshare on facebook! Blog-post, November 2007.

[7] S. Bernstein. Where do we go from here? continuing with web 2.0 at the brooklyn museum. In *Museums and the Web*, pages 37–47, 2008.

[8] M. Blöckner, S. Danti, J. Forrai, G. Broll, and A. De Luca. Please touch the exhibits!: using nfc-based interaction for exploring a museum. In *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services*, MobileHCI '09, pages 71:1–71:2, New York, NY, USA, 2009. ACM.

[9] A. J. B. Brush. Ubiquitous computing field studies. In *Ubiquitous computing fundamentals*, chapter 4, pages 161–202. CRC Press, 2009.

[10] J. S. Cabrera, H. M. n. Frutos, A. G. Stoica, N. Avouris, Y. Dimitriadis, G. Fiotakis, and K. D. Liveri. Mystery in the museum: collaborative learning activities using handheld devices. In *Proceedings of the 7th international conference on Human computer interaction with mobile devices & services*, MobileHCI '05, pages 315–318, New York, NY, USA, 2005. ACM.

[11] M. Caon, E. Mugellini, and O. Abou Khaled. A pervasive game to promote social offline interaction. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication*, UbiComp '13 Adjunct, pages 1381–1384, New York, NY, USA, 2013. ACM.

[12] L. Clarke and E. Hornecker. Experience, engagement and social interaction at a steam locomotive multimodal interactive museum exhibit. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '13, pages 613–618, New York, NY, USA, 2013. ACM.

[13] N. Correia, T. Mota, R. Nóbrega, L. Silva, and A. Almeida. A multi-touch tabletop for robust multimedia interaction in museums. In *ACM International Conference on Interactive Tabletops and Surfaces*, ITS '10, pages 117–120, New York, NY, USA, 2010. ACM.

[14] P. Dalsgaard, C. Dindler, and E. Eriksson. Designing for participation in public knowledge institutions. In *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, NordiCHI '08, pages 93–102, New York, NY, USA, 2008. ACM.

[15] S. Deterding. Gamification: Designing for motivation. *interactions*, 19(4):14–17, July 2012.

[16] S. Deterding, D. Dixon, R. Khaled, and L. Nacke. From game design elements to gamefulness: Defining "gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, MindTrek '11, pages 9–15, New York, NY, USA, 2011. ACM.

[17] E. Dicker. The impact of blogs and other social media on the life of a curator. In *Proceedings of the International Conference for Culture and Heritage Online*, 2010.

[18] D. W. Fellner. Die vorstandsperspektive. *Informatik-Spektrum*, 36(5):429–430, 2013.

[19] B. Fogg. A behavior model for persuasive design. In *Proceedings of the 4th International Conference on Persuasive Technology*, Persuasive '09, pages 40:1–40:7, New York, NY, USA, 2009. ACM.

[20] T. Geller. Interactive tabletop exhibits in museums and galleries. *Computer Graphics and Applications, IEEE*, 26(5):6–11, Sept 2006.

[21] I. Graziola, F. Pianesi, M. Zancanaro, and D. Goren-Bar. Dimensions of adaptivity in mobile systems: personality and people's attitudes. In *Proceedings of the 10th international conference on Intelligent user interfaces*, IUI '05, pages 223–230, New York, NY, USA, 2005. ACM.

[22] R. Hardy, E. Rukzio, P. Holleis, and M. Wagner. Mobile interaction with static and dynamic nfc-based displays. In *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services*, MobileHCI '10, pages 123–132, New York, NY, USA, 2010. ACM.

[23] U. Heitmüller. Europeana: Geschichtsprojekt digitalisiert erinnerung an 1. weltkrieg. `http://www.heise.de/newsticker/meldung/Europeana-Geschichtsprojekt-digitalisiert-Erinnerung-an-1-Weltkrieg-2098217.html`, January 2014. Visited on 08.02.2014 14:20.

[24] J. Hindmarsh, C. Heath, D. Vom Lehn, and J. Cleverly. Creating assemblies in public environments: Social interaction, interactive exhibits and cscw. *Computer Supported Cooperative Work (CSCW)*, 14(1):1–41, 2005.

[25] U. Hinrichs and S. Carpendale. Gestures in the wild: studying multi-touch gesture sequences on interactive tabletop exhibits. In *Proc. CHI '11*, pages 3023–3032, New York, NY, USA, 2011. ACM.

[26] T. Hope, Y. Nakamura, T. Takahashi, A. Nobayashi, S. Fukuoka, M. Hamasaki, and T. Nishimura. Familial collaborations in a museum. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '09, pages 1963–1972, New York, NY, USA, 2009. ACM.

[27] E. Hornecker. "i don't understand it either, but it is cool"; - visitor interactions with a multi-touch table in a museum. In *Horizontal Interactive Human Computer Systems, 2008. TABLETOP 2008. 3rd IEEE International Workshop on*, pages 113–120, Oct 2008.

[28] E. Hornecker and E. Nicol. What do lab-based user studies tell us about in-the-wild behavior?: insights from a study of museum interactives. In *Proceedings of the Designing Interactive Systems Conference*, DIS '12, pages 358–367, New York, NY, USA, 2012. ACM.

[29] C.-K. Hsieh, I.-L. Liu, N.-H. Yu, Y.-H. Chiang, H.-T. Wu, Y.-J. Chen, and Y.-P. Hung. Yongzheng emperor's interactive tabletop: seamless multimedia system in a museum context. In *Proceedings of the international conference on Multimedia*, MM '10, pages 1453–1456, New York, NY, USA, 2010. ACM.

[30] H. Jenkins. *Confronting the challenges of participatory culture: Media education for the 21st century*. The MIT Press, 2009.

[31] S. Jordà, G. Geiger, M. Alonso, and M. Kaltenbrunner. The reactable: Exploring the synergy between live music performance and tabletop tangible interfaces. In *Proceedings of the 1st International Conference on Tangible and Embedded Interaction*, TEI '07, pages 139–146, New York, NY, USA, 2007. ACM.

[32] S. Keene, A. Stevenson, and F. Monti. Collections for people: museums' stored collections as a public resource. 2008.

[33] T. Kuflik, J. Lanir, E. Dim, A. Wecker, M. Corra, M. Zancanaro, and O. Stock. Indoor positioning in cultural heritage: Challenges and a solution. In *Electrical Electronics Engineers in Israel (IEEEI), 2012 IEEE 27th Convention of*, pages 1–5, 2012.

[34] B. Kules, H. Kang, C. Plaisant, A. Rose, and B. Shneiderman. Immediate usability: Kiosk design principles from the chi 2001 photo library. 2003.

[35] K.-Y. Lin and H.-P. Lu. Why people use social networking sites: An empirical study integrating network externalities and motivation theory. *Computers in Human Behavior*, 27(3):1152 – 1161, 2011. Group Awareness in {CSCL} Environments.

[36] A. Lucero, M. Jones, T. Jokela, and S. Robinson. Mobile collocated interactions: taking an offline break together. *interactions*, 20(2):26–32, Mar. 2013.

[37] P. Marshall, Y. Rogers, and N. Pantidi. Using f-formations to analyse spatial patterns of interaction in physical environments. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work*, CSCW '11, pages 445–454, New York, NY, USA, 2011. ACM.

[38] F. Matassa. Active collections: re-visiting our collection for more and better use. In T. J. y. A. W. e. S. Petterson, M. Hagedorn-Saupe, editor, *Encouraging Collections Mobility. A way forward for museums in Europe*, number 49, chapter 2, pages 107–135. Asociación Española de Museólogos, Finnish National Gallery, Helsinki, 2010.

[39] J. Müller, R. Walter, G. Bailly, M. Nischt, and F. Alt. Looking glass: A field study on noticing interactivity of a shop window. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 297–306, New York, NY, USA, 2012. ACM.

[40] D. Museumsbund. Was ist ein museum. *Museumskunde, 43 (2)*, 1978.

[41] C. Müller-Tomfelde and M. Fjeld. Tabletops: Interactive horizontal displays for ubiquitous computing. *Computer*, 45(2):78–81, 2012.

[42] D. Petrelli, L. Ciolfi, D. van Dijk, E. Hornecker, E. Not, and A. Schmidt. Integrating material and digital: a new way for cultural heritage. *interactions*, 20(4):58–63, July 2013.

[43] P. Pierroux, I. Krange, and I. Sem. Bridging contexts and interpretations: Mobile blogging on art museum field trips. *MedieKultur. Journal of media and communication research*, 27(50):18–p, 2010.

[44] L. Pujol, A. Katifori, M. Vayanou, M. Roussou, M. Karvounis, M. Kyriakidi, S. Eleftheratou, and Y. E. Ioannidis. From personalization to adaptivity–creating immersive visits through interactive digital storytelling at the acropolis museum. In *Intelligent Environments (Workshops)*, pages 541–554, 2013.

[45] A. M. Rashid, K. Ling, R. D. Tassone, P. Resnick, R. Kraut, and J. Riedl. Motivating participation by displaying the value of contribution. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '06, pages 955–958, New York, NY, USA, 2006. ACM.

[46] B. Reeves and J. L. Read. *Total Engagement: Usiong Games and Virtual Worlds to Change the Way People Work and Businesses Compete*. Harvard Business Press, 2009.

[47] C. Rocchi, O. Stock, M. Zancanaro, M. Kruppa, and A. Krüger. The museum visit: generating seamless personalized presentations on multiple devices. In *Proceedings of the 9th international conference on Intelligent user interfaces*, IUI '04, pages 316–318, New York, NY, USA, 2004. ACM.

[48] Y. Rogers, K. Connelly, L. Tedesco, W. Hazlewood, A. Kurtz, R. E. Hall, J. Hursey, and T. Toscos. Why it's worth the hassle: The value of in-situ studies when designing ubicomp. In *Proceedings of the 9th International Conference on Ubiquitous Computing*, UbiComp '07, pages 336–353, Berlin, Heidelberg, 2007. Springer-Verlag.

[49] A. Russo. Transformations in cultural communication: Social media, cultural exchange, and creative connections. *Curator: The Museum Journal*, 54(3):327–346, 2011.

[50] A. Russo, J. Watkins, and S. Groundwater-Smith. The impact of social media on informal learning in museums. *Educational Media International*, 46(2):153 – 166, 2009.

[51] A. Russo, J. Watkins, L. Kelly, and S. Chan. Participatory communication with social media. *Curator: The Museum Journal*, 51(1):21–31, 2008.

[52] N. Simon. *The participatory museum*. Museum 2.0, 2010.

[53] B. Sprengart, A. Collins, and J. Kay. Curator: A design environment for curating tabletop museum experiences. In *ITS '09 Demonstrations, the ACM Conference on Interactive Tabletops and Surfaces*, 2009.

[54] D. Stuedahl and O. Smørdal. Designing for young visitors' co-composition of doubts in cultural historical exhibitions. *Computers and Composition*, 28(3):215 – 223, 2011.

[55] A. S. Taylor. Ethnography in ubiquitous computing. In *Ubiquitous computing fundamentals*, chapter 5, pages 203–236. CRC Press, 2009.

[56] L. M. van Mensch and P. van Mensch. From disciplinary control to co-creation – collecting and the development of museums as praxis in the nineteenth and twentieth century . In T. J. y. A. W. e. S. Petterson, M. Hagedorn-Saupe, editor, *Encouraging Collections Mobility. A way forward for museums in Europe*, number 49, chapter 1, pages 33–53. Asociación Española de Museólogos, Finnish National Gallery, Helsinki, 2010.

[57] J. Vassileva. Motivating participation in social computing applications: a user modeling perspective. *User Modeling and User-Adapted Interaction*, 22(1-2):177–201, 2012.

[58] M. Vayanou et al. Towards personalized storytelling for museum visits. In *Proc. 6th Intl Workshop on Personalized Access, Profile Management, and Context Awareness in Databases-PersDB*, 2012.

[59] T. Verhagen, F. Feldberg, B. van den Hooff, S. Meents, and J. Merikivi. Understanding users' motivations to engage in virtual worlds: A multipurpose model and empirical testing. *Computers in Human Behavior*, 28(2):484 – 495, 2012.

[60] D. vom Lehn, J. Hindmarsh, P. Luff, and C. Heath. Engaging constable: Revealing art with new technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '07, pages 1485–1494, New York, NY, USA, 2007. ACM.

[61] R. Wakkary, M. Hatala, K. Muise, K. Tanenbaum, G. Corness, B. Mohabbati, and J. Budd. Kurio: a museum guide for families. In *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction*, TEI '09, pages 215–222, New York, NY, USA, 2009. ACM.

[62] A. Weilenmann, T. Hillman, and B. Jungselius. Instagram at the museum: communicating the museum experience through social photo sharing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '13, pages 1843–1852, New York, NY, USA, 2013. ACM.

[63] J. O. Wobbrock, M. R. Morris, and A. D. Wilson. User-defined gestures for surface computing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '09, pages 1083–1092, New York, NY, USA, 2009. ACM.

[64] E. Woods, M. Billinghurst, J. Looser, G. Aldridge, D. Brown, B. Garrie, and C. Nelles. Augmenting the science centre and museum experience. In *Proceedings of the 2nd international conference on Computer graphics and interactive techniques in Australasia and South East Asia*, GRAPHITE '04, pages 230–236, New York, NY, USA, 2004. ACM.

[65] M. Zancanaro. Shared interfaces for co-located interaction. In A. Krüger and T. Kuflik, editors, *Ubiquitous Display Environments*, Cognitive Technologies, pages 71–88. Springer Berlin Heidelberg, 2012.

[66] M. Zancanaro, S. Oliviero, D. Tomasini, and F. Pianesi. A socially aware persuasive system for supporting conversations at the museum café;. In *Proceedings of the 16th international conference on Intelligent user interfaces*, IUI '11, pages 395–398, New York, NY, USA, 2011. ACM.

A. Personal information about the participants of the online-study

Table A.1.: Information about participants of the online study

ID	age	profession	gender	staff	visits
417	25	PhD student	female	0	year
420	26	Student	male	0	less
423	24	Student	male	0	year
435	25	CEO	male	0	less
440	25	academic	female	0	less
441	29	student	female	0	year
445	27	engineer	female	0	year
446	26	student	female	0	year
453	45	Programmer	male	0	year
469	52	Pastor	male	0	year
479	26	Student	male	0	less
485	26	Student	male	0	less
498	24	Diploma Info	male	0	year
501	51	Self-employed	female	0	year
507	29	Software Engineer	male	0	year
508	35	researcher	male	0	year
518	33	translator	female	0	month
522	26	student	male	0	month
542	33	Stedent	male	0	month
547	32	educationist	female	0	less
549	25	student	female	0	month
552	25	Student	female	0	year
558	26	social worker	female	0	month
562	33	Professor	male	0	year
566	27	Software Engineer	male	0	year
577	22	Student (Computer science)	male	0	year
580	21	Student of Informatics	male	0	less
590	22	student	male	0	less
602	28	computer science	male	0	year
603				0	less

Table A.1.: Information about participants of the online study

ID	age	profession	gender	staff	visits
604	30	Researcher	female	1	year
605	30	Student	female	0	month
608	32	Operations Coordinator	female	0	month
611	47	Museum director	male	1	week
613	26	Diplom Informatiker	male	0	less
620	31	Researcher	female	1	week
622	24	PhD student	female	0	year
625	30	assistant	female	0	year
629	54	ict project leader	male	1	month
631	46	researcher	female	0	year
634	25	Student	female	0	year
636	26	student	male	0	year

Decleration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

---

place, date, signature