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Floating in the Sea/Floating in the Data

The "Immaginario Bragadin" Experience around Venezia, Italy

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Abstract

Extended realities are often oriented in enhancing the perception of space, isolating the subject from the real environment and bringing the user to "another place". In the "Immaginario Bragadin" (imaginary BRAGADIN, IB, from "Marcantonio Bragadin", Venice 1523 – Famagosta 1571, past marine captain) an incredible outside world and the "introvert" virtual environment meet to define a unique and original experience in the Venetian Laguna. From a collaboration between the Laboratories of the Dipartimento di Architettura, University of Florence (DIDALABS) and Lorenzo Parretti, artistic curator of the IB, a specific and itinerant exhibition was developed to offer people the experience of XR, while floating around one of the most fascinating landscape and built heritage place in the world.

1 Introduction

The technology of virtual reality, as well as the augmented reality, allows migrating the perception of the environment in front of us. Thus, the influence of the real place, where the users/devices are present, is an element longly recognized as influent on the general experience [StMK98a], but it is often neglected in the design of the experience. On the contrary, while the users have the possibility to travel freely nullifying the distances, the real context around influences and takes full part to their senses. The decision to set up a virtual museum on a real boat came from the desire to shake the immobility of the structure that contains the computer technology and create a nomadic place, hosting an instrument capable to define a sort of virtual time/space machine exploiting the values of the context. The idea to experiment a series of site-specific aspects, like the smells, the motion, the sounds and the general mood, was extremely interesting and pushed towards the selection and organization of a series of well defined subjects, capable to benefit from such a condition.

1.1 A digital start

To start this project there was the intention to have a proper set of solutions, connecting a well defined exhibition space to a series of "path" across the Venetian Lagoon, starting to develop the hypothesis to have some possible expansion to the whole Mediterranean. The first set of visitable environments has been developed to define a "first release" of the IM itinerant exhibition. In the will of balancing the nature of the water, a specific vision of Venice and the Mediterranean and a group of the above mentioned site-specific elements were prepared to enter the first set of experiences, using advanced, almost experimental, hardware solutions like the wearable HP Z G2 backpack workstation equipped with an Oculus Rift S unit. It is even planned the further use of the high resolution (8k) Pimax visors and the Oculus Quest, but at the moment of the writing this solution is still under development. Together with this set of tools a more common solutions based on personal devices was organized to allow a general, quick and direct access to the resource using "popular" solutions in the logic of an extended dissemination of the contents.

For the personal device it has been developed also a small experience in AR, with the creation of an overlay of the Venice reality, everything made

with iOS hardware and software, using an Apple iPad Pro 11″ and the Arkit Software for developer. It is a first trial of the many possibilities that this technology could offer for the development of user-oriented solutions even if it is quite clear how the variables that may influence the results are many and still ongoing in being fixed.
In the end, the aim is to recreate an itinerant virtual exhibition, with a central core in the former ferry boat, that could give to the people floating in the lagoon a new and different kind of experience about Venice, proposing different themes to explore in time, from historical aspects to the built/cultural/intangible heritage tour. The general structure of the project will be: a main exhibition based on the "Captain Bragadin" ship, with a part supported by advanced visualization devices and full immersive experience and another section dedicated to the use of personal devices.

1.2 What the "Imaginario Bragadin" is

The "Capitano Bragadin" is an offshore ship, once moved by a steam engine, now ready to start a general restoration. It is 26 metres long and was built in 1916 by the ACNIL the society for the public transport in Venice, now named ACTV, the ship exit the dockyard bringing the name "Marcantonio Bragadin", who was the governor of Famagusta in Cyprus, bearing the siege of the town against the Ottoman army from July 1570 to August 1571, the long duration of the resistance, finished with the surrender of the fortress and the horrible death of Bragadin, who longly resisted to tortures, gave time to organize the floats of the Holy League led by Pope Pius V. The Holy League was then able to defeat the Ottoman fleet in Lepanto in October 1571 [Font19]. From this series of heroic and historical events the use of naming an Italian ship "Bragadin" seems a quite common behavior. While operating as a ferry, the Bragadin received the "number" 39, operating in the lines between Burano, Murano and "Fondamenta Nuova" in Venice, up to 1987. Later, it remained in full abandon until 1997 when it was bought and restructured into a private architecture studio in "Rivier del Brenta", it was used as a design place until 2017, in the past three years it started a progressive transformation into an itinerant cultural space. During the storm in November 2019, the Bragadin suffered from various damages and now it is near to enter a new restoration to complete its transformation, in the new asset it will include a large exhibition space, a

book shop, a relaxation area, a laboratory dedicated to teaching and playful activities for children and adults.

1.3 The reasons for a floating venue

The project is based on the belief that the interaction with the environment may be an essential extra value to the virtual/augmented reality experience. Various past researches have shown how the experiences in environments well compliant or even specific in front of the proposed virtual model allow a more convincing result and even a better comprehension/learning of the proposed contents [KWLH13]. In this sense the structure proposed for the exhibition is simple and at the same time well working in front of the first in-place test conducted in February 2020: in the central part of the exhibition area two immersive units take place, both have access to a series of virtual environments, the main two are: 1) The "Teatro del Mondo" by Aldo Rossi, representing the spirit of architecture and modernity in Venice. 2) The Cistern of Constantinople, representing the links between West and East, the mixture of elements due to artistry and needs. A series of secondary contents are dedicated to Lagoon/marine navigation subjects like the interactive point cloud of the "Captain Bragadin" digital survey and by the 3D model of the historical boat "Concordia", now abandoned nearby Porto Marghera and waiting for a recovery (these two elements are under development at the moment of writing). In addition to these immersive elements a specific selection of "guest" works is foreseen to take place in the virtual exhibition, hosting works from other scholars, with the main rule to be connected to mediterranean, coastal or "connected to Venice and its Lagoon" subjects.

Exploiting the large windows of the boat in the same main exhibition room, a series of three points of view are established to host a same number of augmented realities experience: "the imaginary shipwreck", again the "Teatro del Mondo" and the "boats around the Lagoon". The solutions are accessible using in place tablets or the personal devices of the visitors, the connection between the windows and the users is helped by the insertion of QR codes along the frame of the window. Last but not least, at the moment of the writing still at a very preliminary stage, the idea of creating an external experience out of the IM exhibition, with the possibility to take a small boat, navigate to one of the islands nearby and then experience the meeting with some virtual actors with a specific link to the place, like

the imaginary "ghosts" from the Poveglia island [BuSf18] or the people from the leper colony and/or the past Armenian Monks in the *San Lazzaro degli Armeni* island [MaBa99]. A solution to intensify the conclusion of the visit and link together a better knowledge of the historical values of the Lagoon with the logic of slow navigation and sustainable tourism.

2 The set of experiences for the itinerant exhibition

2.1 "Teatro del Mondo" by Aldo Rossi

This iconic temporary architecture was realized between the end of the '70s and the early '80s, it has a strong link with Venice and with the maritime theme. The Theatre of the World (Teatro del Mondo), has been built in Venice in 1979 by the architect Aldo Rossi [BrPR82]. It was assembled at the occasion of the Venice *Biennale* of Architecture; it can be considered as the most representative symbol of the Biennale and of the work of Rossi himself [RoBB04]. The experience was structured through various steps, starting from the documentation. Since the structure was dismantled, it was necessary to collect information on its formal and structural characteristics, consulting the architect's drawings and the various photographic sources. From this knowledge, it was possible to carry out digital modelling of the object, performed with Maxon Cinema 4D. Inside this software was also modelled and mapped the city of Venice; the modeling, the UVW mapping and the exporting process of the file was important for the creation of the context all around the Theatre, and it has been done with the helpful new plugin Datasmith, that can easily, even if with some imperfections, export models directly between Cinema 4D and Epic Games Unreal Engine. At the end, the model of the Theatre, exported using an FBX format, and the model of Venice, using Datasmith, were both imported in Unreal Engine for the developing of the virtual exploration [Gree19]. The experience led to the digital rebirth of this disappeared architecture. An operation that will make it accessible even to people who have never had the opportunity to see it or to retrace memories passed to those who were present at that time. The experience obtained is a complete perception of the physicality of architecture. The boat, leading the user to the place once housed by the building, the beautiful and suggestive *Punta della Dogana*,

will allow the researcher or the interested user to experience the work in its environment.
In the same spot it is possible to visualize the AR content about the Theatre. The camera of the mobile device will trace and recognize the marker which has been set during the phase of creation of the element and the AR content will show up on the device, giving the opportunity to interact with it directly on the screen. It is a less deep kind of immersion than the one offered by content displayed in VR, but still delivers an innovative experience to the people floating on the boat around Venice [FiFi18].

2.2 The "Cisterna Basilica" in Constantinople

It is safe to say that in order to know Venice better it is essential to know Constantinople. The two cities were strongly linked by commerce, art exchange and share some robust environmental aspects. There is this unbreakable bond, whose signs can still be found today in the architecture, mosaics, cuisine, language and history of this city of ours that has inherited so much from the mythical Constantinople.
The Basilica Cistern, in Turkish *Yerebatan Sarnici*, is one of the biggest ancient below the ground of Istanbul, build by the Emperors to satisfy residents' water needs [Onlu10].
The reconstruction of the Basilica Cistern was based on existing surveys, creating a dimensional model, optimally proportioned and that responds to the real. The Unreal Engine software was used to rebuild the Cistern and to offer a format that can be reused in any museum context [RiVP19], in this case an itinerant museum. This is the exact demonstration of the quality of this kind of result, which is an active type of communication, that offers the simulation of a real environment and an unforgettable experience. During the trials carried out on the IB, the presence of the real water and the sound of it, gave to the users an enhanced feeling of the scenario virtually recreated.

2.3 The "Imaginary shipwreck" in Venice

This setup is most of all a provocative proposal. The "large ships" presence in the Lagoon is longly subject of a debate between preservation and economical/market choices [Sett14, DaMa04]. In a certain way, they represent the extreme exaggeration of the touristic approach to the art towns, bringing gigantic cruise ship nearby the fragile and unrepeatable

Built Heritage of Venice. The risk of a tragic event repeating the "Costa Concordia" disaster in 2012 [StPe16] is one of the major concerns about the unarrestable cruises access to the Lagoon. In this way the visualization of a large shipwreck nearby the IB harbour is a way to shock and propose a reflection about the possible risks of an unwise approach to the built/natural environment of Venice. The user can just visualize the large ship in abandon, tilted on one side, in a similar position of the "Costa Concordia", in the will of producing by "fear effect" [Pott12] a sensibilization about this risky situation.

2.4 The user's experience feedback

The test carried out on the boat brought important observations regarding the use of the device by users. This moment was very useful to observe the feeling with the device of the different users and create a division into groups between the speed of learning and tuning with the VR. This cataloging was mainly divided according to age groups and was very interesting for us. The observed group of adults, with an age between 21 and 65 years, quickly understood the explanation of the controls and movement dynamics. However, in this group is useful to distinguish the difference in the safety of free movement, in practice something like taking few steps in the dark. The users on their first experience with VR are often very insecure, and they move in a limited space and in some cases, they do not move at all. While users who already had experiences, they felt freer, at first moving limitedly and then more widely when assisted with continuous or tactile feedback. In this group, however, it should be emphasized that a good part of the 51–65 age group, in addition to performing limited movements, preferred to let themselves be led, on a tour commanded by an external operator. This macro-group is joined by a further one, including the young age group from 8 to 20 years old. More inattentive to explanations and eager to wear the device, young people have demonstrated a very rapid acquisition of safety in movement. Besides, it should be noted that security in freedom and speed in learning the dynamics was faster as young as the user was. The residence time was also wider, with requests for a second use during the test day. Last interesting fact, among the event participants the female component proved more suspicious or declined the invitation to try the experience.

This is associated with direct comments and observations, more the result of emotional inputs than technical ones. These are difficult to summarize, the most relevant to be reported are: the amazement of being in front of an architectural work, which some users had seen live and the manifestation of perceptive sensations, such as the perception of the height or the feeling of the sizing of the spaces.

Therefore, reporting some useful data, the analyzed sample is composed of 21.4% with ages from 8 to 20 years, 14.3% between 21 and 35, 35.7% between 36 and 50 and 28.6 % between 51 and 65. The entire sample is made up of 21.4% of women and the remaining 78.6% of men. Of the users involved, 35.7% had already had at least one experience with VR, while the remaining 64.3% was at the first time. The average overall rating was 7.5 out of 8; an excellent performance over a short test period. The most significant data was obtained on the question relating to the physical environment, namely the use of a boat. As already specified, the theme presented was floating and the desire to propose it on a boat wanted to implement the sensoriality of the virtual visit. All respondents answered positively, regarding the choice of location. Even those who had never had experience with VR said that they could not imagine the experience as complete if done on land. At the end, a part of the interviews randomly selected, to give completeness to the statistical sample presented. Reporting also the comments to other queries requested which are difficult to summarize in numerical terms.

Age	Gender	First time in a VR space?	Vote	„ten words impression“	What did you like more?	What did you like less?	Effect in play	After play
51–65	M	N	8/8	Extremely pleasant	The texture, the representation of the sea, the space perception	Some mistakes in modeling	Loose reference to real, hilarity	Better understanding of the place, Better understanding of the architecture

21–35	M	N	8/8	Excellent job very interesting and perfect installation on the boat.	No answer	No answer	No answer	Better understanding of the architecture
21–35	F	N	7/8	Very nice experience	The possibility to visit an icon architectural place on an iconic water vehicle	No answer	Hilarity	Better understanding of the place, Better understanding of the architecture
36–50	M	N	8/8	Indeed, how to enter another environment and perceive it	Being able to move in space	lacking control of the observer's body	Vertigo	Better understanding of the architecture, Vertigo
10–20	M	Y	8/8	Freedom of movement	Freedom to visit spaces	Nothing	Hilarity	Better understanding of the place
36–50	M	Y	7/8	Perceptually complete, dizziness, presence of objects in space, it needs graphical improvements.	More realism. Adding unreal points of view	No answer	Vertigo, Loose reference to real	Feeling the change virtual/real, Vertigo
36–50	M	Y	8/8	Particular experience	Be suspended	No answer	No answer	Feeling the virtual/real swap
51–65	M	Y	8/8	It was my first time, incredible and fascinating.	No answer	No answer	Loose reference to real	Feeling the change virtual/real

36–50	M	Y	7/8	Very curious	No answer	No answer	No answer	No answer
51–65	M	Y	7/8	Addictive	Emotional	Movement management	Loose reference to real	Better understanding of the real, Feeling the change virtual/real
51–65	M	Y	8/8	An ocean, eye opening. Occasionally it would take this experience	More populated. Ducks, fish.	No answer	No answer	Better understanding of the place, Feeling the change virtual/real
36–50	F	Y	6/8	Emotion; I find the view from the sea spot on	Color	Motion graphics	Hilarity	Vertigo

Table 1: Excerpt from the interviews.

3 Conclusions

The project about the virtual itinerant exhibition is ongoing, the tests and the interviews with the users have confirmed how good can be the choice of a ship like the "Captain Bragadin" for hosting a set of marine experience, the environment in itself influence in an extremely positive way the perception of the virtual experience, the link between reality and virtual "suggestions" is enhanced and at the end the user feel even more interested in discovering the "real" contents just showed in the experience. The potentiality in terms of learning and dissemination of concepts is extremely interesting.

The next steps will be the completion and refining of the contents for all the virtual environments (paying attention to the feedback from the users) and the setup of the exhibition on the "Captain Bragadin", which is going

to face a complete restoration in May/June 2020. The rich and imposing context of Venice and its Laguna have shown their unbeatable strength in influencing the experiencing with technologies.

The main "lesson learned" from the first general test is that the Virtual Environment should not replace completely the real environment and that when it is possible, the connection between the virtual experience and the smells, sounds, movements from what's around may mix well with the final impressions gathered from the users.

The "exceptional" event of being on a boat may influence just some people, but is for sure an additional value that will help in moving visitors towards the set of experience on the IB space. The will of proposing an "alternative" Venice, far from the massive touristic access, reflecting on the special poetry of the Lagoon, mixing the relationship between people, arts, environment, with the luxury option of jumping in space and time and opening the possibility to interact in a new and specific way with an incredibly beautiful context.

Fig.1. Exterior of the "Immaginario Bragadin" during the public presentation in February 2020

Fig. 2: Example of AR technology inside the Itinerant “Immaginario Bragadin”

Fig. 3: Operating with the HP Z1 workstation on the “Immaginario Bragadin”.

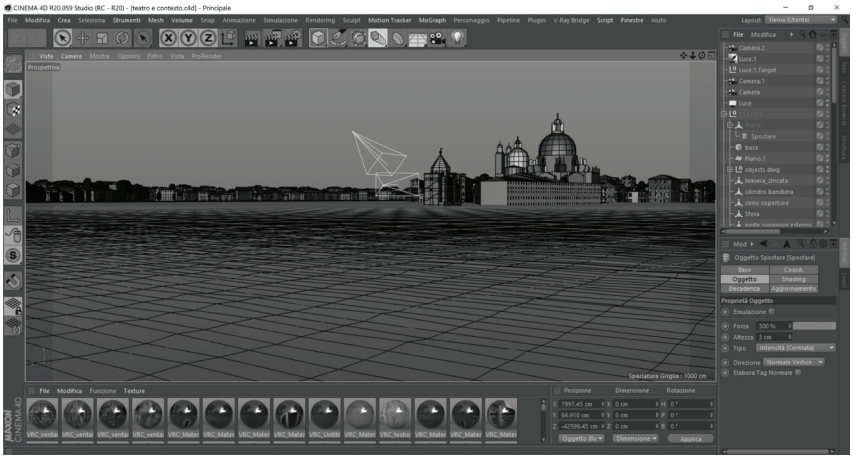

Fig. 4: Screenshot from Maxon Cinema 4D, representing the making of the 3d model of Venice and of the Theatre.

Fig. 5: Screenshot from Maxon Cinema 4D, representing the image rendering phase.

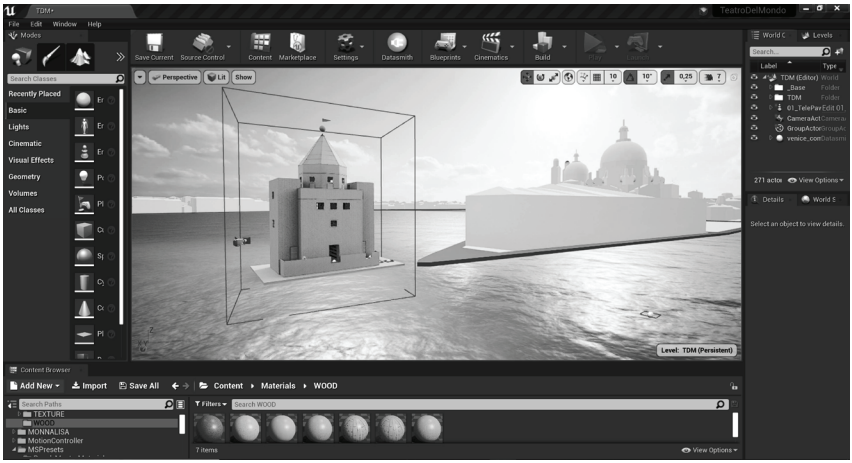

Fig. 6: Screenshot from Epic Games Unreal Engine, building the VR scene of Venice and the Theatre of the world.

Fig. 7: Screenshot from Epic Games Unreal Engine, representing the making of the VR scene of the Basilica Cistern.

Acknowledgments

The activities between the Dipartimento di Architettura, DiDALabs System and the “Immaginario Bragadin” Association were established in November 2019, the testing of the Virtual and Augmented Realities

contents took place in Venice in February 2020, the completion of the exhibition setup is foreseen by September 2020.
The contents for the "Teatro del Mondo" have been development with the collaboration of Eleonora Cecconi from the "Architecture Modeling Laboratory" (LMA) from the DiDALabs System. The contents for the Istanbul's Cistern, the "Imaginary Shipwreck" are a research work from Y. Ricci, A. Pasquali, G. Verdiani. The Concordia Boat is a research developed in collaboration with L. Parretti.
The present harbor where the Captain Bragadin is located in the "Spazio Junghans", Giudecca, Venezia, Italia.

Literature

[BrPR82] Brusatin, M.; Prandi, A.; Rossi, Aldo: Aldo Rossi: Teatro del mondo, Cluva Università, 1982.
[BuSf18] Busato, Davide; Sfameni, Paola: Poveglia. L'isola alle origini di Venezia, Lunargento, 2018.
[DaMa04] Davis, Robert C.; Marvin Garry R.: Venice, the Tourist Maze: A Cultural Critique of the World's Most Touristed City, University of California Press, USA, 2004.
[FiFi18] Fink, Charlie; Fine, Robert: An AR Enabled Guide to AR & VR, Cool Blue Media, 2018.
[Font19] Fontana, Gian Jacopo: Marcantonio Bragadin, Eroe Veneto, Lulu.com, USA, 2019.
[Gree19] Greengard, Samuel: Virtual Reality (The MIT Press Essential Knowledge series), MIT Press, 2019.
[KWLH13] Kim, Mi Jeong; Wang, Xiangyu; Love, Peter ED.; Heng, Li; Kang, Shih-Chung: Virtual Reality for the Built Environment: A Critical Review of Recent Advances, in Journal of Information Technology in Construction, August, Herman, Slovenia, 2013.
[MaBa99] Maguolo, Michela; Bandera, Massimiliano: San Lazzaro degli Armeni: l'isola, il monastero, il restauro, Marsilio, Italia, 1999.
[Onlu10] Onlu, Şehnaz: Analysis of Structural Elements of Basilica Cistern, Istanbul Technical University, Turkey, 2010.
[Pott12] Potter, W. James: Media Effects, SAGE Publications, USA, 2012.
[RiVP19] Ricci, Ylenia; Verdiani, Giorgio; Pasquali, Andrea: Ancient remains from the Roman Istanbul: a transmutation from stone to digital, in "Kultur und Informatik: Virtual History and Augmented Present", Carsten Busch, Christian Kassung, Jürgen

Sieck (Editors), pp. 15–28, VWH Verlag Wemer Hülsbusch, Glückstadt, Germany, 2019.

[RoBB04] Rossi, Aldo; Barbieri, U.; Bertolotto, G.: Aldo Rossi – Teatro del mondo, Alinea, 2004.

[Sett14] Settis, Salvatore: Se Venezia muore, Giulio Einaudi Editore, Italia, 2014.

[StMK98] Stanney, Kay M.; Mourant, Ronald R.; Kennedy, Robert S.: Human Factors Issues in Virtual Environments: A Review of the Literature, in Presence, Vol. 7, No. 4, August 1998, pp. 327–351, Massachusetts Institute of Technology, USA, 1998.

[StPe16] St. John III, Burton; Pearson, Yvette E.: Case 7.2 The Costa Concordia Shipwreck, in Crisis Communication and Crisis Management: An Ethical Approach, pp. 109–116, SAGE Publications, USA, 2016.

Yunnan Garden VR: Re-creation of a Tropical Garden as Virtual Cultural Heritage

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Abstract

The capturing of sites of cultural heritage value for display in real-time VR is now common but has tended to focus on man-made inanimate structures and objects. Less attention has been paid to gardens and similar organic structures that contain living elements. This paper describes the process of creating a room-scale VR re-creation of tropical Yunnan Garden prior to its complete redevelopment. The garden holds cultural heritage value so we explored how the re-creation of living plants, along with architectural elements and the precise mapping of tree locations and forking pathways, can be achieved and virtually preserved. We summarise and evaluate the results and compare different strategies and outcomes. Challenges and compromises are discussed, and best practices suggested.

1 Introduction

The re-creation of existing cultural heritage sites for virtual real-time applications has more commonly been concerned with inanimate, man-made structures [RiHa13] that may include gardens, or virtual recreations of lost historic gardens such as the Labyrinth of Versailles [GiTa17]. While there are numerous examples of gardens captured for VR applications using mono or stereoscopic 360° video, this paper explores re-creating a garden as a photorealistic room-scale walk-in VR experience consisting of a considerable amount of flora in addition to paths and garden structures.

Tropical Singapore is famous for its UNESCO world heritage recognised botanic gardens founded in 1859 and the 'garden city' programme, introduced by Prime Minister Lee Kuan Yew in 1967. The Parks and Trees Act of 1975 [NLB67] enshrined the importance of gardens and green areas to Singapore. Given the significant status of flora in this ever-changing metropolis, it is important to consider how to virtually preserve remarkable examples of trees and garden structures that might be threatened by redevelopment.

In 2016, the development office of Nanyang Technological University began plans to significantly remodel its Yunnan Garden, a historically important garden constructed in the 1950s and inspired by traditional Chinese gardens. The plan called for the removal of a significant number of trees and shrubs to make way for new water features and further landscaping. We initiated a research project to digitally capture and preserve the garden prior to its redevelopment. Considering its huge trees and plants of a wide variety of species, we explored a range of capturing techniques to achieve this goal. Capturing and recording a living subject, such as the plants in a garden, present other difficulties and considerations compared to preserving an immobile object. Plants and trees involve unique challenges for digital detailed capture and representation. Each tree might have many thousands of leaves, with each one slightly different from the others, all combining to create a very complex heterogeneous structure. The complexity and variation of the flora in the park provided significant challenges to our desire to create an impression of the garden with high fidelity.

2 Significance and Main Elements of Yunnan Garden

Describing Yunnan Garden, the architecture-scholar Chen Yu states [Zacc16], the "landscaping with its memorial pagoda and pavilions was the venue for historical events." Mainly, the garden served as a location for graduation ceremonies, large get-togethers, learning and leisure for several generations of students from Nantah University, as the then Chinese language university was called. The Garden used to be an open and empty area, positioned according to Feng Shui principles in front of the main university building, now the Chinese Heritage Centre and Library. The main structural elements of Yunnan Garden are the impressive entrance arch (See Fig. 1), the memorial monument and the seven traditional pavilions. The arch is a replica (built in 1995) of the original university entrance arch, that was located 1 km from the garden in an area that is now a residential neighbourhood (Jurong West Street 93). The university name is embossed in Chinese characters on the arch's central beam, as is 1955, the year when the former Nanyang University (Nantah) opened. The Straits Times [Stra16] noted that the three gates of the historical arch symbolise three elements of Chinese traditional philosophy and three different "talents" – da cai (the wisdom to govern a country); chang cai (the capabilities of a trade); and qing cai (the ethics of man).

The main path through the entrance arch leads to the centre pavilion, designed, as are all the pavilions, according to traditional Chinese architecture, with an octagonal layout, four entrances, eight red pillars and a green tiled roof with eight faces. Continuing on the main path takes us to the Nantah memorial, a four-sided 5 metre tall white pagoda-style monument with tablets on the two sides facing the main path (fig. 4). It was added in 1958 in the same Chinese national style, with reinforced concrete and stylised Chinese motifs like the other constructions in the garden and the Chinese Heritage Centre. Together, they were recognised as a national monument in 1998, including the Gateway Arch. The memorial is accompanied by seven unique sculptural garden rocks, one of the most important elements of traditional Chinese Gardens. Karstic limestones resemble mountainous landscapes with their asymmetric formation, colour and structured surface. [Metr04] Another detail, the forking path structure, enables the visitor to see multiple picturesque sceneries instead of one straight vista. For our reconstruction, we focussed on the main elements and their surroundings.

Fig. 1: Entrance arch in *Yunnan Garden VR* © 2019 The Authors

3 *Yunnan Garden VR* – The Process

3.1 Creating the VR Garden

The garden encompasses an area of approximately 3.4ha and contains hundreds of trees and shrubs. There are seven pavilions, an entrance arch, memorial monument, extensive forking path structure, and of course many green grass areas. Additionally, there are hundreds of flowers, benches, small stones, trash bins, lamp poles, birds, mosquitos, leaves fallen off the trees and seven unique stone sculptures. These elements can be broken down to three primary materials 1 – plants (Tree leaves, grass, flowers, shrubs), 2 – stone (Path structure, monument, gate, stone benches, stone sculptures), 3 – wood (Tree trunks, pavilions, bridges). Of these, the most challenging for 3D-reconstruction and re-creation is the large variety of plant species. Using photogrammetry or LiDAR scanning to create 3D plants is not a viable option, as plants with their crisscrossing leaves produce an almost infinite-appearing number of occluded areas. The sheer number of plants in the garden, in addition to the wide fields of grass, presented a considerable challenge. As well as the path structure and other elements, we would need to create some 500 trees and further 500 secondary plants. Combining all these elements in a 3D environment

with a realistic lighting setup and aiming to run the application smoothly as a Virtual Reality experience, meant that some compromises were inevitable. In the following, we will describe key considerations and findings of some of the process stages involved.

3.2 Topology

Our process of re-creating the garden as a 3D-approximation started with reconstructing the ground topology, plotting the exact tree positions and laying out the walkway path structure by utilising a detailed topographic map combined with an orthographic photo. An aerial survey with a *DJI Phantom 3* drone was conducted, and hundreds of photographs were processed in *Agisoft Metashape* to generate the orthomosaic map, which provided precise measurements of the garden. The topographic map not only indicated the exact height levels of the ground floor but contained the detailed position of each tree. Based on the topographic and orthomosaic maps we reconstructed the exact 3D-topology of the ground floor and positioned 507 placeholders for 16 of the most common tree species (See Fig. 2).

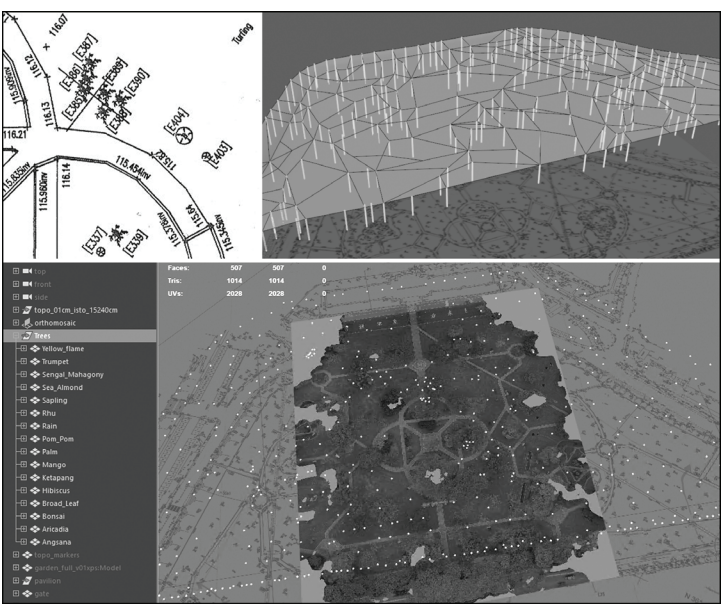

Fig. 2: Topographic map (top left), reconstructed topology (top right), plotting 507 tree placeholders (bottom) © 2019 The Authors

The approximately one-kilometre path structure (See Fig. 3) comprises the wider main path on the vertical axis between gate and monument, horizontally between four outer pavilions, the iconic interlocking circular "knotted" paths around the main pavilion and many shorter connecting ways. The paths are accompanied by a drain canal on either one or both sides. The paths are built of rectangular stone tiles that have become weather beaten while developing a patina of stains and moss, traces of the tropical weather conditions. The surface of the paths has been replaced many times over the years. Our main focus was the layout of the distinct path structure, which can be considered unique and peculiar to the garden, rather than the weathered details of the individual stone tiles. Therefore, we decided against using photographic textures but instead used the 3D software *SideFX Houdini* to construct the path. With this tool the tiles are distributed and aligned automatically, including the seams between crossing paths, and thus saving considerable time.

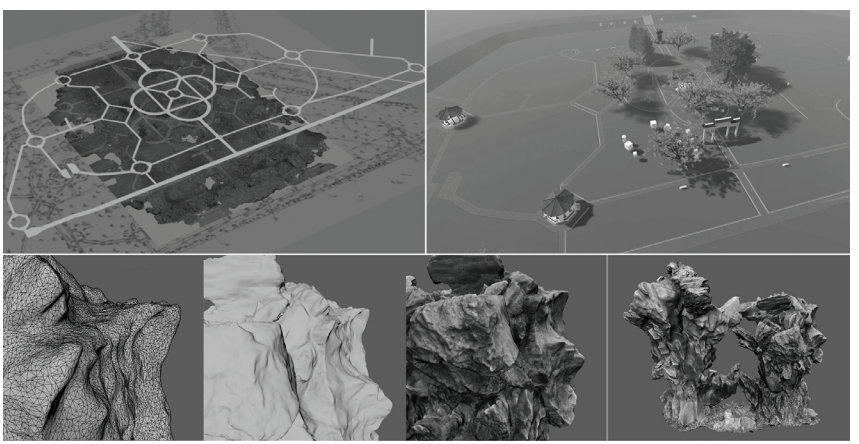

Fig. 3: Constructed paths (top-left), paths and main elements (top-right), reconstruction of stone sculpture (bottom) © 2019 The Authors

3.3 Arch, Pavilions and Memorial Monument

Our efforts in re-creating the garden focused on the central area around the significant structural elements: the entrance arch, the centre pavilion and the memorial monument. We started in early 2018 with a photogrammetric reconstruction of the memorial monument from roughly 660 photos, mostly taken by a drone, with additional photos shot from the ground level. While the 3D reconstruction of the monument appeared

convincing from afar, closer inspection revealed noticeable rigorous smoothing of corners. After investigating manual adjustments and clean-up procedures, we concluded that remodelling based on the photogrammetry, while utilising high-resolution photographs as material textures, was the best approach for not only the monument but also for the arch and pavilions. Compared to the overly smooth corners of the photogrammetry, the recreated 3D-models appeared too sharp and clean and although we added more details to the edges to counter the sharpness, the effect was still noticeable to a small degree in the final 3D-models.

3.4 Stone Sculptures

Some of our starting points for capturing the elements in the garden were the seven unique stone sculptures, an important asset in Chinese gardens. With their specific forms and textures, it would not have been possible to measure and model them exactly. Therefore, we decided to employ photogrammetry, capturing hundreds of images of each sculpture, from all directions and angles. For continuity and precision, we worked with a DSLR-camera with a prime lens, applied bracketing (capturing three images from one point with one over- and one underexposed) and shot in RAW format to achieve a wide dynamic range, as the illumination on the stones varied, even in diffuse light. After selecting the matching images, we used *Agisoft Metashape* for the 3D reconstruction and *Adobe Substance Designer* to create PBR (Physically Based Rendering) materials. Each of the final 3D stones comprises approximately one million polygons (See Fig. 3).

3.5 Trees and Plants

After identifying detailed positions, species and numbers of trees (See Fig. 2), we began a threefold strategy in which we 1) Sourced tree assets to match the required species, 2) Created various variations of these tree assets and 3) Captured trunks and bark textures of existing trees in the garden to combine them with the tree assets. For the prominent Yellow Flame, Rain and Ketapang trees inside the centre area we conducted a photogrammetric 3D reconstruction of their trunks and obtained high-resolution photographs of the bark. The photos were then processed in *Adobe*'s *Substance Painter* to produce tile-able textures, that were then utilised for several trees of the same species. The Rain tree, being very common in Singapore is a host tree for several native epiphytes (plants that

grow on other plants), such as the bird's nest fern [TaYe09]. Accordingly, we added ferns to the branch forks of our rain trees, which enhanced the level of detail and increased the tropical appearance to the VR experience.

Our research differs from the approach of the creation of *Virtual Singapore* [GLTY18], that suggests a typology of seven different shapes of trees, which is relevant for urban planning and a representation of the city structure from birds-eye perspective but lacks the required detail to give the level of immersion we desired.

4 Aural Representation

It is well documented [PoWD13] that sound has an important role to play in helping create immersion and presence in virtual environments. In Yunnan Garden VR the function of the soundscape is fundamentally designed to perform that role and can be considered diegetic and congruent with the created visual world. It does not have a narrative function inasmuch as the sound is not employed to prompt or encourage a particular action of the user. As previously noted [ReWS18], the sound world of the real garden is completely dominated by the roar of traffic from the adjacent Pan Island Expressway. This serves to mask almost totally (especially for recording purposes) most sounds that might emanate from within the garden itself. For this reason, our initial ambisonic recordings were made in a memorial garden located much further away from anthropogenic sound sources. The resulting recordings were further processed with noise reduction software to reduce the presence of undesired sounds caused by human activity. This reflects a specific aesthetic decision and the resulting soundscape abstracts the garden from the world beyond its borders. Additional recordings for specific sound elements such as birds and wind were sourced from existing libraries and used to complete the sound world.

The created soundscape is congruent with the VR representation of the visual world but lacks fidelity with the soundscape of the real garden. It represents an idealised version of Yunnan Garden's soundscape.

5 Results and Variations

5.1 Yunnan Garden VR

With recent advancements in software tools such as *Unity* and *Epic*'s *Unreal* game engine, authoring of real-time environments has become more accessible and easier for researchers to utilize. The Yunnan Garden VR experience is authored in *Unreal Engine 4* which supports PBR (Physically Based Rendering). Our environment lighting reflects a late afternoon atmosphere, close to the equator, although with longer shadows, which we found is the most appealing ambience to reflect the experience of being in the garden based on our site surveys (See Fig. 1 and 4). Although creating near photorealism for an environment has become de facto possible, it still poses a tremendous challenge for a small research team with limited resources. In particular, the high volume of assets required for a large environment such as a garden presented the biggest obstacle. Our creation of an entire garden environment possesses a high level of detail that supports the visual fidelity of the experience, but the ultimate goal of reaching photorealism has not yet been achieved. Even with only near photorealism, the ability to freely explore such a complex environment is itself a unique experience, presenting promising new opportunities to Virtual Heritage.

Fig. 4: Reference photo (left), *Yunnan Garden VR* (right) © 2019 The Authors

5.2 Garden of Changes

The artistic interactive project "Garden of Changes" is contructed within the Yunnan Garden VR world and is based on the initial fascination for the

forking path structure of the garden as it challenged the choice of which path to take at each intersection.

At the entrance to the garden, signposted with the gateway arch, the user is invited to pose a personal question for which an answer will be provided at the memorial monument, across the garden. The answer is based on the ancient Chinese iChing, known as the "Book of Changes" – the inspiration for the title of the project. With reference to the iChing method of casting a hexagram through a binary system such as tossing coins, the user is at each intersection invited to pick up a bundle of three coins and throw them into the chosen direction. This will cast randomly solid or broken lines, representing yin and yang, which will form a hexagram after passing through six intersections. In addition, the main pavilion at the centre of the garden provides information about the iChing and the reference to the garden. The eight possible trigrams, of which two form a hexagram, are positioned in the pavilion according to their assigned cardinal direction and introduce their image in nature from north to northwest: water, mountain, thunder, wind, fire, earth, lake and heaven.

Maps with the positions of the forking paths are placed on the table-top inside the pavilion, at the entrance to the garden and also at the memorial, to support the user in finding all six positions with coins. In contrast to other games, users are invited to slow down, explore the garden in measured movements and reflect on their question, for which an open answer will be provided based on Chinese wisdom.

6 Discussion and Conclusion

The capturing of sites of cultural heritage value for display in real-time VR is now common but has tended to focus on man-made inanimate structures and objects. Less attention has been paid to gardens and similar organic structures that contain living elements. This presented interesting challenges in adapting existing VR capturing techniques to an ever-changing living environment.

In embarking on our ambitious re-creation of Yunnan Garden in VR we had two specific and overlapping goals. These were to create a photorealistic real-time virtual representation of a garden with cultural heritage importance, and to create the sensation of presence, of being in that

place. We have detailed the fundamental processes employed to create the VR representation, described the challenges we encountered along the way, and what we consider to be best practice. The *Garden of Changes* explored using Yunnan Garden VR as a stage to experiment with creating different user experiences while exploring the heritage garden.

Throughout this process, technical realities and limitations inevitably impacted our aesthetic decisions, as did limitations in man-hours and funding for the project. Rendering complex shapes and patterns in VR requires a significantly powerful GPU and even then, optimisation is required to allow smooth playback of the VR world. The compromises demanded by optimisation inherently impact visual fidelity to some degree and is an example of how current technical limitations ultimately influence aesthetic outcomes.

Despite the aforementioned challenges we are satisfied with the results of our research effort and feel we have captured the garden to a reasonably high level of fidelity and photorealism. Lessons learned inform our ongoing research practice in VR for cultural heritage applications.

We explored using the constructed immersive environment as a stage or container for realising other virtual experiences. Three independent versions have been created so far, two artistic/impressionistic interpretations, *Gone Garden* and *Flux Garden* and the third, *Garden of Changes* that was briefly discussed in this paper.

Our future plans include investigating the placing of human agents and additional fauna in the garden. We also intend to explore offering Yunnan Garden VR to other researchers and artists as a platform to experiment with different interpretations and user experiences.

Acknowledgments

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Literature

[GiTa17] Giloth, C., Tanant, J.: *VR in the Garden: The Labyrinthe of Versailles Revisited*, 2017, 23rd International Conference on Virtual System & Multimedia (VSMM 2017), Dublin, Ireland, October 31–November 4, 2017, New York City, NY/Red Hook, NY: Institute of Electrical and Electronics Engineers/Curran Associates, Inc.; doi.org/10.1109/vsmm.2017.8346264.

[GLTY18] Gobeawan, L.; Lin, E. S.; Tandon, A.; Yee, A. T. K.; Khoo, V. H. S.; Teo, S. N.; Yi, S.; Lim, C. W.; Wong, S. T.; Wise, D. J.; Cheng, P.; Liew, S.C.; Huang, X.; Li, Q. H.; Teo, L. S.; Fekete, G.S.; and Poto, M. T.: *Modeling Trees For Virtual Singapore: From Data Acquisition To CityGML Models*, 2018, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-4/W10, pp. 55–62; doi.org/10.5194/isprs-archives-XLII-4-W10-55-2018.

[Metr04] Department of Asian Art: "Chinese Gardens and Collectors' Rocks." In: *Heilbrunn Timeline of Art History*, 2004, New York City, NY: The Metropolitan Museum of Art, metmuseum.org/toah/hd/cgrk/hd_cgrk.htm

[NLB67] *"Garden City" Vision Is Introduced; 11th May 1967*, eresources.nlb.gov.sg/history/events/a7fac49f-9c96-4030-8709-ce160c58d15c

[PoWD13] Poeschl, S., Wall, K., Doering, N.: *Integration of spatial sound in immersive virtual environments an experimental study on effects of spatial sound on presence*, Virtual Reality, IEEE Annual International Symposium (VR 2013), Lake Buena Vista, Fl, United States, March 18–20, 2013, New York City, NY/Red Hook, NY: Institute of Electrical and Electronics Engineers/Curran Associates, Inc.; doi.org/10.1109/vr.2013.6549396

[ReWS18] Reinhuber, E.; Williams, R.; Seide, B.: *The Scale of Immersion: Different audio-visual experiences exemplified by the 360° video Secret Detours*, 2018, Electronic Visualisation and the Arts (EVA 2018), London, UK, July 9–13, 2018, London: BCS, pp. 236–243.

[RiHa13] Richens, P.; Harney, M.: *Beckford's Ride: The Reconstruction of Historic Landscape*, 2013, In: Bowen, J., Keene, S., Ng, K. (Eds.): Electronic Visualisation in Arts and Culture, London: Springer, pp. 259–276

[SEMT03] Song M.; Elias T., Müller-Wittig, W.; Chan, T. K. Y.: *Using virtual reality to bring Singaporean heritage to life*, 2003, Proceedings of Computer Graphics International (CGI'03), Tokyo, Japan, July 9–11, 2003, Los Alamitos, CA: IEEE Computer Society, pp. 240–243; doi.org/10.1109/CGI.2003.1214474

[Stra16] Anon.: *Nantah's historical structures*, August 18, 2016, The Straits Times; straitstimes.com/singapore/nantahs-historical-structures

[TaYe09] Tan, H. T. W., Yeo, C. K.: *The potential of woody plants for enhancing the urban waterways and water bodies of Singapore*, 2009, Singapore: Raffles Museum of Biodiversity Research/Singapore-Delft Water Alliance; lkcnhm.nus.edu.sg/app/uploads/2017/04/native_woody_plants.pdf

[Unes] *Singapore Botanic Gardens*, whc.unesco.org/en/list/1483

[Zacc16] Zaccheus, M.: *Heritage of Yunnan Garden 'Spans Globe'*. March 4, 2016, The Straits Times; straitstimes.com/singapore/heritage-of-yunnan-garden-spans-globe.

Deploying Mobile Augmented Reality for Gameful Exploration of Cultural Heritage

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Abstract

In this contribution we report on "Augsburger 101", a mobile tour guide app, that takes the user on a tour with selected places of interest (POIs) related to cultural heritage across the old city of Augsburg. The app utilizes augmented reality to allow visitors discovery and exploration of heritage assets as well as cultural customs in a playful way. When arriving at a POI, the user is asked to accomplish a gaming task using the smartphone as a physical tool to manipulate virtual objects. Informed by potential app users (here international exchange students) a proof-of-concept prototype has been developed and implemented. In view of an extended app version, we also sketch a framework for evaluation.

1 Introduction

The 2000-year-old city of Augsburg features a rich cultural heritage, including tangible heritage sites and objects, such as ruins and relics from the roman period, an over 800-year-old water management system (granted World Heritage status by [UNES20]), historic buildings, wells, various pieces of fine arts from the renaissance era, and many witnesses of early industrialization, especially of a former textile industry. In addition, many local traditions and customs bear witness to an eventful history as well as flourishing craftsmanship and trade. Tourists come all year round from all over the world and each semester its two universities attract hundreds of international exchange students. Coming to Augsburg, a culturally interested visitor can rely on various classical information sources including books, booklets, brochures, or web-sites (some of them are available from the town's tourism office [Regi20]). As more and more visitors are equipped with modern smartphones, there is a growing desire on the part of both visitors and the Tourist Office to adopt and use the latest advances in mobile technologies to adopt and exploit recent advances on mobile technologies to enhance the overall visiting experience. Augmented Reality (AR) is a promising candidate as it can enable visitors to engage with the heritage content encountered along their tour through the city.
In this contribution we present "Augsburger 101", a concept of a gamified AR tour guide for young first-time visitors interested in cultural heritage and local traditions. The concept emerged in the context of a project with a group of international exchange students at the University of Applied Sciences Augsburg – assuming they are all potential users of such an app themselves.

2 Related Work

Quite a number of attempts have been made to exploit augmented reality in the cultural heritage sector and tourism in general, see, for example, [HaJu18] or [YuKh19]. Some projects have focused on overlying real world objects or spaces with textual or graphical annotations to provide otherwise invisible information. Examples include GPS or geo-based AR-Apps that determine a user's geographical position, such as the mobile

augmented reality travel guides “CorfuAR” [KBBC15] and “MiraAlicante” [MMMH16] which highlight important buildings and monuments at a user’s current location, or “Paris Avant/ Paris Then and Now” (developed by the meanwhile dissolved firm Mavilleavant) that shows photographs of locations of Paris as they looked 100 years ago. Also, some AR apps process image frames shot by the device’s built-in camera in search of a known target image which will then serve as an anchor for a generated graphical overlay. Technically more advanced are apps that use on-device image recognition as well as real-time 3D-graphics rendering for the virtual reconstructions of heritage sites. Such projects aim to integrate historical content into the live camera view of mobile devices. Examples include “LecceAR” [BaCM15], “MaurAR” [Beta20], and “HistStadt4D” [MNBB20]. See [LuRV19] for a recent survey on heritage apps using augmented reality.

Also, AR technology has paved the way for the creation of engaging games. Among them are location based adventure games like “Pokemon Go” [Poke20] as well as treasure hunt games in which players use an AR enabled mobile device to receive clues as well as to discover, unlock, and collect virtual items in their real environment. An attempt to enhance a visit of a cultural heritage site through elements of a treasure hunt game has been made by the NosferRAtu project. In their mobile app the Orava Castle located in Slovakia is used as a playground with hidden virtual objects to be discovered by the player while walking around the castle [MMMH16].

3 Concept

3.1 Idea Formation

Following the idea of a tour guide for visitors developed by visitors, the exchange students from India and the Netherlands who participated in the project were asked to explore the city and take notes about locations they found interesting and curious. In addition, they were instructed to think of how augmented reality (AR) could be used not only to get additional information about the places they encountered, but also to make the tour more engaging and adventurous. For this task each student received an

A4 sized paper-printed tourist map of the local tourism office to give them clues where to go and where they could find places of interest.

Growing up with smartphone games, it is not surprising that all the students' suggestions for a novel mobile guide took up elements of gaming, including ideas known from location-based gaming (like Pokemon Go [Poke20]) to more classical mobile puzzle and arcade games. On the other hand, there was also the goal of a curated tour that would take visitors from one historically or culturally significant location to the next. This led to the idea of embedding interactive elements of gameplay (i.e. mini-games) in a guided cultural heritage tour.

3.2 Concept Development

Concept development involved the following tasks:

- T1: selection of places of interest (POIs) that could serve as corner stones of a tour with walking time between POIs limited to 3–4 minutes. Experience gained from an earlier geo-caching project deploying mobile phones showed that longer walking paths between places of activity are likely to reduce the user experience as users might get distracted and loose attention on the activity.
- T2: creation of mini-games to be played at the POIs. Each mini-game should establish a notable relation between the cultural heritage asset and the gaming activity.
- T3: coherent embedding of the mini-games into an overall tour guide that also provides a navigation aid as well as access to information about the POIs visited.

Based on the notes students took while exploring the town we selected about ten POIs in a neighborhood called "Am Roten Tor". This neighborhood was chosen for pragmatic reasons, it is in the vicinity of the university, but retains the option to easily include further POIs. Selected POIs relate to historic buildings and wells of the water management heritage, a famous "Puppets on the String" theater, and a road that bears witness to historic craft guilds.

Inspired by work on exploratory learning models [DeNe09], task T2 was tackled with the objective to involve the user in an interaction with the subject of interest, and at the same time provide a joyful and memorable experience. In our approach, the interactions are framed as mini-games that use the real environment of a POI as a playground where the user has

to accomplish a gaming task using the smartphone as a physical tool to manipulate virtual objects overlaid on live-camera images of the environment. Starting from the student's experiences in playing computer games, a number of core gameplay elements have been collected and matched against specific characteristics of the selected POIs. The POIs could be roughly grouped into:

- locations featuring a historical building or monument,
- locations where cultural activities are/were practiced, e.g. a theater,
- locations where traditional craftsmanship and trade was/is practiced, e.g. a blacksmith's shop, a bakery, or a local marketplace.

Proposed gameplay elements were borrowed from a diverse spectrum of different game genres, including shooter and combat, adventure, arcade, treasure hunt, turn-based strategy, puzzle, role-play, and simulation. For the sake of simplicity, we excluded any game mechanics that would require a human teammate or opponent. Since the envisioned tour features a number of different mini-games, the time for gameplay per mini-game has to be kept short. This excluded time-consuming game mechanics as it is found in some turn-based strategy games or long-winded adventure games. Linking the POIs and so the mini-games to an evolving storytelling adventure (such as "On the trail of…" or "Discovering the secrets of...") was considered a charming option at a first glance. However, doing so would have forced a story-compliant choice and sequencing of POIs which proved to be too restrictive and inflexible in view of later changes or extensions of a tour. After all, the emerging overarching requirement was that users should be able to easily relate gameplay at a POI to specific characteristics of that POI. As a starting point, our primary gameplay elements for mini-games focus on the imitation of an activity as if it were performed in the real environment. Examples include virtual fishing, forming virtual pretzels, adding virtual extensions to buildings, etc., see Section 3.3 for illustration.

In Augsburger 101 the mini-games are embedded in a mobile tour guide that gives the user route directions where to go next. While the mini-games are intentionally kept independent of each other, a feature common to all mini-games is that successful mastering gets rewarded by a collectible souvenir in the form of an icon related to the game performed. This motivated the addition of a souvenir tray in the user interface (UI). Furthermore, task T3 concerned iterative design-and-test cycles to harmonize the

UI's look-and-feel across the mini-games, and the addition of on-demand animated help instructions.

3.3 Use Cases

The shots 1 to 4 of Fig.1 illustrate the concept. After the user has been guided to the historical water towers, he is asked to explore the spot and take a picture of a sculpture which, in this case, is located near the entrance door of a historical building. When trying to take the picture the user has to get close to the sculpture and thus finds himself on a bridge over a small canal. Once the image of the sculpture has been recognized by the smartphone's image recognition module as the desired anchor image, the user receives a location-specific task to accomplish. In this case, the task is an AR fishing exercise. The real-time camera images of the water flowing through the channel are overlaid with animated virtual fishes in cartoon style. In addition, the user's smartphone now turns into a quasi-physical fishing rod. Imitating a typical movement of a fishing rod, the user must perform physical pitch rotations with the smartphone, in order to direct the virtual hook at the virtual fish and catch them.

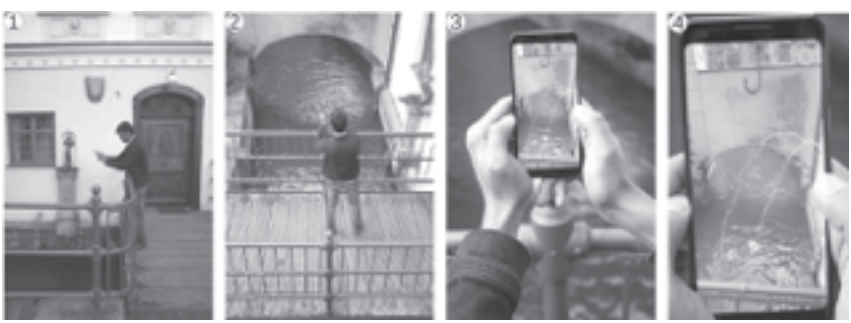

Fig. 1: User engaging in an AR fishing task. The smartphone is used as a virtual fishing rod to catch virtual fish from the canal.

Two further mini-game tasks are illustrated by Fig. 2. The first two shots were taken in front of a traditional bakery. As pretzels belong to the local eating culture like no other pastry, the task at hand is to virtually form and bake a pretzel. To this end, a pretzel shape has to be drawn "in the air" by skillfully moving the smartphone around. Finally, shots 3 and 4 were taken in front of a historical well. Once the well has been identified by the user's smartphone as a target anchor image, the well turns into a virtual wheat beer dispenser and the user is asked to engage in a tricky beer glass

filling task where the mobile device represents the beer glass. In order to prevent the beer from foaming over, the successful completion of the task requires the glass (i.e. the mobile device) to be held at an inclined position while pouring in (virtual) beer.

Fig. 2: Moving a smartphone to draw a pretzel (shots 1 and 2). A user engaging in a virtual wheat beer glass filling task in front of a historical well (shots 3 and 4).

4 Prototype Development

Prototype development followed a double tracked approach. A tool for rapid prototyping (ProtoPie) has been used to quickly draft mockups of the envisioned interaction sequences, and for testing UI versions of different look and feel. In parallel, a proof-of-concept prototype of the AR app has been implemented using the Unity game engine Version 2019.2.17f1 [Unit20] and the Vuforia Engine Library Version 8.6 [PTC20] which leverages Google's ARCore on devices running Android OS. Distinct visual elements from each POI were chosen and images of them were processed in Vuforia's cloud portal to generate so-called anchors. The application uses the anchors to recognize and place the interactions in virtual space. Physical interactions are based on the smartphone's built-in gyroscope and acceleration sensors. The prototype has been tested on Pixel 3 (running Android 10) and Nokia 6.1 plus (running Android 9) smartphones.

5 Evaluation Framework

5.1 Evaluation Targets

Augsburger 101 is a mobile AR app that aims to provide a gamified experience in the cultural heritage domain. Therefore, the following evaluation targets are considered relevant:

- usability of the app
- evidence of enhanced user experience
- evidence of positive learning impacts

5.2 Usability

For an evaluation of the app's usability we orient ourselves on the Handheld Augmented Reality Usability Scale (HARUS) questionnaire which comprises eight questions concerned with potential perceptual issues and eight questions regarding ergonomic issues of the app, see [SPTY15]. While the HARUS questionnaire is usually employed for a summative usability test of a completed system, we already used HARUS questions for guidance during the iterative development of the prototype. Many iterations of design and testing have become necessary to fix usability issues (e.g. ambiguities of icons and text elements, inconsistent interactions across mini-games) and to adjust the level of difficulty of the physical interactions that users must master when playing the mini-games. Functional testing was carried out on-site under varying weather conditions. It was found that the recognition of (anchor) images and the mapping of smartphone movements to actions in the game world worked reliably well.

5.3 User Experience

Augsburger 101 features AR mini-games as central elements to enhance the overall user experience (UX for short). Therefore, an UX evaluation should primarily target the gaming experience while playing the mini-games. [Bern10] provides an overview of a range of UX evaluation methods for computer games including approaches for heuristic evaluations, summative evaluation questionnaires for gamers as well as non-standard approaches, such as capture and interpretation of a gamer's physiological parameters (such as skin conductance, heart rate ec.) during

game play. Obviously, playability of a game is a necessary condition for a positive gaming experience. Assuming major usability issues have been eliminated, the question boils down to identify the relevant factors that contribute to a positive experience while playing a game. As a starting point, the Core Elements of the Gaming Experience (CEGE) approach of [CaCC10] can be adopted. In essence, the CEGE model identifies as factors contributing to enjoyment (or frustration) the player's perception of the game environment and the gameplay, as well as the player's sense of control and ownership during gameplay. The model comes with a 38 items CEGE questionnaire which, for instance, may be used to evaluate different version of a game.

For Augsburger 101, so far only preliminary feed-back on user appreciation was collected at a recent public event at the university. To this end, poster-sized photographs of the real locations were used as a substitute for the outdoor environment. Holding a smartphone in front of the posters enabled visitors to perform physical tasks, such as virtual fishing. All visitors who tried the AR mini-games gave positive feedback on playability and found the concept promising and fun.

5.4 Learning Impacts

Augsburg Visitors interested in cultural heritage may pursue specific learning objectives. However, the question of to what extent a gamified tour guide like Augsburger 101 can contribute to desired learning outcomes of its users is difficult to answer. A visiting tour provides an informal learning context and even an education-hungry visitor might not think primarily of a learning activity when undertaking a tour. As a starting point to evaluate learning impacts, we rely on the Generic Learning Outcomes (GLO) framework developed by Hooper-Greenhill and colleagues to measure the outcomes and impact of learning upon visitors of museums, archives and libraries. In GLO learning is understood as being an open-ended and self-directed process and an experience. The GLO framework suggests measuring learning impacts among five categories: (a) increase in knowledge and understanding; (b) increase in skills; (c) change in attitudes or values; (d) evidence of enjoyment, inspiration and creativity; (e) evidence of activity, behaviour and progression. For an evaluation of Augsburger 101 we plan to conduct post-visit structured interviews with 2–3 questions for each of the five GLO categories. For instance, related to category (a) visitors will

be asked to recall the locations visited and to give a judgment, why a location is of relevance for the town's history. Regarding questions to other categories, e.g. "did you acquire new skills?" or "what was your favorite location?" we expect that visitors relate their answers to the mastering of playing AR mini-games and to the entertaining value of the games. Also, we expect that visitors who played AR mini-games along the POIs of the tour will better remember the POIs visited.

6 Summary

Augsburger 101 aims at providing first-time visitors to Augsburg an entertaining access to the rich cultural heritage and to local traditions of the town. In essence, Augsburger 101 has been conceived as a mobile tour guide app that utilizes augmented reality to allow for playful interactions with the locations visited. The design of the app was informed by exchange students who themselves are potential users of the app. So far, a proof-of-concept prototype has been implemented to illustrate the concept and to gather user feedback.

Future work will focus on the extension of the tour of about one hour duration with about 10 POIs to visit and thus 10 AR mini-games to play. The extended system will serve as a basis for an evaluation along the dimensions outlined in Section 5. We are also in contact with the local tourist office to discuss options for a public roll-out of the app after its completion.

Literature

[BaCM15] Banterle, Francesco; Cardillo, Franco Alberto; Malomo, Luigi: LecceAR: An Augmented Reality App for Cultural Heritage. In: ERCIM NEWS 103, 2015. LecceAR website: http://vcg.isti.cnr.it/LecceAR/ (accessed Mar. 1. 2020).

[Bern10] Bernhaupt, Regina (ed.): User Experience Evaluation in Games: Concepts and Methods. Springer, Heidelberg, 2010.

[Beta20] BetaRoom: MaurAR. BetaRoom UG, Berlin. Website: https://mauar.berlin/ (accessed Mar. 1. 2020).

[CaCC10] Calvillo-Gámez, Eduardo H.; Cairns, Paul; Cox, Anna L.: Assessing the Core Elements of the Gaming Experience. In: [Bern10], 2010, pp. 37–62.

[DeNe09] De Freitas, Sarah; Neumann, Tim: The use of 'exploratory learning' for supporting immersive learning in virtual environments. In: Computers & Education Vol. 52(2), 2009, pp. 343–352.

[HaJu18] Han Han, Dai-I; Jung, Timothy: Identifying Tourist Requirements for Mobile AR Tourism Applications in Urban Heritage Tourism. In: Jung T., tom Dieck M. (eds) Augmented Reality and Virtual Reality. Progress in IS. Springer, Cham. 2018, pp. 3-20.

[HDMJ03] Hooper-Greenhill, Eilean; Dodd, Jocelyn; Moussori, Theano; Jones, Ceri; Pickford, Chris; Hermann, Catherine; Morrison, Marlene; Vincent, John; Toon, Richard: Measuring the outcomes and impact of learning in museums, archives and libraries: the Learning Impact Research Project end of project paper. Research centre for Museum and Galleries, University of Leicester, pp. 1–24. GLO Online resource: https://www.artscouncil.org.uk/measuring-outcomes/generic-learning-outcomes (accessed Mar. 1. 2020).

[KBBC15] Kourouthanassis, Panos; Boletsis, Costas; Bardaki, Cleopatra; Chasanidou, Dimitra: Tourists responses to mobile augmented reality travel guides: the role of emotions on adoption behavior. In: Pervasive and Mobile Computing 18, 2015. pp. 71–87. CorfuAR website: http://www.corfuar.com (accessed Mar. 1. 2020).

[LuRV19] Luna, Ursula; Rivero, Pilar; Vicent, Naiara: Augmented Reality in Heritage Apps: Current Trends in Europe. In: Applied Sciences, 2019, 9, 2756; doi:10.3390/app9132756.

[MMMH16] Mesároš, Peter; Mandicák Tomáš; Mesárošová, Alena; Hernandez, Manuel Ferrer; Kršák, Branislav; Sidor, Csaba; Štrba, Ľubomír; Molokác, Mário; Hvizdák, Ladislav; Blišťan, Peter; Delina, Radoslav: Use of Augmented Reality and Gamification Techniques in Tourism. In: e-Review of Tourism Research (eRTR), Vol. 13 No. 1/2, 2016, pp. 366–381.

[MNBB20] Münster, Sander; Niebling, Florian; Bruschke, Jonas; Barthel, Kristina; Friedrichs, Kristina; Kröber, Cindy; Maiwald, Ferdinand: Urban History Research and Discovery in the Age of Digital Repositories. A Report About Users and Requirements. In: Kremers H. (eds) Digital Cultural Heritage. Springer, Cham, 2020, pp. 63–84.

[Poke20] Pokémon Company: Official Website: https://www.pokemon.com (accessed Mar. 1. 2020).

[Regi20] Regio Augsburg Tourismus GmbH: Official Website: https://www.augsburg-tourismus.de (accessed Mar. 1. 2020).

[SPTY15] Santos, Marc Ericson C.; Polvi, Jarkko; Taketomi, Takafumi; Yamamoto, Goshiro; Sandor, Christian; Kato, Hirokazu: Toward standard usability questionnaires for handheld augmented reality. In: IEEE Computer Graphics & Applications 35(5), 2015. pp. 66–75.

[UNES20] UNESCO World Heritage List: Entry 1580: Water Management System of Augsburg. Online: https://whc.unesco.org/en/list/1580/ (accessed Mar. 1. 2020).

[Unit20] Unity Technologies: Official Website: https://unity.com/ (accessed Mar. 1. 2020).

[YuKh19] Yung, Ryan; Khoo-Lattimore, Catheryn: New Realities: A Systematic Literature Review on Virtual Reality and Augmented Reality in Tourism Research. In: Current Issues in Tourism 22 (17): 2019, pp. 2056–81.

Interactive Volumetric Video Rendering and Streaming

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Abstract

Photo-realistic modelling, real-time rendering and animation of humans is still difficult, especially in virtual or augmented reality applications. Even more, for an immersive experience, interaction with virtual humans plays an important role. Classic computer graphics models are highly interactive but usually lack realism in real-time applications. With the advances of volumetric studios, the creation of high-quality 3D video content for free-viewpoint rendering on AR and VR glasses allows highly immersive viewing experiences, which is, however, limited to experience pre-recorded situations. In this paper, we go beyond the application of free-viewpoint volumetric video and present a new framework for the creation of interactive volumetric video content of humans as well as real-time rendering and streaming. Re-animation and alteration of an actor's performance captured in a volumetric studio becomes possible through semantic enrichment of the captured data and new hybrid geometry- and video-based animation methods that allow a direct animation of the high-quality data itself instead of creating an animatable model that resembles the captured data. As interactive content presents new challenges to real-time rendering, we have developed a cloud rendering system for interactive streaming of volumetric videos that drastically reduces the problem of high processing requirements on the client side.

1 Introduction

Photo-realistic modelling and rendering of humans is extremely important for virtual and extended reality (VR, XR) environments, as virtual humans are essential for most interactive applications like games, film, e-learning, assistance, or communication. However, convincing real-time rendering is still difficult. This is because the human body and face are highly complex and exhibit large shape variability but also, because humans are extremely sensitive when looking at humans. Further, interaction with the rendered content plays an important role. While purely computer graphics modeling is able to achieve highly realistic and animatable human models, achieving real photo-realism with these models is computationally extremely expensive. On the other hand, with the advances of volumetric studios [Micra, Volu], the creation of high-quality 3D video content for free-viewpoint rendering on AR and VR glasses allows highly immersive viewing experiences. However, high-quality immersiveness is usually limited to experience pre-recorded situations.

Here, we present a pipeline for the creation of high-quality animatable volumetric video content of human performances. Going beyond the application of free-viewpoint volumetric video, we allow re-animation and alteration of an actor's performance through (i) the enrichment of the captured data with semantics and animation properties and (ii) applying hybrid geometry- and video-based animation methods. The idea is that we directly animate the high-quality data itself instead of creating an animatable model that resembles the captured data. Thereby, we bring volumetric video to life and combine interactivity with photo-realism.

Additionally, the interactivity presents new challenges regarding real time rendering, as it requires changing the volumetric object according to the user input or position. This is especially challenging on mobile devices with low processing power. Moreover, efficient hardware implementations for decoding of volumetric data (e.g. point clouds or meshes) are currently not available in mobile devices. Software decoding may drain the battery quickly and may not be able to meet the real-time rendering requirements. In this context, we have developed a cloud rendering system for interactive streaming of volumetric videos that drastically reduces the problem of high processing requirements on the client side.

2 Overview and Application

An overview of our pipeline for the creation and animation of interactive volumetric video is presented in Fig. 1. In the following section, we will step through the different components, starting from the capturing and processing of volumetric data over the enrichment with semantic animation data through model fitting to the alteration and animation of the captured content. Note that the proposed pipeline is highly modular. For example, for the capturing and data processing steps, either high-quality professional capturing with sophisticated setups, such as those presented by [SFRZ19, CCSG15, Volu, Micra] as well as lighter and cheaper systems [RCRS16, APTM19] can be used, depending on the use case requirements, considering the trade-off between data quality and captured details and the complexity of the capturing setup. Section 4 describes our system architecture for real-time rendering and streaming of the interactive content. We present a cloud-based volumetric video streaming system that comprises a generic server and two different client implementations: one for Microsoft Hololens (both 1st and 2nd generation) and another browser-based client capable of running on different web browsers.
We present an application where a virtual human viewed on AR or VR glasses follows the user with his head when the user moves in the virtual scene in order to enhance the feeling of a true conversation with the virtual character, e.g. in teaching sessions or pre-captured interviews with contemporary witnesses.

3 Animatable Volumetric Video

3.1 Creation of Animatable Volumetric Video Content

The pipeline (Fig. 1) starts with the creation of high-quality volumetric video content (free viewpoint video) by capturing an actor's performance in a volumetric studio (Fig. 1, I) and computing a temporal sequence of 3D meshes (Fig. 1, II) [SFRZ19, Voul, Micra]. The reconstruction of temporally inconsistent meshes is converted into spatio-temporally coherent mesh (sub-) sequences using template-based approaches in order to facilitate texturing and compression (Fig. 1, III). In order to allow for topo-

logical changes during the sequence, we use a key-frame-based method to decompose the captured sequence into subsequences and register a number of key-frames to the captured data [MoHE19]. The final dynamic textured 3D reconstructions can then be inserted as volumetric video assets in virtual environments and viewed from arbitrary directions (free viewpoint video).

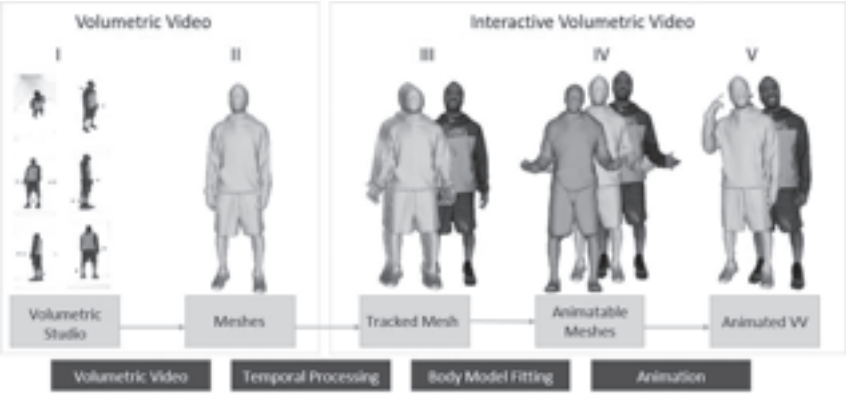

Fig. 1 : Pipeline for the creation of interactive volumetric video content: Starting from multiview capturing (I), we reconstruct a sequence of temporally inconsistent meshes (II), which are then converted into subsequences of temporally consistent meshes (III). Following, we fit a parametric model (IV) in order to allow an animation of the captured data (V).

In order to make the captured data animatable, we learn a parametric rigged human model [ASKT05, FeHE16] and fit it to the captured data [FeHE19] (Fig. 1, IV, Fig.2). Through this process, we enrich the captured data with semantic pose and animation data taken from the parametric model, which can then be used to drive the animation of the captured volumetric video data itself.

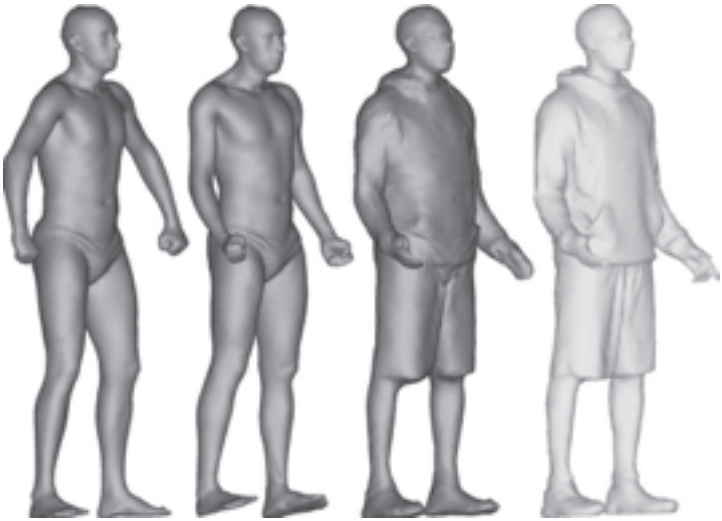

Fig. 2 : Model fitting to volumetric video data: initial model (left), pose adapted model (2nd from left), pose and shape adapted model (2nd from right) and volumetric video frame (right).

3.2 Hybrid Animation

The captured content contains real deformations and poses and we want to exploit this data for the generation of new performances as much as possible. For this purpose, we propose a hybrid example-based animation approach that exploits the captured data as much as possible and only minimally animates the captured data in order to fit the desired poses and actions. As the captured volumetric video content consists of temporally consistent subsequences, these can be treated as essential basis sequences containing motion and appearance examples. Given a desired target pose sequence, the semantic enrichment of the volumetric video data allows us to retrieve the subsequence(s) or frames closest to the sequence. These can then be concatenated and interpolated in order to form new animations, similar to surface motion graphs. Such generated sequences are restricted to poses and movements already present in the captured data and might not perfectly fit the desired poses. Hence, after we have created a synthetic sequence from the original data that resembles the target sequence as closely as possible, we now animate and kinematically adapt the recomposed frames in order to fit the desired poses.

The kinematic animation of the individual frames is facilitated through the body model fitted to each frame. For each mesh vertex, the location relative to the closest triangle of the template model is calculated, virtually gluing the mesh vertex to the template triangle with constant distance and orientation. With this parameterization between each mesh frame and the model, an animation of the model can directly be transferred to the volumetric video frame. Fig. 3 shows an example of an animated volumetric video frame. The classical approach would have been to use the body model fitted to best represent the captured data in order to synthesize new animation sequences. In contrast, we use the pose optimized and shape adapted template model to drive the kinematic animation of the volumetric video data itself. As the original data contains all natural movements with all fine details and the original data is exploited as much as possible, our animation approach produces highly realistic results.

Fig. 3: Animated volumetric video data: The virtual character turns his head towards the user

4 System Architecture

In this section, we describe the key components of our interactive volumetric video streaming system (Fig. 4) as well as the dataflow and interfaces between the components.

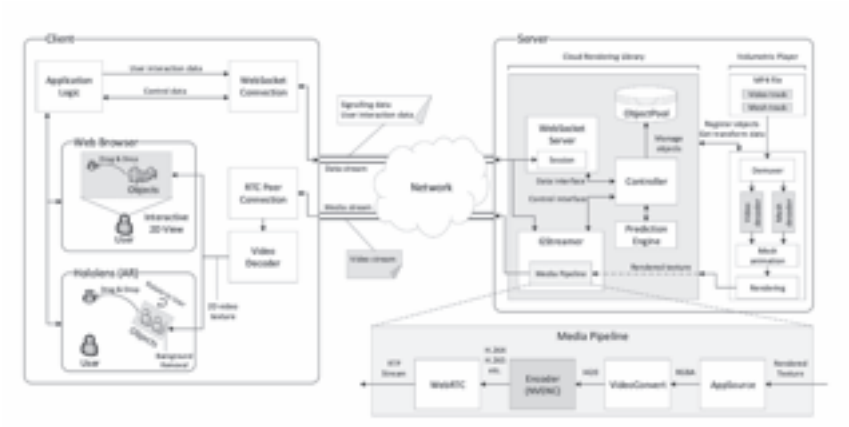

Fig. 4: Overview of our volumetric video streaming system.

4.1 Volumetric asset storage format

We store the different components of our volumetric assets in a single MP4 file to facilitate integration as a dedicated plugin into the established game engines such as Unity. Particularly, the texture atlas is compressed using video compression (H.264/AVC), and meshes are compressed using a standard mesh compression algorithm implemented in Google Draco [Goog18]. The compressed mesh and texture data are multiplexed into different tracks of an MP4 file ready for storage and transmission [SFKE19].

4.2 Server architecture

Our server implementation mainly consists of a volumetric video player and a generic cross-platform cloud rendering library that can be integrated into different applications.

The **volumetric video player** is implemented using Unity and has the necessary demultiplexer and decoder plugins to play volumetric sequences stored as a single MP4 file, as described in Section 4.1. After the registration of the objects, the player demultiplexes the MP4 file and feeds the data into the corresponding video and mesh decoders. The volumetric mesh is altered based on user input, e.g. for the eye contact application described above, the head is turned based on the user position as described in Section 3.2. Each mesh is synchronized with the corresponding texture, and a desired view of the volumetric object is rendered as a Unity RenderTexture. The rendered view is passed to our cloud rendering

library for further processing. Concurrently, the player asks the library for the latest positions of the registered objects and updates the rendered view accordingly.

The **cloud rendering library** is a cross-platform library written in C++ for media processing, application control and communication interfaces between server and client. The library is generic and allows integration into different mixed reality applications. We integrated the library as a native Unity plugin in our server application. In the following, we describe the main modules implemented in the library, each running on a different thread to achieve high performance.

Signaling and control data between the server and client is exchanged via a **WebSocket Server**. Signaling data includes Session Description Protocol (SDP) and Interactive Connectivity Establishment (ICE) messages necessary for establishing the WebRTC connection. Also, scene description metadata as well as control data to modify the position of a registered game object or camera is transmitted over the WebSocket connection.

Media processing is performed using the **Gstreamer** media framework [Gstr]. Our Gstreamer pipeline takes the rendered texture from Unity as input, compresses it as a video stream, and transmits the video stream to the client over a WebRTC connection. In order to keep the encoding latency to a minimum, we use a hardware-based encoder from Nvidia (NVENC) and compress the texture as a H.264/AVC bitstream. However, our Gstreamer pipeline allows using a different format e.g. H.265/HEVC, or using a software encoder like x264. Finally, the resulting compressed bitstream is packaged into RTP packets and sent to the client using WebRTC.

The **Controller** implements the application logic and manages the other modules depending on the application state. Particularly, it retrieves the object states from the **ObjectPool** (a logical structure that maintains the IDs and positions of all registered objects) and sends them to the client as a JSON file in order to inform the client about the object states. Depending on the predictions from the Prediction Engine, the Controller updates the positions of the virtual objects such that the rendering engine creates a scene corresponding to the predicted positions. The Controller is also responsible for initializing/closing the media pipeline when a new client joins/disconnects.

The **Prediction Engine** predicts the head movements of the user in 6DoF space for a given prediction interval. Thus, we aim to reduce the effective motion-to-photon-latency by rendering the frames in advance that match the future head position of the user. Currently, we use an autoregression model for prediction; however, the module allows deployment of different kinds of algorithms that can bring higher prediction accuracy, e.g. Kalman filter. Details of our prediction algorithm and a latency analysis of our system are described in [GPBS20].

4.3 Client architecture

Our client architecture consists of various connection interfaces, a video decoder, our application logic, and a client application. Before the session starts, the client initiates a WebSocket connection with the server and asks for a description of the rendered scene. The server responds with a list of the objects and related metadata (e.g. object positions). The client then replicates the scene and initiates a WebRTC connection with the server. Exchange of SDP and ICE data for WebRTC session negotiation occurs over the established WebSocket connection. After the WebRTC connection is established, the client starts receiving a rendered view of the volumetric video corresponding to the (predicted) user pose. The client can also control the virtual objects by sending control data back to the server over the WebSocket connection.

We implemented both a browser client and a native Hololens client application. While the browser client targets use cases in which the volumetric content is viewed on a 2D screen, e.g. a tablet or a mobile phone, the Hololens client targets more immersive AR/MR applications that potentially offer more natural interaction with the content.

Our **browser client** is implemented in Javascript using the *three.js* library [Thr] that allows users to interact with the volumetric objects using various controllers e.g. a mouse, keyboard, or touchscreen. Particularly, users can move the camera around to observe the object from different angles, change the object's position in the scene, and scale the object using sliders. We tested our client application on different web browsers e.g. Chrome, Safari, and Firefox.

Our **Hololens client** is built as a Universal Windows Platform (UWP) application using Unity. The application renders the 2D scene onto a plane that is orthogonal to the user's viewpoint in the world space. When the

user changes her position, the plane is rotated such that it always remains orthogonal to the user's viewpoint. Consequently, the user perceives the dynamically changing 2D views rendered onto the plane as though a 3D object were present in the scene. Hololens displays black pixels as transparent due to the properties of the optical see-through display [Micrb]. We exploit this property to remove the background of the rendered scene such that the volumetric objects are perceived to be overlaid onto the real world. We achieve this by using a shader in Hololens that sets the background pixels to black which makes them transparent and reveal the real world as the background.

4.4 Deployment

We verified the functionality of our system by running the server application both on a 5G edge server and an Amazon EC2 instance. Running the server on an EC2 instance in Frankfurt and using our browser client connected to WiFi in Berlin, we were able to measure an end-to-end latency around 60 ms.

5 Conclusion

We presented a new framework for the creation, animation, rendering and streaming of animatable volumetric content. Re-animation and alteration of an actor's performance captured in a volumetric studio becomes possible through semantic enrichment of the captured data and new hybrid geometry- and video-based animation methods that allow a direct animation of the high-quality data. Furthermore, as interactive content presents new challenges to real-time rendering, we presented a cloud rendering system for interactive streaming of volumetric videos that drastically reduces the problem of high processing requirements on the client side.

Our framework allows interaction with highly realistic virtual characters captured in a volumetric studio, e.g. in AR/VR scenarios.

Literature

[APTM19] Alldieck, T.; Pons-Moll, G.; Theobalt, C. and Magnor, M.: "Tex2shape: Detailed full human body geometry from a single image," in Proc. International Conference on Computer Vision (ICCV). IEEE, 2019.

[ASKT05] Anguelov, D.; Srinivasan, P.; Koller, D.; Thrun, S.; Rodgers, J.; Davis, J.: SCAPE: Shape Completion and Animation of People. Proc. Computer Graphics (SIGGRAPH), 2005.

[CCSG15] Collet, A.; Chuang, M.; Sweeney, P.; Gillett, D.; Evseev, D.; Calabrese, D.; Hoppe, H.; Kirk, A.; and Sullivan, S.: "High-quality streamable free-viewpoint video," ACM Trans. on Graphics, vol. 34, no. 4, p. 69, 2015.

[Goog18] Google/Draco: a library for compressing and decompressing 3D geometric meshes and point clouds. https://github.com/google/draco (2018).

[GPBS20] Gül, S.; Podborski, D.; Buchholz, T.; Schierl, T. and Hellge, C.: 2020. Low Latency Volumetric Video Edge Cloud Streaming. arXiv preprint arXiv:2001.06466.

[Gstr] Gstreamer, https://gstreamer.freedesktop.org/.

[HTCH15] Huang, P., Tejera, M., Collomosse, J., Hilton, A.: Hybrid Skeletal-Surface Motion Graphs for Character Animation from 4D Performance Capture. ACM Trans. Graph. 34, 2, Article 17, 2015.

[FeHE16] Fechteler, P.; Hilsmann, A.; Eisert, P.: Example-based Body Model Optimization and Skinning. In: Proc. Eurographics 2016. Lisbon, Portugal, 2016.

[FeHE19] Fechteler, P.; Hilsmann, A.; Eisert, P.: Markerless Multiview Motion Capture with 3D Shape Model Adaptation. Computer Graphics Forum 38(6), pp. 91–109, 2019.

[Micra] Microsoft, http://www.microsoft.com/en-us/mixed-reality/capture-studios

[Micrb] Microsoft. https://docs.microsoft.com/en-us/windows/mixed-reality/rendering

[MoHE19] Morgenstern, W.; Hilsmann, A.; Eisert, P.: Progressive non-rigid registration of temporal mesh sequences. In: Proc. Europ. Conf. on Visual Media Production (CVMP). London, UK, 2019.

[RCRS16] Robertini, N.; Casas, D.; Rhodin, H.; Seidel, H.-P. and Theobalt, C.: Model-based outdoor performance capture, in Proc. Int. Conf. on 3D Vision (3DV), 2016.

[SFRZ19] Schreer, O.; Feldmann, I.; Renault, S.; Zepp, M.; Eisert, P.; Kauff, P.: Capture and 3D Video Processing of Volumetric

Video, Proc. IEEE International Conference on Image Processing (ICIP), Taipei, Taiwan, Sep. 2019.

[SFKE19] Schreer, O.; Feldmann, I.; Kauff, P.; Eisert, P.; Tatzelt, D.; Hellge, C.; Müller, K.; Ebner, T. and Bliedung, S.: Lessons learnt during one year of commercial volumetric video production. In Proceedings of IBC conference, Amsterdam, Netherlands, Sep. 2019.

[Thre] Three.js, JavaScript 3D Library, https://threejs.org.

[Volu] Volucap GmbH, http://www.volucap.de

Immersive Sketch-based Modelling Techniques for Generating Models of the Own Body

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Abstract

This article is concerned with the topic of sketching one's own body in three-dimensional space. The aim is to develop interaction techniques to help patients with a disorder of perception of their own body schema. The evaluation of interaction techniques among participants without body schema disturbance shows that they are able to draw their own body relatively accurately. Positive learning effects result especially from multiple drawing of the upper body. Drawing the lower body, on the other hand, does not become more accurate even with multiple repetition. This may be related to the higher physical effort involved in drawing in a crouched position. Overall, the results are promising and an encouragement to further develop the interaction technique.

1 Introduction

Sketching and modelling in an immersive three-dimensional space has recently gained importance, especially in the domains of design, engineering and art. A number of studies emphasize the special character of immersive sketching in terms of interactivity of the sketching process, involvement of the sketching person, and the close relationship between the own body and the three-dimensional sketch. In comparison to other media, users can create inherently three-dimensional objects, act freely in three-dimensional space and already interact with the sketched objects [AKAG17; IWMS09]

A special field of immersive sketching is the freehand modelling of the own body. Possible fields of application are in art, prototyping of scenes, and psychotherapy. In the latter case, the ViTraS project (ViTraS, n.d.) is investigating whether people with body schema disorders can achieve therapeutic success by creating their own 3D representations in an immersive space. The interaction technique "self-sketch" allows users to create a representation of themselves by means of immersive freehand sketching with a 3-D pen in front of a virtual wall.

Compared to the interaction techniques of popular immersive modeling systems from research and industry [AKAG17,; Goog16; Grav18; IWMS09; KAML01; MASL18; ScPrS01; WVWB18], sketching the own body has special requirements. There are many parts of the body that users cannot see while sketching, such as the back, neck and the back of the shoulders. An additional challenge is that users typically move while sketching. This makes it difficult to simply trace the silhouette of one's own body, as a resting body would be advantageous.

This paper describes the self-sketch interaction techniques and presents an informal evaluation with a focus on learnability. Self-sketch creates two-dimensional drawings and could also be implemented without virtual reality techniques. However, as it is intended to be used in a multi-functional immersive therapeutic setup, a VR solution was necessary.

2 Related Work

The use of VR technologies in the medical field is already taking place. In psychotherapy VR is used among other things for the treatment of body schema disorders. Studies show that some patients with weight disorders have a perception of their own body, which deviates from the actual body image. This also occurs for patients who, after successful weight reduction, still have internalized their original body image and cannot perceive the success of the therapy [RGSD18].

Previous works about immersive sketching of the own body are not yet known. Although the above-mentioned immersive sketching systems exist, they focus on the creation of products, annotations, or pieces of art. Schkolne et al. developed a system that allowed the creation of 3D shapes and geometries in space with pure hands. This made it possible to create organic structures and even body shapes in a short time [ScPrS01; Schk06]. However, these had a very rough structure and hardly resembled real persons.

In principle, it is possible to create depictions of the own body with all immersive sketching systems. In this paper we try to simplify the self-sketching process so that satisfactory results are achieved for the users.

3 Interaction technique Self-sketch

The interaction technique Self-sketch was developed to give patients a possibility to visualize deviations of their mental representation of their body scheme from their real body shape. The interaction technique enables the user to draw the mental representation of his body (i.e. his body schema) as a silhouette. In a later phase it is planned to give users the possibility to stand in the silhouette and compare it with their own body; deviations of the drawn shape from the real body shape will then be marked by colour. The prerequisite for this is that the avatar representing the user corresponds to his real body measurements. In the project ViTraS body scans with several high-resolution cameras are created for this purpose (ViTraS, n.d.).

The interaction technology is implemented via a controller (VALVE Index) that the user holds in his or her hand. In the virtual environment, a virtual

pen is displayed at the position of the user's hand, from the tip of which the virtual stroke is extruded as soon as the trigger button on the controller is pressed (Fig. 1).

The research of Rahul et al. about visual and haptic support during immersive sketching suggests that providing the user a virtual canvas can help them to create better results matching the picture they have had in their mind. Following that research, we decided to add a canvas which looks similar to the one described by Rahul [AKAG17]. The canvas is generated in front of the user, where drawings are only possible in a 30 cm wide space in front of it. With each frame the distance between the hand and the canvas will be measured. If the hand is within that area, a pen will appear in the virtual hand. Inside of that area the user will be allowed to draw, while outside of it the drawing function will be disabled. The canvas itself is made of two planes, one with a grid texture put on top of it and the other one as a transparent color as to visually fill the grid for the user so it is more cohesive as a grid altogether and can be better differentiated from the environment.

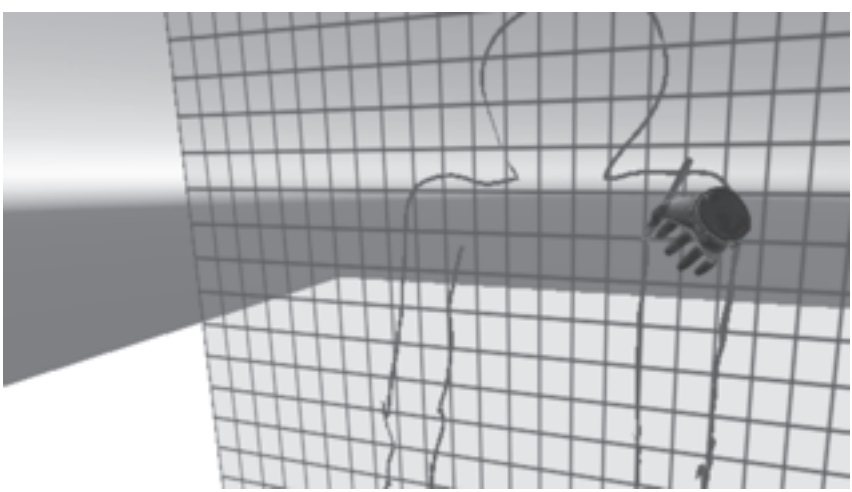

Fig. 1: Self-sketch interaction technique

The graphic representation of the sketched strokes is generated according to the movements of the controller with the trigger button pressed. The strokes are displayed as relatively thin 3D geometry using a polygon mesh. An algorithm creates quads between the previous and the current 3d

sample point. Each of these quads are connected to the following quad, thus forming a continuous stroke.
In the end, all supporting points of the stroke are projected onto the canvas plane to get a flat representation of the silhouette. This is helpful for the later intended comparison of the drawn silhouette with the user's body presented by the avatar.

4 Evaluation

4.1 Subjects and procedure

A study was conducted to investigate the usability and especially the learnability of the interaction technique "Self-sketch". The study involved 4 persons (age M = 37, SD = 15.9), which was obtained by personal contact with colleagues. None of the participants had a known disturbance of the body schema. All participants had a background in computer science: two students, one professor, and one research associate. They received no compensation for their participation.
The test procedure was as follows: After the welcome, the participants received an information sheet on data protection as well as a questionnaire which recorded their experiences in the fields of sketching and virtual reality. Afterwards the participants were briefly informed about how the interaction technique works with the test leader giving a short demonstration. A training phase was omitted because we wanted to determine the learning effect. After the HMD (VALVE Index) was handed over to them, the participants had the task of sketching their own body as precisely as possible using the interaction technique "Self-sketch". The process had to be performed three times by each participant. They were instructed to draw themselves as they would see themselves in a mirror, i.e. right leg and right arm on the right, left arm and left leg on the left. For each sketch an OBJ file and 2D-Screenshot were saved and evaluated afterwards (total height, arm width right and left, waist width, waist height; the narrowest point between hip and torso was chosen as the waist). At the end of the test, the participants filled out the NASA TLX questionnaire, followed by a questionnaire in which they were asked about their positive and nega-

tive impressions as well as suggestions for improvement of the interaction technique.
After the test the above mentioned sizes of each participant were measured with a tape measure. Since "Self-sketch" works with a two-dimensional projection, the width and height but not the circumference was determined. At the end the participants were offered to get the background of the project ViTraS explained.

4.2 Results

The results of the three runs are given in Table 1 and Figure 2. Here the real body measurements were put in relation to the drawn body measurements: ratio = drawn measurement / real measurement. The sign indicates whether the drawn dimensions were smaller (-) or larger (+) than the real ones.

	cycle number						changes from cycle 1 to 3	
	1		2		3			
	Cm	percent	cm	percent	cm	percent	cm	percent
Total height	-18.6	-10.39	-17.02	-9.58	-14.92	-8.37	-3.68	+2.02
Arm length right	-7.85	-10.59	-3.85	-5.34	-5.49	-7.53	-2.36	+3.07
Arm length left	-8.14	-9.6	-4.48	-5.23	-4.27	-4.96	-3.87	+4.65
Waist width	+2.19	+6.60	+0.54	+3.88	+1.16	+6.8	+1.03	-0.20
Waist height	-15.06	-14.43	-19.43	-18.62	-25.26	-24.19	+10.20	-9.76

Table 1: Mean values of the deviations from the real body dimension in cm and percent per cycle and changes from the first to the last cycle in cm and percent

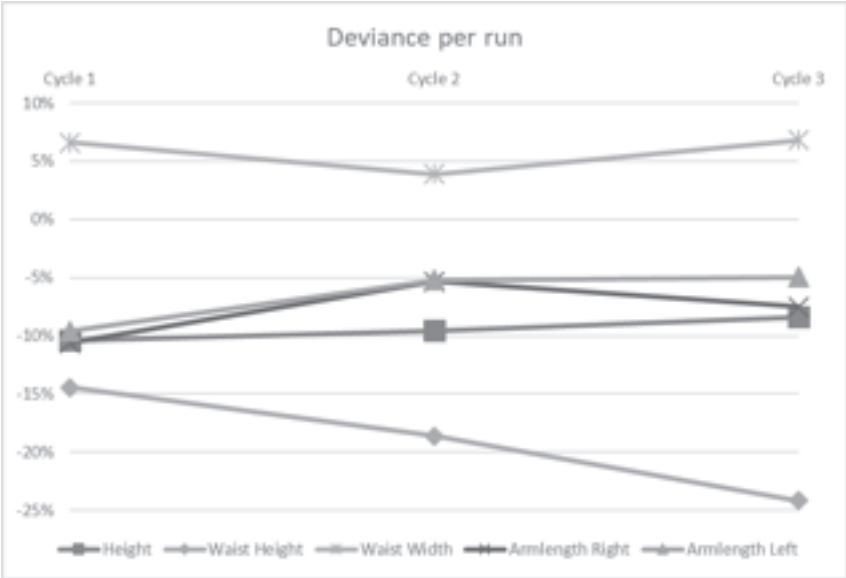

Fig. 2: Average deviance in percent from the sketched silhouette to the actual person per run

The workload was determined using the NASA TLX questionnaire. The original NASA TLX contains 6 scales (Mental, Physical, Temporal Demands, Frustration, Effort and Performance), ranging from 0 (low demand) to 100 (high demand). We added an additional column "Eye Fatigue" to include the eye strain in an immersive application. All scales were added to give an unweighted average value between 0 (low workload) and 100 (high workload). Results of the NASA TLX questionnaire are given in Table 2. The average workload across all participants is M = 35.89 with an SD = 8.47.

Work-load	Mental	Physical	Temporal	Frustra-tion	Effort	Perfor-mance	Eye Fatigue
M	51.25	43.75	8.75	32.5	36.25	56.25	22.5
SD	23.82	21.32	2.17	29.68	16.35	27.47	17.5

Table 2: Mean values and standard deviation of NASA TLX questionnaire

Of all participants, 100% stated that they would sketch with pen and paper, 25% of them several times a week, 50% at least once a week and 25% about 2–3 times a month. Participants sketch on the computer to a much lesser extent from about 2–3 times a month (25%) to once a month (50%) or not at all (25%). Only 50% of the participants had little experience with virtual environments, the other 50% had no experience at all. Participants positively emphasized the quick learnability of the interaction technique and the direct feedback on the interaction. They criticized an imprecise control and jerky movements of the virtual hand, which indicates an occlusion in the tracking system environment. Above all, a function to correct the sketch, such as deleting drawn elements, was desired.

4.3 Discussion

Overall, the results show that the deviations of the drawn body measurements from the real body measurements are only small. The results suggest that a positive learning effect (i.e. an approximation of the drawn to the real body proportions) for the height of the body (improvement 2.02%) and the length of the arms (right: 3.07%, left: 4.65%) has been achieved over the three runs. A small decrease in accuracy is observed for the waist width (-0.2%) and a large decrease for the waist height (-9.76%). A drop in accuracy between the upper and lower half of the body is noticeable. The reason for this may be that the arms are used very actively when drawing and the upper body is in the field of vision of the participants more often than the lower body. Another reason could be that during the interaction the participants saw a virtual hand model that represented the position of their own hand. This might have helped the participants to estimate the actual length of their arms and to draw them accordingly. In the experiment it was also observed that some of the test persons stepped into the drawing and tried to estimate their own arm length using the visible virtual hand as a fixed point. In contrast, there was little or no interaction with the lower half of the body, as the users remained at the initial position. Although the participants bent down to draw the lower half of the body, they did not interact with it. However, this probably had more of an effect on the awareness of their own body height rather than the height of the waist.

The results of the NASA TLX suggest that the interaction technique does not present a major physical or mental hurdle for the users. However,

some participants in the third cycle complained that they found drawing, especially the lower half of the body, strenuous.

5 Conclusion

In this paper, the interaction technique Self-sketch was presented, which should enable users to externalize the mental representation of their body schema by means of freehand sketching. For this purpose, functions were implemented that allow users to sketch their silhouette on a virtual canvas. The results of the evaluation suggest that users are able to create a relatively accurate image of their body silhouette to a certain extent. Over three runs, especially the upper part of the body showed an improvement in accuracy. In the lower part of the body, however, the accuracy decreased. The latter is possibly an indication that the work in a crouched position was perceived as too strenuous and was avoided or carried out as briefly as possible in the course of the experiment. A possible conclusion from this is to develop special interaction techniques in order to draw the lower body area in particular more easily. A virtual platform is conceivable here, for example, which can lift the drawing surface to a comfortable drawing position at the push of a button.
The findings of this informal study are important in order to be able to assess whether this interaction technique could actually be of assistance to patients with a disturbance of the body schema. Based on the results, this assumption can be cautiously affirmed.

6 Outlook

Beside Self-sketch, it is planned to develop another interaction technique called Self-touch. The aim of the development of the interaction technique "Self-touch" is to enable patients with body schema disorders to gradually develop a correct mental image of their own body. Similar to the step-by-step production of a product image in design ("reflection in action", [Schö83]), the user should have the possibility here to iteratively compare his mental body schema with the real one. The idea behind Self-touch is that a more precise mental representation of one's own body is built up

through self-touch and the haptic and proprioceptive feedback associated with it, which may overwrite distorted images stronger than purely visual representations (see sensory fusion [ErBa02])

Using special VR controllers (e.g. VALVE Index), the pressure created by the hands when touching one's own body can be measured. In combination with a tracking system, the position of the hand can also be determined to locate the position of the touch. With the two parameters, position and pressure, a surface can be created at the corresponding location. By repeating the procedure at different parts of the body, a hull can be created which corresponds to the body proportions of the user.

In the future, personalized avatars will be used, which resemble and are controlled by the user. One idea is to make the avatar invisible to the user and to make the corresponding body part appear when touched by the user.

Acknowledgement

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Literature

[AKAG17] Arora, R., Kazi, R. H., Anderson, F., Grossman, T., Singh, K., & Fitzmaurice, G. (2017). Experimental Evaluation of Sketching on Surfaces in VR. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems – CHI '17, pp. 5643–5654. https://doi.org/10.1145/3025453.3025474

[ErBa02] Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. Nature, 415, pp. 429–433.

[Goog16] Google. (2016). Tilt Brush. https://www.tiltbrush.com/

[Grav18] Gravity-Sketch. (2018). A Powerful Design Tool. https://www.gravitysketch.com/vr/

[IWMS09] Israel, J. H., Wiese, E., Mateescu, M. & Stark, R. (2009). Investigating three-dimensional sketching for early conceptual design – Results from expert discussions and user studies. Computers & Graphics, 33(4), pp. 462–473.

[KAML01] Keefe, D. F., Acevedo Feliz, D., Moscovich, T., Laidlaw, D. H. & LaViola, J. (2001). CavePainting: A Fully Immersive 3D Artistic Medium and Interactive Experience. ACM Symposium on Interactive 3D Graphics (SI3D'01), pp. 85–93.

[MASL18] Machuca, M. D. B., Asente, P., Stuerzlinger, W., Lu, J. & Kim, B. (2018). Multiplanes: Assisted Freehand VR Sketching. Proceedings of the Symposium on Spatial User Interaction – SUI '18, 36–47. https://doi.org/10.1145/3267782.3267786

[ScPrS01] Schkolne, S, Pruett, M. & Schröder, P. (2001). Surface drawing: Creating organic 3D shapes with the hand and tangible tools. SIGCHI Conference on Human Factors in Computing Systems (CHI'01), pp. 261–268.

[Schk06] Schkolne, Steven. (2006). Making Digital Shapes by Hand. Interactive Shape Editing, ACM SIGGRAPH Courses 2006, pp. 84–93.

[Schö83] Schön, D. A. (1983). The Reflective Practitioner. How professionals think in action. Basic Books.

[WVWB18] Wacker, P., Voelker, S., Wagner, A. & Borchers, J. (2018). Physical Guides: An Analysis of 3D Sketching Performance on Physical Objects in Augmented Reality. Proceedings of the Symposium on Spatial User Interaction – SUI '18, pp. 25–35. https://doi.org/10.1145/3267782.3267788

[RGSD18] Riva, G., Gaudio, S., Serino, S., Dakanalis, A., Ferrer-García, M. & Gutiérrez-Maldonado, J. (2018). Virtual Reality for the Treatment of Body Image Disturbances in Eating and Weight Disorders: A Guide to Assessment, Treatment, and Prevention. Body Image, Eating, and Weight, pp. 333–351

From Physical to Virtual Memory

Digital Survey for the Creation of an Informative "Double" of Florence Heritage

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Abstract

The aim of the research is to investigate the relationship between digital survey and remote sensing methodologies and the development of 3D models and tools for the dissemination of Cultural Heritage. The use of information and digital data as contents of web platforms and AR and VR applications, permit to develop useful instruments for the transfer of knowledge as well as its critical/analytical use for scientific purposes. Furthermore, the conclusions want to highlight the use of these technologies aim at educational scope, in order to evaluate the communicative experience that they can offer of tangible or intangible cultural spaces and contents, which are difficult to access or that no longer exist.

1 Intro[1]

In recent years, analytical protocols and methodologies for the collection of relevant data about Cultural Heritage, together with the related modeling and visualization processes, have attended a fast development. This evolution increases the interdisciplinary applications, thanks also to a significant increase in specific research in the related sectors, such as remote sensing, geomatics, parametric or procedural modeling, gaming or those connected to Information and Communication Technologies (ICT). New digital technologies, Augmented, Extended, Mixed and Virtual reality [Beke18], allow the development of oriented and specific narrative systems regarding the use and representation of Cultural Heritage (CH). The remote access to information and data promote the safeguarding of CH by spreading knowledge, in order to develop a sustainable, inclusive and flexible memory conservation strategy [Mald05]. Nowadays, this technology can help to pass on information in a more inclusive way and to a wider public, overcoming the barriers of communication and culture. The transfer of reality into a surrogate environment, enriched by the information made available by the new technologies of extend reality and digital investigation, allows to achieve a holistic understanding of space through a system of direct, indirect or mediated use [Riva07].
The paper aims at presenting the results of different case studies in Florence UNESCO city centre, which show different scale of intervention, from the urban scale to the cultural object. The experiences want to analyze the importance and limitations of the use of digital survey and remote sensing for the creation of contents for the development of virtual experiences. The most popular technologies for the acquisition of three-dimensional data today are based on images (for example Structure from Motion SfM or Photogrammetry) or spatial data structured as point clouds acquired by active sensors (for example 3D scanner). The application of the different approaches it depends on the purposes of the survey [DoCh17]. These methodologies allow creating a virtual “double” of the object under investigation at a high level of reliability. The problem that arises is to assess the level of reliability between reality and its virtual “double”, often too

1 The paragraphs 1 and 4 were written by Stefano Bertocci; the paragraphs 2, 3.1 and 3.2 were written by Federico Ferrari; the paragraphs 3.3 was written by Federico Cioli; the paragraphs 3.4 was written by Eugenia Bordini.

rich in unnecessary details for the purposes of virtualization for educational and enhancement. The difficulty of documenting complex systems is the management of large amounts of data necessary for their description. These data, acquired and processed following different methodological approaches, constitute databases rich in useful information, which however run the risk of not establishing a reciprocal dialogue with the real object.

The Florence case study highlights the problems linked to the growing tourism industry in the historic centers and the possibilities introduced by E-Tourism for the promotion of a more sustainable and cultural tourism. The digitalization of cultural heritage and the development of platforms for the organization and dissemination of information related to historical, architectural and demo-ethno-anthropological aspects allow to involve a widest audience and to provide the users with new methods of fruition with a strong communicative impact [BeCB18].

2 Methodology for 3D acquisition and modeling

2.1 Main scope

All the Demonstration Cases are developed in order to meet and test the overall procedure set by the research: from the documentation up to use and re-use of 3D models for the valorisation conservation of Cultural Heritage (CH) by innovative tools. CH workflows can be performed for tasks such as preservation, site management, connect tangible and intangible information, etc.

Starting from these workflows, it is possible to define the required user tools and technical solutions. The main workflow set is related to the understanding of the evolution of the building for historical research, as a support for restoration or dissemination.

The workflow allows the definition and implementation of what a user can do to retrieve, provide, link, analyze, validate, interpret and use data.

2.2 Data acquisition process

The data acquisition of the demonstration cases has been performed by applying a specific Data Acquisition Protocol [DMPM17]. Using a 3D

morphometric survey, it was possible to identify the complexity of the volumetric composition of the object using different technologies such as:

- the 3D laser scanner in order to obtain a 3D database;
- the topographic survey for geo-referencing of the database;
- aerial imagery for the 3D survey and the texture mapping of the roofs;
- structure from Motion SfM or Photogrammetry survey for detail and texture;
- HDR-RGB photographic survey aimed at the implementation of a comprehensive knowledge of surfaces state of conservation and for texturing;
- 360° HDR-RGB photographic for documentation and virtual tours; historical and archival research, for reconstruction phases, for example.

The overall documentation aimed at the creations of a 3D models that could allow multimedia visualizations and VR/AR applications to enhance and to create innovative ways to explore the artistic and architectonic heritage and new forms of accessibility.

Since the project started, the main aim was the achievement of a three-dimensional metric database aimed at understanding spaces as a function of accessibility and for future conservation and restoration work.

2.3 3D or BIM modelling for User-Oriented Application

Three-dimensional data captured in the form of point cloud and the massive variety of significances that are represented by a building, needed to be aggregated into a 3D or BIM environment [Hich13]. The three-dimensional modeling used for communication and enhancement purposes therefore comes from a high density and precision database discretized/reorganized/restructured on different LODs (Level of Detail/ Development) [often working independently on LOG (Level of Geometry) or LOI (Level of Information)] according to the different applications developed. We identified in the so-called “final scope”, in this case VR and AR apps addressed to cultural tourism, the element that leads the data modeling aggregation and the interconnections between geometries and information. In order to give an example, a VR application needs for a more accurate geometrical detail rather than an AR application, where

probably we'll not see only the historical enrichment popping up from the reality.
When we have a point cloud of a building as in our cases, we usually have a bunch of data still uninterpreted and unsegmented. Thus, the 3D models was created out of the point cloud, trying to strike the right balance between minimizing deviation of the object (from the point cloud), segmenting the point cloud into single objects, defining the right level of geometric detail needed for each final application [Mett16]. The level of geometrical detail, that describes objects with a certain degree of geometrical accuracy, is dependent on the final scope due to the final appearance that a 3D models need to have (i.e.: VR application) or rather the coherency of the quantity take-off (i.e.: maintenance). While the level of object granularity is still dependent on the final scope but with a more strictly link with the knowledge that we want to attach at it.
In this specific case, we preferred to ignore parametric capabilities of BIM but foster on the informative part.

3 Florence Case Study

3.1 Intro

The Florence case study highlights the problems linked to the growing tourism industry in the historic centers and the possibilities introduced by E-Tourism for the promotion of a more sustainable and cultural tourism. The digitalization of cultural heritage and the development of platforms for the organization and dissemination of information related to historical, architectural and demo-ethno-anthropological aspects allow to involve a widest audience and to provide the users with new methods of fruition with a strong communicative impact [MoRi06].
The illustrated case studies range from the scale of the city as container of several other containers, represented by the built heritage, to the more detailed scale of the artifacts, deeply connected with the intangible aspect of traditions, and the educational aspect of museum collections.

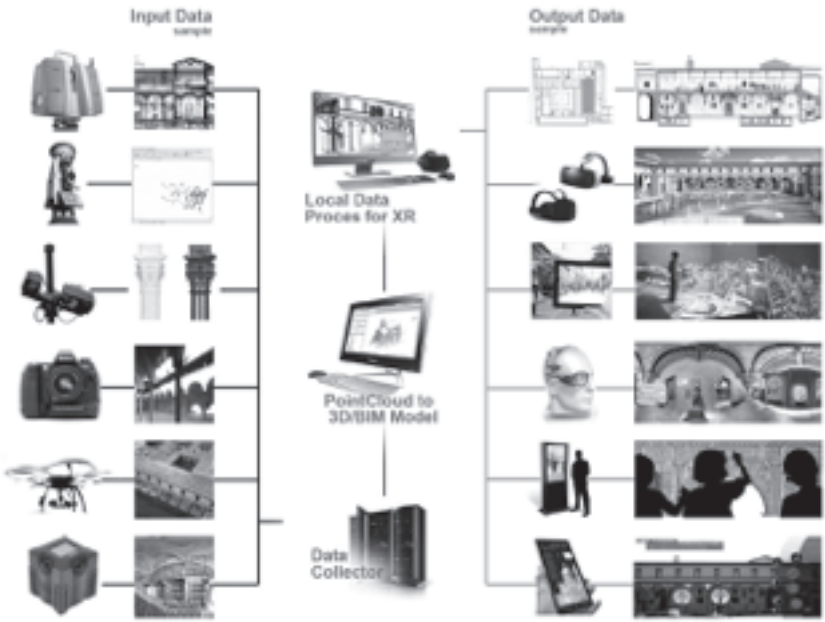

Fig.1: Ospedale degli Innocenti.
Methodological scheme. From survey to Extended Reality for conservation to restoration

3.2 The Ospedale degli Innocenti

The Ospedale degli Innocenti (Hospital of the Innocents) was built in several phases and the first phase (1419–1427) was under Brunelleschi's design and direct supervision. It is one of the main relevant example of early Italian Renaissance architecture [Mula16]. The hospital, originally a children's orphanage, which features a nine-bay loggia facing the Piazza SS. Annuziata. The building reveals a clean and clear sense of proportion. The height of the columns is the same as the width of the intercolumniation and the width of the arcade, making each bay a cube. The building's simple proportions reflect a new age, one of secular education, and a sense of great order and clarity.

Today the building also houses a museum of Renaissance art with works by Luca della Robbia, Sandro Botticelli, Piero di Cosimo and Domenico Ghirlandaio, reopened in 2016, after restoration works, with expanded and renovated exhibition spaces, new services and activities available to visitors and citizens.

The 3D integrated survey was the basis for using for restoration and the new museum project.
The virtualization of Piazza SS. Annunziata, through historical reconstructions and the description of the current physical features, analyzes the perceptive aspect connected with the environment for the creation of more immersive models. The experimentation begins directly during the restoration and construction of the new museum inside the "Spedale degli Innocenti" complex. The multiscale three-dimensional surveys, the analyses, the historical and material insights, merged within a BIM-Based model (Building Information Modeling) linked to the needs of the restoration project, have become the stimulus to create a story about the factory, its evolution and its content. The aim of the project range from the BIM-Based model for project and construction site management to Augmented or Virtual reality models for Onsite and Offsite use, to hybridization with 360° images or raster video.
The implementation of the overall documentation and data aggregation for the 3D modelling semantic approach, allowed data association among survey data, modelled geometries (parametric modelling), raster data and information enrichment focused on the main purposes (building evolution, historical analysis, new form of accessibility to the Museum). The "Time Machine" functionality is directly provided by the BIM/IFC model. The information included comprehend the date of construction of the single object (components or building parts) so it is possible to ask how the building was in a certain period. The model working on the "INCEPTION Time Machine[2]" exploits the advantages offered by the integration of the OWL-Time Ontology, providing the possibility of navigating nonlinearly over time and therefore in the history of a building.
The applications developed are intended to provide a deeper understanding of the building, its history and virtual accessibility of the building and its contents or of those that no longer exist.

- AR app for museum guided tour with particular reference to the picture gallery, testing mixed reality linked to main exhibited works;
- VR app for building tour from abroad, with the construction phases (time machine);

2 Research performed by the Department of Architecture of Ferrara within the project "INCEPTION – Inclusive Cultural Heritage in Europe through 3D semantic modelling", funded by the European Commission under the Horizon 2020 Programme, Research and Innovation Action under Grant Agreement No. 665220.

- AR app for building maintenance with particular reference to the hypogeum.

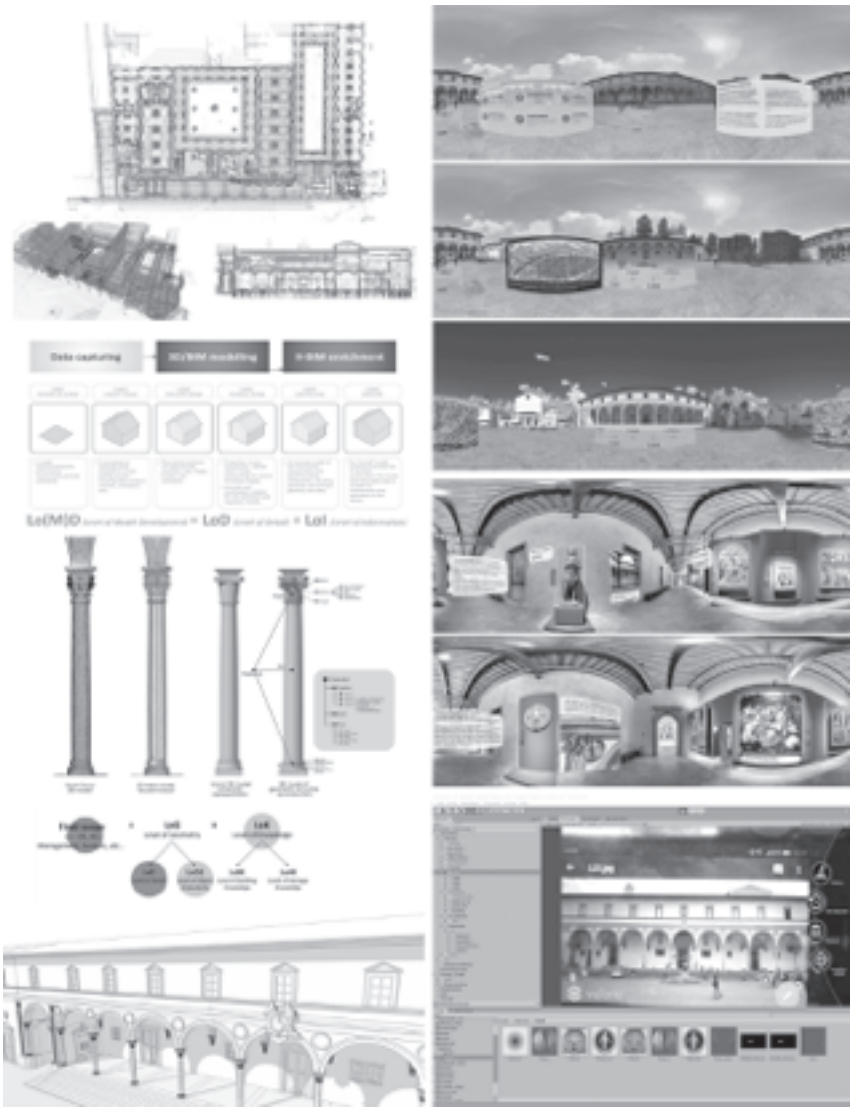

Fig.2: Ospedale degli Innocenti.
In the left column, the process from 3D survey for conservation and restoration to 3D/Bim modeling in relation to the different granularity levels. On the right different outputs, from the VR off-site for time machine, the VR Raster based for the Museum and the AR application for enhancement of the artworks on the facade.

3.3 Historical Shops

The documentation of the Intangible Heritage of the Historical Shops highlights the issue of the musealization of historical city centres under UNESCO protection. The documentation involves several methodologies of approach, starting from the data sheet census and photographic campaigns, to the digital survey conducted with laser-scanners and 360° panoramic images and videos, producing a great amount of heterogeneous data. In order to manage and develop a system for the use and dissemination of this data has been designed a virtual open-air museum system in the city accessible by mobile devices.

The longstanding presence of traditional local shops has been identifying cities and their urban "image" for a long time. The research focuses on the case study of artisanal and historical commercial activities in the center of Florence under UNESCO protection, investigating the issue of documenting Tangible and Intangible Cultural Heritage. Under the great pressures of the mass tourism era, the main streets are slowly turning into stereotyped scenes. The commercial activities and traditional crafts that were related to the social and cultural background of the city are disappearing, while the massive arrival of multinationals is transforming the historic center into a Renaissance-themed mall [Amen06]. The city preserves its tangible assets but it is losing the anthropic heritage that constitutes, with residents and artisans, a fundamental controller and catalyst of urban reality. The social dynamics and the relationships established between the seller and the client, between the artisan and the citizen are the same that define the neighborhood identity, which represents a microcosm of the city [ZuKC15]. To develop a plan of intervention and enhancement of historical commercial activities, the Department of Architecture DIDA of the University of Florence, in collaboration with the Municipality and the UNESCO office, carried out a research project to document the current situation. The first phase concerned the listing of all activities through a structured census system taking into account the architectural and historical-artistic features and the relationship of the businesses with the surrounding urban context; at the end of this evaluation, a new urban regulation was approved. The field research has directly involved shopkeepers and artisans, who pass down traditions and skills to date. The census has been matched by a photographic campaign aimed at representing the identity of these activities and by the realization of 3D

digital surveys. The great amount of data acquired during documentation and digital survey campaigns constitute a rich updatable and upgradable database, which run the risk to remain unused. The issue of digital data and its preservation is also connected with the constant changing of file extensions, which quickly become obsolete. The necessity to integrate the physical archive with new digital data is a fundamental aim for cultural institutions. To implement a promotional campaign for historical activities that involves the application of these digital tools, data accessibility is an issue of primary importance. It is necessary to collect and digitalize a large amount of heterogeneous data, acquired during the documentation activities, in a single digital database. Commencing from a "static" database, the creation of a web platform as storage of interconnected data (multimedia, text, etc.) is useful to provide complete and understandable documentation to the user. The present research proposes to structure an interactive virtual experience for the promotion of cultural tourism of the historical activities and artisanship, which includes the development of an online platform and the integration of the new Virtual Tourism technologies. The strategy consists of providing an interactive and user-friendly interface, combining traditional and innovative techniques, which connects the datasheet census system with the archive data to develop an open-air museum of the city.

One of the aims of the research is to experiment the use of point-clouds deriving from 3D laser-scanner and SfM-IM surveys for the development and creation of virtual environments, reducing the time for modeling and texturing procedures. The high defined and reliable point cloud produced during the digital laser-scanner 3D survey campaigns on the historical shops, appropriately optimized, and has been used as a support to experiment the use of the three-dimensional model in a virtual environment, using the plug-in Lidar Point Cloud of the software Unreal Engine (Epic Games).

The documentation of the heritage rather than through static databases should be operated through dynamic information systems that allow authorized third parties to implement them by adding information, thus obtaining a degree of democracy and scientificity never achieved in the documentation of oral and intangible cultural practices [Bort08].

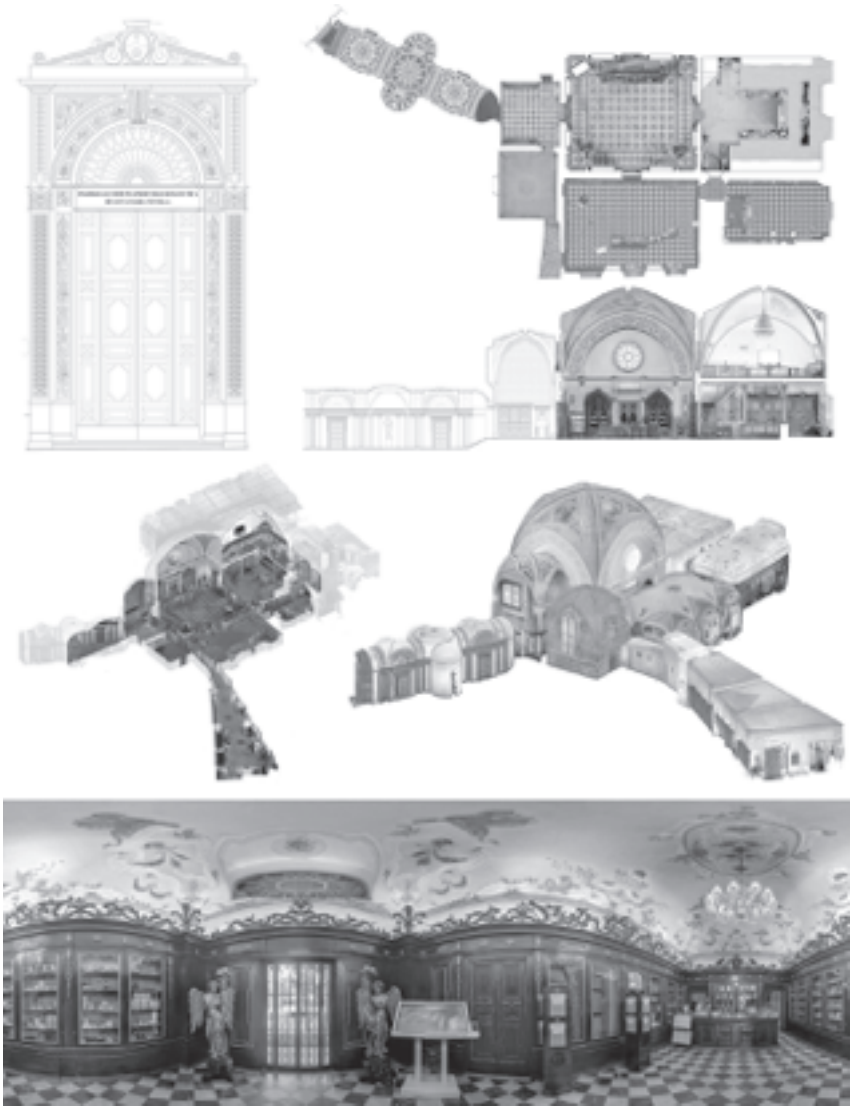

Fig.3: Officina Profumo-Farmaceutica di Santa Maria Novella
Top: examples of the detailed digital drawings produced using the descriptive point-cloud; centre: the optimized point cloud 3D model obtained by the laser-scanner campaign conducted with a Z+F 5016; down: an example of the photo-sphere acquired by the integrated camera of the laser-scanner in order to color the point-cloud.

3.4 Scientific Museums of the University

The digitalisation project on the Scientific Museums of the University of Florence deals with the survey and analysis of some collections objects to create a single system of virtual fruition of university museums artworks. The different museums' sites spread throughout the municipal area collect a large number of objects of great scientific and educational interest, creating a network of culture extended on 14 locations. The project focused on the case study of the collection of the Museum of Pathological Anatomy of Careggi, with the purpose to create 3D models usable for a wide range of applications: 3D digital database, educational apps, AR/VR systems.

The Museum hosts a collection of pathological waxes dating back to the 19th century, some of which were made by the artists of the renowned Wax Model Workshop established in 1771 in Florence. The waxes, highly realistic reproductions of anatomical parts affected by particular pathologies, were used in the past by doctors and scholars as scientific and educational tools to spread the medical knowledge throughout the community [NeST07]. Therefore, the Museum represents a real three-dimensional pathological compendium, but today it is unfortunately closed to the public and accessible only through guided tours.

The documentation process involved a 3D laser scanner survey, the acquisition of 360° panoramas and a Structure from Motion (SfM) survey of some collection objects selected among the waxes hosted in the Museum. The photogrammetric SfM survey produced high-poly 3d models, textured through the application of the photographic data, and then scaled to their original dimension thanks to the reliable metrical support of the laser scanner survey. Because of the high polygons count, it was necessary to optimize and post-produce them through specific processes to reduce the file size and make the data manageable and viewable through different applications. Then, each 3D model was implemented with various types of data (historical/medical information, photos, videos, etc.), thus becoming a vehicle of knowledge available to the user/visitor. The challenge of valorising scientific collections is the need to combine historical memory and scientific knowledge with innovative methodologies that allow to re-contextualise the objects, making visible and communicating their history and their original sense to the visitors. While in an art exhibition the object can be left alone, thus acquiring more importance and expres-

siveness, scientific and technological objects need elements that explain and communicate them to the public [MeRo07].
The different types of data obtained from the digital survey campaign were the basis for the creation of a 3D digital database and educational and valorisation systems: from a web platform, useful both as management and conservation tool, to implementation systems for the museum sites through Virtual and Augmented Reality apps.
Starting from the case study of the Museum of Pathological Anatomy, the final aim of the project is defining a broader strategy for the enhancement and promotion of the entire University Museum System. The purpose is to creating a common fruition platform, not only to provide services to students and researcher but also to create systems to support staff, citizens and visitors, making these structures usable and available to the community.

Fig. 4: The Museum of Pathological Anatomy of Careggi
Top: schematic phases proposed for the development of the project; centre: the 3D point cloud obtained by the laser-scanner survey and an example of 3d model created by SfM scquisition; down: graphic representation of a possible implementation of the museum's exhibition through AR/VR apps.

4 Conclusion

Thanks to Virtual Reality, it's possible to rebuild past worlds, monuments and ancient cities: because of the possibility of comparing different historical periods and their physical transformation, architecture and archaeology needs to deeply explore this technology to enhance the understanding of cultural heritage.

Experiments on the creation of an immersive virtual reality (VR) have already been tested. The raster data produced can be used both for immersive reality and for 3D point cloud model and 3D model texturing. The captured raster data will be also used to test the construction of 3D point cloud models through PhotoBased software.

Moreover, AR can be used to aid archaeological and architectural research, by augmenting features onto the modern landscape, enabling researcher to formulate conclusions about site placement and configuration or to more general users to understand what they are looking at. Computer-generated models can be superimposed into a real life to rebuild ruins, buildings, landscapes or even ancient characters as they formerly existed. This technology can be useful only on the field because it needs real-world environment or objects to be augmented. The recent Declaration "Cooperation on advancing digitization of cultural heritage" signed by Member States during the Digital Day 2019, confirmed the commitment by the European Council, the European Parliament and the European Commission in fostering digital technologies to record, document and preserve Europe's cultural heritage and their accessibility to European citizens.

Moreover, the Declaration states "The Union needs to collaborate to advance 3D digitisation of our cultural heritage. European research institutes and start-ups have developed world-leading expertise and are pioneering technologies in these fields and can contribute to advancing the digital transformation of the cultural heritage institutions. The Union also needs to ensure that its digitised cultural content and related applications are available, where appropriate, on European platforms, in line with our values".

The research developments, outcomes and future follow-ups on the Florence Cases will move in the direction stated by this declaration. Future researches will include data recording and digitization in order to meet the need of documentation and preservation due to the increasing threats

to cultural heritage due to natural disasters, pollution, mass tourism, deterioration over time, terrorism and vandalism, increasing at the same time the accessibility off-line heritage sites at risk [FeMe17]. High quality 3D models, interoperable formats and open access to digital cultural heritage assets are essential to an effective use of digital contents, increasing digital engagement and fostering sectors such as tourism, education, creative industries.

Big data, artificial intelligence, natural language processing, augmented-virtual-mixed reality and 5G to enable innovative use of digitized cultural resources, knowledge extraction and more engaging experience of heritage content are future research avenues that can benefit from what has already been developed.

Literature

[Amen06] Amendola, G. (Ed.): La città vetrina. I luoghi del commercio e le nuove forme del consumo. Liguori Editore, Napoli 2006.

[Beke18] Bekele M.K.; et al.: A survey of augmented, virtual, and mixed reality for cultural heritage. Journal on Computing and Cultural Heritage (JOCCH), 11.2: 7, 2018.

[BeCB18] Bertocci S.; Cioli F.; Bordini E.: Virtual models for the valorisation and promotion of the business heritage in the historic centre of Florence. In DISEGNARECON, 11.21, 2018, pp. 2.1–2.19.

[Bort08] Bortolotto, C.: Il patrimonio immateriale secondo l'Unesco. Analisi e prospettive. Istituto Poligrafico e Zecca dello Stato, Roma 2008.

[DMPM17] Di Giulio, R.; Maietti, F.; Piaia, E.; Medici, M.; Ferrari, F.; Turillazzi, B.: Integrated data capturing requirements for 3D semantic modelling of cultural heritage: the INCEPTION protocol, 2017.

[DoCh17] Docci M.; Chiavoni E.: Saper leggere l'architettura. Gius. Laterza & Figli Spa, Roma 2017.

[FeMe17] Ferrari, F.; Medici, M.: "The virtual experience for cultural heritage: methods and tools comparison for Geguti Palace in Kutaisi, Georgia." Multidisciplinary Digital Publishing Institute Proceedings. Vol. 1. No. 9. 2017.

[Hich13] Hichri, N.; et al.: "From point cloud to BIM: a survey of existing approaches". 2013.

[Mald05] Maldonado T.: “Reale e virtuale”, Feltrinelli Editore, Milano 2005.

[MeRo07] Merzagora, M.; Rodari, P.: La scienza in mostra. Musei, science centre e comunicazione. Bruno Mondadori, Milano 2007.

[Mett16] Mettenleiter, M.; et al.: Laser Scanning. Phase-based laser measurement technology for rapid, high-precision 3D surveying. Süddeutscher Verlag onpact, Munich 2016.

[MoRi06] Morganti, F.; Riva G.: Conoscenza, comunicazione e tecnologia: aspetti cognitivi della realtà virtuale. LED Edizioni Universitarie, Milano 2006.

[Mula16] Mulazzani, M.: L’Ospedale degli Innocenti di Firenze. La fabbrica brunelleschiana. Gli Innocenti dal quattrocento al Novecento. Il nuovo museo. Il progetto di recupero e l’allestimento di Ipostudio. Mondadori Electa, 2016.

[NeST07] Nesi, G.; Santi, R.; Taddei G.L.: Historical outline of the Museum of Pathological Anatomy in Florence. In: Medicina nei secoli, 19 (1), 2007, pp. 295–303.

[Riva07] Riva G.; et al.: Affective interactions using virtual reality: the link between presence and emotions. In CyberPsychology & Behavior, 10.1, 2007, pp. 45–56.

[ZuKC15] Zukin, S.; Kasinitz, B.; Chen, X.: Global Cities, Local Streets: Everyday Diversity from New York to Shanghai. Routledge, New York 2015.

Old | Future Music – New | Past Tricks:

Designing Opera for the Immersive Aesthetics of Zukunftsmusik

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Abstract

"Zukunftsmusik" (transl. music of the future) marks a series of doctrines of the 19th century that aimed to renew the aesthetics, as well as the entire concept of classical music. Along the same lines, musicians of the present-day rely on related aesthetic desiderata and enrich them with advanced creative technologies that aim to expand audience experience from passive sensation towards active involvement. This brings along questions related to the aesthetics of the technological artefact and the actual essence, identity, creation (i.e. composer), performance (i.e. tape), and rendering (i.e. multichannel speaker system) of contemporary music. In light of these considerations, the paper presents two case studies that also mark the first ever VR experiences of an entire opera, "She" (2017) and "Croak" (2018). By examining these case studies on the dimensionality of diegetic perspective, we highlight essential commonalities with the Zukunftsmusik doctrines and their potential for future audiences: The Users.

1 Introduction

The availability of advanced technologies plays an increasingly important role in music composition, performance and its associated aesthetics and techniques of present-day classical music culture. The majority of these technologies fall between the subdisciplines of algorithmic composition, machine learning, virtual reality (VR), augmented reality (AR), gamification, interactive music systems, extended instruments, and various combinations of mixed-media content. However, their usage has not been limited to present-day contemporaries. Composers throughout history have been eager to imagine, predict, and mould the future of their artform. The term "Zukunftsmusik" (transl. music of the future) refers to this very notion due to its attribution to the novelty of works by composers such as Chopin, Liszt, Berlioz, as well as its most widely known proponent, Richard Wagner, who cemented its footing in his essay of the same name. Although previously used by certain parties with a negative connotation (for example, by the music critic L.A. Zellner in reference to Wagner´s music), the followers of Wagner soon owned the terminology, starting to refer to themselves as "Zukunftsmusiker", with an objective of re-defining the music of their time, as well as the way it should evolve. Most notably, the doctrines of Zukunftsmusik foreshadow the aesthetic ideas of perspective that would only be considered decades later when Luigi Russolo published his futurist manifesto "The Art of Noise" (1913), the purpose of which was to change the way we think about music, and what we regard as music in the first place. The same curiosity and attraction towards the idea of future music still widely prevails among composers of the 21st century. The multitude of the aforementioned technological options also brings along new questions related to the aesthetics of the technological artefact per se as well as the actual essence, and identity of musical compositions, the circumstances of its creation (i.e. composer), performance (i.e. tape), and its rendering (i.e. multichannel speaker system). To which direction is contemporary music heading at the moment, is there a common denominator to be considered as its aesthetic, and how is future music going to sound (or look) like?

To examine these questions, this paper provides a short outlook towards what Zukunftsmusik means for today's composers, performers, and audiences, as well as what challenges and potentials it may hold in the

future. Within this context, the paper will limit its focus to VR implementations of one of music histories most renown genres, the opera. Our case studies describe the first ever interactive VR experiences of an entire opera, with "She" (2017) utilizing a traditional stationary, 3-dimensional framework and "Croak" (2018) taking advantage of a novel concept for interactive opera experience in six degrees of freedom (6DoF). These realizations significantly expand the aesthetic ambition of traditional music performances and enable audiences to take on the roles as experiential co-creators by interacting with volumetric, 360-degree video and 3rd-order Ambisonics spatial audio from multiple perspectives within a bespoke software interface. Notably, we review the touching points between the interpretation of (deictic) perspective in Zukunftsmusik and its consideration in the presented case studies within the framework of situational context [see Gass15].

2 The Production of She (2017) and CroakVR (2018)

The operas "She" (2017) and "Croak" (2018) were composed by Maria Kallionpää (the latter work in collaboration with Markku Klami) and their VR recordings realized by Hans-Peter Gasselseder. "She" and "Croak" represent the first full-length recordings of an opera in an immersive format that supports 3-dimensional 360-degree video and audio for playback and control in virtual reality (i.e. head movements as well as six degrees). The works strongly differed in terms of musical language and staging, which necessitated individual recording techniques to honor their respective deictic perspectives. Whereas the staging of "She" suggested a two-dimensional, fairytale-like environment, "Croak" was set to account for multiple projections of the same character. Despite these differences, both operas share a common paradigm in their recording philosophy, that is to offer the user a perspective otherwise unattainable to an audience member of the live show.

With regards to the video material, for "She", a two-dimensional 360-degree format was to account for the entirety of stage properties being simulated by projections on a translucent screen positioned anterior to the characters on stage. Due to the play directors' intentional use of a stage design that was to mimic a two-dimensional perspective in reference

to the mythological character of the narrative, it was decided to uphold this quality while extending its immersive potential by placing the main camera rig (Insta360 Pro in 2D at 8k resolution, [Inst17]) closer towards the characters on stage (approx. 2 meters to camera objects) as compared to standard setups in VR production (approx. 4–6 meters if shot close-up). This allows users to experience the characters from up close but also to zoom out of the equirectangular source (an option provided in the user interface of the bundled software) as to get a view of the overall 'canvas' that the stage design was intended to convey. For audio, the same rationale came to effect by placing a prototype 3rd-order Ambisonics microphone (Zylia ZM-1d; prototype kindly provided by the manufacturer Zylia [Zyli18]) in front of the orchestra at the ear level of the conductor. This acoustic perspective was chosen to underline the staging (i.e. everything placed in front of the user), but also to add the sense of place (i.e. offering a more holistic acoustic representation of the situational context with less direct and more reverberant sound reaching the microphone) by positioning the microphone further back from the camera rather than placing both at the same position (see [ScIr18]). When reflecting on the methodological insights gained while recording "She", for the visual domain, on the one hand, the added sense of 'being there' was achieved by moving closer and thus offering more detail on the character interactions. For audio, on the other hand, while not intuitive per se, the counterapproach seemed most effective by moving further away from the scene and subsequently adding a holistic sense of space and situational context to the experience (see [Gass15] for some theoretical considerations related to this finding).

In contrast, the production of "Croak" made little use of stage properties but rather had its characters explore the depth of the stage to large extend. Moreover, the nature of the main characters being represented by life-size puppets controlled by puppeteers would have made users prone to confuse character relationships if the same two-dimensional recording setup had been used as in "She". Thus, rather than positioning the recording gear close-up (visual)/far-off (audio), the recording rationale opted for a wide and more distant view of the stage that embraced depth by means of a three-dimensional video and a more surrounding audio experience. This allows users to differentiate the suggested layers of diegesis that are inherent in puppet theater where the representative characters ("puppets") are accompanied by puppeteers, and in the special case of opera, also by

individual singers. With puppets commonly positioned in the mid-front, singers at the side edge of the stage, and puppeteers further behind the former two, a three-dimensional video in 360-degrees enables users to differentiate these (hierarchical) diegetic layers. In order to capture the depth of the stage as well as an alternative perspective of the hall from the audience's view, the main camera rig (Insta360 Pro in 3D at 6k resolution [Inst17]) was placed approximately 6 meters at the edge between stage and orchestra pit. Furthermore, the primary rig was extended by a secondary 360-degree camera setup (2x Kodak SP360 4k [Koda15]) positioned between the first row of the audience seating area as well as above the conductor in the orchestra pit. For the final VR experience, this configuration enables a change of perspectives during playback when zooming out from the footage recorded on the primary camera and blending over to the material that was shot on the secondary camera rig. Due to the lack of available software allowing for the playback and control of different camera perspectives in VR, we developed a custom player accounting for the aforementioned requirements within the game development platform Unity 5. Opting for a 2.5D paradigm that involves the mapping of flat surfaces onto 3D-objects, the player software devises cube projections and dynamic displacement maps to place the camera footage within a 3D-environment. The footage obtained from either camera perspective can be assigned to individual hotspots. These come to effect upon reaching a threshold value of the zoom control parameter and allow for seamless transitions and blending of both camera perspectives. "CROAK VR" uses a mixture of photogrammetry of the static scene while blending in extra layers that exclusively contain the moving parts of the scene (i.e. puppets and puppeteers) from the perspectives of stage and audience hall. As only the primary camera position was recorded in stereoscopic 3D, the required depth information was projected from the primary onto the secondary camera rig by utilizing metric measurements taken on-site. However, the extrapolation of virtual perspectives may suffer of artefacts related to the lack of resolution and spatial synchronization between depth maps obtained from the different camera models and positions. Moreover, due to the nature of the flat capturing inherent to video, we are missing out on information that lies behind those objects facing the camera (i.e. accuracy of textures is two-dimensional but displaced within a three-dimensional volumetric simulation). Whereas this working method would

pose the risk of artefacts separating acting characters from the remainder of the scene, the specific staging situation of Croak allowed to make such sacrifices at the benefit of the overall experience. In this connection, it was found that in comparison to the unprocessed footage, the artefacts resulting from unsynchronized depth processing contributed to an appearance of puppet characters that was more abstract and divorced from reality, whereas the remaining acting parties (puppeteers, singers, orchestra/conductor, audience) were almost left untouched by the alterations. It is believed that this technique supports the user in distinguishing the different layers of the diegesis, which suggests three acting parties (puppet, puppeteer, singer) as an agent of a single character and thus has to tackle the issue of assigning agency of various expressions (appearance, action, singing) to a single originator. As for audio, the staging as well as setting of "Croak" implied moving closer with the Ambisonics microphone (Zylia ZM-1d prototype) towards the stage action. Therefore, the microphone was placed between the stage and the orchestra (rather than in front of the orchestra as in "She"). The rationale for a closer acoustic perspective goes in line with the previously outlined reasoning behind the camera setup. The recording intended to capture the singers more up-close as to enable users to locate the source of a voice and identify characters at a higher accuracy, thus facilitating diegetic orientation. As a result, the audio tracks of the VR presentation place users in the middle of the action, with the singers and choir positioned at the front and the orchestra at the back of a 360-degree sphere.

3 Discussion

Conversely to the findings on "She", the sense of spatial awareness within the audio recording of "Croak" was less invested into the room/environmental aspects of the concert situation rather than the dramaturgic nature of character relationships and its construction of absorption (see [Gass15]). In contrast, the video material served as a means of enhancing the sense of space and context, a function that in "She" was predominantly covered by the audio recording. Following this, the varying conditions of two opera productions led to two quite different recording approaches of immersive content for VR, a format that in other genres holds the common notion

of standardized camera and microphone configurations. However, these two examples demonstrate the need to consider the individual requirements of the specific content as well as its associated genre. Whereas an opera recording in a legacy format (i.e. two-dimensional 16:9 aspect ratio) leaves it to the film director to edit camera cuts and foci of the action, VR hands over such responsibility to the user. It is thus even more important to suggest the user with specific contextual functions respective to the visual and acoustic domain of the presentation to establish guiding markers of the diegesis between the meta-virtual (i.e. the depiction of the stage performance) and its (infra-) virtual realm informed by the nature of the physical environment (i.e. the concert hall). If made aware of these roles on an implicit level during initial contact with the content (i.e. the overture of "Croak"), users were more likely to recognize the meaning structures as well as the extend of possible actions on different layers of abstraction (i.e. what's to be depicted on stage versus what physical setting it is being staged in). Giving users of VR an initial understanding of the relevance and modal representation of each of these realms builds an authentic representation of a truly immersive experience that is more than a documentation of its original performance. By making use of volumetric simulations, "CROAK VR" allow its users to roam around the characters and experience different close-up perspectives of the staging. More importantly, 6DoF and volumetric simulations enable users to explore what lies in-between these camera positions and disclose a more immersive experience than what was originally bargained for with traditional stereoscopic recording equipment.

4 Conclusion

We argue that a commonality of the Zukunftsmusik doctrines refers to the connotative co-creation or simulation of alternate or suggested realities, as often attributed towards a traditional music listening paradigm. Whereas listening alone may be inherently atomistic due to its reliance on a single domain, Zukunftsmusik intends to encompass a holistic experience incorporating the active participation of all senses with its corresponding action (cf. Wagner, 1850). Robert Schumann reiterates this by comparing the aesthetics of one artform to another in presence of differing

materials (1854/1965, p. 21). Following a more apt definition of aesthetics (study of senses rather than beauty), this desideratum may be reframed as a translation between senses and their dominant artforms at the point of contact between the diegetic, mentalizing of the bodily (i.e. bottom-up) and the non-diegetic, embodiment of the mental (i.e. top-down) (cf. Grillparzer in [Hans02]). Schumann has laid out a further desideratum pertaining to the consensus, interaction and blending between creation and performance when he calls upon the utopia of a music culture that will find a "[…] great fuge, to which various peoples will alternate in their singing" [Schu65]. Classical music recordings have traditionally focused on conveying two-dimensional representations of concert performances that remain the same every time one watches them. Virtual reality breaks up this linear paradigm by handing over control over the hierarchies of diegesis to the user. Users can customize from which angles to watch, which character to pay attention to and listen to the musical drama, this way enabling them to engage more deeply into the artistic content. Similarly, the mode of recording does not dictate or limit a productions' artistic or technical decisions. Typically, one may aim for mitigating artefacts arising from 6DoF post-conversion for perceptual realism. The paradigm of deictic perception, however, can account for a higher tolerance of artefacts if the respective reference frame of the experience is to suggest a hybrid format that embraces both the stage presence as well as the artificial nature of a concert setting. If used in accordance with the diegesis of the display as well as the narrative-dramaturgic characteristics of the content, the experiential gains of naturalistic simulation as well as creative manipulation may emerge in function of user interaction. As in Zukunftsmusiks' understanding of deictic perspectives, these user maneuverable angles of meaning can reach beyond the limits of a perceptually realistic opera staging, but, notwithstanding their creative expansions, are still to pay resemblance to the situational context of an audience setting. This balancing between non-diegetic and diegetic perspectives corresponds to dimensionalities commonly found in constructs of immersive experience, where imaginary components of absorption relate to a non-diegetic perspective on the narrative and sensory-spatial components of presence refer to diegetic perspective of drama experience. Our case studies highlight a prospect to fulfil some of these desiderata by affording a congruent user-aware interaction on a within (i.e. absorption) and between (i.e.

[social] presence) dimensionality of Zukunftsmusik. By moving from music absorption towards sensory and imaginary immersive experience, a new understanding of music aesthetics may arise beyond its resemblance to prototypes of set standards (i.e. widely accepted music culture). Furthermore, a renewed technological consideration of Zukunftsmusik may help to reach out towards an audience demographic that previously was mostly unknown in contemporary music: The user.

Literature

[Gass15] Gasselseder, Hans-Peter: The Role of Agency in Ludoacoustic Immersion: Experiencing Recorded Sound and Music in Situational Context. Proceedings of Audio Mostly (AM'15). ACM, New York 2015.

[Hans02] Hanslick, Eduard: Vom Musikalisch-Schönen. Ein Beitrag zur Revision der Ästhetik der Tonkunst. Breitkopf und Härtel, Leipzig 1902, p. 3.

[Inst17] Insta360: Insta360 Pro. 360° 3D Camera for VR. https://www.insta360.com/product/insta360-pro (accessed 16.03.2020).

[Koda15] Kodak: Kodak SP360-4K. 360° 3D Camera. https://kodakpixpro.com/Europe/cameras/vrcamera/sp3604k (accessed 16.03.2020).

[Schu65] Schumann, Robert: Gesammelte Schriften über Musik und Musiker. Reclam, Leipzig 1965, p. 34.

[ScIr18] Schütze, Stephan and Irwin-Schütze, Anna: New Realities in Audio. CRC Press, Boca Raton 2018.

[Wagn50] Wagner, Richard: Das Kunstwerk der Zukunft. Wigand, Leipzig 1850.

[Zyli18] Zylia: Zylia ZM-1d. Ambisonics Microphone Array. http://www.zylia.co/zylia-pro.html (accessed 16.03.2020).

Intuitive Human-Computer Interaction through One-Shot Gesture Learning and Recognition

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Abstract

In this paper we will present a novel human-computer interaction approach that uses the one-shot principle for gesture learning and recognition. The method uses a MobileNet based convolutional network, transfer learning and a k-Nearest Neighbours classifier. The approach allows very quick and responsive learning and re-learning of gestures and hand-postures, allowing the end-user to quickly customize their interaction gestures or replace them when necessary. The approach was evaluated on several datasets and compared with other state-of-the-art approaches.

1 Introduction

The rapid development of Virtual Reality (VR) technology in the recent years has led to a rising demand for natural, intuitive and responsive ways of controlling and interacting with the virtual environment. This is important for cultural and educational applications or entertainment, but it's even more crucial for clinical settings, such as virtual rehabilitation or surgery.

Most of the popular VR headsets, such as Oculus Rift and HTC Vive, come equipped with hand-held controllers that support accurate and responsive tracking, as well as interaction by means of buttons, analogue sticks and even finger tracking, such as in the new Valve Index headset.

However in some cases using the controllers brings in certain issues, such as: having to position or mount the camera-sensors, needing to set up the controllers, only having to rely on the available buttons and the fact that some people might find using the controllers difficult due to health related reasons. The latter is especially relevant for medical and clinical settings.

Many researchers instead turn to using visual tracking devices such as Leap Motion, most often by mounting it to the VR headset itself (first-person inside-out perspective). This approach allows having an accurate 3D hand representation and immersive interaction physics. However, besides typical hand tracking errors mostly due to occlusion, it also has a limited field of view and a limited operational distance, the latter of which can result in incorrect hand representation when the arm is fully extended away from the headset.

Another approach is using visual tracking from the third-person outside-in or egocentric perspective, specifically the depth sensors like Intel Realsense and Microsoft Kinect, as well as stereo-camera setups, which allows easy mapping of the hand coordinates into the virtual environment, provided a calibration process took place beforehand. This also allows the integration of visual gesture recognition, making interaction more intuitive and customizable.

With this in mind, we are proposing an approach based on visual tracking and deep-learning, that consists of hand tracking using an RGB-D camera, and a one-shot hand gesture learning and recognition system.

2 Related Work

Gesture detection and recognition provides a natural, creative and intuitive interaction experience for many human-computer interaction applications.
Recently, deep learning-based methods have emerged and advanced the research in this area. A novel approach based on combining traditional hand-crafted features with a convolutional neural network (CNN) was proposed in [CCVM18].
A trend to use even deeper and more complicated CNNs for higher classification performance could also be observed [HuSS17], as well as a turn to more lightweight networks [MoLI19].
Fusion of different modalities to help CNNs improve recognition performance was also considered, like Motion Fused Frames (MFFs) in [KöKR18].
Generally, most of the deep learning-based methods still require time-consuming training sessions and large datasets. One-shot based methods mostly solve that problem [LQLX20], however there still remain problems such as lack of a hand-detection pipeline or interactivity of training.

3 Our Approach

The interaction approach proposed in this paper is based on deep learning, which with the advent of readily available powerful GPUs has become very prominent in the recent years. Deep convolutional neural networks have shown very impressive results in various applications, particularly the tracking of different features and keypoints in humans, as well as gesture and posture recognition.

3.1 Hand Tracking

The hand tracking algorithm was discussed in-depth in our previous publication [KCFP19]. It uses the depth-images from the RGBD sensor (Kinect or Realsense), which are passed through our *body keypoint detection model*.
The keypoint model is based on the existing VGG-structure [SiZi14], which is used as the backbone. The backbone's output is refined through several convolutional stages, until a stack of four heatmaps, one for each

hand, one for face and one for the background, is produced. A non-maxima suppression algorithm is then used on the heatmaps, resulting in a list of hand keypoints.

The hand locations are used to estimate the region-of-interest bounding boxes for both hands, based on their depth (i.e. the distance from the sensor). The Hungarian method (Kuhn-Munkres algorithm) is used to track the bounding boxes across the time space. Finally, the regions are mapped into the colour space and used to cut out the hand regions.

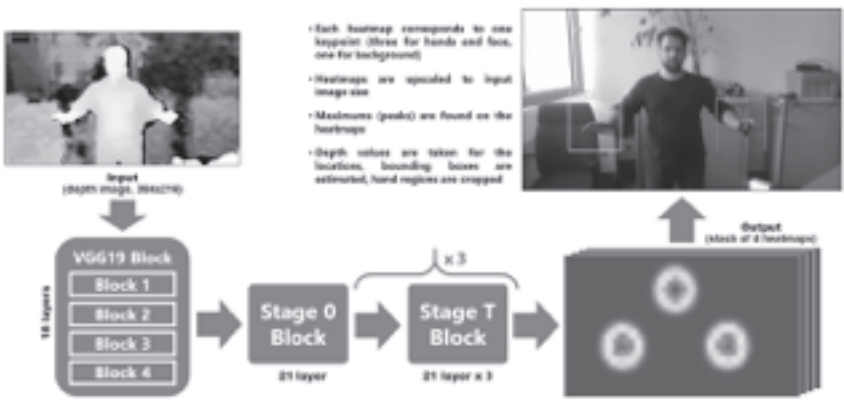

Fig. 1: The hand keypoint tracking pipeline

3.2 Gesture Recognition

The hand regions cropped from the RGB image are fed into the gesture recognition pipeline. The gesture recognizer is based on the transfer-learning principle [TeMa20]. The hand image is first passed into a MobileNet network [HZCK17], with the top dense layers removed. The network is initially trained on the ImageNet dataset [DDSL09] to recognize a thousand different classes of objects, which means that it allows us to use the high-level abstractions that the neural network has learned in order to recognize the ImageNet classes.

Using the transfer learning principle, we additionally refine the network on images of human hands from the COCO dataset [LMBB14] to re-specialize the network for extracting hand and finger features. With the top layer of the network removed, instead of the prediction values for the ImageNet classes it outputs a flattened vector of 1024 most prominent raw image features.

Using the self-same transfer learning principle, these feature vectors are then fed into a k-Nearest Neighbours classifier in order to quickly train and recognize various custom hand gestures.

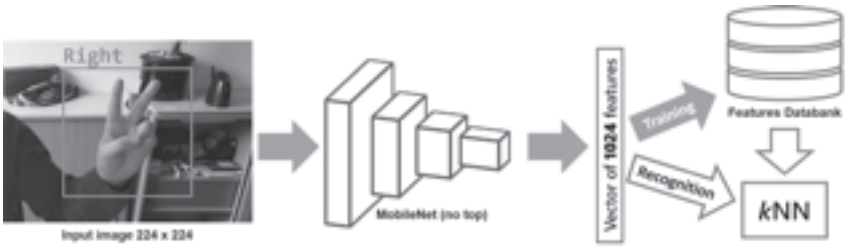

Fig. 2: Gesture learning and recognition pipeline

To make the recognition more robust and the training process quicker, each image that we feed into the gesture training pipeline is copied several times (we're using 10 copies for most of our experiments) and each image is subjected to a series of random augmentations, which include: horizontal flipping, translations, rotations, scaling, Gaussian noise, resizing artefacts, compression artefacts, changes in contrast, brightness and gamma, as well as slight changes in colour hue, each with a 50% chance of happening.

4 Performance and Evaluation

The experimental tests that we performed for our gesture recognition approach can be divided into three types: synthetic, live and comparative. For the synthetic test we have gathered a hand gesture dataset of seven hand gestures, with approximately 10 thousand pictures per gesture in total. The gestures include hand postures that are very similar to each other: "fist", "pointing", "italian" (all fingertips touching in one point), "flat hand", "flat hand with spread fingers", "thumbs up" and an "unknown" gesture (for all other possible gestures or when there's no gesture detected at all).

Our gesture recognition approach was then trained with a random sample of 50–100 images from each class and then evaluated on our whole dataset of 70 thousand images, and then the process was repeated several more times, taking different image samples, and the averaged result was

calculated. The confusion matrix for the synthetic evaluation is shown on figure 3a.

For the live test we've invited several of our colleagues to try out the gesture recognition application, asked them to train a series of four gestures ("fist", "open hand", "thumbs up" and "victory") with a pre-recorded fifth "unknown" gesture, and then perform the same gestures, recording the predicted gesture and the ground truth. The averaged results of the evaluation in the form of a confusion matrix are shown on figure 3b.

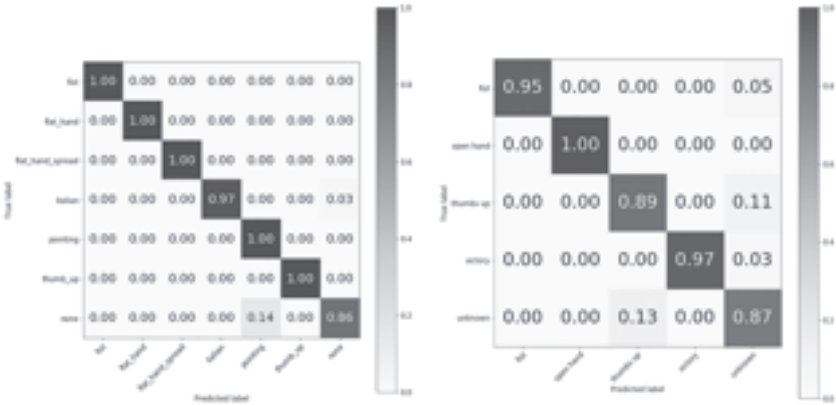

Fig. 3: Results of the synthetic (a) and live (b) test of gesture recognition

During this test we also measured the performance of our method, and the entire pipeline, from hand detection to gesture recognition, ran at a comfortable 26.3±3 frames per second on a relatively modern hardware.

Lastly, for the comparative test we have compared the performance of our approach with one of the existing state-of-the-art gesture recognition approaches [MoLI19], as well as our own depth-based gesture recognition method described in our previous publication [KCFP19]. For the comparison, we used our methods without random image augmentations, as well as with 10 and 20 augmentation per image.

The evaluation metric used is the Precision, Recall and F1-Score, which are calculated using true positives (TP), false positives (FP) and false negatives (FN):

$$Precision = \frac{TP}{TP + FP} \quad Recall = \frac{RP}{TP + FN} \quad F_1\, score = 2\,x\,\frac{Precision\ x\ Recall}{Precision + Recall}$$

The datasets used for the evaluation are the LaRED Benchmark dataset [HSLH14] and the TinyHands dataset [BMBG17]. The averaged comparison results are summarized in table 1.

Methods	**Precision (%)**	**Recall (%)**	**F1 Score (%)**
Baseline method [MoLI19]	96.05	96.71	96.37
Ours (depth) [KCFP19]	95.85	96.24	96.01
Ours (one-shot, no augments)	93.42	92.91	92.58
Ours (one-shot, 10 augments)	95.99	95.72	95.70
Ours (one-shot, 20 augments)	94.78	93.67	94.22

Table 1. Results of the comparative testing

The comparative test shows, that though the recognition accuracy is slightly lower than the pre-trained approaches, our one-shot approach has several advantages over more traditional machine learning approaches, as it does not require long training sessions or large datasets, and also allows the end-user to quickly customize their interaction gestures or replace them when necessary. The lower relative recognition rate can be explained by the fact that the model was not trained to extract features and recognize the specific set of gestures, but instead extracts generalized object and hand features.

5 Conclusion

We have developed a hand-tracking and gesture recognition pipeline for simple, immersive and contact-free human-computer interaction. The goal of the approach is to eliminate the need for hand-held controllers or head-mounted sensors like Leap Motion, and only use a third-person perspec-

tive RGBD stream for hand tracking and gesture recognition, though an egocentric perspective is still possible.

Hand tracking in our pipeline is performed via a deep convolutional network on the depth stream from an RGBD sensor. The gesture recognizer is based on a MobileNet network without a top layer, which is trained to recognize many object features, and a k-Nearest Neighbours classifier.

This approach does not require long training sessions or large datasets, and quick customization of interaction gestures and re-learning for new users or new requirements.

The approach was evaluated using several tests, including synthetic and comparative tests using datasets created by us and openly available ones, and existing state-of-the-art methods, as well as live tests.

Literature

[BMBG17] Bao, P., Maqueda, A. I., del-Blanco, C. R., & García, N.: Tiny hand gesture recognition without localization via a deep convolutional network. IEEE Transactions on Consumer Electronics, 63(3), 2017, pp. 251–257.

[CCVM18] Cordeiro, F., Chevtchenko, S., Vale, R., & Macario, V.: A Convolutional Neural Network with Feature Fusion for Real-Time Hand Posture Recognition. Applied Soft Computing, 2018.

[DDSL09] Deng, J., Dong, W., Socher, R., Li, L., Kai Li, & Li Fei-Fei.: ImageNet: A large-scale hierarchical image database. 2009 IEEE Conference on Computer Vision and Pattern Recognition, 2009, pp. 248–255.

[HZCK17] Howard, A. G., Zhu, M., Chen, B., Kalenichenko, D., Wang, W., Weyand, T., Andreetto, M., & Adam, H.: MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications. CoRR, abs/1704.04861, 2017.

[HSLH14] Hsiao, Y.-S., Sanchez-Riera, J., Lim, T., Hua, K.-L., & Cheng, W.-H.: LaRED: a large RGB-D extensible hand gesture dataset. Proceedings of the 5th ACM Multimedia Systems Conference, MMSys 2014, 2014, pp. 53–58.

[HuSS17] Hu, J., Shen, L., & Sun, G.: Squeeze-and-Excitation Networks. CoRR, abs/1709.01507, 2017.

[KöKR18] Köpüklü, O., Köse, N., & Rigoll, G.: Motion Fused Frames: Data Level Fusion Strategy for Hand Gesture Recognition. CoRR, abs/1804.07187, 2018.

[LQLX20] Li, L., Qin, S., Lu, Z., Xu, K., & Hu, Z.: One-shot learning gesture recognition based on joint training of 3D ResNet and memory module. Multimedia Tools and Applications, 79(9), 2020, pp. 6727–6757.

[LMBB14] Lin, T.-Y., Maire, M., Belongie, S. J., Bourdev, L. D., Girshick, R. B., Hays, J., Perona, P., Ramanan, D., Dollár, P., & Zitnick, C. L.: Microsoft COCO: Common Objects in Context. CoRR, abs/1405.0312, 2014.

[MoLI19] Mohammed, A. A. Q., Lv, J., & Islam, MD. S.: A Deep Learning-Based End-to-End Composite System for Hand Detection and Gesture Recognition. Sensors, 19(23), 2019.

[SiZi14] Simonyan, K., & Zisserman, A.: Very Deep Convolutional Networks for Large-Scale Image Recognition. ArXiv 1409.1556, 2014.

[TeMa20] Teachable Machine, https://teachablemachine.withgoogle.com, (last visited: 2020-03-16).

Memory Card Action Game in Augmented Reality

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Abstract

The recent advances of technology in AR make it possible to create interesting applications which can help people to develop their creative potential and also to learn something new. Environment and animals as a topic for an AR-application is a good example where AR can could be used effectively for entertainment and educational purposes. Taking the already existing concepts for games and extending them with modern technology in order to provide educational entertainment application is the main goal of this paper.

1 Introduction

In the recent years, augmented reality has gained extraordinary importance among the different IT-technologies, standing in one line with machine learning and Blockchain [Digi19]. The rapid breakthrough in the development of the concept of augmented reality is especially important for the gaming industry, which will be discussed [BuKS18] in following. The most of the modern smartphones are initially concepted to provide the possibility to use AR applications and there are also frameworks and plugins such as Vuforia, ARKit, and ARCore which allow us to develop AR applications easily. Despite the big advances in AR and the ease of development of AR applications, there are not so many games which provide an entertaining experience combined with educational aspect.

2 Main idea

For our application, we took an already existing concept of memory games where the user has to flip the cards and should memorize the positions of the cards with the same picture in order to win. For a fun and socializing experience we also added the multiplayer-feature with some elements of the battle strategy-game. This idea was borrowed from some well-known card based mobile games [AdTu11]. The combination of the genres “memory” and “strategy” together with the socializing multiplayer feature and also the fact that we are using animals for our cards adds an educational aspect to our application and altogether creates an interesting concept for an application [Bond17].

3 Game concept

Both players have the same number of cards, each of which has a virtual animal attached to it. Different animals have different parameters, such as health and attack. During the turn, the player chooses one certain animal and then also one of the enemy ones, that he wants to attack. The player does not know exactly which animal is attached to the card he is attacking, but it is possible to reveal the animal behind one certain card,

which will cost the player one move. After defeating of some opponents cards, the animal behind this card will be revealed to the player. The main goal of the game is to defeat the opponents' cards as fast as possible. In order to provide an interesting gameplay, a good balance between the cards is needed: the animals with high attack-parameters have only few health-points and animals with many health-points have a weak attack. This approach makes the player think about his every move and remember the cards that he looked at. With augmented reality we were able to implement some interesting, movement based interactions (The user rotates and moves some special action cards which do affect the game). Since the player's time and the amount of available action cards is limited, there is some aspect of risk while playing the game, which makes it more entertaining. There are also not only action cards, which give us new ways of interacting with the game, but there are also ability cards which can be placed on some of the player's animal-cards: each ability card has a certain effect on characteristics of the animals, such as adding health or enhancing attack. The ability cards increase the degree of strategical thinking while playing the game. You can win either by defeating all the animal cards of the enemy or by causing more damage than the opponent (In the case that the time is out).

4 Implementation

The possible scenarios while playing the game are nearly endless. The animal-themed game combined with new AR-based user-interactions creates an overall interesting user experience. In following we will describe the details of the implementation of our application.

4.1 Developing tools

While implementation

- Unity3D cross-platform development environment [Bond17];
- Vuforia AR engine plugin [Unit19];
- Blender3D graphic development environment.

4.2 Gameplay Rules

The game is supposed to be played on the table.

The game field contains 12 cards, 6 for each player. Each player can only see the animals of his cards. The game is also supposed to be played on one smartphone: if the turn of the first player is over, the screen becomes black and the first player is supposed to pass the smartphone to the second player. Both players have 10 seconds to make a move. Even though it may seem like it is too much time for one move, it gets more intensive when a user decides to add health or attack damage to his card with "ability cards". Such type of interaction makes the game more intensive and dynamic. Also the feature which allows the player to reveal the opponent's card has the same effect on the gameplay. If the time is out or the "End Turn" button is pressed, the turn goes to the second player. When the game comes to an end the game announces the winner, based either on a comparison of the total amount of health left for each player, or if some player defeats all animals of the second player within some certain amount of time.

Fig. 1: Player move

4.3 Characters

As it was already mentioned, since it is a game with some strategical elements, the balance between different animals is very important for the game. Animals are classified into 3 types:

- Attacker – causes a lot of damage but has just few health points. Represented by a snake;
- Defender – has a lot of health but few attack points. Represented by an elephant;
- Common – has both attack and health points on an average level. Represented by a bull.

All the animals are placed on cards in random order but the amount of animals of each type is always the same which means that both players have equal chances of winning the game at the beginning.

4.4 Action cards

A very special interaction with the game, which is only possible with AR are the action cards. The amount of these cards is limited: each player has two of them and one card can be used only once.

There are two different kinds of action cards:

- Tranquilliser gun – causes the deactivation of an opponent's animal for three turns. While using this card, the user holds it in his hand and aims at some of the opponent's card he wants to deactivate. Then he taps on the virtual tranquilliser gun displayed on the card on the screen of the smartphone. If the player aimed correctly, the tranquilliser-bullet will hit an animal and eventually deactivate it.
- Waterfall – a card that spawnes a waterfall which causes damage to every enemy card it touches. Just like a tranquilliser gun card, the player has to take the card in his hand and then bring the waterfall, which will appear on the card, near to the opponent's cards.

Fig. 2: Action Cards

4.5 Shape recognition

Another feature of the game is the “Shape recognition” script that defines, whether the set of cards follows a specified figure pattern. If the user builds a “Triangle pattern“ with his 6 cards on the table, the game will recognize it and will then add some attack points to every animal. If the “Circle pattern” was recognized, all animals will receive some additional health points. The decision of the shape recognition algorithm is based on the distances between the different cards.

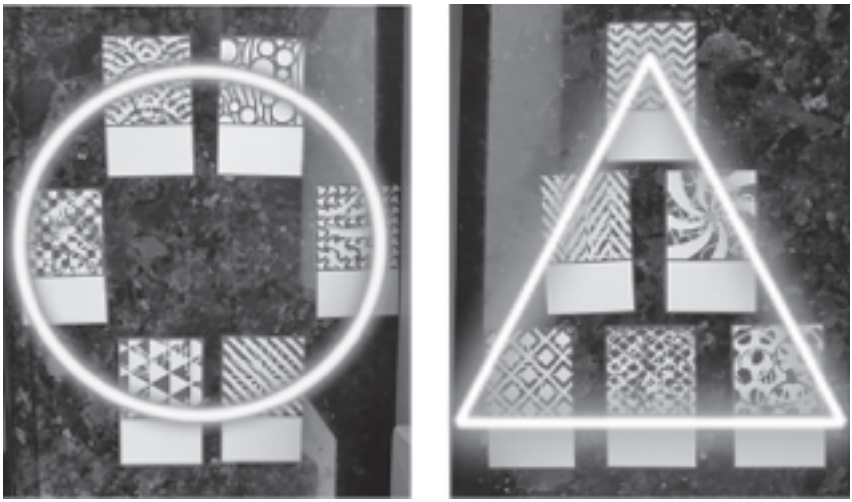

Fig. 3: Shape recognition

5 Conclusion

An overall interesting concept for the game combined with the animals will help to get young people interested in topics such as environment and animals. Our card based AR application introduces also some new possible ways to interact with an application with some special cards. Especially the action cards make the gameplay interesting and also more dynamic. So the concept of the game which could actually exist also without the AR-application, was extended with some interesting use cases which are only possible with augmented reality, which shows how some simple and well known concepts could be easily improved with AR.

Literature

[Digi19] Digi-Capital. Virtual reality and augmented reality startup valuations hit $45 billion (on paper). October 28, 2019. [Online]. Available: https://www.digi-capital.com/news/2019/10/virtual-reality-and-augmented-reality-startup-valuations-hit-45-billion-on-paper/

[BuKS18] Busch, C.; Kassung, C.; Sieck, J. (Ed.): Culture and Computer Science: Hybrid Systems. Verlag Werner Hülsbusch, Glückstadt, 2018, pp. 53–77.

[AdTu11] Adinolf, Sonam & Turkay, Selen: Collection, creation and community: a discussion on collectible card games. 2011, pp. 3–11. [Online]. Available:https://www.researchgate.net/publication/262326293_Collection_creation_and_community_a_discussion_on_collectible_card_games

[Bond17] Bond, J.C.: Unity and C#. Game development from idea to realization. 2nd ed., 2017, pp. 39–298.

[Unit19] Unity Vuforia Documentation [Online]. Available: https://docs.unity3d.com/Manual/vuforia-sdk-overview.html

Virus Computer Invasion in Augmented Reality

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Abstract

AR and VR technologies are becoming more popular every day. They are already represented in medicine, education, art, entertainment and other areas.

Sometimes it's hard to decide which of these technologies should be used for specific contents and if it makes sense to use one of them instead of making a classic 3D application.

This paper shows how it's possible to combine educational and entertaining aspects to build an Augmented Reality application that informs about computer viruses in a playful way and why AR is good applicable for this topic.

Further, the communication with and the instruction of the recipient on how to interact with the application is an important aspect. Which is nowadays still a problem, because there are no common interface metaphors for AR yet. A good approach for this circumstance is to adapt already established metaphors from other areas for the new technology. This paper offers examples on how this can be done.

1 Introduction

Nowadays, applications using the technology of Augmented Reality are gaining immense popularity. The potential for using AR is vast. The introduction of it in the everyday life is carried out in many areas, such as medicine, the military-industrial complex and many others [AGGL15]. This technology has received the most frequent application in the educational sphere. Due to this technology, it is possible to show or demonstrate difficultly comprehensible stages of training in more detail and comprehension of non-visual concepts. An example is the fight against computer viruses. Since viruses do not have a specific form, users themselves try to imagine the viruses. To facilitate the process of perceiving information about viruses and computer devices, it was decided to create a training application that is able to perform this task in a game form.

2 Technologies Used

The application was realised with the Unity game engine. To implement the Augmented Reality functionalities Unity's AR Foundation framework was used. This framework combines the common functionalities of Google's ARCore and Apple's ARKit SDKs and enables the development of cross-platform AR applications [Unit20].
To create 3D models the software Blender was used.

3 About the Application

The final application is suitable both for children who are just beginning to understand computers, and for those who want to refresh their knowledge in this area. A convenient and fast interface will help to use the application. The main advantage of this application is the AR feature, which will deeply immerse the recipient in the atmosphere of the game.
The application consists of several levels, along which users will learn new information about viruses and means of combating them.

3.1 User Interface

Because AR is still a new technology, there are no standard Interface Metaphors yet [Ku18]. Interface Metaphors symbolize knowledge that users already have from other usage domains. For instance, most of the people know that the trash can icon is used to delete files on many systems and are able to interact with it intuitively. One question in the context of AR is, which interactions are needed. Should the user navigate with hands, with body motion, with eyes or even with voice? Is a visual UI even needed?

One approach to find good Interface Metaphors for new technologies is to have a look at similar ones and to adjust them to the new requirements. Moreover, a lot of testing with actual users is mandatory.

To place the AR content of the virus application in the real world three steps are required in the beginning: At first the user has to look around in the room with the smartphone to find so-called feature points, so the application knows where the smartphone is located in the room. In the next step planes must be found. These consist of many feature points that are supposedly on the same vertical or horizontal surface. In the specific case only horizontal planes are searched.

Finally, the user has to tap on one of the found planes to place the content on it. The testing with more than ten users showed that each of the described steps needs to be explained.

In Fig. 1 the resulting UI can be seen. The smartphone symbols at the top and the bottom are moving animations to get the user's attention. This tutorial UI improved the usage of the application in future tests a lot. Still not every user knew what to do. So, this UI still could be improved.

Fig. 1: Placement UI

After the content was placed the user gets a scene which should only be observed. However, most of the people were trying to find something to interact with. The current approach of the virus application is a simple command on the top of the screen as seen in Fig. 2. Half of the testers didn't see it. So, this needs to be improved in future iterations. Especially this UI is important, because also in other parts of the application information needs to be provided to the user.

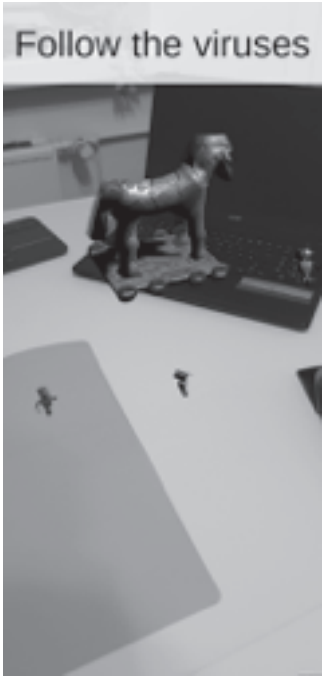

Fig. 2: Command UI

Another finding that was made while developing and testing this application was that too many UI elements on the screen can be distracting. In AR the camera view is the most important part. And the more of it remains, the more immersive is the content. Here appear the questions, if the application should have less or smaller UIs, or if they should be placed not on the screen, but in the world itself.

3.2 Playable Contents

When writing this paper, the application consists of three pieces of content.

In the first content three different types of viruses leave the smartphone and fly to a Trojan Horse. The intention is to make the user think about the symbolic character of this event. When the viruses reach the horse, it travels with them to the inside of a computer, where they exit the horse and jump on the motherboard.

In the second level an endless number of viruses is attacking different components of the computer and the user has to defend them by shooting

appropriate types of antiviruses at the viruses. When a specific score is reached the computer was saved and the viruses leave to the next level.
The third level illustrates a network as seen in Fig. 3. In the future this should show how easy it is to spread viruses over the internet, and the user should learn which possibilities exist to defend the own system against such threats.

Fig. 3: Network Level

4 Conclusion

The developed AR application is a small showcase on how education and entertainment can be combined to deliver a new kind of experience.
Of course, the application is expandable and will need to get in touch with the virus topic more deeply in future iterations.
Such kind of application can also be used for other learning tasks that are usually hard to visualize or too abstract. The biggest advantage is that with

the AR technology the user is more involved in the taught contents, which motivates her or him and eases learning [Thin20].

Literature

[AGGL15] Arth, C.; Grasset, R.; Gruber, L.; Langlotz, T: The History of Mobile Augmented Reality. 2015, https://www.research-gate.net/publication/275974448_The_History_of_Mobile_Augmented_Reality

[Ku18] Ku, Anastasiia: VR Interface Metaphors. 2018, https://medium.com/inborn-experience/vr-interface-metaphors-5698a98bcc0a

[Thin20] Thinkmobiles Team: Augmented Reality in Education. 2020, https://thinkmobiles.com/blog/augmented-reality-education/

[Unit20] Unity: AR Foundation, 2020, https://unity.com/de/unity/features/arfoundation

Interactive Time Machine: the Museum of Industry in Gabrovo

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Abstract

The article is created in the conceptual space of *digital heritage theory*, which offers innovative solutions for museum operations and museum exhibitions in the contemporary cultural environment. The new *Interactive Museum of Industry* in the city of Gabrovo is presented as a unique for Bulgaria institution, which reconstructs (arti)facts from the economic and social past through digital technologies, models and devices. An analysis of its main components shows the wide potential of high tech solutions for historical expositions – especially in the area of industrial and social history. Some recommendations for improving public relations of the new museum are systemized at the end of the text.

1 Introduction

As Andrea Bandelli says, in his specialized academic research, virtual spaces noticeably expand its multifunctional presence in contemporary museum exhibitions [Parr10, 150–151]. Without shifting the central role of original artifacts, more and more digital components construct narratives – visual, audio or/and textual – involving images, ideas, sounds, stories that were not part of the traditional museum methods of display and interpretation. In the place of our classical guide, a virtual one emerges. A 3D projection visualizes an important event. An augmented reality session enlivens circumstances and personalities that no longer exist – buildings, interiors, prominent figures, battles, clothing, furniture, agrarian and industrial technologies, etc. Computer configurations provide access to metadata and images of artifacts that are not included in our exposure. Described innovations created new forms of the museum vitality, attract new audiences, and provoke new forms of communication [VaLe17].

Being in the initial phase in our country, the interactive components of museality gradually penetrate into permanent exposures of certain Bulgarian heritage institutions. During the last decade, virtual realities were built in some existing or newly created expositions – Sofia, Varna, Shumen, Stara Sagora, Karlovo, Plovdiv, Troyan [VaPe19[. The vast majority of them are multimedia presentations, digital kiosks and films. Recently, QR codes and augmented realities are also embodied in some museum displays. However, the museum innovations are still not enough regarding their quantity and quality. That's why the ongoing focus on the completely new interactive museum in Gabrovo is important as a good example for Bulgarian cultural landscape end for the future development of national museum network [Bone14].

2 The City of Gabrovo

Gabrovo (pop. 70,775) is a city located in the geographical center of Bulgaria. It is an essential administrative, cultural, end economic urban space with regional end national importance. The city was founded in the late 14th century during the Ottoman invasion of the Balkans as a secure refuge of Christians from the destructive raids of new Muslim rulers. The

settlement was booming in the 18th and 19th centuries through a thriving hand-made industry and in 1860 it was declared a town – a rare practice of Ottoman authorities. After national liberation in 1878/79, in the late 19th and first half of the 20th century, Gabrovo has become a leading industrial point of the modernizing country. At the mentioned time the city had a clear nickname – *Bulgarian Manchester* [Gots03]. During the period of state socialism, pointed out tendency persists and dozens of factories – mainly in the light industries – attract workers from the region and from the whole country. In the early post-communist period there was a decline, but nowadays industry is again a leading branch on the municipality of Gabrovo [Fabe15].

3 Local Cultural Landscape

The city's cultural traditions are strong, multi-genre, and rich. Nowadays, 15 separate cultural institutions create meaningful and diverse products and events – exhibitions, spectacles, educational programs, touristic attractions, etc. National Museum of Education, Regional Historical Museum, Regional Ethnographical Museums and Municipal Art Gallery are main units responsible for the cultural heritage safeguarding. Since 2017 Gabrovo is a part of Creative Cities Network – a UNESCO programe for sustainable urban development[1]. The Museum of Humor and Satire in Gabrovo is a unique cultural organisation with tangible presence in Bulgaria and Europe[2]. In the area the only open-air museum of our country is located[3]. The described context [Cult04, 24-53] clearly explains why exactly in Gabrovo the first fully virtual museum in the country was created six years ago.

1 More information about mentioned program and Gabrovo membership in it is available at official UNESCO site – *www.unesco.org* [07.03.2020].

2 The Humor and Satire Museum presents the funny glory of the city and organizes international art biennial of humor and satire in art - *www.humorhouse.bg* [07.03.2020].

3 Ethnographic complex "Etar" is one of the most visited museums in recent years – *en.etar.bg* [07.03.2020].

4 Interactive Museum

Motivated by their wealthy manufactory history, the citizens of Gabrovo approved the idea to build a museum of the local industry. The project was implemented between 2012 and 2014. The main funding comes from the EU Operative program "Regional Development" – more than three million euros. The rest financing comes from the Gabrovo Municipality. As a result, on March 21st, 2014 a new museum in Gabrovo was inaugurated – Interactive Museum of Industry[4]. The municipality inhabits new cultural institution in a lovely neoclassical building, constructed in 1893 as home and office of a prosperous local merchant. The house is located in the very city center that makes it easy for tourist access.

The exhibition is arranged in a chronological way. *Revival period* (18th and 19th centuries) is displayed on the first floor. The interactive guide (fascinating lady dressed in era clothes) welcomes visitors and presents a 5-minute narrative. The adjacent screen illustrates the mentioned stories with appropriate virtual materials. Nearby a digital device stands. It enables every visitor to open himself history pages and learn more about the handheld industry. One of the walls is covered by a wide digital screen, on which by mechanical movement of our left or right hand we move along the timeline, comparing local manufactural development with the industrial increase of other European cities. The *bourgeois era* from the first half of the 20th century is illustrated by digital copies of documents, newspapers end pictures. Some prototypes of machines, tools, and products are displayed, too. Most of them are museum copies or models since the institution does not possess original era items. Visual environment is intelligently balanced and supplemented with appropriate sound backgrounds. Interior and content decisions are consistent with the leading concepts of virtual miseality [DBYA18]. Many predominant ideas in terms of industrial heritage interpretation have been successfully embodied in the exposure [Bang11]. This is especially true for the curators' preferred sectoral, institutional, and personal approaches.

Gabrovo Interactive Museum is among the few Bulgarian heritage topoi that interpret the *communist period* [Ivan17]. A spacious display on the second floor narrates about industrial branches of the city after the

4 These circumstances are described in detail at the museum site – *imi.gabrovo.bg* [07.03.2020].

violent nationalization of private factories in the late 1940s. Here, the virtual guide is in her role, too. Models and original artifacts, a digital wall of time, computer-generated narratives, and none yet secret military machines return visitors into the controversial socialist epoch. Multiple screens in this part of exposure a disperse the viewers' attention, but this is no serious problem in the course of a slower movement among the exhibits.

With the same means of expression on the third floor, a short story about the *post-communist period* is created. For now, this is the only museum narrative in Bulgaria, dedicated to the last three decades of our national developement. That's how the museum turns into an important national heritage topos, connected to the interpretation of the recent Bulgarian and European past [Ivan17]. Museum experts report that most tourists perceive the exhibition in the logic of the aforementioned historical realities – sosialist era and pos-tsosialis period [Ivan09]. Thus, the weight of the object on the map of our cultural tourism sites gets heavier. Gradually, the museum becomes part complex processes of (re)thinking the communist legacy in Bulgaria.

5 Perspectives

Between its inauguration (March 21st, 2014) and my last visit (February 29th, 2020) the Interactive Museum in Gabrovo has welcomed thousands of tourists and has opened its doors to the many students groups. Trought the exhibition, lovers of history have touched of cutting-edge technologies – interactive guide, interactive digital wall, 3D mapping, augmented reality, personalized computer installations, historical games. Alongside, the ancient building shelters more and more original artifacts, gadgets, and models – "Formula 1" car simulator, for example. More and more active becomes the educational activity of institution in line with politics to our school authorities. The team is also working hard in the international arena. All products and materials are available in Bulgarian, Russian and English. This is tailored to the prevailing guest profile. Joint initiatives are being launched with other local and national memory structures. The *museum is becoming more recognizable* in our national museum network [Petk09]. However, they are not yet sufficient support from local businesses and

from the media that set the cultural theme in the underprivileged position. Another upcoming issue refers to the complete museification of the object – moving it from the governing body of the local municipality to the institutional structure of Gabrovo Regional Historical Museum. Thus, it will become a proper museum within the meaning of the *ICOM Statutes* and will be able to collect and maintain its own fund of cultural property – a key component of the full cultural heritage establishments[5].

Acknowledgements

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Literature

[Bang11] Bangstad, Torgeir, Routes of Industrial Heritage: On the Animation of Sedentary Objects. // Culture Unbound. Journal of Current Cultural Research, 2011, volume 3, pp. 279–294.

[Bone14] Boneva, Vera: Музейната мрежа в България. // The museum network in Bulgaria. Veliko Tarnovo: Faber, 2014.

[Cult04] Cultural and historical heritage of three Bulgarian districts: Veliko Tarnovo; Gabrovo; Lovech: Guide. Veliko Tarnovo: Vital, 2004.

[DBYA18] Diaz, Paloma; Bellucci, Andrea; Yuan, Chien-Wen; Aedo, Ignacio: Augmented Experiences in Cultural Spaces through Social Participation. // Journal on Computing and Cultural Heritage, 2018, volume 11, issue 4, Article No. 19, pp. 1–18.

[Fabe15] 155 години Габрово град: илюстрована хроника// 155 years city of Gabrovo: an illustrated chronicle. Veliko Tarnovo: Faber, 2015.

[Gots03] Петър Гоцев. Габрово – българският Манчестър. София, 2003. // Petar Gotsev. Gabrovo – the Bulgarian Manchester. Sofia, 2003.

5 The more consistent and international valid description of museum standards is systematized in the *ICOM Code of Ethics for Museums*. It sets a requirement for institutional affiliation with the heritage sector, which the museum does not have as a unit of Gabrovo municipality – *network.icom.museum* [07.03.2020].

[Ivan09] Ivanov, Stanislav: Opportunities for developing communist heritage tourism in Bulgaria. // Tourism: An International Interdisciplinary Journal, volume 57, No. 2, 2009, pp. 178–192.

[Ivan17] Ivanova, Milka: The Inclusion of the Communist/Socialist Heritage in the Emerging Representations of Eastern Europe: The Case of Bulgaria. // Tourism Culture & Communication, volume 17, No 1, 2017, pp. 31–46.

[Petk09] Petkova-Campbell, Gabriela: A place in Europe: Bulgaria and its museums in "New" Europe. Oxford: Archaeopress, 2009.

[Parr10] Museums in a Digital Age. Edited by Ross Parry. Routledge, 2010.

[VaLe17] Museums in a Digital Culture: How Art and Heritage Become Meaningful. Edited by Van Den Akker, Chiel and Legene, Susan. Amsterdam, 2017.

[VaPe19] Vasileva, Sofia and Petrova, Tina: Virtual Reality Development and the Socialization of Bulgarian Cultural Heritage. // Journal of International Cooperation and Development, volume 2, No 1, pp. 34–39.

ˈʊmˌvɛltn̩ – Umwelten

An immersive and interactive composition in Virtual Reality

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Abstract

In cooperation with the research group INKA at the University of Applied Sciences (HTW) Berlin, a composer and a visual artist, the Konzerthaus Berlin has developed an interactive composition in virtual space "Umwelten". In the virtual environment, the user interacts with fantastic plants and can change and manipulate their shapes as well as their sound. "Umwelten" is a highly interactive Virtual Reality (VR) experience that encourages users to think about their direct influence on their own environment in a figurative sense. Ambisonic recordings of the Konzerthaus Berlin orchestra, placed throughout the scene and attached to the plant models, are contributing to a fully immersive experience.

1 Introduction

The 2020/21 season celebrates a major anniversary for the Konzerthaus Berlin, marking the 200th anniversary of its first opening in 1821. Based on the opera "Der Freischütz" by Carl Maria von Weber, which premiered that same year, the new creation "The Pact with the Devil" takes up the anniversary theme. The Konzerthaus Berlin also wants to explore this theme digitally - and for this reason has been looking for a composer and a visual artist for a corresponding commissioned work. After a call for proposals, a jury selected composer Mark Barden and visual artist Julian Bonequi to create the interactive composition in Virtual Reality.
The interactive installation "ˈʊmˌvɛltn̩ – Umwelten" (Environments) re-explores the design possibilities at the interfaces of contemporary music, visual art and Virtual Reality and is created in cooperation with the University of Applied Sciences (HTW) Berlin. Ever since 2016, the Konzerthaus Berlin has been developing innovative concepts for mediating classical music in digital space together with the research group INKA at HTW Berlin in the EU-funded cooperation project APOLLO.

2 State of the Art

"Umwelten" is a surrealistic auditive and visual Virtual Reality experience. VR [Azum97, MiTa94] has come a long way since Sutherlands 'Sword of Damocles' [Suth65] and is now being used in many different areas, ranging from entertainment and medicine to education as well as the industry [KLPK18, SiMu18, KNOH19, ShMX07]. It has also found its way into the topic of classical music, where its applications vary from teaching users to play an instrument [SANT17, NREM08], to experiencing conert halls [LeSi19] as well as whole concerts [Kasu19] in VR. In contrast to experiencing a prerecorded concert, "Umwelten" will allow users to directly interact with their virtual reality and influence their auditory experience. The name of the project is based on Jacob von Uexkülls definition of the term Umwelten, as the sensory, animal-like experience of the auditory, olfactory, haptic and visual components of one's surroundings [Uexk10]. The title of the project should also be depicted using its phonetic spelling: ˈʊmˌvɛltn̩.

A similar concept of creating music in a fantastic VR world has been done by Always & Forever in their "Playthings: VR Music Vacation"[1] project, where users use an HTC Vive to experience playing xylophone sounds by interacting with a very colorful virtual world. Their aim was to have users experiencing a childlike joy in making music, thus choosing models like hot dogs and gummy bears for their VR world. Despite its drastically different visual experience, many aspects of this correlate with the concept of "Umwelten".
The project "Moving Sound Pictures"[2] of the University of Music and Theatre (HfMT) Hamburg also aims in a similar direction. In this project paintings are made audible: Users have the opportunity to interactively explore pictures by well-known painters in Virtual Reality through playful interactions. The sounds are created by shifting, enlarging or reducing 3D objects of the painting. However, the sounds are not a composition in the classical sense, but individual sounds that are assigned to the 3D objects.

3 Concept

Inside the VR application, users experience an interactive sound environment in digital space. Surrounded by fantastic plants and creatures they design their own sounding world in a surreal virtual world. The plants and creatures react to interaction from users – they deform, shrink, change colour, but also change their respective sound. This means no visit is like any other: Every interaction with the environment leaves traces that are unpredictable – on the visual as well as on the auditory level.
The project is a metaphorical playground for the interaction between users and the plants and non-human creatures (see Fig. 1). "Umwelten" wants to make it possible to experience a connection between the sounds, the virtual contact and the reaction of the virtual objects by simply walking through the space and interacting with objects. The fragility and sensitivity of a (virtual) world is picked up on by the anniversary theme "The Pact with the Devil": "Umwelten" wants to encourage users to think about their direct influence on their environment.

1 Always & Forever: Playthings VR: http://playthingsvr.com
2 Moving Sound Pictures, HfMT Hamburg: https://www.hfmt-hamburg.de/innovative-hochschule/moving-sound-pictures/

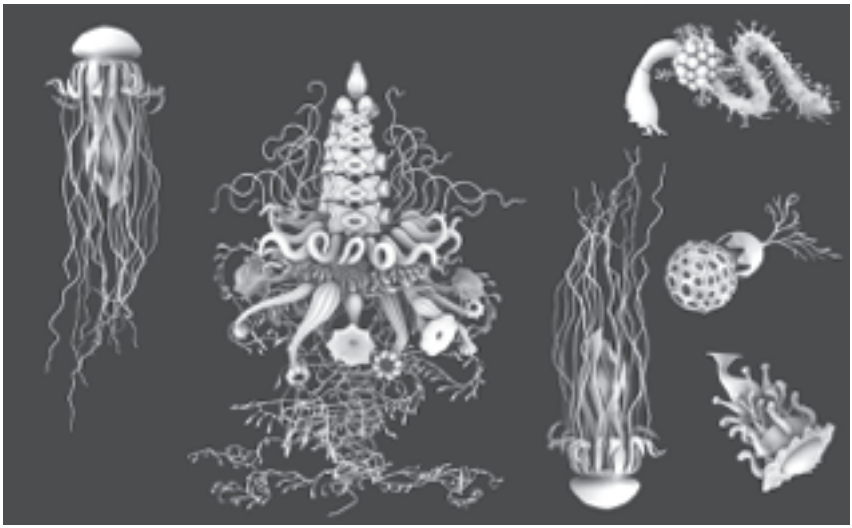

Fig. 1: The 3D models are oriented on the visual world of the zoologist Ernst Haeckel. Credit: Julian Bonequi

3.1 The auditory level

The musical environment in "Umwelten" consists of a large quantity of spherical sounds recorded by the Konzerthausorchester Berlin under Mark Barden. To create the sounds, the musicians not only played on their classical instruments, but also used things like spatulas, beans, lenses, electric toothbrushes or styrofoam (see Fig. 2). This alienation gives some sounds a synthetic sound impression – and sometimes an unsettling effect, which also corresponds to the visuals.

The sounds are linked to the plants of the virtual garden with which the user comes into contact. He can change them, control them individually and manipulate the sounds within the virtual space. Everyone is thus a composer of their own world: the user has a great deal of freedom to decide how to design his virtual environment.

Fig. 2: Experimental sound recordings: Bow strokes on a spatula and electric toothbrushes on a metal barrel with lenses. Credit: Markus Werner

3.2 Interactions in VR

"Umwelten" is an experience that can be rediscovered anew every time, since every interaction has an impact on the VR environment. Interaction is therefore an important factor in VR to create a strong immersion and to inspire the user for the content (see Fig. 3). Users can interact with selected 3D objects, change their shape and form and thus design their own environment: Flower blossoms and tentacles can be grasped, plants can be moved and brought together with others. The user can also interact with the sound: If, for example, they grab an object and throw it away, its sound becomes quieter; if they approach a plant, its sound becomes louder. The individual sounds that adhere to the objects can also be manipulated or switched on and off.

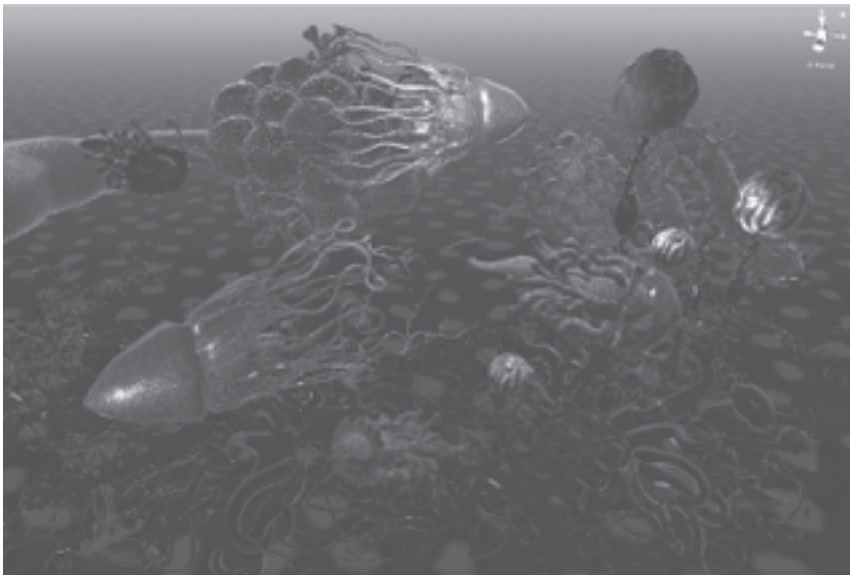

Fig. 3: A screenshot of the creation phase of the virtual environment.
Credit: Julian Bonequi

3.3 Aim of the project

With the interactive composition the Konzerthaus Berlin wants to present contemporary music and digital art in an experimental and individually experienceable application. The aim of the project was to initiate an artistic process and dialogue that transcends the boundaries of the individual disciplines. Different approaches, representations and possibilities of interaction were discussed in the team in order to create something new. "Umwelten" wants to show that high artistic and musical standards are not contradictory in virtual reality, but that modern technology is capable of connecting different disciplines, creating new, innovative formats and thus offering an expansion of artistic possibilities.

4 Technical details

The concept of the project led to a few technical questions, that had to be solved during the concept and development phase of the project.

Since users should be able to walk around freely in the three-dimensional world, a VR headset connected to a computer would be less than ideal, disturbing the immersion of the user. While in other locations this can be helped by having the cables connected to the headset coming from the ceiling, it could not be done in the vestibule due to limitations by the Konzerthaus and its architecture. Therefore, the cable-free Oculus Quest was decided to be the goal hardware.
Another problem that arose from the complex interaction possibilities thought up by the artist, was that often users of past VR applications exhibited in the vestibule of the Konzerthaus, were rather timid when using these applications, thus resulting in them not being able to find all that the experience had to offer. In a survey of user behaviour using the Virtual Tour application, users did often not even make use of the 360° view in the tour [DrTh20]. It is to be assumed, that using controllers will prove a similar problem of users not making use of all of their given opportunities in VR.
This means the application needed a really easy to understand tutorial, showing all the different interaction possibilities the application provides.
As for the software, the project made use of the easy integration of the Oculus Quest into Unity via the OculusVR plugin.

4.1 Three-dimensional sound

Instead of using traditional stereo sound it was decided to use three-dimensional ambisonic sound in order to highten the immersion in VR. In order to achieve this, the recordings of the Konzerthaus orchestra were done using four Sennheiser ambeo microphones, each placed in different parts of the orchestra. The resulting ambeo files are placed in four different locations as spatial AudioSources in the Unity scene. Thus, depending on where users are located in the scene, they can hear one or multiple of these AudioSources while walking through ‘Umwelten’. The user can thereby listen to the audio as if walking through the orchestra during the time of the recording.
The orchestra and individual musicians were also individually recorded in stereo as well. These other AudioSources are attached to different models located in the scene. Due to them having a set point in the world, ambeo is not necessary for them and would excessively use memory, since ambeo files are larger than mono or even stereo files.

4.2 3D Modeling

The models in the VR scene were created by the artist Julian Bonequi using the 3D software Maya. The archetype for the models were drawings by Ernst Haeckel from his book Artforms of Nature [HBEH98]. While during the early stages the project was planned to resemble a secret garden, it was later decided after the first tests in VR, that the aesthetic matched an underwater world more closely. The 3D sculpting was therefore adapted in order to fit the new environment, with models like the jellyfish-like creature shown in figure 4 being built. In order for the models to come to life, animations had to be created. For this instead of bone-based animations, blendshapes were used. These blendshapes can now be triggered by users entering the collider of each of the tentacles with their controller.

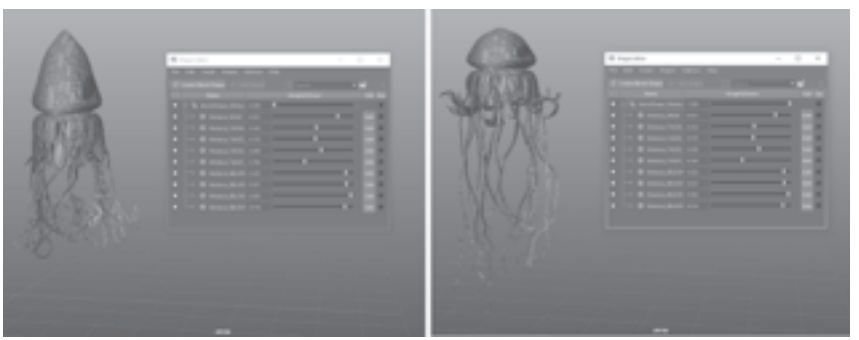

Fig. 4: Individual controls for each of the blendshapes of the tentacles of the jellyfish. Screenshot in Maya Credit: Julian Bonequi

4.3 Technical Limitations

One of the biggest limitations of the project was the wish for the project to be able to be shown on an Oculus Quest. While the Quest provides a lot of advantages when it comes to mobility, it unfortunately lacks in computational power. The many models, audio files and especially the ambeo sound files are a challenge for the small headset. In order to economise, it was decided to not use 96kHz audio files, but only 48kHz and in some places even 44kHz. For some of the files this means less than half of the file size, heavily reducing the computational power needed. The models were also shrunk down by the artist to use as little polygons as possible, as well as GPU instancing being enabled. This can render multiple instances of the same mesh in a scene while using fewer draw calls.

Since the project is still being developed at the point of writing this paper, it's unsure, whether the hardware might have to be exchanged in order to provide the necessary computational power. However, in order to still bring the project to other locations than only the vestibule of the Konzerthaus Berlin, a lighter version might be developed with a smaller version of the project.

5 Conclusion

In the anniversary season 2020/21, the VR project will be presented to visitors of the Konzerthaus Berlin. Like all other projects in Virtual and Augmented Reality, which were developed in the cooperative project APOLLO, "Umwelten" will be embedded in the digital exhibition in the vestibule of the Konzerthaus Berlin. The exhibition is open almost daily during the summer months and is free of charge for everyone visiting the Konzerthaus. The most important thing is to generate a low-threshold access to both contemporary music and modern technology for the user.

Acknowledgments

The project "Umwelten" is being created in close collaboration with the APOLLO members of the University of Applied Sciences (HTW) Berlin and is kindly supported by "experimente#digital" – a cultural initiative of the Aventis Foundation.

Literature

[Azum97] Ronald T. Azuma. 1997. A survey of augmented reality. Presence: Teleoper. Virtual Environ. 6, 4 (August 1997), pp. 355–385. DOI: https://doi.org/10.1162/pres.1997.6.4.355

[DrTh20] Droste, M., Thoma, A., 2020. The Virtual Konzerthaus Tour – Opportunities of interactive immersive technologies for cultural mediation. ArCo Conference, Italy, 2020.

[HBEH98] Haeckel, E., Briedbach, O., Eibl-Eibesfeldt, I. & Hartmann, R. P. (1998). Art forms in nature: The prints of Ernst Haeckel. Munich: Prestel.

[Kasu19] T. Kasuya et al., "LiVRation: Remote VR live platform with interactive 3D audio-visual service," 2019 IEEE Games, Entertainment, Media Conference (GEM), New Haven, CT, USA, 2019, pp. 1–7.

[KLPK18] S. Knopp, M. Lorenz, L. Pelliccia and P. Klimant, "Using Industrial Robots as Haptic Devices for VR-Training," 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Reutlingen, 2018, pp. 607–608.

[KNOH19] H. Kim, S. Nah, J. Oh and H. Ryu, "VR-MOOCs: A Learning Management System for VR Education," 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Osaka, Japan, 2019, pp. 1325–1326.

[LeSi19] J. Letellier and J. Sieck, "Visualization and Interaction Techniques in Virtual Reality for Guided Tours," 2019 10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), Metz, France, 2019, pp. 1041–1045.

[MiTa94] P. Milgram and H. Takemura et al. 1994. Augmented reality: A class of displays on the reality-virtuality continuum. Telemanipulator and Telepresence Technologies. 2351. 10.1117/12.197321 (1994).

[NREM08] A. Nijholt, D. Reidsma, R. Ebbers and M. t. Maat, "The Virtual Conductor: Learning and Teaching about Music, Performing, and Conducting," 2008 Eighth IEEE International Conference on Advanced Learning Technologies, Santander, Cantabria, 2008, pp. 897–899.

[SANT17] S. Serafin, A. Adjorlu, N. Nilsson, L. Thomsen and R. Nordahl, "Considerations on the use of virtual and augmented reality technologies in music education," 2017 IEEE Virtual Reality Workshop on K-12 Embodied Learning through Virtual & Augmented Reality (KELVAR), Los Angeles, CA, 2017, pp. 1–4.

[ShMX07] F. Shu, W. Mi and Z. Xu, "The Information Sharing Platform for Port Container Terminal Logistics using Virtual Reality," 2007 IEEE International Conference on Automation and Logistics, Jinan, 2007, pp. 2570–2575.

[SlMu18] Y. Slavova and M. Mu, "A Comparative Study of the Learning Outcomes and Experience of VR in Education," 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Reutlingen, 2018, pp. 685–686.

[Suth65] I. Sutherland. 1965. The Ultimate Display. Proceedings of the IFIP Congress. (1965), pp. 506–508.

[Uexk10] Uexküll, Jakob von: About the invisible in Nature. In: Österreichische Rundschau 25 (1910), pp. 124–130 14, 16, 57, 98, 107, 108, 123, 124, 125

is a rose – A Performative Installation in the Context of Art and Technology

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Abstract

The advancing technology allows new forms of contemporary art expressions which, however, require a large set of skills to be developed and therefore involve a team with diverse backgrounds. In this paper, we present implementation details and the artistic background of the art piece *is a rose* that was developed and exhibited in 2019. Based on this example and our previous experience of work on different art applications, we provide an insight into the interdisciplinary work between artists and developers.

1 Introduction

The diversity of new technologies and their possible applications have considerably expanded the creative possibilities and the scope of artistic practices. Artists that are using technology as a medium are continually testing the boundaries of what is conventionally considered art, simultaneously developing a new notion of aesthetics.

Ever since the paradigm shift from modernism to postmodernism in the 1960s, art has been increasingly changing its form from a fixed, distant and observable object (material piece of artwork or a performative work) to an *immersive experience* created at the moment of interaction between the audience and the artwork. In the field of contemporary art this led to a development of new genres like *live art* and *performance art*[1], which are often based in their non-repeatability, and thus named as *ephemeral art* [Coog11]. This period was generally marked by an advancement of interdisciplinarity and questioning of the long indisputable notions of artwork, author, necessity of a medium and the artistic market itself. The institutions that have long been considered as the gatekeepers of the exclusive art – museums, galleries, theatres, etc. – have, since then, been gradually embracing the idea of the permeability of their structures and processes through participatory approaches and flexible curatorial concepts [see Smith12].

A few decades later, towards the end of the 20th century, the development of ubiquitous technology takes place, imbuing almost all human activities with some of its forms. This phenomenon is widely known as democratization of technology [Frie99] and is in the HCI context closely related to another type of paradigm shift, namely the one from second to third wave of HCI [HaST07, Bøde15]. Stating several intellectual commitments of the third wave HCI, Harrison at al. emphasize the notion that "meaning is constructed on the fly, often collaboratively, by people in specific contexts and situations", and position "interaction itself (...) [as] an essential element in meaning construction" [HaST07]. Open for this kind of considerations, the third wave of HCI reveals a potential common ground with contemporary art. The latest interactive tech products, especially those in the field of Mixed Reality, can be evaluated concerning the impression of

1 The *performance art* owes a lot to dance as one of the art forms it originated from [Gold11], which is important in the context of the paper later on.

immersion, additionally expanding the artistic playground. Whether and to what extent the topics democratization of technology, the third wave of HCI and new tendencies in art have been interrelated exceeds the subject of this paper. However, the potential for interdisciplinary collaboration between art and interactive technology, anchored in their essentially very similar motivations for interactivity and immersivity, can be defined as its backbone.

Although it has been gaining a considerable public visibility only in the last decades, the collaboration between art, science and technology (AST) is not as novel as it might seem. Already in 1967, more than half a century ago, one of the most known AST programs was initiated in the USA by artist Robert Rauschenberg and engineer Billy Klüver under the name "Experiments in Art and Technology" (EAT) [Shan05]. The EAT was a platform that was connecting 2000 artists and an equal number of engineers and had set a ground-breaking foundation for similar endeavors. One of the leading interdisciplinary hubs in the world today is the MIT Media Lab. Professor Neri Oxman, the founder and director of the Mediated Matter, one of the Lab´s research groups, presented the *Krebs Cycle of Creativity* [Oxma16] – an antidisciplinary hypothesis and the attempt to work regardless of disciplinary boundaries towards a more interdisciplinary, entangled approach of research. Institutions such as Zentrum für Kunst und Medientechnologie (ZKM) in Karlsruhe or the Ars Electronica Center in Linz are still among the best examples of European AST programs [Shan05]. There is a growing number of AST programmes funded by local governments and the EU. Both art and technology have been contributing to their encounters in their own way. By using technology as its new medium, art witnesses not only the prospects of technological accessibility but also reconfirms its postmodern tendency to subsume and refer to everything that surrounds it. Contemporary art both intuitively appropriates technology as a medium of its expression, at the same time wittingly commenting it and reflecting on its role as such.

In the rest of the paper we will touch upon related work on interdisciplinary collaborations in art and technology and offer a terminology for differentiation between various types of application of interactive technology in the field of art in order to delineate the specific nature of the artist-technologist collaboration. As our best practice example, we will bring closer the conceptual and technical aspects of the artwork *is a rose*, open

a discussion about the experience of the interdisciplinary collaboration on this specific project through own participant observations.

2 Related Work

There is a wide range of works that offer a comprehensive overview on the achievements in the field of art and technology, like the encyclopedic work "Information Arts: Intersections of Art, Science, and Technology" by Wilson [Wils02] and the thought provoking collection of essays "Art@ Science" edited by Sommerer and Mignonneau [SoMi98]. The practical side of artistic applications of technology has been also widely reported. However, there are not many works that discuss the actual experience of collaboration between the artists and technology experts. An interdisciplinary view on the challenges and potentials that partnerships in dance and technology open, is given by Whatley and Sabiescu, who describe the "tight interplay between theory and practice, research and arts making" as a "gradual configuration of intertwined and mutually influencing *interdisciplinary artscapes* and (...) *knowledgescapes*" [WhSa16]. How the process of collaboration and implementation in art, design and technology works out in practice, with a number of illustrative case studies, is also reported by Earnshaw [Earn17]. From an HCI design perspective, a recent work by Pender and Lamas presents three case studies, one of which is related to physiological computing for performing arts, that demonstrates various challenges specifically in the exploratory front end of a design process in the transdisciplinary creative collaboration [PeLa20]. As an AR developer, Portalés gives an interesting personal insight and reports on lessons learned from her own experience in collaboration with artists [Port18].

3 Collaboration between Art and Technology

The application of interactive technology in the field of art and culture has been one of the main research interests of our interdisciplinary team during the last five years. Through different national and international projects, we collaborate both with traditional cultural institutions and the independent cultural scene, create synergies with private companies in

the field of creative industries and venture into experimental projects that support individual artistic concepts through artistic residencies. The developers in our team work side by side with artists, cultural anthropologists, exhibition and communication designers, bringing different perspectives inherited from diverse disciplinary backgrounds into discussions. On the one hand, our work in the field of art focuses on the use of interactive technologies for conveying, interpreting and curating already existing artistic or cultural content. Projects of this kind are usually conducted together with institutions that need expert support in using new technological tools. User experience design approaches that are important in these cases are here coupled by audience studies that are of central importance for such actors. On the other hand, we offer a space for collaboration and creation of new artistic content, supporting artists with technology tools and expertise throughout their creative process. In this case, the artwork is not (necessarily) created with a user/visitor in mind but designed according to the artistic concept of its author. This kind of interdisciplinary collaboration highly relies on the mutual professional respect and trust in the choices and visions of the artist, which we will further touch upon in the discussion part of the paper.

When trying to define the role of interactive technology in relation to an artistic content, a taxonomy can be offered where the interactive technology is seen as a tool for: experiencing art (A), augmenting art (B), creating art (C), as well as an art form in itself (D). While *experiencing art* (A) can be exemplified with various forms of virtual museums and exhibitions which use technology for transferring artistic content across space and time and is often used as a sort of documentation or archival, *augmenting art* (B) usually extends the basic artistic content with additional information or effects and is thus often related to AR technologies. Both are mostly, but not strictly, developed in collaborations with institutions. The role of interactive technologies in *creating art* (C) in the artistic field is one that marks the transformation between an auxiliary tool towards a creative, authoring tool. Depending on their level of accessibility and usability, they can be used by amateurs and/or artists. Finally, the fourth type of technology application, the *interactive technologies as an artform in itself* (D), is almost always related to a particular artistic appropriation. It is not necessarily following any rules derived from HCI design approaches, but is rather characterized by an idiosyncratic logic created by the

artist,mastering of which is inseparable from the artistic meaning attached to it.
The suggested interrelations between the types of technology application (A-D) and their contexts are used here as a simplified depiction of art and technology relations and a clear demarcation of our field of interest in this paper. In the following pages we will be focused precisely on the last category (D), exemplified by an interactive performative installation emerged from an interdisciplinary collaboration.

4 The Performative Installation *is a rose*

4.1 Description

The interactive performative art installation *is a rose* (2019) created by artist Charlotte Triebus and an interdisciplinary team is aiming at the question of agency from an artistic point of view, focusing on the interaction of different agents and exploring the intersection of art, dance and science. Moreover, the work is inspired by nature's strategies where communication between species is driven by subtle expression abilities [RoFi99], hardly visible to the human perception apparatus.
The mixed media installation is composed of a set up circle of nine hanging plants, the roots of which grow in a ball of moss, a low-resolution LED screen, a tracking system (with an Azure Kinect) and a computer with a small form factor. The computer runs the tracking software which detects movements and imprints of the visitors through the impact the same produces in the leaves of the hanging plants. *Asparagus plumosus* was chosen as the preferred plant to exhibit up to the tiniest movements. The plants hang from the ceiling on three thin nylon cords each to bring back the plant to its initial position as quickly as possible after moving it. The mounting, featuring 27 transparent cords appears very light, however small light reflections are visible when moving around the installation. The interaction with the plants, caused either by direct touch or indirect breeze of air, is captured as a seismographic impression of the plants and is displayed on an 1.5 m x 1.5 m^2 low resolution LED-screen. The screen is showing an interactive, computer generated modulation of a three dimen-

sional, red sphere, designed as a raster graphic, which is rotating around its own axis.

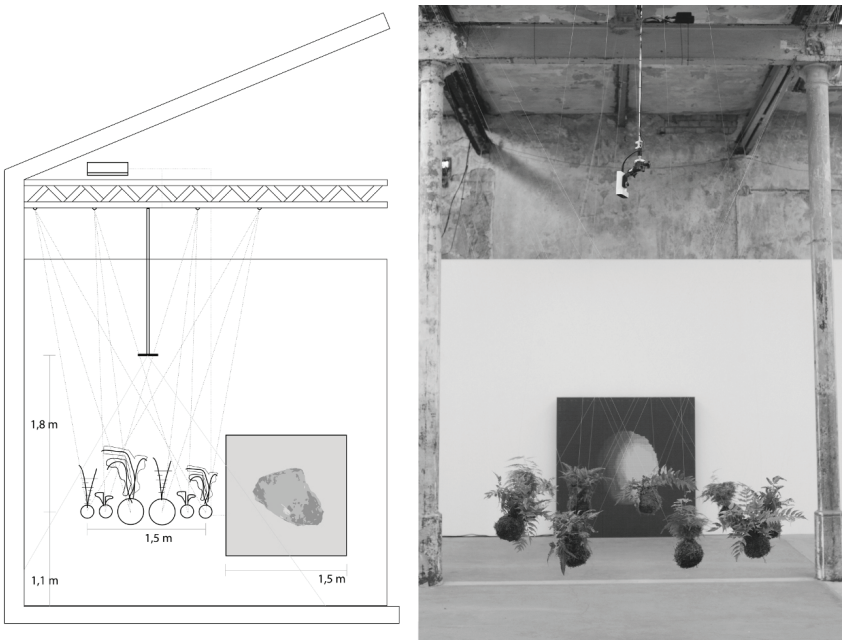

Fig. 1: Construction sketch of is a rose and finished installation at Baumwollspinnerei Leipzig 2019/2020

The animation shows each impact in real-time, using different means of deformation (such as growing, notching, tilting). The intensity of the impact corresponds to the interaction caused by breeze or touch, however the exact location of the transformation is rather not selectable. All impressions received by the plants add up over a day as a unified interaction and manifest themselves in the shape of a unique daily object shown on the screen. In this way the resulting graphics show the interaction of both intended and unintended interactions of the visitors and thus represent a temporal-spatial, living representation of a non-repeatable constellation of movements in the exhibition space.

The title *is a rose* relates to the quotation *Rose is a rose is a rose is a rose* by Gertrude Stein, that refers to different layers of possible interpretations and (visual or verbal) metaphors, one expression may bear. It is a conceptual quotation taken from literature studies and philosophy, stating the possibility of various potential connotations of the same modes of

presentation and representation. In general, the metaphor of a rose in reference to the described artwork (which in this case despite its colours is obviously no rose) convey the doubting of reality and its derived implied qualities. Comparing asparagus plants to roses underlines a discrepancy of expectation and reality as it shows parallels towards the dichotomy of the "romantic, innocent" plant and its surveilling function towards the movement of the visitors.

The work *is a rose* was realized in 2019 and premiered at *Baumwollspinnerei Leipzig* in November. It was also shown at *tanzhaus nrw* in Düsseldorf and the gallery *Priska Pasquer* in Cologne from January till April 2020.

4.2 Artistic Background

The theoretical background of *is a rose* targets two main aspects: The question of agency (the competence to act) of animate and inanimate objects such as the questioning of the traditional dichotomy of nature and culture.

is a rose is categorized as a *performative* installation, alluding to being set at the intersection between contemporary art and contemporary dance. Understanding *is a rose* as a piece of performance draws attention to the fact that it places its focus on the body as a legitimate material, the body and its movement being seen as a potential that enables to act and engage with the other. This ability to act relates to the term of agency in sociology [EmMi98] and performance [Böhm16] studies. Whoever is able to act and is enabled to take part in the formation of the piece transforms into an active or passive agent (see also [Witz16]) of the same. Agency means the capacity of an individual to act independently. Questioning humans to be the only agents within a performative arrangement to own agency, the discussion is open towards not only the audience but also other types of objects as agents within this structure. Given that individuals of other forms (such as living plants [Bara12]) have their own agency, the artwork *is a rose* creates a link between the formally unequal interacting parties.

Taking into account the definition of agents and agency mentioned earlier, we are able to define two different types of agents in this case – the visitor, being able to detect one's ability to interact and modify the installation, and the plants, serving as the transforming agent from touch to visual. Perceiving an own modus of communication between the visitor and the plants, the impression of a mimetic [Dörr16], reciprocal observation is

created. Plants and humans are forming a network where each part owns a sensory system. The perception of the visitors' own body forms part of the work of art and transforms the visitor in this moment into an active part of the performative, yet mimetic work.

Plants are widely considered passive, almost like they would not be living organisms. A reason could be that their own growth and movement is normally not perceivable by the human eye. On the other hand, the term nature has its own strong connotation in different epochs, religion and traditional symbolism. Research of sociology and philosophy reveals a common understanding of nature as a moral, historically-romantic construct [Bara12]. The 20th century develops a definition of nature way more abstract and more active – scientists do not only observe nature as given but reflect on it as being an active stakeholder of the ecosystem [see also Reck00]. With *is a rose* the artist is insinuating the analogy between artificial functions and natural capabilities in plants and intends to open the discussion for breaking the dichotomy between the traditionally connoted term of nature and contemporary technology (standing for the term *culture*).

Recent biological research has shown that plants are responding way more to their environment than commonly expected. Apart from well-known functions of response to sunlight and humidity, biological organisms are able to actuate or react to events or messages sent by other organisms close by. It is a communication [RoFi99] established due to sensing the environment around. To draw a direct connection between natural and technological resources, the artist decided to use plants as natural interfaces for an interdependent interaction between the visitors and the exhibited plants, in order to open up a discussion to consider plants as an equitable actor. There are two present forms of equitability present: the plant being equitable towards the visitor in terms of agency as well as the surveilling plant being equitable to a technological device. Other than projects using biological sensors [for example SaMa19], the movement of the plant is tracked visually (passively) only illustrating the possible biological process for interactive use.

4.3 Technical Implementation

The software implementation was carried out in an iterative and agile development process that was aimed at being very responsive to chan-

ging demands of the artist. Compared to other development of standalone computer systems, it was challenging to specify what kind of system had to be created since the artist's vision of the installation was still in development as the initial resource planning and decision for an approach had to be made. The development consists of two main aspects: the detection of movement of plants and the deformation of the computer generated sphere.

The detection of movement was an experimental part of the development. Different approaches were considered, e.g. using diverse microelectronics or camera images. By testing different approaches and considering advantages and disadvantages from technical, pragmatic and artistic perspective, it was decided to use an Azure Kinect IR-Depth-sensor to detect movement of plants and using basic image processing operations of the depth image such as thresholding and calculating difference between two images, as most reliable and most promising. The system is designed in a semi-autonomous manner: After the initial setup, a supervising operator marks the position of each plant in the depth image and defines clipping planes. During startup, the system automatically gathers noise data for each plant to determine threshold values for each plant. If during the runtime the determined noise threshold for a specific plant is exceeded, that plant is considered 'moving'. The deformation is implemented in the 3D-realtime-engine Unity3D 2019. The three-dimensional sphere is procedurally generated by subdividing a icosahedron multiple times to create a three dimensional sphere with 40962 vertices and rendering it with a resolution of 180 x 180 pixels and a custom shader that creates the impression of red LEDs with 5 discrete levels of light emission. Multiple invisible deformers move on the sphere's surface and deform the sphere's mesh with a distance dependent smoothstep modulated multi-octave perlin noise with individual parameters for each deformer that were designed to produce shapes of natural stones. The strength of deformation of each point is controlled by the strength of detected movement of a manually assigned plan.

As *is a rose* is intended to be exhibited at different locations, one challenge was to make it possible to remotely monitor and maintain the application. This is done using a remote desktop software and plain-text configuration files that allow examining the system status at any time.

5 Discussion and Conclusion

Using interactive technology in the field of art remains a challenge for all stakeholders. In contrast to its the different uses from category A to C, as introduced in chapter 3, which are either transmitting existing artistic content (A), augmenting existing art (B), or using interactive technology as an amalgam of auxiliary and creative tool (C), projects belonging to category D, where technology is used as an artform itself, do need a different approach in the process of creation.

Art projects cannot be characterized as homogeneous because they usually aim for uniqueness. This often involves more human resources, as each art piece that incorporates technology requires individual development and a diverse team that provides backgrounds in various fields of engineering and science to support the creation of the artist's vision. As interdisciplinary collaboration implies using different approaches and expectations, challenges arise in regards to differing *vocabularies*, *norms*, *working practices* and *paradigms* that allow the evaluation of the project outcome [Earn17]. Furthermore, the object of the evaluation itself is subject to discussion: while the developer evaluates the understanding and usability of the work from the perspective of the users/ visitors, the artist evaluates the extent to which the outcome manifests the intended artistic vision. For example, art pieces do not necessarily have to be task-oriented or user-centered from the HCI point of view and could still function properly from the artist's point of view. This is comparable to the difficulty of evaluating non-task-oriented systems, which need their own methods and techniques for evaluation [HaST07].

A big challenge for the supporting team seems to be the discrepancy of, on the one hand, assisting and consulting the artist in creating an art piece that utilizes state-of-the-art technology by providing expert insight into a field of engineering, and on the other hand, accepting that some rules from the very same field do not apply for art. In the case of *is a rose*, we experienced the discussion where HCI developers wanted to make sure that the usage of the plants as a natural interface is obvious to each visitor – the artist nevertheless was very pleased by visitors being puzzled and insecure whether to interact with the installation or not. The purpose set by the artist was rather the exploration of the possibility of interaction than the successful communication of the task. The same applies to the

deformation of the visual that was produced by visitor's interactions – the HCI developer intended to show a strong and clear impact of each interaction, the artist however decided for a subtle and not assessable impact to underline the perception of exploration for the visitor.

From our point of view, each constellation of the stakeholders brings divergent starting points and goals to an art project and they have to be considered individually. A proposed way in order to develop a good work environment is a clear decision structure and the open and respectful communication between each stakeholder. In order to target a common vocabulary it is necessary to clarify milestones and common wording. Currently, we are working on deriving guidelines that emerged from reflecting on the challenges, obstacles and successes encountered during the process, and which might be reconsidered by other similar projects and simplify the development process by providing best-practice structures and communication strategies.

Literature

[Bara12] Barad, Karen: Nature's Queer Performativity. In: Kvinder, Køn & Forskning Nr.1–2, 2012, pp. 25–53

[Bødk15] Susanne Bødker. 2015. Third-wave HCI, 10 Years Later – participation and Sharing. interactions 22, 5:2015, pp. 24–31.

[Böhm16] Böhme, Hartmut: Agency, Performativität und Magie der Dinge. In: Beseelte Dinge. Design aus Perspektive des Animismus. transcript, 2016, pp. 25–51.

[Coog11] Coogan, Amanda: What is... Performance Art?. Irish Museum of Modern Art 2011. pp. 4–21.

[Dörr16] Dörrenbächer, Judith: Design zwischen Anthropomorphismus und Animismus. In: Beseelte Dinge. Design aus Perspektive des Animismus. transcript, 2016, pp. 71–94.

[Earn17] Earnshaw, Rae: Art, Design and Technology: Collaboration and Implementation. 1st ed. Springer. 2017

[EmMi98] Emirbayer, M.; Mische, A.: What Is Agency? In: American Journal of Sociology, Vol. 103, No. 4 The University of Chicago Press (January 1998), pp. 962–1023

[Frie99] Friedman, T.L. (1999). The Lexus and the Olive Tree: Understanding Globalization. New York: Random House.

[Gold11] Goldberg, RoseLee: Art: From Futurism to the Present. 3rd ed. Thames and Hudson, New York 2011.

[HaST07] Harrison, S., Sengers, P., Tatar, D.: The Three Paradigms of HCI. Alt. CHI 2007, ACM Press, New York 2007. pp. 1–18.

[Oxma16] Oxman, Neri: Age of Entanglement. In: MIT Press, https://jods.mitpress.mit.edu/pub/AgeOfEntanglement 2016

[PeLa20] Pender, H.; Lamas, D.: The Challenging Front Ends of Accelerated Transdisciplinary Design Processes. In: ARTECH 2019: Proceedings of the 9th International Conference on Digital and Interactive Arts. ACM New York 2020. Article No.: 44, pp. 1–8.

[Port18] Portalés, Christina: When Augmented Reality Met Art: Lessons Learned from Researcher–Artist InterdisciplinaryWork. In: Multimodal Technologies and Interact. 2018, 2(2), p. 17

[Reck00] Reck, Hans Ulrich: Neue Natürlichkeit? Alte Vorstellungen, skeptische Betrachtungen. In: Breidbach, O.; Lippert, W. (Hrsg.): Die Natur der Dinge. Springer-Verlag Wien 2000, pp. 29–37

[RoFi99] Robinson, D.; Fitter, A.: The magnitude and control of carbon transfer between plants linked by a common mycorrhizal network, Journal of Experimental Botany, Vol. 50, No. 330, pp. 9–13, January 1999

[SaMa19] Sareen, H.; Maes, P.: Cyborg Botany: Exploring In-Planta Cybernetic Systems for Interaction. CHI'19 Extended Abstracts, May 4–9, ACM 2019

[Shan05] Shanken, A. Edward: Artists in Industry and the Academy: Collaborative Research, Interdisciplinary Scholarship and the Creation and Interpretation of Hybrid Forms. Leonardo 2005, 38, pp. 415–418.

[Smit12] Smith, Terry: Thinking Contemporary Curating. Independent Curators International (ICI), New York 2012.

[SoMi98] Sommerer, C. (Ed.), Mignonneau, L. (Ed.): Art@Science. 1st Edition. Springer 1998.

[WhSa16] Whatley, S.; Sabiescu, G. A.: Interdisciplinary Collaborations in the Creation of Digital Dance and Performance: A Critical Examination. In: Cultural Heritage in a Changing World. Ed.: Borowiecki, J. K.; Forbes, N.; Fresa, A. Springer 2016. pp. 111–124.

[Wils02] Wilson, Stephen: Information Arts Intersections of Art, Science, and Technology. Leonardo 2002.

[Witz16] Witzgall, Susanne: Immanente Relationen: Von der Handlungsmacht der Dinge zur nicht-repräsentionalistischen Kunst und relationalem Design. In: Beseelte Dinge: Design aus Perspektive des Animismus. transcript, 2016, pp. 97–117

Bauhaus Meets VR

Time Travel into a Virtual Reconstruction of the German Building Exhibition of 1931

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Abstract

The celebrations in the Bauhaus year 2019 documented a trend towards the integration of immersive media applications, which were intended to provide guests with a new experience of perception. Examples of the visualization of historical exhibition rooms include the virtual reconstruction of a hall of the legendary Werkbund exhibition "Film und Foto" from 1929, the exhibition "Zukunftsräume" (Dresden Albertina), the visualization of a "Stadtkrone für Halle" or the room installation on the "Frankfurter Küche" (exhibition "Moderne am Main 1919–1933"). As a best-practice example, an interdisciplinary team of experts and students from architecture, immersive computer technologies, and history and communication science from two universities in Erfurt launched a VR reconstruction of the exhibition hall of the building trade unions (Baugewerkschaften) at the "Deutsche Bau-Ausstellung" (short BGWA) of the Werkbund (May 9 – Aug 2, 1931) in Berlin.

1 Background

Designed to provide information, the BGWA exhibition was compiled by the influential trade unions and their business enterprises. The introductory text explains that "the free German trade unions want to bring the lifestyle of the workers to the highest possible level and to ensure that they have a permanent and humane share in the achievements of culture". As a cooperation of the former Bauhäusler Walter Gropius, Herbert Bayer and László Moholy-Nagy, it set standards in information design in its time by using large photos, image statistics and interactive elements [Röss19].
An interdisciplinary team of experts and students from architecture, history and communication science, and immersive computer technologies from two universities came together to let everybody discover those almost forgotten, remarkable solutions in a lively and "natural" manner. At the same time, the diverse background of our team members reflects the origins of the BGWA formation, which emerged from a fruitful cooperation of officials from politics and the Unions on the one and the architects, exhibition and graphic designers on the other hand. This indicated already in 1931 the spirit of Bauhaus education, where students were also trained in a broad range of subjects before specializing in their individual field of expertise. With our team we not only faced the challenge in the reproduction of the objects but also in the coordination of the different disciplines synchronizing different mental concepts and wording. While the geometrical elements were reconstructed mainly from architects, the technical setup and implementation of rendering, movement and interaction were covered by students and experts of computer science.

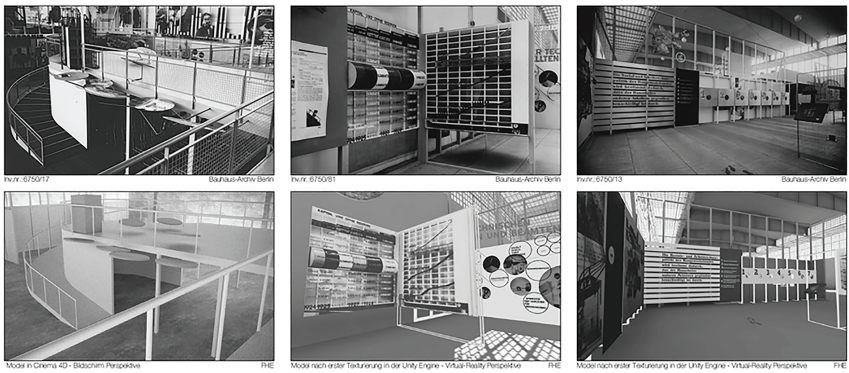

Fig. 1: Comparison of the historical photo documentation with screenshots of the VR implementation

In historical comparison, this exhibition could be reconstructed relatively well, since the Berlin photojournalist Walter Christeller was hired to produce a comprehensive photo documentation of the hall. Additionally a blueprint of the original floor plan from the Bauatelier of Prof. Walter Gropius, which reproduces the planned arrangement of the individual stands and their display elements in DIN A1 format, was available. Based on this material it was possible to digitally reconstruct the approximately 850m² hall with its several booths (Fig. 1), and to set individual interactive elements in motion as exemplars. The VR presentation is shown using a VR-Headset (HTC Vive); a screen recording of the VR experience is available at https://player.vimeo.com/video/341519354#t=15s. The presentation was embedded into a set of twelve large printed panels with context information about the exhibition, its designers and its significance as well as the development of the reconstruction. The images on the panels could be augmented with several animated spatial presentations by Augmented Reality-App (prototype for tablets and mobile phones).

2 Realization in Past and Present

2.1 Visualization

With Walter Gropius and his team, the organizers of the 1931 exhibition had deliberately engaged the most progressive architects and designers in the German Reich, who had caused an international sensation just the

year before with their design of the "Section Allemande" in Paris [Jaeg07]. While the focus there was on three-dimensional objects – from glasses and cutlery to interior design and entire room ensembles – this part was drastically reduced at the BGWA: only a few architectural models were actually used as three-dimensional exhibits to illustrate modern building methods. In addition, however, the Gropius team succeeded in turning the entire exhibition hall into one big three-dimensional exhibit with the built-in, walk-in room object, which could be perceived on different levels via the ramp and staircase. Statistics and messages were assembled into gigantic murals, which, via the built-in gallery, had an effect on the visitor as a spatial experience ("The best view from above!").

The creative two-dimensional visualizations of brittle data, text-heavy information and trade union demands are certainly regarded today as an epoch-making pioneering achievement in information design. Herbert Bayer, already one of the pioneers of "New Typography" [Röss17] at the Bauhaus, has not only created exemplary clear and reduced exhibition panels for this purpose, which also present the relevant contexts in a way that is understandable for the flâneur. In addition, he used the stylistic feature of photomontage, which was popular at the time, to visually condense facts, or developed display boards based on the pictorial statistics, which were significantly influenced by Otto Neurath and his "Viennese method of image statistics" [EvBu10]. In addition, the efforts to transfer the two-dimensionally presented information into a three-dimensional situation of reception are repeatedly striking. Visitors encountered "floating" imprints on transparent, upstream planes, through transversely tensioned cords as connecting lines, or even a motor-driven element that allowed a series of vertically mounted, printed slats to rotate, which thus joined together to form different overall images (Fig. 2).

Fig. 2: Changing pictures exhibit with rotating photo panels

The use of hardware and software applications of VR enables the creation of realistically experienced situations through particularly strong immersion and natural forms of interaction (DGBJ13: 17). This approach is particularly suitable for complex rooms with a high information density. The immersion effect describes the illusion of being present in a virtual space and depends on various presentation factors [ScTs18: 20].

As added value to just looking at the historical photos the VR experience gives users the feeling of being present in the exhibition space and discovering its content just like a visitor in the past. Unlike in a movie with fixed sequences this can happen in personal order and speed and helping to understand dimensions and spatial relations better. How different the views on the bridge were from those from the corners can now be experienced close to natural. Additionally to the realistic – or better: plausible – visual presentation, audio effects like ambient and effect sounds support the feeling of presence.

One challenge for the redesign was the interpretation of the spatial arrangement and construction from given flat photos. Since the exhibits were based on some overt construction principles, the reconstruction was

possible in most cases. More difficult and partly unsolved was the definition of objects that transformed by itself or could be changed by visitors. If the mechanics are can be reconstructed, the technical implementation as animated objects is complex but possible. Since photos are just black and white it is not known what colors were actually used in the exhibition. Therefore the reconstruction is also only toned in shades of grey.

2.2 Navigation

It is known from the exhibition designers from the Bauhaus environment that they attached great importance to sensible visitor guidance to make orientation in the room easier. To this end, the empty hall was given a rhythm by individual booths along the walls, but especially by variable partition walls and free-standing display boards. Bayer was also known for the use of footprints glued to the floor to direct the streams of visitors and mark important positions for the viewer. The application of arrows to direct the viewer's gaze was already a popular feature in the layouts of the "New Typography" [Röss18], which also made it easier to navigate through the high density of information in the exhibition. Finally, the aforementioned bridge element also gains in importance in this context: the possibility of being able to overlook the exhibition in its entirety from a central, elevated point also made it easier for visitors to orientate themselves during their tour of the individual booths.

The limited interaction space of the VR Setup of about 4x4 meter in the replica does not allow for a corresponding physical movement within the entire exhibition of appr. 850 square meters. Because so called "joystick movements", known from video games played on monitors, cause motion sickness we implemented a teleportation mechanism where one points to a valid target point with a handheld controller and jumps to it when clicking. This enables the visitor to first approach an exhibit in leaps and bounds, and then to walk towards it. While this is an efficient method, it takes (older) people with no prior use of game controllers some time and learning to adapt.

2.3 Interaction

The BGWA also plays a pioneering role with regard to the integration of interactive exhibits, which today is regarded as an indispensable must in exhibition design: the visitor is to be stimulated by manually dealing with

the exhibits and his or her gain in knowledge is to be increased by this activation [MüMö14]. The documentation photos show that corresponding components were provided at least in some places: On the one hand, we can observe a young lady turning a crank under a peephole; as a result, different objectives of economic management appear in her field of vision (Fig. 3). In a different area, another crank set a vertically running picture frieze in motion, which illustrated the social consequences of organisational changes (Fig. 4). An elaborate installation by the Association of Social Building Companies included 80 pull-out boards on which the affiliated companies presented their work and their buildings. In addition, one exhibit had a (rotatable?) cylinder attached to it, which was intended to illustrate the growth of open reserves over the six years from 1924 to 1929, but whose functionality is no longer apparent from the documents. Next to it, on a separate wall, the information panels rotated centrally around a horizontal axis, but without any deeper didactic meaning.

While navigating from one exhibit to another is the core type of interaction with an exhibition we followed the idea of the original creators that humans better conceive and understand content by physical exploration. We were not only able to rebuild many of the interactive exhibits but also created types of interactive presentation that are possible with digital technologies only – an adequate effort assumed. One idea to transform the exhibition into present days was to exchange content from the historical exhibition with related information from today. So it is possible to point to the image of a draughtsman with the controller to see it swapping to a computer screen with a CAD drawing. However, it is still a challenge to find an interface solution where all users know how to perform these interactions.

Fig.3 & 4: Visitors moving a crank to interact with the exhibit

2.4 Communication

The public was addressed by the media as early as 1931, both inside and outside the actual exhibition. The most conspicuous element here was certainly the projection of educational and educational films in a cinema hall set up especially underneath the bridge element. Although no screening programme has survived today, it can be assumed that a (socially) critical examination of aspects of ("new") building took place here. Christeller's high-quality, professionally produced documentary photos were certainly intended, however, for external presentation. Today, they allowed our VR reconstruction, but at that time they were certainly also distributed for use in press and public relations work. A meaningful example of this is the extensive report on the exhibition hall in the June issue of the magazine "Soziale Bauwirtschaft", which prints around 20 of the photos, some of them in large format [Rode31]. Of course, the BGWA was also listed in the official catalogue of the German Building Exhibition – but there only with a modest entry and a brief description that conveys none of the spectacular information design that awaited visitors in this hall. Probably even then, the public's interest was more focused on the practical applications and furnishing examples of building activity, and less on the strenuous data, reports and demands of the trade unions.

Initial plans for our 2019 presentation of the reconstructed BGWA included just a single local exhibition with printed panels, the VR and AR applications, flanked by flyers and an exhibition catalogue. But soon our exhibition was invited to be shown in the context of other exhibitions during the Bauhaus anniversary year in various museums. A press release led to supra-regional reporting and a news report was broadcast in the nationwide "Tagesthemen" of the ARD. This could be interpreted as interest that goes beyond research and shows how a democratization of knowledge for a broad public can come into life based on contemporary VR and AR technologies.

3 Reflections on the Project

Our claim for the virtual reconstruction of a historical exhibition from 1931 has always been derived from the necessity of a most authentic, true-to-life reproduction of what was found at that time. Here, however,

discrepancies were already apparent in the past, for example when the ground plan from Gropius' architectural studio was implemented in practice with some significant deviations, as the documentation photos show. However, even the extensive set of 80 high-quality illustrations was not able to cover the hall completely, which is why some gaps remained in the wall design as well as in the reproduction of the architectural models on the bridge and the functionality of the interactive elements. This clearly raises the question of what is and what is not allowed in the process of digital VR reconstruction? Are the gaps filled with self-generated content to enable a fluid perception of space? Or do we show the "blind spots" of historical tradition for what they are – flaws in the visual memory of the 20th century?

But of course, the surviving documents also have obvious weaknesses: first and foremost the fact that the photographs were taken in black and white, but the exhibition itself was designed in colour by the designers. Here, too, it would be conceivable to appreciate the original colourfulness on the basis of the shades of grey and thus intensify the visitor's sensation, but does the result still meet the requirements of a scientifically correct presentation?

Many events with our VR environment have already shown that users are initially overwhelmed by the VR experience and are busy processing the new spatial impressions. This is regularly followed by astonishment at the time machine effect, while the actual content – i.e. the messages of the exhibition at the time – is consumed rather selectively and without much reflection. In some ways, this resembles the thrill that the audience felt during the first silent film screenings when they saw a locomotive racing towards them. Today, for many people, even VR experiences still have more of the appeal of a fairground attraction than they would be able to make the medium fertile for a serious reception of information.

Looking into the future, we started to work on porting the application to mobile VR hardware like Oculus Quest to reach more users more easily. Additionally, we would like to enable users to visit the exhibition virtually together with other users sharing the visit and discuss contents like you do in reality.

Literature

[DGBJ13] Dörner, R.; Broll, W.; Grimm, P.; Jung, B. (Hg.): Virtual und Augmented Reality (VR/AR). Springer Vieweg, Berlin/Heidelberg: 2013.

[EvBu10] Eve, M; Burke, C (Hg.): From hieroglyphics to Isotype: a visual autobiography. Hyphen, London 2010.

[Jaeg07] Jaeggi, A. (Hg.): Werkbund-Ausstellung Paris 1930. Leben im Hochhaus. Ausstellungskatalog, Bauhaus-Archiv, Berlin 2007.

[MüMö14] Müller, A; Möhlmann, F. (Hg.): New Exhibition Design 1900-200. avedition, Stutgart 2014.

[Rode31] Rode, O.: Bauausstellung und Bauhttenbewegung. Soziale Bauwirtschaft, No. 11/12, 1931, pp. 163–178.

[Röss17] Rössler, P.: bauhaus.typography. 100 Works from the Collection of the Bauhaus-Archiv Berlin / bauhaus.typografie. 100 Werke aus der Sammlung des Bauhaus-Archiv Berlin. Berlin 2017.

[Röss18] Rössler, P.: New Typographies. Bauhaus & Beyond. 100 Years of Functional Graphic Design. Wallstein, Berlin 2018.

[Röss19] Rössler, P.: Die Ausstellung als begehbares Informationsdesign. Das Bauhaus und die Präsentation der Baugewerkschaften auf der „Deutschen Bauausstellung“ 1931, in: Seemann, H./Valk, T. (Hg.): Entwürfe der Moderne. Wallstein, Göttingen 2019, pp. 173–95.

[ScTs18] Schart, D.; Tschanz, N.: Augmented und Mixed Reality. 2. A., UVK, Konstanz/München 2018.

Combining High-Fidelity Visuals and Spatial Acoustics in Virtual Reality

Auralization of a Virtual String Quartet

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Abstract

The case study presented in this paper combines a high-fidelity 3d model of the Konzerthaus Berlin with an auralization based on dynamic binaural synthesis to realise an immersive sound experience in a visually convincing setting. The implementation of the case study is extensible through other 3D models or visualisations (e.g. 360° images or videos) and provides educative elements to users by displaying additional information on the defining features of the sound experience and their visual surroundings. The ability to swap between various environments without interrupting the playback and therefore enabling users to directly compare the spatial effects of different environments is a key element of the application.

1 Introduction

Using virtual reality (VR) for education and research provides vast opportunities for interactive and immersive experiences compared to traditional media. Projects such as the Konzerthaus Berlin VR Tour [LeSi19] show that high-resolution 3D models in an immersive virtual environment are a suitable tool to convey historical and architectural insights, provided that there are appropriate interaction techniques for data manipulation and event triggering. The study described in [Braz18] evaluated the potential of VR technology in education for architectural students and inferred that VR technology assists the development of spatial visualisation.

The research area of virtual acoustics focuses on the simulation of accurate acoustics in virtual environments. The technology of making a virtual sound field audible is called auralization. Auralizations are used today in science and industry to perceptually assess the acoustics of new rooms before they are built or to revive rooms that no longer exist through acoustic reconstruction, for example to gain new insights into different fields of knowledge such as historical sciences [WeLe17]. Aural experiences combined with visuals of historical places such as the Forum Romanum or the Pnyx, for example, are used to examine their functionality in historical political speeches [KaSc18]. The interrelations between the acoustic and the visual appearance of spatial environments can be investigated in fundamental research [CCSD16, MaHo18]. In general, an interactive and immersive approach, similar to gamification, enriches the experience of hearing tests and offers the user incentives to participate in them.

Regarding interactive experiences in virtual environments, the sense of presence that the experience activates in its users is relevant. When the immersive qualities of the virtual environment allow users to feel present, the experienced application can cause emotions and reactions in users similar to a comparable real experience [SVKV01, p. 187]. The effect sound has on the experienced level of presence was examined in various studies. [HeBa96] showed that presence was positively impacted in virtual environments with sound compared to virtual environments without sound. The same study showed that spatialised sound increased the feeling of presence even further. A thorough meta-analysis of the effect of various types of immersive technologies on presence can be found in

[CuBa16]. The authors list multiple studies evaluating the effect that sound has on presence in varying implementations and conclude that sound has indeed a “small- to medium-sized effect on user presence”.

We describe a case study that combines high-resolution 3D models and an appropriate auralization of a string quartet of the Konzerthaus Berlin [LTST18] implemented as an interactive VR application. Simulated binaural impulse response datasets are used to extend the visuals with a matching virtual acoustic environment using the VAS library [ReBW19]. Therefore, users are able to experience the performance of the quartet with acoustics matching the visual scene. The application is controlled using a simple gaze-and-wait interaction to easily switch between positions and halls [LeSi19], which allows the user to compare the visual and acoustical characteristics of the Small Hall, Great Hall and Werner-von-Otto Hall in the Konzerthaus Berlin. The resulting application can be used on several platforms and devices, ranging from VR headsets to desktop computers or laptops (without the visually immersive experience). The implementation was set up to allow extensibility and interchangeability with little effort and supports various types of visualisations. Besides 3D models, 360° images or videos can be used and combined with audio.

Section 2 will outline the technical background needed to achieve a plausible acoustic reconstruction and auralization of a room with the aim to reproduce a classical concert. In section 3 the implementation of the auralization and the overall application will be discussed.

2 Auralization

In room acoustics the technique of auralization describes the rendering of a virtual acoustic environment. Auralizations can utilize both measurement-based and model-based data derived from computer simulations of rooms. Correctly implemented, the playback through headphones or loudspeakers creates the impression that the listener is located in the sound field of the measured or simulated room.

Especially in VR, the acoustics has to match the displayed room and consider the user’s natural movements and dynamically adapt the sound field to these movements. Otherwise, the sound would always be perceived as originating from the same direction despite the user’s move-

ments, similar to traditional stereo reproduction. In the present application, the user is enabled to rotate his head, but not to translate it in space. The data therefore needs to be calculated for all possible head orientation angles but only for a fixed position in space.

The auditive presentation used is based on the technique of dynamic binaural synthesis, which is perfectly suited for use with VR glasses, as these are usually used with headphones for spatial audio reproduction. This allows the playback to be controlled very precisely in comparison to a complex setup with speakers. In dynamic binaural synthesis, binaural room impulse responses (BRIRs) are convolved in real time with anechoic audio to auralize a virtual sound field. The BRIRs are exchanged in real time to match the tracked head orientation.

In the model-based approach applied here the underlying data is generated by acoustic computer simulations conducted with the software RAVEN [ScVo11]. As opposed to plug-ins currently usually applied in game engines for the real-time calculation of spatial audio such as Steam Audio by Valve or Resonance Audio by Google, this software is based on physics, well documented and scientifically evaluated [Schr11]. RAVEN also provides users with full control of all input parameters.

The model-based approach of simulating the needed BRIRs offers the advantage over a measurement-based method of being able to flexibly change e.g. listener positions and musician line-ups. The computer simulation is based on a three-dimensional model of the room and the acoustic properties of the original building materials in the room. The acoustic properties consist of sound absorption and sound scattering. The surface properties also include the occupation of the room with an audience. The audience has a decisive influence on the reverberation of a room due to its strongly sound-absorbing and scattering effect.

In addition to the room, the properties of the acoustic sources and receivers must also be integrated into the simulation. For each source, i.e. in this case each instrument, the directional characteristic, which is the directional sound radiation of the instrument, is taken into account [SBVW17]. The same applies to the listener in the virtual sound field. Since the reproduction is done with headphones, the virtual sound field must be calculated up to the eardrum of the listener. For the representation of the listener with torso, head and ears in the virtual sound field so called Head Related Transfer Functions (HRTFs) are used. HRTFs represent

the transmission path of the sound to the ear of a person and contain the acoustic properties of the body that are relevant for directional hearing. This impulse response information is available as a data set for all possible head orientations [BLWG13]. The data dependent on the head orientation is necessary because the sound field must be simulated for each combination of source and receiver individually and for every rotation angle of the head and both ears. The positions of the respective source and receiver as well as their alignment in space are encoded into the result. Therefore, a separate simulation must be performed for each head alignment to allow the free rotation of the head in the application.

Another key element of a successful auralization is a technically and musically suitable anechoic recording. As the reverberation from the simulation is added to the audio signal afterwards, the recorded piece must be anechoic. For the elaborate recording method, a procedure established at the TU Berlin is used, which had already been tested in previous productions with orchestra musicians [BoAW18a, BoAW18b], in order to produce a technically and artistically convincing recording. All instruments are acoustically separated from each other and recorded as individual audio tracks in an anechoic chamber. To ensure good intonation and exact timing, the musicians can listen to each other through headphones.

The final step is the playback via headphones during the visual presentation of the virtual environment through VR glasses. As the technique of dynamic binaural synthesis is used, the audio signal to be reproduced has to be calculated in real time, since it is always dependent on the current head position of the user. The recorded signals of the individual instruments are therefore processed in real time with the data valid for the current alignment and then played back through the headphones. This calculation of the audible output signal is performed directly in Unity by a native Unity Spatializer Plugin developed with the Unity Spatializer SDK [USDK20] and the VAS Library [ReBW19]. In contrast to previous solutions, this offers the advantage of a single running software. In previous projects, these calculations had to be performed on a second computer and had to be synchronized with Unity [HScS20].

The VAS library is a lightweight, cross platform C library, that focuses on the real time calculation of dynamic binaural synthesis. Furthermore, it provides standard DSP functionality such as delays and FIR filters

for headphone equalization and reverberation. Ready-to-use objects (resp. plugins) for Max/MSP, Pure Data and Unity can be found on the library's git repository [VAS19]. The library's main class, the vas_*dynamicFirChannel* performs an uniformly-partitioned convolution that is capable of exchanging the impulse response according to the current angle between audio source and listener. As the angle between source and listener changes, the convolution is calculated for both angles and a cross-fade is performed in the time domain [ReBW19]. The VAS Unity spatializer [ReHa19] combines two vas_dynamicFirChannels (one for the early direction-dependent reverberation, one for the late reverb) to perform the audio rendering with a non-uniformly-partitioned convolution algorithm. Using a short partition size for the early part results in a low latency which is an important factor for a smooth, dynamic binaural rendering [Li09]. A long partition size for the late part reduces the required CPU power significantly. Unlike the common spatializer plugins mentioned above, the VAS Unity plugin is able to load an individual impulse response set for each audio source. This is a necessary prerequisite for polyphonic, BRIR-based rendering.

3 Case Study

Utilising the acoustic technologies described in section 2, we developed a case study that combines an auralization of a string quartet playing the beginning of Franz Schubert's "Death and the Maiden" and high-resolution 3D models of the halls of the Konzerthaus Berlin to an immersive experience. Complementary to the audio recording, a green-screen video of the musicians is used in the application to enrich the visualisation. The video recording of the string quartet has been used previously in an augmented reality project that allows users to explore the musicians and their respective part in the play individually or combined in any arrangement [LTST18]. Having individual recordings of each musician provides benefits for many use cases, especially in immersive 3D environments where the videos can be placed in the environment.

The application was implemented using the game engine Unity, which offers a feature-rich development environment that provides essentials for interactive multimedia applications, e.g. animations, video and audio

control as well as event handling for user input. Unity was chosen because it supports most modern VR headsets natively and allows to port the application to all desired target platforms with little further effort.

Visualisation and Interaction

As part of the the research project APOLLO, a high-detailed model of the Konzerthaus Berlin was produced as content for their digital exhibition. This model consists of the exterior view of the building as well as the five major halls inside the building. The aim for the model was to be as photo-realistic as possible, as it is used in the digital exhibition to represent the parts of the buildings that are inaccessible to tourists and visitors without a concert ticket and therefore often the only experience they get of the halls. The textures of the models are based on close up photographs of elements of the interior, condensed into multiple texture atlases.

To reduce the computational complexity of rendering the detailed model, the lighting in all halls but one is fixated: The lighting was calculated once with high accuracy and was written into the texture. The obvious drawback of this approach is that the lighting cannot be altered at runtime or even inside the engine during development without generating a new set of textures. The hall with dynamic lighting is the Werner-von-Otto Hall (WOH) which is mostly used for contemporary music. Reflecting the deviating kind of music played in the hall, the WOH is a lot less complex regarding its architecture as well as its textures and therefore manageable to light in real-time on most devices. Further details on the production and optimisation of the model for the targeted hardware may be found in [LeSi19].

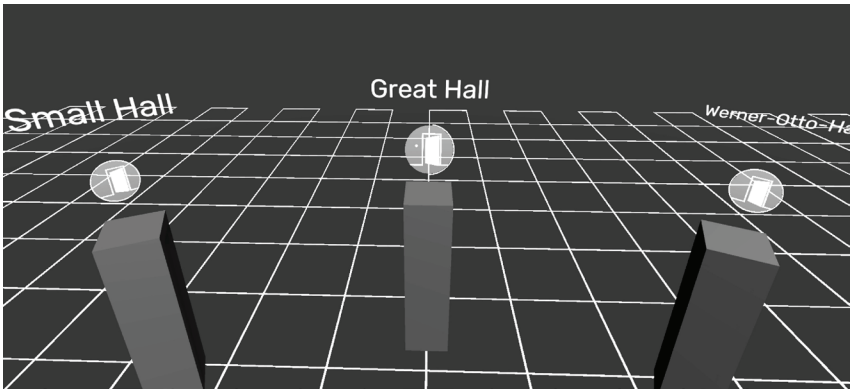

Fig. 1: Connecting hub of the application

Besides the Konzerthaus model used in the case study discussed in this paper, the application can be easily extended with further models or other visualisations. The application features a hub that allows to navigate the visualisations (see fig. 1) by utilizing the aforementioned gaze-and-wait interaction. Through further gaze-and-wait controlled elements it is also possible to connect different visualisations with each other, which in result allows the user to switch between them at runtime and directly compare their acoustic qualities. As this comparison is one of the core ideas of the application, the mechanic is designed to realise the switching between two visualisations and their respective auralization with as little interruption as possible. The interaction technique is described in more detail in [LeSi19] and was tested in multiple user studies.

The application starts with the aforementioned central hub that allows users to choose a virtual environment. The hub is a mostly featureless, dark room and represents each virtual environment as a stele labelled with the name of the respective environment and a sphere on top of it that can be used for a small preview. The hub is meant to be used in the future to install new environments from a content management system (CMS). In this case study, users can choose between the Small Hall, Great Hall and Werner-von-Otto Hall in the Konzerthaus Berlin. Once selected, the user is able to hear and see the virtual quartet from four distinct positions switching between them using the gaze-and-wait interaction technique.

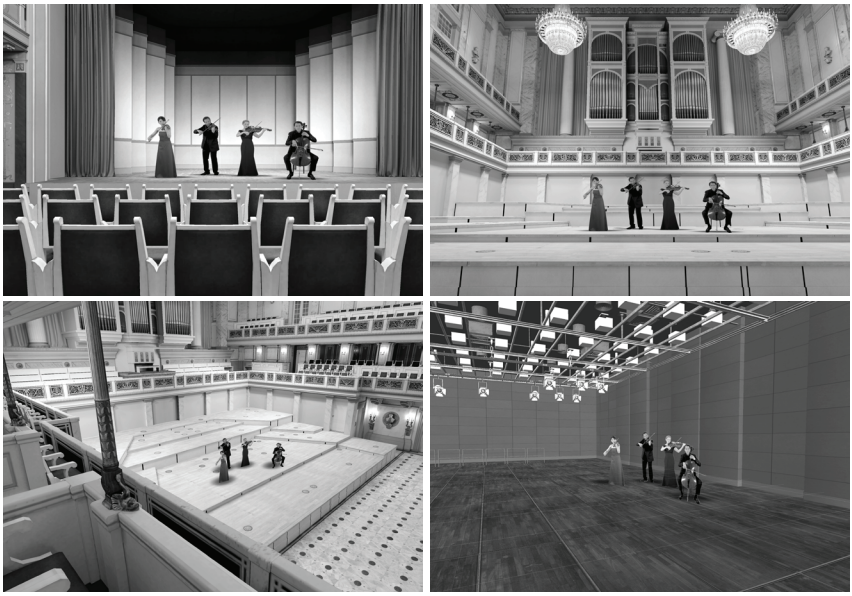

Fig. 2: Screenshots from the four positions currently featured in the application: Small Hall (top left), front row of the Great Hall (top right), upper tier of the Great Hall (bottom left) and Werner-von-Otto Hall (bottom right)

The listener position in the Small Hall provides a straight view on the musicians from the fifth row. This is a realistic representation for the type of concerts the recorded string quartet belongs to, as the hall provides the right acoustical conditions for chamber music. The second position is situated in the first row of the Great Hall. While this also provides a direct view on the stage, the hall is typically used for larger orchestral arrangements. Users are able to hear distinct differences between these two positions. The application features a second position in the Great Hall and another one in the Werner-Otto-Hall. The latter room also provides distinct acoustical characteristics and is mostly used for contemporary music. Fig. 2 demonstrates the view a user experiences from each of the positions. Additionally, users are presented with plus icons that provide information on the different characteristics of the positions and halls. Fig. 3 illustrates an example of such an educational element. These elements can be used in other models as well and should be integrated into the CMS.

Fig. 3: An example of an activated plus button with its information displayed

3.1 Implementation of the Auralization

The 3D models of the visualisations were simplified for the acoustical simulation of the halls, as the resolution necessary for acoustic simulations is considerably lower than the resolution required for photorealistic visual quality. The geometry of the room and the interior is modelled with a resolution of about 0.5 m. Every detail smaller than this threshold is not drawn in the model but considered by the scattering coefficient of the corresponding wall. For the surfaces of the rooms, absorption was first determined according to the respective building materials. In an iterative process, the reverberation time of the virtual room calculated with these parameters was adapted to previously performed measurements in the real environments.

In a next step, the positions of the musicians in the room were determined and two receiver positions for the later auralization were defined for each room. Suitable directivity patterns from [SBVW17] were used for the sources, whereas the FABIAN data set [BLWP17] was used as HRTF data set for the simulation. At the receiver positions BRIRs were calculated for all head orientations in the horizontal plane with a resolution of 2 degrees.

This required 4320 simulations for all rooms and positions. The impulse responses thus obtained were saved in the text file format accepted by the VAS-Unity plugin used to render the audio in real time during playback of the visuals.

In Unity, all BRIR data sets for all instruments, rooms and listener positions are loaded by the VAS plugin at the start of the program. This results in a relatively large memory load but ensures that no further delays during runtime are necessary. The same applies to the anechoic music tracks. When switching between rooms and positions on a visual level in the application, the corresponding instances of the plugin that are needed for the currently required signals are activated and the instances that are not needed are switched off. This limits the computing power required to the four sources that are to be convolved simultaneously. These changes are controlled by C# scripts that access the properties of the VAS Plugin explained in section 2.

The required anechoic recordings of the string quartet were made in a previous project [LTST18]. As described in section 2, the four instruments were recorded acoustically separated from each other in the anechoic chamber of the TU Berlin. This separation allows the reproduction in the virtual environment as individual voices and extends the authentic reproduction by technical features such as the possibility to hide individual voices during playback.

4 Conclusion

The presented use case shows that by combining high-fidelity 3D models with an auralization of the audio sources, an immersive virtual environment can be created of a complex multimodal space. While it offers a convincing experience of culturally important sites, it also can also be a valuable tool for research and provides new ways of imparting knowledge, e.g. about classical music and the related performance venues, as in our use case. Finally, it also allows any interested person to experience the acoustical characteristics of individual rooms and with different audio content.

Future implementations could provide authoring tools to easily create these virtual environments without expert knowledge in 3D development.

This should pave the way towards widespread usage of the described technology for smaller research institutions and a broad range of cultural applications.

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Literature

[BoAW18a] Böhm, Christoph; Ackermann, David; Weinzierl, Stefan: A Multi-Channel Anechoic Orchestra Recording of Beethoven's Symphony No. 8 Op. 93. (2018)

[BoAW18b] Böhm, Christoph; Ackermann, David; Weinzierl, Stefan: Eine Mehrkanalige Und Nachhallfreie Aufnahme Von Beethovens 8. Sinfonie. In: Fortschritte der Akustik: Tagungsband der 44. DAGA, pp. 112–15 (2018).

[BLWP17] Brinkmann, Fabian; Lindau, Alexander; Weinzierl, Stefan; van de Par, Steven; Müller-Trapet, Markus; Opdam, Rob; Vorländer, Michael: A High Resolution and Full-Spherical Head-Related Transfer Function Database for Different Head-Above-torso Orientations. In: Journal of the Audio Engineering Society, Vol. 65 (10), pp. 841–48 (2017).

[BLWG13] Brinkmann, Fabian; Lindau, Alexander; Weinzierl, Stefan; Geissler, Gunnar; van de Par, Steven: A High Resolution Head-Related Transfer Function Database Including Different Orientations of Head Above the Torso. In Fortschritte der Akustik: Tagungsband der 39. DAGA, pp. 596–99 (2013).

[Braz18] Brazley, Michael Duwain: Architecture, virtual reality, spatial visualization, learning styles, and distance education. International Journal of Architecture, Arts and Applications, Vol. 4 (2), (2018).

[CCSD16] Gil-Carvajal, Juan C.; Cubick, Jens; Santurette, Sébastien; Dau, Torsten: Spatial Hearing With Incongruent Visual or Auditory Room Cues. Scientific Reports 6, 37342 (2016)

[CuBa16] Cummings, James J.; Bailenson, Jeremy N.: How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. In: Media Psychology, Vol. 19 (2), pp. 272–309. Taylor & Francis (2016).

[HeBa96] Hendrix, Claudia; Barfield, Woodrow: The sense of presence within auditory virtual environments. In: Presence: Teleoperators & Virtual Environments, Vol. 5 (3), pp. 290–301. MIT Press (1996).

[HScS20] Holter, Erika; Schäfer, Una Ulrike; Schwesinger, Sebastian: Simulating the Ancient World : Pitfalls and Opportunities of Using Game Engines for Archaeological and Historical Research, pp. 217–32. London: Bloomsbury Academic, 2020.

[KaSc18] Kassung, Christian; Schwesinger, Sebastian: Saxa Loquuntur: The Function of (Multi-) Media for Antique Architecture. In: Digitisation of Culture: Namibian and International Perspectives, pp. 171-185. Springer, Singapore, 2018.

[LeSi19] Letellier, Julien; Sieck, Jürgen: Visualization and Interaction Techniques in Virtual Reality for Guided Tours. In: 10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), pp. 1041-1045, Metz, Frankreich, 2019, ISBN 978-1-7281-4068-1

[LeTh18] Letellier, Julien; Thoma, Annette: Das „Virtuelle Konzerthaus“: Kulturelle Teilhabe durch Digitalisierung. In: EVA Berlin 2018: Elektronische Medien & Kunst, Kultur und Historie, pp. 84–91, Berlin, 2018, ISBN 978-3-88609-817-0

[Li09] Lindau, Alexander: The Perception of System Latency in Dynamic Binaural Synthesis. In: Proceedings of the NAG/DAGA. Rotterdam, Netherlands, 2009.

[LTST18] Letellier, Julien; Thielen, Elisabeth; Sieck, Jürgen; Thoma, Annette: Bringing a Virtual String Quartet to Life. In: 2nd African Conference for Human Computer Interaction (AfriCHI ’18), pp. 208–211, ACM, New York, NY, USA, 2018

[MaHo18] Maempel, Hans-Joachim; Horn, Michael. Audiovisual Perception of Real and Virtual Rooms. Journal of Virtual Reality and Broadcasting Vol. 14 (5), pp. 105–106 (2018).

[ReBW19] Resch, Thomas; Böhm, Christoph; Weinzierl, Stefan: VAS - A crossplatform C-library for efficient dynamic binaural synthesis on mobile devices. In: International Conference on Headphone Technology. San Francisco, CA, USA, 2019

[ReHa19] Resch, Thomas; Hädrich, Markus: The Virtual Acoustics Spaces Unity Spatializer with custom headtracker. In: Proceedings of the Spatial Audio Conference. Ilmenau, Germany, 2019.

[SBVW17] Shabtai, Noam R.; Behler, Gottfried; Vorländer, Michael; Weinzierl, Stefan: Generation and Analysis of an Acoustic Radiation Pattern Database for Forty-One Musical Instruments. Journal of the Acoustical Society of America Vol 141 (2), p. 1246 (2017).

[Schr11] Schröder, Dirk: Physically Based Real-Time Auralization of Interactive Virtual Environments. Dissertation diss., Rheinisch-Westfälische Technische Hochschule, 2011.

[ScVo11] Schröder, Dirk; Vorländer, Michael: Raven: A Real-Time Framework for the Auralization of Interactive Virtual Environments. Forum Acusticum, pp. 1541–1546 (2011).

[SVKV01] Schuemie, Martijn J.; Van Der Straaten, Peter; Krijn, Merel; Van Der Mast, Charles A.P.G.: Research on presence in virtual reality: A survey. In CyberPsychology & Behaviour, Vol. 4 (2), pp. 183 - 201. Mary Ann Liebert, Inc (2001).

[USDK20] Electronic Resource: https://docs.unity3d.com/Manual/AudioSpatializerSDK.html, Last reached on 22.02.2020.

[VAS20] Electronic Resource: https://github.com/funkerresch/vas_library, Last reached on 28.02.2020.

[WeLe17] Weinzierl, Stefan; Lepa, Steffen: On the epistemic potential of virtual realities for the historical sciences. a methodological framework. In: Augmented Reality. Reflections on Its Contribution to Knowledge Formation (Berlin Studies in Knowledge Research 11), Berlin: De Gruyter (2017): pp. 61–80.

HoloMuse – Augmenting the Museum

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Abstract

Introducing Augmented Reality (AR) to museum mediation poses huge opportunities for the field. However, we still lack media-specific and needs-based concepts and strategies for the effective employment of AR based experiences for museum venues.

This paper introduces insights from the research project "HoloMuse" which developed concepts and implementation strategies for curators, educators or community managers to use AR for the creation of inspiring visitor experiences, cultural and science learning. Chapter 1 gives an overview of AR as an enabling space for mediation, followed by suggested AR mediation concepts in chapter 2 and technological challenges in chapter 3. Chapter 4 then discusses real-world use case studies which implemented some of the developed AR mediation concepts at the Deutsches Museum (Munich) and the Kunsthistorisches Museum (Vienna). Chapter 5 rises the need for future research towards standardization and generic solutions for AR experiences in museums.

1 Augmented Reality as Enabling Mediation Space

Whereas in the 1990s digital media and especially the Web were regarded as "parallel space", today this dichotomy does not hold true anymore. Digital media is deeply integrated in the society [Cast10; Karv07], participatory culture [JCPR09] as well as the mindset of many users and visitors [Sand14]. Current theoretical concepts such as Web Squared [ORBa09] and Net Locality [GoDe11] furthermore highlight that the digital and the physical space become intertwined. As Manovich described already in 2006 the agenda of the 21st century moved towards "the physical space filled with electronic and visual information", focusing on how to "dynamically deliver dynamic data to, or extract data from, physical space" [Mano06, p. 2219]. By now we have arrived in post-digital times, where digital media is a ubiquitous part of everyday life. Thus, the physical and the digital museum cannot be regarded as separated anymore but need to be designed and conceptualized in an integrated, holistic visitor experience.

The collection is at the core of any museum work, putting it online already poses a major challenge for all museums. However, the potential of a digitized collection is immense, and the goal must therefore be to use the digital for a successful communicative strategy in the mediation work.

Ideally, digital mediation shapes the perception of the originals and supports the visitors in their own examination and interpretation of the objects. Augmented Reality – as medium – plays exactly with the integration of physical museum space and digital information space, opening up new opportunities for holistic visitor experience design. In contrast to Virtual Reality (which offers an immersive experience in a computer-generated parallel world and, if necessary, encapsulates the user with closed glasses from the surrounding space), Augmented Reality locates the digital information in the physical space that surrounds the person. Exhibited objects thus become information hubs, the museum space being a coordinate system for digital information.

Moreover, Augmented Reality enables explicit mediation [MWFW15] in the museum, which gives visitors not only access to information but also a better understanding of situations and processes. Users interact directly with the physical object, and the medium can help them find their own access to the object and translate the object history. From a technical

perspective, special AR glasses such as Microsoft HoloLens therefore are the best solution since digital information is displayed directly in the transparent glasses and thus in the view of the visitors.
Many experiments with AR in museums and cultural heritage were conducted in the last decade. And similar to the development with Virtual Reality in museum (see e.g. [FACM16]) we see an increase of AR in the museum. With the development of affordable, market-ready Glasswear, museums will be able to extend the augmented experience beyond touch-devices.

2 AR Museum Mediation Concepts

As of today, however, what is still missing are effective media-specific and needs-based mediation concepts for the emerging possibilities of Augmented Reality technology. The opened-up mediation space of AR needs to be filled with concepts. Within the 2-year R&D project "HoloMuse", interviews with museum experts from Austria and Germany confirmed that many understand the potential of AR, but the use is limited due to open questions on added value for the mediation work. Thus, Fluxguide started to conceptualize AR mediation together with museum stakeholders. By identifying concepts such as close-looking, reconstruction or personal dialogue (real persons or avatar based), ideas were formed for cultural learning experiences where the medium AR is to strengthen the "manipulation value" [deMu09] of digital cultural objects. AR can also play a role in processes of personal appropriation of exhibition content. A recurrent question was how AR may be used sensibly to promote user-generated content during the exhibition, which then can be integrated into exhibitions or shared via the museum's social media channels. Aesthetic creation and personal stories related to urban or cultural history represent a valuable, intangible legacy for museums, which is brought in by the visitors themselves and can be secured not only for the museum, but also for the future.

Some examples of AR cultural learning experiences are:

- **Close-looking**: AR enables to show details or invisible elements of an exhibited object, that otherwise remain hidden. E.g.: a story may be told about the painting-technique of an artist and the change of an artwork over time during the process of its creation. This kind of technique was used in the mediation of the exhibit "Egon Schiele – Wege einer Sammlung" at Belvedere Museum in Vienna[1]. Other examples are cross-section views that highlight the functionality of the inner part of exhibited machines. Via annotation highlighting of specific parts of an object and explaining their functionality through media-annotations is possible. These techniques are for instance employed in the projects of the VR-Lab at Deutsches Museum in Munich[2].
- **3D Reconstruction:** The AR experience shows how an object or building could have looked like in the past. AR overlays help to understand how the object works – for example a historic machine or clock – or was used in the past. Poignant examples are augmenting a building where only ruins remain visible today with digital reconstructions or re-creating a historic site such as a Celtic grave within an exhibit as contextualization of fragmented findings shown in the museum.
- **Gamification:** It is well established that by "gamifying" learning processes it is possible to produce fun, motivation, autonomy, progressiveness, feedback, error tolerance, experimentation, creativity, or adaptation to the specific case [LDVR16]. By combining real world, 3D models, and interactivity, AR is a suitable enabling technology implementing the concept of gamification (see below the second scenario in chapter 4.2).
- **Personal dialogue:** AR brings paintings or findings alive, with storytellers presenting the object from an intrinsic perspective. These avatars may be real or imaginative persons acting as first-person narrators about what knowledge can be derived from the specific exhibited objects. At the same time these AR-Avatars act as virtual

1 For a preview of the possible AR Experience in this exhibition see: https://www.youtube.com/watch?reload=9&v=jEv6jZcRgrU

2 https://www.deutsches-museum.de/en/exhibitions/special-exhibitions/vrlab/

tour guides. But also, actual human tour guides can be featured in on-site AR-experiences. The Nationalpark Hochwald Hunsrück (Germany) employs one of its rangers as a virtual guide who guides the visitors through their tour. The person was filmed in front of a greenscreen and can be embedded on-site, giving the explanation a human touch, a face beyond just his voice, that could be featured in an Audioguide too. This gives the guide the possibility to work with body language and also physically point at specific details or actually show people around.

- **User-generated content**: The expansion of a physical exhibition and its object-stories with objects that cannot be on display physically or objects brought in by the visitors themselves, expanding the gallery display into the public space. Or – as implemented in the "curating room" at the Austrian federal museum Ferdinandeum – the virtual exhibition space can be used for personalization and user-engagement, as users can not only collect their favorite items throughout the exhibit but actually hang them in an virtual exhibition space within a mobile app and interact with their own curated exhibitions in a designated augmented room[3]. Those interested in their own creative design can also present, share and comment on their work (be it during a museum visit or by working with digitized material) on the specially created digital platforms, such as at Tate Collectives[4].

In the project HoloMuse, selected mediation scenarios were then implemented technically and piloted in renowned museums such as the Kunsthistorisches Museum (KHM) in Vienna and the Deutsches Museum in Munich.

3 See https://youtu.be/3dxuU7lJ-iQ.
4 "Tate Collectives", Online Platform of Tate Galleries, https://www.tate.org.uk/tate-collective.

3 Technological Frame and Challenges of AR at Museums

Recent technological improvements like the new frameworks "AR Core" (Google) and "AR Kit" (Apple) enable developers to offer AR efficiently, reliably and sustainably for the mobile mass market. As of today, the main devices for AR experiences are smartphones or tablets and also room projections. The acceptance of Glasswear in the museum is currently still low; the hardware is perceived as problematic (the display of digital information layers directly in the field of view of the user sometimes causes nauseance). But upcoming technological improvements will bring dedicated Glasswear to a mass and museum market, allowing a handsfree museum experience and an interaction with the experience via view, gestures and voice.
It is therefore important to develop the technological means to integrate AR-experiences into an existing mobile mediation framework and therewith a variety of guiding and learning solutions already employed in museums (smartphones, tablets, and loan-devices). Unity programming, Android/iOS programming allows to bridge experiences on mobile platforms and dedicated Glasswear inside and outside the museum. This does not only power dedicated, standalone AR-applications (including 3D Development and 3D modeling). It also makes it possible to integrate this novel technology into existing digital infrastructures of a museum.
For the technical implementation of the HoloMuse application, software was developed and tested on both mobile and wearable devices.

Some software challenges were to be tackled:

- Reliability of AR classifiers and marker-based approaches to image recognition.
- The coupling of content and spatial aspects (spatial structure of the image, representation of spatially related aspects in an image) also poses potential constraints.
- Data structures for storing the spatialized, temporally running narrative as a combined audio and marker geometry.

4 Two Scenarios of AR Based Museum Mediation

During the HoloMuse project, two real-world museum scenarios were identified, led by the questions:

a) How can visitors interactively learn about complex processes?
b) How can art-historic storytelling evolve from being a story about an artwork to directly involving the original artwork itself?

To give possible practical answers to these questions, we implemented some of the AR mediation concepts, discussed in chapter 2.

4.1 AR Gamification for Museum Learning: Deutsches Museum

How can visitors interactively learn about complex processes? To show a way in tackling this question, the concepts of "3D reconstruction" and "Gamification" (as discussed in chapter 2) were implemented at the Deutsches Museum (Munich).

For the exhibition "Kosmos Kaffee" a playful experiment was implemented that shows the influence of the climate on the yield of a coffee plant. 36 months of growth are experienced in 3 minutes in fast motion via an AR App deployed on iPads in the exhibition space. At a certain point in the game the visitor can influence the climate conditions – rain and temperature – and gets feedback on how that affects the plant and crop. This turns the interactive game into a virtual experiment and the exhibition into a digital laboratory. It follows the paradigm of "show, don't tell". The user learns by observing, doing and experiencing, not just by being given information.

Fig. 1: AR application in the exhibition Kosmos Kaffee in the Deutsches Museum. Photo: © Fluxguide

In the temporary exhibition the AR-application was installed on three tablets inside an installation that shows a coffee plantation. Visitors could see their own virtual coffee plant in the middle of the coffee plantation in the exhibition and watch it grow (on the tablet) between the other plants.

Moreover, the mediation space was extended beyond the museum itself by additionally providing the AR experience on a publicly available App in the Appstores. Hence, the same virtual experiment could be taken outside the museum – into a classroom, the visitor's kitchen or virtually anywhere. This shows the potential of AR to transform any place into a learning place or a museum and increasing the accessibility but also the possibility to interact with museum-objects or experiences also outside of

the gallery walls. Using AR, virtually any location can become a museum-based learning space.

4.2 AR Storytelling of Fine Arts: Kunsthistorisches Museum Wien

How can art-historic storytelling evolve from being a story about an artwork to directly involving the original artwork itself? To show a way in tackling this question, the concept "close looking" was implemented at the Kunsthistorisches Museum (Vienna) at the famous painting "Children's Games" by Pieter Bruegel the Elder. The painting is very rich in details, depicting 200 different games and references that are important for understanding and interpreting the artwork.

We wanted to enable visitors to explore the rich imagery visually as well as to receive profound image storytelling[5]. A personal guide was used to explain the image, pointing out and explaining the context of specific visual details as well as the depicted children games. The gaze of visitors should be led towards the details of the painting and was paired with context information to trigger own engagement with the artwork and ultimately to foster own interpretation.

The implementation of this AR application was inspired by Aby Warburg's method of "iconic annotation" from his project of the Mnemosyne Atlas (cf. [vanH95]). Digital annotation offered the possibility of locating and depicting information on the children's games directly in the painting. It also offered the possibility to create inherent references within the image as well as to other objects within the collection of the museum[6].

The scenario worked as follows: visitors were using AR-glasses (Microsoft HoloLenses) while standing in front of the painting. Thus, it was possible to both see the original itself and all physical surroundings, as well as to

5 The documentary video on the implementation of the two scenarios described can be viewed on Youtube: https://www.youtube.com/watch?v=XcKBAdEYMpY&t=96s.

6 In future mediation attempts, referencing could be extended towards other cultural institutions. Large international collection databases, such as Europeana, already offer the opportunity to deepen multimedia storytelling in Augmented Reality. In addition, a strong current development is the opening of digital museum collections to the free use of data sets in open source formats. For example, the Paris museums recently made over 100,000 works of art from their digital collections freely available. From a technological perspective, it would be more than possible that art historic storytelling in AR could be enriched by the possible access to hundreds of reference images and datasets.

receive digital information and media placed within the physical surroundings directly in the field of view. As the artwork was detected by the automated image recognition of the Glasswear, digital annotations of the image were displayed directly on the original painting.

Fig. 2: Piloting of the HoloMuse prototype "Children's Games" at KHM Vienna on October 21, 2019. Photo: © Fluxguide

Two main modes were offered. On one hand the user saw hotspots highlighted graphically on the artwork, signifying potential entry points into the work and serving as anchor-points for the gaze. By fixating these points and performing a gesture, the user was able to select a hotspot which was enriched by multimodal information: texts, images, videos and audio storytelling contextualized the selected visual detail. The second mode offered storytelling that guided the visitor along a linear storyline through a number of highlights amongst the image details which were visually highlighted while the story was evolving. This introduced the artwork in a similar way a tour-guide would do. Besides interactive hotspots, as visual anchor points, also graphic highlights, a loupe function, and audible questions would lead the gaze.

Fig. 3: Looking through the HoloLens: Highlighting of picture details directly on the original painting "Children's Games" by Pieter Bruegel d. Ä. Photo: © Fluxguide.

For museum mediators, iconographic annotation in AR opens up the possibility to address different users and their perspectives being integrated in the sense of an interpretative storytelling. Various levels of specialization may give users the choice on which story to follow and how deeply to immerse themselves in the story.

The AR device becomes a lens that the visitor can use to frame and channel the subjective experience of an artwork. How this very subjective and personal approach can be translated into a digital mediation experience and implementing it seamlessly into the museum experience will be the task for upcoming research projects.

5 Outlook: Generic AR Software Solutions for Museums?

All above discussed scenarios were customized application developments. Thus, one of the questions resulting from the HoloMuse project was how AR based experiences can be standardized for content creators. This is

what will be needed in the museum context to provide generic ways in creating AR experiences in museums.

In contrast to tailor-made AR experiences, which have emerged in increasing numbers worldwide for art and culture in recent years, we need to emphasize on standardized AR narrative forms and reproducible AR experiences for different images in a similar context. Easy-to-use editorial system with which (Art) mediators themselves can create narrative structures will be needed in this regard. Future research and development will have to further develop the above discussed AR mediation concepts towards generic solutions to allow non-tech museum experts to develop exciting and didactical senseful mediation experiences.

Literature

[Cast10] Castells, M.: The Rise of The Network Society: The Information Age: Economy, Society and Culture. Wiley, Oxford/Malden, MA 2010.

[deMu09] de Mul, J.: The work of art in the age of digital recombination. In: van den Boomen, M., Lammes, S., Lehmann, A.-S., Raessens, J. & Schäfer, M. T. (Eds.): Digital Material. Tracing New Media in Everyday Life and Technology. Amsterdam University Press, Amsterdam 2009, pp. 95–106. Retrieved January 13, 2020, from http://mtschaefer.net/media/uploads/docs/Digital-Material.PDF

[FACM16] Freeman, A., Adams Becker, S., Cummins, M., McKelroy, E., Giesinger, C., Yuhnke, B.: NMC Horizon Report. 2016 Museum Edition. The New Media Consortium. NMC, Austin, TX, 2016. https://doi.org/10.1111/j.2151-6952.2010.00064.x

[GoDe11] Gordon, E. & de Souza e Silva, A.: Net Locality – Why Location Matters in a Networked World. Wiley-Blackwell, West Sussex 2011.

[JCPR09] Jenkins, H., Clinton, K., Purushotma, R., Robison, A. J. & Weigel, M. (2009): Confronting the Challenges of Participatory Culture: Media Education for the 21st Century. Retrieved January 13, 2020, from http://digitallearning.macfound.org/atf/cf/%7B7E45C7E0-A3E0-4B89-AC9C-E807E1B0AE4E%7D/JENKINS_WHITE_PAPER.PDF

[Karv07] Karvalics, L. Z. (2007): Information Society – what is it exactly? (The meaning, history and conceptual framework

of an expression). Retrieved November 9, 2014, from http://www.ittk.hu/netis/doc/ISCB_eng/02_ZKL_final.pdf

[LDVR16] Llorens, F., Durán, F., Villagrá, C., Rosique, P., Satorre-Cuerda, R. & Molina-Carmona, R.: Gamification of the Learning Process: Lessons Learned. In: IEEE Revista Iberoamericana de Tecnologias del Aprendizaje, 2016, 11 (4), pp. 227–234. https://doi.org/10.1109/RITA.2016.2619138

[Mano06] Manovich, L.: The poetics of augmented space. In: Visual Communication, 2006, 5(2), pp. 219–240. https://doi.org/10.1177/1470357206065527

[MWFW15] Moesgaard, T., Witt, M., Fiss, J., Warming, C., Klubien, J. & Schoenau-Fog, H.: Implicit and Explicit Information Mediation in a Virtual Reality Museum Installation and Its Effects on Retention and Learning Outcomes. In: Proceedings of the 9th European Conference on Games Based Learning, 2015, pp. 387–94. Retrieved January 13, 2020, from http://vbn.aau.dk/files/220338775/Implicit_and_Explicit_Information_Mediation_in_a_Virtual_Reality_Museum_Installation_and_its_Effects_on_Retention_and_Learning_Outcomes_ECGBL2015.pdf

[ORBa09] O'Reilly, T. & Battelle, J. (2009): Web Squared: Web 2.0 Five Years On. Retrieved January 13, 2020, from http://assets.en.oreilly.com/1/event/28/web2009_websquared-whitepaper.pdf

[Sand14] Sandersdorf, M. (ed.): Sharing Is Caring. Openness and Sharing in the Cultural Heritage Sector. Statens Museum for Kunst, Copenhagen 2014. Retrieved January 13, 2020, from http://www.smk.dk/fileadmin/user_upload/Billeder/forsiden/94124_sharing_is_Caring_UK.pdf

[vanH95] van Huisstede, P.: Der Mnemosyneatlas. Ein Laboratorium Der Bildgeschichte. In: Galitz, R. & Reimers, B. (Eds.): Aby M. Warburg. Ekstatische Nymphe... Trauernder Flußgott. Portrait Eines Gelehrten. Hamburg, 1995, pp. 130–71.

Challenging Authorities: A Postcolonial Interactive Exhibition Codesigned by Namibian Born-frees

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Abstract

Even though public participation and using interactive technologies in museums is becoming popular around the world, museums in Namibia have not yet embraced interactive and emerging technologies to enhance participation, support meaningful interactions or attract visitors. The Independence Memorial Museum (IMM) in Windhoek Namibia, which houses the colonial history of Namibia, more specifically the German colonial era and the liberation struggle from South Africa [WiMa19] is a classic example of authoritarian and traditional curation: maintaining an obvious bias towards the colonial history, displaying monumental huge wall paintings, still images of past struggle and artefacts from the colonial period with textual descriptions in English over three floors. In this paper, we present an interactive exhibition on postcolonial narratives of the born frees which was co-designed with a group 10 youth and 5 interaction design students. The exhibition challenged traditional curation methods, introduced the youth voices in a traditional museum whose voices provoked the postcolonial narratives by addressing everyday experiences and issues relating to education, languages, economics and indigenous knowledge.

1 Introduction

Creating interactions and increasing visitor's participation in museums has over the years attracted researchers and designers within the field of Human Computer Interaction. Research in museum and heritage work has focused on designing for participation [DaDE08], enhancing the experiences of visitors [KBCB04], involving different stakeholders in the design process and engaging youth and museum audiences in dialogic discussions to contribute to the design of future museum experiences [SmIv14], [SmOt16].

Participation in museums through technology has also been used to address power structures in museums, in which traditionally curators decide what goes into the exhibition [Simo10]. Participatory design approaches applied during the design of interactive installations and used to engage the audience during the exhibition allowed visitors to interpret the exhibition, creating new meaning and creating heritage in the process [SmIv14], [Giac12].

Though there is a significant shift in engaging community members in museums around the world, this has not been the case for Namibia. However, there has been a series of events on museum conversations, problematising issues on how museums can be more inclusive, and discussing visions for the future of African museums [Muco19]. This type of events can be seen as a good way of creating consciousness among the curators, and community members on addressing issues such as power, and using contextualised methods for encouraging participation.

To attract more visitors and enhance experiences, a couple of interactive prototypes were previously designed for the Independence Memorial Museum, such as location-aware interactive guide app [KaHS16], a virtual welcome guide [WeMM14], and persuasive souvenirs [MuOM14], yet they were never installed in the museum. For us, the Independence Memorial Museum was the perfect context for an experimental interactive exhibition, to challenge and infuse life into the authoritative and normative representations of Namibian colonial past. The exhibition was conceptualised with Namibian 'born-frees'; young people born after independence in 1990, whose voices are not normally part of the contemporary public debates on the past, and as a way of creating a wider discourse on post-colonialism. In this paper, we briefly describe the six-month co-design

process with 10 born-frees and 5 interaction design students led by a born-free PhD candidate, supported by a Professor in Interaction Design as well as PhD candidate in media and communication studies exploring how social justice ideas are communicated to and by middle classes. It resulted in a two-weeks public interactive exhibition consisting of three distinct augmented reality installations, one soundscape, one overlay photo booth, a raspberry-pi phone creating contexts and opportunities for embodied engagement.

2 Namibian Context

The Republic of Namibia is one of the last countries to attain its independence from external colonial forces in 1990 [Saun17]. Namibia's dual colonial history started late 19th century, when Namibia was colonised by the German empire from 1884–1914. This colonial era was mostly remembered for the genocide of the Herero and Nama people and the signing of land treaties with the locals [Köss15], [Melb19]. After the German colonial era, Namibia was put under the administration of South Africa, of which the south African government applied apartheid laws to segregate people based on race [Saun17]. Other significant happenings during the south African apartheid is the resistance and fight for freedom by South West Africa People's Organisation (SWAPO) [Silv15]. Today, significant events of colonialism are commemorated and memories of colonialism are preserved and presented in different forms. The colonial history of Namibia is exhibited in the Independence Memorial Museum, a landmark standing tall between 'Christuskirche' and 'Alte Fest' fort [Beck18]. The exhibition halls inside the museum are filled with artefacts, huge wall paintings, some with descriptions written in small letters and some lacking descriptions [WiMa19].

The young people of Namibia, born after independence do not have first-hand colonial experiences but see traces ingrained in contemporary cityscapes, infrastructures, processes and people [Köss15], [Silv15]. They witness ongoing post-colonial debates, such as the 1904 genocide repatriation, and the land reform, as a legacy of colonial misappropriation of land. Today, postcolonial discourses barely contain the voices of the

youth, as they are considered too young or with no experiences on issues that relate to colonialism.

3 Methodology

In our design process, we merged components from two pragmatic methodological approaches to engage the youth and students. We used approaches from design anthropology which are instrumental in understanding cultural realities of the youth being designed with, and also preeminent in designing alternative futures [GuOS13]. Secondly, we used localised Participatory Design methods to co-design technologies, whereby all team members had a say in the design process to achieve the set goals and visions [WCKB10, WiBB12, SeSm12].

In May 2019, we conducted individual ethnographic interviews, to enquire into the cultural realities and to recruit the youth, who were either active in social media postcolonial discourses, in youth led organisations or known otherwise to the researchers. In the first workshop with all the youth, we set individual and common goals to be achieved within 6 months [GoKW18]. The youth stated that as 'agents to bridge today for tomorrow' they would create an exhibition to engage more people and to display their everyday postcolonial experiences. Among others they expressed their frustration of being excluded from postcolonial discourses, and how the 'comrades' (a term politicians in Namibia use, mostly for those who were present during colonial times) feel entitled to drive the narratives. Thus, the youth argued that an exhibition could provoke postcolonial discussions while showing appreciation for the past.

To situate our exhibition, we explored the IMM and identified gaps in the current exhibits. The youth discovered that the museum lacks interactivity, voices of young people and women, everyday memories and experiences of ordinary Namibians, descriptions on some artefacts and the unavailability of curators to engage with the youth. The exhibitions are mainly glorifying the ruling party which fought for the liberation struggle against the South Africans.

The research team and youth conducted a series of workshop sessions to problematize the current issues relating to postcolonialism. Recordings of these sessions were used in the exhibition's soundscape. While the youth

complained not having had a safe space to freely discuss those issues, they also felt surrounded by 'noise', oversaturated with meaningless information on social media and certain voices louder than others. This analysis fuelled the desire to create a public exhibition, thereby creating new meanings to initiate a new postcolonial narrative including minority voices. At this point the interaction design students joined the team. The students were mostly responsible for the technical aspects while the youth focused on the content. However, in the sessions all parties involved contributed to the design of the individual exhibits and the visitors' flow through the exhibitions.

4 Postcolonial Narratives of the Born-frees an Interactive Tech Exhibition

The exhibition was launched on 21 October 2019 outside the Independence Memorial Museum, with a number of invited delegates and the media. The event was broadcasted during the news sections, printed in the newspapers and aired on radio. The launch programme broke protocols in terms of speaking slots only attributed to the creators and not dignitaries. It is to be noted that the launch of the exhibition preceded the 2019 election, which by some politicians was interpreted as a direct provocation of the government.

The exhibition consisted of themes that the visitor was channelled through in a singular possible path. The first installation at the entrance was a soundscape, which represented the current state of confusion, playing a mixture of born-free voices all at the same time, with some being heard more than others. It provided control stations where voices can be amplified or silenced. To understand the present better and why things are the way they are, visitors were channelled into the "Learning from the past" section. The visitors experienced sharing of indigenous knowledge around a projected fire as well as attempts to make sense of the past through an augmented reality technology puzzle. Appealing to the wish expressed by some born-frees to have been part of the liberation struggle, a photo booth took the visitor right back in time by taking a picture with freedom fighters or war themed backgrounds. On the path to the future section, visitors were reminded of the necessity to take actions to create better

futures, by crossing a bridge. On this path, visitors could also listen to how languages remind the youth of colonialism, at the phonebooth. The road to the future also presented economic challenges as observed by the born-frees, which were presented in an augmented reality room for social justice [AsAV18]. Finally, in the future section, we engaged the visitors in answering questions on the wall, as a means of creating participatory and inclusive futures. The visitors also got to reflect on the exhibition, and future imaginations by playing interactive games. The interactive installations are explained in details below.

4.1 Present Section

4.1.1 Soundscape

The soundscape was set up in a 4*8 meter tent (as a way to contain the noise from the other parts of the exhibition). We used board dividers to create a maze-like feature, with some hidden dead-end to confuse the visitors and create a narrative that illustrates the confusion state. Light emitting diodes LEDs, were installed on the base of the boards, which provided illumination to the installation. Along the boards in intervals of 2 meters dressed up mannequins were placed to give the impression the voices emanate from them.

The installation was designed to cater for a sound-based user experience from which audio projections were meshed up per device in order for multiple voices to play at the same time or individually. The users were able to control the voices on an iPad, which was running the Unity game engine. Two iPad devices were placed in different sections of the soundscape installation. Each iPad was connected to 2 x subwoofers and 4 small speakers, concealed at the base of the tent. This layout was intended to not only create a surround sound, but also ensure that the audio projections for each device meshes with others to create one chaotic sound when all audios are playing simultaneously.

Once the museum audience enters the exhibition, they could hear multiple voices playing at the same time. The iPad prompted people to mute some of the voices, by tapping on the picture of the youth on the screen. The youth who were available in the exhibition halls did not have to explain a lot on how the technology works, but rather engaged the audience in

discussing the topics being addressed in the recordings relating to the usage of slang languages and their relation to languages used during the colonial times to confuse the colonisers. Some recordings related to how the education system is still colonising; having the bible translated into local languages but not the science books. In the recordings the youth have also addressed issues relating to how lack of consciousness among community members is like permanent enslavement.

Fig. 1: Inside the soundscape room © A.P Kambunga

4.1.2 Telephone

4.1.3 Booth

For the phone booth installation, we used an old Analog phone, which was reprogrammed with a raspberry pi. The intention was to show how colonial languages are at times considered as business language in public and private offices, and how some people use indigenous languages in public offices instead of the official language -English. The visitors engaged with the installation by calling specific numbers and listening to audios, such as a dentist receptionist speaking in Afrikaans with a patient, instead of English; a police officer insulting a young person for speaking in English when they surely speak the same indigenous knowledge.

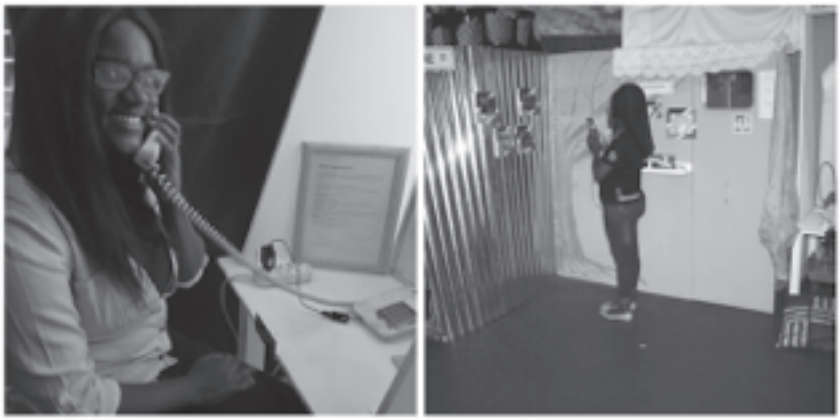

Fig. 2: Telephone booth on the left and room for social justice on the right.
© A.P Kambunga

4.1.4 The "Room for Social Justice"

The Room for Social Justice contrasted the wealth and poverty that exist side by side in Namibia, which remains one of the most unequal countries in the world [WoBa18]. The installation was constructed with two walls, a painted wall symbolising an upmarket house in the wealthy suburbs and a corrugated iron wall representing the shacks in the other side of the city. The walls featured images portraying social challenges the young curators had identified as most pressing for post-colonial Namibia. These images functioned as augmented reality markers the visitors could scan using an application installed on an android phone. Each scan would open video content on the phone screen and connected headphones, challenging the visitor to reflect on the various issues. The visitors also had to choose between potential solutions to the problems and to indicate their choice by donating play money to their chosen solution. Finally, a mirror hanging on the wealthy wall triggered augmented content, which asked the visitor to reflect on what they themselves were doing about the challenges by acting – or not acting – as "responsible" citizens.

The visitors' reactions to the Room may be characterised by dividing them into two groups. One group, comprising mainly young visitors, were mostly interested in augmented reality technology. When prompted to comment on the content, most reacted in a cynical manner, saying that

they were tired of hearing about the same problems all the time and were not interested in talking more about them – especially since the decision-makers, in their view, were not getting anything done about the problems in any case. Another group, comprising mainly of visitors in their 40s and above, were focused on the content from the onset, some criticising it as portraying the country in a manner that was too negative and some engaging in lively debates about possible solutions.

4.2 Past Section

4.2.1 Augmented reality of indigenous knowledge

The indigenous knowledge installation was created for people to learn from the rich indigenous knowledge shared orally by elders in rural areas. The installation was set up with dressed up mannequins and traditional objects around a fire, resembling Namibian traditional homes fireplaces. The burning fire was projected on a wall with a projector and the visitors sat on logs (traditional chairs). The visitor used an android mobile phone to scan markers which were placed on a traditional pottery. Each marker was embedded with stories from indigenous elders telling stories relating to using traditional medicine, hunting, and analysing animal carcases. The scenario was to simulate the "talking to the ancestors" who share their wisdom with us. While the IMM focused on the liberation struggle and its pre and post-era, at no point does it acknowledge the country's vast richness in indigenous knowledge.

Fig. 3: Audience at the indigenous knowledge installation left, and making sense of past right. © A.P Kambunga

4.2.2 Making Sense of the Past Installation

The visitors interacted with the AR puzzle installation by moving the markers, printed on magnets, around on the Namibian map and placing them on the right spot. After placing the marker on the map, the visitors scanned the marker using an android mobile phone, and if placed in the right spot, a video plaid showing the cultural reality of the ethnic groups, else an error was displayed. If some markers were placed together, they showed the relationship between the two ethnic groups, for example the nama-herero war. This installation was more of an educational game as well, allowing people to play and learn about Namibian ethnic groups by placing the magnets in the right spots. The application was coded using C#, and used Unity game engine and Vuforia for the backbone. Inside the exhibition, the application required extra lighting because the room was quite dark. We have experienced the same issue with other apps used for the IK installation and the social justice room as well.

4.2.3 The Photobooth

The photobooth installation used dslrBooth (professional edition) to enable the audience to take pictures with backgrounds from the colonial times and or with some of the late early colonial resistance leaders such as

captain Hendrik Witbooi. The installation required special spot lights and a green screen as backdrop. The installation enabled the audience to take pictures almost in the same quality and colour as the original photographs, giving an illusion that the person was part of the colonial times. For those who gave consent for their pictures to be shared, the pictures were shared on the exhibition Twitter account @thebornfrees. While the intention was to allow people to "be part of the struggle", the question raised as to what extent it could be offensive to post these kinds of pictures on social media. Yet no negative comment was received and many "fun" photos were taken by the visitors.

Fig. 4: Photographs from the photobooth. © A.P Kambunga

5 Conclusion

The exhibition presented multiple voices in co-existence on issues relating to postcolonialism's past, present and future in an immersive interactive manner leveraging emerging technologies, such as augmented reality and soundscapes. The co-creation process explored new ways of engaging young people into museum activities and for our Namibian museums to start embracing contemporary digital heritage rather than an authoritarian approach. The exhibition created a deeper understanding of the youth's postcolonial experiences in Namibia. Thus, locating this exhibition in the Independence Memorial Museum, was of utmost significance considering

that the Namibian postcolonial youth is shaped by the surrounding representations of the national history.

Acknowledgements

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References

[AsAV18] Ashikoto, L. I., Ajibola, D., & Virmasalo, V. (2018). A room for social justice. Proceedings of the Second African Conference for Human Computer Interaction on Thriving Communities - AfriCHI 18. doi: 10.1145/3283458.3283505

[LuBa07] Ciolfi, L., & Bannon, L. J. (2007). Designing hybrid places: merging interaction design, ubiquitous technologies and geographies of the museum space. CoDesign, 3(3), pp. 159–180. doi: 10.1080/15710880701524559

[Beck18] Becker, H. (2018). Changing urbanscapes: Colonial and post-colonial monuments in Windhoek. Nordic Journal of African Studies.

[DaDE08] Dalsgaard, P., Dindler, C., & Eriksson, E. (2008). Designing for participation in public knowledge institutions. Proceedings of the 5th Nordic Conference on Human-Computer Interaction Building Bridges – NordiCHI 08. doi: 10.1145/1463160.1463171

[KBCB04] Ferris, K., Bannon, L., Ciolfi, L., Gallagher, P., Hall, T., & Lennon, M. (2004). Shaping experiences in the hunt museum. Proceedings of the 2004 Conference on Designing Interactive Systems Processes, Practices, Methods, and Techniques – DIS 04. doi: 10.1145/1013115.1013144

[Giac11] Giaccardi, E. (2011). Things we value. Interactions, 18(1), p. 17. doi: 10.1145/1897239.1897245

[Giac12] Giaccardi, E. (2012). Heritage and social media: understanding heritage in a participatory culture. New York, NY: Routledge.

[GuOS13] Gunn, W., Otto, T., & Smith, R. C. (2013). Design anthropology theory and practice. London: Bloomsbury.

[SeSm12] Iversen, O. S., & Smith, R. C. (2012). Scandinavian participatory design. Proceedings of the 11th International Conference on Interaction Design and Children – IDC 12. doi: 10.1145/2307096.2307109

[KaHS16] Kandjimi, H. Muyingi, H and Sieck, J. 2016. A usability study of indoor micro location-aware interactive guide application in museum: case of Namibian Independence Museum. Conference: XIV. Conference Culture and Computer ScienceAt: Schloss Köpenick, Berlin DE. Retrieved from https://bit.ly/2TwZAEO

[Köss15] Kössler, R. (2015). Namibia and Germany: negotiating the past. Windhoek: University of Namibia press.

[Melb19] Melber, H. (2019). Colonialism, Land, Ethnicity, and Class: Namibia after the Second National Land Conference. Africa Spectrum, 54(1), pp. 73–86. doi: 10.1177/0002039719848506

[MuOM14] Muchinenyika, S. H., Weede, O., & Muyingi, H. N. (2014). Persuasive souvenir. Proceedings of the 13th Participatory Design Conference on Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium Papers, and Keynote Abstracts – PDC 14 – Volume 2. doi: 10.1145/2662155.2662225

[Muco19] Museum Conversations. (2019). Retrieved from https://www.goethe.de/ins/na/en/kul/sup/mus.html

[Saun17] Saunders, C. (2017). Decolonization In Southern Africa: Reflections On The Namibian And South African Cases. Journal for Contemporary History, 42(1). doi: 10.18820/24150509/jch42.v1.6

[Silv15] Silvester, J. (2015). Re-viewing resistance in Namibian history. Windhoek: Unam Press.

[Simo10] Simon, N. (2010). The participatory museum. California: Museum 2.0.

[SmSe11] Smith, R. C., & Iversen, O. S. (2011). When the museum goes native. Interactions, 18(5), p. 15. doi: 10.1145/2008176.2008182

[SmIv14] Smith, R. C., & Iversen, O. S. (2014). Participatory heritage innovation: designing dialogic sites of engagement. Digital Creativity, 25(3), pp. 255–268. doi: 10.1080/14626268.2014.904796

[SmOt16] Smith, R. C and Otto, O. 2016. Cultures of the future: Emergence and intervention in design anthropology. Design Anthropological Futures (2016), pp. 19–36.

[SVKO16] Rachel C. Smith, Kasper Tang Vangkilde, Mette Gislev Kjærsgaard, Ton Otto, Joachim Halse, Thomas Binder. 2016. Design Anthropological Futures. Bloomsbury Academic. London.

[WeMM14] Weede, O., Muchinenyika, S. H., & Muyingi, H. N. (2014). Virtual welcome guide for interactive museums. Proceedings of the 13th Participatory Design Conference on Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium Papers, and Keynote Abstracts – PDC 14 – Volume 2. doi: 10.1145/2662155.2662222

[WiMa19] Williams, C. A., & Mazarire, T. (2019). The Namibian Independence Memorial Museum, Windhoek, Namibia. The American Historical Review, 124(5), pp. 1809–1811. doi: 10.1093/ahr/rhz1163

[WCKB10] Winschiers-Theophilus, H., Chivuno-Kuria, S., Kapuire, G. K., Bidwell, N. J., & Blake, E. (2010). Being participated: a community approach. Proceedings of the 11th Biennial Participatory Design Conference on – PDC 10. doi: 10.1145/1900441.1900443

[WiBB12] Winschiers-Theophilus, H., Bidwell, N. J., & Blake, E. (2012). Community Consensus: Design Beyond Participation. Design Issues, 28(3), pp. 89–100. doi: 10.1162/desi_a_00164

[WoBa18] World Bank. 2018. GINI index (World Bank estimate) Retrieved September 1, 2018 from https://data.worldbank.org/indicator/si.pov.gini

Augmented Reality and Renaissance Painting

An AR Experience for the Fitzwilliam Museum in Cambridge

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Abstract

This conference paper aims to demonstrate the effectiveness of Augmented Reality technology as a powerful tool for communication and dissemination of Cultural Heritage. The case study examined in this paper is an Augmented Reality (AR) app designed for the Fitzwilliam Museum in Cambridge (UK). The app, called *Ways of Seeing*, conveys to the public conservation reports and non-invasive technical analysis about an Italian Renaissance artwork, created in the 15th century by the Florentine painter Jacopo del Sellaio. Using this kind of Extended Reality interactive digital interpretation, museums can bridge the gap between scholarly research and public knowledge, giving accessibility to a largely unknown set of facts.

1 Introduction

Augmented Reality is rapidly and progressively gaining widespread use and popularity in a vast range of fields [Mani16]. Publishing, healthcare, engineering, gaming, and many more vital industries of our modern world rely on visualisation and communication technologies that could exploit the benefits associated with AR. Very popular smartphone apps, like *Pokemon Go*, and – more recently – features of Google services like *Translate* and *Maps*, have contributed over the last two decades to disseminate the basic principles of AR technology, which is now growing in terms of numbers of active users and developers specialized in its design and implementation [Mand19]. In addition, research teams all over the world have contributed to the spread of the knowledge on this field with an ever growing range of academic publications illustrating techniques, best practices, and refining theoretical frameworks for the use of AR for the enhancement of the Cultural Heritage [Comm12] [Empl15] [CaBr17].
In this paper I explain how AR has been used as a powerful tool to communicate very complex technical and conservation information relating to a masterpiece of the Italian Renaissance held in the Fitzwilliam Museum, in Cambridge[1]. Using this particular approach, onsite visitors can access an unprecedented quality and amount of technical information not generally available to the public [NeEg17]. Innovative and unobtrusive user experience design makes this experiment user friendly and interactive, allowing museum visitors to engage with the painting in a compelling and critical way. As we will discuss, this type of digital experience, using a site-specific installation, can be used to complement both temporary exhibitions and permanent collection settings.

2 The focus painting

2.1 History and context

The focus of this digital experience is a Florentine artwork, painted around 1473 using tempera and gold on a wooden panel, depicting the mythological subject of *The Story of Cupid and Psyche*. The artist is Jacopo del

1 https://www.fitzmuseum.cam.ac.uk/, last accessed 05/03/2020.

Sellaio (born 1441– died 1493), a prolific painter active in the second half of the fifteenth century [Fahy89] (Fig.1). It is a painting of a considerable size, measuring 58,6 cm in height and 178,8 cm in width. Its format, low and wide, along with its profane subject, suggests that it may have been originally a part of a *spalliera,* a typical Renaissance furnishing element serving as a backrest, often decorated with paintings. Spalliere also had a thermal function, insulating the internal walls of homes from the external cold and damp. If not a spalliera panel, the Cambridge painting may instead have been the frontal panel of a *cassone*, a genre of storage chest, usually found in Medieval and Renaissance bedrooms and decorated with scenes painted with tempera and gold [Mizi19].

Fig. 1 : Jacopo del Sellaio, *Story of Cupid and Psyche,* c. 1473. Cambridge, Fitzwilliam Museum.

The Fitzwilliam painting portrays the first half of the *The Story of Cupid and Psyche,* a common subject for bridal chests in Renaissance Florence. The story, which has a deep allegorical meaning, is the mythical romance of the mortal princess Psyche with Cupid, the God of love and son of Venus. The first panel depicts the beginning of the tale, beginning with the episodes of the birth of Psyche and Cupid falling in love with her. The development features a complex plot of deceptions and riddles involving the other major characters of this story: Psyche's suitors, sisters, and parents [Vert79]. Another painted panel, now held in a private collection, shows the second half of the story and its happy resolution with Psyche's marriage to Cupid, and has also been identified as a work by Jacopo del Sellaio. As the dimensions are nearly identical, it seems certain that this second painting formed a pair with the one in the Fitzwilliam Museum [Kroh08]. At a time when most art was religious, secular romance subjects such as the *Story of Cupid and Psyche* were generally associated with

marriage [Vert93]. Therefore, this pair of painted panels could have been commissioned on the occasion of a wedding between wealthy Florentines, and also paraded through the streets of the city to display the status of its patrons [Call98].

Sellaio's painting, part of the permanent collection of the Fitzwilliam Museum, is normally displayed in the Upper Marlay gallery, with other Italian works from the 13th to the 15th century. It is currently the centrepiece of the *Inspire 2020* exhibition curated by Kate Noble, held in the Octagon gallery of the Fitzwilliam Museum (10 December 2019-22 March 2020)[2]. *Inspire 2020* showcases primary school children's artworks inspired by and responding to Sellaio's painting. Over the course of 2019, 3,800 children and teachers researched and studied the painting in schools across Cambridgeshire, producing numerous drawings, paintings, sculptures, and installations, a selection of which are displayed within the Octagon gallery in dialogue with the Renaissance artwork.

2.2 Technical analysis and conservation

The children's own research into the materials and techniques used by Del Sellaio in his Renaissance workshop prompted the Fitzwilliam's experts to carry out their own research on the panel. In order to check the painting's condition and to undertake scientific analysis, the panel was transported to the Hamilton Kerr Institute (HKI), the paintings conservation department of the Fitzwilliam Museum[3]. Dr Paola Ricciardi, Fitzwilliam Museum's Research Scientist, and Vicky Sutcliffe, Paintings Conservator at HKI, captured technical images of the painting and undertook a full non-invasive investigation of the painting's materials over the course of two weeks. The technical images obtained include infrared reflectograms, microphotographs, and X-ray scans. All these technical analyses are non-invasive, i.e. they do not require sampling of material from the wood support or the paint layers. The painting was deemed to be in good overall conservation condition, and the painted surface was lightly cleaned and consolidated before the start of the exhibition. Also, the painting was glazed with a thin anti-glare glass to protect it from physical damage and sudden thermo-hygrometric variations.

2 https://www.fitzmuseum.cam.ac.uk/calendar/whatson/inspire-celebration-childrens-art-response-jacopo-del-sellaios-cupid-and-psyche, last accessed 05/03/2020.

3 https://www.hki.fitzmuseum.cam.ac.uk/, last accessed 05/03/2020.

These technical imaging methods were very helpful for the study of the painting from an art historical and also technical point of view. Pigment analysis was coordinated with microphotography, while the X-ray scan revealed the presence of canvas patches under the gesso ground and nails within the panel structure.

The most interesting information was obtained from infrared scanning. Thanks to this imaging technique, it is possible to clearly identify later retouching, but also, more importantly, preparatory underdrawings made by the artist below the final layer of paint. The infrared image shows clearly an abundance of underdrawings, made with ink and pen, all over the painted surface. For instance, the artist worked out the flying Cupid's final position making several adjustments to the arrangement of his wings and feet. Evidence provided by the infrared frequency imaging means that it is also possible to see underdrawings that were initially outlined by the artist, but then were left out from the final composition. These are the figure of Cupid, armed with his bow and standing in a niche in the façade of his palace on the right-hand side of the scene, and three other figures (probably Psyche herself and her parents) bowing to the statue of the oracle in the temple in the left-hand side background. These elements are not visible to the naked eye, as the artist decided not to include them in the final composition, and are therefore covered by an opaque layer of tempera paint.

The range and the results of the technical analysis executed by the Fitzwilliam's conservators and scientists are discussed in a separate publication [CoNo20], but from this brief summary it is possible to appreciate how the findings shed light on the process of creating the artwork from its material wooden support to its final execution. High-resolution microphotographs, infrared, and X-ray scans are suitable for presentation to the public in a visual form, as they carry a good level of detail which allow the user to appreciate the aforementioned features below the visible painted surface [Bruz13]. Furthermore, this technical data is rarely disseminated to a broad public, and a traditional form of interpretation display, such as a text panel, can be perceived by the public as too complex or intimidating. The particular affordances of AR, however, offer new ways to bring the scientific analysis of paintings into the gallery space.

3 The *Ways of Seeing* AR App

3.1 Partnerships and Multidisciplinarity

Ways of Seeing is the product of an international and interdisciplinary partnership between several institutions. Art historians, museum educators, conservators and scientists, digital specialists and software developers have all contributed in different ways to this project, with a multi-faceted approach. The development of the app was funded by the Arts and Humanities Impact Fund and the Department of History of Art at the University of Cambridge, and has been carried out by Maggioli Group, an Italian IT company based in Florence. Concept, design, and development of the app were structured as a research collaboration between the Fitzwilliam Museum, the Department of History of Art at the University of Cambridge and the SAGAS (Department of History, Archaeology, Geography, Art, and Performing Arts) at the University of Florence.

To create the app, the author (currently a PhD candidate at the University of Florence), and Dr. Donal Cooper, Senior Lecturer in Italian Renaissance Art at the University of Cambridge, worked together with colleagues at the Fitzwilliam Museum and the developers at Maggioli Group to integrate the new research within an effective user experience, which exploits the potential of mobile-based augmented reality to encourage visitors to look more closely at the original painting. The author was the project manager, coordinating and organizing the work between all the different teams and university departments involved in Cambridge and Florence[4]. Without this degree of close collaboration between the different units, it would not have been possible to design, develop, and test the software in the short time frame of the project (December 2019 – February 2020).

4 Concept, design and development of the Ways of Seeing app are the work of Giovanni Pescarmona (University of Florence) and Marcello Massidda (Senior developer, Maggioli Group). Research on the painting, text content included in the app, and design of the user experience are a joint work of Giovanni Pescarmona, Donal Cooper (University of Cambridge), Kate Noble (Fitzwilliam Museum), Daniel Pett (Fitzwilliam Museum), Paola Ricciardi (Fitzwilliam Museum), Rosanna Evans (Fitzwilliam Museum), Elsbeth Geldhof (independent conservator), Vicky Sutcliffe (Hamilton Kerr Institute), and Chris Titmus (Hamilton Kerr Institute). Filippo Fineschi coordinated the project at Maggioli Group.

3.2 Concept, Design and Development

The App *Ways of Seeing* runs on low-end Sony smartphones owned by the Fitzwilliam Museum that can be borrowed free of charge by Museum visitors in the gallery. Two smartphones are kept beside the painting, where visitors can use them independently. Framing Jacopo del Sellaio's painting with the smartphone camera, the device overlaps the real image with virtual elements. In doing so, the user enjoys an empowered vision, and can identify features within the artwork that are not visible to the naked eye, such as the underdrawings made by the artist, the structure of the wooden planks, or the microscopic texture of pigment brushstrokes (Fig. 2).

Fig. 2: *Ways of Seeing* app in use in the Octagon Gallery. Fitzwilliam Museum, Cambridge.

The basic functionality of the app allow the user to "see through" the painting to access technical and conservation information. To achieve this, AR technology is used to overlay a computer-generated image on top of the real environment, creating a perceptual illusion. The user can see "through" the painting, visualising three layers of digital images (microphotography, infrared, and X-Rays), experiencing a sense of progressive zooming into and below the visible surface.
To create a strong perception of identity between the digital image rendered on the device and the real object that is in front of the user for the whole duration of the experience, a very accurate alignment of the computer-generated image with the real object was needed. In order to achieve this technical specification, the *Ways of Seeing* app has been developed using the marker-based Vuforia Software Development Kit (SDK), allowing high levels of detail and smooth graphic rendering. The Vuforia SDK has been implemented within the Unity game engine platform for the creation of the structure of the app (Fig. 3).

Fig. 3 : Screenshot of the *Ways of Seeing* project viewport on the Unity game engine.

The image of the painting has been assimilated to a perfectly flat 2-D image, and it has been used to create a *marker*, giving 3D coordinates for correctly orienting and placing the virtual elements in relation to the real environment. Then, a virtual layer has been created with each one of the three types of technical imagery (microphotography, infrared, and X-Rays). Each one of these three images constitutes one of the three "modes" of the

app, and represents the core of the user experience, each one offering a set of interactive elements.

The interface displays, on the lower part of the screen, a simple touch bar, or "navigator", showing the titles of the three modes: *Microscopy*, *Infrared*, and *X-Ray*. By tapping on one of these three words, the correspondent mode is activated. A virtual image, showing the selected technical data, will appear with an animation effect, and is superimposed at a 1:1 scale over the painting. Zooming levels on the images are synchronised on the hand held device with the user's movements when held up to the original painting, and help create the effect that the smartphone itself is doing the scanning work in real time. The recognition rate of the Fitzwilliam painting by the Vuforia SDK software is very high, a fact allowing the user to get very close to the painting, to a limit of 10 cm from its surface. This translates into a very stable and high-quality experience, with little or no trembling or shaking of the virtual elements, and a considerable amount of freedom of movement for the user, who is free to frame the artwork, explore its features, pause and then start again, with ease and without frustration.

The user interface has been designed keeping in mind an expected user-time by visitors of about 2–6 minutes. Therefore, the team decided to minimise the number of buttons, switches, and sliders of the user interface, with the aim of creating the most intuitive and self-explanatory experience as possible. Theoretically, users do not even need to read the instructions provided in the interpretation panels on display in the gallery to correctly engage with the app, and first-hand feedback on the digital experience (which is currently still ongoing) seems to confirm this assumption.

3.3 Curated content

While scanning the painting with the device camera is by itself an engaging and revelatory experience, the team working on the app concluded that a curated form of content was needed in order to offer a more in-depth exposition of what technical analysis can tell art historians and conservators about Renaissance art. We also wanted to convey this data in an engaging and interactive way, without forcing the user to pass through an obligatory path of subsequent steps to follow [ViId17]. This was a complex problem to solve, as there were many conflicting design priorities, and we

had to pass through many iterations of prototyping, testing, and correction to get to the final result.

The compromise we agreed on is to select for each one of the three modes a total number of four Points Of Interest (POI) marked by white circular hotspots (HS), as shown in Fig. 4. Each one of these is an interactive element: by tapping on it on the surface of the touchscreen, the user is provided with an info sheet, carrying a magnified detail image of the selected point of interest along with a concise descriptive text. We set the maximum length of all the texts in the interactive info sheets to 300 characters, including spaces, to provide essential but also digestible knowledge about every POI. The hotspots appear and disappear rhythmically with a gradual fade-in and fade-out effect every four seconds. This solution was chosen in order to allow the user to appreciate the whole technical image without any form of distraction and, at the same time, to guide the user by presenting curated content for the most meaningful information emerged from each one of the three chosen technical images. These include: for microphotographs, details of liquid gold, and various types of different pigments used to create shading and highlights; for infrared, sketches made by the artist to figure out the position of anatomical elements, or characters that were sketched, but not included in the final composition; for X-rays, wormholes, metal nails in the wooden support, and pieces of canvas fabric to protect the painted surface.

Also, for each one of the three modes, a general info sheet is provided with information about the scientific technique used to produce the image, and can be accessed by tapping the info button on the top right-hand side corner of the touchscreen. Using smartphones owned by the Fitzwilliam Museum allowed a quicker development time, as there was no need to create a responsive user interface with a flexible layout capable of detecting the visitor's touchscreen size and change accordingly. The experience is also more user friendly, as visitors do not have to download any app on their personal smartphone. In the future, it would be possible to expand the project by creating a free downloadable app that could be used outside the Museum setting, maybe using a printed image as a marker for the AR experience, and including more artworks in the digital platform.

A hidden analytics page can be accessed by the Museum's team, and has been developed to gather non-personal data to assess the impact of the app and how people tend to use it. Each smartphone tracks the total usage

time in *Explore mode* (that is while the camera is rendering the AR images), the total number of *Sessions* (each time a user activates the app), and the total number of *Tracked Markers* (each time a user frames the painting with the camera, action that can be performed multiple times within a single session). Data gathered so far during the short period of deployment, however, is as yet insufficient to draw solid statistical conclusions from the analytics panel, but visitor services at the Fitzwilliam Museum have gathered positive spontaneous feedback from the users, highlighting how the digital visualisation tool helped them in looking in a new way at a Renaissance painting.

Since the marker recognition is not very sensitive to the lighting conditions and the glazing of the artwork, given the good recognition of the marker, the app could still be used to encourage visitors to engage with technical data as an integral part of their gallery experience when the *Inspire* exhibition ends and the painting returns to the permanent collection of the Fitzwilliam Museum.

Fig. 4: Screenshot of the *Ways of Seeing* app running on the Sony smartphone. The *Infrared* mode is selected, and the four white circular hotspots are shown on the virtual image.

4 Conclusion

This type of multimedia experience represents an important addition to the visitor experience at the Fitzwilliam Museum, complementing the *Inspire 2020* exhibition and, in the future, the permanent collection in the Upper Marlay Gallery. The AR app provides a powerful, engaging and meaningful experience through an accessible medium, conveying information that is not easily communicable with traditional forms of display. In a future phase of the project, feedback left by the visitors will offer valuable insights, enabling an assessment of the impact of the app and elements to improve, moving towards an experience that can be also accessed remotely, outside the museum. In conclusion, this paper explored how applications like *Ways of Seeing* can close the gap between technical analysis, scholarly research and public knowledge, raising the awareness about the methods and practices of technical art history. An Extended reality approach of this kind, while technologically simple, can be very effective for communication and dissemination purposes for museums, galleries, and cultural institutions worldwide.

Literature

[Bruz13] Bruzelius, Caroline: Teaching with visualisation technologies. How does information become knowledge? In: Material Religion, IX, 2013, 2, pp. 245–253.

[Call98] Callmann, Ellen: Jacopo del Sellaio, the Orpheus Myth, and Painting for the Private Citizen. In: Folia Historiae Artium, n.s., 4, 1998, pp. 143–158.

[CaBr17] Carrozzino, Marcello; Brondi, Raffaello: An Augmented Reality system for assisting art conservation and restoration. In: Kermes. Restauro, conservazione e tutela del patrimonio culturale, Application for 3D technology in cultural heritage, XXX, July–September 2017, 107, pp. 82–85.

[Comm12] Communication Strategies Lab: Realtà Aumentate. Esperienze, strategie e contenuti multimediali per l'Augmented Reality. Apogeo Education, Milano 2012.

[CoNo20] Cooper, Donal; Noble, Kate: Schoolchildren, science and smartphones shine new light on a Florentine masterpiece. In: Apollo. The International Art Magazine (online), 6 April 2020,

https://www.apollo-magazine.com/jacopo-del-sellaio-fitzwilliam-museum-cambridge/, retrieved 5 May 2020.

[Empl15] Empler, Tommaso: APP design con uso della realtà aumentata per la divulgazione dei Beni Culturali. In: Disegnare – idee: immagini, XXVI, 2015, 50, pp. 60–69.

[Fahy89] Fahy, Everett: The Argonaut Master. In: Gazette des beaux-arts, 6th ser., 114, December 1989, pp. 285–300.

[Kroh08] Krohn, Deborah L.: Jacopo del Sellaio (catalogue entry n.136). In: Bayer, A. (Ed.): Art and love in Renaissance Italy, Exh. cat. The Metropolitan Museum of Art, New York, Yale University Press, New Haven and London, 2008, pp. 293–295.

[Mand19] Mandarano, Nicolette: Musei e Media Digitali. Roma, 2019.

[Mani16] Maniello, Daniele: Augmented Heritage per la valorizzazione dei beni culturali. Suoni e luci per il Königorgel di Nijmegen. In: Disegnarecon, IX, 2016, 17.

[Mizi19] Mizioek, Jerzy: Jacopo del Sellaio's adaptation of the Primavera. In: Debenedetti, A., Elam, C. (Eds.): Botticelli past and present. UCL Press, London, 2019, pp. 73–90.

[NeEg17] Neuburger, Larissa; Egger, Roman: An Afternoon at the Museum: Through the Lens of Augmented Reality. In: Information and Communication Technologies in Tourism. Springer International Publishing, 2017, pp. 241–254.

[Vert79] Vertova, Luisa: Cupid and Psyche in Renaissance painting before Raphael. In: Journal of the Warburg and Courtauld Institutes, Vol. 42, 1979, pp. 104–121.

[Vert93] Vetova, Luisa: La fortuna della favola di Psiche da Cosimo Pater Patriae al Gran Principe Ferdinando de' Medici. In: Giuseppe Maria Crespi nei Musei Fiorentini. Exh. cat., Galleria degli Uffizi, Florence, 1993, pp. 27–62.

[ViId17] Viola, Fabio; Idone Cassone, Vincenzo: L'arte del coinvolgimento. Emozioni e stimoli per cambiare il mondo. Hoepli, Milano, 2017.

Investigating Modes of Activity and Guidance for Mediating Museum Exhibits in Mixed Reality

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Abstract

We present an exploratory case study describing the design and realisation of a "pure mixed reality" application in a museum setting, where we investigate the potential of using Microsoft's HoloLens for object-centred museum mediation. Our prototype supports non-expert visitors observing a sculpture by offering interpretation that is linked to visual properties of the museum object. The design and development of our research prototype is based on a two-stage visitor observation study and a formative study we conducted prior to the design of the application. We present a summary of our findings from these studies and explain how they have influenced our user-centred content creation and the interaction design of our prototype. We are specifically interested in investigating to what extent different constructs of initiative influence the learning and user experience. Thus, we detail three modes of activity that we realised in our prototype. Our case study is informed by research in the area of human-computer interaction, the humanities and museum practice. Accordingly, we discuss core concepts, such as gaze-based interaction, object-centred learning, presence, and modes of activity and guidance with a transdisciplinary perspective.

1 Introduction[1]

As in other areas of society, there is a growing interest within cultural heritage institutions to expand existing formats of interpretation and communication by means of digital technologies. With the case study presented in this article, we contribute to this growing interest in digital mediation efforts by exploring how we can conceptualise and design a mixed reality application with a transdisciplinary approach that draws from museum discourses and human-computer interaction. We are particularly interested in two aspects of museum mediation: object-centredness and guidance. Our case study is based on the concept of the "trained gaze", which we seek to translate into a "digitally augmented gaze" for non-expert museum visitors. More specifically, we explore how a visitor can independently examine a museum object in a mixed reality experience while the system supports the visitor in deciphering the visual characteristics of the object and, thus, reveals which properties form the basis for understanding the symbolic or historical meaning of the object. The case study is motivated by three leading research interests, which we investigate with our prototype in an *in situ* user study at a later stage.[2] Firstly, we are interested to see whether and to what extent visitors perceive the "presence" of the physical object exhibited, even if it is supplemented with digital content and virtual objects. Secondly, we adapt different mediation strategies to implement a "digitally augmented gaze" in three modes of activity: a guided narrative, a self-guided exploration mode and a co-active, bidirectional format, in which the system and the visitor can take the initiative. We are particularly interested in the extent to which these modes of activity and guidance affect the learning success of visitors. Finally, we aim to determine whether and how the three different modes affect the overall user experience.

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2 Due to the closure of museums caused by COVID-19, it was not possible for us to conduct the in situ user study that we had planned for March 2020 before finishing this paper.

In the following, we first lay out our interpretation strategy of augmenting a "trained gaze" and contextualise it in related museum discourses. We then describe the considerations we derived from this concept for the design and technical realisation. This is followed by a discussion, firstly, of object-centredness and object presence in a museum context and in human-computer interaction and, secondly, of different modes of activity and guidance in museum mediation. The second part of the paper presents the findings from a two-stage visitor observation study and formative study that are part of a user-centred approach that informed the content creation and development. In the third and final part of the paper, we describe systematically how research insights from human-computer interaction have informed the realisation of our concept of augmenting a physically present museum object in three different modes of activity. With this paper, we want to illustrate a transdisciplinary approach for the design and development of interactive digital media, especially mixed reality applications in museum contexts. We conclude our article with a discussion on the future steps needed.

2 Interpretation Strategy and Design Considerations

Museum mediation promotes understanding and meaning-making among visitors. Although there are different understandings of what exactly is meant by the term *mediation* – depending on the country, cultural institution and tradition of practice – the term generally covers three interconnected aspects: education, interpretation and communication [Medi14: 20]. *Interpretation*, in this context, refers to a dynamic process that aims at assisting visitors to develop the skills to explore an exhibition or object independently and enhance their understanding [Blac05: 185]. The term *interpretation* is normally used to describe informal, voluntary and enjoyable learning in museums that caters to the interest of the visitor [ibid.: 183], whereas *museum education* refers to rather formal learning situations.

Museums make use of a variety of media, in both analogue and digital formats, to offer interpretation about objects. However, most interpretive media require the visitor to avert their eyes away from the objects exhibited, at least to some extent, be it to read wall texts, handouts, catalo-

gues, labels, to interact with digital displays, or even during guided tours, where people might focus on the guide or engage in other social interactions with their group. Even with audio guides, which allow visitors to listen to additional information while viewing exhibits or strolling through a museum, visitors have to shift their focus of attention away from the objects in order to select the next audio clip on their device. Furthermore, the systems used for delivering the audio content have no way of detecting whether the visitor is actually looking at the object for which it is providing additional content. Based on these considerations, we decided to develop an object-centred interpretation strategy that minimises the need to avert the eyes away from the object while using a system that allows us to directly connect interpretation to the visual properties of the object at which a visitor is currently looking.

We took inspiration for our prototype from the concept of a "trained gaze" or of acquiring "viewing skills", which include observational skills, the ability to probe and to find a variety of possible meanings [RiYe02]. By building our interpretation strategy on the idea of a "trained gaze", we take into account the assumption that a work of art can only be truly understood and grasped through precise and prolonged observation [teHe12: 15]. However, this assumption presupposes a high degree of expertise and connoisseurship and can only apply if the viewer has the necessary art historical and iconographic knowledge to "read" an object and its formal properties [Dudl12a: 11]. Art historians rely, among other things, on a "mental archive of images and style" [HaKl06: 12] when observing an artwork. This incorporated implicit and explicit knowledge combined with acquired viewing skills are part of a "trained gaze". The latter does not only influence the ability to derive meaning from the act of visually observing objects, but it also influences the perception and aesthetic judgement of art [NoLK93].

Regarding the realisation of this interpretation strategy, we focused on three main principles and considerations for our choice of mediation technology and interaction design that we present in the following sections: gaze-based interaction in a pure mixed reality experience (2.1), object-centredness and a sense of object-presence (2.2), and different modes of activity and guidance (2.3).

2.1 Gaze-based Interaction in Pure Mixed Reality

With our interpretation strategy in mind, our choice of technology has to allow thorough observation of the museum artefact without obstructing the view of the visitor. Moreover, we seek to minimise the need to avert the eyes away from the object while visually exploring it. Taking these requirements into account, we decided to explore the potentials of mixed reality, which led to our choice of Microsoft's HoloLens [MS20a], a head-mounted holographic see-through projection system with a mobile processing unit and various sensors. In contrast to conventional augmented reality technology, these glasses enable a true merge of digital content with the physical world, rather than superimposing it. Carlos Flavian et al. [FIIO18] call this type of mixed reality "a pure mixed reality" (PMR) and position this concept between augmented reality and augmented virtuality in Milgram and colleagues' "Virtuality Continuum" [MTUK94]. Visitors are enabled to equally and simultaneously interact with virtual and physical objects in a PMR.

In the context of the HoloLens technology, we considered three main aspects for the realisation of our PMR application. Firstly, the merging of physical and virtual objects is made possible through the *spatial mapping* feature, which provides a detailed real-time representation of the physical surfaces in the environment around the HoloLens. This so-called "world mesh" enables the designer of a PMR environment to interweave physical objects convincingly with the virtual space. *Inter-reality physics* becomes possible, as virtual objects can, for example, bounce off tables, floors, chairs, or other spatial or physical elements that have been integrated into the world model of the HoloLens. Interaction techniques based on the spatial mapping feature, respectively, on inter-reality physics, can contribute to a strong sense of PMR.

The *sliding puck*, a "cursor" that is attached to the user's gaze, is the second important aspect in the design of our PMR. In combination with the *world mesh*, the *sliding puck* behaves equally to virtual objects as it does to physical objects. The puck slides over the surface of the object of which the system has created a world mesh (see Fig. 1). While the users let their gaze wander, the puck simultaneously aligns with the surface of the objects mapped. The users, metaphorically speaking, can "touch" the objects with the sliding puck. Physical and digital objects can be treated equally in a PMR, since the gaze aligns with the surface of virtual objects

in the same way as it does with physical objects. This offers the opportunity, for example, to virtually augment missing elements of an object while treating both object surfaces, the physical and the virtual, equally from an interaction point of view.

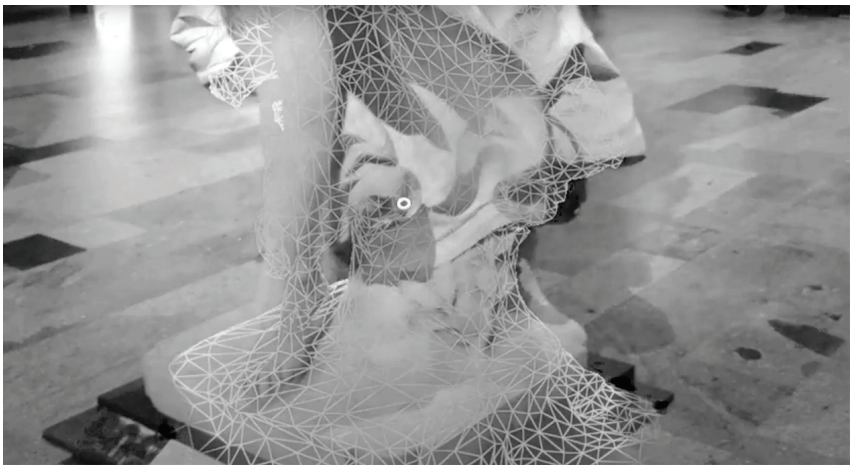

Fig. 1: HoloLens' spatial mapping feature creates a "world mesh" of its physical surroundings. The "sliding puck" (centre) aligns to the surface of all objects included in this world mesh – both existing physical objects and virtual objects that are added to the world mesh.

The third aspect which can contribute to a sense of being in a PMR is the *"unbroken" holospace*. This relates to the limited field of vision in the HoloLens. Especially large virtual artefacts that surpass the field of vision emphasise the boundaries of the holospace and might break the illusion of the PMR. To avoid the impact of a "broken" holospace, virtual objects can be designed rather small or distant. However, to mitigate this restriction, interaction techniques such as the "tag-along" technique [MS20b], which is a feature that lets an object follow the gaze axis, can be employed to create the illusion of a larger holospace. Also gestalt rules such as reification can be used to avoid exposing the edges of the holo field of vision.

2.2 Object-centred Learning and Sense of Object-Presence

As has already been implied with our interpretation strategy, our use case is focused on museums of art and cultural history. Regarding this type of museum, special attention must be paid to the significance of the original object – more precisely, the original artwork or the authentic historical

artefact. Objects act as material witnesses that help us to understand art, cultures and the past. Consequently, the original object is at the centre of educational practice, especially in museums of art and cultural history [RiYe02].

Object-centredness relates to the concept of *presence*, which, in our case, needs to be discussed from two perspectives: its meaning in a museum context and human-computer interaction and the design of virtual or mixed reality. Object-centredness *per se* in museology and the humanities does not automatically invoke a preoccupation with the material presence of an object. Gumbrecht, for example, points out that from an epistemological standpoint, the core practice of the humanities constitutes an institutionalised tradition of interpretation, understood as "the identification and/or attribution of meaning" [Gumb04: 1]. However, he calls for a "reconfiguration of some of the conditions of knowledge production" (ibid.). He suggests that we instead "conceive of aesthetic experience as an oscillation (and sometimes an interference) between 'presence effects' and 'meaning effects'" [Gumb04: 2], which emphasises and acknowledges the influence of materialities on our experience and understanding of the world. We explore in our case study whether and how museum interpretation, while in itself focused on the attribution of meaning, can also simultaneously highlight the material presence of an object. This approach is set against the observation that objects in museums often "feature as mere illustrations punctuating the story being told" [Dudl12a: 6], which, in turn, distances objects from visitors by putting a focus on "the story *overlying* the physical thing" [Dudl12b: 10).

At the same time, the term *presence* also plays an important role in research on virtual, augmented and mixed reality. Although in this context, the term relates more to the feeling of "being present" or fully submerged in a virtual, augmented or mixed environment. Presence is understood as the outcome or purpose of immersion [ScFR01]. Research in this area, among other things, aims at understanding how a sense of presence emerges in such environments and how the sense of presence (or lack thereof) can be measured [UCAS00]. Furthermore, discussions of numerous types of presence have emerged since then. Exemplarily, mixed reality, specifically, aims at creating a "co-presence", a sense of being together in a shared space [WBJK09].

Our approach combines these two concepts of *presence*: the *material presence* of an object and its effects on understanding and meaning-making, and a sense of *co-presence* with the object in a mixed reality environment. We aim at creating a PMR that brings the visitor and the museum object together into a shared space in which the attention of the visitor is directed towards the material presence of the object. As Wagner et al. point out, the experience and, thus, perception of presence is created by a co-constructed reality that is "filtered through the purpose of the actions in which we are engaged" [WBJK09: 273]. This aspect also relates to and emphasises the importance of active visual exploration, which is implied in our interpretation strategy, in a mixed reality setting. Similarly, Schubert et al. point out that attention allocation and the awareness of possible action patterns both contribute to the emergence of presence. They argue "that a virtual environment, like any other environment, is perceived and understood by mentally combining potential patterns of action" [ScFR01: 267].

2.3 Modes of Activity and Guidance

The scope of action for visitors in museums is usually structured along two main conditions: interpretation is either conveyed in a guided or a self-guided mode. Guided, in this context, especially includes tours through an exhibition or museum where visitors are accompanied by a museum guide. These guided tours often follow a linear narrative that highlights certain aspects or perspectives on a given topic. Here, the museum guide takes on the active part, decides on a narrative and sets the route and timing, while the visitors follow rather passively. Apart from interpersonal guided formats, audio guides can be used during a visit, or an exhibition design might suggest the visitors follow a predefined path through a curatorial narration. However, even when curators or educators establish such predefined paths through an exhibition, there is evidence that suggests that visitors sometimes assert their own agency and, thus, explore exhibitions by way of their own initiative and interest; they "go where they want to go. They skip elements, visit only one-third of them, and spend much less time than is often assumed" [Serr97: 120].

A museum visit in a completely unguided modus, without resorting to any interpretative media, would presuppose that a visitor can draw from previously acquired viewing skills and a "trained gaze". However, since

our interpretation strategy aims at digitally augmenting such a "trained gaze" for *non-expert* visitors, we assume that a minimum of guidance and instruction during the observation and viewing process would be needed. Such a condition can also be called "self-guided". During a self-guided tour, the visitors decide independently what they want to see or how much time they want to spend with what activity, while they receive interpretation through, among others, wall texts, labels or leaflets. Most audio or multimedia guides can also be used in a self-guided mode, which means that visitors would not use them to follow a predefined narrative through an exhibition, as in a guided format, but rather to access information about individual artefacts when desired. There has been a shift in museum mediation practice, especially in recent years, that has led to a diversification of formats and activities in museums. This includes low-threshold educational formats such as interactive games, or inclusive media such as multimedia apps in sign language, but also a variety of participatory formats that invite visitors to actively contribute to the narrative of an exhibition. This exemplifies a growth in openness towards bidirectional (or multidirectional) formats of museum mediation.

Our approach to conceptualising these conditions of activity and guidance for our prototype was informed by the concept of *conversational agents* from the domain of natural language processing (NLP). The communication here between human and computer is understood as a *dialogue* of two or more agents. Initiative, in this research domain, refers to the concept of "who is in control of the communication" [LiMC15]. We consider that the concept of *initiative* is not limited to dialogues using natural language [Horv99]. It can be extended to other modalities, such as gesture, gaze and movement-based interaction.

Public displays that facilitate the dialogue between human and computer in the domain of human-computer interaction are commonly described as either *autoactive, reactive* or *interactive* systems [Saut04]. In the case of autoactive systems, the computer system performs a monologue during which it holds 100 % of the control over the dialogue (Table 1). Some agency might be given to the human by choosing a *reactive* communication strategy. Examples of a *reactive* system design are interactive videos, an automated call centre or automatic self-opening doors. Still, the degree of agency of the system remains quite high in a reactive system. *Interactive* systems offer the participant of a "communication" the primary control of

the dialogue. Nonetheless, the user has just a medium degree of agency, as the system demands a certain behavioural style to follow and decides on the topic of a "dialogue". Examples are office software applications or games.

However, using the HoloLens technology allows us to conceptualise a third mode of activity – the co-active strategy. In the latter, there are times when the system takes or gives the initiative, but, at the same time, the human can interrupt and take the initiative. Both entities, human and computer, form a more natural dialogue, since both can initiate an activity or topic. This mode of activity in NLP is called mixed initiative (Table 1).

From a museum perspective, autoactive and reactive systems would be considered *guided* (in NLP terms system-initiative) and an interactive system *self-guided* (in NLP terms user-initiative). Co-active systems resemble bidirectional mediation in museums (in NLP terms mixed-initiative). Since we want to explore whether and how our interpretation strategy of augmenting a "trained gaze" and the experience of *presence* in our PMR is affected by the mode of activity, we decided to realise all three conditions in our prototype in order to be able to test the effect in an *in situ* user study at a later stage.

Human-Computer Communication Continuum				
Domain	*Domain-specific terminology*			
Museum Mediation	guided		self-guided	bidirectional
Natural Language Processing	system-initiative		user-initiative	mixed-initiative
Human-Computer Interaction	autoactive	reactive	interactive	co-active

Examples				
	- 3D Movie - self-playing piano	- interactive video - automatic self-opening door	- software application - arcade slot machine	- natural dialogue systems - adaptive menus
Degree of Agency				
Human	none	low	medium	dynamic
Computer	maximum	high	medium	dynamic

Table 1: Human-computer communication continuum with domain-specific terminology for the three different modes of activity.

3 Visitor Study and Formative Study: User-centred Content Development

We decided to create a prototype for the purpose of our study that exemplifies our concept with a single museum exhibit. The object we selected through a formal object scouting process is the figurative sculpture "Viktoria" from the collection of the Deutsches Historisches Museum (DHM). This 3.90-m tall allegorical representation of the goddess of victory, completed in white marble by the German sculptor Fritz Schaper in 1885, opens up especially two interconnected lines of interpretation which are easy to link with the visual and material properties of the object: the iconographic meaning of a number of attributes and the object's biography and its interconnectedness with German history.

We conducted a two-stage visitor study and a formative study including the HoloLens in order to better understand how visitors interact naturally with the sculpture in an unguided modus and what elements of the sculpture spark their interest. For the visitor study, we observed the visitors' behaviour with and around the sculpture. We randomly selected visitors who entered the area where the sculpture is located and observed and

manually noted their movement and behaviour without interacting with them.

Fig. 2: "Viktoria from the domed room – the Rulers' Hall – of the Berliner Zeughaus" by Fritz Schaper, 1880/1885, DHM, Berlin. Images taken during the creation of the world mesh and three-dimensional model with the HoloLens.

The marble sculpture is placed in the middle of the lower entrance hall of the DHM, approximately 10 m from the ticket counters and 9 m from the staircase that leads to the permanent exhibition. About 30% of visitors passed the sculpture without stopping to look at it; 70% of visitors approached the sculpture and looked at it and about 25% of visitors took a picture of or selfie with the sculpture. After having noted their behaviour, we approached the visitors, including those who had not looked at the sculpture, and asked them to participate in our survey. The observation and survey took place over five days, spanning 3–4 hours on weekdays and weekends in March and April 2019, during which we were able to complete 62 questionnaires. Our main interest was to learn more about the visitors' information needs. We wanted to find out with our first question whether the visitors were able to identify the allegorical figure as the goddess of victory. Out of the 62 respondents, 67% were not able to speak about either the meaning or name of the sculpture, 19.4% of

the respondents were able to correctly state the name or the allegorical meaning ("Nike", the Greek equivalent to "Viktoria", or "goddess of victory" were also accepted as a correct answer), while another 12.9% were able to quote the name of the figure because they had just read it on the label.

We then asked the respondents which feature or aspect of the sculpture made them particularly curious. Recurring answers mentioned wings (25%), size (17%), missing arm (9%), overall appearance (6%), robe (5%) and place of installation (5%). When asked what they would like to know more about, the most commonly mentioned aspects were the history or biography of the object (25%), for example, in relation to art history and the history of Berlin, the symbolic meaning of the sculpture or certain attributes (20%), the production process of the artwork (17%), its original place of installation (15%) and details about the visible damage to the sculpture (12%), such as the missing right arm. Interestingly, further information on the artist only made up 6% of the answers, despite authorship and artist attribution being one of the most common pieces of information given on labels and interpretative media in museums.

Having gathered these insights, we then conducted a formative gaze-fixation study with the HoloLens in order to confirm that the self-reported visual aspects that spiked the visitors' curiosity match their actual viewing behaviour as recorded by the HoloLens. Convenience sampled visitors were instructed in putting on the HoloLens and confronted with two tasks: 50% of the participants were told that we wanted to test the wearing comfort of the HoloLens and that they could just walk around the sculpture and look at it for as long as they wanted to. The other half of the participants were told that they had to answer questions about the sculpture at the end of the test.

We were able to confirm that there is a general overlap between the visual features and aspects that visitors had verbally reported as "sparking their curiosity" and the gaze-fixation on the sculpture that we recorded with the HoloLens. In both studies, some important attributes or properties, such as the palm branch and the missing arm, received less attention than we had expected. Furthermore, the gaze-fixation study showed that smaller material aspects, especially those that would require a thorough observation from the side or back of the sculpture, would likely go unnoticed. This included the inscription on the bottom right side of the sculpture's base

denoting the artist name and year of creation. The gaze-fixation study also showed that people observed the sculpture more thoroughly when under the impression that they had to answer questions about the sculpture after exploring it (an average of double the time).
Based on the insights from both the self-reported interest and the gaze-fixations recorded with the HoloLens, we defined a total of seven "Regions of Interest" (ROIs) and used them as reference points for the content development process. In this selection, we also included those ROIs that had been missed by visitors during the gaze-fixation study, especially when these ROIs could be linked to the interpretation about recurring self-reported areas of interest derived from our visitor study. We added an introduction and a conclusion to these seven ROIs, resulting in a total of nine content units that can be accessed in the prototype of our PMR experience.

4 Content and Design

We generally aimed at creating a PMR that would encourage visitors to thoroughly observe the sculpture, its material presence and attributes. Following our object-centred concept of augmenting a "trained gaze", we made sure that the content linked to our seven ROIs does not distract from the visible elements of the sculpture but reinforces thorough observation. We chose a content type for each of the ROIs that would support the understanding of the associated meaning and its particularity for the sculpture, while also making use of the specific design options of a PMR created with the HoloLens. This led to the decision to use spoken texts to explain the meaning of attributes and material properties of the sculpture. Interpretation in our PMR also includes still images, animations, three-dimensional objects, visual effects and text, each positioned in relation to the sculpture. In the following, we describe the content of the ROIs and how we decided on the selection technique for those. Finally, we detail the different navigation paths which interconnect the ROIs and how they relate to the three different modes of activity.

Fig. 3: Regions of interest highlighted in white: missing arm (ROI 1), palm branch (ROI 2), front of the wings (ROI 3), head (ROI 4), back of the wings (ROI 5), inscription on the base (ROI 6) and garment (ROI 7).

4.1 Linking Content to Regions of Interest

We are able to augment and, thus, extend the sculpture with the HoloLens by creating a virtual reconstruction of the missing arm (ROI 1) that was originally stretched upwards and held a laurel wreath. The laurel wreath is one of the main attributes of "Viktoria" and supports the identification of the sculpture as the goddess of victory – it already symbolised fame and victory in ancient Rome – which is explained in an audio text. The arm with the laurel wreath was damaged and lost during the Second World War. It was sculpted from an individual piece of marble and attached to the body of the sculpture at the armpit, where it was held in place by a hexagonal mould that is still visible today. The second attribute of "Viktoria" is the palm branch (ROI 2) that she holds in her left arm. When this ROI is selected, a text displays the palm branch's allegorical meaning of victory, triumph and peace, alongside a selection of images from various art historical epochs, allowing the visitor to visually compare the depiction of palm branches. Together with the wings (front of the wings: ROI 3), which trigger an audio text, these two attributes allow the visitor to identify the sculpture as a representation of the goddess of victory. The head (ROI 4) triggers a visual augmentation of the size and weight of the "Viktoria" directly on the object while additional information about the production process is delivered as audio alongside still images that show the assembly in the museum. In contrast to the finely worked marble on the front, the back of the wings (ROI 5) show distinct traces of the chisel that was used by the artist. An audio text related to this ROI interprets the visible difference in the surface texture as a hint that the sculpture was

created with a distinct front side and that the back of the wings was not visible at the original location of the sculpture.

Regarding the self-reported interest of visitors to understand the historical relevance of the object in relation to art history better as well as its significance and symbolic function for Berlin, we decided to develop a spatial data visualisation as part of our PMR. A visitor with a "trained gaze" would be able to access a "mental archive of images and style" [HaKl06: 12], which our non-expert visitor would not be able to do. In order to enhance the untrained viewer with a "trained gaze", we had to find a way to place the "Viktoria" in context with other artworks. The visitors should be supported in understanding how the emulation of works of art led to the incorporation of visual characteristics and symbolic meaning known from Greek and Roman antiquity in sculptures created during Prussian Classicism (19th century). To achieve this, a timeline visualisation is rolled out behind Schaper's "Viktoria" in our PMR experience, creating a shared space that the visitors can explore: the physical museum object occupies the space together with a selection of other "Viktorias" and "Nikes", dating from Prussian Classicism as well as Roman and Greek antiquity ("Nike" being the Greek equivalent and predecessor of the Roman "Viktoria"). The two-dimensional images of the related sculptures are placed in three distinct rows on the timeline: one row with artworks created during Prussian Classicism, the second with sculptures dating back to Roman antiquity and a third row with Greek sculptures. The Roman and Greek sculptures are all placed on the timeline according to the year in which they were found or excavated during the 18th and 19th century. Consequently, all sculptures can be observed in a shared historic framework that supports the interpretation that Schaper and his contemporaries took inspiration from and emulated these Greek and Roman sculptures. The timeline is linked to the inscription on the lower right side of the statue's base (ROI 6), which shows 1885 as the year of completion and the artist's name "Schaper", thus, the first mark of the virtual timeline is created by the year 1885 as a visible aspect of the physical object.

Lastly, a fold of the garment at the back of the sculpture was included as ROI 7 with an associated audio text that encourages the visitor to examine the skilfully sculpted folds in the dress closely and to circle around the sculpture in order to follow the figure's movement.

The final view (conclusion) in the PMR experience augments Schaper's "Viktoria" in its original location. Before its partial destruction during the Second World War, the "Zeughaus", the building that nowadays houses the DHM, was used as a military museum. "Viktoria" was placed here at the centre of attention in the "Ruhmeshalle" (Hall of Fame), where she stood on a pedestal in a wall niche at the end of the domed hall. Based on historical photographs, we created a virtual 2.5-dimensional reconstruction of the "Ruhmeshalle". By lowering the virtual floor in the PMR below the actual floor level, it seems like "Viktoria" is again placed on a pedestal in the wall niche. This final view is also accompanied by a conclusion delivered as an audio text. Apart from the introduction and the final view that have fixed positions at the beginning of the experience and after completing all other content units, the content had to be created in such a way that it could be received in a guided, self-guided or bidirectional mode. We had to make sure that all three conditions of initiative were created with exactly the same content in order to be able to accurately analyse the influence of the mode of activity (as described in chapter 2.3) on the learning results and user experience. The content has to lend itself to being received in no particular order in the self-guided and bidirectional mode but also support a smooth and interesting narrative in a guided mode.

4.2 Designing the Selection Technique for the ROIs

Apart from the order of the content units, the modes of activity are distinct in their selection technique, which is used to trigger the content. A selection technique typically consists of navigating a sort of pointer (in our case, the sliding puck) to the target, followed by a confirmation that the area currently pointed at should be selected. Many HoloLens applications use the "air tap" gesture [MS20c] as the confirming action, which requires the user to learn this interaction technique [TaAL18]. We decided to not employ "air tap" as an interaction technique in our application to keep the learning phase low and emphasise our gaze-based interaction concept. We initially considered developing a dwell-free selection technique, similar to Sarcar et al. [SaPC13], Porta et al. [PoTu08] or Wobbrock et al. [WRSD07]. However, we found that the currently known and tested dwell-free selection techniques require a similar learning phase to the air tap. Therefore, we decided to fall back on a dwell time-based selection, which has been shown to perform quite well [YGYY17]. Dwell time-based

selection techniques typically bear usability problems, such as the Midas touch problem [Jaco95], which means that users are hesitant to look at certain parts of an object because they are afraid of accidentally selecting things. One solution to avoid this is to explicitly design a virtual button attached to the physical object that could be used to confirm selection. However, this does not correspond with our concept of assisting the untrained viewer with a digitally augmented "trained gaze". The search for such buttons would dominate the visual exploration of the sculpture, which, instead, should be focused on the material presence of the object in its entirety. Furthermore, attaching fixed virtual buttons to the sculpture for each content sequence would create a harsh aesthetical interference that we tried to avoid. Instead, the content is selected by first entering a defined collider area around an ROI with the gaze (sliding puck) and a subsequent dwell time-based confirmation (Fig. 5). This means that the visitor's gaze has to remain inside the collider area of the ROI in order to confirm the selection (Fig. 4 right), thus, encouraging thorough observation.
Confirmation constitutes only one part of the two-part selection technique and is similar in all three modes of activity. The second part, navigation, which precedes confirmation, is used to differentiate our modes of activity and guidance, which we describe next. For both parts of the selection technique we established a design solution that would create minimal obstruction and keep the sculpture visible at all times. This solution builds on the decision to use an ephemeral style of particles as visual cues and interaction feedback.

4.3 Navigation in three different modes of activity

Navigation can be either user- or system-initiated. In the self-guided, user-initiative mode, visitors have to actively explore the object with the sliding puck attached to their gaze in order to find ROIs with linked interpretation. The sliding puck reacts with the surface of the sculpture and starts to emit particles only when their gaze enters the collider area of an ROI (Fig. 4 left). After two seconds of hovering over the ROI, the associated collider mesh highlights the entirety of the ROI with particles. A dwell timer (2-s long) then forms around the sliding puck and indicates the approaching act of confirmation (Fig. 4 right). When the dwell timer is completed, a selection sound is played and the content associated to the ROI is delivered (see Fig. 5 left). In this self-guided mode, content can be selected in

any order, since the user actively explores the statue's features while the system only cues possible links to further information by emitting particles that indicate that the gaze has entered one of the seven ROIs. The visitor can also decide to select content units several times.

Fig. 4: In the self-guided mode, particles emit from the user-controlled gaze as soon as it enters the collider area of an ROI (left). In the guided mode, the system displays particles over the entirety of the ROI, which has to be confirmed by the user (middle). A dwell timer forms around the sliding puck and has to be completed before the content that is linked to this ROI is delivered (right). As soon as the content is triggered, all particles disappear. Particles are edited and enhanced for visibility in these images.

The agency of the user is reduced in the guided, system-initiative mode of activity, and the system decides what should be selected next. The system initiates the selection process by highlighting an ROI with particles (Fig. 4 middle). If the user follows this visual cue and enters the highlighted ROI with their gaze, the dwell timer becomes visible (Fig. 4 right), and when it is completed, a selection sound is played and the content is delivered (see Fig. 5 right). In this mode, the users can only confirm they have followed the system's cueing, are looking at the ROI and are ready to receive the associated content. The narrative structure of this guided mode is sequential, with a given order and duration. Once played, the content unit cannot be selected again, and the system visually asks the user to confirm the selection of the next ROI by highlighting it with particles.

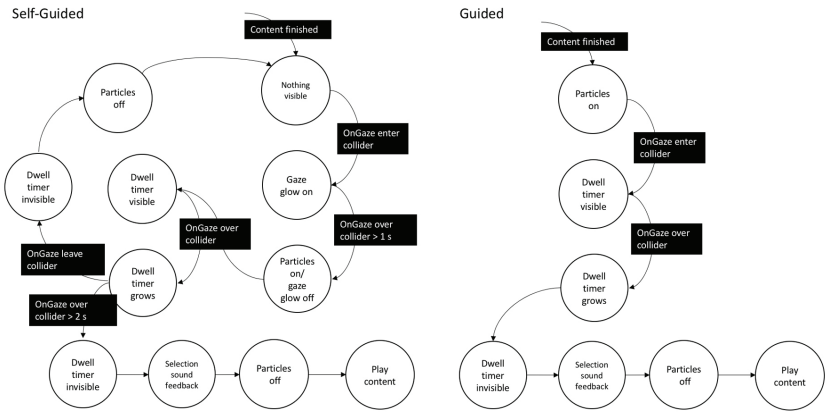

Fig. 5: State diagram showing the initiative design in the self-guided (left) and guided (right) mode.

The bidirectional, mixed-initiative mode uses a mix of both cueing and navigation mechanisms laid out above, depending on who is taking the initiative in the "dialogue"; either the system has the initiative to cue an ROI (system-initiative) or the initiative is given to the user to explore the statue actively (user-initiative). The content structure in this mixed-initiative mode is dynamic and follows a semi-scripted structure. After the introductory audio text, which is automatically played in all three modes, the system firstly switches to the self-guided mode, and the visitor can actively explore the statue and freely select an ROI. In order to be able to initiate a reasoned and purposeful initiative shift, four of the seven content units that we identified as crucial for the understanding of the allegorical and historical meaning of the statue were declared core "learning goals". This included the laurel wreath (ROI 1) and palm branch (ROI 2) – the two main attributes of the goddess of victory – and the head (ROI 4), that is linked to information about the size, production process and assembly of the sculpture in the museum, and, finally, the inscription on the base (ROI 6), that triggers the spatial timeline visualisation (see above). Human and computer have equal amounts of "talking time" throughout the dialogue in the mixed-initiative mode, as initiative switches after each content selection [AlGH99]. The "intention" of the system is to only "talk" (cue ROIs) about the four content sequences that we had declared as important, one at a time. In this bidirectional condition, the system takes the initiative to

support the visitor in identifying key concepts, which should subsequently allow the visitor to engage in a more self-determined process of exploration and meaning-making. As soon as all four important ROIs have been received, either by the initiative of the visitor or that of the system, the conclusion sequence is played.

5 Discussion and Next Steps

In this paper we have put a focus on illustrating the concept of our study prototype, which we have based on related research in HCI and museum practice. In order to explore the research questions laid out at the beginning of this paper, we will as a next step conduct an in-situ user study with our prototype. We will explore a variety of research interests or topics with the user study, which are briefly summarised in the following.

First of all, we explore whether the presence of the physical museum object is maintained even when it is augmented with additional content. For this purpose we designed a questionnaire that contains heuristics that aim to help us understand the perception of object presence. Additionally, we want to investigate whether and to what extent the users experienced a sense of "being present" in the PMR application. The concept of presence in the second sense has been a focus in research on virtual reality for almost 40 years. The emergence of presence is likewise commonly studied with the help of questionnaires. However, Usoh et al. [UCAS00], for example, were able to point out the challenge of "measuring" presence through questionnaires. They conducted an experiment that showed that these questionnaires were only useful when all subjects experience the same type of environment, whereas they are not suitable for the comparison of experiences across environments. Although our subjects will all experience the same type of environment (PMR), they will explore the application in three different modes of activity, which may also have an impact on the comparability of the results we derive from our questionnaire. Generally, it will be interesting to see if we can observe a difference in the perceived sense of presence in our PMR, depending on the type of activity, since awareness of possible action patterns has been identified as contributing to a sense of presence [ScFR01]. In addition to the importance of patterns of action, Schubert et al. [ScFR01] point out that

attention allocation is also involved in the emergence of presence. While we may not be able to determine the level of presence for our experience through a questionnaire alone, tracking the users' gaze in six degrees of freedom may provide us with valuable insights into whether we were able to guide the visitor to thoroughly explore the museum object in its material presence.

One key aspect that is thought to influence the creation of a pure mixed reality experience is the unbroken holospace (see section 2.1). Nonetheless, the final view, a large-scale 2.5-dimensional reconstruction of the "Ruhmeshalle" that augments the museum object in its original location, consciously ignores this principle. We hope to be able to observe user reactions that allow us to derive indications as to whether or not the fractured holospace in fact reduces the PMR experience.

As we have illustrated in section 2.3, different formats of museum mediation can be understood as prioritising different modes of activity and guidance. In our user study we will explore whether the three corresponding conditions (user-, system- and mixed-initiative) have a noticeable effect on the perceived sense of agency, overall user experience and learning result.

Building on the assumption that museum visitors are driven and influenced by a variety of identity-related motivations [Falk10] [Bond12], our user study also includes a simplified version of Falk's [Falk10] approach towards the allocation of visitor motivation. By including this aspect, we want to explore whether we can observe differences in the study results depending on the visitors' motivation type.

Although we have made a conscious decision to use exactly the same content in all three modes of activity to ensure comparability of results, we are aware that this limitation might not be practical outside a study context. In common museum practice, different modes of activity and guidance would also require specialised and ideally visitor-dependent content. This is related to the notion that the production of meaning and interpretation, especially in contemporary approaches to art history, is understood as emanating from a personal perspective [HaKl06: 20]. Such an understanding also infers that the act of viewing and interpretation – the "trained gaze" – is not only influenced by scholarly knowledge but also by political and social aspects as well as the interest of the beholder. This understanding of interpretation as dynamic, flexible and viewer-

dependent encourages us to consider different lines of interpretation and thus offer more diverse content as part of the next iteration. In this way, we will be able to truly exploit the potentials of digitally supported museum interpretation that not only caters to different needs or preferences for guidance and modes of activity but is also able to account for a variety of interests, learning levels, narratives and media.

Literature

[AlGH99] Allen, J.E.; Guinn, C.I. & Horvitz, E: Mixed-initiative interaction. In: IEEE Intelligent Systems and their Applications, vol. 14, no. 5, 1999, pp. 14–23.

[Blac05] Black, Graham: The engaging museum. An interpretative approach to visitor involvement. Routledge, London 2005.

[Dudl12a] Dudley, Sandra: Materiality Matters. Experiencing the Displayed Object. In: Working Papers in Museum Studies (8). University of Michigan 2012.

[Dudl12b] Dudley, Sandra: Encountering a Chinese Horse. Engaging with the Thingness of Things. In: Dudley, S. (Ed.) Museum Objects. Routledge, London 2012.

[FlIO18] Flavian, Carlos; Ibáñez Sánchez, Sergio & Orús, Carlos: The impact of virtual, augmented and mixed reality technologies on the customer experience. In: Journal of Business Research, 2018.

[Gumb04] Gumbrecht, Hans Ulrich: Production of Presence. What Meaning Cannot Convey. Stanford University Press 2004.

[Jaco95] Jacob, R.: Eye tracking in advanced interface design. In: Barfield, W. and Furness, T.A. (eds.): Virtual Environments and Advanced Interface Design. Oxford University Press, New York 1995, pp. 258–288.

[HaKl06] Hatt, Michael & Klonk, Charlotte: Art History. A Critical Introduction to Its Methods, Manchester University Press 2006.

[Horv99] Horvitz, Eric: Principles of mixed-initiative user interfaces. In: Proceedings of the SIGCHI conference on Human Factors in Computing Systems (CHI ’99). ACM, New York 1999, pp. 159–166.

[LiMC15] Limerick, Hannah; Moore, James & Coyle, David: Empirical Evidence for a Diminished Sense of Agency in Speech Interfaces. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI ’15). ACM, New York 2015, pp. 3967–3970.

[MS20a] Microsoft: Microsoft Hololens. https://docs.microsoft.com/de-de/hololens/hololens1-hardware. Last accessed: 08.04.2020.

[MS20b] Microsoft: Billboarding and Tag-Along. https://docs.microsoft.com/de-de/windows/mixed-reality/billboarding-and-tag-along. Last accessed: 08.04.2020.

[MS20c] Microsoft: Gaze and Commit. https://docs.microsoft.com/de-de/windows/mixed-reality/gaze-and-commit. Last accessed: 08.04.2020.

[MTUK94] Milgram, Paul; Takemura, H.; Utsumi, A. & Kishino, F.: Augmented Reality: A class of displays on the reality-virtuality continuum. In: Proceedings of Telemanipulator and Telepresence Technologies, 1994, pp. 2351–34.

[Medi14] Museum Mediators: Guidelines for Museum Mediators professionals in Europe, 2014. http://museummediators.eu/wp-content/uploads/2014/09/MMediators Europe_ResearchResults_finalReport.pdf. Last accessed: 08.04.2020.

[NoLK93] Nodine, Calvin F.; Locher, Paul & Krupinski, Elizabeth: The Role of Formal Art Training on Perception and Aesthetic Judgment of Art Compositions. In: Leonardo, 26, 1993.

[PoTu08] Porta, Marco & Turina, Matteo: Eye-S: a full-screen input modality for pure eye-based communication. In Proceedings of the 2008 symposium on Eye tracking research & applications (ETRA '08). ACM, New York 2008, pp. 27–34.

[RiYe02] Rice, Danielle & Yenawine, Philip: A Conversation on Object-Centered Learning in Art Museums. In: Curator (45/4), 2002.

[SaPC13] Sarcar, Sayan; Panwar, Prateek & Chakraborty, Tuhin: EyeK: an efficient dwell-free eye gaze-based text entry system. In: Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction (APCHI '13). ACM, New York 2013, pp. 215–220.

[Saut04] Sauter, Joachim: Das vierte Format. Die Fassade als mediale Haut der Architektur. Publiziert auf netzspannung.org: http://netzspannung.org/positions/digital-transformations, 2004. Last accessed 02.04.2020.

[ScFR01] Schubert, Thomas; Friedmann, Frank & Regenbrecht, Holger: The Experience of Presence: Factor Analytic Insights. In: Presence, Vol. 10, No. 3, 2001, pp. 266-281.

[Serr97] Serrell, Beverly: Paying attention. The duration and allocation of visitors' time in museum exhibitions. In: Curator, 40(2), 1997, pp. 108–125.

[TaAL18] Tang, Ym; Au, KM & Leung, Yohana: Comprehending products with mixed reality: Geometric relationships and creativity. In:

International Journal of Engineering Business Management, 2018.

[teHe12] te Heesen, Anke: Theorien des Museums zur Einführung. Junius, Hamburg 2012.

[UCAS00] Usoh, Martin; Catena, Ernest; Arman, Sima & Slater, Mel: Using Presence Questionnaires in Reality. In: Presence: Teleoperators and Virtual Environments. 9, 2000, pp. 497–503.

[WBJK09] Wagner, Ina; Broll, W.; Jacucci, G.; Kuutti, K.; Mccall, R.; Morrison, A.; Schmalstieg, D. & Terrin, J.J.: On the Role of Presence in Mixed Reality. In: Presence. 18, 2009, pp. 249–276.

[WRSD07] Wobbrock, Jacob; Rubinstein, James; Sawyer, Michael & Duchowski, Andrew T: Not Typing but Writing: Eye-based Text Entry Using Letter-like Gestures. In: Proceedings of the 2007 COGAIN Conference on Communication by Gaze Interaction (COGAIN 2007), Leicester, 2007, pp. 61–64.

[YGYY17] Chun Yu; Yizheng Gu; Zhican Yang; Xin Yi; Hengliang Luo & Yuanchun Shi: Tap, Dwell or Gesture? Exploring Head-Based Text Entry Techniques for HMDs. In: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI ’17). ACM, New York 2017, pp. 4479–4488.

"What if me Were Another?"

Extended Realities, Extended Bodies and the Challenge of Extended Empathy

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Abstract

This contribution takes up the diction of VR/XR as the "ultimate empathy machine" and critically discusses concepts of immersion and embodied interaction. A case study of *The Machine to be Another,* an XR embodiment system, serves as an exemplary assemblage which aspires to translate current discourses in collective and individual psychology, neurosciences and STS into the field of artistic research and artistic intervention. Taking *The Machine to be Another* as a paradigm, different concepts of illusionary embodiment and virtual body swap, physical and virtual presence as well as different dimensions of empathy are discussed. It is argued that the concept of immersion should always be accompanied by critical disimmersion – a kind of estrangement that reminds user-interactors of the contingency of mediated emotions and affects.

1 "Hype and Hope" – VR as "the Ultimate Empathy Machine"?

In 2015, Milk got the ball rolling when he referred to virtual reality as "the ultimate empathy machine" [Milk15]: an early promise of virtual reality non-fiction was its promise to open up space for immersive and transformative affective experiences: The idea was that "through providing viewers with the means of standing in their shoes' of the filmmaker's subjects – […]VR non-fiction could allow audiences to experience and connect to 'the real' in ways beyond what could be achieved with traditional two dimensional film". The hypothesis often brought forth was that users – or rather interactors – would not be restricted to being passive observers of a story but could experience physical presence and a feeling of embodiment which then led to immersion in the actual setting. These discourses fuelled a hype – allied with a hope – around VR, AR, MR and XR configurations to possibly enhance mutual understanding and deeper emotional connections. By now, this first excitement has cooled down, but XR still inspires experimental-experiential man-machine-assemblages that go beyond merely functional use of technologies. With VR becoming more and more a cultural technique fathoming its technological as well as socio-cultural affordances, both art [MTSG15] and experiential non-fiction storytelling discover VR and XR – accompanied by critical discourses. Among others, Rose [Rose18b], Sutherland [Suth15], Nash [Nash19], Bailenson [Bail19], Bevan et al. [BGFR19], McRoberts [McRo18] and Farmer [Farm19] discuss the potential VR in non-fiction and complex assemblages. Drawing upon considerations from neurosciences, individual and social psychology, but also taking into account aesthetics and media ecological discourses, they set out to probe into what VR and XR configurations already *are* and what they might *become*.

This contribution will focus on three sets of interrelated issues – starting from more basic reflections about VR, and then passing on to a more specific usage of VR/XR applications in the field of empathy-building and closing with more general media-ethical thoughts.

- Which paradigm shifts are implied in the movement from ocular-centrist to embodied experiences? What happens when XR not only affords a swap of bodies but also of minds?

- How can the immersive perspective provided by VR/XR actually increase empathy?
- What is our conceptualization not only of others but also of ourselves mediated in VR/XR assemblages?

2 Virtually Extended Realities and the Challenge of Virtually Extended Empathy

2.1 *The Machine to be Another*

An especially ambitious project in the field of artistic research that probes into the potential of VR, AR, MR and XR at the intersection of neurosciences, theatrical practices and new media art is *The Machine to be Another*. Equipped with an Oculus Rift headset and headphones, participants swap perceptual systems with another participant or a professional performer (depending on the script) who mirrors whatever they are doing. If they lift their hand, their physical other lifts his/her hand, but if they look at 'their' hand, the headset shows them the hand of 'the other' as their own one. Moreover, a camera transmits what the other sees: If the participant for example looks at his/her hand, the camera worn by the other participant doubles this gaze but produces the image of the other's hand.

Fig. 1: The coupling of 'human' – 'machine' (VR-technology) – 'human' in *The Machine to be Another*. Combining a body swap with a gender swap. Source: ars.electronica http://archive.aec.at/prix/showmode/48981/

This makes *The Machine to be Another* a very special exploration of the possibilities of VR and XR configurations: in contrast to self-contained systems, in which the physical and narrative experience is comprehensive and is comparable to a game or 360° video, *The Machine to be Another* can be more accurately described as a "protocol" or "embodiment system" [BGCP13]. In this context, "embodiment systems" are complex configurations in which the experience is a formalized, structured interaction with 'an other'. The interplay has cues, but it is not fully scripted. Like in happenings or artistic interventions of the Fluxus movement, the framing of interplay is roughly planned, but the actual interaction is improvisation, requiring creative audience participation which makes each experience a unique experimental-experiential encounter.

Usually, the experience begins with the participant being fitted with an opaque Oculus headset and led into a room where 'the other', who will be sharing the experience by mirroring the participant's movements, is already waiting. Then, the participant is invited to open his/her eyes and to slowly start moving. This is the moment when looking down at herself, she for the first time discovers the body of 'the other'. Typically, the first impulse is to touch oneself and to physically examine one's own 'new' strange body – e.g. a body of colour, a body of a different sex or the body of someone disabled. The configuration as a complex technologically enhanced assemblages feels fragile, movements are usually very tentatively – especially at the beginning. Eyes and bodies have to be tuned together, and movements must be agreed upon with 'the other'. If gestures are performed too abruptly, the invisible 'bondage' which develops between the two interactors will be suspended. This makes the encounter of oneself with 'the other' but also oneself with one's new (visually illusionary) self a precarious achievement that requires cooperation – a fact that sets *The Machine to be Another* apart from single-user only VR/XR configurations and that reminds one more of collective VR experiences such as CAVE-live virtual reality theatre experiences as e.g. described by Layng et al. [LPHB19]) .

2.2 From the Eye to the Body: Paradigm Shifts from Ocularcentrism and Tactile Visuality to Embodiment Systems

A further twist is added by involving objects in the experience or in the case when participants touch themselves. In the sense of Actor Network

Theory [Lato96; 05; Law99], the hybrid assemblage is getting more complex if, for example, both participants are handed a more or identical apple each. Both participants feel the apple and can explore it 'haptically' – but each of them sees it in 'their own' strange hand – i.e. the hand of the other. Or – what is even more disturbing: Both participants touch their own body. Their hands feel the body, and their body feels the touch – but their eyes see something different – the body of the other.[1]

Fig. 2: Further complication of the hybrid configuration in *The Machine to be Another*: participants touching their own bodies
Source: ars.electronica, http://archive.aec.at/prix/showmode/48981/

Hence, it can be stated that the notion of 'tactile' or 'haptic visuality' as coined by Marks [Mark02] is extended by a further dimension or rather enhanced by a further amendment: For Marks, 'tactile vision' regards both the qualities of visual perception and the haptic qualities that are assigned to the images of the objects represented. As Huhtamo underlines, this implies that "in actual practices of looking, the 'optical' and the 'haptic' can never be entirely separated." In this paradigm, however, one still resides in the realm of ocularcentrism:

The idea of 'haptic visuality' implies the transposition of qualities of touch to the realm of vision and visuality. It confronts the issue of the physicality of touch indirectly, through a corporeal operation involving the eyes and the brain. The hands are not part of it, except as an imaginary 'projection.' Although useful, the notion of 'haptic visuality' cannot be applied as such

1 At this point it should be remarked that the discussion of the haptic quality of vision originated already around 1900. Among others, German art historians like Adolf Hildebrand and Alois Riegl explored in how far there exists such a phenomenon as the 'visual touch'.

to the analysis of phenomena like interactive art, where the body – sometimes coupled with a 'body image', like the 'levitating hands' in virtual reality applications – is directly involved. [Huht07; p. 73].

In *The Machine to be Another,* in contrast, the eyes do not see what the tactile senses submit, and the other way round: the eyes see some else's other's hand touching the apple, and still, they feel it not only 'as if' it were their own hand, but they actually have the physical sensation of the apple because their own hand touches the apple, too.

However, *The Machine to be Another* not only comprises such rather straightforward scripts. Moreover, the configuration enables body swaps as well as gender swaps, and it allows participants to 'stand in the shoes' of groups of people who are often discriminated against – whether because of their colour of skin, their cultural background or a physical disability. In one script, for example, the user-interactor swaps body with Youssoupha, an immigrant from Senegal, and in "In Merce's wheels", users with no disabilities participate in what Bertrand et al. describe as "functional diversity exchange" [BGCP13] when swapping body with Merce, a young woman in a wheelchair, and listening to Merce's experiences when interacting with people with no disabilities. Thus, so the aspiration of the setting, they are able to temporarily experience what it means to face the everyday challenges of sitting a wheelchair while listening to very intimate stories. Such scripts are intended to have a transformative potential as they stimulate a reconstructive-cognitive emphatic reaction as well as an immediate-emotional one.[2]

2.3 From the Body to the Mind – Virtual Body Swap and Swap of Mindset?

A further aspect makes the configuration of *The Machine to be Another* once more complex: the participants do not only see themselves embodied as 'the other' and haptically feel what the other probably feels as movements are mirrored (e.g. in the setting with the apple); in addition to the visual impression, the participants can also listen to the 'thoughts' of 'the other' like in a stream of consciousness. While, for example, exploring an object or while touching themselves, the mirroring participants speak out their thoughts aloud. By doing so, they do not only describe

2 Empirical data in how far the objectives of the providers of *The Machine to be Another* are achieved is provided in the following.

– again – haptic sensation; rather, they exposit their emotional states in the actual situation. Thus, the idea is not only to probe into the potential of a virtual visual body swap but also to inquire the possibilities of a swap of mindset – and in this sense to extend the working of the mirror neurons beyond mere vision.

Interestingly, the collective standing behind *The Machine to be Another* – the *BeAnotherLab* –, does not so much aspire a complete reconstruction or representation of the subjective experience of 'an other', nor are they interested in only "straightforward social perspective-taking", as Sutherland [Suth15] notes. Rather, they are fathoming the potential of extended reality to enhance extended empathy through extended embodiment. Apart from making the participant experience another person's body including the emotional set-up, the assemblage is used "to stimulate pro-social behaviour and overcome intergroup social barriers" [BeAn19]: With the interactor listening to another person's often very intimate emotions, the bondage that is created through the tentative cooperation in movement is once more fostered.[3] Hence, one of the crucial aspects in *The Machine to be Another* is that it shifts the focus of interest from a rather ocularcentrist paradigm to embodiment *and* cognition and affect. In this context, embodied simulation mechanisms in conjunction with the simulation of actions and physical corporeal sensations as well as the sharing of emotions have been reported to have deep implications not only for an understanding of the perception of one's body but also social cognition, the forming of empathy and what psychologists describe as "neural plasticity" and the formation of concepts (cf. [BGCP13]; [Gall05]). In this manner, *The Machine to be Another* sets out to "provide a unique way for the exploration of identity and how it relates to embodiment and narrative in a deeply immersive way" [BGCP13].

At this point, at the latest, a further aspect comes into play: empathy. Empathy – a concept difficult to define with several differently nuanced notions even within one and the same discipline – is hereby characterized by the transdisciplinary team of *BeAnotherLab* as "the ability of one individual to feel another individual's emotional state *while preserving the knowledge about its personal origin*" [BeAn19; emphasis A.W.]. Empathy in this understanding is based on an understanding of the other *and* at

3 For further experiments in the field of pro-social behaviour stimulated through VR non-fiction cf. among others [BGRM18]; [BGCP13].

the same time the awareness of possible differences between the other's and one's own experiences.[4] 'Taking perspective' in this context is both employed in the literal and the metaphorical sense to promote "prosocial behavior such as altruism and compassion" [BeAn19] – at least this is the intention of the producers of *The Machine to be Another*. This can be regarded (cf. below) to be at least the prerequisites for a better sympathetic as well as empathic feeling for the other through an embodied experience including a sense of presence, body agency and narrative as well physical immersion.

2.4 From Interventionist Art Performance to Transdisciplinary Public Experiment: Where Art and Science Meet

As *The Machine to be Another* comprises not only the temporary setting of the performances but is backed-up by thorough scientific enquiry, it can be described as 'artistic research' or 'public experiment'. Whereas the first concept has gained a standing as an interdisciplinary practice, the latter calls for more explanation. Building on the reflections by Nowotny, Scott and Gibbons [NoSGi01], Born and Barry suggest exploring issues of scientific and social relevance and actuality in the form of 'public experiment', i.e. settings where improvisational artistic production suggests new options for research, helps to discover connections, and sets the agenda for future initiatives. These new avenues comprise both scientific work *and* its artistic realization *for* and *with* a great public (cf. [BoBa13]). In this sense, public experiments are deeply embedded in transdisciplinary endeavours that challenge Snow's hypothesis of 'two cultures' – arts on the one hand, 'hard' sciences on the other [Snow59]. "We consider alternative ways of knowing as equally valid in our processes: qualitative, bodily, and affective knowledge are fundamental for us, but we also value the importance of quantifying for generalizing knowledge." [BeAn19]. This bridge between social psychology, ethnography and anthropology, STS and computer sciences and at the same time interventionist art performance and the opening up of spaces for intersubjective encounters

4 For a detailed survey of the origins of different notions of empathy, especially in terms of emotional and cognitive empathy cf. Fisher [Fish2017]. In this context, Fisher underlines that "emotional empathy is the instantaneous and somatic reaction to a subject's emotions without the conscious intentionality of that subject. Emotion is seen as a contagion that colonizes the observer with feelings that are not their own" [Fish17; p. 236] whereas cognitive empathy is a "primary epistemic perceptive mode" which results in perspective taking [Fish17; p. 237].

characterizes *The Machine to be Another*. And in fact, the members of *TheBeAnotherLab* explain that through their position as artists, they are able to work more swiftly and improvisationally than would be possible in a classic research setting.

With the authors suggesting that their artistic interventions provoke specific changes in attitudes and bias, the project is subject to a contemporary public expectation of scientific validity and empirical data surveys. Thus, *TheBeAnotherLab* flanks their interventions with qualitative research in form of questionnaires and in-depth interviews with participants. Apart from empathy – a concept already difficult to define let alone to be measured – participants were asked to answer a questionnaire concerning their feeling of presence[5] – one of the prerequisites not only for a body swap but also for a swap of mind and thus enhanced empathy. One experimental setting in this context was measuring the sense of presence and the impact of feeling in another person's body in two groups – one group being confronted with a Second Life virtual tour without a real 'other' vis-à-vis but being represented with a computer-generated avatar, the other one with the setting of *The Machine to be Another* and a 'real other' with whom they swapped bodies.

In both cases, the user-interactors were leaving 'their own' worlds and bodies and got immersed into another reality with the difference that in the setting of the Second Life environment, there was only immersion through a first-person perspective in the exploration of a virtual space, whereas in *The Machine to be Another*, the experience included seeing another body through the first-person point of view. Questions regarded among others a sense of acting in the other person's body, rather than operating something from outside, awareness of one's own body, being captured by the body swap also mentally and affectively, as well as the realism of the experience. The questions were measured on a 7-point Likert scale ranging from -3 ('I completely disagree') to 3 ('I completely agree'), with 0 corresponding to 'I neither agree nor disagree'. The evaluation of the data collected showed significant differences between the experience of *The*

5 There exist various approaches to measure and evaluate presence in literature. Generally speaking, there are two kinds of approaches – objective and subjective approaches. Where the former are based on physiological data to *quantify* presence such as e.g. changes in skin conductance, hear rate and blood pressure, muscular tension, respiration rate and depth, as well as neurologic data [LoDW09], the latter work qualitatively and try to survey subject opinions [OBLP16; p. 82].

Machine to be Another and the virtual tour in the Second Life environment. As Oliviera et al report, the setting of *The Machine to be Another* promoted high levels of presence (M=1.80, SD= .62; compared to the Second Life experience which rated moderately in comparison (M=.21, SD=1.37)), and also the body agency had high rankings.
However, *The Machine to be Another* not only induced high perception of presence; moreover, in the post-experimental interviews, participants stated that they "felt closer to the other person especially in the narrative step" [OBLP16; p. 85], that they were drawn to their virtual vis-à-vis and even started fusing their self-perception and mental conceptualization with the other, as participants repeatedly reported: "It felt confusing to be me and, at the same time not to be me!" [OBLP16; p. 85]. This induced the transdisciplinary team of *BeAnotherLab* to conclude that the configuration has a stimulating effect with regard to empathy and mutual understanding – whether cross-cultural as in the case of 'the other' coming from a different cultural background or whether with regard to gender differences or physical abilities.[6]

3 Conclusion: (Im-)proper Distance, *Dis*immersion and the Issue of 'Making the Familiar Strange'

Still, one point must be made with regard to a critical discussion of *The Machine to be Another*: Maybe it is not so much the *immersion* afforded by configuration but rather a form of dis-immersion that takes place – a feeling of ostranenie or estrangement in the Brechtian sense – that makes *The Machine to be Another* such an outstanding configuration worth further discussion. The encounter with a physical 'other' in combination with tactile sensation as well as being in a kind of 'enclosed' setting due to the HMD enhances a feeling of immersion. Immersion in this context comprises three dimensions: spatial, narrative and interactive immersion.[7] With regard to actual evocation of immersion in *The Machine to be*

6 For a detailed statistic evaluation, qualitative data and a critical discussion of the results of the experiment conducted by researchers from the *BeAnotherLab,* the Polytechnic School of the University of São Paulo, Paris Descartes, University of Valencia and University of Zürich, cf. [OBLP16]; [BGCP13]

7 Building on both the theoretical conceptualisations of presence and immersion drawing on the philosophical tradition of phenomenology and existentialism on the one hand and rather practical issues on the other as to the design of HCI, XR

Another, all three dimensions achieve considerable peaks results: spatial immersion is given through the physical setting of the encounter, narrative immersion is achieved through the stream of consciousness which the user-interactors listen to through the earphones, and especially the degree of agency and interactive immersion is extremely high: though the two participants have to coordinate their movements, there is a vast space of possible interactions as the scripts are rather open for improvisation.[8] This all results, for one thing, in a high degree of immersion and allows the creation of a bondage between the participants who start feeling really close, as the testimonials of participants as reported above have shown. However, at the same time, this effect attracts the attention to Nash's apprehensions about the moral risk of "improper distance. Drawing on the work of Chouliaraki [Chou11], Nash describes this risk as "a form of ironic morality in which 'truths about ourselves' are elevated above the experiences of others" [Nash18; p. 120]. And in fact, in many non-fiction VR settings, the user-interactors start putting *their* feelings over those actually experienced by the other. They start confounding *their* emotions for those of *the other* – though 'seeing through the eyes of someone else' as a visual illusion does not automatically imply seeing things and perceiving them as the other does – despite the metaphorical usage of 'point of view' and 'perspective'. In this context, Fuchs differentiates between three forms of empathy: "primary, intercorporeal empathy", "extended empathy" (i.e. empathy that is based on what one self thinks that the other feels), and "fictional empathy" (i.e. empathy with fictitious persons) [Fuch14; p. 152]. And indeed, one of the arguments of VR as an 'empathy machine' consists in the fact that self-contained VR configurations tend to foster fictitious empathy – which is rather a shallow feeling in terms of a transformative moment – and which in some way can even become abusive with regard to the respect one should bear to the other and their originality in feeling.
This finally brings us to the last point which sets *The Machine to be Another* apart from most self-contained VR non-fiction: the configuration not only works by evoking a feeling of immersion presence, it also produces moments of self-reflexive experiencing a gap between 'primary empathy' and 'extended empathy' which can also be described as critical

applications investigate how a 'sense of presence' is mediated by technologies. This has led to a rich output of empirically based immersion and presence studies by HCI designers, new media researchers and psychologists (cf. among others [Youn07]).

8 For detailed data as to the actual scores cf. [OBLP16]; [BGCP13]; [BeAn19].

*dis*immersion [Weid18] – moments in which the user-interactors become aware that they are *different* from the other, though they perceptively swap bodies, and that they have *different* feelings, though they are readily trying to feel *with* the other – without imposing their own feelings on those of the other whom they are listening to. Thus, one can conclude that there are different dimensions of empathy here at play: reconstructive-cognitive and immediate-emotional as well personal-individual and social ones.

In relation to emotional engagement, Ryan [Ryan05] distinguishes three levels: an emotional reaction to 'the other' (such as sympathy, like, dislike etc.), the imagination of the emotions probably felt by 'the other' (empathy), and the emotions felt for oneself. As McRoberts notes, "VR has the ability to incorporate all three levels of emotional engagement, but the medium in its uniqueness approaches higher levels of presence as the second and third levels overlap" [McRo17; p. 109] – or we would like to put it rather like this: these two levels in *The Machine to be Another* are co-present to alternating extents. It is exactly this paradox of immersion and disimmersion, empathy for the other and one's own emotions that *The Machine to be Another* productively uses: the configuration subtly oscillates between different sets of feelings and different impulses: first of all the one of bodily presence and sensations on the one hand and the virtuality of one's projected body on the other; secondly one's own experience and subsequent inner monologue versus/while listening to 'the other's' experiences and thoughts; and thirdly, the impulse to exert body agency and the need to coordinate one's movements with those of 'the other'.

This all leads us to the conclusion that maybe, one of the greatest potentials of XR application such as *The Machine to be Another* still to be explored is that of playing with this oscillation of presence and distance, immersion and disimmersion, empathy and critical self-reflection – and the fact that making the familiar strange and at the same time the strange familiar can promote a better understanding not only of 'the other' but also of oneself.

Literature

[BeAn19] BeAnotherLab. 2019, online at http://beanotherlab.org/home/work/tmtba/, last visited 29.02.2020.

[BGCP13] Bertrand, Philippe; Gonzalez-Franco, Daniel; Cherene, Christian; Pointeau, Arthur: 'The Machine to Be Another': embodiment performance to promote empathy among individuals. 2013, https://pdfs.semanticscholar.org/3c49/68463c596f58d0915ff3013681752e263003.pdf, last visited 29.02.2020.

[BGRM18] Bertrand, Philippe; Guegan, Jérôme; Robieux, Léonore; McCall, Cade Andrew; Zenasni, Franck: Learning Empathy Through Virtual Reality: Multiple Strategies for Training Empathy-Related Abilities Using Body Ownership Illusions in Embodied Virtual Reality. In: Front. Robot. AI 2018, 5, pp. 1–18

[BGFR19] Bevan, Chris; Green, David Philip; Farmer, Harry; Rose, Mandy; Cater, Kirsten; Stanton Fraser, Danaë; Brown, Helen: Behind the Curtain of the 'Ultimate Empathy Machine': On the Composition of Virtual Reality Nonfiction Experiences. In: Association for Computing Machinery, CHI Conference on Human Factors in Computing Systems, 2019. Glasgow, pp. 1–12.

[BoBa13] Born, Georgina; Barry, Andrew (2013): Art-Science: From public understanding to public experiment. In: Andrew Barry, Georgina Born (eds.): Interdisciplinarity. Routledge, London 2013, pp. 247–272.

[Chou11] Chouliaraki, Lilie. Improper Distance: Towards a Critical Account of Solidarity as Irony. In: International Journal of Cultural Studies 2011, 14 (4): 363–381.

[Fish17] Fisher, Joshua A. (2017): Empathic Actualities: Toward a Taxonomy of Empathy in Virtual Reality. In: Nuno Jardim Nunes, Ian Oakley, Valentina Nisi (eds.): Interactive storytelling. Springer, Cham 2017, pp. 233–244.

[Fuch14] Fuchs, Thomas: The Virtual Other. Empathy in the Age of Virtuality. In: Journal of Consciousness Studies 2014, 21 (5–6), pp. 15–173.

[GaLa05] Gallese, Vittorio; Lakoff, George: The Brain's Concepts: The Role of the Sensory-motor System in Conceptual Knowledge. In: Cognitive neuropsychology 2005, 22 (3), pp. 455–479.

[HuBa19] Huang, Sabrina A.; Bailenson, Jeremy: Close Relationships and Virtual Reality. In: Thomas D. Parsons, Lin Lin, Deborah Cockerham (eds.): Mind, Brain and Technology. Learning in the Age of Emerging Technologies. Springer, Cham 2019, pp. 49–65.

[Lato96] Latour, Bruno: On actor-network-theory. A few clarifications and more than some complications. In: Soziale Welt 1996, 47, pp. 369-381.

[Lato05] Latour, Bruno: Reassembling the Social. An Introduction to Actor-Network-Theory. Oxford University Press, Oxford 2005.

[Law99] Law, John: After ANT – complexity, naming and topology. In: Law, J. (ed.): Actor network theory and after. Blackwell, Oxford 1999, pp. 1–14.

[LPHB19] Layng, Kris; Perlin, Ken; Herscher, Sebastian; Brenner, Corinne; Meduri, Thomas: CAVE: Making Collective Virtual Narrative. In: Leonardo 2019, 52 (4), pp. 349–356.

[LoDW] Lombard, Matthew; Ditton, Theresa; Weinstein, Lisa: Measuring presence: the temple presence inventory. Proceedings of the 12th Annual International Workshop on Presence 2009, pp. 1–15.

[McRo17] McRoberts, Jamie: Are we there yet? Media content and sense of presence in non-fiction virtual reality. In: Studies in Documentary Film 2017, 21 (5), pp. 101–118.

[MTSG15] Magnor, Marcus A.; Theobalt, Christian; Sorkine-Hornung, Olga; Grau, Oliver (eds.): Digital Representation of the Real World. How to Capture, Model, and Render Visual Reality. Taylor and Francis, Hoboken 2005.

[Mark02] Marks, Laura: Touch: Sensuous Theory and Multisensory Media. University of Minnesota Press, Minneapolis and London 2002.

[Milk15] Milk, Chris: How virtual reality can create the ultimate empathy machine. TED talks, 2015, https://www.ted.com/talks/chris_milk_how_virtual_reality_can_create_the_ultimate_empathy_machine, last visited 29.02.2020.

[Nash18] Nash, Kate: Virtually real: exploring VR documentary. In: Studies in Documentary Film 2018, 12 (2), pp. 97–100.

[NoSGi01] Nowotny, Helga; Scott, Peter; Gibbons, Michael: Re-thinking science. Knowledge and the public in an age of uncertainty. Polity Press, Cambridge 2001.

[OBLP16] Oliveira, Elen Collaco de; Bertrand, Philippe; Lesur, Marte Ernesto Roel; Palomo, Priscila; Demarzo, Marcelo; Cebolla, Ausias: Virtual Body Swap: A New Feasible Tool to Be Explored in Health and Education. 18th Symposium on Virtual and Augmented IEEE, pp. 81–89.

[Rose18a] Rose, Mandy: Technologies of Seeing and Technologies of Corporeality: Currents in Nonfiction Virtual Reality. World Records, https://vols.worldrecordsjournal.org/01/11, last visited 29.02.2020.

[Rose18b] Rose, Mandy: The immersive turn: hype and hope in the emergence of virtual reality as a nonfiction platform. In: Studies in Documentary Film 2018, 12 (2), pp. 132–149.

[Rose19] Rose, Mandy: Virtual Realities: Immersive Documentary Encounters. 2019, https://immerse.news/virtual-realities-immersive-documentary-encounters-51b1b5d5b73, last visited 29.02.2020.

[Ryan15] Ryan, Marie Laure: Narrative as Virtual Reality 2: Revisiting Immersion and Interactivity in Literature and Electronic Media. John Hopkins University Press, Baltimore, MA 2015.

[Snow59] Snow, Collin P.: The Two Cultures. Cambridge University Press, Cambridge 1959.

[Suth15] Sutherland, Ainsley: The Limits of Virtual Reality: Debugging the Empathy Machine. MIT OpenDocumentaryLab 2015, http://docubase.mit.edu/lab/case-studies/the-limits-of-virtual-reality-debugging-the-empathy-machine/, last visited 29.02.2020.

[Suth17] Sutherland, Ainsley: No, VR Doesn't Create Empathy. Here's Why. BuzzFeed News 2017, https://www.buzzfeed.com/ainsleysutherland/how-big-tech-helped-create-the-myth-of-the-virtual-reality?utm_term=.nc9bE2rYQ#.axmqVAw9B, last visited 29.02.2020.

[Weid18] Weidle, Franziska: How to reconcile that flinch: Towards a critical analysis of documentary situations in 360° and VR environments. In: Participations 2018, 13 (1), pp. 412–426.

[Youn07] Youngblut, Christine: What a Decade of Experiments Reveals about Factors that Influence the Sense of Presence: Latest Findings. Institute for Defense Analysis, Virginia 2007.

Public Space and Literature:

Novel Artistic Augmented Reality Applications in Cooperation with the Independent Arts & Culture Scene in Berlin

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In August 2018, the EU-funded project AURORA School for ARtists has started to offer artists and other creative freelancers in Berlin training courses on Augmented Reality (AR), giving them access to workplaces in the AURORA Production Lab and support by the interdisciplinary AURORA project staff. First results were presented at the conference *Culture and Computer Science* in 2019. Furthermore, artists such as Banz & Bowinkel, Bianca Kennedy, The Swan Collective or Dani Ploeger have shown their AR applications at own exhibitions, e.g. at the DAM Gallery in Berlin or the Bruthaus Gallery in Waregem (Belgium).

The project's research on the mutual influence between creative disciplines and computer science led to a paper being published in the conference proceedings of the *Electronic Media and Visual Arts* (EVA) Florence 2020 [SSBB20]. Based on a qualitative survey among twelve artists and computer scientists in the AURORA Production Lab, the article regards AR as a perfect breeding ground for creative processes on both sides – a permanent interplay of thinking and rethinking both artistic and programming concepts.

Whereas the main focus of the previous artistic results was on the augmentation of analog artworks shown in the interieur – such as paintings, prints or sculptures –, four of the five new AR applications deal with or reside in the public space. In this context, the latest technological innovations went

hand in hand with the artist's needs for markerless tracking: Providing this functionality, Unity's AR Foundation was used for the applications by Anke von der Heide, Olga Bedia Lang and Julia Laube, Peter Sandhaus and Robert Seidel. Nevertheless, Vuforia's image tracking is still valuable, e.g. for the AR application prototype by the author Juliane Wünsche.
These and other high-quality AR art examples produced in the AURORA Production Lab or archived as part of the AURORA research are going to be bundled in a comprehensive database by the AURORA team. The project strives to publish this searchable *XR Archive* in the summer of 2020.

1. Download the **INKA-AR-App** for free.

2. Look for images marked with the **AR-Symbol.**

3. Hold your **smartphone over the image.**

Olga Lang and Julia Laube, *Karla* – a project by *Urban AR Productions* at Karl-Marx-Allee

2019/20, Augmented Reality Staging in the Public Space

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Berlin is full of history.

How can we work with the urban space in a literary and scenographic way, while taking its historical dimension into account? How can we tell stories in a way that is connected to the places? Julia Laube and Olga Bedia Lang have formulated an answer to this question under their label *Urban AR Productions*: Augmented Reality (AR) offers them an interesting possibility to establish a temporal-spatial intermediate level in urban space and to use it as a medium.

Karla is the title of an integrative theatrical production on Karl-Marx-Allee in Berlin. In the AR application *Urban AR,* visual and auditory content is combined with the context of the real setting of Berlin's urban space.

As soon as the users are in the corresponding GPS room, they can access the various chapters of the story using their smartphones or tablets and headphones. The story begins in front of the former Karl Marx bookstore and develops dramaturgically over seven further locations, which can be walked through in a performative city walk.

Karla is the story of a love affair in the context of political criticism and resistance in the 1980s in the former GDR. The female protagonist leads to the individual chapters via the audio, sharing her personal memories and the love story of her youth. When she was in her early twenties, searching for an attitude towards the world, she met a man who was active in political resistance. She felt connected to him through her love, the shared vision of a better world and a common future.

In addition to the contents of the AR story, users are given further assistance in the app to orient themselves in the urban space and to find the chapters. In addition, each chapter also contains a section with historical background information, on the basis of which the script for the Karla story was developed. The visual AR content was also developed from collages of historical material.

The tracking and general application concept underwent a few changes during the development process. The first idea was to use pictures of the real life locations of the tour as markers. Despite the common thought that this would be a bad idea due to surroundings, lighting and weather changing all the time, using the Vuforia SDK actually worked rather well – given the location mostly matched that of the time the picture was taken. However, since the augmentations shown at these

places were mostly three dimensional, visual scenes the tracking algorithm has to provide the option for the users phone or tablet to lose the marker and still be able to view the content. While Vuforia offers a very basic version of this as part of their Extended Tracking, the placement of the content in the real world was not secure enough to view the whole scene without contents jittering, moving or disappearing. The other option, image tracking using ARKit and -Core however was not feasible, since their marker tracking is not as good as Vuforia's yet.

Another approach inquired by the artists – just like with Peter Sandhaus – was to have the application work purely location based. While this works in order to activate general information concerning a hotspot, it is not suitable to place augmentations when it should appear in a very specific place and look the same for each user. For this application, the AR content was supposed to appear in front of specific backdrops relating to the story and needed a more exact method of placement than GPS. GPS was still used in the application to limit the application to work at only the planned hotspots so that users have to actually be at the locations in Karla's narration in order to experience the application.

Finally, it has been decided to use ARKit's and -Core's markerless tracking approach. While the camera is active, these SDKs procedurally generate a pointcloud of the devices' surroundings where content can be securely anchored in a scene. This works a lot better than Vuforia's Extended Tracking and since the main feature of the app was supposed to be the viewing of the 3D scenes, this was preferred over Vuforia's better image tracking. In order to place the augmentations, a stencil approach was used: After entering the hotspot's GPS-area, the AR mode is unlocked. In this mode the AR camera is started and users see a stencil image of the location they are supposed to find. After finding the exact location and matching the stencil image to the camera view, users can click "Place augmentation" in order to place the content. The scene in Unity is built in relation to this stencil image angle, and a prefab of this scene instantiates in relation to the AR camera when pressing the "Place augmentation" button – the content therefore appears in relation to the user's position (device position = AR camera position). Placing the augmentation also triggers the scene's audio narration.

In this way, a multi-sensory experience is created that playfully conveys the historical dimension of the place. The theatrical space is placed in the

urban context and the Urban AR app enables its users to enter this intermediate world.

About the artists

Julia Laube
In addition to costume and stage design at the UDK Berlin and the Kunsthochschule Weißensee, Julia Laube also studied scenography and media art at the Hochschule für Gestaltung Karlsruhe. In 2016 she graduated with a degree in stage design from Kh Weißensee. Since then she has worked on her own performances and theater work as well as on other various film productions and theatre projects.

Olga Bedia Lang
Olga Bedia Lang is an author and also works in joint projects with other artists. She has a master's degree in Oriental Studies, Art History and German Studies and worked for several years as a mediator of contemporary art. Besides prose, poetry and essays, she writes scenic texts and stages them in radio plays.

Nach Louis Schmidt, Signet der AEG, 1888

Peter Sandhaus, *ELEKTRA.app*

2019, Augmented Reality Simulation of the New Landmark for Berlin-Oberschöneweide

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The *Lichtgestalt ELEKTRA* by Peter Sandhaus emerged as the winner of the open art competition for a landmark on the square at Kaisersteg in Berlin-Oberschöneweide. Advertised by the *Industrial Salon Schöneweide* in cooperation with the Treptow-Köpenick district, this is the construction project currently in the preliminary design phase. The small wind power plant integrated into the artwork is being developed in cooperation with Prof. Jochen Twele of FB 1 Renewable Energies at the HTW.

The new landmark for Oberschöneweide is an embodiment of electrical energy. It is in the tradition of the famous AEG signet from 1888. This represents the "goddess of light", who hovers casually on the winged wheel of progress. Her dynamic pose is not fully balanced. She seems to be still in motion and has only just turned towards the viewer. Curvaceous and sensuously exhilarating - her hair as if under electric power - she illuminates the night. Her promise of salvation is enlightenment in the form of electric light. The message of this allegory is clear: From now on, electricity and light are an inseparable unit and can be equated with progress. The new landmark inherits both its name *ELEKTRA* and its dramatic appearance as a figure of light. As a contemporary interpretation, however, it is not allegorical or illustrative. The new appearance is constructive and abstract. Nevertheless, this *Lichtgestalt ELEKTRA* also heralds the beginning of a new era. It combines the tradition of the electronics industry in Schöneweide with a departure signal for a renewed Electropolis, characterized by regenerative energy generation, smart electromobility and electronically virtual networking.

In collaboration with the AURORA production lab, an augmented reality app was developed to enable the experience of the building as a real-time simulation prior to implementation on site. In this way, the proportions and the urban planning effect of the 34meter high tower can be clearly experienced. The app is also intended to improve the participation of citizens in the run-up to the construction project, fueling the imagination of the people in Schöneweide and discussions about the project.

A few approaches were tested during the development process. The easiest of the approaches, the usage of the Vuforia image tracking SDK, was not viable for the prototype, since Vuforia's extended tracking functionality is not stable enough for the planned size of the model. While extended tracking can work on the scale of a desk for example, the display of the 34 meters of the sculpture requires a more stable tracking algorithm. Thus the

next iteration made use of AR-foundation, Unity's own augmented reality library combining Apple's ARKit and Google's ARCore functionalities into one cross-plattform AR library. Both Google's and Apple's SDKs provide very robust environment tracking. However, when testing the purely markerless approach, the tracking of the model was still not completely stable. Given the height of the tower, even small instabilities at the bottom of the tower lead to visible shaking at the top of the tower.

The initial idea of the artist was to use the GPS coordinates of the Kaisersteg and to have the object placed automatically on recognized planes whenever the user reached the set GPS point. However, since GPS tracking is not accurate enough to have the object always placed in the same position for each user, this approach was scrapped.

The final implementation uses one of the manhole covers at Kaisersteg as an image marker. As soon as the marker is recognized, the current world position of the marker is used to place the sculpture inside the tracked environment. Especially when moving further out from the point of instantiation the sculpture does jitter a little, but this can not be prevented with the current state of the markerless tracking algorithms. The sky that is often the main or at least a large part of the background when viewing the top of the tower, contains little to no features for the feature tracking algorithm to track the users' movement.

The sculpture itself was created as a 3D model, with movable wind turbines, that are rotated by script after the import of the .fbx-file into Unity. Different kinds of shadow techniques were tested during the development process in order for the object to blend more naturally into the scene at Kaisersteg. High-quality real-time shadows however slowed down the device considerably due to them being very computationally intensive, at times even crashing the application on the device. In the end, shadow images were created and laid at the bottom of the scene, after the decision that even fake shadows would suffice in blending the object more into the scene.

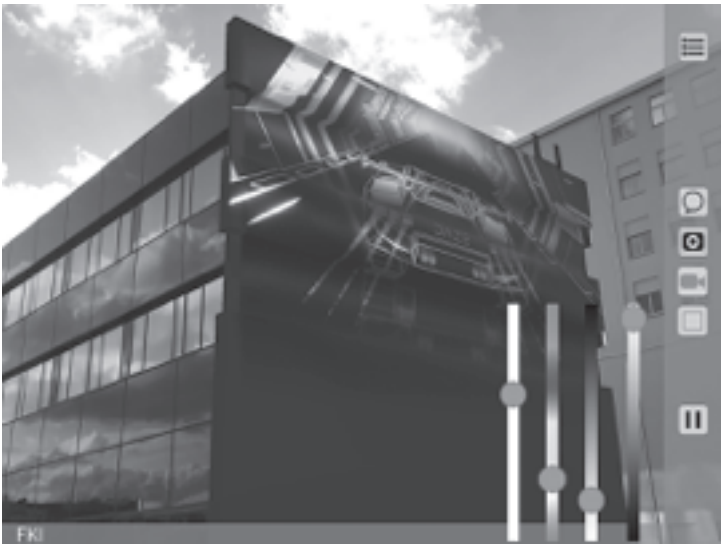
The planned standalone application will also contain functionalities for users to screenshot the sculpture at Kaisersteg, and offer their opinions on whether, where and how the tower should be built there. The application already contains the first draft of a menu in order to allow users to give feedback and post their screenshots and comments to facebook. A

few adjustments are still necessary, but a standalone application for both Android and iOS is planned in the future.
As the *INKA AR* application still uses the Vuforia SDK, the *ELEKTRA* augmentation could not be incorporated into the app as it was. Since the full application will be released as a standalone application anyway, the *INKA AR* app only contains a preview of the application on a postcard marker, as well as as video of the finished application. No tracking of the environment is used, the sculpture is scaled to fit the size of the postcard. Users can look at and explore the model and imagine the model in the real world with the help of the video on another marker, showing the application being used directly at Kaisersteg, Oberschöneweide.

About the artist

Peter Sandhaus makes art in public space. He always firmly believes in the opportunity to construct meaning and significance on site. The artist, who is trained as an architect, has already won several competitions. In 2017 the *Stadionwelle* was realized in Erfurt and last year his *Antikörper* was finished at the Regensburg University Hospital. He is currently responsible for the planning of the electrifying landmark *Lichtgestalt ELEKTRA* in Schöneweide in the immediate vicinity of HTW Berlin.

petersandhaus.blogspot.com



Anke von der Heide, *MIRAR – MediaArchitecture-AR*

2019/20, Augmented Media and Narrative Interventions for the Public Space

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Whether media art, media architecture or corresponding curatorial activities: preparing large-scale facade projections requires elaborate test setups with mostly expensive production technology. However, thanks to a concept by the curator and media artist Anke von der Heide, these unpopular resource guzzlers could soon be a thing of the past: her augmented reality application *MediaArchitecture-AR* (MIRAR) enables the testing of moving image-based content such as video art on site by augmenting the chosen media facade with the corresponding content.

This combination of real and virtual worlds allows media content to be assessed in the current lighting conditions. The spatial and social use of urban space and the resulting visual axes – with regard to narrow paths, busy streets and the changing use of public squares – can also be taken into account. The colors, speed and brightness of the video image can be adapted to the real conditions of the recorded surface and to the viewer's line of sight to enable a realistic preview.

At any location in front of the facade, notes can be created, screenshots and video recordings saved and timestamps and GPS coordinates attached. With this information, the test can be discussed later in the production team, and the findings can then be incorporated into further planning.

Within the app, own projects can be set up with an existing building that is linked to a digital content (e.g. a video). For augmentation, the real building is overlaid with a virtual representation (a 3D model of the building). The media content is projected onto this digital object using virtual projectors. Since real and virtual buildings coincide perfectly, the illusion of a live facade projection is created.

From a technical point of view, two important questions had to be answered: How can the virtual building be placed exactly over the real building? How can this link between real and virtual stay stable without losing the free movement of the users?

In order to be able to automatically align the virtual building correctly, the position and orientation of the real facade would have to be determined exactly in the camera image using image recognition algorithms. Such marker-based approaches have so far only worked to a limited extent with three-dimensional objects and, moreover, often have problems in poor or changed lighting conditions. However, dark lighting situations are the normal case for projections on buildings and are hence a main use case for the application. To tackle these challenges a simple manual approach

was chosen. In order to position the virtual building, at first the users see a mask (transparent 2D representation of the building) on the display. In the the second step they can place this mask on the real building by changing their own position and, if necessary, using the positioning sliders.
Thanks to the markerless tracking (*visual-inertial odometry*) provided by Unity's ARFoundation (Apple ARKit/Google ARCore), the virtual building and its projection remain anchored in the physical world, so that users can move freely and look at the building from different angles. Due to the current state of the art, the virtual world may slip slightly away from initiated position, respectively a perfect positioning is not always possible due to the large distances to the building. In cases of extreme changes in the visual axis the virtual building can be repositioned using a the same positioning mask.
The next step would be to enhance this first version of the app by additional functions such as adding logos and texts. This would allow to test where and on which part of a building what is best visible in which line of sight. A much larger extension would be the integration of various types of luminaires and the simulation or integration of virtual and real light cones, including changeable beam angles and brightness. The app could also serve as an archive for light festivals and integrate the mostly temporary installations via scans or mappings into an urban and even nocturnal tour.

About the Artist

Anke von der Heide is a curator and media artist with an interdisciplinary curriculum vitae starting with a degree in visual communication at the Bauhaus Universität Weimar, in architecture and urban design at the Technische Universität (TU) Berlin and the Tongji University Shanghai as well as a research project in Intermedia Art at Tokyo National University of Fine Arts and Music.
She works in the field of media architecture in a transdisciplinary research area between technology and public space. Her special attention is paid to media content and how the urban environment is narrated anew through media.
Anke von der Heide curated the facade projection festival *Genius Loci Weimar* and the *Festival for urban Light-culture* in Berlin as well as various

symposia on media architecture and the scientific and artistic approach to the material light. She has been researching at the TU Berlin in the area of Smart Cities and since 2013, she has been teaching in the field of media architecture and human-computer interaction departments of the Bauhaus Universität Weimar and the Quality and Usability Lab of the TU Berlin. In this context, her work and research have always been concerned with the message and effect as well as the innovative design of media architecture.

http://urban-lightculture.de

Juliane Wünsche, *Zittau 1999*

2019/20, augmenting the novel *Nationalbefreite Zone*

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With an application accompanying her novel *Nationalbefreite Zone* (Nationally Liberated Zone), the author Juliane Wünsche shows how augmented reality (AR) can be used to expand literature. The story takes place in the small town of Zittau in East Saxony in 1999: in the region, which is characterized by unemployment and lack of prospects, the economic and social disruptions of the post-reunification period lead to national pride and xenophobia. The East German student Franziska Wendt and the West German professor Alexander Harten get into the struggles between left and right and have to make a decision: interfere or look away, fight or give up, go or stay.

Many descriptions in the novel are based on real events – with describing the situation in Zittau, the author devotes herself to a piece of recent German history that stands as an example for the economic and political development of numerous small towns in East Germany after 1989 and provides valuable information about current developments. Here, great things are told in the details – and not just by Juliane Wünsche.

In the prototype for the AR application created in the AURORA Production Lab, contemporary witnesses from Zittau also have their say. They speak from historical newspaper articles and videos, fading in using AR, and the novel characters also appear as animated illustrations. Furthermore, political, economic and cultural backgrounds are conveyed through a commented AR slide show, a playable dialect memory and a simulated car trip through the border triangle around Zittau – including changeable radio stations. The diverse AR content is evoked by a card set with illustrations for the novel by Kerstin Welther and Matthias Ries. These markers can be scanned individually and in different combinations to create a total of 12 different augmentations.

East and west, true events and fiction, analog and virtual world: *Nationalbefreite Zone* is a cross-border commuter in several ways. Its experimental multimedia aspects have new potential for a lively communication of politics and history, which could for example be used in the educational field such as secondary schools.

The technically characteristic feature of the application is that in order to display the individual contents, several markers have to be recognized at the same time. During the development process, a list of rules for special situations was created, such as the recognition of too many or too few markers, or what should happen when the already recognized marker

is found again. These special situations were primarily identified when Juliane Wünsche regularly tested the application with various users. This allowed the development of a user-oriented application, which among other things has a positive effect on the user interface, the instructions for individual content and the selected types of interaction.
A selection of the application will soon be part of the INKA AR app.

About the Artist

Juliane Wünsche was born in Löbau in 1974 and is a blogger and author. During her training as an editor and her degree as a translator for English and Czech, she wrote reports, portraits and features about the economic and social upheavals in Upper Lusatia (Oberlausitz) for the local editorial offices of the Sächsische Zeitung in Löbau and Zittau. Juliane Wünsche has lived in Berlin since 2003. On her blog she reviews books, plays, exhibitions and other cultural events. *Nationalbefreite Zone* is her debut novel.

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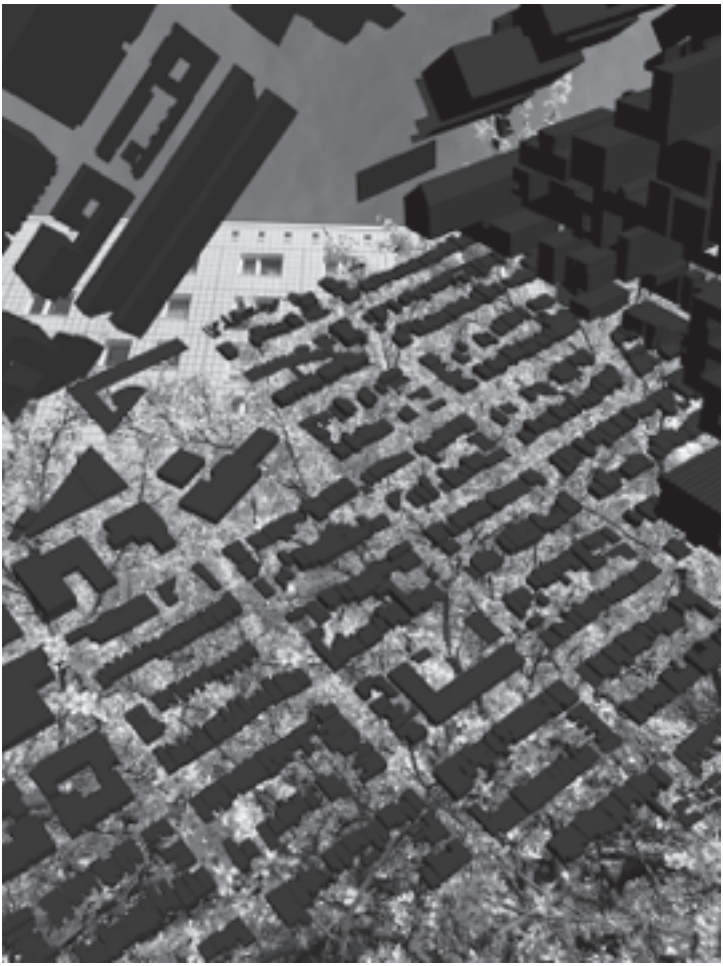

Robert Seidel, *GLACIER*

2019/20, Augmented Reality Sculpture

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The virtual AR sculpture GLACIER spans the entire earth like a giant glacier. The folded, sculptural shape is based on the GPS coordinates of the device and the map information derived from it. As you walk through, you can see that the sculpture is initially anchored in local reality, but that you leave it behind with each step. In this way, you can step through an inverted world in "seven-mile steps", but start again in the immediate vicinity with every restart. There are no visual AR markers, GLACIER only consists of the geolocation data and the movement patterns of the user. In an abstract form, the context of a global world is highlighted, in which every movement and information leads to far-reaching traces and reactions.

From a technological viewpoint, the sculpture is assembled from real buildings close to the user's geo-position. The building information - their locations, orientations and shapes in the form of 3D meshes - is retrieved from the mapping service *MapBox*. When the user moves, her movements change the shape of the sculpture. The assembly of the sculpture follows a complicated algorithm, which approximately works like this: The user's movement is mapped onto a cross-like shape that travels over the flat map of buildings. This shape is then folded into a cube of buildings - the sculpture -, in which the user resides. As the cross (unfolded cube) moves over the map the contents of the six sides change continuously. Because of that each side of the cube must be able to show the buildings of multiple map patches and thus is actually four times its visible size. The resulting 3D object in turn looks like a cube with extended sides or a 3D hash sign (see image X). To turn this object back into a normal cube, the overlapping areas of the sides are cut off visually using a special cutting shader.

The user's movements, that shape the sculpture, are tracked using Unity's AR SDK ARFoundation, which internally uses Apple's ARKit or Google's ARCore, respectively. These libraries provide stable user movements relative to the app's initial position using a method called visual-inertial odometry. The AR app maps these movements (user space) to the movement of the cross across the flat map (world space) and thus the shape of the sculpture. To have visible results within small distances, a scale of 1m user space to 100m world space is used.

This project shows how the artist's intentions must be shaped according to the technological possibilities. Robert Seidel's initial idea for the project was to form a sculpture by overlaying existing buildings with their virtual

equivalents, albeit distorted e.g. using refraction or geometry shaders. Unfortunately, current sensors like GPS and magnetometer are not accurate enough for such an exact positioning of virtual objects. After initial tests, this approach was thus aborted. Within the near future, this initial idea may be implementable, though! Various companies like Google and Facebook are currently developing visual positioning services, which allow to track user positions and orientations far more accurately than GPS – indoors and outdoors – and as such making location-based AR more feasible. Because the technology is based on real-world image data, it only works for places that have been properly filmed and scanned, though [Rein19] [OHea20].

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Literature

[OHea20] O'Hear, S.: Facebook Has Acquired Scape Technologies, the London-Based Computer Vision Startup, 08.02.2020, https://techcrunch.com/2020/02/08/scapebook/, accessed 26.02.2020.

[Rein19] Reinhardt, T.: Using Global Localization to Improve Navigation, 11.02.2019, https://ai.googleblog.com/2019/02/using-global-localization-to-improve.html, accessed 26.02.2020.

[SSBB20] Stark, M.; Selmanagic, A.; Barsht, L.; Bischof, D.; Schürrer, D.; Thielen, E.: Between Technical Realization and Creative Process: A Berlin Pioneer Project Supporting Artistic Augmented Reality Applications. In: Electronic Media and Visual Arts (EVA) Florence 2020 Proceedings (forthcoming).