EuroVR 2020 Application, Exhibition & Demo Track

Proceedings of the Virtual EuroVR Conference

Kaj Helin | Angélica de Antonio | Arcadio Reyes-Lecuona (Eds.)

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VTT Technical Research Centre of Finland Ltd

Angélica de Antonio (Ed.)

Universidad Politécnica de Madrid

Arcadio Reyes-Lecuona (Ed.)

University of Malaga

Graphical design & Technical editing: Päivi Vahala-Partanen
VTT Technical Research Centre of Finland Ltd

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VTT
PL 1000
02044 VTT
Puh. 020 722 111
https://www.vtt.fi

VTT
P.O. Box 1000
FI-02044 VTT, Finland
Tel. +358 20 722 111
https://www.vttresearch.com

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EuroVR 2020: Valencia, Spain

The focus of EuroVR 2020 is to present novel Virtual Reality (VR) up-to Mixed Reality (MR) technologies, including software systems, display technology, interaction devices, and applications. Besides papers on novel results, industry-oriented presentations (automotive, medical, etc.), the EuroVR conference series creates a unique opportunity for participants to network, discuss, and share the latest innovations around commercial and research applications.

As in previous years, we welcome industrial and academic exhibitors, as well as sponsors, to connect with our community.

Our major priority is to provide authors the opportunity to prestigiously disseminate their innovative work within the wide community of end-users, from large scale industries to SMEs.

25-27 November, 2020

Valencia, Spain

Conference organizers

Preface

We are pleased to present these conference proceedings in the VTT Technology series, the papers accepted for the Application and Demo&Exhibition Tracks of EuroVR 2020, the 17th annual EuroVR conference, organized by LabLENI and the Universitat Politècnica de València, which has been held on-line from 25th to 27th November 2020.

In previous years the EuroVR conference has been held in Bremen (2014), Lecco (2015), Athens (2016), Laval (2017), London (2018) and Tallin (2019). This series was initiated in 2004 by the INTUITION Network of Excellence in Virtual and Augmented Reality, supported by the European Commission until 2008, and incorporated within the Joint Virtual Reality Conferences (JVRC) from 2009 to 2013. The focus of the EuroVR conferences is to present, each year, novel Virtual Reality (VR), Mixed Reality (MR) and Augmented Reality (AR) technologies, including software systems, display technologies, interaction devices, and applications, to foster engagement between industry, academia, and the public sector, and to promote the development and deployment of VR/MR/AR technologies in new, emerging, and existing fields. This annual event of the EuroXR association (https://www.euroxr-association.org), former EuroVR, provides a unique platform for exchange between researchers, technology providers, and end users around commercial or research applications.

This publication is a collection of the industrial papers presented at the conference. It provides an interesting perspective into current and future industrial applications of VR/AR/MR. The Application and Demo&Exhibition Tracks are an opportunity to put together industry and research and development communities. You will find presentations from large and small industries, as well as academic institutions from all over Europe and beyond.

Due to the COVID-19 pandemic, the EuroVR 2020 conference was held virtually in order to guarantee the best audience while maintaining the maximum-security conditions for the attendees. We would like to warmly thank the committee chairs of these tracks for their great support and commitment to the conference, and special thanks go to the local organizing committee for their great effort in making this event happen in such a difficult year.

On behalf of the organising committee,

Angélica de Antonio

UNIVERSIDAD POLITÉCNICA DE MADRID

Head of the Madrid HCI Lab and Professor at Universidad Politécnica de Madrid, Spain

Arcadio Reyes-Lecuona

UNIVERSIDAD DE MÁLAGA

Head of DIANA Research Group and Professor at the University of Málaga, Spain

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The Application Track

Exploiting Augmented Reality for improved training and safety scenarios for large passenger ships

Spyridon Nektarios Bolierakis, Vassilis Nousis, Lazaros Karagiannidis, Giannis Karaseitanidis, and Angelos Amditis

National Technical University of Athens (NTUA), Athens, Greece

Corresponding authors: spyros_bolierakis@esd.ece.ntua.gr, vasilis.nousis@esd.ece.ntua.gr, lkaragiannidis@esd.ece.ntua.gr, gkara@esd.ece.ntua.gr, & aamditis@mail.ntua.gr

Keywords: Augmented reality, large passenger ships, training scenarios, safety application.

Introduction

Recent advances of Augmented Reality (AR) and Virtual Reality (VR) technology, has made this technology attractive for the cruise line industry. The AR and VR applications the cruise line sector is targeting is mainly related in enhancing the passenger experience on-board, i.e. using augmented reality virtual excursions[1], or in providing virtual reality gaming for cruise passengers[2]. As it is reported in[3] advanced AR, VR and XVR (mixed virtual reality) technologies will facilitate a hyper-personalised entertainment future for the cruise passengers. Besides the use of immersive technologies such as VR in marine education and training and ship bridge simulators, another domain where AR/VR has gained recently interest in maritime industry and in particular due to COVID-19 crisis, is related to remote and augmented surveys and ship inspections, already offered by leading ship classification societies. While AR/VR technology is constantly growing in several application domains such as health, manufacturing, education, safety training and retail, its full potentials for the use for real-world applications[4] in real environment of large passenger ships for training and safety applications have not been exploited yet.

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[1] Arlati S., Spoladore D., Baldassini D., Sacco M., & Greci L. (2018) VirtualCruiseTour: An AR/VR Application to Promote Shore Excursions on Cruise Ships. In: De Paolis L., Bourdot P. (eds) Augmented Reality, Virtual Reality, and Computer Graphics. AVR 2018. Lecture Notes in Computer Science, vol 10850. Springer, Cham. https://doi.org/10.1007/978-3-319-95270-3

[2] https://www.royalcaribbean.com/cruise-activities/sky-pad

[3] MSC Cruises: The Future Guest Experience, http://cdn.msccruises-platform.com/msc/press/media/press-materials/attachments/msc-cruises-the-future-guest-experience-full-report-low-res.pdf

[4] Mallam, S.C.; Nazir, S.; Renganayagalu, S.K. Mallam, S. C., Nazir, S., & Renganayagalu, S. K. (2019). Rethinking Maritime Education, Training, and Operations in the Digital Era: Applications for Emerging

To this end, tailored AR applications for training and safety applications for large passenger ships as part of the EU funded H2020 project SafePASS[5],[6] are presented in this paper abstract. SafePASS is an EU H2020 funded project aiming to radically redefine the evacuation processes, evacuation systems and international standards for passenger ships in all environments. SafePASS aims to develop a combination of innovative systems that will collectively monitor, process and inform during emergencies both safety personnel and passengers of the optimal evacuation routes, coupled with advanced, intuitive and easy to use, lifesaving appliances that go beyond current state-of-the-art. This includes AR applications targeting both training of crew personnel as well as safety related scenarios in case of evacuation of large passenger ships.

SafePASS AR toolkit application environment

SafePASS AR toolkit is a set of AR applications being developed, in order to assist and enhance already existing training and emergency procedures and tools for large passenger ships. The SafePASS AR toolkit includes three different applications. The SafePASS AR Training Tool, the SafePASS AR Crew Rescue Assistant, the SafePASS AR Passenger Assistant Application. Each application of the AR toolkit is not only focused in fulfilling different aspects and scenarios of emergencies and trainings, but also targets different actors involved in the safety and emergency management process as well as in the crew training process. Due to the maritime application environment of the proposed AR toolkit, special attention needs to be taken in the maritime regulatory landscape imposed by international organizations an conventions such as, the International Maritime Organization (IMO), the International Convention for the Safety of Life at Sea (SOLAS), as well as the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STWC). In addition, the emergency phases on-board of large passenger ships and the different alarm phases, actors and procedures as summarized in Figure 1 needs to be carefully analyzed, in order to adapt to the specific operational environment.

Immersive Technologies. Journal of Marine Science and Engineering, 7(12), 428. https://doi.org/10.3390/jmse7120428

[5] http://www.safepass-project.eu/

[6] Boulougouris, E., Vassalos, D., Stefanidis, F., Karaseitanidis, G., Karagiannidis, L., Amditis, A., Ventikos, N., Kanakidis, D., Petrantonakis, D. (2020), SafePASS – Transforming Marine Accident Response, Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020, Helsinki, Finland

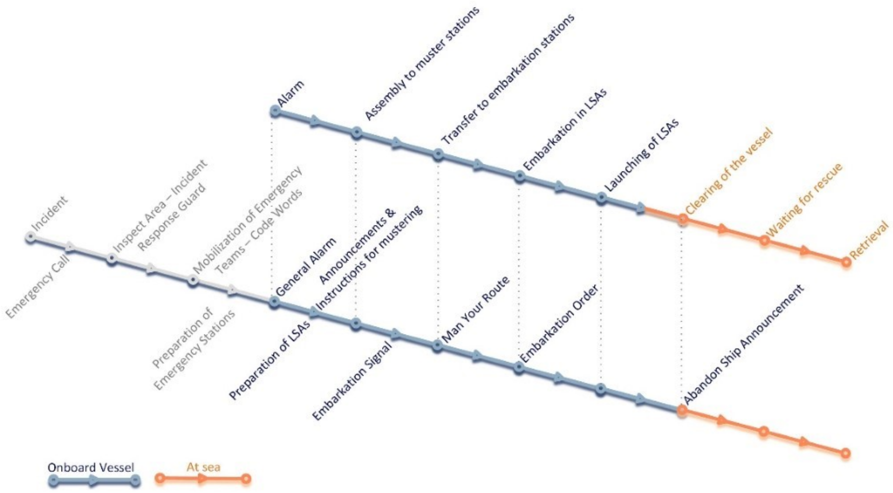

Figure 1. Emergency phases and alarm signals from incident to rescue on passenger ships.

AR toolkit application development

The SafePASS AR Training Tool is an Augmented Reality application that consists of two parts. The first part targets to assist crew members to train on handling Life Saving Appliances (LSAs), such as life boats, life rafts and mass evacuation systems through various scenarios provided. The training is accomplished on a virtual LSA (3D model) allowing users to interact with it in order to successfully accomplish each step of the training scenario. For each step useful information are provided through images, text, videos and animations on the corresponding virtual parts of the LSA. The second part of this application aids crew members during the LSA maintenance procedure. It provides the necessary steps for the maintenance along with useful annotations on the actual equipment of the ship. This application is developed for the Hololens 2[7]. The respective mock-ups are depicted in Figure 2.

[7] https://www.microsoft.com/en-us/hololens

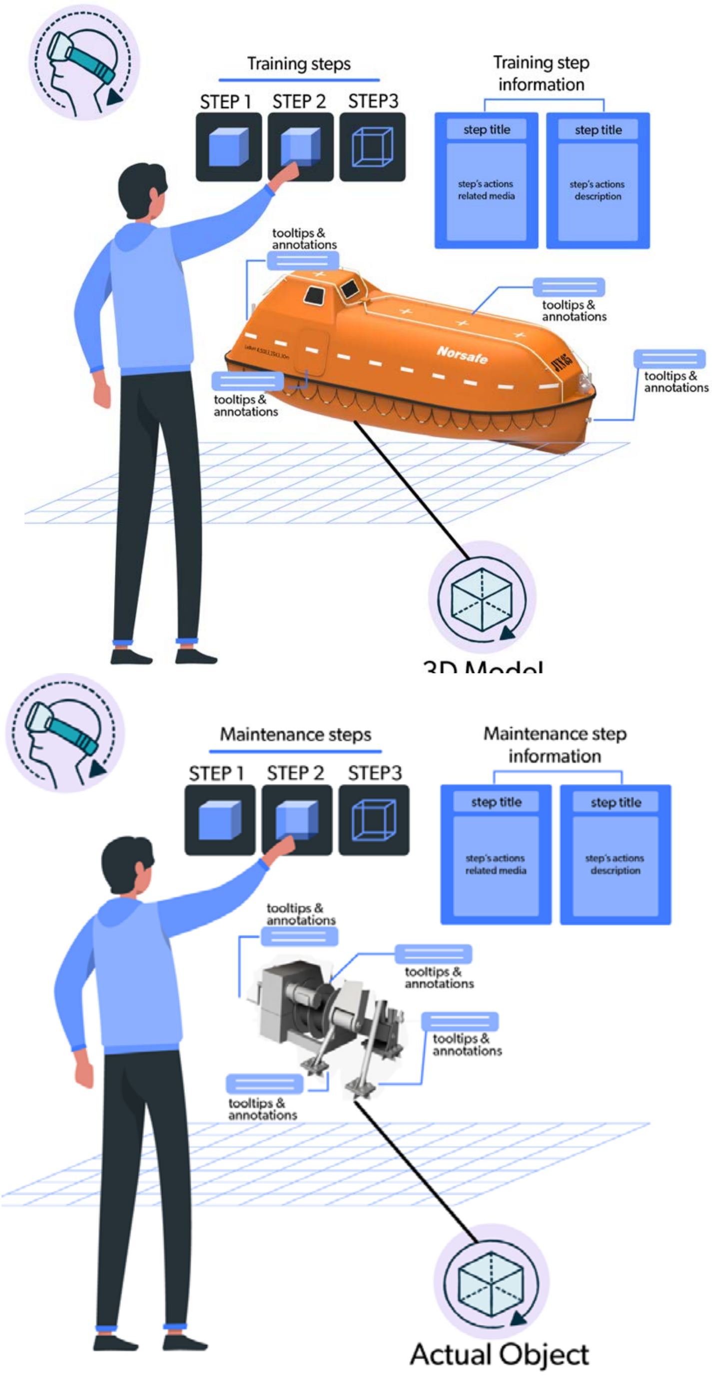

Figure 2. Mock-ups of the AR crew training application

The SafePASS Crew Rescue Assistant is an application developed on Hololens2 and used by ship's crew members responsible for assisting passengers in danger. The application as a first step notifies a crew member that there is a passenger in need along with all necessary information. This information includes position, status and special health conditions of the passenger collected by the central SafePASS system. As a second step it navigates the crew member to the passenger through an optimal safe route provided by the central SafePASS system (as illustrated in Figure 3). For the navigation, the application uses an indoor localization system based on Ultra-Wideband technology installed along with Hololens2 spatial awareness capabilities.

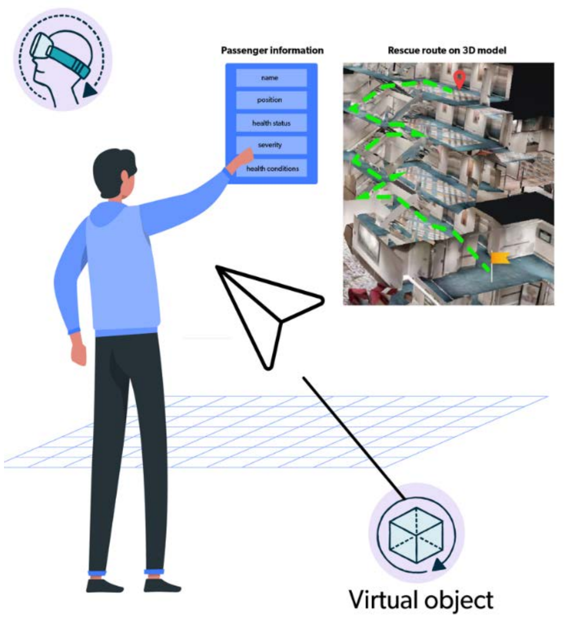

Figure 3. Mock-up SafePass passenger assistant application

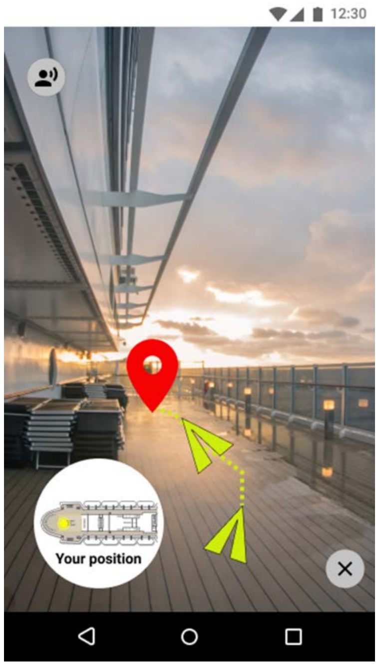

Figure 4. Mock-up SafePass Crew rescue assistant application

The SafePASS Passenger Assistant (Figure 4) is an application developed for mobile devices and used by ship's passengers. The application requests a personalized evacuation route to the nearest safe point from the central SafePASS system. Since the route is provided it navigates the user using augmented features along with audio assistance. For the navigation to keep track of passenger's position the application uses the indoor localization system installed.

Conclusions

The AR applications will be tested in real environment on a large cruise ship, as part of the integration, demonstration and validation activities of the SafePASS project. Nevertheless, some limitations of testing the AR applications in real emergency conditions on a ship (i.e. smoke, fire), how to emulate human stress factor and ship conditions such as ship leaning need to be addressed appropriately. On the other hand, technical challenges related to the navigation feature through the use of the indoor localization system combined with the spatial awareness will be further studied.

Acknowledgement

The SafePASS project has received funding from the European Union's Horizon 2020 Research and Innovation programme under the Grant Agreement No. 815146. The opinions expressed herein are those of the authors and the European Commission is not responsible for any use that may be made of the information it contains.

The First Functional Prototype of XR System for Additive Manufacturing System's Maintenance Support

Kaj Helin[1], Jaakko Karjalainen[1], Timo Kuula[1], and Gaetano Patrimia[2]

[1]*VTT Technical Research Centre of Finland Ltd, Tampere/Espoo, Finland*
[2]*Prima Industrie S.p.A, Turin, Italy*

Corresponding author: kaj.helin@vtt.fi

Keywords: Extended Reality, Manual Work Support, Usability, Human Centred Design.

Introduction

This application abstract introduces the first functional prototype of XR system for additive manufacturing (AM) system's maintenance support. It has been developed in European Commission funded H2020 project called "QU4LITY - Autonomous Quality Platform for Cognitive Zero-defect ManUfacturing Processes through DigitaL ContInuity in the ConnecTed FactorY of the Future". The development is following main principles of Human Centred Design (HCD)[8].

XR and/or AR based guidance and training are in maintenance and assembly; also termed AR instructions[9], AR-based job aid[10], AR-assisted maintenance system and AR-based assembly guidance[11]. AR guidance means that instructions are given to the user in textual, and/or visual format, augmented on the target objects. The benefits of XR/AR guidance in industrial work (e.g.

[8] ISO 9241-210:2010(en) (2010). Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems. Standard. International Organization for Standardization, Brussels. Available online at: https://rb.gy/9rk51h. Last accessed 16.10.2020.
[9] Re, G. M., & Bordegoni, M. (2014, June). An augmented reality framework for supporting and monitoring operators during maintenance tasks. In International Conference on Virtual, Augmented and Mixed Reality (pp. 443-454). Springer, International Publishing, Switzerland. https://doi.org/10.1007/978-3-319-07464-1_41
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maintenance) have been noted in several studies: the tasks were easier to handle, they were performed more effectively, with fewer mistakes compared to other instruction formats, and skill transfer could be enhanced[11]. XR system has been also tested in the space domain in the fields of training and manual work support[12]. The XR and/or AR usability has reached acceptable level in space related training and maintenance support[13].

The results of this application abstract are from the first development cycle of HCD and user evaluations at Prima Industries premises in Turin with the real AM system on February 2020.

The First Functional Prototype of XR System

The XR-system is based on IEEE Draft Standard for an Augmented Reality Learning Experience Mode[14] and it could be used with the Microsoft HoloLens 1 & 2[15] and latest mobile devices (iOS and Android). The whole system is configured around the Activity and Workplace JSON files. The Workplace JSON describes workplace-related information such as points of interest, sensors, etc. It is parsed with the Workplace manager and information is transferred to the data layer. The Activity JSON describes all action steps and the content that should be active for each step. It is parsed with the Activity manager and information is transferred to the XR layer via local storage. The user can interact with the XR player via a multi-modal user interface (see Figure 5). The following modalities can be used simultaneously (1) Gesture, e.g. doing a “Click” gesture to go to the next work step, (2) Voice commands, e.g. saying “Next” to go to the next work step, and (3) Physical button, e.g. “Click” to go to the next work step.

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[12] Tedone, D., Marello, M., Musso, G., Frangakis, N., Oliveira, D. M., Agostinho, S., & Helin, K. (2017). Augmented reality for the support of space exploration missions and on-ground/on-orbit operations. In Advances in Human Factors and System Interactions (pp. 141-151). Springer, Cham. https://doi.org/10.1007/978-3-319-41956-5_14

[13] Helin, K., Kuula, T., Vizzi, C., Karjalainen, J., & Vovk, A. (2018). User experience of augmented reality system for astronaut's manual work support. Frontiers in Robotics and AI, 5, 106. https://doi.org/10.3389/frobt.2018.00106

[14] P1589 - IEEE Draft Standard for an Augmented Reality Learning Experience Mode. https://standards.ieee.org/develop/project/1589.html. Last accessed 21.6.2020.

[15] Microsoft (2020). Microsoft HoloLens mixed reality platform. https://www.microsoft.com/en-us/HoloLens, Last accessed 21.6.2020.

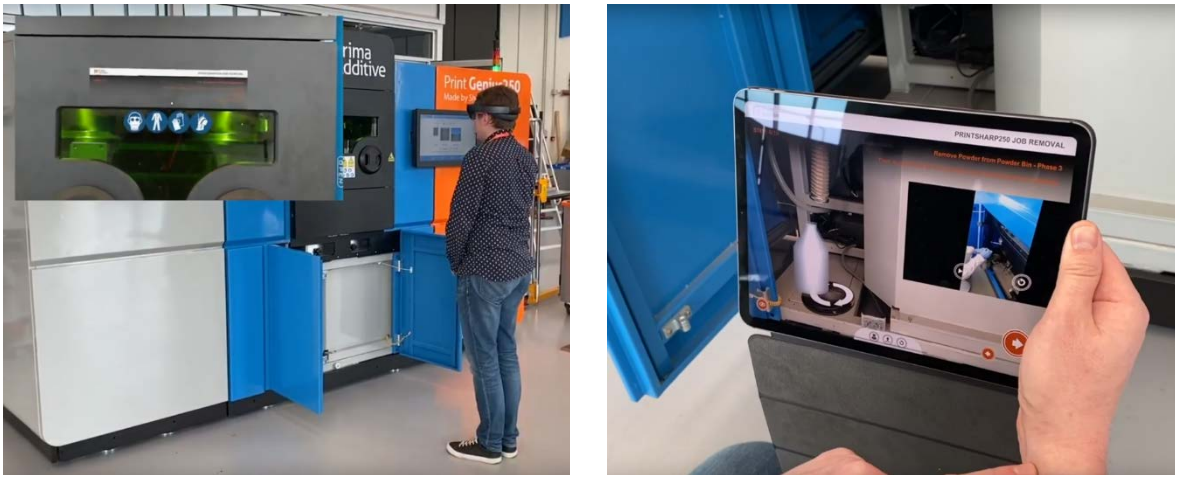

Figure 5. Left: HoloLens 1 version. Right: iPad version

Evaluation case

The evaluation case was Prima's Print Sharp 250 AM system's maintenance work. AM system could be seen in left hand side in Figure 5 The evaluation was done Prima Industries premises in Turin on February 2020. The evaluation/use case contains 10 steps procedure of powder bin removal. Three (3) Prima Industries experts participated in the user test. After the test, each participant was interviewed. They were also asked to fill in SUS (System Usability Scale) questionnaire. Users were testing HoloLens and iPad Pro version of XR system.

Evaluation results

SUS is a tool for measuring usability and learnability. SUS scores have a range of 0 to 100. SUS score starting from 68-70 represents the level of acceptable system usability. Acceptability ranges: 0-50 not acceptable; 50-70 marginal; 70- acceptable[16], [17].

Average SUS results:

- Tablet version: 84
- HoloLens 1 version: 70

The SUS scores indicate clearly acceptable usability for the tablet solution, whereas two experts evaluated HoloLens solution with not acceptable scores. The results are still approximate and preliminary in nature due to low number of participants. They are however in line with the expectations of the developers, since the XR content was less optimized for the HoloLens solution.

The interview results on the overall experience with the both solutions were quite positive. The users' expressions on the experience with the tablet solution emphasised good usability and

[16] Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. Journal of usability studies, 4(3), 114-123. Available online at: https://rb.gy/yjadvd Last accessed 16.10.2020.

[17] Brooke, J. (2013). SUS: a retrospective. Journal of usability studies, 8(2), 29-40. Available online at: https://rb.gy/i7ncfw. Last accessed 16.10.2020.

usefulness, such as "easy to use, well developed, appropriate for demoing, user friendly, useful". The expression related to HoloLens focused more on the novelty of the solution and its smart interaction: "Interesting, very interactive, smart, and surprisingly easy to interpret". HoloLens was also experienced as strange to use and not easily adjustable. The strength of HoloLens is that it enables hands-free working. It was suggested that tablet solution is more suitable for on-site training purposes, whereas HoloLens would be good for demonstrating XR for customer. Additionally, a number of minor improvements for content and usability were mentioned in the interviews.

Conclusion

As the XR-system usability has reached a reasonable level (average SUS scores: 70 HoloLens 1 & 84 iPad Pro version), even the test population was quite small. Both the pragmatic and emotional aspects of the user experience were considered fulfilling. It can be suggested that the current XR-system is good bases for the second development cycle of HCD. Also, system will be updated to support HoloLens 2 and base on the first experience of the HoloLens 2 the new version should solve most of the usability issues such as the narrow field-of-view. Future work also includes project monitoring features such as real time process info via IoT interface and video stream from AM machine chamber.

Acknowledgment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825030.

Appendix

Video of The First Functional Prototype of XR System: https://youtu.be/3Kz_fE8VdG8

Protocols of use for immersive platforms under covid19

Javier Posselt, and René Gosselin

Renault SAS, Boulogne-Billancourt, France

Corresponding authors: javier.posselt@renault.com & rene.gosselin@renault.com

Keywords: HMD, CAVE, Virtual reality, Augmented reality, Automotive industry, COVID19.

Introduction

With the increasing use of immersion systems in the project validation phases, many platforms are being deployed within the automotive industry. At Renault, immersive simulation platforms (see Figure 6) are used in the form of collaborative project reviews. A part of this equipment is therefore shared in self-service (virtual reality and augmented reality immersion headsets) or managed by specialized operators (CAVE's). There are few cases where this material is used in a personal and individual way inside the company but in any case, the immersive technics are used at work from home. Each mode of use requires specific protocol in order to guarantee the hygiene and health conditions for the users. These protocols contain rules of use to avoid psychological problems, physical ailments (simulator sickness), accidents with the equipment (falls, collisions) and specially to avoid contagions by temporary infectious pathologies (skin problems, flu-like conditions and conjunctivitis). To avoid health problems with infectious diseases, the current protocols had already integrated instructions for cleaning helmets before being shared. These measures are very common and not very restrictive. The infectious diseases identified so far were temporary and did not pose fatal risks to the health of users. If any of these conditions were identified, users were then advised to avoid using headsets for their own well-being.

Figure 6. The 3 immersive simulators used at Renault for automotive project design: HMD, Augmented Reality and CAVE.

Motivation

With the arrival of COVID19, the risks are completely different, because this disease is fatal and extremely contagious. Indeed, it is transmitted by contact with the mucous membranes. The virus can then cling to the material for a very long time. This contamination coming due to material handling and several surfaces are in contact with the skin: hands and face. By this reason, our motivations to create a new protocol of use applied to the immersive platforms are due for:

- The company's hygiene and health committees had established a protocol for resuming work in the tertiary and industrial environment. However, these protocols have turned out to be poorly suited to the specific needs of sharing equipment such as is currently done in simulators.
- Create new protocols of use immersive simulators in order to be able to resume activity quickly after the return from the confinement period.
- Any accident where immersive simulators are involved must be prevented because if not, users may abandon them for fear of their use.

Procedure

Our approach has therefore led us to analyse the modes of use of the equipment with its peripherals and the way it is shared. It was also necessary to follow the directives which imposed new constraints such as wearing a mask and controlling the air conditioning in the simulation rooms. To carry out this work, several actors were called upon such as simulator operators, suppliers of virtual reality equipment, experts, and managers of the company's health committee. We sought to find synthesize the scarce information on how to avoid contamination of our equipment with the virus. Protocols were made and validated remotely during confinement to allow rapid opening of the activity from the first day of return to work

The protocol is the result of a compromise and synthesis of other health protocols produced by the company and the health authorities. The objective was also to establish a protocol that was easy to adopt, inexpensive for the company, the least restrictive possible with respect for the environment and the health of users.

Protocole

The final protocol is divided in four descriptions:

1. Preparation of the material, it includes an adaptation of equipment to withstand frequent cleaning and guarantee good hygiene.
2. Provide users with the necessary equipment for the protection and cleaning of equipment. Clean products are the current offered by the company with compatibility with a use in contact with the skin of the face and close to mucous membranes.
3. Recommendations of use and description to how to clean equipment.
4. Management of cleaning products and contaminated waste.

Conclusion

Users and operators of immersive simulation equipment found themselves confronted with a new health hazard overnight. The publication of this protocol enabled Renault to start their activity related to immersive simulators without delay. This information has generated a lot of interest from other users outside the company, Renault has shared and exchanged with other industrial partners.

The constraints resulting from the application of the protocol cause that users no longer find the advantages of use virtual reality such as ease of use, spontaneity, enthusiasm and friendly. Local collaborative functions become very limited.

A relaxation of the protocol is envisaged based on a better knowledge of how viruses survive on hardware. It still takes some time and a better experience to gain perspective on protocols and continued use of headsets.

We have also noticed that with the new regulations and new ways of working, there is therefore a motivation to develop collaborative tools remotely and individually.

Additional literature

Christieans, S. (2015). Nouvelles technologies alternatives à la désinfection chimique Intérêts, limites, avenir, WorkShop EcoSec 1 er octobre.

Manuel de Sécurité Biologique en Laboratoire, OMS, Troisième Edition, Genève 2005

Institut Nationale de Recherche et de Sécurité (INRS) (2014). La Desinfection des Surfaces en Laboratoire de Biologie, Editions INRS ED 6188, 1[re]. Edition.

Indications de la désinfection des locaux par voie aérienne (2012). Note technique de la Commission de Désinfection de la Société Française d'Hygiène Hospitalière (SF2H). Revue Hygiènes 20:3, 98-99

Gamified experience from room 39

Marta Tabernero[1], and Alberto Ruiz[2]

[1]Mecenas 2.0, Spain
[2]3in tech, Málaga, Spain

Corresponding authors: marta@mecenas20.com & alberto@3in-tech.com

Keywords: Museum, virtual reality, gamified experience, culture.

Introduction

On the occasion of the temporary exhibition of "The Rest Gabinet of their Majesties" the Prado Museum has published in its website (Figure 7), available on mobile phones and computers, an innovative way of visiting the history of Room 39. This Room contains the birth and history of the Prado Museum, through the reconstruction of the room in different history periods/eras and a Virtual Reality game.

Through the voice of Luis Eusebi, first custodian of the Prado Museum and one of the most relevant characters in the art gallery, the users will have to find out the objects that will help them travel through time.

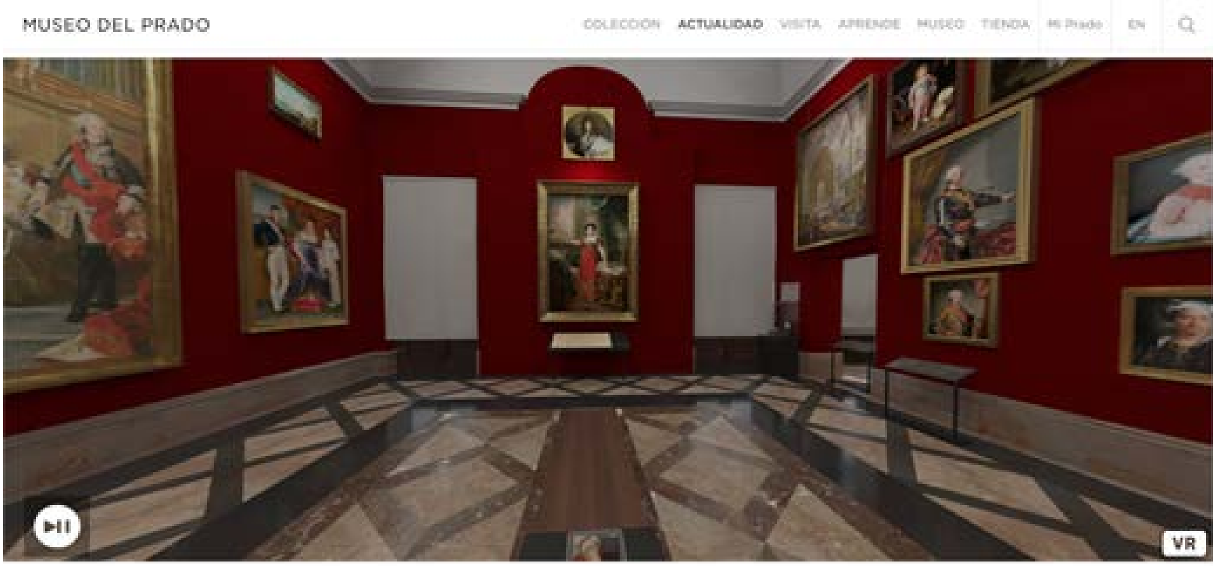

Figure 7. Visualization of the gamified experience on the Prado Museum website.

Through this gamified experience you can travel back in time in 4 different notorious eras - years 1828, 1867, 1936 and 2019 - that are related to historical and representative moments of the history of Spain and the Museum. The technology provides the opportunity to visit the transformation of Room 39 of the Museum in four periods, in which they have been recreated carefully with maximum details: the structural changes of the vault, the works exposed in each period with their wonderful frames, the different floors, the paint on the walls, the lighting, the furniture, the carpets, the toilet of Alfonso VII as well as original documents from Spanish Civil War from the Prado Museum files have been used.

The goal of this project is to transmit the museum content with all the rigor that an exhibition of these characteristics and a contemporary language in order to reach new audiences.

Experiencia Gamificada Sala 39: https://www.museodelprado.es/actualidad/multimedia/experiencia-gamificada-de-la-sala-39/49f16326-8f63-82e0-e8f6-b136103296df

Viewer Room 39: https://www.museodelprado.es/actualidad/multimedia/visor-de-la-sala-39/b739f8df-38b9-638c-829a-31ec3b8d1726

The last report from Museum is:

- Visits to the "Viewer Room 39" page: 18.246 and 3.47 minutes on average.
- Visits to the "Experiencia Gamificada Sala 39" 18.168 and 4.47 minutes on average

Technical aspects

The main technical requirements for the implementation of the experience were Virtual Reality experience and Multi device.

The experience was developed using the framework A-Frame (https://aframe.io/) and Resonance Audio SDK (https://resonance-audio.github.io/resonance-audio/) for the implementation of three-dimensional sound.

Users Experiences

Event Night in White 2019, Málaga (Figure 8)

Place of development of the Polo de Contenidos Digitales experience. Different users' profiles tried the experience with cardboards and Virtual Reality glasses.

During the event, about 200 people could participate in the Virtual Reality experience, having 74 of them completing the survey. The quantitative results are shown in this link: https://docs.google.com/document/d/1BvgYwDgA_rvCiOYXD5oVsOFK9-vYAseYsBVfnp0nBq4/edit?usp=sharing

Qualitative answers

Hypothesis 1: "Gamified and interactives experiences improve the image of the Prado in young range age"

From the qualitatives interviews carried out, in all age ranges it was highlighted that these types of experiences help to discover new aspects of museums and create more expectation and desire to visit them.

Hypothesis 2: "Virtual Reality can be a substitute experience for real sight"

False. The responses received are completely the opposite, immersive gamified experiences are a claim to continue the visit in the Museum as long as that aspect is included in the requirements.

In this way the design of the experience will always try to awaken the desire in the user to visit the Museum. Statement of one of the users "It is like if someone shows you pictures of the Maldives, however 360, photos of videos you see, you will always want to go live the experience. If the destination has quality, we always want to visit, even repeat."

Hypothesis 3: "Experience that can be used as an educational resource"

Those profiles related to training were asked in this aspect, all of them agreed that resources like this are very useful to explain (to all ages) artistic and historical content.

Hypothesis 4: "Operation in 40% of devices, according to source caniuse.com"

The experience was focused on the use of mobile devices with cardboards. Approximately, 80% of the mobiles the users had were able to execute the experience"

Figure 8. Event Night in White. Polo de Contenidos Digitales. Málaga. 2019

Fernando de los Ríos Consortium - Guadalinfo

Guadalinfo is a digital net with strong and solid territorial support: around 800 centers that provide service to 692 Andalusian municipalities with less than 20.000 population and groups at risk of social exclusion in more than 60 points of elder population.

We carry out remote meetings with managers of Guadalinfo network, located in different parts of Andalucia to take needed actions and coordinate all development.

We establish an action/protocol guide for the trainers of those responsables for the Guadalinfo network to pass on the information to all centers. The following points are emphasized:

- Accessibility from different devices,
- Objectives of the actions,
- Enough resources to live the experience. Importance of headphones,
- Survey. Data collection.

Results of the experience in 369 villages in Andalusia. These are the main data from the surveys completed by the users with the collaboration of the Guadalinfo Network technicians (Figure 9).

Quantitative answers

All participants of this experience had access to a survey. In the end we got 163 answers. https://docs.google.com/document/d/1BvgYwDgA_rvCiOYXD5oVsOFK9-vYAseYsBVfnp0nBq4/edit?usp=sharing

Qualitative answers

96% of the users lived in an area with a population inferior to 10.000. 50% of those surveyed were over 46 years old and 25% were over 40 years old.

60% of the participants had never visited the Prado Museum and the majority of those who visited, 83,5% had only gone once. 90% of the surveyed, after the experience, were eager to visit the Prado Museum. 93,6% stated that the experience helped them to learn.

97% answered that they really liked the experience and would like to have more similar events in their villages.

Figure 9. User of the Guadalinfo Network enjoying the Gamified Experience of Room 39

Conclusions

The experiences in virtual reality produce in the user the perception of a real visit

It is an ideal formula for Museums to be more accessible to the user with reduced mobility due to financial, physical or cultural difficulties. These experiences have the ability to create new audiences for the Museum. Technology and Virtual Reality attract all range age.

Facing the crisis of the coronavirus, the virtual reality applied to museums offers interesting solutions

COVID-19 has produced a very significant decrease in visitors to museums around the world that directly affects one of its most important sources of income. Virtual reality can open new ways of consumption for the museum sector.

Educational centers

Multiple paths are opened for the development of digital content in virtual reality for all types of educational centers. One of the most important values of Virtual Reality at an educational level is its sensory capacity. In the tests carried out it is detected that it is able to generate a powerful interest in culture.

Mobile phones and virtual reality

It is necessary to carry on working on the accessibility of Virtual Reality through mobiles phones. The Virtual Reality glasses are expensive and not accessible to most of the society.

Expand the museum through the development of virtual spaces, experiences and games

The possibilities of developing digital content within a Museum are immense, they can be really worth it and very enriching for society.

Acknowledgments

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Review of Haptic Rendering Techniques for Hip Surgery Training

Taha Ziadeh[1], Jerome Perret[1], Maximilian Kaluschke[2], Sebastian Knopp[3], and Mario Lorenz[3,4,5]

[1]*Haption GmbH, Aachen, Germany*
[2]*Universität Bremen, Bremen, Germany*
[3]*Technische Universität Chemnitz, Chemnitz, Germany*
[4]*University Hospital Leipzig, Leipzig, Germany*
[5]*Medical University of Graz, Graz, Austria*

Corresponding author: taha.ziadeh@haption.com

Keywords: Haptics, Force-Feedback, Virtual Reality, Surgery Simulation.

Abstract

In this review paper, we discuss haptic rendering techniques that can be used for hip surgery training. In the context of surgery, the simulation requires high quality of feedback forces and the interaction with the virtual environment must be synchronized in real time. Several studies were presented since the 90s to solve collision detection problem and force feedback computation. In this review paper, we classify haptic rendering techniques under two categories: methods of direct force-feedback computation, and proxy based methods. In the first category, the force is calculated and sent directly to the haptic device once the penetration measure is found. In contrast the proxy based techniques try to follow the haptic device using a proxy or "god-object" which is limited to the surface of rigid objects in the virtual environment, then compute the feedback force based on the behavior of this proxy. Under each category, we present the different techniques and discuss their benefits and disadvantages in the light of surgery training.

Introduction

Virtual Reality (VR) in combination with haptic feedback is a powerful technology for training medical residents in surgical procedures[18]. While such simulators have proven their benefits for training of minimally invasive surgeries, such as laparoscopic or arthroscopic procedures, there

[18] Escobar-Castillejos, D., Noguez, J., Neri, L., Magana, A., & Benes, B. (2016). A review of simulators with haptic devices for medical training. Journal of medical systems, 40(4), 104. https://doi.org/10.1007/s10916-016-0459-8

barely exist haptic VR training possibilities for procedures in which high forces occur. Especially in the orthopedic field where several hundred thousand of joint prostheses are implanted worldwide annually. Therefore young surgeons would greatly benefit from haptic VR training purposes. While only visual training simulations exist in this area, the missing realistic haptic feedback hinders these simulations from unfolding their complete potential. However, providing realistic haptic feedback for orthopedic joint implant procedures challenges the capabilities of current haptic feedback devices and haptic rendering technologies alike. Especially, the occurring forces and torques during the individual surgical steps are largely unknown. Pioneering work in this field was performed by Pelliccia et al.[19] who assessed the occurring forces and torques during acetabulum reaming, which is one step during hip joint replacement surgery. Based on this data Kaluschke et al.[20] were able to implement a haptic rendering algorithm simulating the forces and torques during acetabulum reaming. Knopp et al.[21] were able to utilize this haptic rendering algorithm by using a KUKA iiwa LBR robot. With this robot approach, the occurring average reaming forces of up to 160 N[19] could actually be transmitted to the training surgeon. These combined efforts lead to a research prototype capable of simulating acetabulum reaming in VR with realistic haptic feedback[22].

However, the haptic simulation of the acetabulum reaming is a comparably easy step in relation to the other surgical task in hip replacement surgery: (1) implanting the pan; (2) reaming the femur; (3) implanting the shaft; (4) cutting the femoral head. The first three steps require hammering where very large impact forces are occurring, posing completely new challenges to the haptic rendering techniques and hardware devices alike. In an initial step, the existing haptic rendering techniques have to be analyzed in order to also develop haptic feedback for the steps that involve hammering.

By "haptic rendering techniques", we mean the methods and algorithms which compute a signal to be rendered as haptic feedback to the user through a force-feedback device. This leaves out the problems of: i) creating the 3D model(s) of the virtual environment, ii) measuring and applying material properties, iii) detecting collisions between 3D objects, and iv) computing the changes in the model due to object deformation or material abrasion. We do not discuss these issues of force regulation and actuator control of the force-feedback device either.

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[19] Pelliccia, L., Lorenz, M., Heyde, C. E., Kaluschke, M., Klimant, P., Knopp, S., ... & Zachmann, G. (2020). A cadaver-based biomechanical model of acetabulum reaming for surgical virtual reality training simulators. Scientific Reports, 10(1), 1-12. https://doi.org/10.1038/s41598-020-71499-5

[20] Kaluschke, M., Weller, R., Hammer, N., Pelliccia, L., Lorenz, M., & Zachmann, G. (2020, March). Realistic Haptic Feedback for Material Removal in Medical Simulations. In 2020 IEEE Haptics Symposium (HAPTICS) (pp. 920-926). IEEE. https://doi.org/10.1109/HAPTICS45997.2020.ras.HAP20.74.13165668

[21] Knopp, S., Lorenz, M., Pelliccia, L., & Klimant, P. (2018, March). Using industrial robots as haptic devices for vr-training. In 2018 IEEE conference on virtual reality and 3D user interfaces (VR) (pp. 607-608). IEEE. https://doi.org/10.1109/VR.2018.8446614

[22] Kaluschke, M., Weller, R., Zachmann, G., Pelliccia, L., Lorenz, M., Klimant, P., ... & Móckel, F. (2018, March). Hips-a virtual reality hip prosthesis implantation simulator. In 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR) (pp. 591-592). IEEE. https://doi.org/10.1109/VR.2018.8446370

Our analysis is based on a thorough review of scientific publications discussing haptic rendering techniques, both in a general case and applied to surgery simulation. In the ensuing discussion, the authors' own hands-on experience with the different techniques is reported as well.

Objectives

In our previous research, we aimed at solely simulating the acetabular reaming using haptic feedback. To achieve this, we developed a novel haptic rendering technique that combines ideas of penalty and proxy-based methods[20]. In brief terms, we represent the reamer and acetabulum as a collection of poly-disperse, non-overlapping spheres. The force is computed based on a proxy tool that follows the user input, but doesn't penetrate the acetabulum, which we guarantee using continuous collision detection (see Figure 10). Torques are computed using the penalty formula with a single contact point of the proxy on the acetabulum surface. The material removal is simulated by updating the sphere collections of the acetabulum at runtime.

In the continuation of our research, we still intend to simulate acetabular reaming. Consequently, we will be able to build upon the previously developed algorithm and improve it. In particular, we aim at simulating the proxy motion more realistically and consequently allowing for multiple contact points and a more realistic torque simulation. However, we still need to stay within the 1 kHz update frequency to allow stable operation of the haptic device.

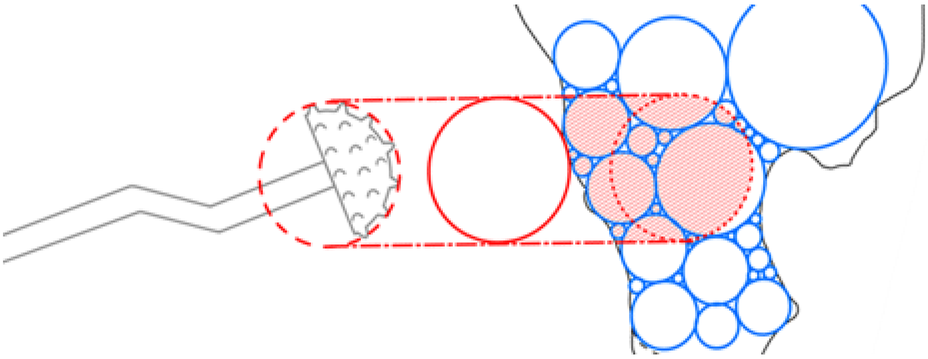

Figure 10. The acetabulum is represented as a set of non-overlapping spheres (blue). The hip reamer (red) does not penetrate the hip, but is bound to its surface.

Haptic Rendering Techniques

For the sake of clarity, we define two categories of haptic rendering techniques.

The first category gathers the techniques which consist in directly calculating a force/torque to be applied to the force-feedback device. Within that first category, we will describe i) the penalty method, ii) the impulse method, and iii) the event-driven method.

The second category is dedicated to techniques which make use of a proxy, also called "god-object", and derive the haptic feedback from the behavior of that proxy. The motion of the proxy can be computed either geometrically, or by using time-stepping physics simulation.

Penalty Method

Penalty-based approach works in two states: "no contact" state is active when there is always positive distance between objects; and "resting contact" state is active when objects interpenetrate. In the latter case, the method calculates forces by penalizing interpenetration proportional to the depth of penetration.

The inter-penetration problem is often modeled using a spring-damper mechanism. Feedback forces applied are proportional to the amount of penetration of the haptic device into the object in contact[23]. In case of 3-DoF (3 degrees of freedom) modeling, a point-probe interaction is used, and the operator feels only forces of contact in the virtual environment. In contrast, when the 6-DoF modeling is implemented, a more complex object-probe interaction is used, and the operator feels forces and torques upon contact in the virtual environment[24]. The forces are easy to calculate when using simplified geometries like spheres and planes. Upon collision, the method starts by detecting the nearest surface then calculates the distance of penetration. Once the distance is found, the force can be easily calculated using Hooke's law[25] [8]. The direction of the feedback forces should be normal to the surface of contact; when modeling with spheres, the force direction is equivalent to the vector starting from sphere center and going through the haptic interaction point (HIP)[26].

The penalty method is a popular and easy approach that is widely used in haptic rendering applications. McNeely et al.[27] implemented the penalty method using the voxel-based approach for 6-DoF haptic rendering in 1999. The authors defined voxel maps as 3D grids in space and used it to represent virtual objects. The user can interact with the voxel based environment using small object-probes modeled as pointshells. Sagardia[24] stated that the Voxmap PointShell (VPS) algorithm is one of the most used implementation of penalty-based method.

As stated in[26], this method has multiple drawbacks. It is hard to choose the right surface upon contact. The corners of objects feel sharp because of the discontinuity of forces. In addition, when facing a thin object, this method cannot generate enough forces to prevent the haptic device from going through the object. Then in that case, the nearest surface will be changed and the operator will be pushed out of the object because of opposite forces. Other problems for the penalty-based methods are listed in[24], like possible visual overlap, and irregular distribution of the stiffness.

If the contact between objects is not simple, it is hard to identify a single penetration depth and many points of contact are considered. For each contact point, a penalty force is associated based on the relevant penetration depth. If multiple penalty forces are in the same direction, the forces sum up and a "stiffness accumulation" occurs. Due to stiffness accumulation, the feedback forces

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[23] Ruspini, D. C., Kolarov, K., & Khatib, O. (1997, August). The haptic display of complex graphical environments. In Proceedings of the 24th annual conference on Computer graphics and interactive techniques (pp. 345-352). Available online at: https://rb.gy/gkex6g last accessed 14.10.2020.

[24] Erasun, S. (2019). Virtual Manipulations with Force Feedback in Complex Interaction Scenarios (Doctoral dissertation, Technische Universität München.

[25] Hooke's Law. https://en.wikipedia.org/wiki/Hooke%27s_law last accessed on 1.9.2020.

[26] Zilles, C. B., & Salisbury, J. K. (1995, August). A constraint-based god-object method for haptic display. In Proceedings 1995 ieee/rsj international conference on intelligent robots and systems. Human robot interaction and cooperative robots (Vol. 3, pp. 146-151). IEEE. https://doi.org/10.1109/IROS.1995.525876

[27] McNeely, W. A., Puterbaugh, K. D., & Troy, J. J. (2005). Six degree-of-freedom haptic rendering using voxel sampling. In ACM SIGGRAPH 2005 Courses (pp. 42-es). https://doi.org/10.1109/IROS.1995.525876

may be exaggerated, and the haptic device will potentially suffer from stability problems. Scaling down stiffness by the number of contact points is usually used to tackle this problem, but this introduces large penetration issues for complex objects. Xu and Barbič[28] proposed a spatially-varying adaptive stiffness method. Using the Gauss map of contact normals, the proposed method guarantees uniform distribution of stiffness in all contact directions. This way, they were able to avoid unwanted penetration of objects and enhance the virtual coupling saturation.

Kim and Park[29] implemented penalty based method for dental implant surgery training. Using PointShell representation for bones and signed distance field for the drilling tool, authors were able to simulate arbitrarily shaped tools having multiple contacts with the bone. During the collision, the bone starts losing voxels in real time relative to the thrust force applied by the surgeon while the feedback forces are accurately and efficiently calculated using the distance field encoded in the tool.

Impulse Method

Brian Mirtich and John Canny[30] proposed the impulse based approach for rigid-body simulation first in 1994. The impulse method is known to be simple and robust at the same time. It is fast enough to work in real time simulation. One single model is used to represent all kinds of contact (collision, rolling and sliding). The authors treated each contact as frequent small collisions called microcollisions. Unlike constraint-based methods (see below under "proxy method"), the impulse method does not apply constraints on the object configuration and does not limit the movement of the proxy. The collision detection implements the closest feature algorithm: it computes the possible times to collision and stores them in a list with prioritized sorting. This sorting leads to dynamic evolution step. If the distance between close features is less than set threshold, a collision is detected. Hence, the impulse force is only applied if the difference of velocity between two objects has a magnitude in the normal direction to the surface of contact.

The method considered three assumptions for simplification: First, collision time is relatively negligible compared to movement duration of the objects in virtual environment. In this case, the impulse method imposes instantaneous influence on the linear and angular velocity upon contact rather than only change on acceleration. Then, the authors considered Poisson's hypothesis which helps for resolving collisions. And finally, the Coulomb's friction theory is applied to ensure the relation between tangential and normal forces.

The impulse method has been implemented by Constantinescu et al.[31] for haptic rendering. They proposed a hybrid algorithm to improve stability and rigidity perception upon interaction with

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[28] Xu, H., & Barbič, J. (2016). Adaptive 6-dof haptic contact stiffness using the gauss map. IEEE transactions on haptics, 9(3), 323-332. https://doi.org/10.1109/TOH.2016.2558185.

[29] Kim, K., & Park, J. (2009, November). Virtual bone drilling for dental implant surgery training. In Proceedings of the 16th ACM Symposium on Virtual Reality Software and Technology (pp. 91-94). https://doi.org/10.1145/1643928.1643950.

[30] Mirtich, B., & Canny, J. (1994). Impulse-based dynamic simulation. California: Computer Science Division (EECS), University of California.

[31] Constantinescu, D., Salcudean, S. E., & Croft, E. A. (2005). Haptic rendering of rigid contacts using impulsive and penalty forces. IEEE transactions on robotics, 21(3), 309-323. https://doi.org/10.1109/TRO.2004.840906.

objects in virtual environment. The proposed method applies impulsive forces upon contact and rely on penalty and friction forces during contact. A suitable controller is used to send computed forces directly to the force-feedback device. The authors presented experimental results that shows increased contact stability on a 2D system, including passivity.

Wang et al.[32] also used the impulse based approach for haptic simulation of bone burring. The burring tool is modeled based on real burr geometry. In their study, they assume that both burring tool and bone materials are rigid bodies. In addition, the authors assume that the velocity is directly affected at the moment of contact as mentioned in[30]. They considered that contact forces can be split into resistance and friction. The friction model includes static and dynamic friction. In addition, a 3D vibration model is proposed to mimic the vibration forces applied to the burring tool. The dynamics of impulse based method allows them to evaluate contact forces of interaction between rigid bones and the surgical instruments. Finally, the sum of the computed forces is transmitted back to the haptic device. An efficient bone removal scheme was also developed in order to provide the user with a realistic visual feedback for the training process. The results presented by Wang et al. show the ability of the impulse based method to simulate feedback forces in real time which are consistent with real bone burring operations.

Event-Driven Method

The event-driven method was first introduced by Kuchenbecker et al.[33] in 2006. The authors aimed to improve the realism of interacting with virtual environments, especially for wooden objects. They added a transient perturbation signal to the feedback force. Adding this perturbation makes virtual objects feel like real wood on a foam substrate, while it is rated as feeling unrealistic with just the penalty-based forces.

Similarly to the penalty based approach, the event-driven method applies standard position feedback forces. In addition, it also applies pre-defined impact transients upon contact detection with a rigid surface. High frequency transient forces help stimulating the human's perception to feel a high stiffness while low-bandwidth closed loop forces are used to capture the user's motion. An exponentially decaying sinusoidal forces is suggested with a frequency dependent on material type.

Kuchenbecker et al. showed how such forces improve the perception of virtual stiffness of objects, by using actual recordings with accelerometers on real material as transient force signals. They demonstrated that users could discriminate between different materials applied to a virtual wall. However, they did not explore the application of their method beyond a single degree of freedom.

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[32] Wang, Q., Chen, H., Wu, W., Qin, J., & Heng, P. A. (2011). Impulse-based rendering methods for haptic simulation of bone-burring. IEEE transactions on haptics, 5(4), 344-355. https://doi.org/10.1109/TOH.2011.69

[33] Kuchenbecker, K. J., Fiene, J., & Niemeyer, G. (2006). Improving contact realism through event-based haptic feedback. IEEE transactions on visualization and computer graphics, 12(2), 219-230. https://doi.org/10.1109/TVCG.2006.32

Sreng et al.[34] used impact events to enhance the haptic rendering with 6-DoF. They chose to apply high frequency force patterns in addition to the standard force feedback provided by their rigid-body simulation method (see below). The proposed solution distinguishes between two types of contact; the continuous contact like friction, and the discrete event based contact like impact and detachment. The generated contact states and events only rely on the position of objects in the virtual environment. The forces related to friction were generated using the tangential velocity of moving bodies. On the other hand, the impact and detachment forces were generated based on the normal velocity between two objects at point of contact. The authors did not conduct a user study in order to evaluate the relevance of their method.

In our review of the state-of-the-art, we could not find any use of the event-driven method in the context of surgery simulation.

Proxy Method

In their paper of 1995, Zilles and Salisbury [26] propose a "constraint based" method as a way to address the limitations of the penalty method. They introduce the concept of a "god-object" or "proxy", which represents the virtual placement of the tool attached to the haptic device, but limited by objects in the virtual environment. If no collision is detected, then the proxy is exactly moving with the haptic device and no force feedback is applied. Upon contact, collision forces and torques are generated by a dampened spring between the god-object and the control point of the haptic device (the "Haptic Interaction Point" or "HIP").

In 2006, Kang et al.[35] filed a patent for the proxy method, which was awarded and is now owned by the company Mako Surgical Corp. Although their application is clearly focused on surgery, the patent claims are much more general and cover potentially all applications. Nevertheless, since there is clear prior art[36], the patent could in no case give rise to an infringement action, and is rather a measure of protection. A very similar patent was filed by Petersik et al.[36] in 2008 for the Hamburg Medical University, including a method for material removal.

The placement of the proxy can be determined using two different approaches: i) geometrically or ii) through rigid-body dynamics simulation.

Geometric Placement of the Proxy

In [26], the authors consider a surface as an active constraint if the line that connects the proxy and the HIP pass through it. When the HIP faces an obstacle, the proxy is limited by the active

[34] Sreng, J., Bergez, F., Legarrec, J., Lécuyer, A., & Andriot, C. (2007, November). Using an event-based approach to improve the multimodal rendering of 6DOF virtual contact. In Proceedings of the 2007 ACM symposium on Virtual reality software and technology (pp. 165-173). https://doi.org/10.1145/1315184.1315215

[35] Kang, H., Quaid, A. E., & Moses, D. (2013). U.S. Patent No. 8,571,628. Washington, DC: U.S. Patent and Trademark Office. Available at: https://rb.gy/g30ild last accessed 14.10.2020

[36] Petersik, A., Hohne, K. H., Pflesser, B., Pommert, A., & Tiede, U. (2013). U.S. Patent No. 8,396,698 B2. Washington, DC: U.S. Patent and Trademark Office. Available online at: https://rb.gy/gvv2pl last accessed 14.10.2020.

constraints, though the haptic device can still penetrate into the object. Using Lagrange multipliers, they are able to calculate the position of the proxy object, so that it stays at the surface of the obstacles.

Ruspini et al.[23] represent the proxy as a mass-less sphere that can be moved along the objects in the virtual environment. Their implementation provides modeling for contact constraints, surface shading, texture and friction. To calculate the position of the proxy during contact, the authors consider several contact half-planes where each constraint plane limits the movement of the proxy to the half space above the plane.

Collision detection can be discrete or continuous. In the former, the movement is sampled to detect inter-penetration between object. In this case, it is possible to miss the collision, especially when having thin objects or high velocity of movement. On the other hand, in continuous collision detection, in-between position interpolation is done where the calculation of the time of first contact between objects is part of the algorithm. In their study, Redon et al.[37] presented a fast continuous collision detection using OBB (Object Bounding Boxes) hierarchies, with integration of arbitrary in-between rigid motions and interval arithmetic technique[38]. In another paper[39], the authors introduced the concept of algebraic in-between motions method where it is possible to compute the first collision time by solving a cubic polynomial equation (degree 3) at most. Using screwing-based motions, they were able to break-down the collision problem to multiple cases and resolve the equation accordingly.

Ortega et al.[40] generalized the constraint-based method and applied it for 6-DoF haptic rendering. They proposed efficient computation algorithm for the force rendering using a separate asynchronous thread. This separation helps them to easily achieve the needed update rate of 1 kHz. The moving position of the proxy and the force feedback are calculated using continuous collision detection and constraint-based quasi-statics. They were able to avoid force artifacts found in other methods.

In our previous research, we applied the continuous collision detection technique in order to determine the behavior of the proxy (Figure 1)[20].

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[37] Redon, S., Kheddar, A., & Coquillart, S. (2002, September). Fast continuous collision detection between rigid bodies. In Computer graphics forum (Vol. 21, No. 3, pp. 279-287). Oxford, UK: Blackwell Publishing, Inc. https://doi.org/10.1111/1467-8659.t01-1-00587

[38] Interval arithmetic. https://en.wikipedia.org/wiki/Interval_arithmetic last accessed 7.9.2020

[39] Redon, S., Kheddar, A., & Coquillart, S. (2000, April). An algebraic solution to the problem of collision detection for rigid polyhedral objects. In Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No. 00CH37065) (Vol. 4, pp. 3733-3738). IEEE. https://doi.org/10.1109/ROBOT.2000.845313

[40] Ortega, M., Redon, S., & Coquillart, S. (2007). A six degree-of-freedom god-object method for haptic display of rigid bodies with surface properties. IEEE transactions on visualization and computer graphics, 13(3), 458-469. https://doi.org/10.1109/TVCG.2007.1028

Rigid-body dynamics simulation

In 2000, Ruspini and Khatib[41] proposed a new haptic rendering technique consisting in "attaching the virtual proxy to a virtual object", which is itself part of a simulated dynamic environment. As a benefit, the "virtual tool [...] is no longer restricted to simple point or sphere". This technique transfers the complexity of haptic rendering to that of rigid-body dynamic simulation, which needs to be completed at a frequency compatible with haptic rates.

The research on fast rigid-body dynamics simulation has been driven by the needs of the graphics computing community since the late 1980s[42]. It has resulted in the development of the real-time physics simulation capabilities integrated in modern computer game engines. Today, the development of a virtual reality system could almost be reduced to choosing between several physics engines and tuning the stiffness and damping parameters of the proxy. However, even GPU-accelerated physics engines are not yet quite up to the task of handling complex object geometries with a high precision at haptic rates. Therefore, a lot of effort is still needed in order to address the challenges in each specific application domain.

For example, Syllebranque and Duriez[43] applied the rigid-body simulation technique to a dental implantology training system. They used the VPS representation of the jawbone and drill together with a 3D distance map in order to compute collision constraints. Then they applied physical simulation in order to update the position of the proxy. Their results demonstrated how the operation process requires increasing forces at the beginning while drilling the cortical part (up to 15N during 6 seconds). Then, they were able to reproduce the cortical breakthrough which must be avoided by surgeons since it could lead to damaging facial nerves.

Discussion

The ultimate goal of any training system is to achieve a good "transfer of training", i.e. the ability of the trainees to learn skills in the virtual environment and apply them successfully in real conditions[44]. In their EAES guidelines[45], Carter et al. define a number of validity criteria for virtual

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[41] Ruspini, D., & Khatib, O. (2000). A framework for multi-contact multi-body dynamic simulation and haptic display. In Advances in Robot Kinematics (pp. 175-186). Springer, Dordrecht. https://doi.org/10.1007/978-94-011-4120-8_19

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reality surgical simulators. The first level is the "face validity", which assesses the realism of the user experience, and it's the only level which can be addressed directly by the haptic rendering.

As explained above, of all haptic rendering techniques the penalty method is the easiest to implement, but it has severe drawbacks. In particular for the purpose of hip surgery simulation, behaviors like snapping through thin bone structures or swapping between contact normals are not acceptable. In addition, the penalty method does not prevent visual interpenetration, which would disrupt the face validity of the training system. Especially in the case of hammering, we can expect the high transient forces to create all sorts of artifacts with the penalty method.

The logical step for overcoming the limitations of the penalty method is to introduce a proxy. Moreover, the virtual coupling with the proxy provides an efficient solution for improving the stability of the force-feedback device. In their paper[46], Sagardia and Hulin compared penalty and constraint (i.e. proxy) methods and showed how the constraint-based algorithm with a stiffness under the maximum possible value, provides the most realistic feedback perception.

However, the proxy method also reduces all haptic information down to a single force/torque wrench applied at the HIP, and therefore loses both the transient signals and the detailed configuration of contact, which is not desirable. More to the point, we can expect that hitting a spring-damper system does not feel like hammering on bone.

The event-driven method is precisely focused on the transient signals. It is recognized as giving the most realistic feedback on material properties, thanks to its relying on actual measurements performed on real objects. Initially, the method was demonstrated on one degree-of-freedom only, and combined with penalty for the static feedback (although in their publication, Kuchenbecker et al. use a proxy for determining the penetration vector[33]). Very little work was done on its extension to more complex setups. Therefore, it is unclear whether a combination of the proxy and event-driven methods are liable to provide a significant improvement of the user experience.

The impulse method would appear to be the best suited to render rigid contact, and handle high transient forces. Indeed, by transferring the problem into the speed domain, it generates impulse forces that should brake the motion of the impacting tool down to zero. In their very impressive body of work, Wang et al. demonstrate that the impulse method can be applied successfully to the interaction with bone material[32]. However, our prior experience leads us to suspect a number of limitations to their work. Firstly, the implementation seems computationally complex, forcing them to compromising between the cycle time and the model resolution. Secondly, their approach is bound to generate many tuning parameters, with no explicit procedure for setting them. Finally, they validated their implementation on a 3-DoF force-feedback device, and it's unclear whether their approach would scale up to 6-DoF successfully.

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Conclusion

In this paper, we proposed a review of haptic rendering techniques in the light of our application, total hip replacement surgery training. We described each technique with some details, and referred to previous usage in the domain of surgery simulation.

At this point of our study, none of the haptic rendering techniques offers a clear answer to our objectives. Therefore, our intention is to proceed with implementing each of them, and their combinations, inside a simple test environment representative of the tasks to be carried out by the trainees. Then, we intend to perform a user study of the face validity of the different approaches.

Acknowledgements

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Move Vree

Gert-Jan Brok, Guy Gilbers, and Kiki Coppelmans

inMotion VR, Sint Maartenskliniek, Nijmegen, The Netherlands

Corresponding author: gert-jan@inmotionvr.com

Keywords: Chronic pain, virtual reality, gamification, embodiment, chronic wrist pain, development, co-creation, cross-overs.

Why develop a Chronic wrist pain training in Virtual Reality.

Introduction

"MoveVree" is a project and study on the effects of altered embodiment in VR rehabilitation on patients with chronic hand and wrist pain. This project is part of the VR4Rehab Interreg project.

The "MoveVree" project is running on the Corpus VR platform. Which is a standalone full body VR training platform which is built on the principles of biopsychosocial modeling. This platform enables us to rapidly explore and prototype rehabilitation principles in virtual reality in combination with external input sources like movement sensors and biofeedback.

We specifically try to create a rehabilitation exercise wherein the user will be using their affected hand to play a game, where they are challenged to perform the movements as much as possible in their painful range of motion. This painful range is recorded at the very start of the game and can be used and adjusted during the game.

Using hand movement

Defining the right way to detect hand wrist and arm movement is dependent on the expected application. Because each solution has its own up and down sides.

It is important to understand these differences. I will explain how the different input methods compare to each other, from controllers, to sensors and computer vision. There is no perfect solution yet that would meet the ideal requirements to not needing an on body sensor solution. Even current state of the art optical tracking solutions like those from Leap Motion, or the build in one from Oculus Quest (2) are all affected by occlusion problems and limited predictive algorithms. Therefore a physical sensor based solution would still be the best way to go for now.

In the end we choose to work with a duo setup of Xsens Dot sensors as they provide us a stable sensor platform with reliable results in the measurements that are needed to control the objects in the virtual game environment. The limitation of this however is that we are not able to track the fingers. Although we could track them by using for example a Sense Glove system, this is out of scope for this project.

Altered embodiment

Very interesting for our research is the combination of altered embodiment, mirror therapy, and cognitive pain diffusion. On the topic of altered embodiment there already have been many studies on using visuo-kinectic VR that prove that our brain is very elastic in the way it visually accepts alterations in the way our body looks, feels and responds. Our brain has in fact never experienced something different than what it perceives visually as being the truth. So the brain takes this, let's call it parameter, into the equation on how to respond to every situation. This link that we create in our brain is related to the noxious stimuli that are triggered due to our memory traces of pain and fear. Promising results have been shown in the research where the process of erasing memory traces of pain and fear is shown to be influenced by counter stimulation. The fact that our brain uses these various parameters, like visual cues, to trigger the perception of pain can limit our ability to overcome that same pain. And thus hampers the road to recovery in a rehabilitation process.

Gamification

With virtual reality, and the environments we create. We have the potential to break that tradition because we can use a combination of processes that each can influence the perception of pain and the recovery itself. Often also used within any form of gamification. Where you use game design principles and mechanics in a none game environment.

The three most important factors within our project are:

1. Positive reward system: Offering people clear and reachable goals with a fitting reward when you manage to reach a goal triggers endorfin, otherwise know as the happiness hormone, but also stimulates internal motivation.
2. Altered embodiment: Using altered versions of your hand and wrist in the virtual environment influences the existing memory traces because it fools the brain that a trigger is no longer resulting in experiencing pain. A disconnection is realized.
3. Cognitive diffusion: When in VR, a user's focus can easily be attracted and guided towards game targets and goals. Because the user has to manage and react to these targets and goals, dissecting them into tasks, it forces the brain to prioritize these tasks, which distracts the user from the pain.

Next steps

We have good hopes that our research on this topic can make a huge difference for all people who are now affected and limited on a daily basis by their pain in relation to their hand function. We foresee that a positive outcome can result in a specialized VR product focussed on people affected in their hand movement, but that would certainly open doors for foot rehabilitation as well. We are open to new collaborations for these next steps.

Movin(g) Reality

Noël Keijsers[1], Cheriel Hofstad[1], René van Ee[1], Bart van Oosteren[1], Carmen Ensink[1], Theo Theunissen[2], David van Dommelen[2], and Jille Treffers[2]

[1]Sint Maartenskliniek Nijmegen, The Netherlands
[2] HAN University of Applied Science Arnhem & Nijmegen (HAN), The Netherlands

Corresponding author: c.hofstad@maartenskliniek.nl & n.keijsers@maartenskliniek.nl

Keywords: Augmented Reality, Rehabilitation, Stroke, Gait, Home-based training, Feedback, Wearable sensors, Inertial Measurement Units, Human-machine interaction.

Introduction

Many patients surviving a stroke suffer from gait and balance problems[47],[48], which can have a large impact on their daily functioning. During clinical rehabilitation, patients receive individual training from physiotherapists often in combination with technological rehabilitation devices to improve their gait capacity. Important in this individual training, is that patients receive feedback on their performance. After discharged from the hospital or rehabilitation clinic, however, we observe that stroke patients would like to keep training at the same level as they did with the multidisciplinary team to maintain or retain their perceived activity level.

Problem

Patient

When stroke patients return to their homes, they experience less motivation to train because they don't receive any feedback regarding training and progress. Furthermore, most patients have no knowledge on how to execute specific exercises and no appropriate feedback how they have performed the exercise because of sensorimotor deficits. One common problem in stroke patients

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underlying their poor quality of gait is reduced foot elevation (drop foot) and/or reduced hip and knee flexion. For these patients it is important that they train these functions in their home situation and receive feedback on their performance. We present two solutions in the Movin(g) Reality project.

Treatment team

The training performance and progress is not only important for the patient, but also for the multidisciplinary team. After the patient is being discharged from the rehabilitation clinic, the multidisciplinary rehabilitation team does not receive any feedback of the quality, quantity and progress of the home-based training of stroke patients. Information of the training is important for optimizing the training program. Moreover, it can be used to monitor the patient and indicate deterioration in their daily life functioning.

Figure 11. Schematic representation of the Movin(g) Reality applications.

Solution

In first instance, we wanted to integrate challenging walking games in an augmented reality (Figure 11). However, current technology is hard to integrate in daily life (e.g. too large unusable glasses). Therefore, we came up with the following two solutions for stroke patients:

Train@Home

The Train@home is applicable when the patient is discharged from the rehabilitation clinic and wishes to apply the training in ADL. It includes an Augmented Reality (AR) solution where a virtual ball is presented in a real-world situation. The patient can kick the ball while an application on his phone can measure the movement of the foot and the amount of dorsiflexion. Every time the virtual ball is kicked away, the virtual ball is ready for a new kick. For this solution, the patient is using a smartphone and IMUs to measure and analyze the movements and present the virtual ball.

The performed training sessions provide feedback on performance to both the patient and therapist. The patient receives feedback in a way that the virtual ball is either kicked or stays at the same place, depending on the performance of the kicking motion. The therapist receives feedback from the IMU data. The solution can safely be performed by the patient in a home situation and does not require the walking or space kicking an actual ball would require.

Furthermore, the game aspect of the training is expected to increase the motivation of the patient to do the exercises. Further development on the Train@Home application is needed since the required processing power of the smartphones is fairly high.

Figure 12. Kicking a ball with Train@home

Train2Go

This solution provides feedback during Activities of Daily Life (ADL) that involve walking. The main difference between the Train2Go and the Train@Home application is that feedback continues in daily life activities and is not limited to a training session. which uses an application on the patients smartphone to continue lower limb function training after discharge from the clinic. Within Train2Go, the patient can select a difficulty level based on the amount of dorsiflexion he wishes to achieve as "minimally enough". While the patient is doing his ADL, the Train2Go uses audio feedback that is minimally intrusive for others. The system is providing a simple beep from the users' smartphone if this minimum amount of dorsiflexion is not reached within each full gait cycle.

The ultimate aim of our solutions is that stroke patients will improve their gait and balance and daily functioning. By providing feedback on their performance and progress, patients will be kept motivated and train more intensively. Finally, the multidisciplinary rehabilitation team will be able to optimize the training.

An AR prototype to rehabilitate memory functions in an ecologically valid environment

Lukas Lorentz

St. Mauritius Therapieklinik, Meerbusch, Germany

Corresponding author: lukas.lorentz@stmtk.de

Keywords: Augmented reality, ecological validity, memory training, compensational strategies.

The Crystal Ball mobile app

Deficits in attention and memory functions are among the most common neuropsychological symptoms following traumatic brain injury and account for a massive decline in quality of life[49],[50]. Traditionally, treatment of these conditions consists of restorative approaches aimed at rehabilitating the affected function itself and compensational approaches that teach the patient to use other means to compensate for his impairments in daily functioning. The restorative approaches, nowadays often computerized, involve highly repetitive tasks that have been found to be rated as boring by patients[51],[52]. Furthermore, many studies have criticized the lack of ecological validity that these trainings offer leading to little or non-existent transfer effects to other cognitive domains and levels of daily functioning[53].

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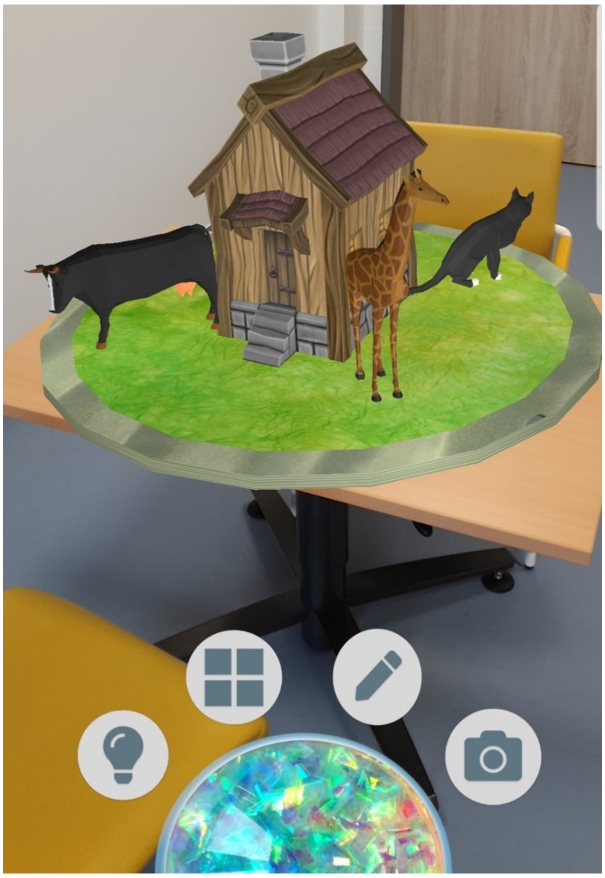
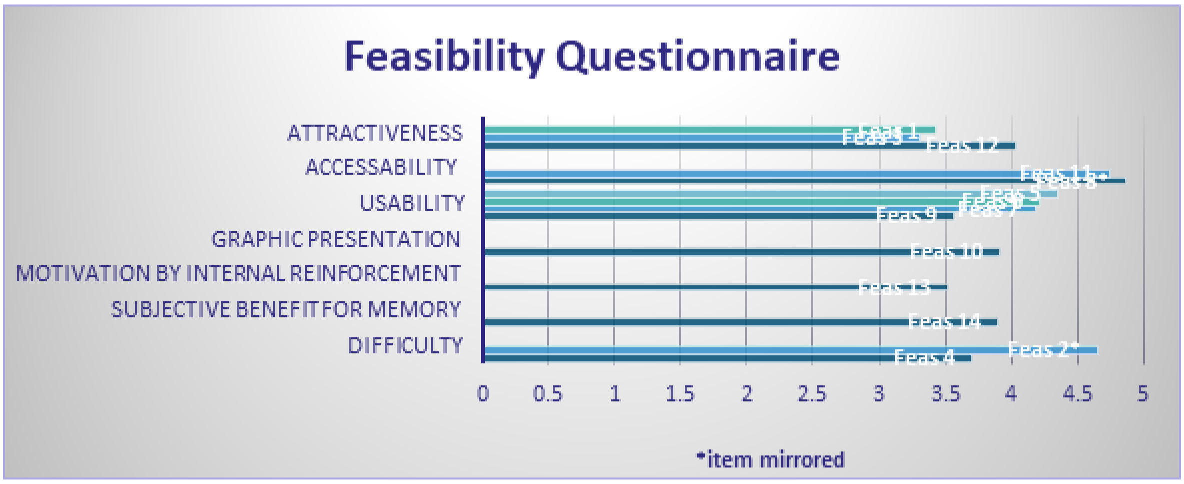
To tackle this longstanding problem in neuropsychological rehabilitation, a Hackathon at the St. Mauritius Therapieklinik in Meerbusch, Germany was tasked to develop new approaches involving Virtual Reality (VR) and Augmented Reality (AR) technology. One of the winning concepts was later developed into the Crystal Ball prototype.

Crystal Ball is an app for mobile phones that combines restorative with compensational approaches and gamification elements in an ecologically valid environment. Patients are first tasked to remember a set of animals and then to collect these animals in their virtually augmented environment. The restorative training component requires several memory and executive functions such as working memory, planning, navigational skills, etc., while at the same time offering more ecological validity than conventional computerized training programs. In addition, the app can assist the patient, if he feels overwhelmed by the task at hand. The Crystal Ball assistant offers several memorization strategies, a note and a photo function, as well as the opportunity to take a second look at the animals that need to be remembered, thereby incorporating several methods of compensation into the training.

Level of difficulty (number of items that need to be collected) and the sort of items used in the task (animals or foods) can be altered in the menu. Crystal Ball also collects crucial performance data (level of difficulty, time until completion, wrong moves, etc.) and can send them to the therapist’s phone.

The aim of the present study is to assess the feasibility of the existing prototype in children, adolescents and young adults. Healthy controls as well as clinically impaired participants were considered. Analyses of the healthy sample (n= 23) show high measures of acceptance and feasibility among most participants. Also, the distinguishability of the different items and technical instabilities were identified as most important issues, impacting participants satisfaction with the prototype. Furthermore, the assistance functions were used less then expected. Although the data collection is not complete yet, preliminary analysis of the clinical group indicates similar trends across all relevant parameters.

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Creating a VR dimension for the Pain Toolkit

Denis Martin, and Pete Moore

Centre for Rehabilitation, Teesside University, Middlesbrough, North Yorkshire, UK

Corresponding author: d.martin@tees.ac.uk

Keywords: Persistent pain, supported self-management.

To date, the clinical application of virtual reality in pain management has been to reduce the perception of acute pain. Most of the research studies on pain management and virtual reality have been carried out in this context as well. The general findings suggest that virtual reality does have the ability to reduce acute pain, with its immersive properties acting as a distraction from nociception, and research continues to grow in this area.

The role of virtual reality in management of persistent pain is less clear. In persistent pain, where pain is frequent or continuous and has outlasted the normal tissue healing time, the neurophysiological mechanisms are much more complex and established and less open to effective pain relief than acute pain. Therefore, the findings from research on analgesic effects of virtual reality in acute pain should not be automatically extrapolated to persistent pain. While there may well be a role for virtual reality as a distraction in management of persistent pain, for example to help manage flare-ups, evidence to support that will need to come from specifically designed research.

For many people with persistent pain, because of its intransient nature, the most attainable goal is to live a full life while living with pain. That is one of the underlying principles of biopsychosocial management of persistent pain. Such management approaches aim to give people skills, and the confidence to use them appropriately, that will support them to self-manage living with pain. There are many educational resources available to promote self-management. However, affecting change through education based on the presentation of information alone is a difficult goal to achieve[54] and there remain many opportunities for innovative ways in which to deliver

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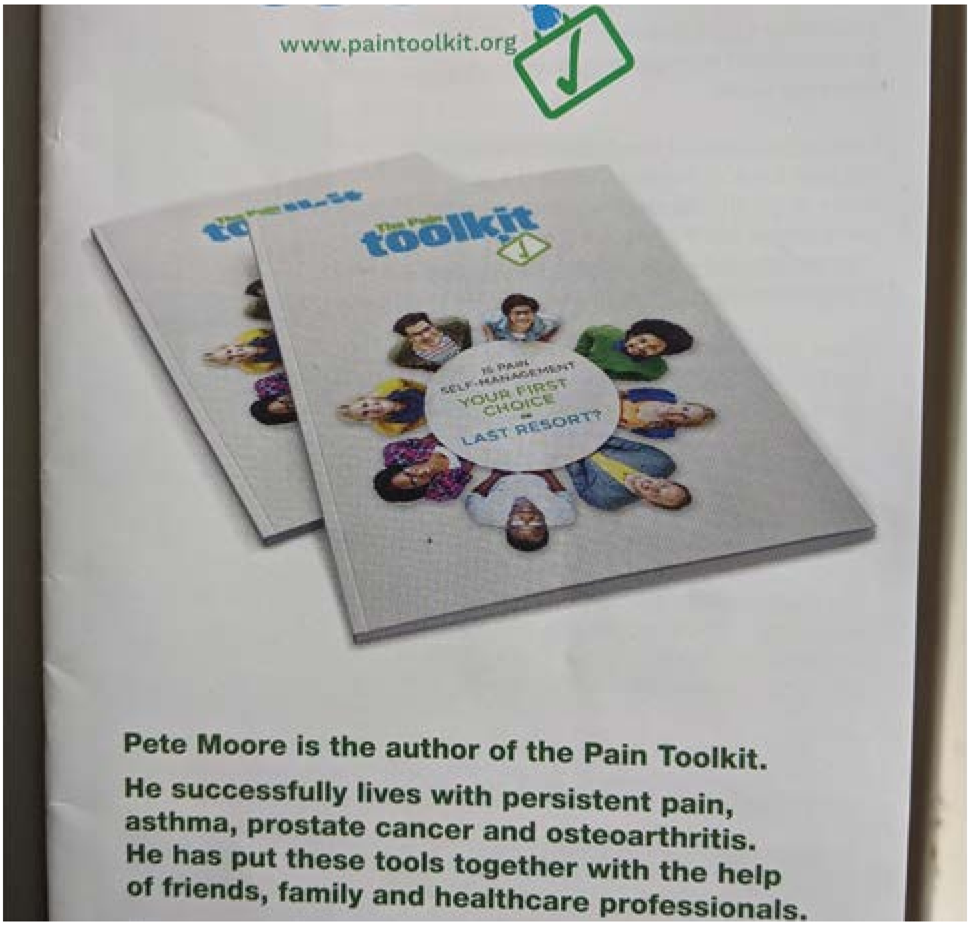
education[55]. This offers another potential design space for virtual reality in pain management and this is the focus of our current VR4Rehab project.

The Pain Toolkit is a widely recognised resource for supported self-management of persistent pain. It is recommended by the UK National Health Service (https://www.nhs.uk/live-well/healthy-body/ways-to-manage-chronic-pain/). The project is to work with the Pain Toolkit to develop a virtual reality dimension for its materials and activities.

This work with VR4Rehab takes two developmental strands. The first is developing the Pain Toolkit skills into digital formats that can be used in virtual reality. The second is developing a group workshop for the Pain Toolkit that can be delivered in a virtual environment in which people can meet and interact. Planned evaluations are underway to gain insight into the value of the Pain Toolkit delivered in different formats[56] and investigate the added value of doing so in virtual reality.



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Trunky XL everybody a six-pack!

Desirée Struijk-Vlaswinkel, Fanny Schils, Noël Keijsers, Lise Winkels, Carmen Ensink, Gert-Jan Brok, Kiki Coppelmans, Colin Rosen, and Hanneke van Duinhoven

Vr4 Rehab, inMotion, Sint Maartenskliniek, Nijmegen, The Netherlands

Corresponding author: Kiki@inmotionvr.com

Keywords: spinal cord injuries, virtual reality, postural balance, development, co-creation, cross-overs.

Why develop a core stability training in Virtual Reality.

Trunk stability is an important condition for walking. During the rehabilitation of patients with balance problems (often due to neurological disorders such as a stroke or spinal cord injury), intensive training of the trunk is necessary so that patients can function independently again. However, because patients regularly experience this training as boring, they find it difficult to keep practising outside of therapy. In addition, the training for therapists is intensive because patients need precise instructions to perform the exercises properly.

A rehabilitation program consists of various parts, of which the training of trunk stability is one that is wrongly often undervalued in rehabilitation. The hull has to provide stability and dynamics at the same time and that makes it complicated. The many instructions the patient receives from the therapist make it difficult to know when the movements are being performed correctly.

In 2018 the VR4Rehab hackathon started. Where we came across the importance of Trunk stability after spinal cord injury and stroke patients. And the difficulty for the patient and the therapist of training that stability.

So together with a number of ambitious and innovative therapists from the Sint Maartenskliniek (SMK) we thought that could be different. “What if we could make trunk training fun and exciting so that patients say, when can I go again? What if the training intuitively challenged patients to make the right exercises? And what if patients can also do these exercises outside of therapy and the therapist can then see the patient's progress from a distance?”

And that's how TrunkyXL was born: a training of trunk stability using VR and movement sensors. TrunkyXL is being further developed within the VR4Rehab project in collaboration with inMotion VR and 2M Engineering. The Trunky XL project is running on the Corpus VR platform. Which is a fully mobile full body VR rehab platform. On this platform we can rapidly build and test VR training applications that can be used for patients with balance problems.

To build such a product which is researched and tested to become a market ready product, is a very interesting but time consuming process for all parties involved.

Why using VR by trunk stability training and for this patient group?

Trunkstability is highly complicated to train since the trunk should provide both stability as well as movement at the same time. Trunkstability training is perceived as uninteresting by patients, often resulting in reduced therapy compliance.

Virtual Reality (VR) rehabilitation enables the possibility of real-time feedback on a personalized training, with high acceptability and excellent usability because of the opportunity to offer patients personalised gamified virtual trainingsworlds.

Previously the centre of pressure measurement, has been used to control a VR-game which can be used as the limits of stability while sitting. But it does not provide any information about the executions of the movement in order to displace the centre of pressure. Therefore more movement data is needed out of various segments of the body.

To build a solution that can give the inside, if the movements are the right exercises, and that it can be done outside the therapy. Has challenges in different fields.

The ultimate goal is that the VR training provokes movements in a natural way. This reduces the burden on the therapist. In addition, patients learn that they can again rely on their own body so that they can eventually practice the training without a therapist. The game element also motivates them to continue with the training and gives the patients direct and continuous feedback. Small improvements can be measured and rewarded (for example by changes in the world), while in practice it now often takes two weeks before the first results are visible.

To accomplish all these requirements research is also an important part in the development.

This is research on the validity of the system, functional research and testing with patients.

Progress of the development

By the development of the Trunky XL VR- training prototype it is important to get input about:

- Which hardware can we use or do we have to adapt to the requirements? What are the therapeutic training principles? What do you want the game to accomplish for the patient and the therapist. What are the requirements of the movement sensors?
- Which measurements you want to come out of it. And are these movements valid? And how can we use that data in the Virtual environments that intuitively challenged patients to make the right exercises? And how do we make it fun?

For instance you can think about, if Inertial Measurement Units (IMUs) could provide a more direct measure of movement execution by placing multiple IMUs on various segments of the body. This way, relative movements between these segments can be calculated and used as an input for a VR-game. [Text Wrapping Break]How can we make the exercises into engaging VR worlds that provoke the movement the therapist wants. And how can we provide the patient form the right feedback so he can see and ultimately feel that he is doing the movement right.

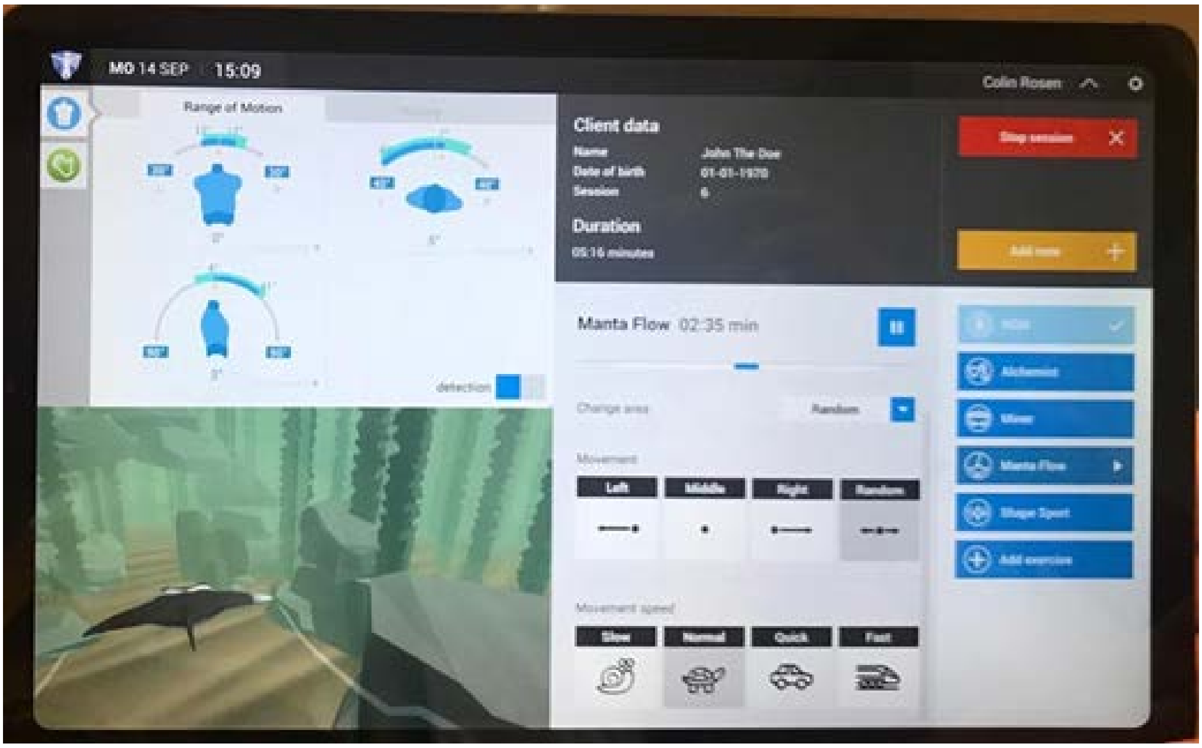
This is now being researched at the Sint Maartenskliniek.

How functional are the placements of the sensors is it possible for people and patients to do this themselves. What instructions are needed for the therapist and the patient. Which patients can do it themselves and who will need assistance.

As well as creating a manual on all fronts of hardware, placement, calibration, therapeutic and follow-up. So that as soon as the product is ready. The implementation of the product can take place in the clinic and other clinics. And other therapists can be trained.

With all this information a VR-training prototype is being developed in order to fill the gap in direct measures of movement execution in combination with VR-training to improve trunk stability.

We are very proud of our Trunky XL team and co-creation, we believe we can help everybody to train until they have a six-pack!



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Posters

Improving the feeling of presence and immersion through convincing embodiment in VR

Eleftherios Anastasovitis[1], Ioannis Dimitriadis[2], Spiros Nikolopoulos[3], and Ioannis Kompatsiaris[2]

[1]*Information Technologies Institute (ITI), Thessaloniki, Greece*
[2]*Multimedia Knowledge and Social Media Analytics Laboratory (MK-Lab), Thessaloniki, Greece*
[3]*Centre for Research and Technology Hellas (CERTH), Thessaloniki, Greece*

Corresponding author: anastasovitis@iti.gr

Keywords: Virtual reality, immersion, feeling of presence, embodiment, serious games.

Introduction

In creative industry of computer games, the simultaneous combination of factors from different sectors, such as arts, psychology and computer science, determines the success of a digital production. In *Role-Playing Games* (RPGs) users are embedded in characters with predefined biographies and their actions rule their future in the virtual cosmos, based on the missions they have to perform. Professional game studios are manned by specialized staff from different backgrounds (e.g. 2D graphic designers, 3D animators, developers, sound engineers, 3D artists, etc.) and their collaboration leads to high quality and top-selling productions that offer the player the feeling of presence and immersion in the virtual cosmos.

Meanwhile, the competitive policy of two of the most-known game engines (*Unity*[1][57] vs. *Unreal Engine*[2][58]), in combination with affordable virtual reality technology for the general public, has resulted in the involvement of a large number of new developers within the creative game industry. Many productions, and especially serious games, are published with the minimum standards and requirements, negatively affecting the aesthetic aspect. For example, using Head Mounted Displays for training in industry, in surgery or in cultural heritage, the user can only see and manipulate his hands and fingers through the touch controllers (Figure 13). The whole body is missing and this restricts the feel of presence, the immersion and the total user's satisfaction. In the best case, developers simply apply texture to the virtual hands, such as leather or gloves.

[57] https://unity.com/
[58] https://www.unrealengine.com/en-US/

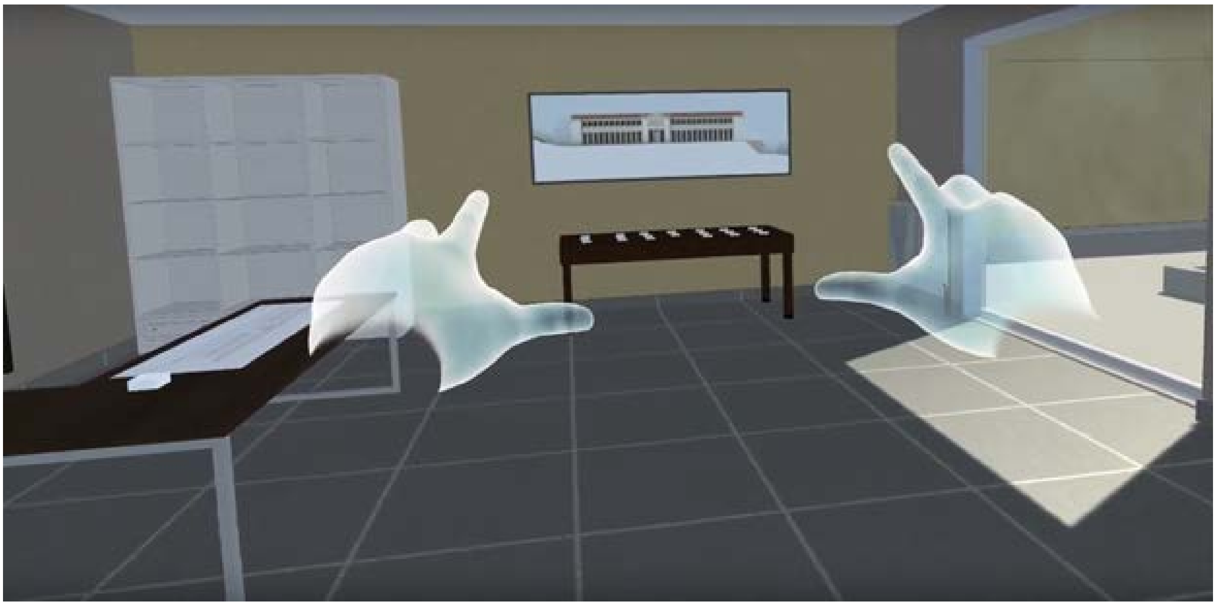

Figure 13. The absence of virtual body in DigiArt's[59] VR Palace of Aigai serious game[60]

The feeling of presence in video games is a crucial factor for user's satisfaction, while in VR game productions this factor strengthens the player's immersion, and this is the reason why we are suggesting a plugin for game engines that aims to offer an effective solution for the aforementioned problem, namely the absence of a responsive virtual body according to player's interaction.

In this contribution, we suggest a solution that will offer to indie studios, individual VR developers, and 3D designers the ability to implement in their productions a real-time full responsive skeleton, that simulates the movement of the arms and body according to the movement of the player's hands through the touch controllers, and photorealistic clothes that simulate textile movement according to the skeleton movement, thus enhancing the player's immersion and feeling of presence in the virtual cosmos.

Methodology

The cardinal objective of our idea is to provide an advanced solution for maximizing the feel of presence to end-users of Virtual Reality applications by combining the creative industry of clothing with the game industry, in a way that VR developers, 3D artists and cloth designers, can easily overcome the technical barriers and provide to all players of VR applications top-level photorealistic and convincing embodiment of a first-person character, in a full-immersive virtual environment.

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[59] http://digiart-project.eu/

[60] Anastasovitis, E., Ververidis, D., Nikolopoulos, S., & Kompatsiaris, I. (2017, June). Digiart: Building new 3D cultural heritage worlds. In 2017 3DTV Conference: The True Vision-Capture, Transmission and Display of 3D Video (3DTV-CON) (pp. 1-4). IEEE. https://doi.org/10.1109/3DTV.2017.8280406

In achieving our primary mission, we have set out two specific objectives. The first objective aims to improve the feel of presence for end users in VR applications, by the interconnection of the touch controllers with a responsive skinned rigging body that will represent all real-time and accurate movements, in the virtual environment. Our skeleton mechanism will virtually reflect the movements of arms and hands, and will also resemble real walking, during the virtual navigation.

The second objective is to maximize the immersion factor via the topping of the produced virtual body with photorealistic digital clothes that will behave in a physical way, according to the player's movements in the virtual world and the material that are made of.

Implementation

To accomplish our first objective, the skeleton representation, we will focus on the creation of a customizable rigging, a connected system of bones as skeleton, according to the height of each user. During this procedure, we will succeed to interconnect the virtual hands that come with the game controllers (e.g. *Oculus Rift S touch controllers*[61]) witrs the rest of the skeleton. The movement of player's hands will manipulate partially the skeleton, while the selection of navigation, will manipulate the steps in the virtual environment. As an extension to the rigging, we will incorporate into the corresponding bones and flesh thickness, by using capsule colliders, to produce the virtual human body.

The cloth representation will lead to the development of a pipeline, for an easy way to import and customize digital clothes in FBX file format, with textured materials, into the game engine. More specifically, we will develop the appropriate algorithms that will affect the behavior of each cloth, such as hardness and elasticity, for various types of clothes, such as trousers, skirts, t-shirts, blouses, dresses, uniforms, and jackets, taking into consideration any relative library such as *NvCloth*[62] by *NVIDIA*. Furthermore, we will examine for the best solution in scaling the digital clothes without any distortion.

Finally, we will interconnect the developed algorithms for rigging body, in combination with cloth behavior, according to user's physical interactions, to implement the core plugin for player embodiment into a virtual body with skin and clothes that behave in absolute physical way. Our suggestion targets to game developers, offering an easy solution for creating responsive dressed virtual body, for first-person characters in VR applications. The plugin will maximize the feel of presence and the satisfaction in VR game productions, as it offers artistic boost to the technical tasks of the developers, and simultaneously, will bridge the technical gap of code development for game designers and artistic specialties, through an easy to use interface with customizable functionalities.

Discussion

Our solution focuses on the improvement of the feel of presence and the player's immersion in virtual environments, through his/her embodiment in a virtual cover. In this context, a numerous of specialties may be involved in the creative industry of video games, such as a) cloth designers,

[61] https://www.oculus.com/rift-s/

[62] https://gameworksdocs.nvidia.com/NvCloth/1.1/index.html

by selling their digital clothes through our plugin, b) 2D/3D artists, by creating digital content for VR game productions such as clothes, accessories for the first person characters.

Moreover, the correlation between the improvement of player's feel of presence and immersion and his/her satisfaction is expected to have positive effect on the process of knowledge transfer in the context of every serious game that is based in Virtual Reality technologies. The effectiveness, and the easy to use way of our plugin in VR productions with game engines, makes it a useful tool in creating full-immersive and enjoyable experiences, where user acts alone or in collaboration with other players.

In addition, the improvement of the immersion through our solution, will affect positively the effectiveness of health related processes, like rehabilitation. As virtual reality is used for simulating simple and complex physical interactions, serious games are used for training and rehabilitation purposes. Our plugin aims to convince users that their virtual body is real, encouraging them to successfully complete the rehabilitation exercises.

Conclusion and future work

In the context of *e-SKAPANI* project (https://e-skapani.gr/), the embodiment of the user into a virtual persona that acts in the roman and byzantine era of Thessaloniki will take place, according the suggested methodology of this contribution. The virtual visitor of the Palace of Galerius will test the enhanced feeling of presence and immersion in the virtual environment. After a testing period for our prototype, the suggested solution will get transformed in a plugin for *Unity* game engine.

Acknowledgements

The project *e-SKAPANI*: "*Thessaloniki during the Galerius era - Reviving a glorious historical period of the city, guided by interdisciplinary research and cutting-edge technologies*" is supported and funded by E.U. and the National Action "Special Actions" - "Open Innovation in Culture", under the operational program "EPAnEK 2014-2020 - Competitiveness - Entrepreneurship - Innovation" (Project Number: T6YBΠ-00202).

EPANASTASIS-1821: Reviving the naval history of the Revolution through full-immersive Virtual Reality

Eleftherios Anastasovitis, Georgia Georgiou, Spiros Nikolopoulos, and Ioannis Kompatsiaris

Multimedia Knowledge and Social Media Analytics Laboratory (MK-Lab), Thessaloniki, Greece
Information Technologies Institute (ITI), Thessaloniki, Greece
Centre for Research and Technology Hellas (CERTH), Thessaloniki, Greece

Corresponding author: anastasovitis@iti.gr

Keywords: Virtual reality, virtual museum, serious game, immersion, naval history, edutainment.

In recent years, through the democratization of the game engines, such as *Unreal*[1] and *Unity*[2], a large amount of digital productions have been published, offering solutions for all Sciences, regardless of their effectiveness and usefulness[63]. In the domain of Cultural Heritage the transformation of physical museums and exhibitions into digital, in combination with the accessibility via Web, caused the expansion of the number of their visitors. Far from the used technologies for the classification between Digital and Virtual Museums, the major difference is the level of dependence on a physical museum. Virtual Museums offer the possibility to use the advances of breathtaking achievements in the field of Virtual Reality for the representation of the artifacts, in top level of photorealism and the feeling of user's presence in the virtual cosmos[64].

The new trend for the Virtual Museums is the inclusion of immersive experiences that are related to a specific thematic section[65]. The user is transferred in time and in place, while through game

[63] Anastasovitis, E., Nikolopoulos, S., & Kompatsiaris, I. (2020). Experiencing the impossible through virtual and augmented reality. Proc. They are not silent after all... Human remains in archaeological museums: Ethics and displays, submitted for publication, Hellenic Ministry of Culture and Sports, 31 October-01 November 2019.
[64] Anastasovitis, E., & Roumeliotis, M. (2018, October). Virtual Museum for the Antikythera Mechanism: Designing an immersive cultural exhibition. In 2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct) (pp. 310-313). IEEE. https://doi.org/10.1109/ISMAR-Adjunct.2018.00092.
[65] Anastasovitis, E. & Roumeliotis, M. (2019). Designing an edutainment serious game for the Antikythera Mechanism in virtual reality. In Helin, K., Perret, J., & Kuts, V. (Eds.). The application track, posters and demos of EuroVR: Proceedings of the 16th Annual EuroVR Conference - 2019. VTT Technical Research Centre of Finland. VTT Technology, No. 357, pp. 94-97. https://doi.org/10.32040/2242-122X.2019.T357

scenarios has the opportunity to interact with the 3D artifacts in the virtual environment. The embodiment of serious gaming converts a Virtual Museum from narrative to experiential. The more documentation is offered, the more immersive stories can be created. The Greek War of Independence between 1821 and 1830 is the ideal case to apply the new aforementioned trend for the Virtual Museums and to provide useful feedback to the research community, through an extensive evaluation.

In this contribution we present the design of full-immersive experiences in Virtual Reality that are applied in the Virtual Museum of *EPANASTASIS-1821*[3], for better understanding of the Naval History, during the Greek War of Independence. Specific 3D artifacts and representative paintings of the Virtual Museum trigger the transfer of user in the era of the naval missions, reviving the History in an innovative and edutaining way, under the prism of serious games.

The context

The purpose of the *EPANASTASIS-1821* Virtual Museum is to communicate important events of the Greek Revolution and to highlight aspects of the National Independence, as imprinted in archival material, books and artistic representations in Greece and abroad. The Virtual Museum targets to the general public and aims, through the use of innovative educational tools of virtual reality of a high degree of immersion, to enhance the user experience and for better understanding of the impact that the events of the Revolution.

The exhibitions of the *EPANASTASIS-1821* Virtual Museum are consisted by different types of representations. There are many documents and archives that inform about the actions that took place during the War of Independence, such as licenses for free sailing, property titles, letters with mission plans, or requests for funding. This archival material is scattered in different areas, but a representative collection is hosted in *EPANASTASIS-1821*.

Due to the lack of photos from the period of the War of Independence, paintings are the main representations for some of the important events, but also from everyday life. Some paintings represent battles and battleships, as well as portraits of the protagonists of the Revolution. These paintings are not only used as exhibits in the Virtual Museum, but also as a source of information for the creation of additional 3D content that will be applied in the full-immersive experiences, such as landscapes, buildings, and objects (Figure 14).

Figure 14. Creating the virtual cosmos (top, middle) through paintings (below)

The naval stories in VR

The Virtual Museum of *EPANASTASIS-1821* is embedding serious games, offering to users the opportunity to interact with the exhibits in a unique way. More specifically, in the thematic section of the naval history, some special artifacts or paintings will trigger the full-immersive experiences, transferring the user in place and in time. Through storytelling, the mission of each naval experience will be clearly defined to the player.

The four full-immersive scenarios that offer the revival of the naval history are a) *The captain's cabin*; b) *Need more warships*; c) *Blow up the flagship* (Figure 15); and d) *The exodus of Ares* (Table 1). The game design of each mission is structured in two levels of difficulty, starting with the easiest. When the mission is fulfilled, the user returns to the last known position in the Virtual Museum of EPANASTASIS-1821.

Table 1. The full-immersive naval experiences in EPANASTASIS-1821 virtual museum.

Naval experience	*Triggers to revive*	*Mission*
The captain's cabin	Archives and 3D artifacts	Review the licenses for free sailing in the sea of the Aegean
Need more warships	3D model of a merchant ship	Convert a merchant ship into a warship
Blow up the flagship	Paintings and 3D model of a fire ship	Engage a fire ship to the flagship and abandon the area
The exodus of Ares	Painting and 3D model of *Ares*	Execute the plan of the escape of *Ares* from the Gulf of Navarino

Immersive technologies and creative game industry

Regarding the additional content creation, *Cinema 4D* by *Maxon*[4] will be used for a) accurate 3D modeling, b) photorealistic texturing and material apply, through UV-mapping and baking methodology, and c) convincing 3D animation, via bones and rigging. For realistic 3D character animations the *Smartsuit Pro* motion capture system by *Rokoko*[5] is the suitable solution. Meanwhile, *Daz3D Studio*[6] will be used for the creation and customization of 3D characters.

Unity game engine will be the cornerstone for the implementation of the full-immersive experiences for the Naval History. Different types of files for 3D representation, such as *FBX* or *OBJ*, will be programmed in *C#* to interact with the player and the rest elements of the virtual environments, such as sounds, visual FX and lights. The *Oculus Rift S with touch controllers* (*2nd generation*) will be the Head Mounted Display for the development of the VR production, as well as the target device for the export of the standalone version for EPANASTASIS-1821 Virtual Museum. In our effort to enhance the emotional engagement of the player, during the immersive experiences, we will composite original music through *FL Studio* by *Image Line*[7].

Figure 15. The revival of the blow up of the Turkish flagship in VR (top), based on the painting by Nikiforos Lytras (source: https://en.wikipedia.org/wiki/Nikiforos_Lytras) (below).

Conclusion and future work

In our presentation we suggest the embodiment of full-immersive virtual experiences for the Naval History of the Greek War of Independence, in the context of the Virtual Museum *EPANASTASIS-1821*. Our contribution leads the Virtual Museums one step forward, converting them to experiential virtual places for better understanding of Cultural Heritage, through the use of VR technologies and serious gaming.

Acknowledgements

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BIMprove User Interfaces: Multi-User-XR for Construction

Matthias Aust[1], Melissa Otto[1], and Kaj Helin[2]

[1]Fraunhofer-Institute for Industrial Engineering IAO, Stuttgart, Germany
[2]VTT Technical Research Centre of Finland Ltd, Tampere/Espoo, Finland

Corresponding author: matthias.aust@iao.fraunhofer.de

Keywords: Multi-User-Virtual-Reality, Mixed Reality, Augmented Reality, Building Information Modelling, Construction.

Glossary of Abbreviations: BIM: Building Information Modelling, AR: Augmented Reality, VR: Virtual Reality, XR: Mixed Reality, UI: User Interface, MU: Multi-User, HMD: Head-Mounted Display

Introduction and Motivation: The BIMprove-Project and its UIs

This poster introduces the idea of a multi-user, multi-device XR-system to be set up at a construction site, for both co-located and remote use. This concept will be reified and implemented during the EU-funded project "BIMprove – Improving Building Information Modelling by Realtime Tracing of Construction Processes", starting September 2020.

Building Information Modeling (BIM) facilitates a cooperative method of working, and transparent communication between all stakeholders of a building (or built asset in general), by the use of digital models that hold all relevant data and information about the building. This includes 3D-CAD-data, but also non-geometrical data. So a building information model is a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception, through construction and operation, to demolition. (Compare definitions of BIM[66],[67],[68])

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[66] British Standards Institution, BS EN ISO 19650 (2019). Organisation and digitisation of information about buildings and civil engineering works, including building information modelling - Information management using building information modelling, London
[67] National BIM Standard - United States V3. National Institute fo Building Sciences (NIBS), Available online at: https://www.nationalbimstandard.org/faqs last accessed 21 08 2020.
[68] German Federal Ministry of Transport and Digital Infrastructure (2015). Stufenplan Digitales Planen und Bauen - Einführung moderner, IT-gestützter Prozesse und Technologien bei Planung, Bau und Betrieb von Bauwerken

Despite this definition, BIModels are nowadays used primarily as static digital representations of buildings which are compiled during the conception and planning phases. They are rarely updated during the construction or operation phases. This means that oftentimes, even though a BIM methodology approach was implemented during its planning, there is never an exact and up-to-date digital representation of the building during its physical existence.

BIMprove aims at going beyond this static representation by creating a cloud-based dynamic digital twin of the building, which is updated continuously during construction. This will be done with the help of autonomous scanning robots and drones, among other technologies. BIMprove will therefore digitally integrate the current status of the construction work in a common workflow. This facilitates the identification of deviations from the original plans, but also the tracking of devices and tools[69].

To make this information easily accessible, BIMprove therefore needs a set of user interfaces that facilitates a) the understanding of complex geometrical problems, b) the easy communication about those problems between people of different educational backgrounds, and c) decision making and planning based on ever changing geometrical data.

These requirements play to the strengths of MUVR-systems. We envision a co-located HMD-based MUVR-system as its main UI, to give the user a holistic overview, with use-case-adapted, personalised "satellite"-UIs for remote access in specific situations.

This idea is conceptualised on this poster. Because the BIMprove-project has just started and this is only the presentation of parts of its UI-concept, the authors are looking to discuss the applicability of these ideas in the construction sector.

State of the Art

Of course, the idea of using VR or AR on the construction site, or at least in the construction sector, is not new. Different combinations of BIModels shown on HMDs or other devices, are either already in use, or are being tested, examples are Redshift by Autodesk[70], Magic Leap: Katana[71], or Trimble Connect with Microsoft Hololens[72]. Examples of systems design to ease access to the projects BIM-Model on the construction site also exist, see[73]. Even the combination of HMD-VR

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[69] Sziebig, G., Palomero Prada, A., Menendez Muniz, M., Lopez, R., Aust, M., Beier, M., Gonzalez, J., Beso, P., van de Wenn, W., Aaltonen, I., & Fjeld Edvardsen, D. (2020). BIMprove - Improving Information Modelling by Realtime Tracing of Construction Processes, 2020. Submitted

[70] Autodesk (2018, August). YouTube: Gilbane Uses VR to Validate Prefabricated Construction. Available online at: https://www.youtube.com/watch?v=lCzzEKofavI last accessed 19.8.2020.

[71] Future Sight AR (2019, September). YouTube: Katana XR Launches on Magic Leap - Construction Tech App. Magic Leap, available online at: https://www.youtube.com/watch?v=0sqZZKhgPvY last accessed 23 08 2020.

[72] Trimble MEP, (2018, January). YouTube: Construction workers try Trimble Connect for HoloLens for the first time. Here is what happened! Trimble, available online at: https://www.youtube.com/watch?v=tAmImhdWYjA last accessed 23 08 2020.

[73] Murvold, V., Vestermo, A., Svalestuen, F., Lohne, J., & Lædre, O. (2016). Experiences from the use of BIM-stations. In 24th Annual Conference of the International Group for Lean Construction, Boston, USA (Vol. 7, p. 20). Available online at: https://rb.gy/a5sbim last accessed 14.10.2020

on site is available[74], but not in the scale we are proposing within BIMprove, and not as a omni-present MUXR-system.

Multi-User and Multi-Device XR, Co-Located in the Construction Office and Remote

As discussed above, the BIMprove-system needs a set of UIs to access, understand, and communicate about all geometry related information of the dynamic digital twin of the building in construction.

Therefore, a MUVR-system as its main UI almost seems natural. In our opinion, a CAVE-system (e.g. similar to the one in Fraunhofer IAO's Immersive Participation Lab[75]) would be ideal, considering the requirements, best with the possibility to access the same scene also with an HMD, remotely or for special issues. Since the idea is, though, to give the people working on the construction site quick and easy accessability to the digital twin, an HMD-based system located in a construction site office[1], is the next best thing.

The envisioned MUVR-system enables four users to join the scene with HMDs in a co-located setup, but also has a big screen for bystanding colleagues to follow what the ones in VR are seeing and talking about. An example for the application of mainly this setup is described as 'use case example A', below, and shown in Figure 16.

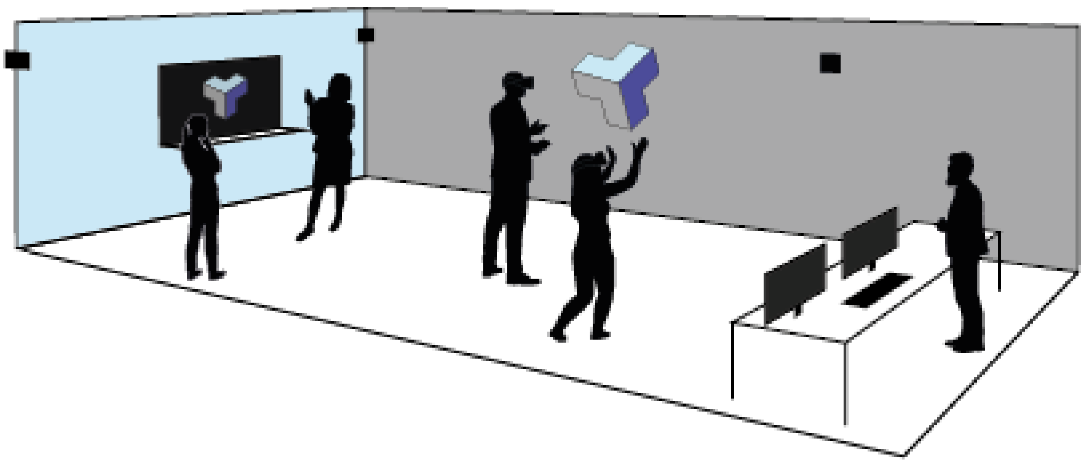

Figure 16. Sketch of the VR-system inside the site office

In addition to the co-located setup, other users can join such sessions from a remote location, with different devices – e.g. VR HMDs, AR HMDs or tablets. As described in the use case examples

[74] As, R. (2020). Rufo. Available online at: https://www.rufo.no/products/bim-kiosker last accessed 1.9.2020.

[75] Fraunhofer-Institute for Industrial Engineering IAO. Immersive Participation Lab, available online at: https://www.iao.fraunhofer.de/lang-en/labs-equipment/976-immersive-participation-lab.html last accessed 21.8.2020.

below. There might also be cases, when the digital twin is viewed from remote, without there being a VR-session in the construction site office.

The challenge in developing the UIs for this system will be the adaption to the use case: How to filter and present information and functionality, according to the situation, the user group, and the devices in use.

These four examples illustrate the use of the envisioned system.

Use Case Example A: Daily Briefing

Users: Site manager, forepersons; Location: Construction site office; Situation: Daily morning briefing; Operation: Site manager explains the work plan for the day, with new situation, maybe acute hazards, etc. while forepersons are wearing HMDs, inspecting and discussing the relevant locations in the VR-model of the current situation of the construction

Use Case Example B: Impromtu Support Calls

Users: Site manager, forepersons, workers; Location: Remote location on construction site, construction site office; Situation: Foreperson or worker is unsure about a construction issue / notices something unknown / reports an error; Operation: Foreperson/worker on site calls site manager at the office and raises their concern. Site manager uses their high fidelity equipment in the office to check VR models of both current construction situation and original plans and discusses deviations with the foreperson on site, to find a solution.

Use Case Example C: Information for Firefighters

Users: Firefighters; Location: Fire truck, construction site; Situation: Firefighters are called to a fire emergency on site; Operation: On their way to the site, firefighters view a current 3D-model of the construction on their tablet computer to get to know the site and evaluate possible navigation paths, strategies for the operation etc. On site they can use their tablet to get an AR overlay of the construction, with information on hazardous areas or materials (e.g. machinery with petrol, gas tanks, etc.), as well as the last known positions of site personnel, which were tracked via wearable devices.

Use Case Example D: Client Briefing

Users: Client (builder-owner of construction), site manager, forepersons; Location: construction site office, anywhere (remote location, e.g. train); Situation: Client gets briefed about the current state and progress of the construction; Operation: Client gets briefed either at the site office with HMD or from remote location via tablet/phone, provided with current digital site model

Plans for technical implementation

For the implementation, the use of the Unity game engine is planned. UIs can be built to run on many devices or in webbrowsers from Unity. For the BIM-models OpenBIM-standards will be used: Mainly IFC for the models, and BCF for facilitating communication about them.

Conclusions and Outlook

As stated above, the proposed use case, poses a great opportunity for XR to prove itself: A single but dynamic data set to be viewed and worked with from different XR- and non XR-devices in a collaborative way. We are looking forward to designing and implementing the UIs, and especially to testing and optimizing their UX.

Additional literature

ABC15 Arizona. (2019, March). YouTube: Virtual reality construction. Core construction, available online at: https://www.youtube.com/watch?v=cmMF7GFLQLI last accessed 23.8.2020.

Virtual Reality for Historical and Cultural Learning: A User Study at the Hollandsche Schouwburg Memorial

Maria Blancas[1,2,3], Sytse Wierenga[1,2], Daniel Pacheco[1,2], and Paul F. M. J. Verschure[1,2,4]

[1]Synthetic Perceptive Emotive Cognitive Systems (SPECS) Laboratory, Institute for Bioengineering of Catalonia (IBEC), Barcelona, Spain
[2]Barcelona Institute of Science and Technology (BIST), Barcelona, Spain
[3]Pompeu Fabra University, Department of Information and Communication Technology, Barcelona, Spain
[4]Catalan Institution for Research and Advanced Studies, Barcelona, Spain

Corresponding author: paul.verschure@specs-lab.com

Keywords: Virtual Reality, Heritage Education, Human-Computer Interaction.

Introduction

Historical and Cultural Learning (HCL) is essential for the reflection on identity[76]. One way of promoting HCL is by visiting historical sites, to learn and about the events that occurred there. However, visitors may find their experiences constrained in spatial, temporal and informational terms, due to the linearity of the predetermined paths, both in physical and virtual terms, followed during museums visits[77]. The FutureMemory (FM) project was created to advance HCL via applying fundamental principles of learning and via using advanced interactive technologies such as Virtual- and Augmented Reality applications. Its goal is to improve and facilitate the access to information on the history of the Holocaust and nazi crimes, serving understanding and reflection.

The Active Learning in Digitally Enhanced Spaces (ALDES) approach comes from the union of educational psychology and neuroscience and new frameworks of Hu-man- Computer Interaction, together with research on human spatial behaviour and memory. Active exploration

[76] Korostelina, K. (2008). History education and social identity. Identity: an International Journal of Theory and research, 8(1), 25-45. https://doi.org/https://doi.org/10.1080/15283480701787327
[77] Mathias, M., Zhou, F., Torres-Moreno, J. M., Josselin, D., Poli, M. S., & Carneiro Linhares, A. (2017). Personalized sightseeing tours: a model for visits in art museums. International Journal of Geographical Information Science, 31(3), 591-616. https://doi.org/10.1080/13658816.2016.1233332

modulates spatial memory and recollection performance[78]. Moreover, previous research in interactive systems and complex information networks shows its effects on a deeper understanding of causal structures[79].

FutureMemory application

The FutureMemory app[80] presents virtual reconstructions of former concentration camps in a multi-modal presentation of its history and its prisoners' experiences. It provides high levels of graphical details and the ability to interact with 3D reconstrued virtual buildings and environments. FM-edit, a dedicated web application, supports experts' selection of content in the database. It also provides a method for fast development and testing, as its connection to the database allows for automatic update of the content's presentation. For more information on its database and a re-view on Augmented Reality in HCL[81],[82] respectively.

The application is divided into the Presentation and Master modes. The former is application-specific, targeted towards the final user, with suitable style and information. Through it, users can navigate in space and content, using a visual representation with the information. The latter includes more detailed information, from historical content (photographs, blueprints and witness descriptions) to maps and geographical data. This platform has been deployed in two applications: an immersive indoor installation (FM-Room, Figure 17) and hand-held version (FM-App, not presented here) for outdoors.

[78] Chrastil, E. R. (2013). Neural evidence supports a novel framework for spatial navigation. Psychonomic bulletin & review, 20(2), 208-227. https://doi.org/10.3758/s13423-012-0351-6
[79] Liao, S. H. (2005). Expert system methodologies and applications—a decade review from 1995 to 2004. Expert systems with applications, 28(1), 93-103. https://doi.org/10.1016/j.eswa.2004.08.003
[80] Pacheco, D., Wierenga, S., Omedas, P., Wilbricht, S., Knoch, H., & Verschure, P. F. (2014, April). Spatializing experience: a framework for the geolocalization, visualization and exploration of historical data using VR/AR technologies. In Proceedings of the 2014 virtual reality international conference (pp. 1-4). https://doi.org/10.1145/2617841.2617842
[81] Pacheco, D., Wierenga, S., Omedas, P., Oliva, L. S., Wilbricht, S., Billib, S., ... & Verschure, P. F. (2015, October). A location-based Augmented Reality system for the spatial interaction with historical datasets. In 2015 Digital Heritage (Vol. 1, pp. 393-396). IEEE. https://doi.org/10.1109/DigitalHeritage.2015.7413911
[82] Noh, Z., Sunar, M. S., & Pan, Z. (2009, August). A review on augmented reality for virtual heritage system. In International conference on technologies for E-learning and digital entertainment (pp. 50-61). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-03364-3_7

Figure 17. Setup of the experience. Bottom: a tabletop application allows users to navigate in space and content. Up: a set of panoramic screens with an interactive map of the BB camp.

The placement and presentation of the content are possible via Points of Content (POCs), which associate latitude and longitude coordinates to items; and Points of Interest (POIs), which group POCs to generate area-related groups and basic routes, depending, for example, in their thematic or topography. POIs can be presented in Free and Guided ways. In Free exploration, the user can see all the POIs regardless of his/her location and access them by being close enough. In Guided exploration, the POIs are revealed stepwise, becoming visible later following the same proximity condition.

This implementation depicts the Bergen-Belsen (BB) memorial site. This camp, active from 1940 to 1945, was 250 acres long and was located 35 miles north of Hannover. The reconstruction was carried out by merging the content (maps, descriptions, photographs and drawings) and the experts' research. That content was also used as a base for 3D modelling, done with Autodesk Maya[83] and Sketchup[84]. To ensure a reliable positioning of the buildings, maps were matched to old aerial photographs and present-day satellite imagery used for the tablet's global positioning system (GPS).

[83] https://www.autodesk.es/products/maya/overview
[84] https://www.sketchup.com

User study

We carried out a user study to assess the visitor's experience with the application. Our aim was to assess users' initial familiarity with the topic and interest, emotional state (before and after interacting with the installation), how they perceived the presentation, their experience, how it affected their interest, and how they navigated through the information. This study was run at the Hollandsche Schouwburg Memorial, in Amsterdam (The Netherlands), which serves as a place to test different approaches to present cultural heritage information, specific about the Holocaust.

19 participants (7 females, age: 40.05 ± 20.52) interacted with the application. They first filled in a pre-questionnaire assessing their initial familiarity with the topic and interest, and their emotional state (based on a 32-items list of emotional states[85]. Then, they interacted freely with the application as much time as they wanted. When they reported having finished, they filled in a post-questionnaire assessing their emotional state, how they perceived the presentation, their experience, if it changed their plans, how they navigated through the information and their demographical data.

Results

We firstly assessed visitors' perceived knowledge and previous experience with the topic, and their goal when using the system. They mainly reported knowing more about the Second World War than specifically about the Holocaust, and around 70% of users had visited the National Holocaust Museum before visiting the installation. A 60% of them reported their goal was "only exploring" the application (instead of specifically wanting to learn about BB or the Holocaust). Before interacting, participants mainly reported feelings of interest (84%), compassion (68%) and sadness (63%). Afterwards, they showed a decrease in guilt (-16%), fear (-10%), hope (-10%); and an increase in annoyance (+10%), affection (+10%) and gratitude (+6%).

Visitors perceived the experience as innovative, interesting and easy to use and to navigate in the space. The parts on children and daily life were perceived as more interesting, with a high focus on personal stories. Moreover, using the application help visitors to understand how the camp looked like and increased their interest in knowing about BB and visiting more memorials and museums on the subject.

Users commented they would improve the system with more data, an overall information of the site and more stories on how the people arrived there and their fate. Other possible improvements would be to present it in more languages (at the moment, it is only in Dutch and English). Finally, regarding the use of technology, older users perceived the application as more directed to younger audiences and presented their concerns on it looking too much like a videogame, what, they said, could be perceived as "sterilizing". In general, despite missing some functionalities (like being able to walk into cabins), users perceived it as immersive, innovative and useful.

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[85] Nawijn, J., Isaac, R. K., Gridnevskiy, K., & Van Liempt, A. (2018). Holocaust concentration camp memorial sites: An exploratory study into expected emotional response. Current issues in Tourism, 21(2), 175-190. https://doi.org/10.1080/13683500.2015.1058343

Discussion and Conclusion

This paper presents the first steps in the validation of an immersive experience to present information about the Holocaust. The application seemed to induce some changes in users' emotional states. It helped them to understand how the camp worked and increased their interest in knowing more about the topic and visiting similar sites. Moreover, we found a strong focus on content about personal stories. This study shows the possibilities of immersive experiences for presenting information about the Holocaust. The main limitation of this study is the sample size, which we plan to increase in further iterations. Due to time and space limitations, we did not conduct interviews or focus groups, which would give us more detailed in-sights on users' perception of the experience. Possible next steps would be to implement an introductory video/text, as some users suggested, to introduce visitors to the history of the camp.

Acknowledgements

We would like to thank the experts from the BB memorial site, the volunteers from the Hollandsche Schouwburg Memorial and the visitors who participated in this pilot study.

Upper extremity movement evaluation using markerless motion capture system

Marietta Gavriljuk, Vladimir Kuts, Helena Gapeyeva, Tauno Otto, and Simone Luca Pizzagalli

Tallinn University of Technology, Tallinn, Estonia

Corresponding author: marietta.gavriljuk@taltech.ee, vladimir.kuts@taltech.ee, helena.gapeyeva@itk.ee, tauno.otto@taltech.ee, & simone.pizzagalli@taltech.ee

Keywords: rehabilitation, upper limbs, motion capture system, virtual reality.

Introduction

Technology-based rehabilitation systems such as virtual reality (VR), can deliver low-cost and challenging rehabilitation activities[86]. In order to create the interaction with a virtual environment and provide the patient with appropriate feedback, the system should integrate the patient's limbs movement and position tracking. Motion capture systems (MCS) are used to support this kind of training. Compared to the marker based MCS, which required experienced technicians and expensive equipment, markerless MCS provides low-cost equipment and are available for home-based rehabilitation[87].

Research Question

The present work aims to 1) develop a game-based application for patients with shoulder movement impairments, 2) implement markerless MCS for data acquisition, evaluation, and feedback.

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[86] Knippenberg, E., Verbrugghe, J., Lamers, I., Palmaers, S., Timmermans, A., & Spooren, A. (2017). Markerless motion capture systems as training device in neurological rehabilitation: a systematic review of their use, application, target population and efficacy. Journal of neuroengineering and rehabilitation, 14(1), 61. https://doi.org/10.1186/s12984-017-0270-x

[87] Cai, L., Ma, Y., Xiong, S., & Zhang, Y. (2019). Validity and reliability of upper limb functional assessment using the microsoft kinect V2 sensor. Applied bionics and biomechanics. https://doi.org/10.1155/2019/717524

Methods

The application is developed using Unity game engine. The data acquisition device for the shoulder joint movement is the Kinect sensor which provides skeleton tracking possibilities. It is represented through the descriptive parameters of the bones length and joints rotation caused by the pose change. Four games were elaborated: Game 1 – abduction, Game 2 – horizontal flexion, Game 3 – vertical flexion, Game 4 – flexion/adduction. A representation of a gaming environment is shown in Figure 18

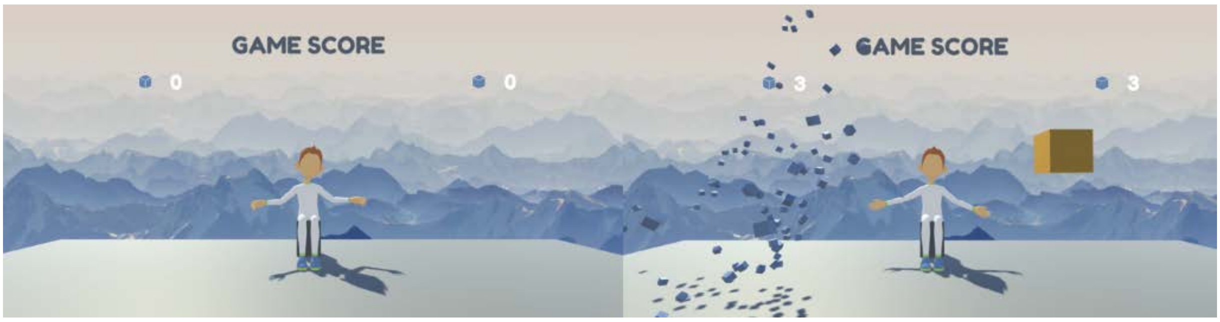

Figure 18. Screen capture of the gaming environment

Results

The exergame (Figure 19) consisting of four different games was developed for the training of the main movement of the shoulder joint. All games allow undergoing training sitting in a chair or wheelchair, which reduces the difficulty of posture control. Real-time feedback is provided for each game. It is also possible to select the game complexity, trained hand, and limit the range of motion.

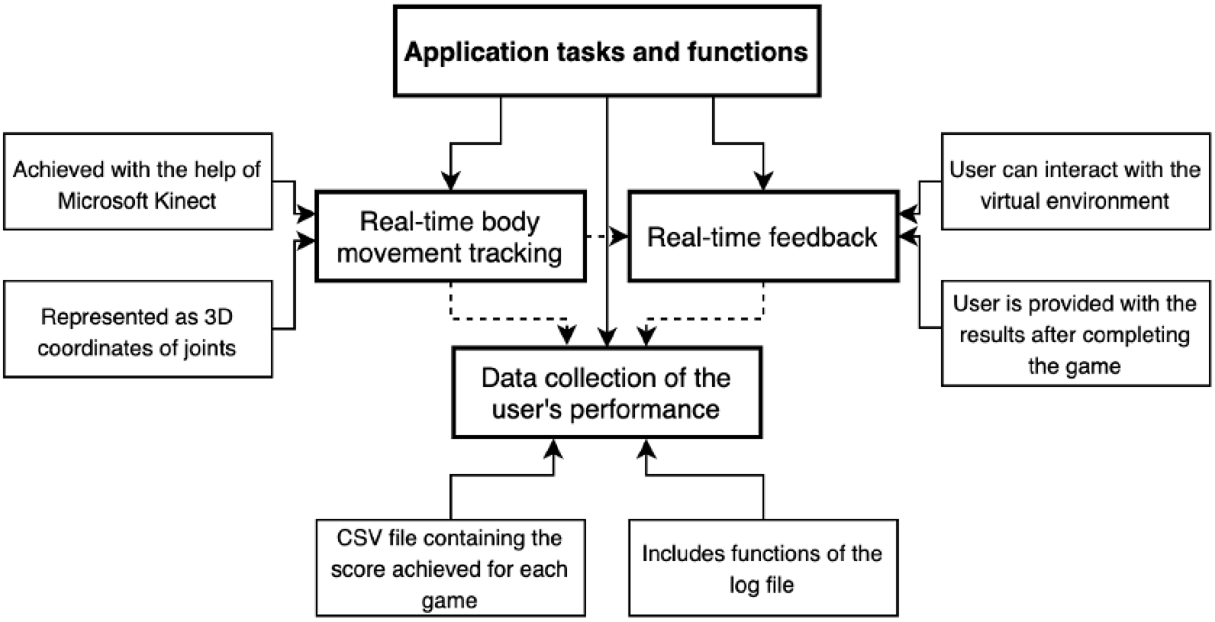

Figure 19. Application tasks and functions

Discussion

The present exergame provides training of shoulder joint range of motion as well as gives the feedback of the function's improvement. The game-based application developed in this work integrates Microsoft Kinect 2.0 as a markerless MCS[88] for the improvement of shoulder joint function and can be defined as an exergame[89]. Although a considerable number of studies have been developed to provide game-based rehabilitation solutions, rather less attention has been paid to game graphics leading for the decrease in the user's motivation. This work aims to provide an attractive design, create an engaging rehabilitation experience and increase motivation among patients. Future development can be carried out in order to implement the monitoring of potential joints injury and provide real-time assistance to the patient. Furthermore, the integration of the database can be implemented allowing remote access for the physician.

[88] Colyer, S. L., Evans, M., Cosker, D. P., & Salo, A. I. (2018). A review of the evolution of vision-based motion analysis and the integration of advanced computer vision methods towards developing a markerless system. Sports medicine-open, 4(1), 24. https://doi.org/10.1186/s40798-018-0139-y
[89] Webster, D., & Celik, O. (2014). Systematic review of Kinect applications in elderly care and stroke rehabilitation. Journal of neuroengineering and rehabilitation, 11(1), 108. https://doi.org/10.1186/1743-0003-11-108

Artists Emerge from their Paintings: Museum AR Experiences of Art and Artifacts

Hyejin Hannah Kum-Biocca

New Jersey Institute of Technology/M.I.N.D. Lab, Newark, New Jersey, USA

Corresponding author: hannahbiocca@gmail.com

Keywords: Augmented Reality, Hololens 2, Museum experience, Special Presence, Embodiment interaction.

Introduction

Artifacts in a museum have both a visible physical presence and an unseen context or history. For example, a painting has its physical display but usually needs additional unseen context and history to be fully appreciated. The background of the artifact might include creator-artist, timepoint, motivation, objects, or people referenced in the image, motivation, social-political-artistic context[90]. For some works, there is also a striving to connect the viewer to the creator of the work such as the motivation and life of famous artists such as Van Gogh, Da Vinci, etc. So, in general we can say that for any artifact there is (1) the foreground object and (2) the background context or story.

Various media are used by museum curators to "augment" the physical art or artifact with information. The oldest and most common is fixed signage that might include title, author, date, and some context. But also "mobile" media are used to augment the object as well. At the low end of interactivity might be a brochure or catalog with annotates the object. At the high end of interactivity is the human guide or docent who describes the context, provides stories, and information.

Various interactive digital media have been devised to augment the experience of the artifact. More recently location-based audio systems annotate the experience of an artifact providing context, actor voicing quotes from the artist, etc. There are sometimes touch screen videos in a separate room[91]. All of these approaches to providing the experience of the artist, the context of

[90] Hooper-Greenhill, E. (2007). Museum and Education, pp. 34-35. Routledge, New York, USA
[91] Dal Falco, F., & Vassos, S. (2017). Museum experience design: A modern storytelling methodology. The Design Journal, 20(sup1), S3975-S3983. https://doi.org/10.1080/14606925.2017.1352900

the art, are limited. Illustration and context are mostly composed of text and still images. They provide no interaction with the artists or the context of the artwork.

More recently various augmented reality displays have been used to assist in providing information and background about museum artifacts. Phone and tablet platforms are the most common[92],[93]. While there are some advantages to these common platforms, there are several limitations. Hand-helds must be kept raised to trigger augmentations fatiguing users in a museum. Looking at a hand-held device is a distraction from seeing the actual painting or object.

Most museum AR applications provide the AR equivalent of signage in the form of annotations and labels but can also provide layers of information such as sketch drawings, image references[92],[93]. But these implementations do not create a full experience of the artist and the context for a painting or art piece.

In this design and an application featuring Van Gogh's Starry Night, we seek to use AR to provide a more intimate connection to the artist and the context of the art. The goal is to augment the reality of the painting by creating an interactive stage of characters and virtual objects adding rich layers of context about the painting or artifact.

Design and implementation

We sought to design an augmented reality interface for staging experiences around objects in museums originally for paintings but also generalizable to other museum artifacts.

[92] Capuano, N., Gaeta, A., Guarino, G., Miranda, S., & Tomasiello, S. (2016). Enhancing augmented reality with cognitive and knowledge perspectives: a case study in museum exhibitions. Behaviour & Information Technology, 35(11), 968-979. https://doi.org/10.1080/0144929X.2016.1208774
[93] Hunsucker, A. J., Baumgartner, E., & McClinton, K. (2018). Evaluating an AR-based museum experience. interactions, 25(4), 66-68. https://doi.org/10.1145/3215844

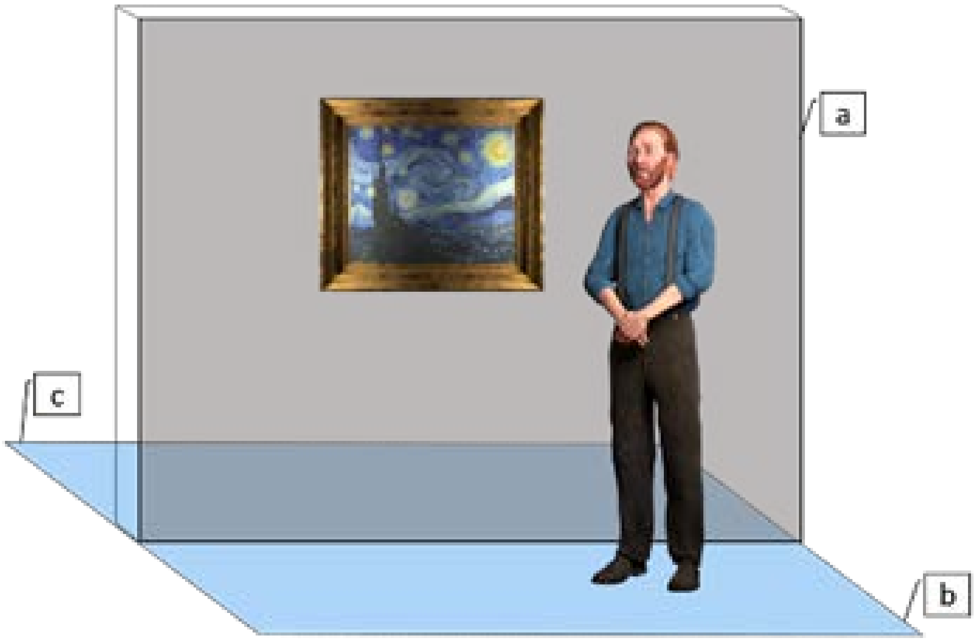

Figure 20. Design of three spaces for staging Augmented ART experiences around the artifact: (a) the picture plane-surface, (b) foreground stage space (c) rear background space.

Museum objects are typically fixed to a wall or encased. This setting is the required context for the AR experience and annotation. Augmented ART design conceives of three stages or spaces for augmented information around a museum object.

The picture plane-surface. The plane surface is the wall space around the object. This AR space can be used to display fixed information such as augmented signage and annotation, parallel or overlaid graphics such as related pictures, objects, etc.

Foreground stage space. The foreground space is defined as the 3D volume of space in front of the art. This space we use to animate 3D characters, touchable artifacts, and other 3D virtual objects or characters that describe the painting or information context.

The rear background space. The rear background space is defined as a limited virtual space projected behind the painting and wall. This space which appears to viewers to be transparently behind the wall can be used to provide 3D context behind the painting or artifact on which the painting "floats." For example, this space can be used to show what the artist was "seeing" while painting such as a landscape, a person, etc.

Van Gogh's emerging from his Starry Night painting

In this implementation, we used Van Gogh's Starry Night painting to demonstrate the approach. The design stages experiences around the painting. The context of the painting is animated within an augmented reality interactive and theatrical format. The goal is to have the user experience a direct connection to the artist Van Gogh and the background and story of the creation of the painting.

Figure 21. Hololens platform supports hands-free viewing and interaction with the theatrical spaces.

Interactive Platform. The animation, models, and augmentations were created using Maya, Unity, and other tools ported to the Microsoft Hololens 2 platform. Hololens was selected as it enables hands-free interaction. The user can seamlessly enter the staged experience around the painting. HMD camera detection of a painting triggers the application and loads all the content for the three stages of the experience.

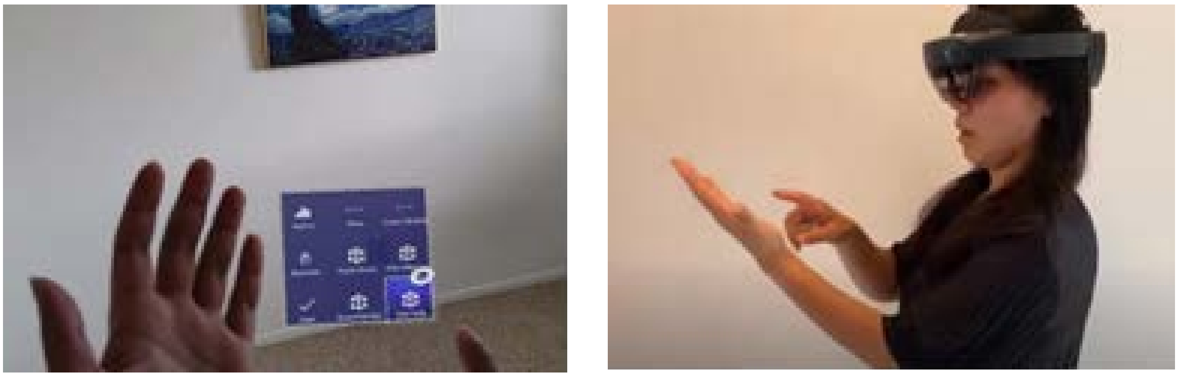

Figure 22. The "picture portal" menu.

The user controls the experience through the picture portal menu or via direct interaction with characters and artifacts staged in a 3D theatrical story around the painting.

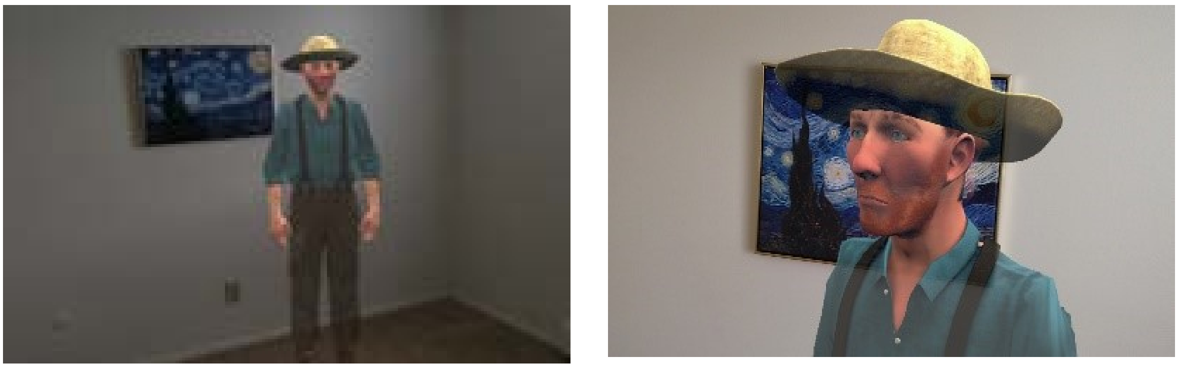

Figure 23. The agent-artist emerges from the painting addressing viewer in Van Gogh's words.

Interactive Embodiment of the artist. An agent representing the artist, Van Gogh, enters the front stage. He looks at the viewer. Interacting beside the painting he talks in first person using Van Gogh's words about why and when he created Starry Night.

Figure 24. The day of creation is reconstructed on the stage.

Creation context, the studio, on the rear stage. Using the rear space, the users see the painting floating on a scene projected behind the painting of the artist painting in his studio.

Figure 25. Sketches superimposed on the picture plane.

Recreation of the artist scene. The front stage is used to embed the character and the viewer in the field of lilacs represented in the painting.

Figure 26. A table with letters triggers audio narration.

Virtual interactive exhibits. The front stage includes objects from Van Gogh's room in his asylum. On the table are letters between Van Gogh and his brother Theo. When the user picks up the letter the text is voiced by the characters.

Discussion

In this paper, we have proposed a design for moving much of the information carried by signage, catalogs, and audio media to augmented reality environment staged around the painting-artifact. Furthermore, we demonstrate a more theatrical presentation of the information involving recreation of the artist, the act of painting, and social context played out in 3D augmented reality on virtual stages in front and behind the actual painting. We created the Augmented ART application and demonstration of the approach with Van Gogh's Starry Night. The method is generalizable to many other paintings and museum artifacts.

Digital Cultural Heritage: Virtual & Augmented Reality 3D Animation of UNESCO World Heritage Site Mỹ Sơn

Tho Luong Nguyen, Hoa Hiep Trinh, Chung Van Le, Nathan Lauer, and Jolanda Tromp

Center for Visualization & Simulation, Computer Science Department, Duy Tan University, Da Nang, Vietnam

Corresponding author: jolanda.tromp@duytan.edu.vn

Keywords: Cham culture, Digital Cultural Heritage, Virtual Reality, Augmented Reality, 3D Animation, My Son, Vietnam.

The UNESCO Charter on the Preservation of Digital Heritage defines Digital Cultural Heritage (DCH) as: "cultural, educational, scientific and administrative resources, as well as technical, legal, medical and other kinds of information created digitally, or converted into digital form from existing analogue resources"[94]. Virtual Reality (VR) and Augmented Reality (AR) technologies have been put forward as powerful digital media for recreating DCH. Museums, cultural heritage sites and similar institutions which feature ancient cultures, share common goals that are handicapped by a common problem: much of what they represent is inherently esoteric. The lay viewer, upon which these institutions rely as both their mission and for income, is therefore often not able to be engaged by the objects they are viewing. In the past, this gap between visitor and institution has been filled by written material, and more recently audio guides and similar technology. However, these methods often fall short for those who are not already enthusiasts of the cultures and objects being viewed. This is particularly true for the culture and artifacts of Champa, as they have unique religious and cultural aspects that are alien to most viewers.

This critical gap is one which AR and VR can fill. By being able to place objects and architecture in context to each other and in context with the modern world, recreating elements missing due to the ravages of time and war, and bringing artifacts to life to tell their own stories, VR and AR offer the potential to bring an end to the engagement problem faced by institutions, cultural heritage sites, and museums for decades. VR allows virtual visitors, while AR in offers an opportunity to directly engage visitors with animations. Being able to digitally bring to life real yet static objects, AR can provide lay viewers with a multi-dimensional understanding of the

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[94] UNESCO, (2013). Charter on the Preservation of Digital Heritage. Available online at: http://portal.unesco.org/en/ev.php-URL_ID=17721&URL_DO=DO_TOPIC&URL_SECTION=201.html last accessed 15.6.2020

artifacts they are viewing. Using the all ubiquitous smartphone that most already have in their pocket, visitors can now walk away with a real understanding and appreciation for ancient relics and the cultures they represent, increasing their awareness of the importance of these relics of the past, their impact on the present, and the need to preserve them for the future.

Towards this end, our team has used VR and AR to create a DCH representation of some aspects of Cham culture and artifacts, as well as recreations of Cham cultural dances, clothing and coloring, which are rapidly becoming lost to time due to damage, destruction, decay, and cultural erosion with the advent of modern socioeconomics.

The Cham people are a Southeast-Asian ethnic minority group of Austronesian origin. Their empire, the Kingdom of Champa, existed from sometime around the 2rd century to the mid-fifteenth century C.E. in Central and Southern Vietnam[95]. The Cham culture and peoples have been minimized in the centuries since due to political and cultural encroachment, and more recently by the effects of modernization and urbanization. Beginning in the 16th century, the Kingdom of Champa experienced a drastic decline, which left their civilization in ruins, and much of their art and architecture to waste away. This also resulted in the dissolution of their vast trade networks and a cultural decline. In part, this was caused by internal and external conflict, including the expansion of neighboring nations across Cham borders, and the Portuguese, Spanish and Dutch entry into the region[96]. In the 21st century, the Cham people in Vietnam are officially recognized by the Vietnamese government as one of 54 ethnic groups. They are a rich and varied culture, in rapidly dwindling numbers, belonging to the high urgency type of DCH preservation of the living heritage of marginalized groups, due to their complex political and historical background as well as cultural and religious differences. The Cham are classified in two primary groups, with one observing a form of Hinduism and the other observing a form of Islam[97]. There is also a third group that observes a unique blend of both Islam and Hinduism.

The most famous Cham architectural site is the complex of temple-towers at Mỹ Sơn (see poster), in central Vietnam. This was their royal holy land, a site devoted to the worship of Hindu deities. While unique, it does share aspects with other ancient religious sites in Southeast Asia, including Borobudur in Java (Indonesia), Angkor Wat (Cambodia), Bagan (Myanmar) and Ayutthaya (Thailand). This is not surprising, given the vast trade network maintained by Champa during its heyday. In 1999 Mỹ Sơn officially became a UNESCO world heritage site.

3D models can be created in several ways: Entity based wire frame models, 3D mesh models, surface based models and solid based models. Entity based models are created from primitives (basic lines, arcs, circles, curves) that are used to generate the 3D models. This is the most limited type of 3D model construction methods as many shapes simply can not be created using simple primitives. The Surface Based models use surfaces to create the geometry. Difficult surfaces like NURBS (Non uniform b-spline surfaces) are non-standard curves, only possible with high end modellers. Solid Modellers are the high end of the spectrum of 3D modelling. This software uses

[95] Andaya, L. Y. (2008). Leaves of the same tree: trade and ethnicity in the Straits of Melaka. University of Hawaii Press, USA, p. 44. ISBN 978-0-8248-3189-9.
[96] Schottenhammer, A., & Ptak, R. (2006). The Perception of Maritime Space in Traditional Chinese Sources. In: Otto Harrassowitz Verlag, Wiesbaden, Germany. pp. 138. ISBN 978-3-447-05340-2
[97] Phuong, T. K., & Lockhart, B. (2011). The Cham of Vietnam: History, Society and Art. National University of Singapore (NUS), Press. ISBN 978-9971-69-459-3.

actual “solids” in construction of the compound shapes. The system can create and use primitives of cubes, balls, torus, pipes and other solids and generate compound forms using Boolean operations, generating a solid model that behaves and looks like the true item in real life.

For most cultural heritage digitization work, all the 3D model types come into use, with the 3D solid model being the most useful. The problem for recording cultural heritage artefacts or structures, is how to create the geometry for the 3D model. There are generally three methods: Direct Input, camera based and scanner based. We used photos for textures, archeological measurements and the Direct Input Modelling method to create the 3D Cham models. For this method the necessary commands and specific measurements to create the geometry of a model are needed. Using direct input of the measured information of the heritage model is a long process depending on the complexity of the model, the capabilities of the software and the proficiency of the developers. Some 3D software packages may be unable to completely model the item accurately either for limitations in the software itself or lack of geometric information collected.

We support the debate for open digital repositories of scientifically authenticated 3D models. Digital preservation policies in most organizations are underdeveloped and archives suffer from deterioration and technological obsolescence. Digital repositories should be based on traditional scholarly methods, with standardized mechanisms for preservation, peer review, publication, updating, and dissemination of the 3D models. For the preservation of Cultural Heritage in digital format there are a number of related research challenges, such as a preliminary needs assessment survey of virtual heritage practitioners, a number of technical research challenges, including digital rights management for the 3D models, clear depiction of uncertainty in 3D reconstructions, version control for 3D models, effective metadata structures, long-term preservation, interoperability, 3D searching, and last, but not least, quality control concerns, including computational analysis tools, the organizational structure of a peer-reviewed 3D model archive and business models.

Additional literature

Koller, D., Frischer, B., Humphreys, G., (2009). Research challenges for digital archives of 3D cultural heritage models, Journal on Computing and Cultural Heritage V2(3):7, DBLP, https://doi.org/10.1145/1658346.1658347

Terras, M., (2015). Cultural Heritage Information: Artefacts and Digitization Technologies, Chapter In Chowdhury, G. and Ruthven, I. (2015). "Cultural Heritage information", London: Facet. p. 63-88. January 2015, https://www.researchgate.net/publication/313903172

Using Audio-Visual Immersion to Improve Acceptance of Wind Energy Projects

Iwer Petersen, Birgit Wendholt, Sebastian Mellert, Dagmar Rokita, and Friedrich Ueberle

Hamburg University of Applied Sciences (HAW), Hamburg, Germany

Corresponding author: iwer.petersen@haw-hamburg.de

Keywords: Virtual-Reality, Auralization, Wind turbine sound, Acceptance of wind-energy.

Introduction

While science and legislation agree that the share of renewable energy production must be increased significantly in the coming decade, the implementation of wind energy projects has declined over the last years. An important factor in this delay seems to be reservations in the public regarding visual and acoustic impact of the employment of wind turbines in the immediate vicinity of living areas. This abstract proposes a method to produce scientific sound, virtual, audio-visual environments to communicate the potential impact to citizens and planners on a factual basis.

Related Work

Different VR based approaches for such a task have been used to expand the visual experience with an acoustic Soundscape. The term Soundscape describes an acoustic environment as perceived by humans[98],[99],[100]. Studies show more negative responses with real-time, dynamic

[98] International Organization for Standardization. (2014). Acoustics-Soundscape - Part 1: Definition and Conceptual Framework (ISO 12913-1:2014). Beuth Verlag, Berlin, Germany. https://doi.org/10.31030/2784629
[99] International Organization for Standardization. (2018). Acoustics-Soundscape - Part 2: Data Collection and Reporting Requirements (ISO/TS 12913-2:2018). Beuth Verlag, Berlin, Germany. https://doi.org/10.31030/3091956
[100] Kang, J., & Schulte-Fortkamp, B. (2018). Soundscape and the built environment. CRC press (2018). https://doi.org/10.1201/b19145

versus static visual VR content[101] but growing acceptance with immersive, audio-visual VR and very similar assessments of virtual and recorded acoustic environments[102],[103]. Hruby[104] emphasizes the positive effect of a combined audiovisual versus exclusively visual presentation and provides the concept of geo-visualization immersive environments (GeoIVE). The use of geographic information system (GIS) data sources for the creation of a visual environment is already adopted[105],[106],[107] but considered a major task[108].

Acoustic simulation of wind turbine sounds until now was rendered offline using custom synthesizers and added to the visual content separately[108] producing a motion along a predefined path. Spatial ambisonic field recordings used alongside spherical 360° video[102] is only applicable for stationary perspectives. With geometric sound propagation methods however, realistic, environmental sound renderings are possible in real-time even in game engines[109],[110].

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[101] Teisl, M. F., Noblet, C. L., Corey, R. R., & Giudice, N. A. (2018). Seeing clearly in a virtual reality: Tourist reactions to an offshore wind project. Energy policy, 122, 601-611. https://doi.org/10.1016/j.enpol.2018.08.018

[102] Cranmer, A., Ericson, J. D., Broughel, A. E., Bernard, B., Robicheaux, E., & Podolski, M. (2020). Worth a thousand words: Presenting wind turbines in virtual reality reveals new opportunities for social acceptance and visualization research. Energy Research & Social Science, 67, 101507. https://doi.org/10.1016/j.erss.2020.101507

[103] Manyoky, M., Hayek, U. W., Pieren, R., Heutschi, K., & Grêt-Regamey, A. (2016). Evaluating a visual-acoustic simulation for wind park assessment. Landscape and Urban Planning, 153, 180-197. https://doi.org/10.1016/j.landurbplan.2016.03.013

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[105] Minelli, A., Marchesini, I., Taylor, F. E., De Rosa, P., Casagrande, L., & Cenci, M. (2014). An open source GIS tool to quantify the visual impact of wind turbines and photovoltaic panels. Environmental Impact Assessment Review, 49, 70-78. https://doi.org/10.1016/j.eiar.2014.07.002

[106] Molina-Ruiz, J., Martínez-Sánchez, M. J., Pérez-Sirvent, C., Tudela-Serrano, M. L., & Lorenzo, M. L. G. (2011). Developing and applying a GIS-assisted approach to evaluate visual impact in wind farms. Renewable Energy, 36(3), 1125-1132. https://doi.org/10.1016/j.renene.2010.08.041

[107] Wróżyński, R., Sojka, M., & Pyszny, K. (2016). The application of GIS and 3D graphic software to visual impact assessment of wind turbines. Renewable Energy, 96, 625-635. https://doi.org/10.1016/j.renene.2016.05.016

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[110] Mehra, R., Raghuvanshi, N., Antani, L., Chandak, A., Curtis, S., & Manocha, D. (2013). Wave-based sound propagation in large open scenes using an equivalent source formulation. ACM Transactions on Graphics (TOG), 32(2), 1-13. https://doi.org/10.1145/2451236.2451245

For a comparative assessment of virtual against real Soundscapes the listening practice of participants must be considered. Objective comparison of e.g. spectral analysis may reveal seemingly large differences, that may not be reflected in a subjective assessments[111].

Ground Truth Acquisition

Acoustic emissions of real wind turbines are analyzed to identify emission locations, spectra and directions. The measurements are taken throughout a year to learn about seasonal variations of acoustic properties for example related to e.g. changing vegetation. Data from a weather station on site is used to correlate certain properties like wind speed, relative humidity or air pressure with acoustic phenomena. Measurements from different positions around the wind turbine give insight on the directionality of certain emission sources.

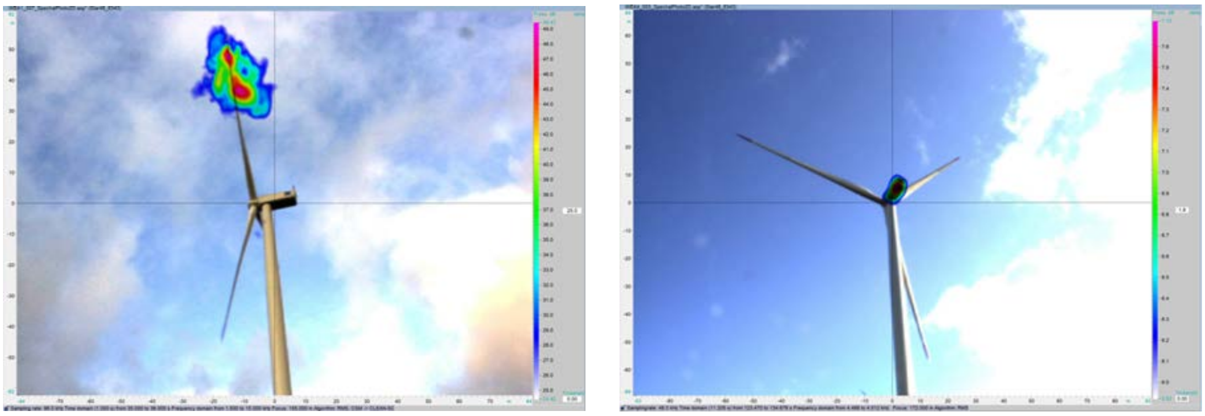

Figure 27. Localization of the dominant sounds in the frequency domain of 1.5 – 15kHz (left).

The main instrument for the measurements is an optical camera, synchronized with a 48-channel microphone array, which can locate the direction of sound components via beamforming algorithms[112]. By combining the locations with the camera images, like in Figure 27, acoustic spectra can be attributed to certain turbine parts. Together with commonly used spectral analysis tools like waterfall plots, isolated acoustic elements are then identified and described by their spectrum, amplitude, modulation and directional characteristics, which later aid the synthesis of point sound sources in the Soundscape.

To be able to reproduce certain environmental and operating conditions for a later subjective evaluation, spatial, first-order ambisonics audio with 360° video is also captured, which can be replayed in a 360° VR-sphere environment.

Virtual Environment Generation

A spatial reference between the world geodetic system (WGS84) and the cartesian coordinate system of the game engine allows an automated import of geo-referenced data from different

[111] Castro, D., Verstappen, A., & Platt, S. (2019, November). Walk-through auralization framework for virtual reality environ-ments powered by game engine architectures, Part II. In Proceedings of ACOUSTICS (Vol. 10, No. 13). https://doi.org/10.3813/AAA.918116

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sources. Globally available digital elevation maps (DEM) are used to generate the base landscape. Data from the *S2GLC* project provides landcover classification which defines the landscapes surface and vegetation. *Openstreetmaps* provides information to construct streets and buildings. Open data initiatives like those published under the EU *INSPIRE* legislation often provide even finer grained data about e.g. waterways for depressions in the landscape. 3D models of wind turbines are animated according to wind speed and technical specifications.

The acoustic environment consists of a simplified 3D model and materials, which define acoustic absorption, transmission and reflection. Synthesized point sound sources are added to the wind turbine models. Defined by land use or building type typical ambient sounds are then added to the environment to provide an acoustic reference for the listener[104]. This includes major emission sources like vehicle noise on streets and highways according to their driving speeds as well as natural sounds like birds or rustling leaves according to wind speed, seasonal and weather conditions.

Conclusion and Outlook

Using global digital elevation models and S2GLC landcover[113] information we can quickly generate a landscape with realistic landcover for most of Europe. This works well in a temperate climate zone regarding the models used for vegetation but not as well in regions where other types of vegetation are typically present. For a more flexible landscape generation the climate zone of a region could define typical vegetation types for each landcover class.

While the measurements are still ongoing major emission sources have been identified and hints about the directionality of certain sources have been found. With the initial findings of the measurements a rough audio model has been developed. This consist of two cone-shaped sound sources per wing which emit broadband noise and a spherical shaped emission source for the engine nacelle which emits a very narrow banded hum. Because the wingtips move very fast, it seems intuitive to process them with a doppler-effect. This simple model already produces a recognizable characteristic of wind turbine noise. With progressing finding from the measurements however this model will be refined and parametrized for different conditions. Verification will be aided by comparing waterfall plots of recorded and simulated spectra under similar conditions.

Acknowledgment

This work has been developed in the projects X-Energy X-Eptance Explore which is funded by the German ministry of education and research (BMBF) within the program FH-Impuls and Open Citizen Soundwalk (OCSW) which is funded by the HAW Digitalization funds.

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Detecting Astigmatism Condition in Human Eye using VR

Shivang Shekhar[1], Sai Anirudh Karre[1], Y. Raghu Reddy[1], and Rajat Kumar Gupta[2]

[1]*Software Engineering Research Centre, IIIT Hyderabad, India*
[2]*Dept. of Computer Science, Govt. College of Engineering and Leather Tech., Kolkata, India*

Corresponding authors: shivang.shekhar@research.iiit.ac.in, saianirudh.karri@research.iiit.ac.in, raghu.reddy@iiit.ac.in, & rajatcube@gmail.com

Keywords: Human Eye, Virtual Reality, Optometry, Human Computer Interaction, Astigmatism, Visual Acuity Test.

Abstract

Purpose: A common imperfection in the Human eye curvature may cause blurred vision and near vision. This condition can be clinically termed as **Astigmatism**. If not treated, the blurriness of eyesight may lead to other complications leading to impaired vision for life. We are working towards developing a Virtual Reality (VR) based approach to detect astigmatism condition.

Outcome: As part of this paper, we propose a technique to detect astigmatism condition. The results of this detection are programmed to be used towards our larger goal on developing an end-to-end substantial visual acuity test using VR.

Motivation

The Eyes are highly developed sensory organs in a human body. However, they are also prone to disorders and diseases. World Health Organization (WHO) fact sheet on blindness and vision impairment estimates that at least 2.2 billion people have vision impairment or blindness [114]. At least a billion among them have vision impairments that can be prevented through early detection[114]. Detection is a major problem in this health crisis. Thus, WHO had come up with a

[114] WHO World Health Organization. (2019). Universal Eye Health: A global action plan 2014-2019. WHO Library Cataloguing-in-Publication Data. https://www.who.int/blindness/AP2014_19_English.pdf?ua=1

strategic plan called VISION 2020[115] to eliminate avoidable blindness. Also, studies from researchers in India warn us about the emergence of severe eye disorders due to insufficient care. Early detection is essential for better and planned eyecare[116]. These eye issues eventually lead to economic impact on the patients and their families.

Given the importance of detection of eye issues, we started working towards a Virtual Reality based Visual Acuity Test Kit called **VREye**[117], a low-cost approach to determine and detect vision disorder. The overall objective of the VREye (split across multiple phases) is to develop a low cost VR device with specific application software that can used for detecting various vision disorders. We currently detect vision disorders like myopia and hypermetropia. However, to accomplish the overall goal of VREYE[117]. **Astigmatism** detection is also one of the sub-problems to be solved in a VR Setup. Astigmatism is a common vision condition that causes blurred vision[117]. It occurs when the cornea is irregularly shaped or sometimes the lens has a different curvature inside the eye[118]. Have clinically verified that there is a strong correlation between the Astigmatism of an eye and the degree of myopia (Nearsightedness), i.e., the total amount of Astigmatism in the myopic eye is proportional to the degree of myopia[118]. This clinical evidence[118] motivated us to work towards a setup for detecting the Astigmatism of the human eye using VR as well as the unavailability of 3D depth corrected solutions to build a robust eye-testing setup using VR.

Fan Test in VR:

Clinically, Retinoscopy and Keratometry are the techniques used by Optometrists to measure Astigmatism. They are elaborate and developing a digitized version of these tests is really difficult especially one that caters depth of vision into account. However, the Fan Test is a simplified Astigmatism detection test. It requires the patient to stay 40 cms away from the screen with fan, as shown in Figure 28 An optometrist is needed for recording the readings correctly. Our overall goal of VREye is to minimize/negate the need for an optometrist. This is made possible by converting this physical test into a VR setup (which offers a depth of field view as well).

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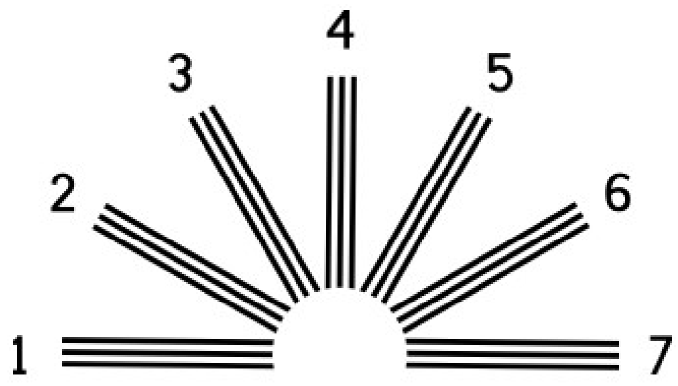

Figure 28. Fan Test Traditional Fan Test contains a series of radiating lines spaced at 10 degrees arranged in the form of sun rays. In the center, there are "V" perpendicular blocks which are mutual to each other. They are rotated through180∘simultaneously.

VR Test Scene Design:

We designed a VR scene using Unity3D platform. We used Oculus Go VR Headset which offers "Crystal-Clear Optics with Optimized 3D graphics with highest visual clarity". Oculus Go Hand controller is used for user response capture. However, our VR Test Scene is compatible with any available VR Headset and its relevant handheld controller. We placed an Astigmatism fan chart in the middle of the scene with a 360-degree field view around the dark environment. As a result, the participants have a reflex action where in he/she is immediately able to identify a source of light in a dark background. We offer a "Yes" and "No" button on screen as overlay to respond to the queries posed in the VR scene. Although, not discussed as part of this paper, the application shall eventually be ported to our custom built head mounted device in the later phases of VREye design and developments.

Test Questionnaire, Astigmatism Chart, and user responses are the essential aspects of this VR Scene. Utmost care has been taken in defining seamless flow of events during this test, i.e., the involvement of both the technician (may or may not be an optometrist) and the patient involved in this sensitive activity is kept fairly simple. We followed and applied principles of minimalist design[119] by displaying the results swiftly with fewer interactions with a fixed information display format.

[119] VanEenoo, C. (2011). Minimalism in Art and Design: Concept, influences, implications and perspectives. Journal of Fine and Studio Art, 2(1), 7-12. https://doi.org/10.5897/JFSA.9000002

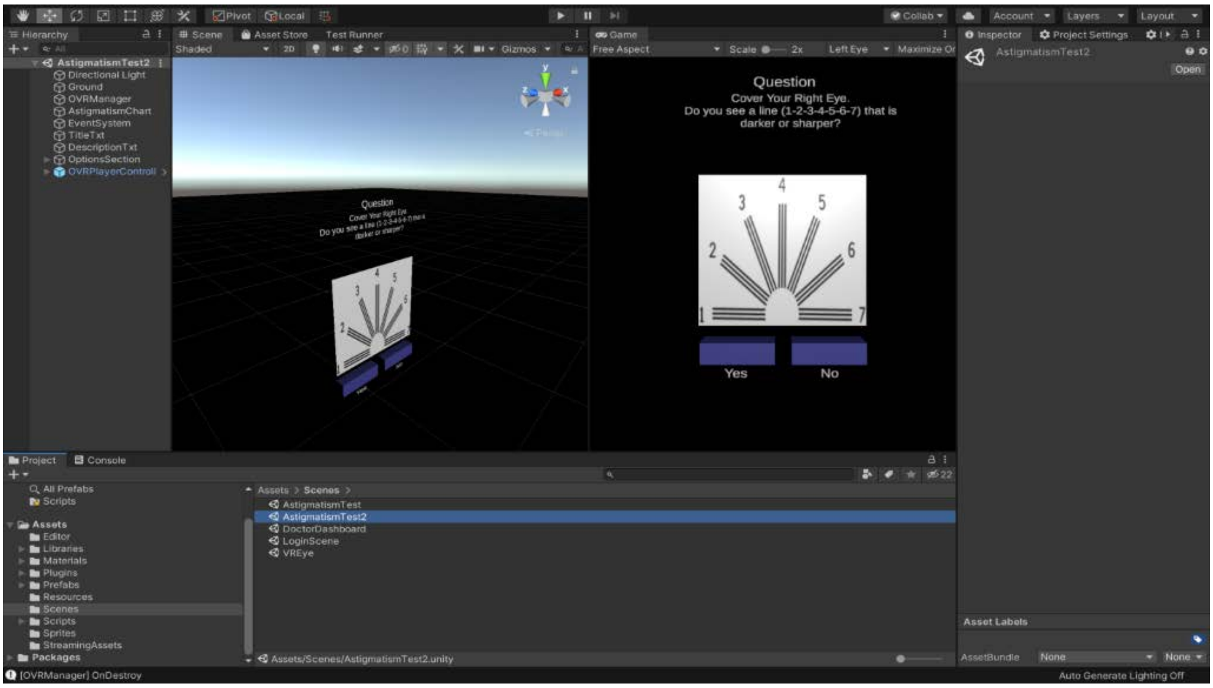

Figure 29. Astigmatism Detection using VR scene.

VR Test Work Flow

The details of test workflow are given below:

1. The technician/user/test subject configures the VR device and chooses astigmatism test. This loads the test assets in VR.
2. The test subject is allowed to join the scene consisting of the astigmatism chart.
3. Fan Test related questionnaire is promoted as an overlay on the screen. The Questionnaire module is flexible for further extension with customization.
4. The test subject now looks at fan chart by covering the left eye without pressing the eyelid. The test subject answers the questions as "Yes" or "No" using a handheld device.
5. The test subject has to repeat the same process while covering his other eye. Covering of the eye is automated within the scene.
6. We store the user responses in a CloudDB for astigmatism judgments. We generate a report card as an outcome of this test for test subject's reference.

VR Fan Test Outcome

Responses from test subjects lead us to 4 clinically defined indicators that can be used for astigmatism judgment. Table 2 explains the possible outcome based on the input and responses to the Fan Test questionnaire. The patient may be advised for further vision examination by an eye care professional to validate the test result. The primary objective of our VR based astigmatism detection is not to test the degree of severity of Astigmatism but to detect the phenomenon. Our VR Scene will aid any technician (not necessarily an optometrist) to detect the ailment from symptomatic data retrieved from our test task. Such an application will be helpful in countries that have large amount of population but the ratio of eye doctors is rather limited.

Table 2. Possible Fan Test Outcome from Right and Left Eye.

	Right	*Left*
Non-Astigmatic	No	No
Astigmatic	No	Yes
Astigmatic	Yes	No
Astigmatic	Yes	Yes

VREye Integration

As part of our ongoing research, we built a test setup for Astigmatism detection of a Human Eye. We are working towards integrating this module with our existing overall eye disorder application – VREye[117]. This integration is for shared eye care testing, which includes myopic, hypermetropic detection and astigmatism detection. The Test kit will be made available to technicians to conduct preliminary detection of the impairments.

Medical Viability

The American Optometric Association believes that vision tests conducted through an app cannot replace an in-person comprehensive eye examination[120]. However, there are various online eye care test applications available to ease eye care testing. Essilor - a leading eye care solution company, offers an online vision test setup for the general public to understand their current eye health[121] but since Essilor tests are done on 2D apps over screens hence are not a medically viable option. Emerging countries who cannot afford proper eye care testing are trying to utilize the best use of online-based tests that follow medical guidelines proposed by leading medical agencies. Our VREye test kit is being built under similar medical guidelines of optometry to have universal acceptance. Upon detection of an impairment using VREye, the test subjects can be sent to the medical practitioners for further tests. This facilitates detection on a larger scale especially in countries that do not have adequate ratio of eye care experts.

Evaluation Factors

There are few evaluation factors that need to be considered while conducting this test. For example, clinically dependent factors *age, ethnic group, genetic presence, ocular surgical history, and syndrome related constraints* need to be considered.

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[120] American Optometric Association (2020). Online Eye Tests. Tämä linkki ei toimi https://www.aoa.org/online-eye-test last accessed 14.10.2020.

[121] Essilor (2020). Test your vision. https://www.essilor.com/en/vision-tests/test-your-vision/ last accessed 14.10.2020

Prior research has established a correlation between keratometry and age. Kertometry values gradually increased with *age*[122]. Corneal astigmatism increased over an increase in age. Most of the astigmatic corneas occur in newborns with the lowest birth weight and lowest post-conceptional age[123]. To address this issue, we plan on including an age constraint while conducting an empirical study on astigmatism detection. Empirical studies have shown that Astigmatism affects populations of different *ethnic groups* differently[123]. The groups of Native American, East Asian, and Asian and Hispanic origin showed high prevalence of Astigmatism. Astigmatic parents may contribute to *genetically developed disorders* in their children[123]. Also, certain types of *Ocular surgeries* in the patient's medical history can contribute to developing asthma[121]. Some *Syndromes* like Down Syndrome, Treacher Collins syndrome, and Spina Bifida are also considered contributing factors towards Astigmatism[123]. Therefore a medical record of the patient can be incredibly helpful in determining Astigmatism. We plan to include these factors while conducting an empirical study on astigmatism detection.

Future Work

Using our Astigmatism detection setup, we plan on conducting an empirical trial on individual participants to capture their user experience about our VR Scene. Based on the feedback, we shall integrate this test setup with VREye[117] and start running large scale trials on detecting eye disorders for all. Additionally, in parallel we will be building a custom head set (with cost less than USD100) that can be used for VREye instead of the high cost Oculus device.

Additional literature

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[122] Yu, J. G., Zhong, J., Mei, Z. M., Zhao, F., Tao, N., & Xiang, Y. (2017). Evaluation of biometry and corneal astigmatism in cataract surgery patients from Central China. BMC ophthalmology, 17(1), 1-7. https://doi.org/10.1186/s12886-017-0450-2

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Augmented Curiosity

Aline Simonetti[1], Alexander Silva Lopera[2], and Enrique Bigné[1]

[1]University of Valencia, Valencia, Spain
[2]Neurons Inc, Herlev, Denmark

**Corresponding author: aline.simonetti@uv.es*

Keywords: Augmented reality, advertising, ad engagement.

Introduction

Augmented reality (AR) for advertising is among the most exciting technologies for businesses and consumers[124]. The global size of AR and virtual reality (VR) market combined is of 18.8 billion US dollars in 2020, and it is projected that the market for only the AR technology reaches this size in 2023[125]. For marketing professionals, AR can deliver a brand's message directly to the brand' target audience[124].

Digital technologies, such as AR, can be used in marketing advertising to engage users with an ad message through involvement, with the hope consumers internalize the ad message[126]. However, professionals perceive challenges in its implementation. Unity, a software company, surveyed 1000 marketing advertising professionals and found that, although there are high levels of excitation towards the technology, they concern about the technical and financial aspects of implementing the tool, and about the lack of users' knowledge and users' reluctance of trying new things. Despite this, the professionals see an increase in consumer demand for AR campaigns. The majority perceives the tool as being positive for advertising, with more than half of the respondents reporting a willingness to use it for a campaign in the next year[124].

Technology and marketing have a close relationship. New tools like AR and digital mediums are providing marketers with opportunities to reach consumers and create interactions in

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[124] Shriar, J. (2019). Creative professionals are struggling to implement augmented reality. Unity Technologies Blog. https://blogs.unity3d.com/2019/06/18/creative-professionals-are-struggling-to-implement-augmented-reality last accessed 10.5.2020.
[125] Statista. (2020). Augmented Reality (AR) - Statistics & Facts. https://www.statista.com/topics/3286/augmented-reality-ar/ last accessed 5.3.2020.
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unpredictable ways[127]. Additionally, social media platforms are expected to facilitate the implementation of AR in marketing campaigns. Among the social media platforms, Instagram and Snapchat are the ones users most engage with AR features (called "filters")[128]. While Instagram is also widely used by teenagers and about 70% of the users are between 13 and 34 years old[129] [6], in Facebook 60% are under 35 years old and there is a more spread division across ages[130]. Businesses are advancing faster than academia in gathering consumer behavior metrics with the use of AR in advertising. Facebook started this movement by partnering with a few brands. An Italian make-up company created an AR experience in which users could try-on different colors of their lipstick and delivered it through a Facebook campaign. They reported a 28-point increase in purchase, 53% higher click-through rate, and almost eight-point lift in brand awareness compared to a typical video ad campaign[131]. By the end of 2019, Facebook announced a beta version of "AR instant experiences" was available for all business[128]. This means that companies can now use the feature in their paid advertising campaigns delivered in the platform. Instagram is going in the same direction and currently is in the test phase with some selected brands of cosmetics and eyewear[132].

Sometimes, technology can grow faster than the understanding of the efficacy of the new tools (e.g., virtual reality). In the context of AR, where the number of apps and features is growing, professionals tend to use a practical approach to define their marketing strategies, based on intuition rather than data and results[127]. Businesses seek for more information on the relationship of AR ads and consumers, and its consequences, such as engagement, receptivity, intention, and word-of-mouth[133]. A recent study found that AR leads to a better attitude towards an ad via a surge in curiosity and an intensification of attention paid to the ad[134]. Even if AR technology can be used to create experience marketing and improve brand communication, there is no actual

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[129] Statista. (2020). Global Instagram user age & gender distribution 2020. https://www.statista.com /statistics/248769/age-distribution-of-worldwide-instagram-user last accessed 10.6.2020.

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[134] Yang, S., Carlson, J. R., & Chen, S. (2020). How augmented reality affects advertising effectiveness: The mediating effects of curiosity and attention toward the ad. Journal of Retailing and Consumer Services, 54, 102020. https://doi.org/10.1016/j.jretconser.2019.102020

model that clarifies the impact of the AR applications in marketing communication[126]. Indeed, there is little understanding of the drivers that motivate consumers to respond favorably to AR ads and why such ads seem to be more efficacious[134]. A relevant finding of the study mentioned above was that the impact of curiosity drops down when users get familiar with AR ads. This stress the importance for marketers to not depend exclusively on the novelty impact of the technology to deliver their messages[134].

The use of social media platforms via mobile makes AR mobile campaign an interesting medium to engage consumers with a brand[127]. In fact, most of the Facebook users access the platform through mobile devices[130]. However, how AR delivered through those devices impact on consumer behavior is still an unexplored field[127]. Harnessing the power of social media to reach consumers of any place in the world, together with the new AR campaign tool of Facebook, this research presents an initial step of a larger endeavor to understand the influence and underlying drivers of AR ad engagement and AR ad sharing. This first step seeks to observe the effects of the simple mention of AR on ad engagement, without investigating the AR feature per se. Furthermore, we aim to detect if the curiosity about the AR experience differs across age groups.

Method

Two A/B tests (T1 and T2) were conducted in June/2020 on Facebook using the A/B test tool of the platform (Facebook for Business). Users that receive the ad A do not receive the ad B, and conversely, characterizing a between-subject design experiment. We selected Facebook's campaign objective "reach", meaning the platform seeks to maximize the number of users that receive the ad [135][12]. The two tests were identical, except for the target ages of the Facebook users (T1: 13- 65+, T2: 18-65+ years old). The experiment was conducted in Brazil (that has more than 100 million Facebook users s[130]), and there were no other restriction criteria for the delivery of the ad. Each test ran for a total period of 24 hours divided into two days, and it was shown exclusively on the News Feed section of Facebook for mobiles.

The ads comprised of a short video (2:37 min) with images of the city of Valencia (Spain). We chose a foreign touristic destination instead of a tangible product to avoid the potential interference of attitude towards the product and the brand to the ad perception. The differences between the two ads relied on the (i) AR feature: ad A had the standard Facebook "play" button placed on the image of the video and no AR experience, and ad B had the Facebook "call to action" AR button inviting the user to try out the AR experience; and (ii) the description of the ad: ad A stated "Vacation in Spain! Take a picture with Augmented Reality!", and ad B stated "Vacation in Spain! Imagine yourself in the city of Valencia!" (Figure 30). The AR filter was not the target of this study. Thus, we kept it simple to avoid its possible influence on the metrics of interest. The filter comprised of a set of four images of Valencia changing in a loop; the user could use the mobile phone camera to superimpose her image on the background and take a picture with each one of the scenarios.

[135] Facebook (2020). Create a Campaign With The Reach Objective. https://www.facebook.com/business/help/906073466193087?id=816009278750214 last accessed 09.6.2020.

Figure 30. The ad layout of the two campaigns. Left: ad A with no AR experience. Right: ad B with the option of trying out an AR experience.

For the analysis, we combined the data of T1 and T2 and used Microsoft Excel 2016. The following metrics provided by Facebook were selected: (i) Post engagement[1]: the total number of actions that people take involving the ad; (ii) ThruPlays: the number of times the video played for at least 15 seconds; and (iii) Instant Experience Clicks to Open: the number of clicks on the ad that opens an Instant Experience (i.e., the AR experience). Only descriptive analyses were conducted due to the format of the data that is provided by Facebook.

Results

The campaigns reached an approximated total number of 150,000 users for ad A and 100,000 users for ad B. The vast majority received the ad on their News Feed only once. The delivery of the ads across age groups was made according to the Facebook algorithm seeking to reach the maximum number of users. It resulted in an unbalanced distribution, following the pattern: age group 13-17 > 18-24 > 25-34 > 35-44 > 45-54 > 65+ years old. To avoid bias on the interpretation of the results both per ad format and age group, we made the metrics comparable by standardizing them (we computed the percentage related to the total number of people reached per group of analysis).

The analysis of the aggregated data per type of the ad showed that for metric (i), 3.04% of the users that received the ad A (no AR) engaged with it in some way, whereas this percentage increased to 5.83 for the group that received ad B (with AR; note that we excluded clicks that opened the AR experience). Regarding metric (ii), the number of people that watched the video for 15 sec or more was rather low compared to the engagement rate, and the ad A performed better (A: 0.32%, B: 0.24%). Metric (iii) applies to ad B and showed 2.57% users clicked to open the AR experience to try it.

Since there is an indication that young people are more attracted by new technologies and experiences[136], we looked at the data segregated by age groups. The division of the groups is provided by Facebook. Figure 31 summarizes the results of the analysis. Concerning the engagement metric, the results are somehow surprising. Even if for most of the groups ad B performed better in general, for the youngest group, as expected, the levels of engagement were substantially high, but also for the groups of older people; whereas there was no much difference in engagement between ads for the users between 18 and 44 years old. For metric (ii), ad A performed better for most of the groups. A plausible explanation is that ad B, with the "call to action" to try out the AR experience, increased the urge to open the experience, harming the amount of time for visualizing the video. The third metric also revealed intriguing results. While users between 13 and 17 years old were the most responsive to the AR "call to action", the second most responsive group was of the users above 65 years old, followed by the ones between 18 and 24 years old. Further investigation needs to be conducted to understand the results of the group with aged users. We can just speculate possible reasons for this behavior: they may have more time available to interact with the platform, they might have thought the "call to action" was the play button of the video.

Figure 31. The results for the three metrics analyzed per ad type across age groups. The percentages were calculated within an age group for each condition.

Conclusion

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136 Venkatraman, M. P. (1991). The impact of innovativeness and innovation type on adoption. Journal of Retailing, 67(1), 51.

The present preliminary research aimed to understand the impact of mentioning AR in an advertising campaign, without investigating the AR features and experience per se. We conducted an A/B test on Facebook with the same video ad for both campaigns, except for the mention of the AR experience in the tested ad. The findings demonstrated how powerful AR is in activating the curiosity of the users. This might be because of the relative novelty of the use of the technology in advertising[137].

We found that the simple mention of the existence of the AR experience in the text of the post and the call to action button placed by Facebook was enough to increase in 92% the engagement with the post (not considering the engagement with the AR feature) compared to the regular video ad post. It is worth mentioning the campaigns did not target users according to their interests or any demographic criteria, instead, they were simply spread among Facebook users, and it was not shown beforehand how the AR feature was. This makes the findings even more interesting. However, the results also raised a concerning issue. Fewer people watched the video for at least 15 seconds in the group of the AR ad than the regular ad group. One suggestion for marketers is to embed the ad message that must be delivered also in the AR experience. But we stress that this study was a pilot, and more research is needed to confirm the findings.

This research has the strength of having high ecological validity since it was conducted in the field. Although this brings unbiased results compared to an artificial laboratory experiment, it also has shortcomings. We were neither able to ask users nor measure their perceived experience and attitude towards the ad and the AR experience, and the reasons that led them to engage with the experience. Moreover, we do not know whether there are differences in behavior depending on the context the user was when received the advertising post. Therefore, the next steps of this research project involve both a behavioral and a neurophysiological experiment in a controlled setting and the assessment of the impact of different AR features.

Acknowledgements

The authors gratefully acknowledge the financial support of Rhumbo (European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie Grant Agreement No 813234).

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Rehabilitation of Carpal Tunnel Syndrome with the Rubber Hand Illusion in Virtual Reality

Jolanda Tromp[1], Andres Molina[2], Guzman Alba[2], Ma Lupiáñez[2], Pedro Cano[2], and Miguel Angel Muñoz[2]

[1]Duy Tan University, Da Nang, Vietnam
[2]University of Granada[2], Granada, Spain

Corresponding author: jolanda.tromp@duytan.edu.vn

Keywords: Carpal Tunnel Syndrome, Rubber Hand Illusion, Virtual Reality, Visuotactile-Proprioceptive Integration, fMRI.

The rubber hand illusion has been used successfully to treat phantom limb pain in amputees and experimentally in other chronic pain diseases. The logic of this intervention consists in the assimilation by the patient of the artificial hand, so that it is perceived as their own, while the de-differentiation of the real hand occurs. In this way, the brain generates new connections incompatible with the sensory processing of pain.

The Rubber Hand Illusion (RHI) was developed by Botvinick & Cohen in 1998[138]. Participants assimilate a fake hand as their own, through a process of embodiment. In their study, the participants sat with their left arm extended on a table, and a screen to hide it from the subject's view. In turn, on the side of the screen that the subjects could see, there was a life-size rubber hand (left hand). The task consisted of stimulating both hands (the real one and the rubber one) in a synchronized way. After a period of stimulation, the participants began to perceive the rubber hand as their own and there were changes in the participant's embodiment. The illusion depends on visuotactile-proprioceptive integration that obeys key spatial and temporal multisensory rules confined to near-personal space. Clinical fMRI studies reveal that illusion increased activity in regions related to the integration of multisensory body-related signals, most notably the bilateral ventral premotor, intraparietal, and cerebellar cortices.

The objective of our project is to develop a virtual reality environment to treat the pain present in one of the most prevalent compressive neuropathies, "Carpal Tunnel Syndrome": a debilitating entrapment of the median nerve in the carpal tunnel. The incidence of this condition has been estimated to be as low as 0.1% to as high as 10%.

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[138] Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel'touch that eyes see. Nature, 391(6669), 756-756. https://doi.org10.1038/35784

Treatments for patients experiencing carpal tunnel syndrome include physical and manual therapy, drug therapy, behavioural and occupational interventions, and surgery to decompress the carpal syndrome in severe cases. Our project explores pain-management via the opportunity of retraining the brain based on neuroplasticity principles, to reset, manage and learn how to moderate the pain experience, using virtual reality technologies. Neuropathic pain (NP) is often severe and represents a major humanistic and economic burden, especially considering the direct and indirect costs, productivity loss, and humanistic impact on patients and their families.

The traditional RHI experiment[138], consists of two phases: training and evaluation. Both presented in the same order and repeating in two different conditions. The conditions differ in the position of the artificial hand:

- congruent condition: the artificial hand is placed in the same position as the subject's hand
- incongruous condition: the artificial hand is placed differently from the subject's

The training phase consists of stimulating the fingers of the subject's hand and those of the artificial hand, stroking them synchronously with some type of brush or similar. While in the evaluation phase, brain activity and physiological responses resulting from training are evaluated by stimulating the artificial rubber hand or the real hand in an alternative way. For the purpose of our project, this procedure had to be adapted in order to be used in a VR environment, because with VR, the experimenter does not interact directly with the participant being stimulated, nor touch their hand, because the real hand wears a vibrating glove and mimics the stimulation of the artificial hand in this case the virtual arm and hand.

In addition, the distinction of the two separate phases and two scenarios had to be developed: the training phase with the aim of getting the subject to get used to virtual hands to achieve the induction of embodiment, and the evaluation phase to measure the extent to which the application is successful. A software application was created in Unity supported by Oculus Rift immersion technology and hand virtualization hardware in virtual environment, Leap Motion. The program consists of two scenes, the training one with the objective of getting the subject to get used to virtual hands to achieve the induction of embodiment and the evaluation one to measure the extent to which this phenomenon has been achieved.

Furthermore, a vibration stimulator glove was made that made it possible to replicate vibrational stimulation in the virtual world in the real world. The participant's hand is stimulated by means of vibration and temperature emitters placed in a glove that they are wearing and, in turn, the virtual hand is stimulated by means of a vibrating pencil represented in the same environment. The incongruous condition has been maintained in this case, so that the virtual hand can be turned the other way around as the participant has it, as well as the condition that hands are stimulated or only the virtual hand but not the real one has been maintained, and vice versa. In addition, in order to measure the experiences of the participants, we developed a pictorial measurement scale to assess it (Figure 32). The evaluation phase has remained as faithful as possible to how it is done in the classic experiment, recreating a simulation of it.

How much did you feel the artificial hand was yours?

Figure 32. Pictographic Scale developed by the researchers for the CPS RHI VR experiment[139]

We report here briefly on the first results from our pilot test of the VR setup. In our first pilot study a group of 12 participants (age 20-26), group A (n=6), underwent the training phase of the traditional procedure for 4 minutes. Group B (n=6) was assigned to the virtual hand procedure, remaining in the training phase for 4 minutes. Via this link a video of the user experience and user interface is available for viewing:

https://consigna.ugr.es/f/KTdVdycXaP9eArds/video%20tfg%20completo.mp4

We developed the RHI pictographic scale to assess the level of embodiment that they experienced with respect to the false hand (whether it was virtual or rubber), in order to determine to what extent the virtual procedure is efficient with respect to the classic one. At the end of the 4 minutes of play, the participant was asked to remove their virtual reality glasses, and they were asked to answer on a pictographic scale of 9 values (see Figure 32), how attached their virtual hand felt. For group A and group B, the mean of the results of each group was respectively Virtual M 7.2, SD 0.89; Classic M 5.8, SD 3.82. Indicating that the virtual reality condition scores as the most realistic according to the participants, while in the classic setting the high standard deviation suggests that some participants had a bad ownership experience with the rubber hand, while most had a good experience, but on average the virtual reality setting generated the highest ownership scores on our RHI scales. While we report these pilot study early descriptive results here, further empirical longitudinal R&D is ongoing, to design and run the VR RHI rehabilitation experiments. As with all longitudinal data-collection, tool calibration is time consuming and important, especially as the experiment is repeated over time on a regular basis and errors can be costly and irreversible. Additionally, a balance between collecting quantitative data and qualitative data must be met, to which end we rigorously develop and test our evaluation methodology and measurement tools of the experimental VR setup.

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Demos

The interplay between Virtual Reality and Eye-tracking technologies in substance use disorders: The ALCO-VR project

Alexandra Ghiţă[a], Jolanda Ruiz[a], Olga Hernández-Serrano[b], Marta Ferrer-García[a], Bruno Porras-García[a], Miquel Monras[c], Lluisa Ortega[c], Silvia Mondon[c], Lidia Teixidor[c], Antoni Gual[c], and José Gutiérrez-Maldonado[a]

[a]*Department of Clinical Psychology and Psychobiology, University of Barcelona, Spain*
[b]*Department of Physical Therapy, EUSES University of Girona, Spain*
[c]*Addictive Behaviors Unit, Hospital Clinic of Barcelona, Spain*

Corresponding author: jgutierrezm@ub.edu

Keywords: Alcohol use disorder, alcohol craving, attentional bias, clinical trial, ALCO-VR.

The "ALCO-VR" project

A growing body of evidence has shown the clinical potential of using the Virtual Reality (VR) technology in individuals with substance use disorders. VR has drawn attention for the past two decades as an assessment or treatment instrument in the field of addictions[140]. In alcohol use disorder (AUD), VR is particularly applied as a tool to explore alcohol craving, described in the literature as being an intense, unbearable desire to consume alcohol[141]; and as a treatment instrument to enhance cue-exposure therapy[142]. Attentional bias (AB), alcohol craving and anxiety are heavily involved in the development and maintenance of alcohol drinking patterns and interfere with abstinence during and after treatment discharge[143].

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[140] Hone-Blanchet, A., Wensing, T., & Fecteau, S. (2014). The use of virtual reality in craving assessment and cue-exposure therapy in substance use disorders. Frontiers in human neuroscience, 8, 844. https://doi.org/10.3389/fnhum.2014.00844
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To address the recent interest in novel technologies applied in the assessment and treatment of AUD, the "ALCO-VR" project is the first project in Spain aiming to develop a Virtual Reality-Cue Exposure Therapy (VR-CET) for resistant to treatment-as-usual (TAU) patients diagnosed with severe AUD. The emphasis of the project is to reduce contextual alcohol craving and associated anxiety, which facilitate alcohol use in daily-life situations and to prompt changes in AB patterns toward alcohol-related stimuli. The "ALCO-VR" software consists of two parts: assessment and therapy.

The "ALCO-VR" project consists of four studies. Each study emphasizes different steps of the project. The last study of the project, a clinical trial, aims to test the efficacy of VR-CET versus Cognitive-Behavioral Therapy (CBT) in patients diagnosed with TAU patients diagnosed with severe AUD.

The first study of the project (N = 75) aimed to identify alcohol craving triggers (alcohol-related cues and contexts) in AUD patients. Based on this study, the "ALCO-VR" software was designed consisting of four VR environments (a pub, house, restaurant and a bar), with different characteristics (e.g., social interaction, daytime/nighttime, menu of alcoholic beverages).

The second study detailed a series of experiments. The aim of this study was to design a Visual Attention Task (VAT) to assess AB in light versus heavy drinkers (N = 30), occasional social drinkers versus AUD patients (N = 48) using the eye-tracking technology. The main eye-movement variables in this study were first fixation, number of fixations and dwell time in a VAT consisting alcohol and neutral images. The VAT resulted from this study was implemented in the last study of the ALCO-VR project, a clinical trial, to explore changes in eye-movement activity before and after the VR-CET intervention.

The third study (N = 27) emphasized the results of the first ALCO-VR study and aimed to validate the ALCO-VR platform in AUD patients and a control group. Particularly, we were interested to assess if the software induced alcohol craving and anxiety responses among AUD patients.

The last study of the ALCO-VR project is based on the results of the previous three studies. The aim of the current clinical trial is to test the efficacy of the VR-CET approach by using the ALCO-VR platform vs. CBT in TAU patients diagnosed with severe AUD. The second and third studies were introduced in the clinical trial as assessment instruments to demonstrate the clinical potential of Virtual Reality applications in mental health care.

Figure 33. Four main virtual environments of the ALCO-VR software.

The project is conducted at two sites: VR-PSY Lab, University of Barcelona and Addictive Behaviors Unit, Hospital Clinic of Barcelona. The first three studies are concluded and the last study is an ongoing clinical trial and results will be available early 2021. The ultimate aim of the ALCO-VR project is to promote long-term abstinence maintenance among AUD patients.

Customizable Vision Correction for Macular Degeneration using Mixed Reality

Rick Hindriks, Tessa Klunder, Lucia Tealdi, and Madelon Molhoek

TNO, Den Haag, The Netherlands

Corresponding author: rick.hindriks@tno.nl

Keywords: Macular degeneration, mixed reality, see-through, personalized, vision.

Abstract

Worldwide, Macular Degeneration (MD) is the third leading cause of blindness and visual impairment[144]. People affected by MD typically suffer from deformations and partial blindness in their visual field, however, part of the visual field often remains fully available[145]. We present a design for a mixed reality system based on off-the-shelf components which can transform live recorded images before showing them to the user. This allows us to counteract some of the visual field deformations caused by MD. Our system is highly configurable, which enables personalization of the applied distortion corrections. We demonstrate the potential of the system design by constructing a prototype implementation.

Introduction

The group of medical conditions known as Macular Degeneration (MD) affect the macula of the human eye. The main symptoms are distorted vision, blurred vision, loss of sensitivity to contrast and partial loss of vision. As the macula is responsible for detailed vision in the center of the visual field, these symptoms are typically noticed in that area. The condition impacts day-to-day life functions, such as reading and face recognition. The most common form of MD is known as Age-related Macular Degeneration (AMD), in patients with AMD, symptoms usually appear gradually and worsen over time. Furthermore, the order and specific location of deformations and loss of vision is specific to each patient.

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[144] World Health Organization (WHO). (2012). Global data on visual impairments 2010, Geneva, 1-5

[145] Mitchell, P., Liew, G., Gopinath, B., & Wong, T. Y. (2018). Age-related macular degeneration. The Lancet, 392(10153), 1147-1159. https://doi.org/10.1016/S0140-6736(18)31550-2,

The visual deformations caused by Macular Degeneration are typically mapped using an Amsler grid[146]. Such a grid can be used to measure deformations and loss of vision as shown in Figure 34.

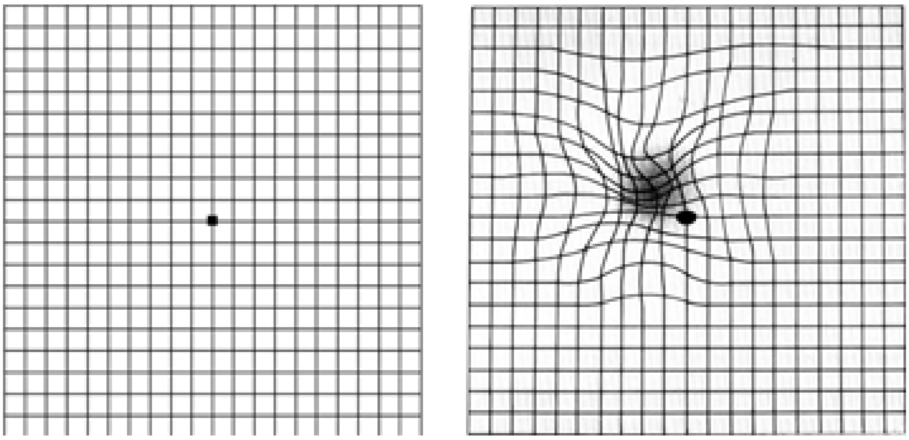

Figure 34. Two Amsler grids. A regular grid to the left, and one showing visual deformation and loss of vision to the right.

Given that we can use Amsler grids to measure and describe the deformations caused by MD, we may be able to also describe the inverse of the deformations as well. To accomplish this, we will outline a mathematical model for visual deformations in the System Design section. We use this model to derive the inverse visual deformations for any input Amsler grid, which provides base for a system to cancel out the deformations caused by MD. This approach would allow us to increase the quality-of-life for early-stage AMD patients.

We present such a VR-based system using off-the-shelf components. The HMD is capable of displaying live recorded video from stereo cameras and is able to apply visual deformations to the recorded video in real-time. We calibrate the system to apply the inverse deformation generated with the method above in order to cancel out the given set of visual distortions.

Related work

In the literature several works can be found where AR and VR systems have been developed to simulate the effect of visual impairments, for different goals and in different context: as an example[147] test the effectiveness of escape route signals for visually impaired people using

[146] Amsler, Marc. 1949. Quantitative and Qualitative Vision. Headley Brothers

[147] Krösl, K., Bauer, D., Schwärzler, M., Fuchs, H., Suter, G., & Wimmer, M. (2018). A VR-based user study on the effects of vision impairments on recognition distances of escape-route signs in buildings. The Visual Computer, 34(6-8), 911-923. https://doi.org/10.1007/s00371-018-1517-7

simulations, Jones[148] and Stock et al.[149] propose simulations as a teaching tool, and Väyrynen et al.[150] propose the same to support designers to better understand users' needs.

Developing AR/VR systems to counteract the effect of visual diseases is a different and much more difficult problem, since the models and techniques used have to be tailored to specific situations and to specific patients. Deemer et al.[151] describe recent results in building low vision enhancement systems using head mounted video display systems, and highlight which challenges have to be addressed to develop effective and usable tools. Lodato en Ribino[152], González[153], and Gupta[154] present possible solutions to those challenges.

System Design

Our system is designed to demonstrate the principle of applying inverse transformations to a video stream in real-time. Intuitively, applying such as system to MD suggests that an AR-based approach may be favorable, as we would like to replace only part of the wearer's field of vision. However, current off-the-shelf AR glasses do not contain a high-resolution stereo camera for recording three-dimensional video, which is required for applying transformations to the users' view.

Therefore, in order to prove our concept, we opted to use a similar solution known as see-through VR, in which we use a regular VR Head-Mounted Display. In order to observe the outside world, we display the view recorded by stereo cameras which are attached to the HMD. An overview of the resulting system architecture is shown in Figure 35.

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[148] Jones, P. R., & Ometto, G. (2018, March). Degraded reality: using VR/AR to simulate visual impairments. In 2018 IEEE Workshop on Augmented and Virtual Realities for Good (VAR4Good) (pp. 1-4). IEEE. https://doi.org/10.1109/VAR4GOOD.2018.8576885

[149] Stock, S., Erler, C., & Stork, W. (2018, November). Realistic simulation of progressive vision diseases in virtual reality. In Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology (pp. 1-2). https://doi.org/10.1145/3281505.3283395

[150] Väyrynen, J., Colley, A., & Häkkilä, J. (2016, December). Head mounted display design tool for simulating visual disabilities. In Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia (pp. 69-73). https://doi.org/10.1145/3012709.3012714

[151] Deemer, A. D., Bradley, C. K., Ross, N. C., Natale, D. M., Itthipanichpong, R., Werblin, F. S., & Massof, R. W. (2018). Low vision enhancement with head-mounted video display systems: are we there yet?. Optometry and vision science: official publication of the American Academy of Optometry, 95(9), 694. https://doi.org/10.1097/OPX.0000000000001278

[152] Lodato, C., & Ribino, P. (2018). A Novel Vision-Enhancing Technology for Low-Vision Impairments. J Medical Systems, 42(12), 256. https://doi.org/10.1007/s10916-018-1108-1

[153] González, M. (2011). Advanced Imaging in Head-Mounted Displays for Patients with Age-Related Macular Degeneration (Doctoral dissertation, Technische Universität München, Germany).

[154] Gupta, A. (2016). Head Mounted Eye Tracking Aid for Central Visual Field Loss. (Master Thesis, University of Minnesota, USA).

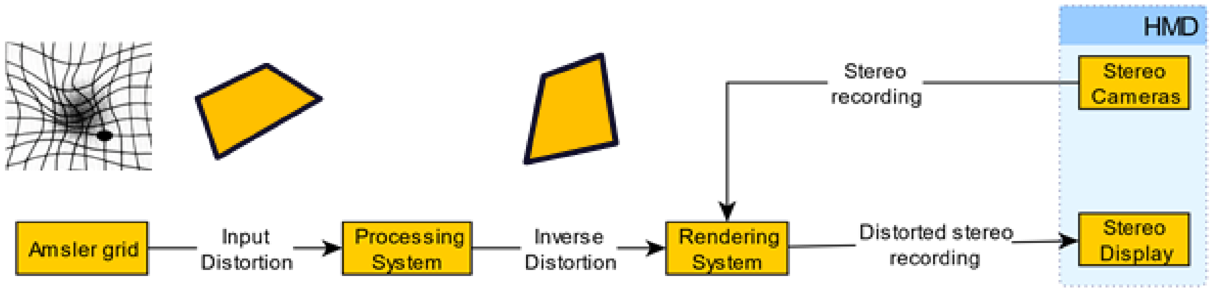

Figure 35. The system processing architecture. The distortion examples are indicative

We decided to use the Valve Index, which is an off-the-shelf state-of-the-art VR HMD. The Index includes built-in cameras which allow capturing the outside world in stereo 3D. We pass the recorded feeds directly into a 3D rendering pipeline, which is configured to apply a transformation using a fragment shader.

To bootstrap the system, we need to calculate the visual transformations required to aid the current user. To this end, we use a centralized processing system which receives as its input an Amsler grid represented as a displacement vector field, which defines the displacement of each node on the grid.

Using this vector field, the processing system calculates the inverse transformation which would cancel out the transformation described by the Amsler grid as shown in Figure 36. Several methods can be found in the literature to deform an image by some control points, see for example Schaefer et al.[155] [12]. Selecting the appropriate transformation for our purpose requires testing with patients.

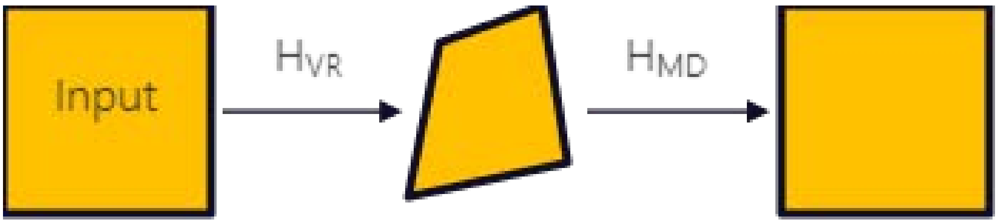

Figure 36. A schematic overview of the transformation process. The system transformation (HVR) is calculated such that when the transformation specified by the Amsler grid (HMD) is applied to its result, the original image is obtained.

Next, the processing system configures the fragment shader to apply that transformation on the stereo recording. This allows the rendering system to apply the transformation in real-time.

[155] Schaefer, S., McPhail, T., & Warren, J. (2006). Image deformation using moving least squares. In ACM SIGGRAPH 2006 Papers (pp. 533-540). https://doi.org/10.1145/1179352.1141920

Discussion

We were able to constructe a proof-of-concept prototype based on the outlined system design. As of yet, we have been unable to test our prototype with actual patients, which prevents us from using a validated transformation system. Therefore, we have opted to validate the system pipeline by using test inputs instead. We simulate the visual field of a fictive patient using a generated Amsler grid, and configure our system to apply the inverse of that transformation.

We display test input (an Amsler grid) displayed on a monitor. When using the prototype and looking directly at the display, the prototype is able to correct the distortion caused by the test input which therefore appears as being straight. A demonstration is shown in Figure 37.

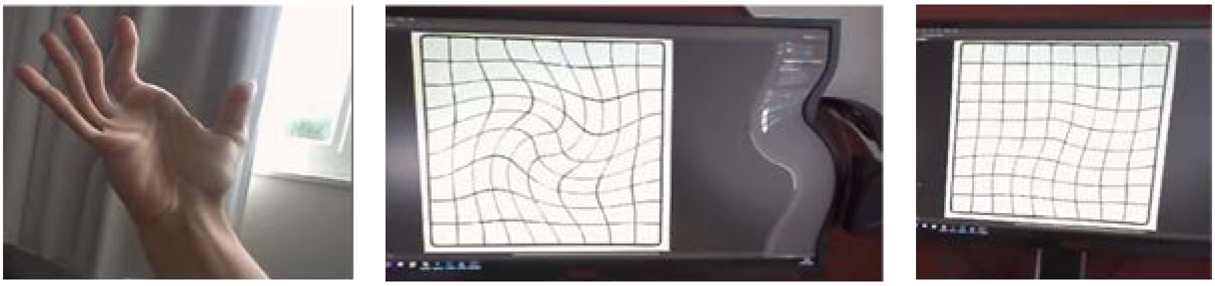

Figure 37. Sample system outputs as observed from the prototype. From left to right: the applied deformation, the input Amsler grid, the corrected Amsler grid.

Conclusion

We have presented the system architecture for a see-through VR-based system which is capable of generating and displaying pre-distorted images such that they cancel out a given set of distortions as specified by an Amsler grid. This allows our system to be tailored to individual MD patients.

Based on our preliminary validation using a proof-of-concept prototype, we expect that a system such as ours may be beneficial to patients who suffer from an early stage of Macular Degeneration. We observe that more work is required to determine a more comprehensive transformation implementation which needs to be fast, robust and reliable; our validation indicates that this may be attainable.

Modifying body-related attentional bias among patients with Anorexia Nervosa. A Virtual Reality and Eye-Tracking based research

Bruno Porras-Garcia[a], Marta Ferrer-Garcia[a], Eduardo Serrano-Troncoso[b], Marta Carulla-Roig [B], Pau Soto-Usera[b] , Isabel Sanchez-Díaz[c], Fernando-Fernandez Aranda[c], and José Gutiérrez-Maldonado[a]

[1]*Department of Clinical Psychology and Psychobiology, University of Barcelona, Spain*
[2]*Department of Child and Adolescent Psychiatry and Psychology, Hospital Sant Joan de Déu of Barcelona, Barcelona, Spain*
[3]*Department of Psychiatry and Mental Health, Hospital de Bellvitge, Barcelona, Spain*

Corresponging author: gutierrezm@ub.edu

Keywords: Anorexia Nervosa, attentional bias modification training, clinical trial, Virtual Reality and Eye-Tracking.

The "AN-VR-Gaze" project

In a phenomenon known as attentional bias (AB), described as the propensity to pay more attention to certain types of stimuli or information (e.g., disorder-relevant information) over other sorts of information[156], adult and young patients with Anorexia Nervosa (AN) show a tendency to focus more on self-reported unattractive body parts than other body parts[157],[158],[159]. Dysfunctional body-related AB presumably maintains body image disturbances, usually reported

[156] Williamson, D. A., White, M. A., York-Crowe, E., & Stewart, T. M. (2004). Cognitive-behavioral theories of eating disorders. Behavior modification, 28(6), 711-738. https://doi.org/10.1177/0145445503259853
[157] Jansen, A., Nederkoorn, C., & Mulkens, S. (2005). Selective visual attention for ugly and beautiful body parts in eating disorders. Behaviour research and therapy, 43(2), 183-196. https://doi.org/10.1016/j.brat.2004.01.003
[158] Tuschen-Caffier, B., Bender, C., Caffier, D., Klenner, K., Braks, K., & Svaldi, J. (2015). Selective visual attention during mirror exposure in anorexia and bulimia nervosa. PLoS One, 10(12), e0145886. https://doi.org/10.1371/journal.pone.0145886
[159] Bauer, A., Schneider, S., Waldorf, M., Braks, K., Huber, T. J., Adolph, D., & Vocks, S. (2017). Selective visual attention towards oneself and associated state body satisfaction: an eye-tracking study in adolescents with different types of eating disorders. Journal of Abnormal Child Psychology, 45(8), 1647-1661. https://doi.org/10.1007/s10802-017-0263-z

by patients with AN, by processing only body information that is consistent with dysfunctional cognitive schema content (such as, *I am getting a fatter belly*), while schema-inconsistent information (e.g., *I am getting thinner*) is not equally noticed or processed, usually being visually neglected[156],[160].

Dysfunctional body-related AB may be responsible for decreasing the effectiveness of body exposure-based treatments used in patients with AN. For this reason, it is necessary to develop new treatment techniques by adding specific components that aim to reduce the body-related AB. In a previous project conducted by our group, preliminary evidence was found in favor of a body-related AB modification among patients with AN, after a Virtual Reality (VR)-based mirror-exposure intervention. A key aspect to understand these results might rely on the procedure conducted, in which, patients had to focus on different parts of the virtual body (from the head to the shoes) and were asked to orally express what they though and felt about those body areas.

The current project aims to go further, and includes AB modification techniques within the body exposure therapy, as an effective treatment to reduce body-related AB, body dissatisfaction and body anxiety among patients with AN. To the date, our group has been the first, to use a combination of virtual reality (VR) and eye-tracking (ET) techniques to assess the presence of a body-related AB in clinical and non-clinical samples. Specifically, this project aims to assess whether adding two separate components of body exposure-based therapy and AB modification training would result in a more effective intervention. It is expected that, adding an AB modification training in the body-exposure based procedure (experimental group), will further increase the effectiveness of the treatment compared with the treatment as usual (control group). Specifically, after comparing measures before and after the treatment, it is expected that patients at the experimental group would show a significant increase in BMI values, and a significant reduction of other AN symptomatology (e.g., fear of gaining weight, body image disturbances) and body-related AB, compared to the group control. Likewise, it is expected that these changes will be maintained at the follow-up after six-month.

The project will be conducted at the VR-PSY Lab, University of Barcelona, and the Eating Disorders Units of the Hospital Sant Joan de Déu of Barcelona and Hospital de Bellvitge.

Patients with AN will be exposed to immersive virtual using a VR head mounted display (HTC-PRO Eye) with a precise ET included. In addition to the two controllers that HTC-PRO usually provides, three additional body trackers will be used to achieve full body motion tracking. The virtual environment will consist in a room with a large mirror on the front wall. The mirror will be large enough to reflect every limb of the body and will be placed 1.5 m in front of the patients. A young female avatar wearing a basic white t-shirt with blue jeans and black trainers will be created.

The following procedure will be conducted at the assessment sessions. The virtual avatar will be generated by taking a frontal and lateral photo of the patient and creating an avatar whose silhouette matched the pictures by adjusting the different parts of its silhouette to the photographs. In the meantime, the other therapist will administer the pre-assessment

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[160] Rodgers, R. F., & DuBois, R. H. (2016). Cognitive biases to appearance-related stimuli in body dissatisfaction: A systematic review. Clinical Psychology Review, 46, 1-11. https://doi.org/10.1016/j.cpr.2016.04.006

questionnaires and answer the patient's questions. Next, the full body illusion (FBI) over the virtual body will be induced using two different procedures, a visuo-motor and visuo-tactile stimulation, both procedures will last three minutes (see Figure 38). Once the FBI is induced, the three visual analog scales (VASs) examining intensity of the FBI, body-related anxiety, and the fear of gaining weight will be assessed. Finally, to assess the body-related attentional bias, participants' gaze will be tracked while they are asked to observe their virtual body in the mirror for 30 s. During the process, and as a cover story, the participant will be told to remain still and avoid abrupt head movements while the virtual avatar position is being recalibrated.

Regarding the treatment, all sessions will last approximately one hour and will take place once a week. All sessions will start by inducing the FBI and assessing the VASs. Exposure treatment on the body will start with a virtual body with the same BMI as the patient. The AB modification training will be based on an adaptation of the AB induction procedure proposed by Smeets, Jansen and Roefs (2011). The training will be developed through the visual selection of geometric figures (e.g. square, rectangle, circle) that fit approximately with specific parts of the body. Each of these figures can have different colors. Specifically, the patient must detect and identify the figures that will appear in different parts of the avatar's body (Figure 39). In half of the trials, the shape of the figure must be discriminated and in the remaining 50% the discrimination will be based on color. Throughout training, the geometric figures will appear on weight-related body parts in 45% of the trials, and in another 45% of the trials it will appear on non-weight-related body parts. In the remaining trials (10%), the test will appear on one of three neutral stimuli located next to the avatar.

The AN-VR-Gaze software is currently under development. Still, the demo that will be presented at the EUROVR conference will allow participants the opportunity of illustrating and clarifying some of the procedures that will be conducted during the study. For instance, the photography procedure, the procedures used to induce the FBI and the AB modification task.

ET raw data will be transformed into suitable quantitative data using the Ogama (Open Gaze Mouse Analyzer) software. Previously weight-and non-weight related areas of interest (AOIs) will be defined. Weight-related AOIs will be defined based on the weight scale of body items from the PASTAS questionnaire[161] and drawn onto a picture of a female avatar in a frontal view. Body parts included in the W-AOIs will be the legs, thighs, buttocks, hips, stomach (abdomen) and waist. After the separation of the weight-related-AOIs, the remaining body parts (head, neck, chest, shoulders, arms, and feet) will be labeled as non-weight-related AOIs. Participants' selective visual attention will be measured using the complete fixation time and number of fixations on the areas of interest (AOIs).

[161] Reed, D. L., Thompson J. K., Brannick, M. T., & Sacoo, W. P. (1991). Development and Validation of the Physical Appearance State and Trait Anxiety Scale (PASTAS). Journal of Anxiety Disorders, 5(4), 323-332. https://doi.org/10.1016/0887-6185(91)90032-O

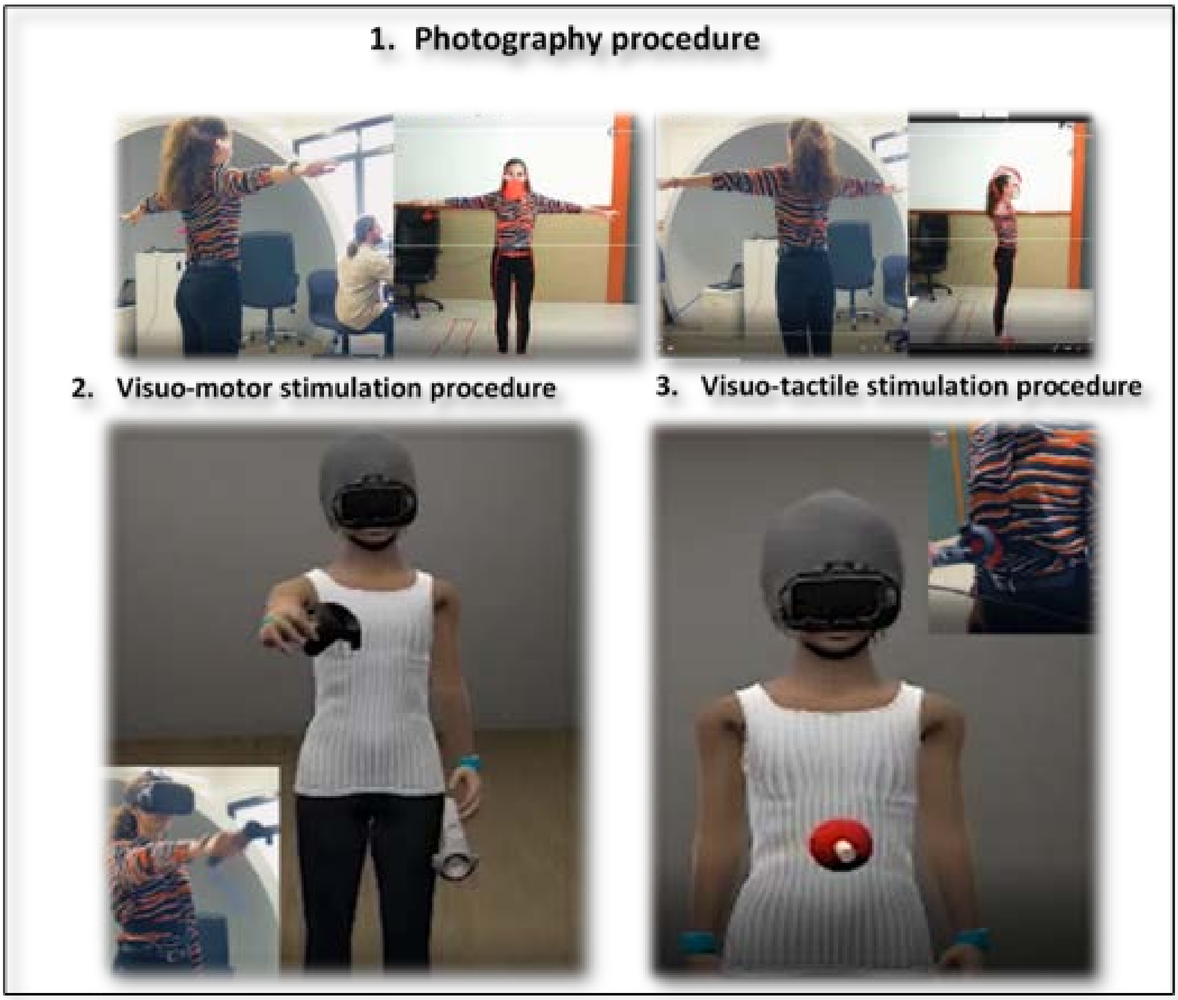

Figure 38. Picture of the procedure to create the virtual body and to induce full body illusion.

Figure 39. Attentional Bias modification training through Virtual Reality

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Series title and number

VTT Technology 381

Title	**EuroVR 2020 Application, Exhibition & Demo Track** Proceedings of the Virtual EuroVR Conference
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EuroVR 2020 Application, Exhibition & Demo Track

Proceedings of the Virtual EuroVR Conference

The 17th EuroVR International Conference – EuroVR 2020 – taking place on 25-27 November 2020 organized by the Polytechnic University of Valencia, Spain. The conference follows a series of successful European VR/AR conferences taking place since 2004 and known as INTUITION, JVRC and recently EuroVR (Bemen 2014, Lecco 2015, Athens 2016, Laval 2017, London 2018, and Tallinn 2019). The Immersive Neurotechnologies Lab (LabLENI) of the Polytechnic University of Valencia (UPV), Spain, is organizing the 2020 virtual edition of this conference.

EuroVR 2020 will bring together people from research, industry, and commerce. Its members include technology developers, suppliers, and all those interested in Virtual Reality (VR), Mixed Reality (MR), including Augmented Virtuality (AV) and Augmented Reality (AR), and more globally 3D user interfaces, to exchange knowledge and share experiences, new results and applications, enjoy live demonstrations of current and emerging technologies, and form collaborations for future work.

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