THE 5TH INTERNATIONAL CONFERENCE OF THE VIRTUAL AND AUGMENTED REALITY IN EDUCATION

SEPTEMBER 18-20, 2019
LISBON, PORTUGAL

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PRINTED IN RENDE (CS), ITALY, SEPTEMBER 2019

ISBN 978-88-85741-42-3 (Paperback)

ISBN 978-88-85741-42-3 (Paperback)
ISBN 978-88-85741-41-6 (PDF)

International Conference of the Virtual and Augmented Reality in Education

September 18-20, 2019

Lisbon, Portugal

Organized by

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WELCOME TO VARE 2019!

On behalf of the Organizing Committee it is a great honor and pleasure to wish you a warm welcome The 5th International Conference on Virtual and Augmented Reality in Education (VARE) held in Lisbon, Portugal.

VARE is an event that brings together trainers in all areas of knowledge and educational levels as well as researchers and scientists from virtual technologies and advanced visualization and virtualization technologies.

The upcoming 5th edition brings to Lisbon prestigious speakers from all over the world addressing the most important advances in the field of extended reality, video-mapping, augmented reality, visual analytics, virtual reality and virtual visualization.

Through its scientific sessions, VARE will provide meaningful insights on current research trends and, in turn, it will contribute to new research directions encouraging constructive debate and synergies among subject matter experts.

Lastly, but by no means least, our host city Lisbon, known for its beautiful architecture with its wealth of monuments and an abundance of cultural attractions, provides the ideal framework to host such event.

Our sincere thanks, to the conference organizing committee for their dedication and hard work in creating an excellent scientific program.

We are very pleased to welcome you all for what promises to be an outstanding educational event.

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Riga Technical University

Jorge Martin Gutierrez
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Monterrey Institute of Technology

ACKNOWLEDGEMENTS

The VARE 2019 International Program Committee (IPC) has selected the papers for the Conference among many submissions; therefore, based on this effort, a very successful event is expected. The VARE 2019 IPC would like to thank all the authors as well as the reviewers for their invaluable work.
A special thank goes to all the organizations, institutions and societies that have supported and technically sponsored the event.

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SYNERGY OF DIGITAL ART, ARCHITECTURE AND DESIGN USING VIDEO-MAPPING IN A COMBINED CLASSROOM

Héctor Nahún Quintero Milián[(a)], Nora Argelia Aguilera[(b)], Pablo Guillermo Ramírez Flores[(c)], Samira Hosseini*

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ABSTRACT
Technological advances within educational domains permit new teaching systems to emerge. Video-mapping is a technique that involves projecting images on three-dimensional surfaces through motion effects. In the case of architectural projects, there are very few uses of video-mapping that focus on urban planning and even fewer when the mapping is interactive. However, it is crucial to scale new ways of interpreting design using technologies such as video-mapping. In this research work, the themes of virtual environments, spatial representation, and basic design are combined with video-mapping. Students from the Digital Art and Architecture and the Industrial Design programs worked together in this effort, creating an architectural model made with 3D impressions; the users interacted and selected from the options of colors and textures available for the model city, generating different presentations according to the changes in the settings of the video-mapping software. Thus, this project opened the doors to welcome digital artists into the world of architecture and urbanism.

Keywords: Educational innovation, Video-mapping, Interactive models, Interactive surfaces, Spatial representation, Ambient design, Augmented Reality, Higher Education.

1. INTRODUCTION

Students nowadays are interconnected and collaborate with their peers in the classroom using different types of technologies. Video projection is a tool to create interactive spaces and environments for learning that can be continuously updated according to the students' needs. It allows the professor to conduct tasks with fewer constraints than in the conventional methods involving monitors or screens. The interactions between the students and the instructors and among the students themselves are freer than in traditional classrooms. Furthermore, there is a higher level of creativity in teaching and in the delivered content, all of this expanding the potential of classrooms as learning spaces.

We define that video-mapping is a form of art that allows the combination of video and light that when projected onto a surface can transform the most ordinary data into dynamic scenes (Factura, Karsch, Jones, Reyneri, & LaPerche, 2018). This technology goes beyond the creation of animations of emblematic buildings.
Considering this, the objective of this project was to use video-mapping as a focal point to bring together the area of descriptive geometry and the creation of virtual scenarios for educational purposes (Roederer & Revat, 2019). One of the challenges of urban planning and architecture is finding ways to represent people, spaces, roads, and vehicles, etc. dynamically. By combining these elements with video-mapping, students and professionals have a new opportunity to visualize proposed changes and improvements to these new spaces.

Video-mapping and architecture many times go hand in hand due to the fact that most of the time, the work involves buildings, murals, and structures. In this case, the work was done on an architectural model with a different twist to what is customarily shown in a mapping exhibition (Rossi, Petrucci, & Fazzini, 2014). The focus of this project was to present multiple possibilities for buildings that are planned using scale models, whether

they are for commercial or residential use, in an urban area. Additionally, what was considered were the textures those models could carry and the location of the buildings with respect to the entry and exit points of the area. This video-mapping project allowed the Architecture and Design students to come together with the Digital Arts students to explore the possibilities that one can imagine within the model.
The purpose of this work was to develop a methodology using video-mapping technology that will be used in classrooms so that future students can use the technology and manipulate the projections on the 3D impressions that they have created and choose how the parts of the structure are divided and observe different textures on the various volumes so they can make design decisions.

2. PREVIOUS WORK

Portman et al. (2015) stated that virtual reality is ultimately a type of "visualization," a technique which has experienced a recent boom in professional and academic literature (pp. 376–377). Andreani et al. (2019) in their article, "Reframing technologically enhanced urban scenarios: A design research model towards human-centered smart cities," claim that "over the last few decades, technology has played a major role in the envisioning of urban scenarios as well as in affecting actual urban operations." The authors believe that future designs of urban developments based on technology would place the human experience as only "a side effect of the intervention of a smart city" (Portman, 2015). So, we can establish that video-mapping gives objects or buildings new forms by changing the perspectives of solid objects and by giving the impression of movement with the projection of light. Such technology generates enthusiasm in spectators because, on the same surface, different features can be simultaneously displayed.

Nofal et al. (2018) described that video-mapping could be used in different areas, as follows:

- Commercial – In interactive publicity for its use at public spaces.
- Artistic – Synchronized animations to trigger emotions and to entertain the audiences.
- Cultural – On-site projections (e.g. historical sites or museums).
- Social – Mapping of socio-demographic data to design the facade of a house.
- Politics – Demonstration of solidarity and sympathy by projecting patriotic symbols onto the country's representative buildings.
- Educational - Projection of synchronized images over tridimensional structures for full comprehension of content.

Projection mapping has been widely used to visualize real-world objects efficiently in various areas such as exhibitions, advertisements, and theatrical performances. To represent the projected content in a realistic manner, the user must consider the appearance of an object. Although there have been various attempts in computer graphics to use digital modeling realistically to show the appearance of materials, it is difficult to combine this with projection mapping because it takes a tremendous amount of time and requires ample space for the measurement. Junho Choi (2016) developed a realistic 3D projection mapping system using the reconstruction of the projector view based on the projector-camera correspondences and polynomial texture maps that can provide effective visualization.

The concept of video installation has emerged with the addition of video technology to combine so that space and art objects are exhibited together (Kaye, 2007). Installation, film, video, video-mapping, animation, Internet and networks, and art software are all new media technologies that do not have a very long history; the production of digital art from these digital platforms results in art that is interactive and dynamic (Tardieu et al., 2010). While digital art forms use technology as an "environment," this environment's possibilities and features reflect new techniques to be used for artistic purposes (Saglamtimur, 2010).

Geometry is needed for the construction of any object or building because the finished work has to be very precise. Teaching geometry is not easy at all, and every new generation has more problems with spatial understanding. With the new digital technologies, the young people are increasingly losing the sense between real, three-dimensional space and the two-dimensional one due to the fact that they are immersed long periods of time on flat screens of two dimensions. Howard Gardner (Gardner H., 1999) writes about this sense, calling it, "Spatial intelligence." Previous works of Patricia Salinas (P. Salinas, 2015) (Salinas Martinez Norma, 2017), and Pablo Ramirez (Pablo Ramirez, 2013) remark about the importance that spatial intelligence has in education. Therefore, the system of learning spatial representation must change to answer to the interest in the use of these new technologies (Aguilera González, 2015).
Augmented Reality (AR) and 3D Printing are the technologies that offer significant advances in the production of prototypes with respect to a spatial representation. A great advantage of applying such techniques is identifying and avoiding possible errors in the early design stages of a production process. This, in turn, results in reducing the number of physical prototypes, thus saving time and resources for companies. These techniques are valuable tools that improve and accelerate many processes (Aguilera González, Suarez-Warden, Quintero Milian, & Hosseini, 2018).

3. METHODOLOGY AND DESIGN PROPOSAL

In the course of "Descriptive Geometry," the objectives are the spatial visualization for the 3D representation, the modular conception for the reproduction of volumes in space, and the application of a project oriented to architecture. In the course of "Virtual Environments Design," what is sought is for students to show their acquired knowledge in virtual spaces and applications throughout the Digital Arts major. This is achieved by assigning them projects with various professors and clients from different areas of knowledge and specialties. In this case, the Digital Art students were assigned to collaborate with the students of Descriptive Geometry in the Architecture and Industrial Design curricula.

In this study, applying video-mapping in the teaching of spatial representation was targeted. As part of this challenge, students of the first semester of Architecture and Industrial Design were assigned together with students in the seventh semester of Animation and Digital Art. The Architecture and Industrial Design students made a modular representation of a residential and commercial sector while the Digital Art students produced a series of visual elements to project over the same buildings and layout within that sector. Therefore, the project was divided into two phases: (i) spatial representation of the buildings in physical form, and (ii) video-mapping of the proposed physical structures and buildings. In the second phase, the students comprehend how they work with this technique and commence to apply it through the learning of a video game in which the objective is to learn the basic concepts of Gestalt (Figure/Ground, Similarity, Proximity, Closure, Common Region, Continuity, Symmetry, Focal Point) and visual communication. The importance of this phase is to comprehend the basic principles of design applied through the functioning of a digital tool. Comprehending the principles of design and the representation of space are objectives to be achieved in the production of 3D models of urban areas in order to elaborate these features further in video-mapping.

The proposed space for this project is presented in Figure 1; it is a mix of multi-purpose buildings in an architectural space that consists of office buildings, departments, and public and commercial areas - the kinds of spaces that are current architectural trends in Mexico.

In the two groups of students, what was sought was for them to develop better the concepts of scale, space, dimension, and spatial visualization of an estate. That is why we started with the 3D modeling of the buildings made in the Descriptive Geometry class, then materialized them with the help of 3D printing, and used the models as a frame of reference for the proposal of the video-mapping project with the Digital Art students.

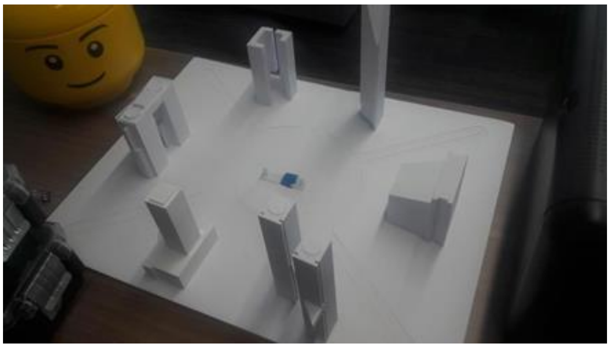

Figure 1: 3D-Printed architectonic model proposal

3.1. Modeling software tools

The 3D modeling software used was SketchUp, which is easy to use and has a fast learning curve, so there was little distraction from the learning of Descriptive Geometry. The students of Descriptive Geometry were in their first semester and therefore were ignorant about other digital tools similar to SketchUp. Thus, the students were motivated to develop their spatial intelligence at an early stage of their professional development by using software facilitating the production of 3D building models (Figure 2). This is in line with Howard Gartner's recommendations (Gartner, 1999).

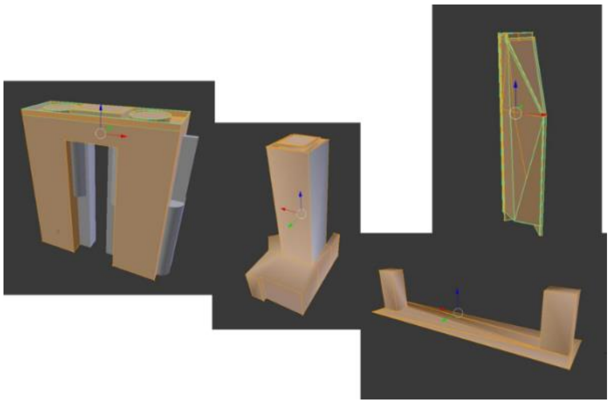

Figure 2: 3D model representation of buildings by Descriptive Geometry students.

3.2. 3D Printing software

For the 3D printing process, it was required to export to a .stl format, which needs to be processed into Solid Inspector, a plugin from SketchUp that allows a figure composed of different polygons to be converted into a solid object to ensure that the 3D printing process will be useful and will not cause a problem. In the Cura software for 3D printing, when importing the models, they are visualized, and their consistency is seen whether the figures are solid or hollow, so the printing time, the external quality of the model, and its scale can be calculated.

To understand the process to follow, the students did practice exercises of their designs to be able to ensure that the final models would come out with correct proportions and adequate quality (Figure 3).

Figure 3: 3D Printed buildings.

SketchUp digital files were exported in .dae and .obj format so that Digital Art students could start working with them in their practice sessions and texture simulations. For this, Autodesk Maya 2018 software was used to generate the UV's (texture maps) that are used in the Adobe Photoshop CC software, where the texture maps for the buildings were generated. Figure 4 presents a sample of textures and the corresponding UV maps of some buildings. The models had to be redone because the normal maps were flipped, and the UV maps could not be obtained due to the fact that there were some errors in the modeling process. So the students from Digital Arts had to recreate some of the pieces so that they could be appreciated in the projection and the textures could be displayed.

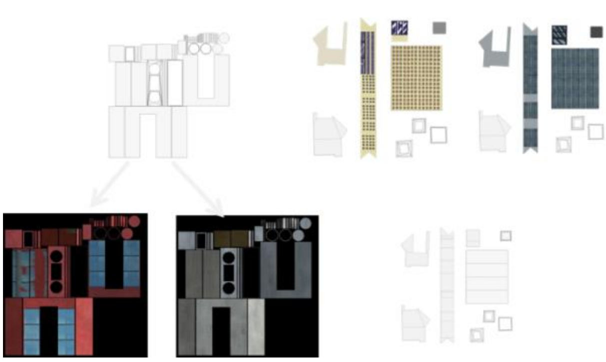

Figure 4: Samples of UV maps and textures for buildings.

3.3. Virtual space integration and user interface

Unity3d was used to integrate the virtual space, define the user interactions, and generate the projection layers for the video-mapping software. The user interface has a main window and four sub-windows, one for each building projection and the other for ground-plane point-of-view.

For video-mapping projection, we used VPT8 software because it is free, and to connect Unity3D with VPT8, we selected KlakSpout plugin (or Syphon for Mac) because it allows connection in a simple way and with excellent response time. We tried other software such as Millenium for Unity3D, but unfortunately, the performance was not usable for the purpose. VPT8 has a limitation up to 4 spout channels; for this reason, we limited the projection to three buildings and the ground plane. Each projection channel has its own layer, and VPT8 allows aligning the projection with the real object and prioritizing layers for correct overlapping projection. In Unity3D, four virtual cameras were projected, and each one was linked to a layer in VPT8 and was arranged and matched with the projection in the physical model.

Figures 5, 6, and 7 present the final results of mapping textures over the buildings and the ground plane.

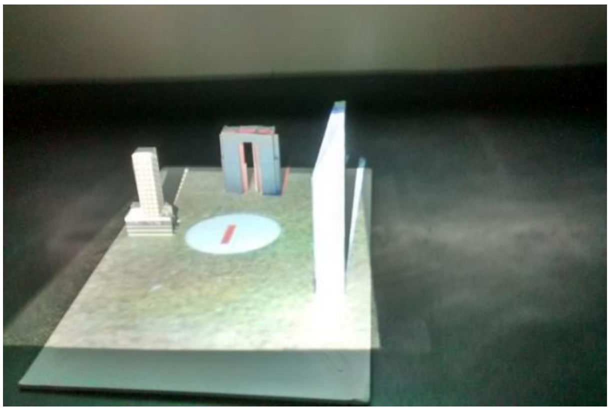

Figure 5: Sample 1 of projection mapping in buildings.

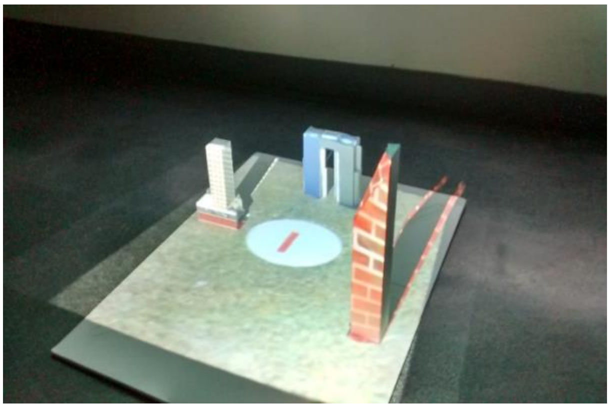

Figure 6: Sample 2 of projection mapping in buildings

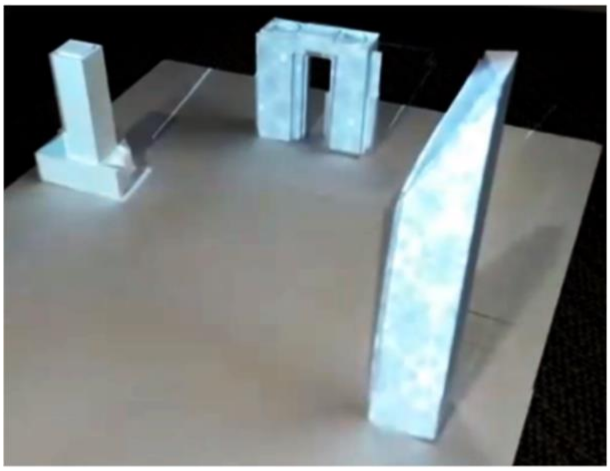

Figure 7: Sample 3 of projection mapping in buildings

Figure 8: Disproportionate tile textures in buildings

4. CONCLUSIONS AND RESULTS

In recent years, computer construction has increased, using digital systems to build constructs. In this project, we achieved a synergy between students in the fields of Architecture and Industrial Design and Digital Art to train successfully two different sets of students via video-mapping. Students actively interacted in this joint program to improve their understanding of both the design of the urban constructs and the production of visual features that further developed into a video game. The program was assessed as highly engaging and informative by the students, and the surveys which were distributed among the participants reported a high level of satisfaction with the training.

Some limitations were identified in the project:

- By using only one projector for video-mapping, we identified a limited coverage of the physical mock-up space; also, the lack of impact projection resulted in the appearance of some undesirable shadows.
- VPT8 only allows 4 layers for Spout/Syphon projection, which limited us from using more buildings in the mock-up space. We need to consider extra projectors for video-mapping.

Reflecting on the collaborative work among students, we identified the following elements:

- Digital arts students need to reinforce their spatial intelligence knowledge. They lack the notions of scale and proportion of real buildings when projecting the textures onto the models. Some of these textures were not in the correct size and proportion (Figure 8).
- The use of 3D printed models motivated the students of Architecture and Industrial Design to leave the established and traditional methods of learning and to focus more on reality through digital systems.
- The concept of video-mapping was liked by Digital Art students because they realized that their digital work could be reflected in real three-dimensional spaces and not be limited only to the restrictions of a two-dimensional screen.
- As we commented, the students worked in two different teams (Architecture and Design students and Digital Art students). On the one hand, this separation allowed them to focus on the part of the project they had to deliver, but on the other hand, a lack of communication and synergy were detected. Students had to do extra work to correct 3d models of buildings for correct UVs and texture mapping.

5. FUTURE WORK

There is always room for usability and workflow improvements in video projection, especially when it comes to supporting different or new file formats that have the potential for live generative content, leveraging software to enhance the visual effects . The combination of projection mapping and moving objects is definitely a development on the horizon. It is a great way to create visual experiences that can be enjoyed by large audiences. The person viewing does not need augmented reality glasses or virtual reality headsets to enjoy an excellent projection-mapping experience.

There is enormous potential that this work can have for urban planning, alternative materials, and finishes in a proposal, not to mention the settings of spaces, including alternative roads, recreational areas, simulations of the weather, behaviors of sunlight reflections at different times of the day, and seasons. Projection mapping can be used for different cases, such as simulations of maintenance processes, repairs, and industrial planning.

"Storytelling" in projections is a step forward in terms of content beyond the simple projection of images and shapes. There is opportunity to engage people in stories that look beyond buildings and delve into history by using the format with a little more narrative.

ACKNOWLEDGMENTS
The authors would like to acknowledge the financial and the technical support of Writing Lab, TecLabs, Tecnologico de Monterrey, Mexico, in the production of this work. We also want to thank the following students who participated in the development of this project: Isaías González, Cristian Tza, Rebeca Fuentes, María de la Luz Nava Rdz., Manolo Zárate Oteiza, Ivanna Campos González, Ithatí Alejandra Lagos Chávez, Debanhi Michell Villanueva, Andrea Chávez Soto, Brandon Eloy Martínez M., Raúl Eduardo Balderrama, Arantxa Alfaro Hernández, Román Nacianceno Treviño, María Fernanda Guerra C., Mauricio De la Peña Cueva, Daniela Renata Nolasco M., Sofía Contreras Sánchez, Mariana Álvarez Castañeda, Brenda Díaz Sánchez;

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AUGMENTED REALITY - A CURATORIAL TOOL

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ABSTRACT
The flood of information in today's society makes it difficult for undergraduate students to source quality support materials to help in their study, as many are ill-equipped to distinguish the good from the bad. Because of this, the lecturer's role as curator of learning resources has developed and become a vital aspect of their job. It is no longer sufficient simply to provide reading lists. As more and more content of various levels of quality has become available online, some lecturers have taken it upon themselves to create personal websites with module content, a reading or resource list and extra materials to support their students' learning.

This paper looks at a simple approach where using AR can successfully bring online and published materials together to create a unique curatorial combination that takes support learning to a new space.

Keywords: reading lists, resource lists, augmented reality, AR, curatorial tool,

1. INTRODUCTION

Reading lists have long been a common feature on programmes of study in higher education (Stokes & Martin, 2008). In a study of tutors, it emerged that the "primary purposes of constructing a reading list was the pastoral aim of offering students a 'sense of direction' in relation to writing on a given field" (Stokes & Martin, 2008). However, these reading lists now "constitute a conventional information resource, which in recent years has been complemented by a plethora of supplementary electronic information sources, most potently, for example, the Internet and virtual learning environments such as WebCT" (Stokes & Martin, 2008). The flood of information in today's society makes it difficult for undergraduate students to source quality support materials to help in their study as many are ill-equipped to distinguish the good from the bad, the personal points of view from the peer-reviewed & accepted theories of academics. Reading materials provided by college courses develop critical reading skills in students. "Close reading leads students to infer and extend meaning by identifying main points and distinguishing supportive statements from illustrative details" (Conley, 2008). However, where once the library and the librarian were the first point of call for all students, they have since been replaced by search engines. Unfortunately, the Internet is home to the voice of the masses rather than the voice of the well-articulated structured opinions of research and academic-approved materials. And even when the search engines provide such results, the 5-minute read or the 2-minute video from a blogger that gives a full overview is generally preferred by the undergraduate over the 20-page paper that is arguing only one aspect. However, while the blogger may have made a good point and the video makes sense, they cannot hope to provide the level of detail required for a full appreciation of the topic and they are not good academic references that can be cited in an assignment.

With published books, the content has been rigorously reviewed by the publisher before printing and reviewers from an academic community will have accepted or rejected it. Consequently, the book comes with a degree of authority and as such, a lecturer can confidently add it to a reading list. The same cannot be said for websites. No publishing standards exist for online content, so while many websites have good content there is no guarantee of the quality of the writing across all websites. Even some of the best websites fail in their own standards when advertising revenues demand daily content regardless of the effect it might have on the quality of the content. Also, websites change. With printed publications there is a date and edition, so lecturers can refer to a document knowing the student is reading the same text as they cite. However, when citing websites lecturers do not have the same confidence that the student is seeing the same content if they visit a website at a point in time after the lecturer added the url to the reading list.

Due to the increasing number of different types of information sources, reading lists have evolved to incorporate a wide variety of different resources resulting in a significant amount of non-textual information with many now referring to them as resource lists (Brewerton, 2014). In order to strike a balance some lecturers have taken it upon themselves to create personal websites with module content, the reading or resource list and extra materials to support their students' learning. These websites can and have grown into a vital support for their students on which both students and lecturer can confidently rely. Lecturers are satisfied that they are giving their students access to up-to-date key information that will help develop their knowledge in a given subject area. The websites give lecturers the freedom to add information and links to books, articles, essays, videos and a host of other rich resources that they know are of good educational quality and will supplement the main key texts and themes of the subject area.

Augmented Reality (AR) is a technology that can help lecturers to link their content by knitting together online resources with printed resources.

A scan of popular college courses globally reveals that they still cite books as their main resource on reading/resource list. As books remain the main point of reference for students to read from, AR provides an array of exceptional opportunities that can enhance, supplement and create one-off learning experiences for students that centre around books & printed materials. This paper looks at a simple approach where using AR can successfully bring online and published materials together to create a unique curatorial combination that takes support learning to a new space.

2. AUGMENTED REALITY

Augmented Reality is an experience that supplements the real world with a virtual layer of information (Lowry, 2015). The virtual layer of digital content is overlaid into a person's view through a device such as a smartphone, smart glasses or an AR headset.

While the technology that enables AR has been around for some time, AR as a communicative medium is still being explored. Many sectors of industry have adopted AR as a demonstrative or an assistive tool for onsite applications and training (Little, 2018), marketing (Sandler, 2018) and education (Ingram, 2017), whereby they have taken the immediacy of the medium to give access to contextual information.

AR has been used for many years by magazines & marketing companies to link the static content of the magazines to online content such as interviews, behind-the-scenes videos of photoshoots, product demos and much more. It is a rich and dynamic way of linking static print to related online content in a tangible way.

A good example of this interaction between print and digital is the 2009 December issue of Esquire magazine. The cover featured Robert Downey Jnr,. When activated through AR, the cover "comes to life" with Downey talking and chatting promoting his movie. The animations, and use of video and embedded trailers provide an insight into what is achievable with AR when it is linked to a printed resource.

3. READING LISTS & THE ROLE OF LECTURERS

A simplistic view of the role of the lecturer is to prepare and deliver the content of the module and to supply recommended and optional reading lists. Reading lists are developed as part of modules to help deepen the understanding of the subject area and of the thought and opinions that shape the knowledge domain of a particular subject. While many students understand the value of reading lists, many more have expressed frustration at how many of the recommended texts are not easily understandable or readable (Stokes & Martin, 2008). Couple this frustration with the ease of access to bite size nuggets of information on the internet and it is easy to understand the attraction of online resources.

While there is very little literature on reading lists (Brewerton, 2013), they are still in place as they offer support and indication for the student learner (Stokes & Martin, 2008). However, due to the ease of access of information online, the role of content curator has developed and become a vital aspect of a lecturer's job. Lecturers are uniquely positioned to know the good from the bad, the academically sound from the well-formed personal opinion, which makes their role of curator invaluable to students. With the proliferation of online content of various levels of quality, it is important for lecturers to point and guide students in the direction of the best resources.

As with most academic writing, the majority of the best is still within the confines of a printed book. That is not to say that there isn't some very good and useful content available online. As previously mentioned, many created their own websites where they have carefully created and curated content within the context of their modules that is suitable for their students and supports student learning. Where once these websites simply provided an overview of the module and made the lecture notes available, they now provide more material and a full list of resources, giving students 24-hour support in their learning. The websites bring together both the books and the online resources for their students. This approach gives lecturers confidence that they are guiding their students in the right direction. The websites are a perfect tool for lecturers as it gives them the freedom to update and grow the content as needs change.

However, as with any good idea there is a downside, as when information is provided in such an easy and accessible way, students may neglect the booklist and instead skim the website and select a few of the links to give themselves a general overview of the knowledge instead of fully reading and interacting with all the resources, especially the books. AR is uniquely placed to help avoid this by knitting both online and printed material together to create a contextual learning experience.

4. MAPPING RESOURCES

AR virtual layers can be activated by GPS points, sensor technology and marker technology. Marker technology allows image targets to activate AR layers. It is this aspect of AR that best suits this curatorial application - knowing that some of the printed texts are vital for students to grasp subject themes, lecturers could build an AR space around these specific printed texts. Making the essential books the markers to activate the AR virtual layer, emphasises the importance of the material in the book.

Art History & Appreciation courses and modules, have extensive and varied reading lists with much of the quality content in book format. A World History Of Art by Hugh Honour & John Fleming, is a mammoth book of over 900 pages. Currently in its 7th edition, it gives an overview of and insights into periods of art across the world, starting at approximately 30,000 BC and continuing up to the modern era. It is one of the most popular art books and finds itself on the majority of reading lists for first year undergraduates for critical and contextual studies. It is a good reference book as it gives concise explanations and overviews and also includes in-depth essay extracts from other publications. It shows full images and detail images and so is a very good overall descriptive book.

Alongside such books, lecturers now have a wide variety of rich content to point to, including online resources such as articles, essays, documentaries and new research now available online. However, while a website is ideal for listing and giving access to these resources AR has the opportunity to organise the content in a more visual and tactile manner while also emphasising the fact that the books are the most important of all the resources by mapping the other resources on to the books.

Using AR marker technology a specific image can activate an AR layer. This provides an opportunity to map the resources to the main texts that they support. The resources can be put together visually in a contextual manner. So instead of a webpage that lists all the resources, the resources are now visually plotted to a marker in the context of the book and the section which all these external resources support.

Utilising the books as the marker to launch the other resource materials underlines the importance of the books and highlights that everything else plays a supporting role to the main text. It also successfully groups the information and maps the module content in an easily accessible manner. Different sections in each book can be points of access to different resources. Essentially, AR becomes the ultimate sticky note, full of tangible resources for students.

AR has the ability to be a better communicative medium than websites for this curatorial purpose. Where the website is removed from the printed material, such as the books and or handouts, AR puts the printed material at the centre. The AR layer that houses the support resources is only available when accessed through the books. This creates a rich learning environment with visual links that encourages learning. AR becomes a curatorial tool for lecturers to use to make a new rich learning platform.

5. TOWARDS A WORKING PROTOTYPE

The Renaissance is an influential and pivotal part of art history for many reasons and so there are many cross-referencing additional texts that relate to this period in art. In the last 30 years, more has been written about the period and some of its most prolific artists such as Michelangelo. The period is a rich area for research papers, essays, articles and tv documentaries, as different discoveries have been made and new theories about the period and the artists have been proposed.

There is a lot of material from a variety of sources that can be hard to pull together at times. However, AR could prove to be the tool required to do this.

Figure 1 shows a double page spread from the book, A World History Of Art, showing information on Michelangelo including his famous statue of David. While this book is an excellent resource an AR layer could build another level to improve insight by displaying and linking with external resources.

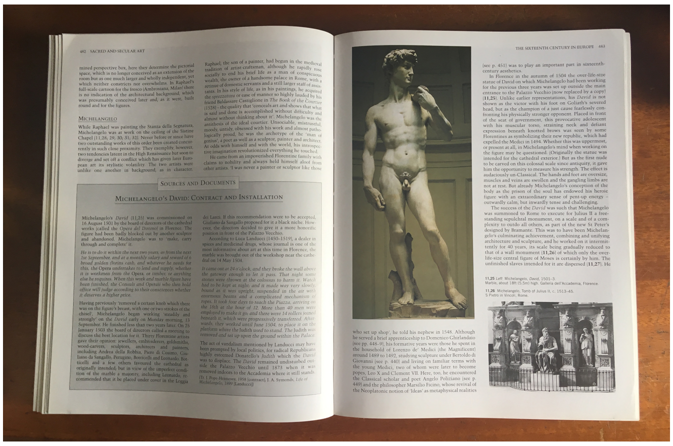

Figure 1: Double page spread from book to serve as marker for AR Layer

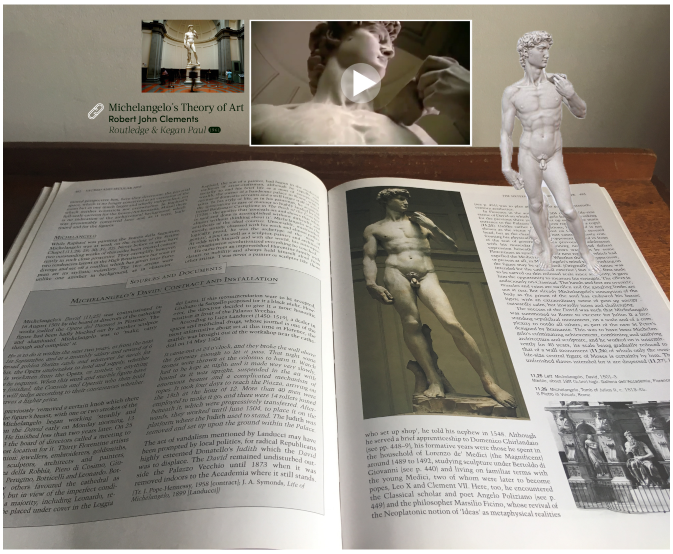

Figure 2: Sample AR layer

Figure 2 is a simple example of what is achievable through AR, whether viewing through a smart phone or an AR headset. The virtual layer is made up of a couple of elements, a 3D model, a video, image, and url links.

It is possible to add a range of content types to an AR layer to bring a variety of resources together. Figure 2 is a simple example, using the double page spread from figure 1 and adding a few different content types to illustrate what is achievable with the AR layer. These are:

- 3D Model
- Video file
- Supplementary image
- Linked resources

3D model: This can be rotated and zoomed in on and can be annotated with labels and descriptions.

Video file: A video file can be embedded into the AR layer.
Supplementary image: The image in the book is a full image of the statue and takes up half the length of the page in order to show it as large as possible, which is the case with most art books; they aim to give the reader as much detail as they can. However, an important aspect of sculpture is its size comparison. The image in the book does not give any clue as to the size, whereas the secondary image in the AR layer gives a very clear indication of the size and its position in the gallery where it resides.
Linked resources: Links to essays and articles can have a visual form, from which they can be downloaded.
This results in a new rich experience for learning.

While this paper has focussed on books as the main marker for activating the AR virtual resources, this does not mean that it can only be books. The printed handouts given out in class can also serve as a marker.

6. CONCLUSION

Building an application like this that groups textual and non-textual, printed and digital information together in one place, placing the book or the handout at the centre of learning creates a rich learning environment. This highlights the importance of the information within the book or handout, while giving access to reliable external resources. This gives students tangible points to access during their study. This type of application of AR system has been highlighted as having a positive impact on user experience (Li & Fessender, 2016). An AR system such as this is proactive by taking appropriate action when triggered, meaning that there is a decrease in interaction cost. In our proposed system we have created a new environment that has all the resources displayed in one place, making the interaction efficient and requiring little action from the user. Consequently, combining multiple resources minimises attention switching (Li & Fessender, 2016). So instead of the student switching their attention from the book to an external source, e.g. an interactive 3D model on a website, all the materials are instead combined in one place, making for a richer deployment of content.

AR gives lecturers a new platform to grow their resource lists for students in a fully contextual way. Plotting the selected external resources to the main reading text makes for a more diverse learning environment for learners but also allows lecturers to arrange quality content in the way that best suits the learning of the subject area. AR as a curatorial tool for lecturers gives greater freedom and flexibility for arranging the reading and resource materials together, knitting the digital and the print together in a bespoke learning environment.

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ACKNOWLEDGMENTS

3D model of Michelangelo's David by Gerry Fisher - https://sketchfab.com/jerryfisher

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Nina Lyons is a graphic designer with over 15 years of experience in the industry. She holds a BDes from the Limerick School of Art & Design, Ireland, a Masters in Design Practice from the Dublin Institute of Technology Dublin (now TU Dublin) and HDip in Science in Computing from Institute of Technology Blanchardstown (now TU Dublin). She is currently completing the second year of a full-time structured research masters at TU Dublin, where she successfully applied for a fully funded scholarship to work with Dr. Matt Smith on a project investigating how AR can improve the experience of visitors to outdoor Irish cultural heritage sites.

Dr. Matt Smith is an academic who has researched and lectured for over 25 years at the University of Winchester and Middlesex University in the UK, and TU Dublin, Ireland. His work involves investigating the design and evaluation of interactive multimedia interfaces, especially for systems that formally, or informally, support learning. In recent years Matt has targeted the exploitation of game technology (he is author of Unity Cookbooks published by Packt), and novel interface techniques including Virtual and Augmented Reality

A MOBILE VISUAL ANALYTICS APPROACH FOR INSTANT TREND ANALYSIS IN MOBILE CONTEXTS

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ABSTRACT
The awareness of market trends becomes relevant for a broad number of market branches, in particular the more they are challenged by the digitalization. Trend analysis solutions help business executives identifying upcoming trends early. But solid market analysis takes their time and are often not available on consulting or strategy discussions. This circumstance often leads to unproductive debates where no clear strategy, technology etc. could be identified. Therefore, we propose a mobile visual trend analysis approach that enables a quick trend analysis to identify at least the most relevant and irrelevant aspects to focus debates on the relevant options. To enable an analysis like this, the exhausting analysis on powerful workstations with large screens has to adopted to mobile devices within a mobile behavior. Our main contribution is the therefore a new approach of a mobile knowledge cockpit, which provides different analytical visualizations within and intuitive interaction design.

Keywords: Mobile Visual Analytics, Visual Trend Analysis, Decision Support Systems, Business Analytics, Human-Computer Interaction, Information Visualization, Mobile Devices

1. INTRODUCTION

Big data counts as the oil of the 21st century. Massive collection and storage of data does not lead to new insights or knowledge. Hence, appropriate analysis methods and graphical tools are required to be able to extract a meaning from data. In particular, the combination of data mining approaches together with visual analytics leads to real beneficial application to support decision making in business management. However, these big data analyses are predominantly performed with computers which are connected to high-resolution monitors. These high-resolution monitors are essential to show all available dimensions and facets of the data in multi-variate and analytical visualizations – also sometimes named semantics visualizations (Nazemi, Burkhardt, Ginters et al. 2015). Also, combinations of visualization with brushing and linking enables an encompassing view on the data and therewith a solid insight.

Perpendicular to the development of big data analysis, there is also a trend using mobile devices more often in daily business. Smartphones and tablets are more frequently used in mobile environments e.g. on business travels or meetings. Actually, there do only few solutions existing that enable a data analysis in principle on these mobile devices; however, especially for trend analysis, no mobile solutions exist. Due to the fact of small screens, imprecise interactions in visualizations via touch, slow internet connections and missing calculation performance on the devices leads to failure of classic analysis strategies (Booth 2014). So, the pure shift and transformation of appropriate desktop solutions on mobile devices will most probably not lead to a successful solution.

To be precise, there are currently three major challenges that limits practical use of visual trend analysis on mobile devices: (1) limitation of the result visualizations, due to approx. 5-inch displays on smart-phones or approx. 9-inch displays on tablets (Wang 2006), (2) associated with the small screen sizes there is even a much smaller interaction area with imprecise finger touch interaction (Roudaut 2009), and (3) the reduced available performance, in particular due to 2-3 GB memory limitation (Wang 2006). Due to these challenges, most of the transformation of actual desktop solutions to mobile devices had failed (Wang 2006). It is essential to address the challenges and create new approaches that on the one hand takes in to account the limitations and on the other hand makes use of mobile device benefits, such as gesture interactions.

In this paper we present a new approach to handle visual data analytics, in particular mobile trend analysis. To enable a satisfactory user interaction, we aim on reducing visual spaces on the one hand and introducing a Mobile Knowledge Cockpit metaphor on the other hand. The concept of a Mobile Knowledge Cockpit considers the raised issues and tries to find a solution such that the user can comfortably use the visual trend analysis system in mobile environments. The proof the concept, we apply the mobile solution on DBLP data. A followed user evaluation should show the advantage for the concrete mobile usage of our solution.

2. TREND ANALYSIS FOUNDATIONS

Today's markets, in particular in western world, underlay rapid changes, which makes more and more important to be aware of market and business changes. Almost any market branch is going to revolutionized with the ongoing digitalization. This leads to the challenge that business executives and managers needs to be aware of ongoing trends to be able to react on them soon. Otherwise there is the risk that a new trend or market change leads to a business crash. Organizations and businesses can take advantage of such information by identifying new opportunities and ideas for concepts and products and invest in research and development for those ideas (Think Design 2018).

As foundation, a *trend* is defined as "a method of identifying and describing specific changes over a long period of time, and the future can thus be predicted using past patterns" (Hwang 2017). And even more, *trend analysis* is defined as "a process of estimating gradual change in future events from past data" (Sharma 2016).

2.1. Goals for Trend Analysis

Trend analysis is a quantitative method that requires precise specification of objectives that will be fulfilled from such investigation of data. Following is a list of goals, presented by Chandler (2011) and Gray (2007), that can be achieved by performing trend analysis:

- To describe the past behavior of a process.
- To try and understand the mechanisms behind observed changes.
- To make assessments of possible future scenarios, by extrapolating past changes into the future.
- To enable analysis of systems where long-term changes serve to obscure the aspects of real interest.
- Detect and estimate the magnitude of a trend.
- Identification of time periods in which there was a substantial trend and times in which there was negligible trend.
- To predict and forecast a trend.

2.2. Trend Detection and Trend Extraction

Trend detection, in principle, can be defined as (Kontostathis 2004): "Knowledge of emerging trends is particularly important to individuals and companies who are charged with monitoring a particular field or business. […] Manual review of all the available data is simply not feasible. Human experts who are tasked with identifying emerging trends need to rely on automated systems as the amount of information available in digital form increases."

Detecting trends are important as well as tricky for an organization to lead a business. Several studies have been conducted in this area. Kontostathis et al. (2004) had evaluated several semi-automatic and fully-automatic systems that detect emerging trends from text data mining. Allan et al. (1998) use single pass clustering algorithm and thresholding model that handles emerging stories in the news stream.

2.3. Trend Analysis in Technology Management

A specific field of trend analysis it the identification of trends for technology management. Especially the computer science domain is driven by rapid changes and there regularly coming new technologies on the market.
To be able to identify a trend, Nazemi et al. (2015, 2019) refers to five important question in that context:

1. *When* have technologies or topics emerged and when established?
2. *Where* are the key-players and key-locations?
3. *Who* are the key-players?
4. *What* are the core-topics?
5. *How* will the technologies or topics evolve?
6. And *which* technologies or topics are relevant for an enterprise?

Even those question refer to technology management, they are also relevant for other trend analysis areas, such as strategy or innovation management as well.

2.4. Trend Analysis on Mobile Devices

Variety of literature exist for trend detection, trend discovery, trend analysis, and trend forecasting techniques in different domains. Kim et al. (2009) created a probabilistic model to discover technological trends from patent text by extracting problem and solution key-phrases comprising a technology and propose a Technological Trend Discovery (TTD) system that automatically captures technological mainstream from several related documents. Lent et al. (1997) address the problem of discovering trends in textual databases by using mining techniques like phrase identification using sequential pattern mining and trend identification and use therefore shape queries and finally visualize the trends over the mined data. Pottenger et al. (2001) used radar system analogy to move out stationary topic areas in a semantic sense with respect to time and user queries the hot topic regions of semantic locality in a set of collections.

Few types of research have also come up with new interesting ideas like ThemeRiver (Havre 2002), which includes a river metaphor along the horizontal axis to depict thematic variations over time from the document collection. Similar to this, yet more detailed, text insight via automated, responsive analysis system TIARA (Liu

2008) performs more complex text analysis and shows detailed thematic contents in keywords.

Trend Analysis has been discussed many times so far, yet the concept for mobile devices has no significant literature and research work. In fact, rare numbers of concepts toward trend analysis concept for smaller devices like mobile phones or tablets do exist. The current work is focused on techniques to derive an efficient solution to achieve trend analysis or visualization for desktop computers.

2.5. Use-Case Scenarios

Trend analysis is commonly a complex task that is made at special equipped high-resolution PCs by experts. However, there are a couple of scenarios where an analysis is required on-demand.
An example of such a scenario could be a direct client meeting, where certain solutions or ideas will be discussed and the uncertainty is too high to really be able to focus on a selected number of options. Here it can be extremely helpful to be able to eliminate options that are nowadays definitely out of use or relevance. Or imagine the situation you want to gather a certain overview, e.g. about a market, on players or important technologies. An instant analysis could help to gather a rudimentary overview and brings you in the situation to formulate an initial draft of an idea or goal.
Even more, it can help to proof upcoming ideas in meetings toward relevance, current usage etc. This includes also performance of quick evaluations of mentioned market situations by comparing certain topics.

Similar to the use of google for upcoming questions to check the facts, in particular in business and technology management, there are often situation where the uncertainty is high. In contrast to simple fact checks, it is not so easy to say if certain technologies are useful in specific fields. Of course, such a quick trend analysis is never solid, but it can help to make strategy meetings and similar discussions more fruitful since a couple of aspects could be quickly checked and at least help to tight the focus more on real options, that afterwards can be checked in detail.

As principal application scenarios, we defined the following three for the first prototype:
(1) The *general* or *target analysis* should enable to get an overview about a certain field, such as “cloud computing” or “big data analytics”. The purpose is to identify most relevant and upcoming topics, but also identifying the most relevant authors or affiliations. However, also the concrete publications can be in scope, to more precisely answer questions about used algorithms etc.
(2) The *author analysis* is a more specialized search toward certain authors. Since authors are sometimes named differently, a disambiguation should help to find all papers from a certain author. The dedicate focus on authors seems at the beginning a little strange, but is to consider that authors of scientific publication are often experts of their domains. So, they are not “only” authors, they are high professionals or experts. From the principal behavior, the analytical capabilities e.g. used visualization are similar to the general/targeted analysis, the major difference is almost the disambiguation feature.
(3) The *comprehensible analysis* is most likely to compare results from two authors, topics etc. On this way competing issues could be analyzed, for instance in perspective of a higher attractiveness or benefits for certain usage scenarios.

3. A VISUAL TREND ANALYTICS APPROACH FOR MOBILE ENVIRONMENTS

In the following sections the concept and design of our new mobile visual analytics approach is described. Since the principal data processing actions are equal to those we already presented (Nazemi, Retz, Burkhardt et al. 2015; Nazemi 2019), we focus strongly on the visual aspects.

3.1. Data Processing and Infrastructure Foundations

Our principal data processing model builds upon on our previous work on visual trend analysis with digital libraries (Nazemi 2015) that uses the reference model of Card et al. (1999) as foundation. According to our previous model, we subdivided the transformation process for visual trend analysis in digital libraries into the steps of (1) Data Enrichment, (2) Data Transformation, (3) Visual Mappings, and (4) Visual Orchestration.

Data Enrichment gathers additional data from external repositories to enhance the quality of data and uses text analysis techniques to extract valuable information from these data. Data Transformation structures the data for a proper visualization. It detects relevance, amount and content of queried data and uses these features to create models revealing certain aspects of the data. Visual Mappings transforms the data models to appropriate visualizations. Visual Orchestration uses textual and visual information gathered in the previous transformation steps to create static and dynamic elements for human interaction.

The existing solutions consists of two major components, the mobile analytics web-service as well as the web-frontend. The mobile analytics web-service provides the main relevant publication data, coming from the already explained digital library web-service, as well as the major pre-processing that are required to show the charts and visualizations on the mobile devices.

3.2. Data Processing Architecture

Since we already have a fully working digital library web-service to process the main publication data for trend analysis, we just added an additional mobile analytics web-service as service between the digital library web-service and the client with the visual frontend (Fig. 1). The additional mobile analytics web-servers has the task to pre-processes the data for the mobile visualization. Herby the calculations focus strongly on the behavior of the mobile devices and the specifically used charts and visualizations, which are limited among other in perspective of performance. Especially the lower memory is a special challenge to enable bigger calculations on a mobile device as it is possible on a desktop PC. Even more the battery consumption is a significant restriction, since a mobile trend analysis would be not user satisfying if it quickly empties the smartphone or tablet battery.

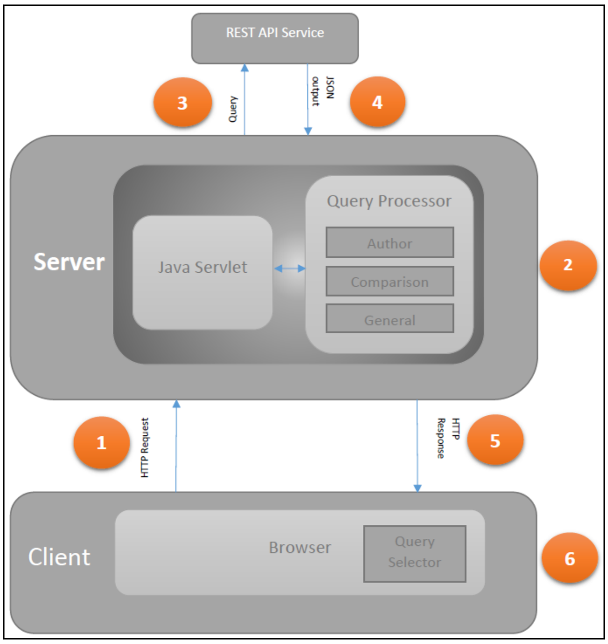

Figure 1: Visual Trend Analysis Architecture

From the data processing side, the user initiates the analysis by performing a request on the client, which sends a query to the query processor on the mobile analytics web-service. Here, the requested data is sliced into further request on the digital library web-service, to get the document-based data. The returning data from the digital library web-service and then further processed on behalf of the required data to generate later on the visualization on the client. The final calculated data is turned back to client, which shows the result on the screen.

3.3. Aspect-oriented Visualizations

For the initial mobile version, we focused on basic visualizations that enable beside trivial trend analysis question also general information gatherings such as most relevant authors or affiliations in a specific field next to the main publications. Since it was not the goal to provide similar encompassing and extensive analytical capabilities as the desktop version does, the focus laid more on easy and intuitive operate-ability that requires from the users only few understandings about visual analytics or trend analytics.

The initial screen (Fig. 2) shows the search field and above the use-case scenario selection. The search enables advanced queries e.g. by concatenating different phrases with "or" and "and". The main visualization that can be further used are the bar charts (Fig. 3). Bar charts are highly intuitive and effective to use visualization types, which are in particular in mobile environments most easy to use and the shown information can be quickly extracted and understood by the user.

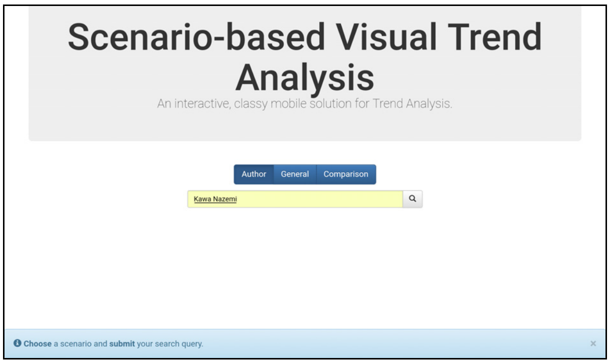

Figure 2: The initial screen where the user performs the search and selects the analysis scenario

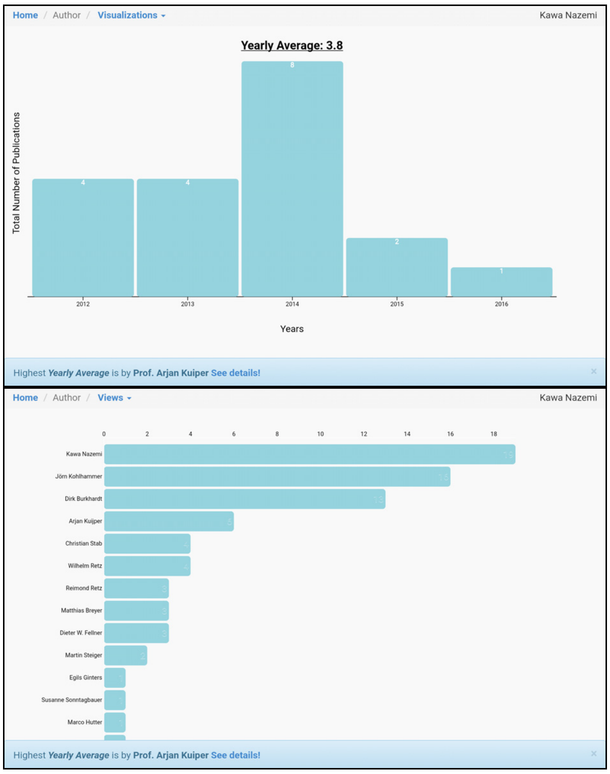

Figure 3: Different forms of the included bar charts, the vertical one (bottom) enables sorting and scrolling

For an advanced view on topics or publications of certain authors per year, the stacked bar-chart is used (Fig. 4). Due to the small amount of space, it is one of the few visualizations that enables still a good readability on small smartphone screens.

The concrete publications will finally be shown in the publication result view (Fig. 5). By clicking on a concrete publication title, further meta-information such as the DOI-link are shown. A click on the URL or DOI-link opens the full paper if the user owns right for it of the corresponding publisher.

The system is designed to allow integration of further visualization layouts. However, the goal of this prototype laid on the general feasibility and the identification of the principal application benefit. And the used visualization set seems to be appropriate to perform an evaluation.

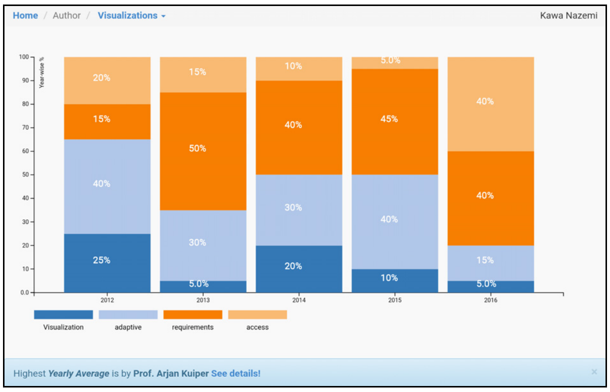

Figure 4: Stacked bar-chart for a comprehensible view on a yearly basis

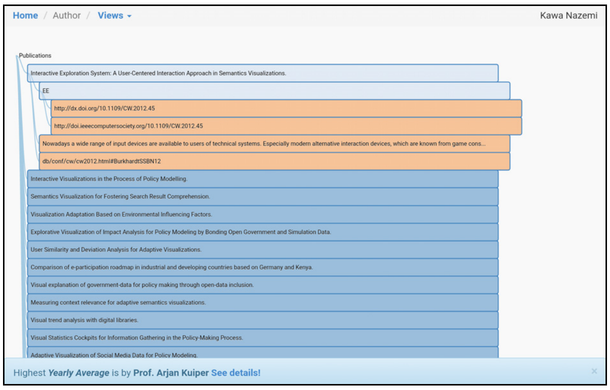

Figure 5: Publication result view as extendable list to show further details on demand

3.4. Mobile Knowledge Cockpit

Especially on small screens, the interaction logic is a very important aspect. Traditional approaches that are well known from (large resolution) displays on workspaces do not work apparently on mobile devices. However, in perspective of intuitiveness we successfully introduced the knowledge cockpit metaphor on stationary computers (Nazemi 2010, Nazemi 2019). The idea we had was to follow this principle idea, but rethink it for the use on mobile devices.

As a result, conceptualized and implemented the idea of a Mobile Knowledge Cockpit that seriously considers the specific limitations but also advantages of nowadays mobile devices. The major difference of the Mobile Knowledge Cockpit is that only a single visualization is shown at a time, but it can be switched between different visualization by the use of moving touch-gestures.

A touch movements form left to right lead to show data visualization from abstract to concrete, in regards of Shneiderman's (1996) visual information seeking mantra. And touch movements upward or downward lead to switches between different aspect-oriented visualizations but of similar data granularity level (see Fig. 6).

The combination of single shown visualization and inclusion specific visualization arrangement in the background that can be controlled via gestures ensures that the user could find and understand a logic.

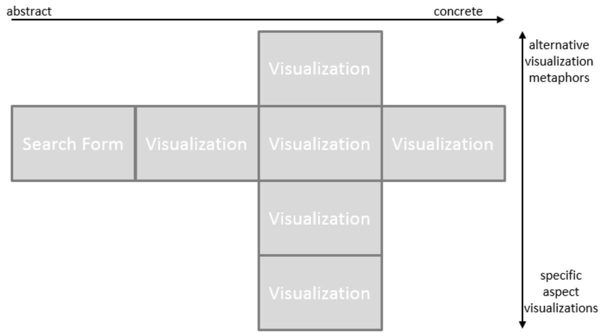

Figure 6: The different axis-meanings of the Mobile Knowledge Cockpit metaphor

From the application look and feel, the user will only see the current selected visualization. The other available visualization layouts are hidden, but can be indicated on the edges (see Fig. 7).

Figure 7: An example mockup of a current active visualizations next to hints of other available visualizations on the screen edges

In the current Mobile Knowledge Cockpit prototype, we considered only a few visualizations and charts, but the system is designed to extend it with further visualizations (Fig. 8).

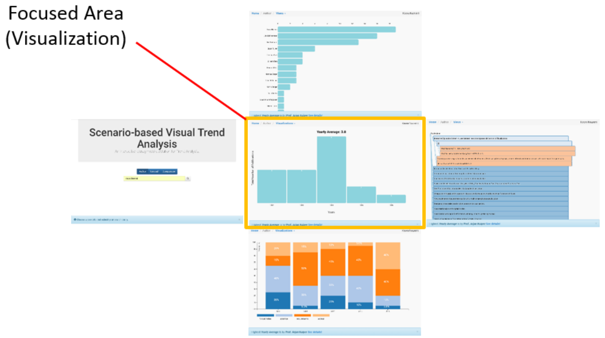

Figure 8: The arrangement of the visualizations in the background between which the user can switch by wiping touch gestures on the screen.

3.5. Use-Case Scenarios Integration

As mentioned before, for the initial proof-of-concept, we focused on three scenarios: (1) general/targeted analysis, (2) author analysis including disambiguation and (3) comprehensible analysis. From the principle look & feel the first two scenarios look identical, because the major difference is handled on the backend in the data. But it has no impact on the frontend visualization (as shown in Fig. 9). As sketched, the visualization aiming just on showing results to a single searched author or topic.

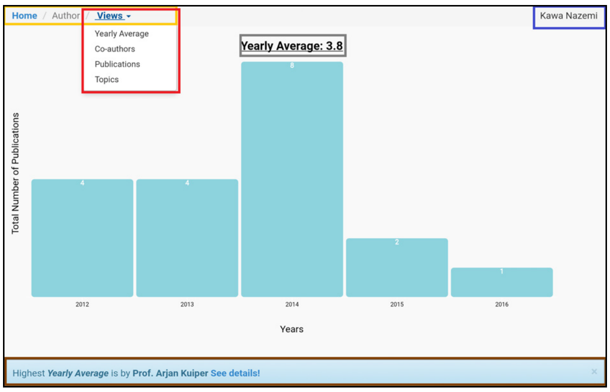

Figure 9: General/targeted and author analysis

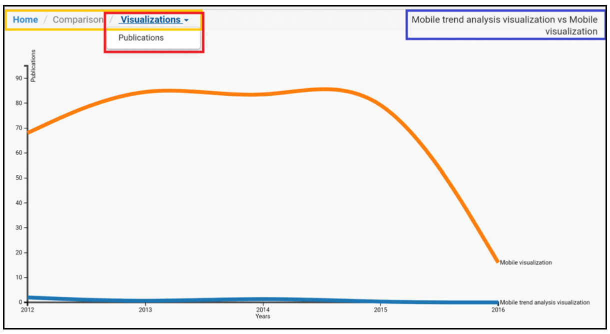

Figure 10: Comprehensible search and analysis

In contrast to the first two scenarios, the comprehensible search is aimed compare two topics. Therefore, some different visualizations are included, that enable to compare the retrieved data visually (Fig. 10). The comprehensible view enables identification of gaps or similarities, which can help to identify the most relevant topic or solution in a certain field.

In the future it is planned to consider our recent introduces search intentions analysis approach (Burkhardt 2016; Burkhardt 2011) to automatically identify the intended search type.

4. EVALUATION

To proof our concept, we performed an evaluation via a web-based evaluation system (Nazemi, Burkhardt, Hoppe et al. 2015). Here, the participants had to perform a couple of tasks online on a mobile device (we recommended a 9-inch tablet). To ensure that the participants really perform the tasks with a mobile device, we checked the send browser agent string for names that match to mobile devices.

On the mobile device the users had to perform a couple of tasks on two different analysis systems. One system was our new developed mobile trend analytics prototype, the other was our desktop-based trend analysis tool (Nazemi, Retz, Burkhardt et al. 2015; Nazemi 2019).

The evaluation was performed with 24 participants consisting of 17 (approx. 71%) males and 7 (approx. 29%) females, all of them have an academic background in computer sciences and declared to own basic understandings in visual analytics. Furthermore, the participants where between 25 and 36 years old, with in mean 28.4 years of age.

4.1. Methodology

As already mentioned, the evaluation was performed via a web-based evaluation system. So, there was no option to introduce the participant face to face or give some hints. However, the evaluation system is designed to guide the participant along the full predefined procedure. At the beginning he will also be introduced to do not guess and to perform the evaluation in a row without brakes, since we measure the time for better quantitative insights.

At the initial screen the user gets introduced about the evaluation itself, the goals, principal procedure and what information will be collected during the evaluation. After the participant clicks okay, the evaluation starts.

The first view is a questionnaire about some principal demographic information, such as age, highest degree etc.

In the next block the participant has to use the new mobile trend analytics system as well as the already existing desktop trend analytics system. It is important to mention that the block selection is randomized, so that one participant starts with the desktop version and another participant will start with the mobile version. The randomization is important to avoid learning effects that gives an advantage to the system that is presented

as second, since some basic metaphors etc. are then still known from the first.
In each of the blocks, the user has to perform three given task (see Tab. 1) which are for each block similar, but not equal. To every block the user could only select one or no answer. In the background the system observes if the answer is correct and how long the user needs to make the choice.
After the practical tasks, the user had to give a feedback based on the INTUI questionnaire, to measure the intuitiveness level.

Table 1: Multiple choice questions, which the user has to answer by using the system practically.

Question	Answer options
How many publications do you find by [author name] for the year [specific year]?	4
With whom does the researcher has most publications?	4
[topic name] is the dominating topic [author name] had worked on. However, he has less publications related to this topic for the past 2 years (2015 and 2016). Do you think this is a diminishing trend for this topic by the researcher?	4

After the participant has performed any task blocks, the evaluation ends.

4.2. Results

The results of the evaluation show that for the given types of the task the mobile trend analytics prototype gains in average and total better results. Except for the first task, the mobile version always achieved a higher task correctness (Fig. 11) and better task completion time (Fig. 12).

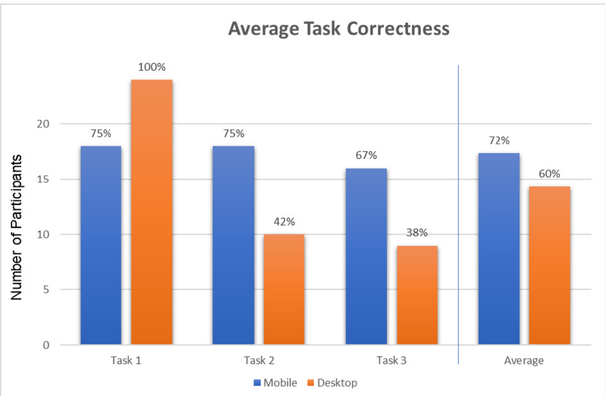

Figure 11: Average task correctness (more is better)

In summary we can say that the mobile trend analysis approach is appropriate for answering immediate upcoming questions in fast and effective manner. However, it is to consider that the results may not be valid and do just provide a quick overview. Also, such kind of mobile analysis solution can not avoid the fundamental analysis regarding solid trends. It is just a small helper that can make consulting, meetings or discussions more fruitful due the opportunity to shrink the agenda and the more relevant aspects.

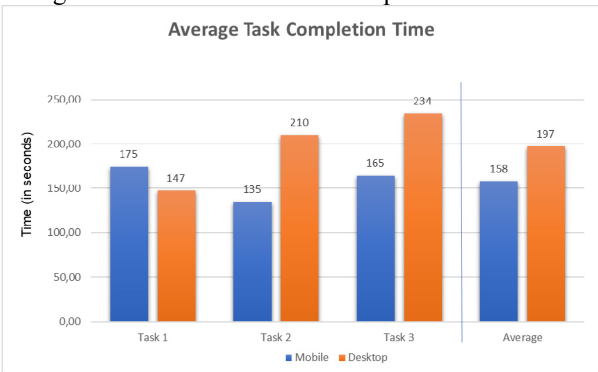

Figure 12: Average task completion time (fewer is better)

5. DISCUSSION

(Visual) Trend Analysis is still a relatively new field with a high relevance for the business domain, but currently there are only a very approaches and systems available that make use of it. To apply this new field into a mobile context at that early stage leads inevitable to the question, if it has a solid fundament and makes sense. Solid trend analysis requires from the analyst large amount of experiences, analytical competences and technologies that analysis the relevant information in a correct manner – and of course needs to be validated by expertise of the analyst. A quick analysis as we intended in this mobile trend analysis is neglecting many of the quality criteria that a good analysis should take care.

Furthermore, it is still open of analysts really see a need for a system like this. The challenge is, that there is indeed a need to quick check certain topics or trends, but it is important that the insights are valid. It can be interesting to check, if it maybe a predefined and analyzed set of topics would be a compromise. However, it is to consider that therewith the validity is given, but upcoming new topics and trends would miss.

Under the framework of FP7 FUPOL project No. 287119 “Future Policy Modeling” was designed Skopje Bicycle Inter-modality Simulator (Ginters 2014) which assisted the municipality and citizens to simulate recommendable bicycle routes in urban area. The aim of the research was finding the appropriate ways to move as much as possible citizens to green transport area. However, it would be reasonable to visualize the trends of citizen habits to assess the sustainability of used approach. There could be applied the findings of current research.

6. CONCLUSION

In this paper we presented a new approach to handle visual trend analytics in a mobile environment. This should help to indicate trends within consulting, meetings or strategy discussion more efficient and fruitful. Therefore, a couple of use-case scenarios where identified, where a mobile trend analysis could make sense. Additionally, a concept and design were made, how the trend analytics could be realized on mobile devices, in regards of the specific limitations of mobile devices, such as small resolution, lower performance and imprecise interaction via touch interaction. One of the major contributions is the new Mobile Knowledge Cockpit metaphor that enables an intuitive interaction through varicose visualizations.

A performed user evaluation could show that the prototype faces the intended goals. However, since the field of mobile trend analysis is a very new one, it is hard to estimate if the idea has higher value for the industry, since flexible use decreases the determined insights in perspective of quality.

ACKNOWLEDGMENTS

This work has been carried out within the Research Group on Human-Computer Interaction and Visual Analytics (http://www.vis.h-da.de). The presentation of the work was partially funded by the Research Center for Applied Informatics (FZAI, http://www.fzai.h-da.de) of the Darmstadt University of Applied Sciences.

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THE CONCEPT OF AUGMENTED REALITY APPLICATION FOR PUTTING ALIGNMENT IN GOLF

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ABSTRACT
Virtual and augmented reality (VR / AR) applications have successfully overcome the critical part of the Gartner curve. Investments are made and new products entering the economy. However, a very small percentage of society have also heard about AR glasses, mainly linking these with potential identity threats and personal data breaches. The authors dealt with the design of application of AR to improve golf skills by improving the putting technique. The above solution is complicated by requiring complex object recognition, tracking and advanced AR software designing.

Keywords: augmented reality, objects recognition and tracking, intelligent training, Android

1. INTRODUCTION

Modern technologies are becoming a routine component and affects every sector of the economy, as well as the leisure and sports industry. Although golf is quite conservative and also a relatively expensive sport, golf courses are always filled. Golf is becoming more and more democratic and spreading to wider social strata. Historically, the first IT products were allowed to record golf video and use them for training to ensure player error analysis and promotion of the right techniques. Laser-based range finders provided accurate distance detection in the golf course, but the build-up of RFID elements reduced the number of lost balls. For example, GameGolf (Winters 2018), and others, have come up with features to track the golf game by embedding the chips in golf clubs. Then, every swing is recorded in an app on a smart phone that gives data on the player (fairway accuracy, scrambling percentage, green in regulation, etc.).
In its turn, the GPS application allowed the creation of a digital map of the field of play, incorporating elements beyond the boundaries of direct vision, which made it possible to determine the choice of a golf club for a given shot. The player's technical arsenal was complemented by the attraction of Internet resources that provided weather. The emergence of virtual and augmented reality technologies not only created new opportunities for golf training, but also facilitated a real game.
Golf simulators entered the training. With the Indoor Golf Simulator (Winters 2018) it becomes possible to swing with real golf clubs, get stats and yardages on those swings while a simulated golf course or a driving range was projected on the wall. Usually, such a simulator was located in a separate room, which is determined by the safety considerations, as real golf clubs are used. The latest generation simulator PuttView Indoor (Exist Grant 2018) visualizes the ideal putting-line by beam as well as all information for putting practice directly on the green / floor.
Stationary equipment cannot be used on the real golf course, so usually either smart phone or virtual or augmented reality glasses are used.
One example is the VGolf solution (VGolf 2018), where a player sees the golf resort on the virtual reality glasses. The player can simulate the golf game and store data about club speed, orientation, ball velocity, launch angle, trajectory ball spin etc. Similar one is the Aguila Golf Virtual Reality Golf Trainer for Smartphones (Virtual 2018). Águila Golf is a virtual reality-based and mental game designed to walk a golfer through the toughest shots in the game. The golfer can visualize the shot before making it and is immersed in a 360 ° learning environment giving the opportunity to improve strokes through a precise shot evaluation.
Another VR application is the Vuzix-based golf swing monitoring system, where the player can see for himself and control his movements. The camera is placed on the field and simultaneously the video is transmitted to the player's glasses. Motion dynamics can be recorded and repeated to detect errors.
The Live View Golf Plus solution (Golf 2018) is used for training and improvement the skills of players. On the other hand, HoloGolf (Singletary 2018) developed by CapitoliaVR allows the creation of virtual ball movement tracks and assesses the possible movement of the ball on the VR glasses HoloLens screen under certain conditions. The solution can be usable for

assessing the situations and playing out different scenarios.

Augmented reality features are often provided by the smart phone. The augmented reality software by Golfscape AR (Golfshot 2018) allows to display a location in the golf resort on the iPhone's mobile phone screen, displaying information on obstacles, holes and distances that are detected using the built-in GPS.

PGA Tour ARkit (LeFebvre 2018) for iPhone allows the golf course to be placed on the table. It allows to watch real-time shot trails appearing on select holes during live competition. It is possible to compare up to four different player shots in a virtual map of six different golf holes.

Golf Scope's (Golfscope 2018) is an iPhone application that uses computer vision to accurately understand the slope, elevation, and distance while putting the ball. It lets you draw the line between the ball and the hole. However, restrictions apply for this application. The player must first take both ball and the target hole for recognition, as the Golf Scopes AR software does not automatically recognize the objects.

However, lately, golf add-ons augmented reality glasses have become more and more popular. Nike (Mallis 2018) patented a set of AR glasses that would give real time analysis, including tracking the speed of the ball, how far the ball is carried and how long it is in the air. The application is programmed to detect the movement of the game ball. The ball is visible through the transparent display area of the glass screen.

2. GENERAL REQUIREMENTS MODEL OF AUGMENTED REALITY APPLICATION

New technologies are emerging as a product of interaction of engineering and society. In digital society practically all the systems are sociotechnical respecting interoperability of both parts – technical and social.

Technical systems usually are closed and determined, but social systems are open and stochastic. The architecture of the system (abstract or physical) is determined by the existence of logical and physical structures and the interaction of these structures.

The logical structure includes requirements, guidelines, algorithms, rules and personalize the particular system, while the physical structure includes hardware and software. The physical structure is the environment for implementation of the logical structure (Aizstrauta and Ginters 2013).

Virtual and augmented reality (VR/AR) solutions are typical sample of sociotechnical system and the same time digital technology.

In 1997 Azuma (Piekarski and Thomas 2003) determined the most significant AR features. It was defined that AR is a combination of real and virtual worlds, and at the same time interaction and activities in the 3D space.

Many of the AR applications have a common core architecture. In addition, many basic components and subsystems can be seen in different applications. MacWilliams, Reicher, Klinker and Bruegge (MacWilliams, Reicher, Klinker, and Bruegge 2004) offered a view on generic AR reference architecture based on the software engineering concepts. The aforementioned model explains the basic functions of AR though views the application of AR as a relatively closed system and involves separate VR functions, for instance, new 3D objects rendering that cannot be an AR attribute.

Modified reference model of AR application (Ginters, Puspurs, Griscenko and Dumburs 2018) involves two interoperable subsystems for visual recognition and voice processing. More detailed the visual recognition model will be discussed.

Visual recognition BPMN2 model comprises some basic activities: identification, recognition, tracking and visualization (see Figure 1).

The system visually identifies five different object types: face, marker, landscape, virtual object and text. All these objects form a common scene or visual layout (Nazemi and Burkhardt 2018). If in the simplest cases, such as the marker type object, the analyzer performs matching patterns in pattern data base, then facial or text recognition is a labour-consuming process, which may require analyzer training using artificial intelligence techniques.

The processed data are visualized on head-mounted display (HMD), replicated to other devices, or become available to other subsystems, including voice processing, since the recognized and / or translated voice content sometimes must be displayed in printed form.

These are the general principles of visual recognition subsystem design, which can be adapted to suit specific AR application requirements.

3. AUGMENTED REALITY ROLE IN PUTTING ALIGNMENT

Below, let's look at AR-based application that can be used in a golf game for putting. The player's task is to hit the golf ball with the smallest number of strokes. If in the initial conditions we assume that the ball is on the green but the relief is even, then the nearest path from ball to hole is a straight line called putting line (PL) (see Figure 2).

To hit the ball the golf club is used which name is putter. The putter centre is usually marked to ease the player's task. The player is in position to simultaneously match the putter and ball centers to the PL, as well as the centre of the hole. Unfortunately, players make mistakes in striking, even at a short distance, but the probability of sampling errors increases significantly over several meters. Of course, the shot force can be controlled only by the player himself, but the AR solution can help point the ball to the hole.

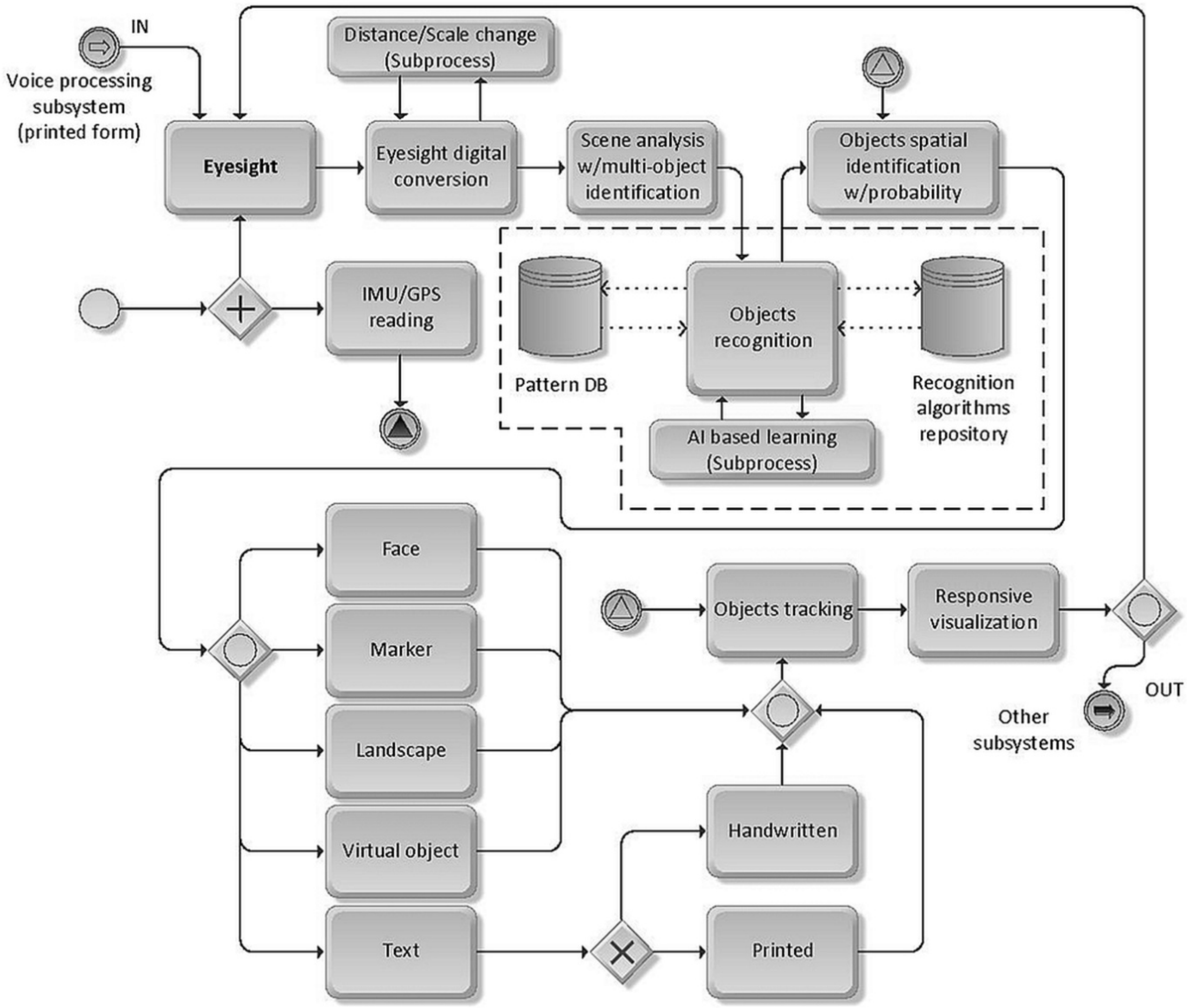

Figure 1: Reference Model of Visual Recognition Subsystem (Ginters, Puspurs, Griscenko and Dumburs 2018)

The player has AR glasses, where the web camera employs two lines on a real green image: putting line PL in red between the ball and the hole, and the X line perpendicular arrow in yellow to the putter centre. The X line owes the direction in which the ball will move if the player hits it from a particular position. If the putter changes the position, the line displacement angle α (1) also changes on the glasses screen:

$$\tan\alpha = (Y_2 - Y_1)/(X_2 - X_1) \quad (1)$$

$$PL^2 = (X_1 - X_2)^2 + (Y_1 - Y_2)^2 \quad (2)$$

As the player receives GPS data from the smart phone, it is possible to graduate the existing eyesight of the camera. Then you can calculate the coordinates of the important points and perform the putter tracking if we assume that the ball does not change its position. The player's task before strike is to stand so that the yellow arrow and red lines will overlap.

As an additional information, the player receives a distance PL measurement from ball to hole (2). This, of course, is not very important, however, an analytical player according to distance can adjust his shot power. Even more these data are gathered for further analysis.

The putting alignment AR software designed in conformity with conceptual model (see Figure 3) runs on an Android smart phone of the player. In fact, there are several parallel processes: Eyeshot coordinates grid computation, Hole data processing and Putter tracking.

After launching the application, putter, ball and holes are recognized. The nearest hole is selected, which is calculated on the coordinates grid map. Putter, ball and hole centers are calculated. Further a X axis yellow arrow is drawn perpendicular to the centre of the putter. And as well as the red PL, connecting the ball with the centre of the hole, is marked. The distance from the ball to the centre of the hole is computed, as well as the displacement angle α is determined. The putter tracking is parallel and real time process. The software operation is cyclical while the equipment is switched on.

The key factor is quality of recognition. The recognition quality is determined by AR software training opportunities. A simple comparison with standard markers in the database is not suitable because this method can only be used for ball recognition.

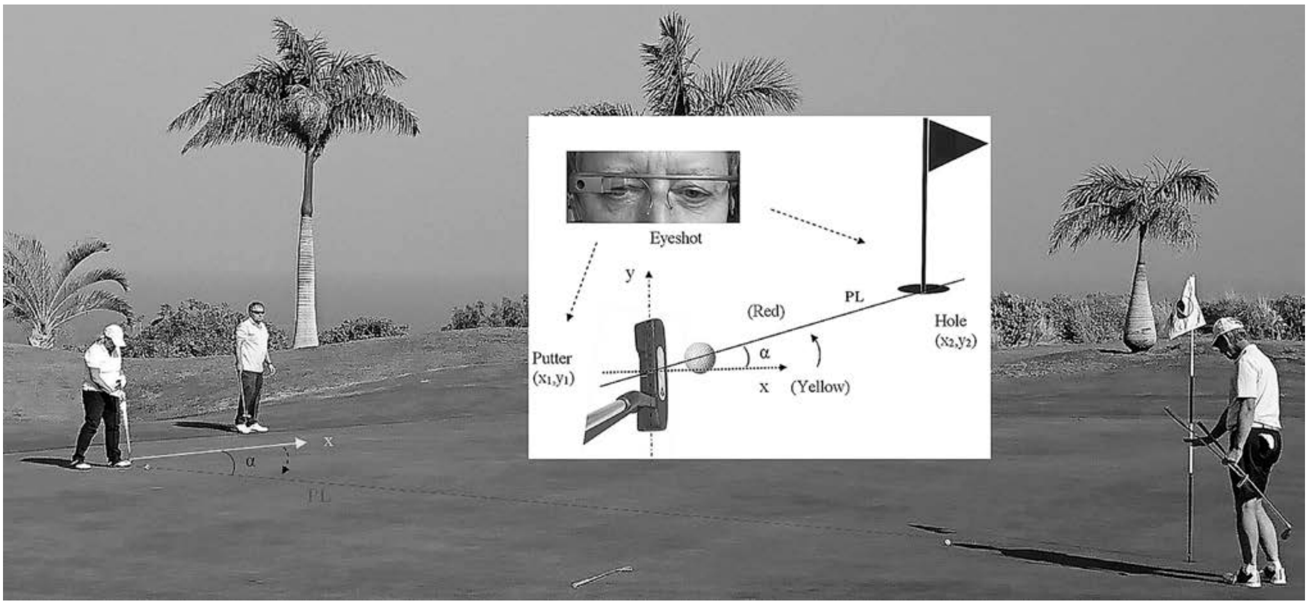

Figure 2: Visual Layout of Putting Eyesight

The hole, of course, is standard and the dimensions are well known, but the viewing distance and the angle of view can be very different. Therefore, the software should be sufficiently intelligent to achieve a correct result. It requires recognition algorithm training using the methods of artificial intelligence. The situation with putter clubs is analogous. Although the putter club is visible in direct sight, unfortunately, contrary to the hole, the shape of the putter is not standardized and is very diverse. The most complicated problem is the determination of the putter centre, which may not be marked on the club. Therefore there is a problem with comparing the appropriate AR marker and a typical image in the database.

Another problem that affects recognition is lighting, because the game can take place at different times of the day, may be shadows, reflections and image can be directly disturbed by the sun's rays. Putting alignment AR software is a local solution and cannot use the cloud services while respecting the fact that not all golf courses have appropriate mobile data coverage.

The player cannot voluntarily move the golf ball, as he has to shoot it from the spot to the green where the ball is located. It's relatively easy to create a demonstrator for the ideal situation, but it's quite complicated to adapt it to the real conditions of the game.

During the golf game, important statistical data are accumulated, and further analysis would help to improve the skills of the game. The accuracy of the shot depends on the distance of the putting, angle, terrain, quality of the green, wind and lighting. The total number of shots depends on the accuracy of each individual shot. The result is also influenced by time spent in game, distance travelled, player experience, resort complexity and other factors (see Figure 4). The above data can be analyzed using semantic methods (Nazemi et al 2015; Nazemi and Burkhardt 2019), which allows to show causal relationships between the essential parameters.

One of the key issues is the choice of appropriate hardware, which must be accessible for wide enough audience. First of all, it's a smart phone that works in the Android environment. However, the choice of AR glasses is rather complicated. The author's study of 2018 (Ginters, Puspurs, Griscenko and Dumburs 2018) identified several popular models that could be used in the AR application of the putting alignment. The models were analyzed using an integrated benchmark model that involved analysis of several technical requirements, such as weight, operating system, WiFi interface, resolution, RAM, additional memory, CPU, Bluetooth, battery capacity and price. Several smart glass models were analyzed: Recon Jet, Telepathy Walker and Jumper, Vue, Moverio BT-200, Jins Meme ES, ODG R9, SED-E1, Google Glass and Vuzix. The authors did not consider the HMD models that did not meet the conceptual requirements and are focused on the implementation of VR functions, such as Oculus Rift VR, Samsung Odyssey, and others. Of these models, only HoloLens (Microsoft 2018) was reviewed.

The choice of appropriate equipment is not straightforward, but it must be concretely grounded. The task does not involve complex and resources consuming procedures, such as face or landscape recognition, therefore a critical resource is neither performance nor resolution. Critically important parameters for putting alignment AR application are weight of glasses, battery capacity and price. The most powerful is the ODG R9 model, however, while respecting the requirements of smart glasses weight limits and sufficient battery resources, it was rejected. It was decided that Google Glass (Digital trends 2018) and Vuzix Blade AR (Statt 2018) are significantly superior in several categories.

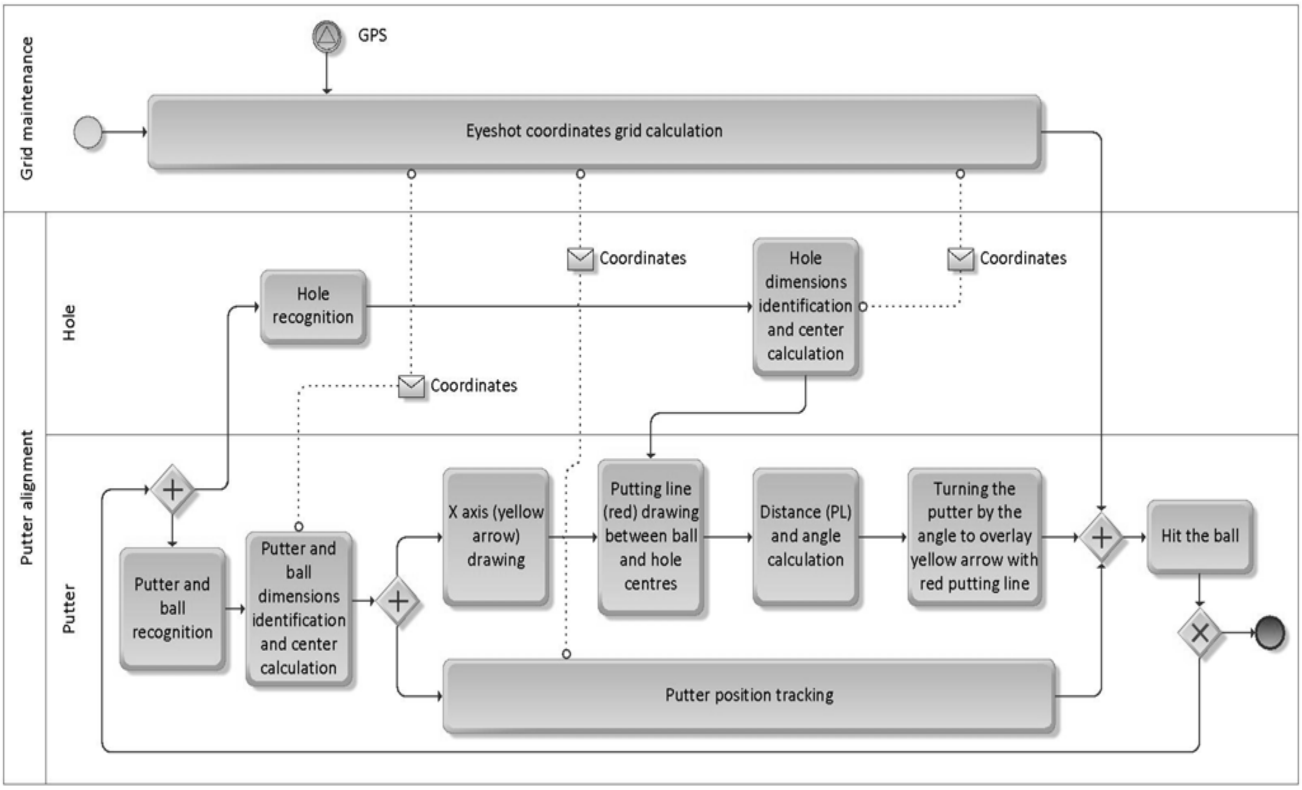

Figure 3: Conceptual Model of Putting Alignment

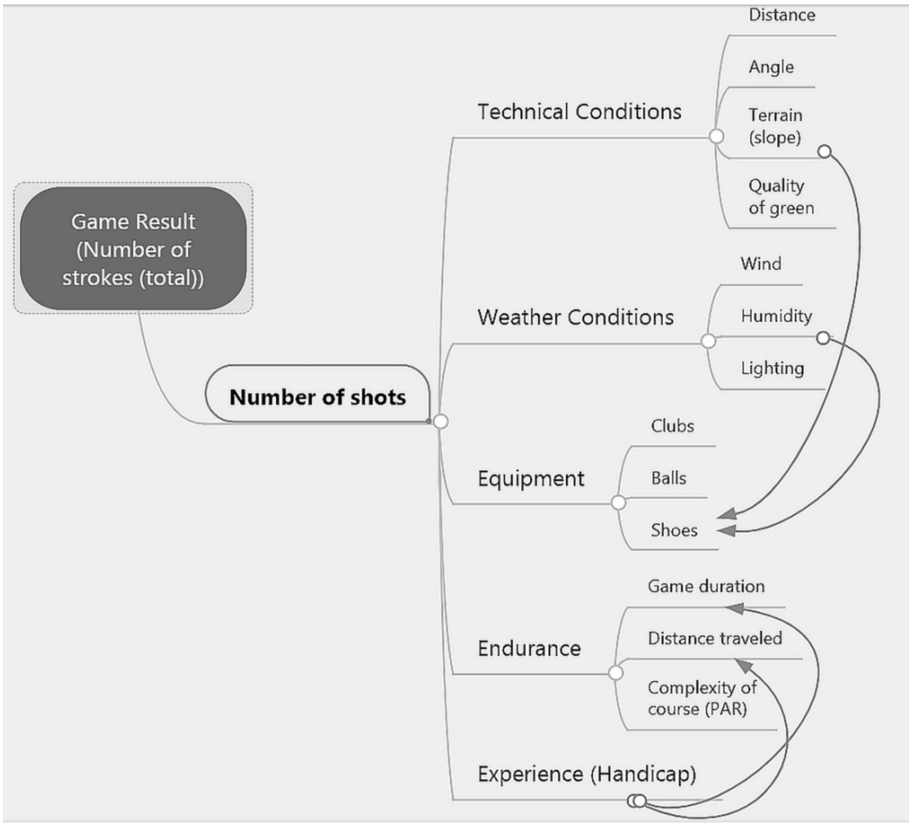

Figure 4: Graph of Essential Factors

The first version of Google Glass Explorer (Google Glass 2018) was released in 2014 (see Figure 5). The headset was criticized due to privacy and safety concerns. The reason was the capabilities to recognize the object and receive up-to-date information about it. Due to public protests, Google stopped the sale of Glass, which was renewed in 2017 when the new Google Glass Enterprise Edition was announced. Practically the main problem was the obvious features of technical surveillance that caused the discomfort of the surrounding persons.

Figure 5: Google Glass vs Vuzix Blade AR

The new Google Glass (Digital trends, 2018) version in 2018 is no significantly different from the Explorer. Additional storage capacity is increased to 32GB, but RAM up to 2GB. Intel Atom CPU performance is higher, but the battery capacity is 780mAh, which could provide 8 hours of operation, of course, depending on the operating conditions. Enterprise edition has GPS/GLONASS support and barometer. Wi-Fi Dual-band 802.11n/ac has a higher performance as the previous one. It has 8 megapixel camera, allowing 720p video recording, a hinge sensor, ambient light sensing and proximity sensor, 3 axis (gyroscope, accelerometer, compass) and a mike with headphone. Except of built-in touchscreen users have control via audio commands. The Google Glass weighs at least 43 grams. However, visually the glasses still remain the previous fashion of surveillance equipment. To reassure the society, Google Glass still places more emphasis on industrial application.

Vuzix Blade AR smart glasses (see Figure 5) (Statt 2018) provides a wearable smart display with a waveguide optics. Finally fashion meets technology in the wearable display arena. The technical parameters and functionality is close to Google Glass, however Vuzix glasses are significantly cheaper. The Vuzix Blade® Smart Glasses received 'Best in Show Overall' Auggie Award at AWE Europe 2018 held in Munich, Germany October 18-19.

In order to properly choose the Google Glass or Vuzix as basic solution for putting alignment AR application the sustainability simulation by IASAM model and state space analysis was done, based on both market information and practical experience (Aizstrauta and Ginters 2013; Piera, Buil, and Ginters 2013). The quantitative values of the evaluation parameters were, of course, subjective, and therefore the overall assessment was subjective. Both solutions were assessed as sustainable and usable for introduction, however Vuzix Blade AR had certain benefits related with equipment fashion, service quality, ownership and also is free of previous faults in public relations.

4. CONCLUSIONS

The golf game is a lovely and democratic way of active recreation without age limits that improve your health. For the beginner it is at least 3 hours and 7-8 km walk, which takes around 150 shots of golf ball. However, the spirit of the competition, which makes you want to play better, is also important.

One of the most significant components that can spoil the results of the game is putting. It is a complicated but rather routine procedure, in which, while maintaining peace of mind, the player must attack a golf ball hole, located a few meters or closer.

The main problem is the proper putting line detection and ball pointing to the hole. The good news is that these skills can be developed as a result of long-term training. But what to do for beginners and players who are not self-confident? The answer is augmented reality applications.

The AR solution offered by the authors allows the player to improve the accuracy of the ball's pointing through tuning the angle between the putter direction and putting line.

One of the most complicated phases of developing an AR solution is an appropriate choice of AR equipment, which must match the specificity of the golf game and also be sustainable. This equipment must not interfere with the player and pay extra attention of other players. So, those can be AR glasses, the design of which would not differ from ordinary sun glasses. In addition, those must be lightweight and comfortable, but the battery must provide several hours of operation. The virtual image must be designed and refreshed in real time, as the player's field of vision moves. Delay in data processing can cause discomfort to the player and affect the game. In addition, the eyesight must be wide enough. The application must be cyclical during the game and must not require any additional action of the player or some data entry. Because computing resources of glasses are limited, the application needs to work on a smart phone, which today, in most cases, works in the Android environment. Today, there are enough options for technical equipment, but sustainability factor is important, as glasses are not cheap. Respecting the above-mentioned functionality, restrictions and technical requirements, as well as sustainability simulation results, the authors given priority to Vuzix Blade AR glasses.

The adaptation of the beta version to real-game conditions may take some time. The main problems are the variety of putters, which affects the recognition of the object. One of the most complex problems is the sensitivity of the object recognition algorithm. A golf hole must be known regardless of whether there is a flag in the hole or not. The shape of the flag as well as the thickness of its stem must be ignored. The golf club must be recognized despite its variety of shapes and the centre of the shot must be calculated and visualized. This can be achieved through adaptive software training using artificial neural networks. Each user is provided with the ability to tune an individual algorithm's sensitivity factor. The quality of the application is also influenced by the peculiarities of lighting and the variable distance to the objects, which complicates the tracking (see Figure 4). The authors' future activities therefore will be devoted to AR software training and other related issues.

ACKNOWLEDGMENTS

The article publication is initiated by FP7 FLAG-ERA project FuturICT 2.0 (2017-2020) "Large scale experiments and simulations for the second generation of FuturICT".

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VIRTUAL REALITY POSTSTROKE REHABILITATION WITH LOCALIZATION ALGORITHM ENHANCEMENT

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ABSTRACT The work presents an analysis of the application of virtual reality technology in rehabilitation after the occurrence of stroke. The needs in poststroke therapy, as well as the requirements and technological possibilities were investigated, with the result being the creation of the application for post-stroke rehabilitation. Tests on the application, as well as analyzed studies have shown that this way of rehabilitation as an isolated therapy is not enough to improve the condition of patients. The combination of rehabilitation in a virtual and conventional manner provides a positive effect on the improvement of medical patient motor functions based on the surveyed patients.

Keywords: virtual reality, poststroke rehabilitation, stroke therapy, 3D localization, Time-of-Flight, localization algorithms

1. INTRODUCTION

Virtual reality technology enables one to experience the virtualized world in digital space. It introduces the immersion effect, providing a real experience of being in a different reality. This includes visualization, sound, touch and interaction with objects in a virtualized system, along with hardware that enables users to connect to the virtual space.

There are many commercial systems available that connect the user to the virtual world and enable interaction. This technology has great potential and is used in many consumer-focused applications, mostly in entertainment as a medium for games, simulations or filmography. Another branch is the development towards its use in medicine. Simulators of treatment are being developed, as well as for exercises and rehabilitation. It has been noted that some commercial projects are able to provide the appropriate amount of movement to support rehabilitation therapies.

The creation of dedicated systems for this purpose include the works of Da Gama and Weiss. (Da Gama et al. 2015, Weiss et al. 2006), in addition to conventional therapy being transferred to the virtual world (Dias et al. 2019, Covarrubias et al. 2015). This solution was beneficial for people after stroke, as their attention could be focused only on the task, and not on the inhibiting factors to exercise, such as pain or lack of motivation, with all this due to immersion. When the experience is engaging, one can forget about troublesome ailments and use virtual reality as an alternative way of poststroke rehabilitation.

2. METHODS AND MATERIALS

2.1. Literature Review

2.1.1 Rehabilitation System for Stroke Patients

The work by Cho et al. (2014) examines the design of a Virtual Reality (VR) proprioception platform designed specifically for patients who suffer from strokes. People with shielded hands move their hand to the target depicted as:

- A transparent cylinder moved with one hand;
- A colored cylinder being the target.

The patient considers the afflicted position of the hand to correspond to the target, the hand that is unaffected presses the button. The distance between the target and hand is measured.

The work presents simple correlations before and after testing with the proprietary system. The results are based on conventional post-workout behavioral tests, though it is shown that efficacy and adoption of VR to regain proprioception of patients suffering from stroke has potential. The noteworthy aspects of the implementation include:

- VR environment utilizing magnetic-based hand movement sensors;
- Employing proprioception in the VR platform, the sense of orientation of the body part being tested;
- Testing of hand function using Jebsen-Taylor approach; and
- ANOVA and T-testing were used to compare training effects.

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2.1.2 Patient Platform for Cognitive Rehabilitation

Covarrubias et al. (2015) has developed a system of moving objects in VR, that generates aromas such as chocolate, rose and orange essences. The rehabilitated person should move these objects according to the instructions, and the scent should generate adequate concentration for the user to identify.

These studies were partly developed from the Tele-Rehabilitation Ability project. This integrated platform enables remote control and delivery of cognitive and physical rehabilitation, as well as independent management. The equipment used for the experimental platform includes:

- Monitor utilized to display and render virtualized environment;
- Oculus Rift headset adopted to display a virtualized environment stereoscopically;
- Leap motion controller tracks user hand movements and gesture detection in free space;
- Multi-Fragrance Olfactory Display (MFOD) delivers odorous compounds;
- Arduino embedded microcontroller board controls the MFOD component in a logical manner.

2.1.3 Patient Platform for Cognitive Rehabilitation

Laver et al. (2018) provides a comprehensive review of VR in stroke rehabilitation, confirming that VR is readily acceptable for physiotherapy rehabilitation purposes. The work considered 72 samples, in which 2470 participants in total took part. The review factors 35 supplementary studies, as well as the studies included in previous reviews. The size of the research trials was generally small in nature, and the interventions differed in both the goals of the treatment and the VR devices being used for experimentation.

2.1.4 Reinforced-Feedback Rehabilitation Platform

Kiper et al. (2011) discusses a rehabilitation application in VR, which was controlled by the hand using gloves with receivers. The application image was displayed on a digital projector. The methods used in the platform include:

- TNR: Traditional Neuromotor Rehabilitation; and
- RFVE: Reinforced Feedback in Virtual Environment.

The use of RFVE, combined with the principles of TNR lead to more improvement than treatment with only TNR. Therapy in a virtualized environment included with TNR was inherently effective by twice as much compared to intensive TNR in patients, after ischemic as well as hemorrhagic stroke. The improvement after RFVE concerned not only patients after ischemic, but as well as hemorrhagic stroke conditions.

2.2. Rehabilitation Approaches in Virtual Reality

The main guidelines used in the virtual reality of stroke rehabilitation are based on neurobiological principles. The learning of new strategies and movement patterns are dependent on them. Improving motor skills are achieved by using the brain's ability to learn and adapt with increasing intensity of motor tasks, with the motor regeneration principles as follows (Ovbiagele and Turan 2015, Laver et al. 2018):

- Brain plasticity,
- Mirror neuron systems, and
- Brain reward system.

This is made possible by the plasticity of the brain, which is influenced by the reorganization of the cerebral cortex and changes in the damaged brain (Kiper et al. 2011). Intensive training and the observation, practice and representation of task-related activities on the screen can facilitate the reorganization of the cerebral cortex. This is also influenced by the involvement of mirror neuronal systems. Learning by imitation can lead to activity-dependency organizational concerns with the motor-neural cortex via mirrored neural networks. Participants receiving sensory feedback throughout training in virtual reality systems learned the motor pattern through imitation (Jang et al. 2005), with the so-called brain reward system used, thus increasing the motivation of the patients.

This system is a group of mesolimbic pathways mediated by dopamine. They are activated while the patient experiences the influence of video games. Virtual reality applications use appropriate concepts in stroke rehabilitation including frequent repetition, high intensity and tasks aimed at training paresis limbs (Cho et al. 2014), ranging from non-immersive to fully engaging activities. They also provide clinicians with the ability to control and evaluate tasks, with programs often including multimodal, real-time feedback (Weiss et al. 2006), as one can test tasks and dangerous situations in practice being designed to be used unattended. This allows one to increase the dose of therapy without increasing external labor and to conduct rehabilitation treatments at home, without loss in the quality of rehabilitation.

It is noted to assess the effectiveness of VR technology in its aims to give direction to the design and use. Much research is still being done, with the abovementioned studies already carried out showing positive results, and this area is developing rapidly in pace and scope.

2.3. Effectiveness of the Platform

To check the effectiveness of the hitherto applied poststroke rehabilitation with the use of VR, the latest available studies have been researched. There were materials used between the years of 2015 to 2018. The results in the analyzed group of studies are relatively similar. A 2015 study by Cochrane (Laver et al. 2015) found that adopting VR and interactive-based video games can be advantageous in optimizing upper limb functionality and restoring daily activity. This is possible when applied as a supplement to normal care or when considering the similar dose of conventional-based therapy. Current work has not been confirmed whether the effects obtained will persist in the long term, with further evidence required to draw conclusions about the impact on:

- Gripping power,
- Walking speed, or
- Global motor functions.

In 2017, the research work was extended with additional data (Laver et al. 2017). The results for upper limb function were not statistically significant when comparing virtual reality with conventional therapy. However, utilizing VR in combination to normal care it provided a greater dose of therapy, so there was a significant level of improvement statistically. It was found that this alternative method could be advantageous in assisting upper limb ability and regular life functions when complementing normal care. The most recent diagnosis has also shown that conventional therapy is more effective than isolated rehabilitation in virtual reality. The review showed that the following rehabilitation factors did not significantly affect the outcome (Laver et al. 2018):

- The effective dependence of time on stroke occurrence,
- Extent or severity of medical handicap of the patient, and
- Type of VR hardware device.

By using virtual reality to complement normal care, as well as raising the number of participants in the work, it showed statistically significant differences to groups using only one type of treatment. It was also noted that personalization of rehabilitation programs in virtual reality was better than commercial games, but the results were not statistically significant. It should also be noted that the size of study samples was mostly small, the virtual reality devices used differed from each other, as well as the purposes of treatment of the conducted analyses. Further studies are being carried out, in addition to virtual reality technology still being developed. It now can be observed that it brings significant results in combination with conventional care. However, more targeted research on a larger scale is needed.

2.4. Application for Poststroke Rehabilitation

The main objective of the project was to create an application in a virtual environment, which can be used as an aid in poststroke rehabilitation in the field of performing precise movements of upper limbs and recognizing and identifying objects. The application includes exercises in conventional physiotherapy, which are to be performed based on reaching the next levels in the game and scoring greater points. The tasks performed having different levels of difficulty. For the newly designed VR application to be useful to the patient and medical clinician, the rules for user immersion and the sense of presence in the game had to be applied. The object manipulation tasks include:

- ***Articulation:***
  Reaching out to ultimately grab the virtual object by means of articulation, by the extension of the patient's hand towards the object they want to manipulate,
- ***Grasping:***
  Acquiring the target by squeezing the object to determine its plasticity or sponginess, to determine the ability of the patient to grip the object for further exercises by a medical specialist or clinician, and
- ***Manipulation:***
  Moving the object to place the object from one region of space to another, to determine the level of precision or accuracy that the patient can conduct the specific task or exercise for assessment by a third party.

After creating the application, it was possible to test it on people after a stroke, with experiments conducted at the Department of Neurological Rehabilitation, Regional Specialized Hospital in Wrocław, with rehabilitation using virtual reality applied at the facility for the first time with patient consent.

The medical center provides care and rehabilitation for patients with cancer, inflammatory consequences of central nervous system diseases, multiple sclerosis and systemic primary atrophies occupying the central nervous system, as well as after stroke care. This work will continue to build upon the previous research done in the hospice, and that we will continue to collect and refine test data on a larger group of patients.

3. CURRENT PLATFORM RESULTS

3.1. Current Technology Framework

The created platform uses Oculus Rift. It is a tool that enables to connect the user with virtual reality. It meets all the conditions to ensure that the immersion is maintained. The Oculus Rift consists of goggles and two sensors. Moreover, the Leap Motion controller is used. It is a device capable of tracking all ten fingers of a hand. It provides gesture tracking for control in a virtual reality environment. In conjunction with Oculus Rift, it reproduces the position and actions taken by the user to the computer system. The following software was used to create the application:

1. *Unity 2018.1.6:* A multi-platform game engine, which is the necessary programming tools selected for the project. Oculus SDK, which is attached to the applied Unity version and additionally the Leap Motion SDK.

2. *MonoDevelop:* Integrated open-source programming environment used to create C# scripts.
3. *Blender:* 3D software for creating computer graphics.

The platform uses the Oculus headset, that is connected to a laptop computer with an Intel Core i7 processor, a GeForce graphics processing unit and 16 gigabytes of main memory. The computer runs the Microsoft Windows 10 Professional operating system, with additional software development toolkits installed including the Leap Motion and Oculus device libraries to interface the hardware with the software subsystem.

3.2. Rehabilitation Exercise Platform

Three patients approached the preliminary studies of the application. The patients were in a similar condition. All had efficient upper limbs, however there were various degrees of problems with loosening and grabbing one of the hands. Patients performed three rehabilitation tasks shown in Figure 1 on the following page.

The first patient started the test with a positive attitude. It took him a while to get acquainted with the new technology. No major difficulties were encountered while performing the tasks. During some tests he was able to spread his hand completely and release the ball. In the case of unsuccessful grabbing, he picked up the ball from the bottom and moved it to the designated place. All three tasks were completed.

The second patient had some skepticism and was scared, but after getting acquainted with the equipment the fears were dealt with. The patient had more difficulty in using the right hand and put more effort into completing the tasks. In case of a failure to catch the ball, he compensated for the force and instead of grabbing it with his hand, he 'threw' it which made it easier to carry out the command. The biggest problems occurred during the third exercise. Small breaks were needed between activities. The help of the physiotherapist in mobilizing the patient was important. The patient was able to complete all the tasks, after which he showed enthusiasm for the completed training. As the exercises progressed, opening the hands to move the ball became more efficient.

In the third attempt, the patient showed no prejudice. He willingly went on to tasks that did not cause him any major problems. He did not always manage to open his paresis hand, but many attempts made it easier. Here too, the activity of grabbing the ball from below was used, making it easier for him to complete all his exercises.

The opinions expressed by the test patients were favorable, as they considered it an interesting experience and expressed their willingness to use the application in everyday rehabilitation, although sometimes it required concentration and reflection on their part. The usability of the system was an important focus in the system design, such that patient needs were considered throughout the experimental task. Because of observing patients during the exercises, it was possible to draw conclusions that could not be deduced easily in the computer laboratory.

The experimental work was enhanced through practical on-field assessment of patients and their interaction with the rehabilitation platform in the following manner:

- ***Mode of Operation:***
  Grabbing of the ball in a clenching motion in by the medical patient within the virtual rehabilitation platform.
  - The way the virtual balls are grabbed is essential, as it is important to clench the hand and move the ball in the virtual space.
  - In many test cases, the ball was picked up from the bottom without much or minimal hand work from the current set of test patients.
  - This indicates that familiarity with the system was accomplished with recurring usage.
- ***External Intervention:***
  Actions required to ensure the medical patient is comfortable with the use of the virtual rehabilitation platform.
  - Accomplished by means of changing the patient's attitude and calming them down as necessary.
  - It is possible that initial hesitation and uncertainty over the technology was caused by the first experience with the application.
  - Assumptions cannot be made into the patient's prior experience with VR systems.
  - Incremental improvement over the user interface design is essential to help overcome technological barriers with the test patients.

Repeated attempts would eventually eliminate this problem through familiarity of the virtual environment, as well as positive encouragement with the patient as they engage with the rehabilitation platform. However, the intervention of the rehabilitator assists in the initial use of the experimental system, such as to train up the patient to be familiar and ultimately be at ease with VR technologies.

4. MAIN REHABILITATION OUTCOMES

The next step is to evaluate the effectiveness of the experimental application on a small test group. As observed in the Functional Classification of Handling Grip scores elaborated in Table 1 (Enjalbert, Pelissier and Blind 1998, Pélissier, Benaïm and Enjalbert 2002), connecting the handling gripping parameters to existing research would enhance platform usability into human mobility.

Thus, this allows for a thorough comparison and contrast between VR and physical testing approaches.

The testing classification approach will be consulted with medical professionals in conjunction with Wrocław Medical University to determine the optimum assessment approach. There are many other methods for measuring effectiveness of poststroke rehabilitation (Scrutinio et al. 2019, Turner-Stokes 2010). We decided to apply the mentioned system as shown in Table 1.

After the rehabilitation exercises, each patient got an appropriate mark shown at Table 1. Obtained results are present at Table 2. Mark in the column 'Start' describes initial state of patient and in the column 'End' final state. A small improvement after the test is observed. In our opinion, the optioned results seem to be promising. We expect more results during the next session of rehabilitation exercises.

Table 1: Functional classification of handling grip (Enjalbert et al. 1998, 2002)
Note: Test Only Valid in Vascular Hemiplegics

Level	Test Description
0	• No recovery in grasp; • Zero gripping ability.
1	• Syncinetic reflex approach in abduction-shoulder retropulsion; • Includes elbow bending.
2	• Analytical approach without possible grasp.
3	• Analytical approach with global grasp; • Without actively releasing grasp or letting go.
4	• Analytical approach with global grasp; • Actively releasing grasp or letting go.
5	• Existence or the ability of a tri-fingered grasp.
6	• Gripping normally with fine clamp of the object.

Table 2: Observed results of poststroke rehabilitation

Patient	Start	End
1.	4	4
2.	3	4
3.	3	4

A new series of tests for a larger group of patients will be carried out in August. The results will be presented at the VARE September 2019 conference session in Lisbon.

5. FURTHER WORK

5.1. Application Development Approach

In this research, the application will be used to study the position of hands in space, with the consideration made into applicable localization algorithms useful for medical diagnosis purposes (Olech 2018). It will employ extensive use of the Leap Motion controller, a device that tracks hands across a wide range of lighting and environmental conditions. The software is developed in C++ and utilizes the Qt library.

Integration of the coordination data with the existing platform can be accomplished using readily available Application Programming Interfaces (API) included with the controller hardware. The application displays various tracking data provided by the Leap Motion Application API for three axes of positional coordinates in time.

In this manner, it verifies if the hand position at a given time has not exceeded the admissible range for a healthy person. For each rehabilitation task, a new session is created in the application and recording the hand position during the task. The collected data is displayed on visual charts and will be exportable for further analysis by medical experts. The length and path of the hand movements are to be recognized in a logical manner, such that the smoothness of the path can be properly evaluated by the clinician in real-time.

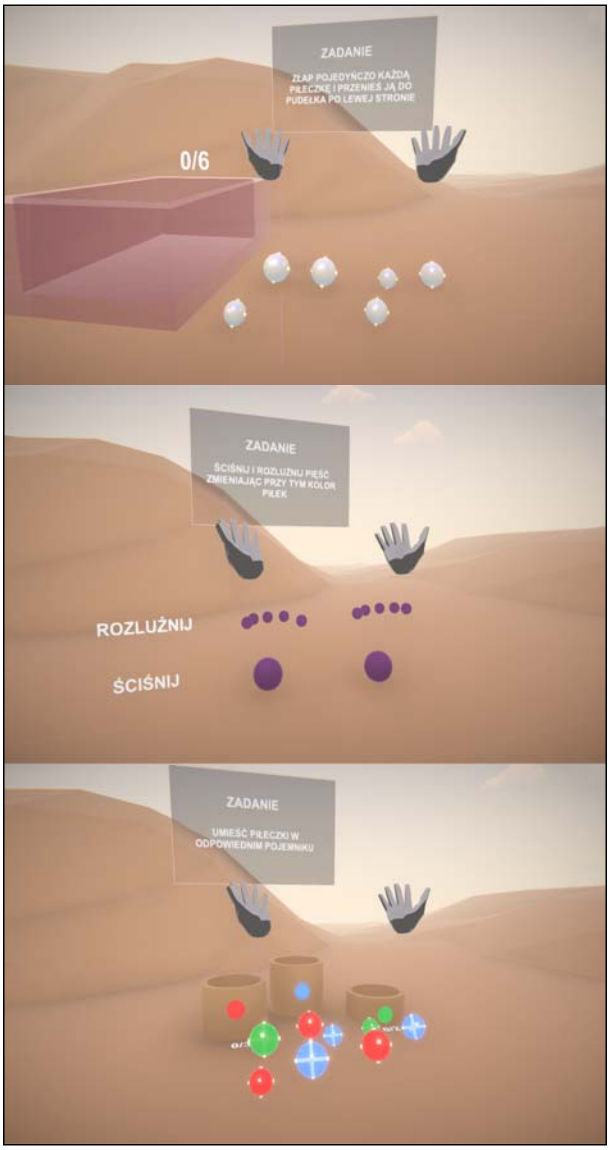

Figure 1: Experimental rehabilitation application scenes demonstrating coordination testing system; with the scoring based on the number of balls successfully placed in a generic bin (*top*), digit coordination (*middle*) and color-coded bins (*bottom*) (Marzec 2018)

The fine motor coordination skills of the patient will be determined by the amount of oscillation observed during the path of the hand, and eventually compared against a database of anonymized patients with healthy hand movements of a similar age range. In this way, a comprehensive process can be established for diagnosing patients in a structured manner, that aims to minimize potential subjective bias in the testing program that can occur with manual assessment.

The next step is to evaluate the effectiveness of the experimental application on a larger test group to improve the platform. As observed in the Functional Classification of Handling Grip scores elaborated in Table 1 (Enjalbert, Pelissier and Blind 1998, Pélissier, Benaïm and Enjalbert 2002), connecting the handling gripping parameters to existing research would enhance platform usability into human mobility.

Thus, this allows for a thorough comparison and contrast between VR and physical testing approaches. The testing classification approach will be consulted with medical professionals in conjunction with Wrocław Medical University to determine the optimum assessment approach.

5.2. Research Scope of Platform

Currently, rehabilitation in a virtual environment is not enough as an isolated therapy, as test patients require physical exercise and training for a more holistic experience. This is the result of extensive research being carried out on existing VR rehabilitation systems, as well as the testing of the created application for patients at the Department of Neurological Rehabilitation, Regional Specialized Hospital in Wrocław.

The initial responses from the test patients show that further work into the platform is warranted, along with additional enhancements into the interaction experience to improve user immersion.

Therefore, this is expected to optimize the familiarity of exercises performed in the virtual environment in the following manner:

- ***Patient Survey:***
  Their personal opinions will be considered as part of the application design phase, for technical refinement and quality assurance purposes.
- ***Continuous Feedback:***
  Assessing the regular feedback of users is part of the iterative design principles, as well as make incremental changes into the experimental platform after all relevant stakeholders are factored into the rehabilitation process.
- ***User Centric Design:***
  In this way, we seek to integrate usability concerns, which is an important qualitative issue typically overlooked in system design.

The application in the virtual environment was positively received by patients and physicians. Its immersive action encouraged the users to participate in rehabilitative exercises and seek out additional remediation therapies as necessary. The technology was an initial barrier, as with any reticence for new platforms, that was overcome through familiarity and engagement with VR technologies and their associated use cases. Such a concern will take time to overcome, but current work shows initial promise.

As the current experimental work deals with an effective VR training process, it builds upon on the important physiotherapy work of Kiper et al, 2011 and Laver et al. 2015, 2017 and 2018. It is important to note the current work is expandable to a larger patient test base – thus accommodating a wider variation in demographics and physical capabilities of medical patients.

Even though the current method itself shows promise, putting on the VR equipment did present fear and anxiety in some patients. Thus, the current work needs to continue focusing on the most notable limitations when designing such rehabilitation and training programs. Furthermore, VR is still not widely used in the rehabilitation of people after stroke in centers where this type of rehabilitation is carried out, so it presents new opportunities for human development and technical evaluation.

6. CONCLUSION

The research work examines the efficacy of the rehabilitation platform after a certain period of use. The influence on motor coordination functions was not satisfactory in comparison with normal therapy in isolation, although experimental factors including small test patient samples and technology limitations could affect the eventual rehabilitation outcome of the patient given research into this medical domain.

In combination with virtual and conventional rehabilitation, the effect on motor function was better than with normal therapy (Kiper et al. 2011), as well as the analytical diagnosis data generated from the VR exercises. This data was forwarded to physiotherapists for further analysis and examination. Comparing the results with conventional rehabilitation is key to assess the advantages of this newly designed approach into medical healthcare.

Along with building a database of healthy hand movements for rehabilitation assessment, this will assist in the analytical process – such as to provide a greater longitudinal study into this field of research. Rehabilitation tasks can be diversified by focusing on the creation of personalized exercises adjusted to the patient and their needs, tailoring physiotherapy techniques as necessary.

The cooperation with the Department of Neurological Rehabilitation, Regional Specialized Hospital in Wrocław along with Wrocław Medical University will continue as current results have proven fruitful, with further contact and engagement with patients and doctors being essential to effectively construct an authentic rehabilitation medium.

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THE IMPACT OF VIRTUAL VISUALISATION: PERCEPTION AND DESIGN OF SPACES IN ETHNOGRAPHIC PROJECTS

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ABSTRACT
The use of VR technology within education is an area that has generated great interest in recent years, so this work follows that trend and contains nuances related to user-centred design education. The objective of this work is to identify students' perceptions of the use of VR technology for ethnographic research. A group of 20 industrial design students from Tecnologico de Monterrey conducted a field investigation, which included interviews and surveys, using HMD with videos and stereoscopic images of a public park in Monterrey, Mexico. Based on the research and information analysis, areas of opportunity were identified and urban furniture proposals for the public park that place were generated. Once the design process was completed, an evaluation instrument was applied to measure, through statistical analysis, the students' perceptions of their experience using technology in the design process; gender, qualification obtained and the relevance of the technology used was also considered.

Keywords: educational innovation, stereoscopic images, urban space, furniture, didactic.

1. INTRODUCTION
The visualisation techniques employed by mobile devices have changed a lot in recent years, to the point that the quality of visualisation is comparable to any other display device, such as High Definition (HD) or high resolution television screens. However, this reality has impacted the different standards, uses and available applications of display options.
The perception of different scenarios, landscapes, etc., involve multisensory and simultaneous processes. These actions involve active observation that requires action, control and manipulation by those in contact with the scenario being perceived, in addition to the content of meaning and emotional messages that the people are subjected to (Zube, Sell, and Taylor 1982). In this sense, the concept of architecture or the visualisation of space are largely conditioned by issues related to identity and to the socio-cultural sphere (Leila and Naima 2016). Hence why the perception of spatial elements or architecture is related to several factors that include the socio-cultural exploration of different regions (Zube and Pitt 1981).
Environmental simulations, which play a fundamental role in the practice of certain disciplines, such as architecture and design (Sainz 2005), are not exempt from the use of more traditional techniques, such as paper, until new technologies – in this case, the use of stereoscopic vision devices and virtual reality – are incorporated (Ackerman 2002, Ervin and Buhmann 2003). All of these techniques are also conditioned to the theme of culture and use, which is why the implementation of any type of simulation system should be carefully considered through the practice of space and element perception. This initiative is based on the fact that the use of technology for the purpose of visualiation may be subject to the expertise of both designers and users, so care must be taken to develop valid proposals (Llinares and Iñarra 2014).
With regard to the adoption of virtual reality technology and visualisation, the current trend suggests that a common language is needed, that the technologies are intuitive and that such adoption primarily occurs naturally (Chang and Huang 2014). In the context of architectural and design applications, virtual reality and similar technologies provide opportunities to train professionals in a process of natural adoption, giving them new competencies (Fonseca et al. 2014).
There are, however, additional examples of how to use VR technology and how it can impact an individual's perception of reality and ability to visualise real and virtual spaces, as well as about the places or experiences that can significantly influence an individual's emotional state or quality of life (Rojas et al. 2018, Higuera-Trujillo and Rojas 2019). Among academic subjects, the application of technology is considered one way of improving the experiences of engineering and design students, since technology can create emotional bonds and impact students' performances, as illustrated by Núñez, Rojas and Rodriguez-Paz (2019).
This paper is about the use of stereoscopic images as a didactic element (Baeten, Kyndt, Struyven, and Dochy 2010) to identify different aspects of urban places

(Jordan 1998), with the idea that this technology allows users to generate furniture improvement proposals and, from their usage experiences, consider the impact of different times of day and weather conditions (Ayllon 2013).

2. METHODOLOGY

This work was implemented in a second-year course in the Industrial Design bachelor's program of Tecnologico de Monterrey. The goal of the project, which was developed by 20 design students (11 female, 9 male), was to determine opportunities for improvement to the experiential experiences and interactions with urban furniture (Norman 2011) at different times of the day and under different atmospheric conditions, allowing for immersion in the environment regardless of whether they were in the same place.

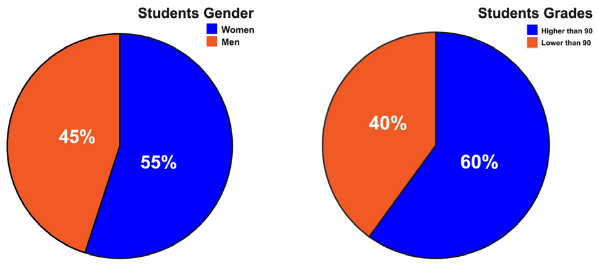

Figure 1: Students who used HMD to analyse the images and videos.

To start the process, a specific urban place was analysed based on 360° videos and images captured using stereoscopic image viewers or Head Mounted Display (HMD) units and smartphones with the THETA S® app (Fu and Hwang 2018). The selected urban space was a 'pocket park' created for the Distrito Tec project, in the city of Monterrey, Mexico (see Figure 2).

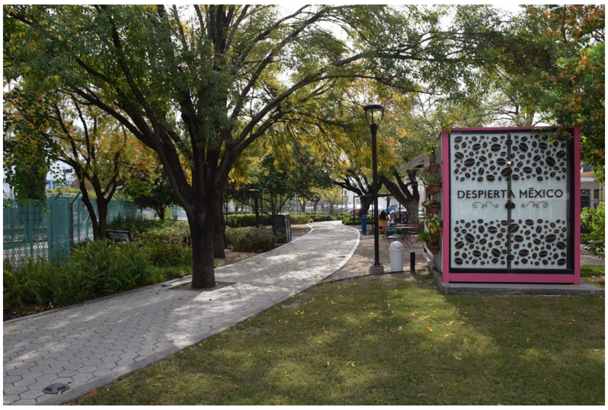

Figure 2: Selected urban space. Pocket park near the Tecnologico de Monterrey campus in northern Mexico.

Figure 3: Sequence of the methodological process followed by the students who participated in this project.

Using the videos and stereoscopic images, we sought to determine areas of opportunity where user experience and interaction with street furniture could be improved (Norman 2011). We considered different times of day and different weather conditions (cloudy, sunny, rainy, etc.), which allowed us to appreciate possible changes in the user experience depending on the environmental conditions and time of day (see Figure 4 for an example of a stereoscopic image).

Figure 4: Stereoscopic image of the selected urban space. Pocket park near the Tecnologico de Monterrey campus in northern Mexico.

ISBN 978-88-85741-41-6; Bruzzone, Ginters, González, Gutierrez and Longo Eds.

Figure 5: Students in the classroom using HMD to analyse the images and videos.

The course focus allowed students to introduce visual technology to the user-centred design process (Figure 5). Subsequently, the class was split into seven groups in total to perform two ethnographic exercises (10 interviews and 30 surveys) (Hernandez, Fernandez, and Baptista 2010; Zapata 2005). Students used a comparative dynamic between traditional visual elements and visual elements perceived using the HMD to determine the influence of technology on the results obtained from the ethnographic exercises.

Figure 6: Example of the HMD devices used.

The construction of ethnographic instruments was a fundamental part of the process. The instruments were designed to contemplate the intrinsic relationship while considering real and virtual immersive visualisation (Higuera-Trujillo, Rojas, Perez, and Abad 2017; Russell 1979). Other relevant questions included estimated time of use, activities carried out, individual or shared use and identification of problems. Data analysis was completed via open coding (Strauss and Corbin 2002), along with multiple choice questions that allowed us to establish patterns, before passing through selective coding (Hernandez, Fernandez, and Baptista 2010) to finalise certain design requirements and key specifications (Ulrich and Eppinger 2013).
To complete the project implementation, a survey-type evaluation was completed by the 20 students who participated in the study in order to assess the impact of technology on their perceptions of their learning. The survey consisted of eight questions, which the students ranked on a scale of one to five. This evaluation allowed us to develop three types of statistical analyses and revealed information about the impact of technology on the perception and design of products and spaces, as presented in the analysis, below.

3. ANALYSIS

The data analysis was divided into three parts, or observations, in order to distinguish the students' VR technology experiences and performance. The first analysis was an observation of the final instrument and the results of the students' general perception based on the eight-question survey. The second analysis was a revision of the statistical comparison obtained by segmenting the data based on gender, opinion and perception of the final instrument. The third analysis was a revision of the statistical comparison obtained by segmenting the data based on the students' performance and perception of the final instrument.
The first analysis assessed the questions about the users' perception of the VR technology, all of which were possible to measure, except for the question of whether the interviewed user was intimidated by VR, as the scale marked a lower value. The data is presented in Table 1.

Table 1: Descriptive statistics of instrument perception.

Opinion perception questions	Mean	Std. Dev.
How much do you consider the use of VR impacts the proposal's relevance?	3.80	0.834
Do you consider the use of VR increases the number of proposals generated?	4.05	0.999
Do you consider that, without VR, you would not have reached the final proposal?	3.05	1.14
Do you consider the interviewed user was intimidated by the VR experience?	2.45	0.999
Do you consider the use of VR influenced the opportunities for detection?	3.90	0.912
How useful do you consider VR to be for ethnographic research for the purpose of design?	4.10	0.912
Do you feel there is a significant difference between using and not using VR technology?	3.65	0.875
How probable is it that you will use VR technology again for future ethnographic research?	4.15	1.040

For the second analysis, a one-way analysis of variance (ANOVA) was performed to compare the opinions gathered from the VR technology experience questions against the students' genders. A complete table of descriptive and statistical results is presented in Table 2. This analysis revealed that two of the eight variables offered significant value (<0.05). Gender represented a significant value for the questions, 'Do you believe the use of VR increases the number of proposals generated?' gender factor showed a significant value ($p=0.008$) and 'How useful do you consider VR to be in the design of ethnographic research?' ($p=0.040$).
For the third analysis, another one-way ANOVA was performed to compare the students' opinions that were

Table 2: Descriptive and statistical results of assessment questions, based on gender.

Opinion perception questions	Factor	Mean	Std. Dev.	F	Sig (ANOVA)
How much do you consider the use of VR impacts the proposal's relevance?	Women Men	3.55 4.11	0.820 0.782	2.454	0.135
Do you consider the use of VR increases the number of proposals generated?	Women Men	**3.55** **4.67**	1.036 0.500	8.801	**0.008**
Do you consider that, without VR, you would not have reached the final proposal?	Women Men	2.73 3.44	1.104 1.130	2.045	0.170
Do you consider the interviewed user was intimidated by the VR experience?	Women Men	2.45 2.44	0.820 1.236	0.000	0.983
Do you consider the use of VR influenced the opportunities for detection?	Women Men	3.64 4.22	1.027 0.667	2.169	0.158
How useful do you consider VR to be for ethnographic research for the purpose of design?	Women Men	**3.73** **4.56**	1.009 0.527	4.928	**0.040**
Do you feel there is a significant difference between using and not using VR technology?	Women Men	3.55 3.78	0.820 0.972	0.337	0.569
How probable is it that you will use VR technology again for future ethnographic research?	Women Men	4.00 4.33	1.183 0.866	0.495	0.491

gathered from the questions about their experiences with VR technology and their performance (grades) on this project. A complete table of descriptive and statistical results is presented in Table 3. The test revealed that only one of the eight variables presented a significant value (<0.05). For the question, 'How probable is it that you will use VR technology again for future ethnographic research?', grades represented a significant value (p=0.031).

4. RESULTS AND DISCUSSION

This work is the beginning of a series of studies that seek to expose the relevance of VR technology within the design process and the teaching of them. In general, the students felt that VR was relevant, and they had a positive experience using this technology. The students primarily found VR helpful in generating new proposals (M = 4.05), useful as an ethnographic method (M = 4.10) and would probably use it again for the same purpose (M = 4.15).

As part of this study, we wanted to observe students' perceptions regarding the use of VR technology for ethnography subjects in design courses. Hence why gender comparisons were made; as there was a high proportion of female students in the class, this observation was relevant. The question, 'Do you consider the use of VR increases the number of proposals generated?', produced a noticeable difference between women (M = 3.55, SD = 1.036) and men (M = 4.67, SD = 0.500), with men appearing to be more invested than women in technology. The question, 'How useful do you consider VR to be for ethnographic research for the purpose of design?', also showed a relevant difference between women (M = 3.73, SD = 1.009) and men (M = 4.56, SD = 0.527), with men apparently considering VR to be an ideal technology for this type of project.

We also observed, with particular interest, the perceptions of students who achieved high or regular grades (on a scale of zero to 100) for their performance on the project. To obtain this result, one of the eight survey questions asked, 'How probable is it that you will use VR technology again for future ethnographic research?' There was a difference of opinion between the students who scored higher than 90 (M = 3.75, SD = 1.138) and those who scored lower than 89 (M = 4.75, SD = 0.463), where students who scored below 89 responded that they would use technology more safely. This difference can open a window to related research, such as the relevance of this technology for similar projects and empathy for students who seek higher qualifications. These results are presented in Figure 7.

Table 3: Descriptive and statistical results of assessment questions, based on performance (grades).

Opinion perception questions	Factor	Mean	Std. Dev.	F	Sig (ANOVA)
How much do you consider the use of VR impacts the proposal's relevance?	Higher than 90 Lower than 89	3.92 3.63	0.900 0.744	0.575	0.458
Do you consider the use of VR increases the number of proposals generated?	Higher than 90 Lower than 89	4.17 3.88	1.267 0.354	0.396	0.537
Do you consider that, without VR, you would not have reached the final proposal?	Higher than 90 Lower than 89	3.08 3.00	1.311 0.926	0.024	0.878
Do you consider the interviewed user was intimidated by the VR experience?	Higher than 90 Lower than 89	2.67 2.13	1.155 0.641	1.445	0.245
Do you consider the use of VR influenced the opportunities for detection?	Higher than 90 Lower than 89	3.83 4.00	1.193 0.000	0.153	0.700
How useful do you consider VR to be for ethnographic research for the purpose of design?	Higher than 90 Lower than 89	4.17 4.00	1.115 0.535	0.153	0.700
Do you feel there is a significant difference between using and not using VR technology?	Higher than 90 Lower than 89	3.83 3.38	0.937 0.744	1.340	0.262
How probable is it that you will use VR technology again for future ethnographic research?	Higher than 90 Lower than 89	**3.75** **4.75**	1.138 0.463	5.486	**0.031**

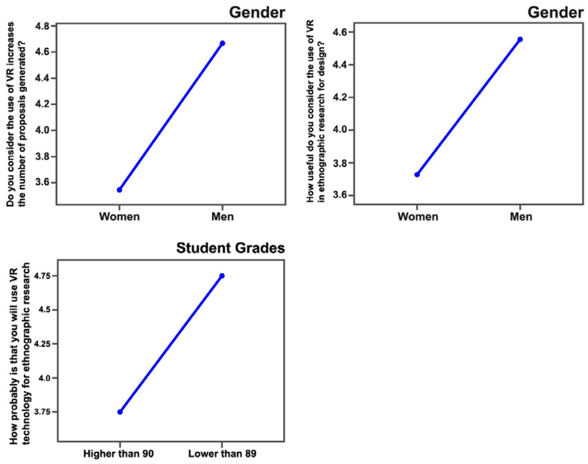

Figure 7: Graphic results of the comparison analyses for gender and grades.

Finally, all of these results allow us to establish a very interesting relationship between the impact, the use of technology and the direct results of the design projects completed by the students. This relationship allowed the students to identify, immerse themselves within and understand the influence of a space (pocket park) under different conditions. Likewise, it was possible to observe the differences and similarities when traditional and 360° visual elements were introduced. The students developed seven proposals that consider design aspects that were enhanced by the use of immersive, more so than traditional, visualisation.

5. CONCLUSION

This paper creates an opportunity to continue researching the relevance and impact of virtual visualisation technology in areas that require constant use of spatial perception. Thanks to cutting-edge technologies, new application possibilities have been developed that have not yet been explored in-depth. Additionally, the use of different technologies within educational environments offers the possibility of relating different elements that exist not only for the communication or transmission of content, but also to allow for the integration of different variables that can directly affect the teaching-learning process and help each individual develop different professional competencies.

This particular research, despite the inherent limitations, allows us to generate important approximations regarding the significance of technology usage for generating design projects and, in general, for ethnographic research.

Finally, it is important to emphasise that this research project is ongoing and will continue with another group of students, with whom the process will be repeated for the same subject and under similar conditions, in order to finish consolidating the results and to generate more consistent conclusions regarding the impact of VR technology on the teaching of design.

ACKNOWLEDGMENTS

The authors would also like to acknowledge the financial support provided by the Novus grant (Laboratorio de diseño, exploración y validación de productos y espacios), with PEP No. PHHT002_ 18ZZ00041, as well as the support of the Writing Lab and TecLabs at Tecnologico de Monterrey, Mexico, throughout the production of this work.

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EVACUATION TRAINING USING SCENARIO-BASED AUGMENTED REALITY GAME

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ABSTRACT
Evacuation training is important as disaster education that covers how to survive disasters. However, traditional evacuation training does not provide realistic simulated evacuation experience (SEE). To provide the such, we developed game-based evacuation training (GBET), where trainees are required to reach a shelter in the real world within a time limit while making decisions against virtual disaster situations presented as digital contents (e.g. video and single-choice question) on GPS-enabled smartphones or tablets. However, the GBET was insufficient in the audiovisual reality. To provide a more realistic SEE, we created an evacuation training using scenario-based augmented reality (AR) game that integrates marker-based AR and scenario-based game. Although only applicable in indoor activities, the evacuation training (the extended GBET system) presents AR that expresses disaster situations (e.g. flood and fire) by superimposing three-dimensional computer graphics onto the real-time view through a handheld head-mounted display.

Keywords: evacuation training, reality, AR game, branched scenario

1. INTRODUCTION

Natural and man-made disasters are threats to our lives and properties. Thus, substantial energy has to be invested in disaster management (disaster risk reduction) to counter these threats. There are two types of disaster management: structural (e.g. shelters and coastal levees) and non-structural (e.g. education and information systems). It is indisputably important to combine these for steady disaster management, but it would depend eventually on our decision-making on whether we can survive disasters. Emphasising on the importance of non-structural disaster management, this study focuses on disaster education that covers how to evacuate, that is, how we should make decisions against disaster situations.

A typical example of disaster education is evacuation training, which provides simulated evacuation experience (SEE). For example, in an earthquake evacuation training, trainees (participants) take actions of 'drop, cover and hold on' and simply evacuate to a fixed shelter via a recommended route. This simplicity is necessary for a wide range of trainees (i.e. from children to the elderly) but can sacrifice the reality. In actual evacuations, we can encounter disaster situations where it is difficult to make decisions (e.g. which to detour instead of a closed route). Traditional evacuation training frequently excludes such difficult disaster situations and makes SEE unrealistic. However, the unrealistic SEE, which excludes decision-making, cannot encourage trainees to have a sense of tension and earnestly learn how to evacuate. Hence, we need to create novel and effective evacuation training that involves realistic SEE.

In recent years, virtual reality (VR) and augmented reality (AR) have been actively applied to disaster education. There have been many examples of VR-based training for emergency responders, commanders and crane operators (see, e.g. Cha and Han, 2012; Bacon et al., 2013; Molka-Danielsen et al., 2018; Xu et al., 2018; Longo et al., 2019). In addition, VR-based evacuation training has attracted much attention especially in terms of the integration with gaming elements (Feng et al., 2018). For example, Smith and Ericson (2009) developed a VR game using cave automatic virtual environment that encourages children to take proper body actions during evacuation. Chittaro and Sioni (2015) developed a desktop VR serious game where players can learn how to evacuate from terrorist attacks while receiving instructions about proper decisions. Lovreglio et al. (2018) developed a VR serious game using a head-mounted display (HMD) that requires players to evacuate from an earthquake-damaged hospital while interacting with environments and agents (non-player characters). To define better emergency protocols and procedures, Nicoletti and Padovano (2019) examined the relationships among emergency managers' workload, stress and outcomes in a virtual reality (VR)-based serious game where the managers can experience responses to a conflagration in an industrial plant.

Compared with VR-based evacuation training, AR-based evacuation training has not been popularised yet and can be regarded as a new field (Lovreglio, 2018). Traditional evacuation training requires trainees to move in the real world, and the trainers must be concerned about avoiding the trainees' injury. In VR-based evacuation training, an evacuating world (virtual disaster world) is modelled as three-dimensional computer graphics (3DCG), and the trainees can safely move around the world with gamepads or body actions. Thus, VR-based evacuation training can provide not only realistic but also immersive safe SEE. Meanwhile, AR must adopt the real world as the evacuating world and express disaster situations by superimposing 2D/3DCG onto the real-time view captured via a mobile device (e.g. smartphone). In other words, for realistic SEE, AR-based evacuation training must ensure safety as a prerequisite and geometric consistency (i.e. the accuracy of the superimposition in position, size and angle).

In this study, we aim to create an evacuation training that integrates marker-based AR and scenario-based game while believing that AR leads to providing more realistic SEE than VR.

2. GAME-BASED EVACUATION TRAINING

A typical cycle of disaster management starts from the occurrence of a disaster and consists of four phases: response, recovery, mitigation and preparation (NGA, 1979). To survive disasters, we should primarily focus on the response phase (i.e. a short time immediately after a disaster occurs) and learn how to evacuate. However, trainees in traditional evacuation training do not necessarily have high motivation. This is because disasters infrequently occur and they do not necessarily receive benefits from the training. Such trainees may fail in evacuation in actual disasters. In other words, there is little effect of the training.

Evacuation training should have a motivational impact as a prerequisite for improving the effect. To create such training, we focused on geo-fencing (location-based) game using global positioning system (GPS). This is because geo-fencing games (e.g. Pokémon GO) have been popularised due to their motivational impact and share similarity with evacuation training in terms of moving into the real world.

2.1. Design

Focusing not only on the motivational impact but also the training effect, we proposed game-based evacuation training (GBET) that adopted a geo-fencing game mechanism. In the GBET, trainees are required to reach a shelter in the real world within a time limit while making decisions against virtual disaster situations at designated locations or times (Mitsuhara et al., 2015). The GBET aimed to provide realistic SEE by expressing the virtual disaster situations with a branched scenario and digital contents and encouraging the trainees to effectively learn how to evacuate. An ideal model of the GBET is based on Kolb's experiential theory that consists of four stages (Kolb, 1984):

- Concrete experience (CE): A trainee is provided with the first SEE. Here, the trainee evacuates (moves) in the real world while making decisions against virtual disaster situations.

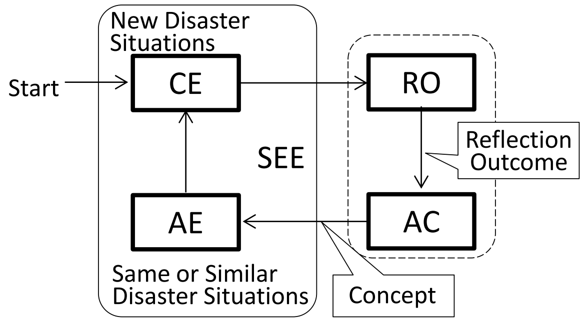


Figure 1: An Ideal Model of GBET

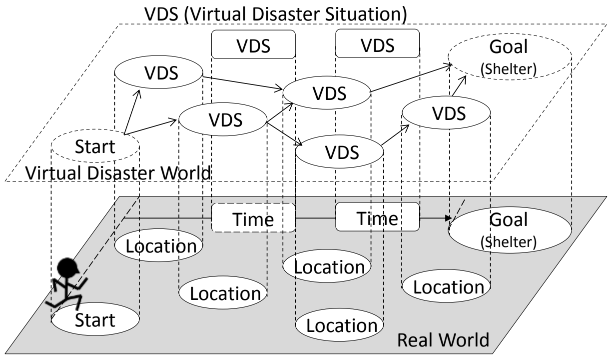


Figure 2: Relation between Virtual Disaster World and the Real World

- Reflective observation (RO): The trainee reflects on his/her first SEE.
- Abstract conceptualisation (AC): The trainee conceptualises better evacuation from his/her reflection outcomes.
- Active experimentation (AE): The trainee attempts his/her concept in the second SEE with similar or the same disaster situations.

In this model, the trainee follows the cyclic stages and eventually learns how to evacuate in various disaster situations, that is, to survive disasters. Figure 1 shows the ideal model of the GBET. Figure 2 shows the relation between the virtual disaster world and the real world.

The GBET uses the strength of being conducted in the real world to provide more realistic SEE in terms of physical experience. For example, trainees who decide to rescue an injured person in a virtual disaster situation are made to evacuate while conveying a heavy doll in the real world; they may fail in evacuation due to fatigue and decrease of their moving speed. This kind of real-world burden can promote the trainees to reflect on their decision (e.g. whether they should have rescued the injured person during speedy evacuation).

2.2. System

We developed a GBET system that works on GPS-enabled Android smartphones or tablets and is available for outdoor evacuation training (CE and AE). By always checking a trainee's current location and the current time from a branched scenario, the system recognises designated locations and times and then presents corresponding digital contents (e.g. video, slideshow and single-choice question). The trainee stops to look a virtual disaster situation (e.g. whether to rescue an injured person) presented as a digital content and then chooses his/her decision from options presented as digital content. Figure 3 shows an overview of the system components together with examples of digital contents.

2.2.1. Branched Scenario

The GBET introduces a branched scenario and digital contents to express virtual disaster situations. The scenario begins and ends at designated locations or times—successful and failed evacuations will end at a shelter and a time limit, respectively. In the scenario, the designated locations and times are referred to as scenes shown as follows:

- Stay scene (SS): Each SS corresponds to a location (a rectangular area designated by latitude and longitude) and is used to express a disaster situation that may arise at the location.
- Interrupt scene (IS): Each IS, independent of locations, corresponds to an elapsed time or a designated time and is used to express a time-dependent disaster situation.
- Move scene (MS): Each MS, conceptually assigned between SSs, is prepared for trainees to reach the next SS.

Each scene has at least one cut, which corresponds to presenting digital content. A single-choice question is included in the digital content and frequently used to branch the scenario. The scenario is branched according to the following conditions:

- Option selected: The next cut depends on which option a trainee chooses.
- Already visited: The next cut/scene depends on which cut/scene the trainee has visited in/till the current scene.
- Visited: This condition is valid only for an MS linked with multiple SSs as the next scene. The trainee visits one of the SSs from the MS.
- Elapsed time: Since visiting a scene exceeds a threshold, when time elapses, the trainee compulsorily visits (enters) an IS.
- Designated time: When a designated time comes, the trainee compulsorily visits an IS.

The branched scenario, written in extensible markup language (XML), controls the storyline of disaster situations (CE and AE) and realises interactive SEE based on decision-making. This interactivity can be regarded as a gaming element—e.g. multiple endings can be provided. Figure 4 shows an overview of the branched scenario.

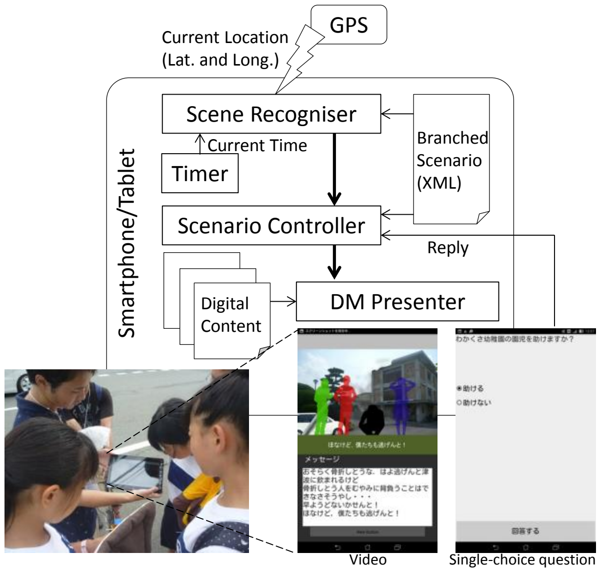


Figure 3: System Components and Digital Contents

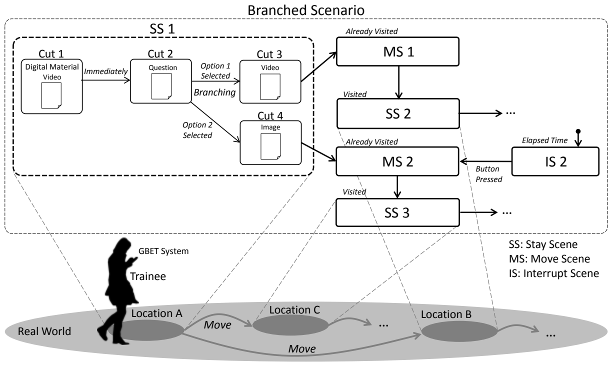


Figure 4: Branched Scenario

2.2.2. Reality

In the GBET, the reality can be regarded as actual expressions of possible disaster situations which depend on how the virtual disaster world is fused with the real world. The reality can be divided into two:

- Situational reality: This reality is related to the branched scenario and depends on whether trainees perceive that virtual disaster situations are possible. For example, in actual disasters, worsening disaster situations (i.e. the extent of damage) will be influenced by not only time and location but also psychological factors. This reality focuses on how these factors are reflected in the scenario.
- Audiovisual reality: This reality is related to digital contents and depends on whether trainees perceive virtual disaster situations as if the situations occur in front of them. This reality focuses on how audiovisual effects are reflected in the digital content.

If both the realities are at high levels, then the trainees can be immersed in virtual disaster situations, and they urgently make decisions against the situations.

3. EXTENSION TO SCENARIO-BASED AR GAME

In the GBET, the digital contents are created reflecting possible disaster situations in actual locations (SSs) and times (ISs) but insufficient in the audiovisual reality. In particular, the digital contents with a low level of visual reality can prevent trainees from perceiving virtual disaster situations as real. Ideally, the digital contents should express disaster situations more realistically so that the trainees can feel as if they encountered disaster situations.

To present the ideal digital contents, we extended the system to a scenario-based AR game that is available for a handheld HMD (Mitsuhara et al., 2018). The handheld HMD, which consists of a smartphone and a lightweight frame, realises more immersive AR. In the GBET, the handheld HMD is easy for trainees to wear (hold to their eyes) when looking digital contents in SSs or ISs and take off when moving in MSs.

3.1. Why not VR but AR

With the recent advancement of VR technologies, VR-based evacuation training has been realistic, immersive, safe and thus, popularised. Meanwhile, due to difficulties in ensuring safety and geometric consistency, augmented reality (AR)-based evacuation training has not been popularised, though mobile AR technologies are becoming increasingly common in various fields (e.g. navigation and geo-fencing game). Currently, AR-based evacuation training may be a challenging issue.

Thus, AR-based evacuation training can be advantageous for promoting trainees to look more squarely at reality (i.e. risks). In particular, possible disaster situations superimposed onto the real-time view (i.e. daily scenery in their local communities) can promote the trainees to think and take practical measures for the situations. In this study, we deal with not VR- but AR-based evacuation training, expecting a higher training effect.

3.2. Extended System

By attaching importance to easier implementation and broader utility, the extended system adopts marker-based AR. Currently, we suppose that the extended system is available only for indoor GBET (e.g. fire evacuation from a building) because printed fiducial markers are difficult to use outside based on loss, break or defacement due to the wind, rain, etc.

3.2.1. Mechanism

The extended system recognises SSs from captured fiducial markers and presents AR corresponding to the recognised SSs; a fiducial marker is prepared for each SS. The AR is implemented using a game engine (Unity 3D) and a marker-based AR software development kit (Vuforia).

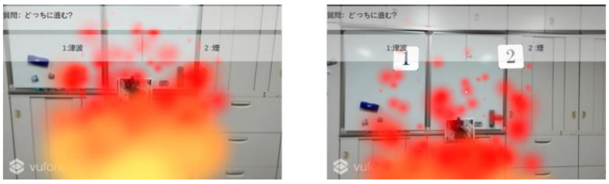


Figure 5: Single-choice Question

In an MS, a trainee finds and gazes at a marker through the extended system (a handheld HMD) and then, the corresponding AR is presented via the following steps:

1. The extended system recognises the next SS by checking the captured marker based on the scenario. If the captured marker matches one of the SS candidates, the matched SS is recognised as the next SS.
2. It presents the AR corresponding to the recognised SS by superimposing the corresponding 3DCG onto the real-time view.
3. It adjusts the superimposition of 3DCG synchronously based on the direction in which the trainee is looking (i.e. the direction in which the smartphone’s rear camera is pointing).

It is difficult to touch the smartphone’s screen in the handheld HMD. Hence, the extended system does not adopt finger-touch operations in a single-choice question and for pressing a ‘next’ button; instead it enables the trainee to choose his/her reply (decision) by gazing at one of the presented options and move to the next cut or scene. Figure 5 shows a screenshot of a single-choice question.

To provide realistic SEE, the extended system should ensure the geometric consistency. However, the extended system has not enabled trainers to set the initial geometric settings (position, size and angle) of superimposed 3DCG automatically or easily. The initial geometric settings depend on how large a fiducial marker is prepared and where it is placed on. This means that to ensure the geometric consistency, the trainers must adjust every marker in a trial-and-error method beforehand.

3.2.2. AR Examples

Presently, the extended system can present AR that expresses six disaster situations: flood, fire, smoke, a crack, debris and an injured person (Fig. 6). Animation and sound can be added to the AR. Text messages can be superimposed onto the upper area of the real-time view to supplement the expressed disaster situation.

As a scenario-based AR game, the extended system can provide realistic, immersive and interactive SEE including decision-making. By looking at the AR, trainees are expected to have a sense of tension and learn earnestly how to evacuate. For example:

- When encountering a fire, they will think which way to detour.
- When entering a smoke-filled room, they will think of how not to inhale smoke.

ISBN 978-88-85741-41-6; Bruzzone, Ginters, González, Gutierrez and Longo Eds.

- When finding an injured person, they will think of whether or not to rescue the injured person.

3.2.3. Extended Scenario

To describe the settings for the AR, we extended a GBET scenario (XML) while adding the following property values in ‘content’ tag:

- ‘AR’ for ‘type’ property: This value means that AR is presented as digital content in the cut.
- ‘Flood,’ ‘Fire,’ ‘Smoke,’ ‘Crack,’ ‘Debris,’ and ‘Injured Person’ for ‘name’ property: These values mean which disaster situation the AR expresses.
- ‘Small’ and ‘large’ for ‘intensity’ property: These values mean how much the disaster situation has been worsened.

Figure 7 partially shows a GBET scenario that covers fire situations. Disaster situations can be worsened as time passes. Hence, a GBET scenario should express disaster situations that vary with time. The combination of the branching conditions (e.g. ‘Option selected’ and ‘Time elapsed’) can be used to express such time-variable disaster situations. However, it may be difficult for trainers to describe the settings for the expression (i.e. complex branching control). For the easier description, we added a new tag (timer) in the scenario. For example, the extended system presents the AR according to the following settings in the scenario shown in Fig. 7:

- It recognises SS-3 (line #1) by capturing the marker of fire (line #3).
- It reads Cut-1 for presenting a digital content that expresses a time-variant fire situation (line #6).
- It checks how many minutes have elapsed since a trainee first visited this scene. If 0 min (i.e. his/her first visit), it sets ‘1’ to the branching value (line #7). If more than 10 min, it sets ‘2’ to the value (line #8).
- When the value is ‘1,’ the next cut is Cut-2 (line #10). When the value is ‘2,’ the next cut is Cut-3 (line #11).
- In Cut-2, it superimposes 3DCG of small fire (line #16). In Cut-3, it superimposes 3DCG of larger fire to express a worsened situation (spread damage) (line #22).
- If gazing at a ‘next’ button on the screen for several seconds, the trainee moves to the next scene (line #25).

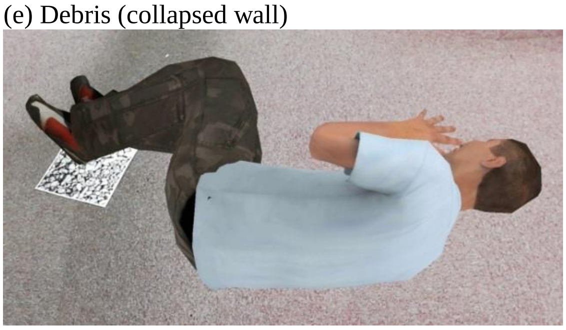
(a) Flood

(b) Fire

(c) Smoke

(d) Crack (in the floor)

(e) Debris (collapsed wall)



(f) Injured person

Figure 6: AR Examples

```
<scene id=”3” type=”stay”>
  <name>Fire occurred!</name>
  <condition sensor=”marker”>Fire</condition>
  <cut id=”1”>
    <name>Fire Expansion</name>
    <content type=”time”>
      <timer id=”1” min=”0”>1</timer>
      <timer id=”2” min=”10”>2</timer>
    </content>
    <next condition=”immediately” value=”1”>2</next>
    <next condition=”immediately” value=”2”>3</next>
  </cut>
  <cut id=”2”>
    <name>Small Fire</name>
    <message>You Found Fire on Corridor!</message>
    <content type=”AR” name=”Fire” intensity=”small”/>
    <next condition=”end”>-1</next>
  </cut>
  <cut id=”3”>
    <name>Large Fire</name>
    <message>You Found Fire on Corridor!</message>
    <content type=”AR” name=”Fire” intensity=”large”/>
    <next condition=”end”>-1</next>
  </cut>
  <next condition=”button_pressed”>4</next>
</scene>
```

Figure 7: Example of GBET Scenario for Presenting AR

3.3. Related Work

Lovreglio (2018) reviewed research on AR applications for building evacuation and presented five research projects that focused on training. For example, Mañas et al. (2010) developed a mobile phone application for fire evacuation training that detects a trainee’s current position and speed in a building by using WiFi positioning techniques and accelerometer sensors. Without fiducial markers, this application can superimpose 3DCG of fire onto the real-time view when the trainee comes to designated positions. Our research group has developed AR-based evacuation training applications using tablets (Mitsuhara, et al., 2013), smart glasses (Kawai et al, 2015), a binocular opaque HMD (Kawai et al., 2016) and a handheld HMD (Iguchi et al., 2016; Mitsuhara et al., 2017).

Recently, markerless AR has been attracting much attention, and there have been markerless AR applications available for evacuation training. Dong et al. (2016) developed a markerless AR-based training application in which first responders can attempt to adequately assess disaster situations and plan responses by using a smartphone’s GPS, electronic compass and disaster scenarios. Itamiya (2017) developed a markerless AR simulation application that visualises flood and smoke realistically using Google Tango and handheld HMDs.

AR can be used for evacuation support, that is, navigation to a safe place in actual disasters. AR-based navigation applications detect an evacuee’s current position using personalised pedometry (Ahn and Han, 2012) and radio-frequency identification (Atila et al., 2018) and superimpose a directional indicator (arrow) guiding to the safe place onto the real-time view. These applications or technologies can be used for evacuation training.

4. PRELIMINARY EXPERIMENT

In this section, we conduct a preliminary experiment focusing particularly on how the AR-based expression of a time-variant disaster situation (TVDS) influences SEE to examine the training effect and the reality of the extended system.

4.1. Settings

In this experiment, participants (trainees) used the extended system in a small-scale building evacuation training.

4.1.1. Participants and Procedure

The participants (twenty university students) were divided evenly into two groups on the basis of their replies to a question that is asked about their awareness of disaster management.

- Group A (*N = 10*): At the SEE (i.e. CE), the participants evacuated according to a no-branch sequential scenario with a TVDS.
- Group B (*N = 10*): The participants evacuated according to the same scenario without the TVDS.

We did not take into account of RO, AC and AE; the participants were not encouraged or forced to reflect on their first SEE, conceptualise their evacuation and attempt their concept in the second SEE.

Also, the participants who were given the extended system (a handheld head-mounted display (HMD)), were given brief instructions on how to use the system (e.g. gaze-based operation) and then shown the time-unconstraint condition of evacuation success (i.e. reaching a safer place) and the rule in the training (i.e. ‘if you find a fiducial marker, please gaze at it’). After the end of the training, the participants replied a questionnaire with the following 5-degree Likert scale questions (options: 1 = definitely no, 2 = no, 3 = neutral, 4 = yes, 5 = definitely yes):

- Question 1. Do you agree that you felt your awareness of disaster management improved through the training?
- Question 2. Do you agree that you felt a sense of fear through the training?
- Question 3. Do you agree that you felt a sense of tension through the training?

In making the questions, it was assumed that the training effect could be regarded as their improved awareness of disaster management. Almost all the participants had not evacuated in a real disaster and had difficulty in judging the reality. Thus, we regarded the reality as their senses of fear and tension in the training and asked about the reality by Questions 2 and 3.

4.1.2. Scenario

The scenario expressed three disaster situations caused by a big earthquake: fire, flood (huge water leak) and crack. The evacuation started from the fifth floor and thus, the participants were required to move downstairs from the fifth floor to escape from the building. The fire situation (the size of fire) changed by the TVDS. The scenario unfolded as follows (see Fig. 8):

1. A big earthquake occurs and a participant takes a proper action (e.g. hides under a table) against strong shake.
2. Immediately after the shake stops, the participant starts to move to the nearest stairs (the emergency exit).
3. However, the participant finds a small fire on a corridor to the stairs.
4. The participant moves toward the stairs on the opposite side.
5. On the corridor, the participant finds a crack on the floor and keeps moving carefully.
6. The participant moves downstairs through the opposite-side stairs but encounters a flood at the low level and cannot move downstairs any more.
7. The participant moves back to the emergency exit, expecting that the fire has disappeared. In the TVDS scenario (group A), the fire has enlarged. In the non-TVDS scenario (group B), the fire still remains.
8. The participant decides to move up to the roof to wait for rescue.
9. The participant reaches the roof; the training ends.

4.2. Results and Considerations

By assuming a normal distribution and homoscedasticity, we analysed the questionnaire results with nonparametric statistics. Table 1 shows the medians and mean ranks of the participants' replies. For all questions, the medians were the same or similar between the two groups; Wilcoxon rank sum test revealed no significant differences.

Regarding their improved awareness of disaster management (Q1), the medians were the same. However, the mean rank of group A was higher than that of group B. With regards to their sense of fear (Q2), the median of group A was higher than that of group B. These results indicate that the TVDS improved their awareness and aroused their sense of fear. With regards to their sense of tension (Q3), the medians were the same and the mean ranks were almost the same. This result indicate that the TDVS did not arouse their sense of tension. Tension in evacuation can be influenced by various factors such as time pressure, distance to a shelter, etc.

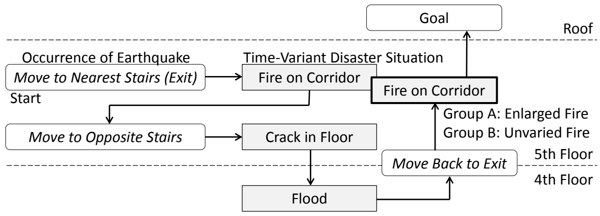


Figure 8: Scenario in Preliminary Experiment

Table 1: Questionnaire Results

Q1. Improved awareness of disaster management			
Group	Median	Mean rank	P
A	4	10.6	0.43
B	4	8.3	(n.s.)
Q2. A sense of fear			
Group	Median	Mean rank	P
A	4	11.5	0.10
B	3.5	7.4	(n.s.)
Q3. A sense of tension			
Group	Median	Mean rank	p
A	4	9.2	0.87
B	4	9.7	(n.s.)

not significant (n.s.); probability (p); question (Q).

For both groups, the medians of all questions were favourable. These results indicate that the extended system (i.e. the scenario-based AR game) is effective as evacuation training regardless of whether the TDVS is used. A few participants expressed positive opinions about the audiovisual effects (e.g. 'It was easy to think how I should evacuate this building because I saw a fire and crack in front of my eyes'). The favourable medians may result from the high visual reality of the presented AR. However, there were the following complaints:

- The scenario was not realistic. I do not know why we have to visit the fire corridor again, encounter flood on the fourth floor, evacuate to the roof in a building fire, etc.
- I got motion sickness by viewing AR.
- I disliked holding the handheld HMD during the training.

Three participants complained about the scenario's reality (i.e. the situational reality). In this experiment, the scenario aimed at examining the TVDS and did not significantly take the validity of situational reality into account. From this complaint, we realised the significance of not only the audiovisual reality but the situational reality.

5. CONCLUSION

In this paper, an evacuation training using scenario-based AR game, which was implemented as the extended system of the GBET to provide realistic SEE, was described. In the evacuation training, disaster situations (e.g. flood and fire) corresponding to designated locations and times are expressed by marker-based AR based on a branched scenario; 3DCG-rendered disaster situations are superimposed onto the real-time view captured via a handheld HMD. Trainees who look at the disaster situations at high levels of visual reality and immersiveness are expected to have a sense of tension and earnestly learn how to evacuate. In this paper, the results of the preliminary experiment indicate that the scenario-based AR game is effective as evacuation training, but the TVDS did not significantly contribute to improving the training effect and reality. Furthermore, we need experiments that adopt scenarios with high situational reality.

VR-based evacuation training is becoming common due to the popularisation of VR devices (e.g. low-priced HMDs), whereas, AR-based evacuation training has not yet been acknowledged by the public although many of them may be interested in AR itself. We believe that the higher reality leads to the higher training effect, and AR involving the real world is superior to VR in reality. For the acknowledgement, we must overcome possible difficulties about the geometric consistency, safety and easiness in practice, etc. In addition, we must clarify the training effect through experimental practices and develop systems that totally support AR-based evacuation training, taking account of RO and AC in the ideal model of the GBET. If the training effect exceeds the difficulties, the public (trainers) may get motivated to conduct AR-based evacuation training.

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ACKNOWLEDGEMENTS
This work was supported by the Japan Society for the Promotion of Science Grants-in-Aid for Scientific Research (Grant No. 18H01054).

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LESSONS LEARNED ABOUT LANGUAGE LEARNING AND EXTENDED REALITY FRAMEWORKS

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ABSTRACT
The knowledge of a second language is an obligation in educational systems of the European Community for many years and the quality of teaching and learning, especially in Italy, could be largely improved for a better outcome. Methods like Game-based Learning and Gamification could improve and change this outcome, combined with new tools used as educational technology in an immersive context. This paper presents some lessons learned from the adoption of VR / AR within two applications related to language learning. In this context, being immersed in an engaging and fun simulated situation is a good way to practice language conversations. In the last few years the great clamor of new VR / AR devices (HMD, controller, tracker) promotes the creation of new frameworks of extended reality for language learning.

Keywords: extended realty, educational technology, language learning, game-based learning

1. INTRODUCTION

In the context of Globalized World, the need for bilingualism/multilingualism is increasingly felt (Byram 1992; EduPlacements 2018). In 2004 the European Parliament and the Council promulgated the Directive 2004/38/EC on the right of citizens of the Union and their family members to move and reside freely within the territory of the Member States; as a consequence, in Italy the study of English as the second language became mandatory at any educational level (European Parliament 2004). Nevertheless, the recent statistics of EF-Italia about the level of knowledge of the English language places Italy at 34th place out of 88 countries in the world, and the European ranking reveals a 24th place out of 32 in the countries of Europe (EF Italia 2018). The major criticism that could be moved to Italian Educational system concerns a not optimal use of teaching methodology, with an excessive study of grammar compared to other competencies, like listening and dialogue. John Peter Sloan, actor and English teacher, answering the question about why Italians struggle so much with English said: "Because they don't have fun. Besides, a language is a puzzle and learning should be fun, just like practicing your favorite hobby. You should want to improve without struggling. Instead in Italian classrooms fun is zero, using methods and courses that are not designed for Italians; everything is based on grammar and little on conversation. Not even the English know their grammar as much as the Italians" (Cosimi 2016).

Fun is strictly linked to motivation and motivation is an old issue of second language (L2) learning (Oxford and Shearin 1994; Noels, Pelletier, Clément and Vallerand 2000; Dörnyei, Henry and MacIntyr 2014). In this context the application of game mechanics is discussed in this paper with respect to the opportunities given by VR/AR in language learning. The notion of Extended reality (XR) is presented as a key point, useful to learning frameworks, especially where cross-situational learning methods (Smith and Smith 2012) and game-based situated learning (e.g. Second Life) (Iacono S. et al 2018) showed strong evidences in the educational literature of the last two decades.

2. MOTIVATION & GAME-BASED LEARNING

Motivation and fun have a strong correlation, because fun constructs engagement and engagement gave us motivation. The game designer Ralph Koster said: «Fun from games arises out of mastery. It arises out of comprehension. It is the act of solving puzzles that makes games fun. In other words, with games, learning is the drug» (Koster 2013). The "great power" of games can be convoyed in so many contexts and edutainment is only one of these (Deterding, Dixon, Khaled and Nacke 2011; Werbach and Hunter 2012; McGonigal 2011): this is the positive thrust that language learning might need. Computer Assisted Language Learning (CALL) has been largely used in education starting from early '80s (Chapelle 2001), and Mobile Assisted Language Learning (MALL) is now his natural evolution due to smartphones huge diffusion. Duolingo is a good example of gamified MALL that aims to give extra motivation to the learner with good results in self-study (Nushi and Eqbali 2017), thanks to the intuitive and playful interface, the use of achievements and voice interaction. This app not only pushes the learner to translate, but also to repeat using voice, even if in short sentences. Is it possible to do more?

3. XR WORLD

3.1. From Azuma to Present

In his survey Azuma (Azuma, 1996) describes all the potential of augmented reality as an advanced virtual reality. He identified some important areas of interest such as military, medical and manufacturing. If in these days augmented reality is still a great promise for the consumer market despite the fall of Google Glass (Bilton 2015) and now it is finally maturing, virtual reality is perceived as stable and ready to spread technology thanks to head mounted displays (HMD) like Oculus Rift and Htc Vive and PlayStation VR. (Martindale 2017).

3.2. The role of Presence in VR

The most important factor in a virtual reality experience played with a HMD is the level of Presence, which is " *a psychological state or subjective perception in which even though part of all of an individual's current experience is generated by and or filtered through human-made technology , part of all of the individual's perception fails to accurately acknowledge the role of the technology in the experience*" (International Society for Presence Research 2000). Hardware such as controllers and HMD do the hardest work to create the illusion of being in another place, however the design of the experience is the final touch to avoid the presence break and motion sickness.

3.3. The effectiveness of Virtual Reality

There is strong evidence on the effectiveness of virtual reality, thanks to Presence and the safe environment generated for simulation, appropriate to a training context. Researcher and Professional worker in different area observed stunning results. According to Narendra Kini, CEO at Miami Children's Health System, the retention level e year after a VR training session "can be as much as 80% , compared to 20% retention after a week with traditional training, using Samsung Gear VR for procedures of cardiopulmonary resuscitation (CPR), nasal gastric tube insertion, Foley catheter insertion, intubation, starting an IV, wound care, and the Heimlich maneuver". (Gaudiosi 2015). Mental illness can benefit of the use of virtual reality offering a safe place where the error is not something to fear and where the fear can be dominated. The Schizophrenia treatment with virtual reality produced significant improvement, some patients declare to have strongly improved their life quality. (Du Sert et al 2018). In the area of language learning, Lin and Lan (2015) investigated trends since 2004 to 2013 about virtual reality environments in four top ranked computer-assisted language learning journals (Lin and Lan 2015). In particular authors analyzed contexts as multiuser domains (MUDs), massive multiplayer online games (MOOGs) and synthetic immersive environments (SIEs). Nowadays these types of VR environments are so far from the "power of VR" through HMD, but they showed how a good use of VR simulation was already relevant for language learning, especially when virtual environments were experienced by people with special needs.

Another study (Hsu 2017) shows a high learning effectiveness from the adoption of augmented reality for language learning, regardless of the learning styles of the participants.

3.4. Road to Extended Reality

Extended reality is now just a concept that complete the Milgram's Reality-Virtuality continuum. This term describes different types and modes to interact with different virtual elements in the world. Currently it seems that for each phase of the continuum it is possible to use only one hardware solution, but this is not totally true. Most new-generation HMDs have at least two cameras, used to avoid the installation of an external tracking system. These cameras could be used simply as normal cameras turning an HMD VR − such as Vive Focus − into a sort of prototype for extended reality. Very far but similar in concept to what is presented by Qualcomm in his research paper: "a device to rule them all".

4. PUT PIECES TOGETHER: MONDLY

As a research laboratory, we are currently experiencing the great potential of VR / AR that needs to be explored in more contexts, especially in learning. Our proposal is to find a way to address this potential in language learning. An application, a MALL called Mondly, has tried to follow this path, particularly in the VR and AR version. In the next part we analyze the two modalities of this app to understand if these two modes can have a significant impact in language learning.

4.1. Mondly VR

Launched in 2017, this standalone application is available for Android and iOS using Samsung Gear VR, Google Cardboard and Daydream. It offers 28 different languages, which is a very significant language covering. The selection method can be natural using the voice or "point click" with default pointer typical of the mobile virtual reality app. When the language is selected the app shows a menu of four different learning situations; one of these has two sub-contexts:

1. Hello
2. Taxi
3. Hotel
    a. Reception
    b. Room
4. At the restaurant

Figure 1: Screenshot from the "Hello" context of Mondly VR

Each of these contexts represents a scripted typical conversation as described in the title. The system displays what the character in scene said and it suggests three possible answers with their relative translations. The player may choose to follow suggestions or say something coherent with the conversation. If the player says something “out of the loop”, the system simply replies that it has not understood and goes on stand-by until the correct and consistent flow of the conversation starts again. The computer graphics representation is very basic, and every experience lasts approximately 3-5 minutes.

4.2. Mondly AR

This new version of Mondly was launched in 2018 and it is integrated into the basic app of Mondly. At every launch of the AR function is requested to make a short setup of the environment with smartphone’s camera. After a young woman character has appeared, a tutorial of the application starts showing various 3D animals and objects, describing some particularities of the represented concepts. During the tutorial the female character requests to repeat some brief names or sentences. Furthermore, if an object is stored in the 3D models database, the user can recall it "on stage", by pronouncing the related name.

Figure 2: Snapshot from the Mondly AR addon

4.3. Mondly and Presence

To assess the level of presence, we are collecting volunteers to test the application and submitting to them the International Test Commission - Sense of Presence Inventory (ITC-SOPI) (Lessiter 2001). This standard is designed to measure:

1. Physical spatial presence referred to the sensation of being in a physical space in the mediated environment and having control over it;
2. Involvement referring to the tendency to feel psychologically and pleasantly involved in the virtual environment;
3. Ecological validity referred to the tendency to perceive the environment mediated as real;
4. Negative effects related to adverse psychological reactions.

The data collected are not yet statistically significant. At the moment all the people interviewed are males, aged between 20 and 34 or over 55 years. They had no problem related to VR sickness, such as nausea and headache; only in one case a mild eye fatigue was observed. There was a moderate success from the point of view of engagement and attention, with a peak in the subjects that had never experienced virtual reality through an HMD.

5. CONCLUSIONS

The Mondly VR app looks more solid than the Augmented Reality add-on. However, both Mondly VR and Mondly AR share a significant flaw: the characters have unnatural voices. In general, conversational systems need a robust speech recognition and understanding tools. AR/VR based application without a good conversational user interface are less effective and show a dramatic lower level of presence. In the current version of Mondly the conversational interface is very poor, and it ruins the presence that is already weakened by 3D low quality models. If poor models are pardonable for compatibility reasons of the app, this is less forgivable in the AR app, where the 3d showed objects are very few. On the contrary, the AR app is more convincing with respect to cross-situational learning scenarios than the VR one. The learning context seems really engaging and it takes advantage of the stunning effect of AR and VR, but it’s obvious that the “wow effect” is ephemeral. This app or any other application that aims to improve the language learning needs also to experiment the potential of the tool, not only to create a basic context but an engaging context with a larger structure and narrative. Pokémon GO (2016) is still the Killer App of augmented reality, since it is simple, funny and georeferenced; it merges contexts creating a fusion between the real world and a fascinating virtual world. Can a Pokémon GO-like app be productive? We know that game-based learning is potentially effective, and this could overcome some of the current flaws of Mondly. From now on, in order to improve the immersive experience, it appears crucial the adoption of totally standalone devices (such as Oculus Quest and Vive Focus) to design better immersive XR applications.

ACKNOWLEDGMENTS

The authors equally contributed to this work. We thank Francesco Masnata for the help in data collection of ITC-SOPI.

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INTELLIGENT NAVIGATION OF LINKED DATA WITH A GRAPHICAL INTERFACE BASED ON SEMANTIC SIMILARITY

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ABSTRACT
Semantic Web Technology proposes the use of linked data and ontologies as a mean for providing meaning to information. Even though several tools for the analysis and visualization of linked data exist, these tools require a lot of specialized knowledge to fulfill a purpose. Additionally, this complexity hardens its use for non-experienced users therefore limiting semantic web applications. This paper describes a tool that combines the use of a recommendation system and an intuitive dynamic user interface for navigating linked data. The tool guides the user to find resources of interest by highlighting those related to his search intention. This is, the platform learns on the fly the user interest and makes recommendations based on the connections between resources.

Keywords: Semantic Technology, Linked Data, Recommendation System, Educational Innovation

1. INTRODUCTION
Information is one of the most valuable resources nowadays. The good use and analysis of data are of great benefit for almost every human activity. Eventhough the great amount of existing data and the exponential growth of it has open new uses for the information itself. However, in order to take real advantage of data, it is necessary to have the capability to process, analyze and read it correctly. A proposal for getting the best of data is the use of the Linked Data structure of RDF triplets (Bizer, Heath and T. Berners-Lee 2009). This structure uses the concept of triplets to add meaning to an object in a database. This by connecting each object to other resources in the set using the subject, predicate and object composition established by the World Wide Web Consortium (W3C-REC 1999). This concept applied to web apps is called Semantic Web.

Semantic Web can be described, in concept, as an improvement to the traditional web. This, according to the World Wide Web Consortium. (W3C 2013), by adding meaning to the data in order to create more legible information for computer applications. This is achieved by adding semantic and ontology metadata to the existing data. This additional information helps to describe the content, meaning, and relation of data (Feigenbaum et al. 2008). In the book "Semantic web for the Working Ontologist" (Allemang and Hendler 2008) semantics is described as understanding the nature of meaning. This can describe web semantic as a group of tools that tends to give intelligence to the web, or at least to endow it the capability to understand a more specific meaning of information as a whole and for users as individuals.

Another topic of consideration for semantic data is the representation of information. In the book "Adaptive Semantics Visualization" (Nazemi 2016) it is described how visual representation that adapts to data and human behavior can benefit the user experience and information acquisition. If we want to take full advantage of linked data, it is necessary that users can understand the information that is retrieved by the system. Furthermore, the user needs to be able to interpret the connections between data.

Semantic Web technology is considered as a set of ideas that seek to improve web performance by adding meaning to the resources on the network. However semantic web technology only set the foundations to apply different types of models that take advantage of linked data. This work proposes an algorithm, that in addition to a dynamic visual interface, take advantage of the semantic connections between data to calculate the relevance of an object to a user. This relevance factor is used to make better recommendations to the user with every click.

2. LITERATURE REVIEW
2.1. Semantic Web
Semantic Web technology is a set of concepts and ideas developed upon the World Wide Web platform. The semantic web is developed under the schemes of W3 (World Wide Web Consortium) and is built upon the premise of adding semantic and ontologic metadata inside the administration of databases on the internet (W3C 2013). With this description it can be concluded that Semantic Web is the idea of a web that recovers, access and deploys the data an user needs based on the relations between objects. In 2001 Tim Berners-Lee (Tim Berners-Lee, Hendler and Lasila 2001), known as the father of the world wide web, describe semantic web as a new type of network wich content have a meaning for the computers

2.2. RDF

As described before, the semantic web is a set of activities and elements for the organization, management, and retrieval of data inside an ontology. Given that in semantic web one of the most important concepts is the relation between data, the W3C organization certifies a syntaxes for declaring objects in a database alongside their relations. This scheme is called RDF (Resource Description Framework) (W3C 1999). The RDF scheme is the way information is distributed on the semantic web. The RDF syntax also knows as a triplet, consist of a first element called subject, that is connected to another object (that can also be a subject in another triplet) by a predicate. With the RDF scheme, a database can be visualized as a big graph where all the objects are nodes where the connecting lines are the predicates.

2.3. Linked Open Data

Linked Open data is an architecture that consists of practices within the web to connect and give structure to data. The result of this architecture is a type of database where the objects are connected between them with a semantic relation. This with the objective of making more useful data (Bizer, Heath and Tim Berners-Lee 2009). One of the intentions of the development of linked data is that data is available in a manner that computers can understand it. This with the objective of make more efficient queries. With this the idea of making connections between objects in different databases is possible. According to Tim Berners-Lee (Bizer 2009), with linked open data it is possible to make information "readable" for computers, information with specific and well-defined meaning and have interconnected databases.

2.4. Recommender Systems

A Recommender System is an information filter that based in a model and algorithm identify objects inside a database that has relevance for a specific user. At the same time, a recommender system removes information that is redundant or of no interest for the user. A recommender system compares retrieved information from the user with some characteristics references that can be obtained from the user experience or from a community of similar users (Hanani, Shapira and Shoval 2001). There are two main recommender systems models: based on collaborative systems and based on content.

3. DYNAMIC USER INTERFACE FOR DATA VISUALIZATION

One of the objectives of this research is to apply the concept of recommender systems to take advantage of linked data connections. In this paper an algorithm that shows objects related to each user query is proposed. The algorithm uses a content-based filter to perform recommendations. The recommendations are done based on the relevance of each object connected to the already retrieved objects and the selections of the user. In order to make this a relevance vector is calculated. This vector helps the system to rank the connected objects and recommend the best ranked. This semantic relation between objects helps to guide the user to find better results to a query. This because the algorithm can learn the relevance an object has to the user and adjust this relevance in every click. An important part of this work is the visualization strategy, which the algorithm takes advantage of to make better recommendations. Semantic web technology lays the groundwork for creating visualization adapted to the user, the tasks and the data (Nazemi, Burkhardt, Ginters et. al. 2015). Furthermore, with the application of artificial intelligent techniques, such as the algorithm proposed in this work, it is possible to take advantage of the semantic technology structure to create a more adaptive visualization

3.1. Visualization Strategy

For the visualization strategy, a web application with a dynamic adaptive user interface is proposed. This strategy is focused on showing the related objects to every query result and the highlight of each node. For most relevant objects the nodes will have a larger diameter. This relevance is recalculated in every user selection and therefore the diameter of each node. An example of this is shown in figure 1. The application of adaptive visualization strategies has been used in linked data structure before showing significant benefits to regular visualization strategies (Nazemi, Burkhardt, et. al. 2014). A benefit of dynamic visualizations it that the semantic relations of data can be better represented according to the user's behavior.

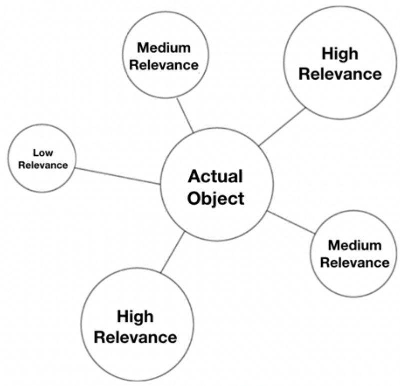

Figure 1: Basic visualization layout

This because even though the objects semantic relations in a database don't change, the relevance of those relations to the user may vary depending on what is the user searching for.

3.2. Cold start

One of the biggest issues of the recommendation systems algorithms is to start from a state where the reference data is small or is none. This issue is called

cold-start problem (Qiu, et. al. 2011). To solve this problem, the *Personalized Video Ranker PVR* system from *Netflix* was used as a reference for this work (Gomez-Uribe and Hunt 2015).
For the case of study, the user is presented with a series of initial recommendations based on the semantic similarities found in the database. For creating this recommendation, a clustering algorithm was used to find the main clusters in the database. The clusters were found considering the tags of the objects and the relations to other similar objects. Once the clusters were identified the object in the center of the group, the one with more connections in the cluster, is taken as the starting point for the search. With this, the cold star problem is reduced. This because even if the user doesn't know the objective resource of the search, at least the user knows the topic. The semantic connections are then used to navigate faster throughout the cluster.

3.3. Data Navigation

Here is specifically described each one of the events that the user will fire to navigate in the proposed recommendation strategy.

1. The user access to the front page of the web app. In this section, the most representative pictures of each category are shown. The user then selects the one that represents better his interests.
2. A first layout is shown with the most representative object of the category as the center.
3. With each click of the user to an object, the relevance to the related objects is calculated. The most relevant objects are shown as the layout shown in figure 1.

One of the main ideas for the visual recommendation navigation is that in a Linked Data architecture all objects are at least connected to another resource in the database. Therefore, while starting the search from an initial object (initial node) to a target object (final node) there is a search space between them.

The recommender system's objective is to find the shortest path. This by searching for the target object by learning those characteristics (connections) that the users favor in each click. This even if the user doesn't know what is the target object. To do this, the system must highlight those objects that represent on higher degree those characteristics the user favors (the most relevant).

Based on this, the expected behavior of the web app is to show, in each iteration, 10 possible nodes to continue the search starting for the latest clicked object. This means that for each iteration the object selected by the user becomes the central node in the layout. From this selected node 10 object recommendations are displayed as nodes considering the parameters of relevance described above. This is repeated in each iteration until the user finds the target object. This process is shown in figure 2

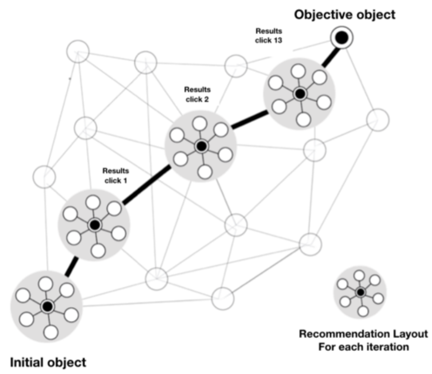

Figure 2: Basic example of the recommendation visual Layout behavior

4. RELEVANCE VECTOR ALGORITHM

The relevance value is the pivotal part for the recommender system to work. In this process, the *weight* with which each object is going to be shown to the user is calculated. It is then deducted that a more relevant object is highlighted more. A characteristic matrix for the relevance of the objects is calculated and the values on it are updated in each iteration. This relevance weight adjustment is considered as learning for the algorithm. This matrix $M \to R{\times}F$ describes R RDF resources in terms of the triplets that describe them (F). Below is described each element that composes the recommendation algorithm.

- R : Is the list of RDF resources.
- F : The triplet existence <R predicate-object> is represented with 1 and it absents by 0 in a SPARQL endpoint.
- |R| : Denotates the number of matrix rows.
- |F| : Denotates the number of matrix columns and is given by the quantity of combinations predicate-object for each resource $r \in R$.
- $S \subset R$: Denotates the objects selected by the user (clicks).
- M[r,f] : If the value 1 is shown its means the <r,f> in the SPARQL endpoint exist, and 0 in the opposite case.
- f : Denotates the index of the column related to the relation predicate-object.
- $\vec{s}$: Is a similarity vector of size |F| where $s[i] = \sum_1^n M[r,f]$ such that $r \in S$ and $n=|R|$
- $\vec{e}$: Is the relevance vector with size |R| where $e[i] = \sum_1^m M[r,f] \times s[f]$ where $r \in S$ and M=|R|
- $\vec{e}_n$: Is a normalize vector in scale of [1-10] where 10 represents the higher relevance $\vec{e}_n = e[i]/\max(\vec{e}) \times 10$ (rounded to integer)

- min_viz : Visualization threshold, any object which relevance value is below this value, will not be shown but will remain in M
- $V \subset R$: Indicates which resource $r \in R$ have $e_n[i] > \min\_viz$
- $|V|$: The quantity of resources shown in the visualization.

The table 1 is an example of a characteristic's matrix in which the relevance value is calculated.

Table 1: Example of characteristic's matrix

Characteristic's matrix						
Resources		TOPIC			Relevance	Normalized
		Topic 1	Topic 2	Topic 3		
X	F1	1	1	1	6	100
1	F2	1		1	5	90
2	F3	1		1	5	90
3	F4		1	1	4	70

The figure 3 is an example of similarity vector ($\underset{s}{\rightarrow}$) in which the weight for each relation is calculated based in the number of selected objects that share the relation.

Figure 3: Example of similarity vector

4.1. Relevance vector calculation

The final step for the algorithm is to calculate the relevance value for each resource. This means how much an object is graphically highlighted in the web application. For this, the vector of similarity $\underset{S}{\rightarrow}$ is obtained. From here the relevance value for each object in the list is calculated in the base of the weight of each label it poses. Therefore, a calculation in which each element k is multiplicated by the value of the label i (1 or 0) for the element with the same index inside the vector $\underset{s}{\rightarrow}$ and adding all the results. This considering that all the results will be given by:

$$\sum k_2{}^i \underset{s}{\rightarrow}[i] \times A[k,i] \qquad (1)$$

in which those elements that contain the related topic with a higher weight in the matrix will have a bigger relevance value.

The resulting vector $\underset{R}{\rightarrow}$ contains the relevance value for each object in the list. This vector is normalized in a vector $\underset{R}{\rightarrow}!$ and is calculated in the following way:

$$\underset{R}{\rightarrow}! = \frac{\underset{R}{\rightarrow}[i]-(\min\underset{R}{\rightarrow}-10)}{\max\underset{R}{\rightarrow}-(min\underset{R}{\rightarrow}-10)} \times 90 \qquad (1)$$

5. NAVIGATION OPTIMIZATION

Part of this research work is to prove that a recommendation system algorithm improves the efficiency of an object search in a linked database. This can be measure by the number of clicks (selections) c =|S| the user does before finding the objective object. This means that the system objective is to reduce the number of clicks. This leading the user to select objects that are better evaluated (high relevance value)

6. CASE OF STUDY WEB APP FOTOTOTECA

For this case of study, the database *Fototeca* (Fototeca. Tec de Monterrey) from *Patrimonio Cultural del Tec de Monterrey* (Patrimonio Cultural Tec de Monterery 2009) was used. Fototeca is a database which holds historic photos. Fototeca holds over 6 thousand objects with over 900 tags available. The resources of this database are linked in *RDF triplets*. This connected structure fits for testing the proposed recommendation algorithm. Furthermore, the triplets structure can be visually represented in the user interface. The web application work as a recommendation system using a graphic interface in which the connections of the resources are visualized.

For this work, a web application was developed for retrieving resources from a SPARQL endpoint implemented in a Fuseki server. The visualization was developed using D3. The application receives as input the *URI* of the most connected resource of the category chosen by the user. The front page is represented in figure 4.

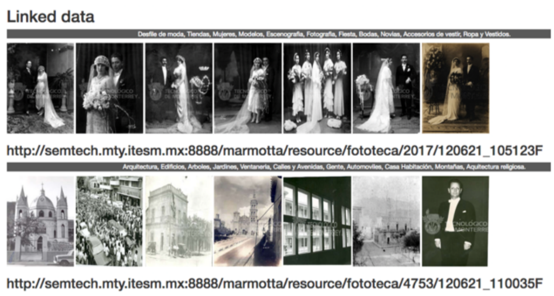

Figure 4: Front page of the web app showing the categories and the most connected phot of each one

Once the user selects an initial object, the system retrieves the 10 most similar photos in the database. The app displays the graph as shown in figure 5. The layout is updated in each iteration where the relevance value is recalculated and represented by the size of the node. The main idea for this is that at each click the algorithm recalculates the relevance value based on the similarity of the pictures. The graphic layout helps the user to visualize the objects that are similar to the actual object and the relevance of each resources to his search.

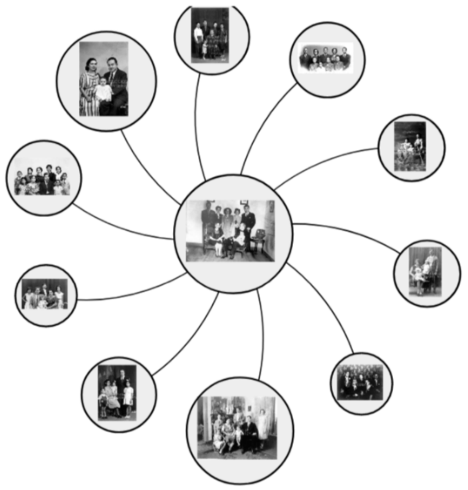

Figure 5: Graphic layout of the recommendation algorithm

7. RESULTS

For the case of study, it was asked to 50 users to search a specific photo using the web app with the recommendation system. The objective of the experimentation was to learn if the recommendation system can guide the users to the objective photo. The results were measured considering if the user finds or not the objective photo, and how many clicks the user makes.
From the 50 users in the test 41 find the objective photo and 9 did not find it (82% find the target photo). For the users that find the target photo the average relevance value for the relevance vector was 70.16 and for those who not find the objective photo was 68.02. This means that those users that follow the recommendations of the system have better chances to find the target photo.
The figure6 shown the average number of clicks in which the user finds the target photo. Also in this figure, it is shown the average relevance value for each click. We can see that users that find the target resource tends to select photos with higher relevance value in each click.

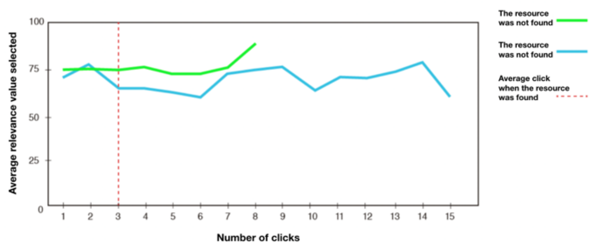

Figure 6: Average value of the relevance vector in. each click

From the 50 users in the test the average age for the users that find the target photo was 22 years and 31 for those who not find the target photo. It was found that younger users have better chances to find the target photo. This can be attributed to the fact that younger users consider more the size of the node as part of a recommendation. Older users tend to consider the content of each photo rather than the recommendation based on the similarity.
The results of this work show that a recommendation system based in similarity to offer relevant resources to a user can be built with Semantic Web technologies and Linked Data. Also, the use of a dynamic adaptative graphic interface to show the connections between the objects and the relevance value helps the user to find the target resources. Also, the selection of the graphic interface helps the algorithm to receive as input the relevant attributes for the user. This work aims toward the optimization of the graphic interface in order to analyze if the selected objects are the best route from the initial object to the target object.

8. CONCLUSSIONS AND FUTURE WORK

This article explores the idea of using recommender systems based on semantic similarity with dynamic visualization in a linked data structure. With this, the intention of taking advantage of semantic relations between resources to calculate the relevance of an object to a user is explored. Based on the case of study results, it can be concluded that dynamic visualization based on relevance in linked data bring considerable benefits to a traditional interface. The concept of adaptative visualization in linked data is a relevant topic in semantic technology. Even though the use of artificial intelligence tools such as recommender systems is still a challenge. This work proves that the use of recommender systems directly connected to a dynamic visualization strategy improves user experience. Future work can be done with the use of emerging technology techniques such as virtual and augmented reality.

An interesting approach for this type of work is the benefit of education innovation. This because one of the most important parts of any educational process is access to information. Furthermore, students and academic professionals must be able to interpret data efficiently. One problem, when retrieving information in most traditional databases, is that data interpretation is subjected to the labels given to each resource. By contrast, in human knowledge semantics is very important to the meaning of information. With tools like the algorithm proposed in this work, it is possible to encourage the use of linked data structure in academic databases. With these, resources like scientific documents can be directly connected by meaning to other objects like authors, subject or institution, not just by labels. Furthermore, tools like these can use semantic connections for helping users to easily discover new resources of great relevance to the query. Future work in this field could include the use of recommendation system algorithms in Open Educational Resources (OER) discovery. Examples of semantic technology apply to OER are Europeana and DBpedia. Using this artificial intelligence tools could enhance user experience and resource discovery.

As today only the relevance value is represented graphically in the interface (node size). Further work in the improvement of graphic visualization is recommended. This to enhance the user experience in order for the user to understand better the semantic relation between resources. Examples of another approach in the graphics interface to be considered in future work is the use of force layout to show the degree of relation between objects and edge weight (connecting line) to represent the similarity between resources.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of Writing Lab, TecLabs, Tecnologico de Monterrey, Mexico, in the production of this work.

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