Aalborg University Copenhagen

Semester:
10th semester

Title:
The Ghosts of the Danish Music Museum: A Markerless Augmented Reality Experience

Project Period:
01/02/2022 – 25/05/2022

Semester Theme:

Master Thesis

Supervisor(s):

Ali Adjorlu & Stefania Serafin

Members:
Jonas Skjønnemann &
Jan Place Jakobsen

Aalborg University Copenhagen

Frederikskaj 12,

DK-2450 Copenhagen SV

Semester Coordinator: Stefania Serafin

Secretary: Lisbeth Nykjær

Abstract:

This paper describes the methodology of iteratively designing an Augmented Reality (AR) application for the Danish Music Museum.

The application allows the user to see displayed instruments, being played by digital performers.

To animate the digital performers, the performance-capture actors wore motion capture suits, while playing on recreated instruments.

The tracking for the AR application was made with Vuforia's Area Target, which allowed for a markerless tracking system.

There was performed a mixture of qualitative and quantitative tests to evaluate the prototype application and the stability of Vuforia's Area Targets. The findings for the prototype were that the application has potential to be utilized as an enhancement for the museum's exhibition.
However, combining multiple Area Targets, resulted in unstable tracking throughout the prototype test.

1. Introduction

This work describes the methodology of the creation of an augmented reality (AR) experience in a historical museum exhibition. In this paper the term AR will refer to the definition by researcher Azuma's [4] three key requirements as well as that of Rekimoto and Nagao [3], which distinguishes between the traditional desktop computer interface and that of AR. Ron Azuma's definition is that AR needs three key requirements: Augmented reality combines real and virtual content, augmented reality is interactive in real time and augmented reality is registered in 3D [4].

This project was created as a collaboration between Aalborg University and the Danish Music Museum.

The Danish Music Museum was founded in 1898 and is a part of the Danish National Museum. The Music Museum exhibits musical instruments from Europe, Asia, and Africa, in the time span of the Bronze age to the 21st century [2]. Most of the artefacts are behind glass displays and are not allowed to be touched by the guests, even though children, who most of the guests consist of, would benefit from further interactions [11]. Music instruments are traditionally utilized for performances, and therefore the museum seeks different ways to experience the instruments. This project seeks to enhance interactions in the real world by combining virtual performers, which are animated with motion capture suits, with real instruments, by designing an augmented reality application for mobile phones.

The application was created in Unity with the Vuforia development kit [20]. Vuforia Area Targets was used for this project, which made it possible to have markerless tracking, which does not need any QR-codes or images to be able to maintain tracking. The prototype was designed to be a treasure hunt where the users had to search for the virtual performers, which was placed throughout the museum. It was designed as an addition to the museum that would enhance the experience and understanding of the exhibitions.

2. Related works

This chapter will investigate state of the art AR experiences, as well as related research on AR applications in museum exhibitions.

2.1. Augmented Reality Application to Museum Visitor experiences

Hassan and Ramkissoon describe how AR can be utilized in museums for visitor experiences, with AR being a powerful tool to further enhance the experiences. Hassan and Ramkissoon believe that the visitor demand needs consideration for what and how the visitor wants to experience the exhibition, and the capacity of the destination by what resources and space the exhibition allows for [1].

The museums may need to prioritize technology applications to meet the demands of the visitors' attention. The museums are competing with technologies that provide entertainment, whereas these technologies may be more accessible to people than going to a museum. The success of AR technology in exhibitions could be based on how well the technology engages the visitors.

As Hassan and Ramkissoon mentions, AR technology should not only be used as a means of attracting visitors, but also appear as a centre in the museum's activities to engage the visitors in more interactive experiences [1].

2.2. AR enhanced art exhibitions

In the paper, "Designing AR enhanced art exhibitions: a methodology and a case study", Pittarello showcases the effect of his methodology in the Biennale Art Exhibition in Venice, by having the visitor being able to utilize a tablet/smartphone device to have an improved experience of the collection which is being exhibited [7]. Pittarello makes use of images, icons, shadows, etc. as targets for the software so that the digital content can be experienced along with the artefacts of the museum.

Pittarello's work contradicts that of Hassan and Ramkisson's [1], as Pittarello believes that a successful Augmented reality experience is an addition to the exhibition, and thus should not change the original layout of the exhibition. The experience should avoid changing the attention of the users, by creating overwhelming visual Augmented Reality installations. The Augmented reality experience should provide a homogeneous interaction paradigm to visitors for all the exhibition's artworks. This ensures that there is the same basic access mechanic for each artwork [7].

2.3. The Fall of the Titans an AR Painting Experience

A company that already uses AR for museum exhibitions, similar to what this project has achieved, is Khora. Khora has made an AR experience for the national gallery of Denmark for the painting: "The Fall of the Titans" by Cornelis van Haarlem. Khora has made it possible for visitors to use the application Instagram through their phones to experience the painting in a new way. The application simulated depth by digitally cutting the painting up into multiple layers and shifting each layer further into the painting. Through animation they made parts of the painting seem life-like and therefore further enhance the illusion of depth.

2.4. AR methods for visualization of lost architecture

M. Cannella describes how the use of AR can be used to offer a visual experience that can be accessed by many users at the same time. In this case Cannella tests markerless AR applications with the use of both cloud storage systems of anchors and Area Target technology developed by Vuforia. Cannella made a 3D model of the Tribuna from the Cathedral of Palermo, which depicted how the Tribuna looked before the renovation. When looking through Cannella's application the user is able to see a digital recreation of the Tribuna [14].

3. Research aim

The research aims at describing the methodology of iteratively designing a state-of-the art markerless augmented reality experience in a historical museum exhibition, which enhances the museum guests experience and understanding of the exhibited items.

4. Design and implementation

This section will explore the design choices and the implementation of said choices for the created prototype. AR lets the user experience the ability to view and interact with virtual objects together with real-world physical objects. If the user is able to accurately perceive the location of the virtual object in the real world, then the augmented reality application is effective [5].

4.1. Digital performers

For this project a library of digital performers was created. Each digital performer is 3D modeled to resemble the ethnicity, and time-period, that the instruments they play on, originate from. The digital performers each have an attached rig in order to animate their body movements with motion capture data [10], as well as blend shapes to animate their facial expressions.

Figure 1: The digital performers

A Rokoko Smart Suit was utilized for the project, in order to capture realistic movements [15] to apply on the digital performers. The motion capture suit was used at the museum with recreational instruments, see figure 2. The motion capture suit is classified as an electromagnetic motion capture system [16]. All the motion capture data needed cleaning and retargeting [17] before they were implemented to the application.

Figure 2: Motion capture performance

Blend shapes are often used to create expressions for the 3D character model. Blend shapes can be created by pulling vertices [8] from the 3d character, by using bones or by simulating muscles that control both the way skin moves and the facial expression [9].

For this project there was created 52 blend shapes for a handful of the characters, which specifically controls parts of the facial expression. These blend shapes are part of the apple arKit, and made it possible to motion capture the faces with an iPhone with a true depth camera.

4.2. Vuforia Area Target

The prototype was created with Vuforia's software development kit, specifically the Area Target which makes use of 3D scans from physical locations to enable positional tracking for the mobile devices based on geometry [13], similar to Cannella's recreation of the Tribuna in Palermo [14].

Vuforia Area Targets are created through an iOS application. The application utilizes the LiDAR camera in the iPhone/iPad for creating a 3D scan of the environment. The environment which the application creates, is then imported into Unity, where the developers can place their content. The 3D scan is then utilized as a point of reference for the phone to track the real world, as well as being used for creating occlusion.

The three 3D scanned Area Targets were imported into Unity and then placed in a manner that resembles how the layout of the museum is in real life as seen on figure 3.

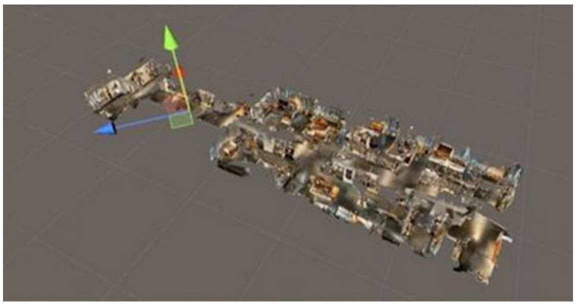

Figure 3: 3D scan of the Danish Music Museum

4.3. Occlusion in AR

To make the digital performers appear as if they are behind objects, occlusion had to be implemented in the application. The occlusion for this project was made with a mixture of Vuforia's own Area Target as well as using Unity's depth shader when the scan was insufficient. Due to the scan being tattered and having a hard time detecting the glass in the glass displays, some digital walls and instruments were made with the depth shader to create the occlusion from the real-life objects [20]. This made it possible to hide performers that were farther away and most importantly make the performers partly hidden by the instruments in the museum.

Similar projects have created occlusion, which considers moving people/objects, but this was seen as unimportant for this project [21]. While the occlusion in this project only acts as a way to hide 3D digital performers behind real life walls and instruments, there are possibilities to make them interactable with both the 3D objects and the user [22], as seen on figure 4.

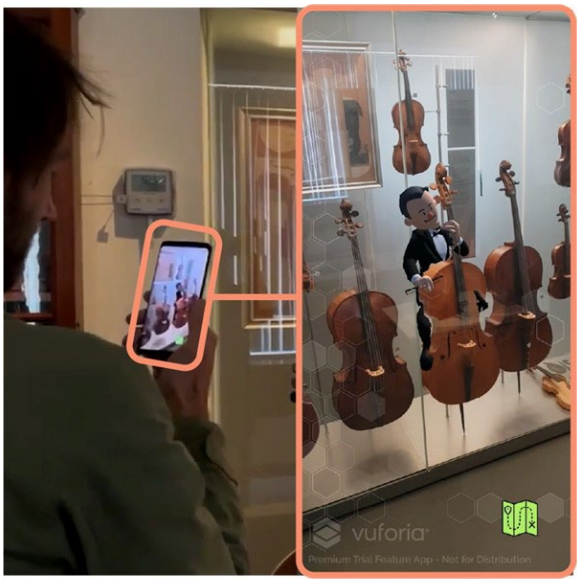

Figure 4: Occlusion of performer behind the 3D scan of a Cello.

4.4. Shadows of the digital performers

The paper "Designing for Depth Perception in Augmented Reality" conducted two experiments using a perceptual matching task to understand how shading, cast shadows, aerial perspective, texture, dimensionality and billboarding affected participant perceptions of virtual object depth relative to real world targets [5].

The findings were that cast shadows were the foremost important factor for improving spatial perception.

The shadows for this project were done in Unity by having a flat cylinder with an almost black and translucent material. This cylinder was placed under the performers and scaled to seem natural under the performers as seen on figure 5. This was a simple solution which could fit into the simple art style.

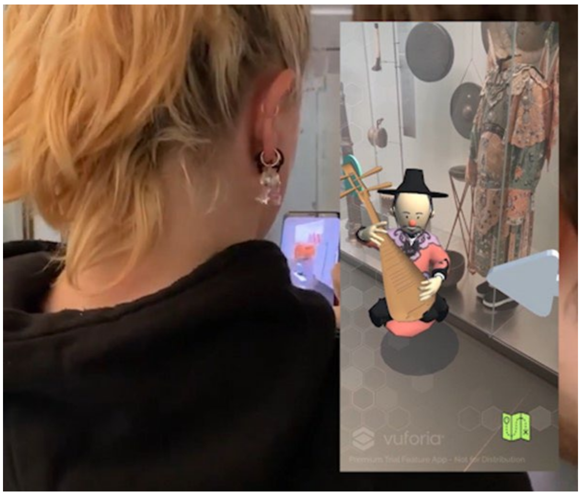

Figure 5: Shadow under digital performer

4.5. Sound design

Recreating the music from the instruments was done in three different ways. The Danish music museum has a library of recreational sounds from their instruments. However, they did not have sounds for every single instrument. If the museum did not have the sound for the instrument, a new sound was recorded from the recreational instruments, see figure 6. Then if the museum did not have a recreational instrument or there was not a sufficient musician to perform on said instrument, the decision was to resort to a recording of the music from authentic videos. The list of videos used for the application can be found in Appendix A.

Figure 6: Recreation of the gong

4.6. Iterative testing

To ensure the quality of the application, there was conducted an initial group test. The test participants consisted of three Sound and Music Computing (SMC) master students and two research assistants. The participants tried the application in pairs of two, and one participant tried it alone. After the participants had experienced the application a mini focus group interview was conducted [6]. The participants were asked about which parts of the experience they found immersive and what technical difficulties they experienced. The interview can be found in Appendix C.

When asked about the experience participants stated that:

All five participants agreed that the experience was a positive one. They stated that the application was intuitive, and that seeing the characters play the instruments were entertaining. It was stated that having to find the digital performers was amusing.

When asked what could improve the application the focus group answered:

Three participants would have liked to see the characters play the instrument for longer periods. One participant stated that it could be up to a two-minute performance.

One participant stated that looking for the digital performers was an entertaining part of the experience, and that it would be fun to explore that part of the application further. The rest of the participants agreed that gamifying the search for the performers would be a positive change to the application and a good way to explore the museum.

It was stated by the SMC students that adding more characters to play on the instruments would enhance the experience, however not every instrument should be a part of the application, as the participants still enjoyed that it was a condensed experience.

One participant expressed that having a narrative for finding the ghost would enhance her experience.

When asked about the technical difficulties the participants experienced while trying the application, the participants stated:

The research assistants expressed that it worked surprisingly well. They stated that they have not tried an augmented reality application which tracked the objects as well as this prototype did. It was stated that it being a markerless AR experience made the experience more enjoyable. It was, however, expressed that the application would benefit from occlusion, as in the digital performers did not look like they were playing on the instruments from certain angles where the instrument is in front of the performer.

Two of the sound and music computing students experienced complete loss of tracking and had to restart the application. This was a repeated problem throughout the project, which sadly was not fixed.

4.7. Second iteration of the application

Following the group interview the AR application went through a second development. Additional digital performers were developed, so that the entire Danish Music Museum was filled with digital content.

The application was developed so that when a user opened the app for the first time, they were met with a start screen, see figure 7. The start screen tells the user that “The museum is haunted, and the ghosts have started playing on the instruments. You must catch them!", to create player engagement by providing a premise for the user [26]. As the target group for the museum consisted mostly of children, it was decided to create a treasure hunt format, as it would provide guests with a goal and still allow for freedom to explore [12]. The user was able to open a map and see which digital performers they had previously interacted with. The new digital performers that were added to the application addressed the desires from the participants in the group interview, as they had longer audio clips, and there was a pair that played at the same time.

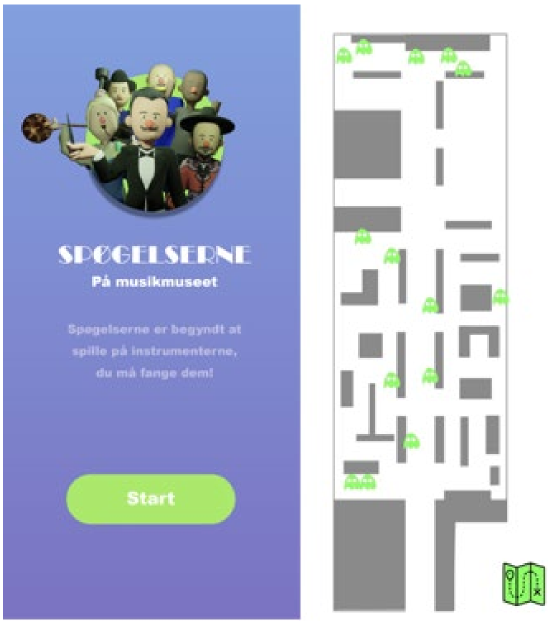

Figure 7: UI of the prototype

4.8. Use case diagram and flowchart

To describe how the users interact with the application a use case diagram was designed. As seen on the use case diagram below (Figure 9). When the user starts the application, they are greeted by the start screen as seen on figure 7, from this interface the participants can click on the start button, which opens the application. After the participant has started the application, the camera turns on and tries recognizing where in the 3D scanned environment that the participant is located. When the app has recognized the location in comparison to the environment, then it will display the virtual objects.

When the user discovers the location of the digital performer, they are met with a 3D object which represents a ghost. If the user clicks on the 3D ghost, the ghost disappears, and the digital performer appears to perform on the nearest instrument. The ghost can be seen on figure 8.

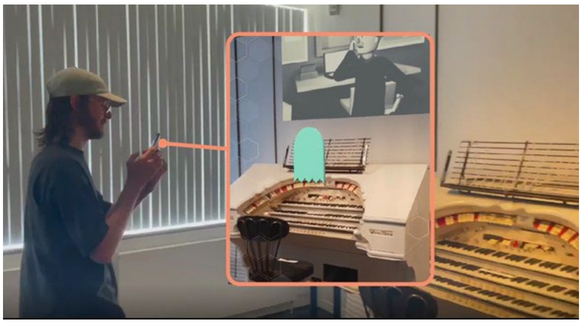

Figure 8: Ghost hovering over organ

The user has an icon in the lower right corner of the screen. By clicking this icon, a map will pop up on the screen, and show a blueprint of the museum floor, with ghost icons, which resembles the before mentioned ghosts (Figure 7). If the user has seen a digital performance, the ghost icon for said performance turns grey.

To gain a greater understanding of the flow of the application, the application can be visualized with the flowchart on figure 10.

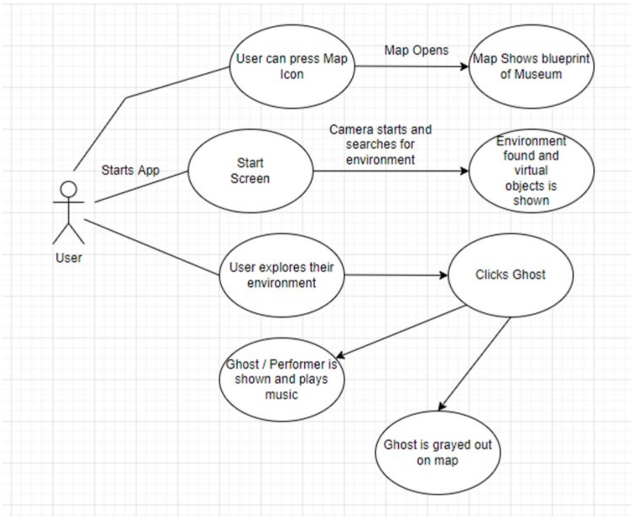

Figure 9: Use case diagram

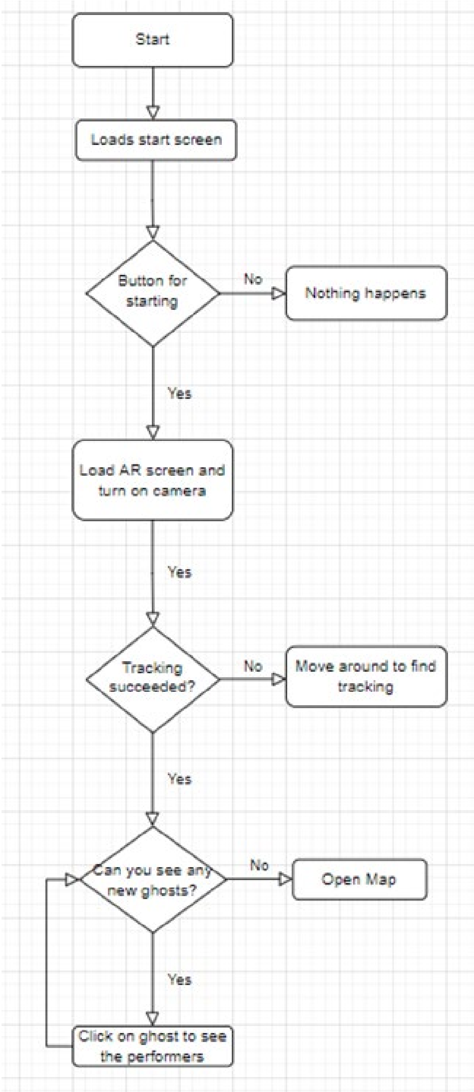

Figure 10: Flowchart of the flow of the prototype application.

5. Methods

The test consisted of a combination of qualitative and quantitative methods.

5.1. Sampling

The participants were sampled using the non-probability sampling method "convenience sampling" [6].

5.2. Pre-interview

In the pre-interview the participants were asked about their age, gender, experience with technology, previous experience with augmented reality and their general experience with musical instruments.

5.3. Observing participants

After introducing the participants to the application, the participants were told to complete the task but had the opportunity to end the task if they expressed the desire, however none of the participants chose to end it early. While the participants were interacting with the AR application, a screen recorder was recording their interactions.

A quiet observer was following the participants to get insight into their interactions, processes, technical difficulties and behaviors. In addition to this the observer documented their path in the museum. The observer acted as an observer-as-participant [23], which means the researcher was formal and short in interaction/contact with the participant.

5.4. Questionnaire – Measuring presence in augmented reality environments

This paper made use of Regenbrecht and Schuberts psychological questionnaire [24], which is based on Regenbrecht, Friedmann and Schuberts previous paper "Embodied Presence in Virtual Environments" [25]. One question was altered to fit the scenario of this application. The questions that the participants were presented with was the following:

- Was watching the virtual objects just as natural as watching the real world?
- Did you have the impression that the virtual objects interacted with the real object, or did they seem separate from it?
- Did you have the impression that you could have touched and grasped the virtual objects?
- Did the virtual objects appear to be (visualized) on a screen, or did you have the impression that they were located in space?
- Did you have the impression of seeing the virtual objects as merely flat images or as three-dimensional objects?
- Did you pay attention at all to the difference between real and virtual objects?
- Did you have to make an effort to recognize the virtual objects as being three-dimensional?

The participants were able to answer each question with a 7-point Likert-scale. This quantitative test was implemented to evaluate whether the augmented reality application conveyed the impression that the virtual objects were present in the real environment.

5.5. Microsoft Desirability Toolkit

After experiencing the application, the participants were introduced to the Microsoft Desirability Toolkit (MDT) also known as product reaction cards [18]. This toolkit was included to spark new conversation with a controlled vocabulary, about the usability of the application [19].

24 words were selected, with equal amounts of positive and negative words, see Appendix B. Before each participant could choose their words from the 24 cards, the order of the words was randomized. If the participants decided to pick a large quantity of cards, they were kindly asked to reduce the number to the 5 most important words [19]. The picked words were used to start a semi-structured interview [6], where the participant will converse about their decision for choosing said words. This methodology was implemented to evaluate the desirability of the AR application in the museum.

5.6. Additional self-reporting interview

In addition to the observation, the questionnaire and the MDT interview there were 6 questions imposed onto the participants. The additional questions were created to gather data on specific parts of the design decisions. The question was:

- Which instruments did you find the most interesting?
- What are your thoughts on the map?
- Do you feel like you have learnt something new?
- Did you find that the ghost moved life-like or was there a disbelief in their movements?
- Do you have any last comments on the experience?

These questions were created to evaluate the design choices, such as the map, motion capture, learning experience and choice of instruments.

6. Results & discussion

This section will focus on the findings and display the results clear and concise. The findings will be evaluated in two sections, one for quantitative and qualitative respectively, and a small evaluation of the participants.

6.1. Participants

There were a total of 11 participants, 7 males and 4 females. The ages spanned from 22 to 63 (mean: 33 standard deviations: 13,05). The participants had varying levels of experience with technology, and most of them had a low level of experience with augmented reality. The participants had a high level of interest in music and musical instruments, see figure 11, 12, and 13.

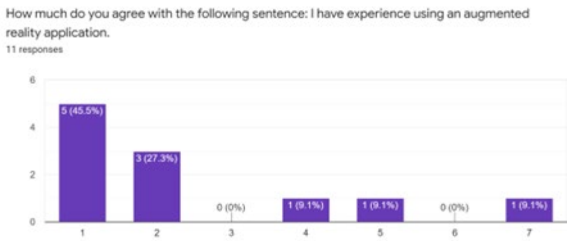

Figure 11: “I have experience using an augmented reality application”

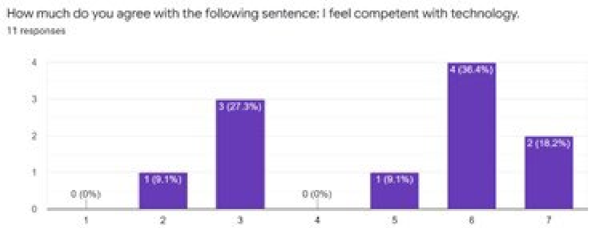

Figure 12: “I feel competent with technology”

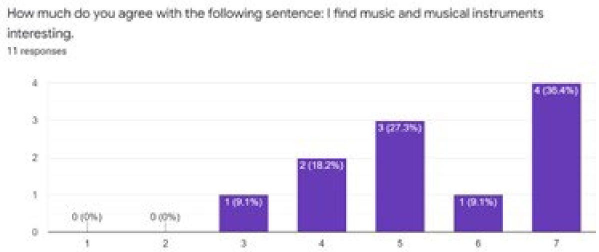

Figure 13: “I find music and musical instruments interesting”

6.2. Quantitative data from questionnaire

All participants answered seven questions to evaluate whether the augmented reality application conveyed the impression that the virtual objects were present in the real environment. The mean and standard deviation of the participants' answers is displayed in the figure graph.

The quantitative test by Regenbrecht and Schubert [24] had 353 participants, whereas this project focused on qualitative measurements, which means that the sample pool from this questionnaire was deemed insufficient for quantitative data processing.

The data, which is displayed in figure "graph", will be used to support claims from the in-depth interviews and observations. The data appears to slightly agree with the fact that the virtual objects had a sense of spatial presence and realness, as well as having a low amount of perceptual stress [24]. This project differs from that of Regenbrecht and Schubert in that the aim was not to create a realistic AR experience. The characters were described by participants as "cartoonish", which will be further explored in the section "In-depth interviews".

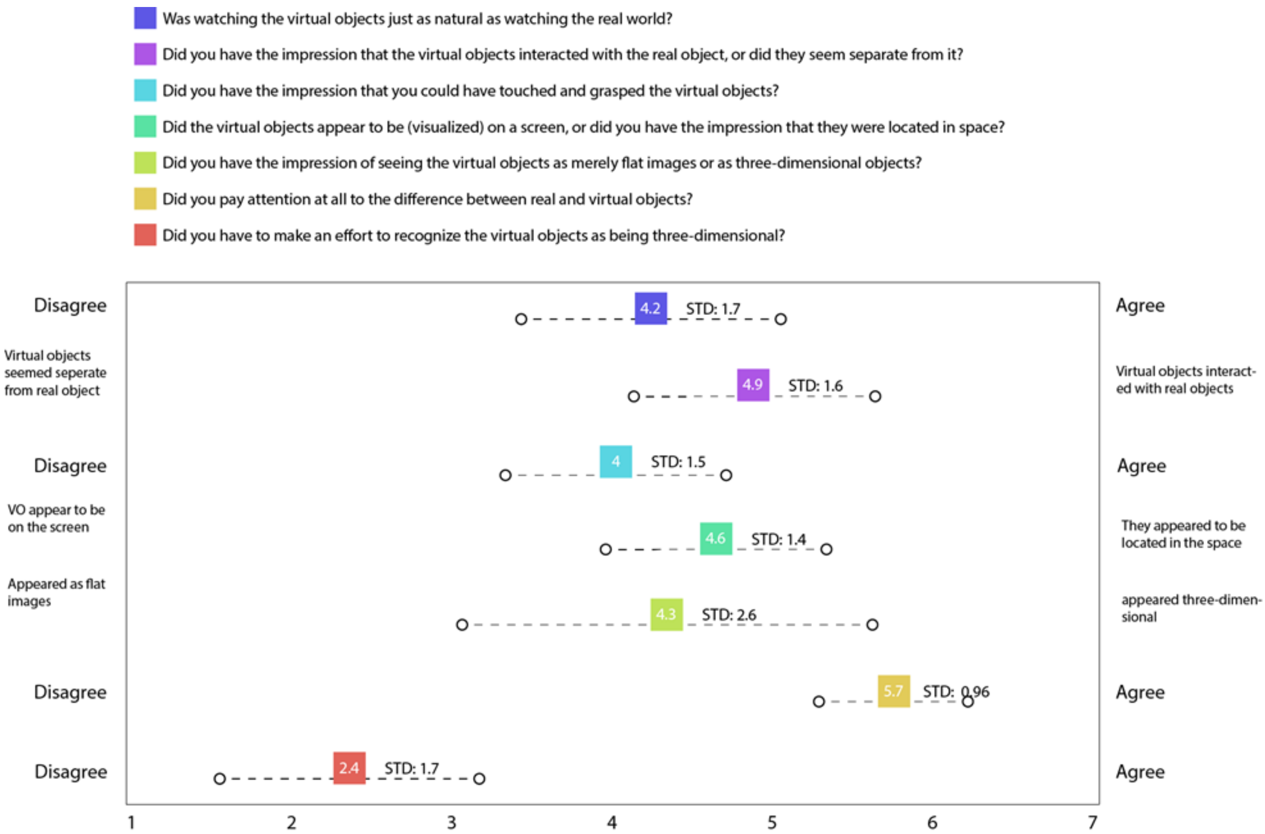

Figure 14 – Graph displays the means and standard deviation from the questionnaire

6.3. Qualitative data from observations and in-depth interviews

In-depth interviews

When testing for desirability with the MDT, the finding where that:

The most chosen word was “creative”, 81.8% of the sampling pool chose that word. The participants found it creative that they were able to interact with the museum exhibitions, instead of being passively watching it. When asked about the word, creative, all the participants expressed that it was the implementation of the application that they found creative, and not that they themself felt creative using it.

72.7% of the participants chose “appealing”. One participant stated that: “I chose it (appealing) because it was easy to use. The UI was generally easy for someone that don’t have experience with AR. It looked fun and I liked that you had to actually find the ghosts, and then you got to see the old timey people play on the instruments.”

When asked about the words appealing and/or creative several of the participants stated that they enjoyed that the different digital performers visually represented the ethnicity and time-period of the instruments they were playing. One participant stated that she did not have to read the plaques, because she could see from the digital performers where the instrument originated from. This could imply that the user enjoyment would benefit from cultural accurate virtual object, when presented with

One participant expressed a desire to be able to utilize AR for virtual environments around the digital performers. He enjoyed the cultural accuracy of the performers, and therefore thought it would further enhance the experience if the real environment would change based on the digital performer's ethnicity and country of origin. This was only implemented at the digital performer that was playing on a film organ, where a virtual black and white film was playing on the white wall above an organ. The problems that may occur with adding additional environments could be, depending on the device used, that the application could become slower. Another problem that might take place with having an additional environment throughout the whole museum, would be that it takes the center of the exhibition instead of enhancing it. This is discussed by Pittarello, Ramkissoon and Hassan, see chapter related works.

81.8% of the participants chose either the words “easy-to-use” or “effortless”. The participants stated that handling the application was intuitive and that starting the digital performers was easy. Most of the participants mentioned that the map made it effortless to find the digital performers, however two participants found it difficult. The two participants that did not benefit from the map, expressed desires to be able to see their own locations on the map. This indicates that the human computer interaction paradigm was intuitive for the most part, but the application would benefit from adding a location-based map.

Only two negative words were chosen, even though 50% of the words they could choose between were negative. The negative words that were chosen were: “boring” and “difficult”.

The word difficult was chosen in relation to the map in the application. The user found it frustrating not being able to see their own location. The word boring was chosen because the participant wanted to see the digital performers do more than just merely playing on the instruments. That participant expressed that it became repetitive seeing the performers only playing on instruments.

Other words that were chosen frequently were: “convenient”, “calm”, and “cutting edge”.

“Chose it (convenient) because it was easy to use, it was very convenient to hear the instrument. The app solved a problem I had when I arrived. I immediately wanted to play on the instruments when I got here, but all of them have a do not touch sign. And for me, I’m curious what they would sound like.!”

Several participants stated that they wanted to pick the word “fun/entertaining”, but that word was not available in the word sample.

The digital performers were described as cartoonish and fun to look at, and that because they appeared that way the animation did not have to be as detailed. The oldest participants were a retired teacher and expressed a desire for the application to be used in an educational context. He stated that if there were a possibility for either a different order of finding the ghost, or if the kids could have separate digital performers to look for, then the application would allow for primary school kids, in groups, to explore the museum without interrupting each other. Two of the other participants also stated that the application would work well with kids.

The participants were asked additional questions about the application at the end of the experiment. They were asked which instrument they found the most interesting of the ones that the digital performers played on. All the participants chose instruments where the digital performer played on the actual instrument and not a digital replica. There was also a tendency to pick instruments which the participants had not seen or heard of before.

When asked if the participants felt like they learnt anything new, most participants stated that they now have new knowledge of antique instruments and have an idea of how it looks when said instrument is played.

The participants were asked whether they thought that digital performers were moving life-like or if there was a disbelief in their movements. Participants replied with: “It was pretty obvious it was animation”, “It was believable, but it is hard with animated character since its computer animated.”, “The hand was going back and forth it seemed a bit static.”. The majority of participants were not under the impression that the digital performers moved life-like.

A participant stated that he usually does not come back to exhibitions he has already seen once, but now wants to experience in the music museum twice, with and without AR.

Observations

This section will look into the observations that were made while the participants were experiencing the application.

The problems that occurred while testing, were observed to be mainly issues with the tracking of the 3D scan of the museum. In the initial group test, there was only a single Area Target scan, but in the final test two additional scans of the museum were added to the program. This made it possible to track objects throughout the whole museum, but also gave the application issues. The 3D scans were aligned inside of unity by hand, which meant that the scans were not located exactly. This meant that if the application did not switch Area Targets, then the digital performers would be placed in the wrong location, which shattered the illusion of them performing on the instrument. This problem occurred for every single participant, however when the application found geometry that matched that of another Area Target, the application would switch to another scanned Area Target, and therefore place the digital performers correctly. The Area Target 3D scans were made with a LiDAR equipped iPad, but the other 3D scanning possibilities could potentially have better and larger scan capabilities, which in turn could make a more coherent scan.

As described above, Vuforia finds its location based on geometry, which meant that the application had trouble with the floor and some of the walls, as these objects were trite. The application was prone to losing tracking all together which happened to six of the participants. In these cases, the application had to be restarted in order to reestablish the tracking. This problem occurred when the participants’ motion with the phone was too rapid.

The prototype test was conducted in one day with one mobile phone. As the day progressed, the phone started to heat up and the application started to become slower, thereby increasing the risk of tracking errors.

7. Conclusion

This conclusion will consist of: An evaluation of Vuforia Area Target as a tool for building AR application in museum exhibition, and a conclusion of the desirability of the prototype application.

7.1. Vuforia Area Target in museums exhibitions

Vuforia’s Area Targets have the ability to use a real-life location as a tracking tool, which makes it usable for more flexible AR designs. AR applications usually use either a QR-code or an image as a target, but due to these methods having to be inside the camera’s field of view, it can be hard to have larger digital objects in view without losing the tracking. This is less of a problem for the Area Targets, which our initial test showed with multiple digital models being able to be shown at the same time, while the user was free to move around.

To have AR in larger rooms, multiple Area Targets are needed to cover the area. The first iteration of the application with only one Area Target worked almost flawlessly in the initial group-test. However, when multiple areas were used to cover the whole museum, the observations on the final test revealed that the Area Targets could have troubles switching between the different Area Targets, and the digital performers could be located in another place than designed, or directly lose tracking. This resulted in the application having to be restarted several times. Another problem that was observed was when testers accidentally pointed the camera down towards the floor or directly into a completely white wall, the tracking got lost due a lack of available geometry that the camera could see.

The Vuforia Area Target works well in museum installation, as the exhibited items remain at the same location for longer periods of time. If the objects inside the environment changes location frequently, the marker less targets become unreliable due to the recognition of the 3D scanned area, and therefore decreases the chances of having a successful tracking.

7.2. The desirability of the prototype

Several of the participants expressed enjoyment for the cultural accuracy of the digital performers, which was described as an enhancement to the experience. One participant even stated that he would like to see the environment change based on the origin of the digital performers. Being culturally accurate with the digital performers meant that some of the participants gained a better understanding of the exhibited items. Three participants, one of whom was a retired schoolteacher, expressed in the interview that the application could benefit school trips to the museum.

Having the digital performers play the real instruments gave the participants an understanding of how the instruments were played. Not all instruments were in a position that allowed for the performers to play them directly, which meant that a few of the performers played on digital replicas of the instruments. Participants from both the initial group test, as well as the Pittarello MDT test, expressed increased desire in the performances that combined virtual performers with real instruments.

81.8% of the participants stated that the execution of the application was creative. Several of these participants claimed that they would have liked to pick the words fun or entertaining as well. As stated in chapter “related works”, Ramkissoon and Hassan believe that museums need to prioritize entertaining technology as museum exhibitions compete with the entertainment industry [1].

The application was described as effortless, easy-to-use and convenient. The participants did not have problems interacting with the application and expressed that children and elderly people would be able to use it without trouble. As stated in chapter “related works”, Pitarrello believes that a successful AR application must be a self-imposed addition to the experience [7]. Participants from the prototype test expressed that the convenience of having it as a mobile phone application, made it possible to select whether the user wanted to see the augmented digital performers.

The quantitative data from the questionnaire showed positive results in spatial presence and realness, as well as having a low amount of perceptual stress. However, further validation of these calculations would need a larger sample size with more variation of participants.

8. Bibliography

References

[1] Hassan, Azizul, and H. Ramkissoon. "Augmented reality application to museum visitor experiences." Visitor management in tourist destinations 3 (2016): 117.
[2] The Danish Music Museum, https://en.natmus.dk/museums-and-palaces/the-danish-music-museum/
[3] Rekimoto, Jun, and Katashi Nagao. "The world through the computer: Computer augmented interaction with real world environments." Proceedings of the 8th annual ACM symposium on User interface and software technology. 1995.

[4] Azuma, Ronald, et al. "Making augmented reality work outdoors requires hybrid tracking." Augmented Reality: placing artificial objects in real scenes: proceedings of IWAR'98. 1999.
[5] Diaz, Catherine, et al. "Designing for depth perceptions in augmented reality." 2017 IEEE international symposium on mixed and augmented reality (ISMAR). IEEE, 2017. https://ieeexplore.ieee.org/abstract/document/8115410
[6] Bjørner. T. Qualitative methods for consumer research
[7] Pittarello, Fabio. "Designing AR enhanced art exhibitions: a methodology and a case study." Proceedings of the 13th Biannual Conference of the Italian SIGCHI Chapter: Designing the next interaction. 2019.
[8] Lewis, John P., et al. "Practice and theory of blendshape facial models." Eurographics (State of the Art Reports) 1.8 (2014): 2.
[9] Kerlow, Isaac V. The art of 3D computer animation and effects. John Wiley & Sons, 2009.
[10] Tobon, Ricardo. The Mocap Book: A Practical Guide to the Art of Motion Capture. Foris Force, 2010.
[11] Piscitelli, Barbara, Michele Everett, and Katrina Weier. "Enhancing young children's museum experiences: A manual for museum staff." The QUT Museums Collaborative. Australian Research Council. http://eab. ed. qut. edu. au/activities/projects/museum/manual/QUTMC_Manual_for_Museum_Staff. pdf (2003).
[12] Hall, Tony, and Liam Bannon. "Designing ubiquitous computing to enhance children's learning in museums." Journal of Computer Assisted Learning 22.4 (2006): 231-243.
[13] Neves, Miguel, et al. "Using 3D Reconstruction to create Pervasive Augmented Reality Experiences: A comparison." 2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW). IEEE, 2022.
[14] Cannella, M. "AR METHODS FOR THE VISUALIZATION OF THE LOST MARBLE "TRIBUNA" IN THE MAIN APSE OF THE CATHEDRAL OF PALERMO." The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 46 (2022): 129-134.
[15] Ribeiro. G. Viera. MH. Motion Capture Technology – Benefits and challenges. International Journal of Innovative Research in Technology & Science(IJIRTS). Vol 4. No 1. 2016
[16] Vandana, Syal, "Digital Art is a Convergence of Technologies A review", International Journal of Innovative Research in Technology & Science (IJIRTS), Vol 3, No 3, Maio de 2015, pp 46-49.
[17] Kitagawa, Midori, and Brian Windsor. MoCap for artists: workflow and techniques for motion capture. Routledge, 2020.
[18] Benedek, Joey, and Trish Miner. "Measuring Desirability: New methods for evaluating desirability in a usability lab setting." Proceedings of Usability Professionals Association 2003.8-12 (2002): 57.
[19] Moran. N. Using the Microsoft Desirability Toolkit to Test Visual Appeal. Nielsen Norman Group. 2016 https://www.nngroup.com/articles/microsoft-desirability-toolkit/
[20] Vuforia, Developer Library, https://library.vuforia.com/features/objects/object-reco/occlusion-model.html
[21] Bajura, Michael Alexander. Merging Real and Virtual Environments with Video See-Through Head-Mounted Displays. The University of North Carolina at Chapel Hill, 1997.
[22] Breen, David E., Eric Rose, and Ross T. Whitaker. "Interactive occlusion and collision of real and virtual objects in augmented reality." Munich, Germany, European Computer Industry Research Center (1995).
[23] Bjørner. T. Qualitative methods for consumer research, page 66
[24] Regenbrecht, Holger, and Thomas Schubert. "Measuring presence in augmented reality environments: design and a first test of a questionnaire." arXiv preprint arXiv:2103.02831 (2021).
[25] Schubert, Thomas, Frank Friedmann, and Holger Regenbrecht. "The experience of presence: Factor analytic insights." Presence: Teleoperators & Virtual Environments 10.3 (2001): 266-281.
[26] Fullerton, Tracy, Christopher Swain, and Steven Hoffman. Game Design Workshop: A Playcentric Approach to Creating Innovative Games. Amsterdam: Elsevier Morgan Kaufmann, 2008. page 105