THE 4TH INTERNATIONAL CONFERENCE OF THE VIRTUAL AND AUGMENTED REALITY IN EDUCATION

SEPTEMBER 17-19, 2018
BUDAPEST, HUNGARY

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WELCOME MESSAGE 2018

Virtual and augmented reality technologies are nothing new and unique. They have long existed, but mostly they were related to the entertainment industry. The main reasons were their cost and incompatibility, as well as the lack of real applications in the economy. Today VR/AR technologies have overcome the critical phase of the Gartner's Hype Cycle curve, and their entry into the economy is irreversible. There are serious investments. VR/AR technologies are used in a variety of industries, from medicine to agriculture. They are used for training, learning, research, e-work and other applications.
The VARE 2018 biannual conference is a meeting place for industry professionals, students and scholars to facilitate the exchange of experiences and the introduction of new VR/AR solutions.
We would like to thank the authors for their contribution to the promotion of VR/AR technologies, which extends the scope of application and allows to select the most useful and sustainable solutions.
We really hope that the VARE 2018 conference will be a pleasant and useful event, which will promote the development of business and scientific contacts of authors.

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Riga Technical University

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University of La Laguna

Eduardo González Mendívil
Monterrey Institute of Technology

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This International Workshop is part of the I3M Multiconference: the Congress leading **Simulation around the World and Along the Years**

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MOTOSTUDENT AND THE REALITY-VIRTUALITY CONTINUUM

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ABSTRACT
In university engineering education there are usually many problems to obtain a spatial ability of the student, especially in the first courses. So, we have dared to raise other resources that facilitate spatial ability through models in three dimensions (3D) easy to reach by the student and easy to manipulate to obtain a better vision of all their geometry and functionalities. Through the augmented reality (AR) and the virtual reality (VR), we can obtain using open software, different projections and visualizations of the bodies that are generated in an assembly as is the case of Final Degree Projects or projects that students voluntarily perform, as is the case of Motostudent. This is done through the publication of web pages and viewers that allow to see the objects or in this case the pieces in 3D with the ability to manipulate them as if we had them in hand.

Keywords: Augmented and Virtual Reality; engineering; models; CAD; Mechanical, elearning university

1. INTRODUCTION
In this paper we continue our research (Olmedo, Olalde, and García 2015; Olalde Azkorreta and Olmedo Rodríguez 2014) to analyse the different options we have to represent an object in AR and VR, from 3D design programs for engineering, such as Catia (CATIA 2018), Solid Edge (Solid Edge 2018) , Solid Works (Solid Works 2018), AutoCAD (AutoCAD 2018), etc. Our main aim is to make a product designed with Computer Aided Design (CAD) projects more accessible to potential customers and students with limited resources to buy licenses of expensive CAD software. AR (Martín-Gutiérrez 2011; Ciollaro Rodrigo-Magro 2011) is a technology through which the vision for the user in the real world is enhanced or augmented with additional information generated from a computer model. The improvement may consist of virtual devices placed in a real environment or the display of "non-geometric" information about real objects. AR allows the user to work with and examine real 3D objects while receiving additional information about these objects. AR adds information to the real world of the user and allows the user to stay in touch with the real environment. This is clearly different from the VR, where the user is totally immersed in an artificial world and completely separated from the real world. In VR systems (Dangelmaier and others 2005), there is no possibility for the user to interact with objects in the real world, only with the ones in the Virtual Environment (VE). AR does allow users to interact naturally with a world that is a mixture of virtual and real. AR systems carry the computer-generated elements to the real world where the user is, while VR systems make the user be immersed in a virtual world. However, such applications impose demanding requirements. Combining models states that these models are very accurate. This mixture requires objects that are introduced in the real scene behaving in a very realistic way. To achieve this reality, AR requires a very detailed description of the physical setting.
AR is a new area of Computer Graphics that also relies on other computer related disciplines such as hardware (Liarokapis and others 2004), computer vision (Kaufmann, Schmalstieg, and Wagner 2000), sensing (Kaufmann and Schmalstieg 2002) and tracking (Klopfer and others 2005). It allows the user to view the real world with superimposed computer-generated annotations and graphics. AR systems may be used by a multitude of users at the same time. This provides the opportunity for collaborative applications, such as engineering design, architecture, multi-user games, and education, among others.
We are interested in applying AR to drawing in engineering education at university level. We are specifically interested in showing to the students' different points of view to improve their spatial capacity, thus it is important to show them in 3D, and to allow the students to move and manipulate them. The goal is for them to gain a spatial intuition of the structures, a key skill for students to understand and solve drawing in engineering such views, boundaries, sections, etc.
In this paper firstly, we will introduce CAD software used for teachers and students at the University to develop 3D models. Later, a brief explanation about AR/VR and the use of them in education will be presented. The relationship between AR/VR and engineering will be fully justified describing objectives, benefits and the classroom setup. After showing first impressions the setup for the MotoStudent project will be described. This project allows sharing of designs on the Internet with fully 3D interaction universally at very

low costs because only open source software is used. So, the designs will be shown on almost any connected device. As the techniques used at this project, the so-called Web3D, are the basis of the future of Internet where 2D websites will be substituted by amazing 3D sites with multimodal interaction (Olmedo, Escudero, and Cardeñoso 2015), AR.js and X3DOM will be introduced with the supported platforms for Desktop/Laptop and Mobile devices. 3D printing will be also considered as one of our proposals and we will talk about the programs used. Our proposed workflow defined to share on the Internet the designs made by the students with expensive CAD software platforms used at the University, its relationship with the reality-virtuality continuum and the technologies introduced, will be presented. And finally, at the end of the paper, results and conclusions with our new ideas for developing future work will be introduced.

2. CAD SOFTWARE

CAD software, which we will discuss in this article, refers to the most widely used in the field of mechanics such as aerospace, automotive engineering and many other fields of engineering mainly in manufacturing. What we intend to show in this article firstly, is the use which has been given so far to the designs in CAD (Kosmadoudi and others 2013), and different outputs that we provide such software to work at a later stage display through AR/VR. This type of software is always expensive and there are students, customers and partners that cannot afford to buy licenses. Sharing 3D contents using websites and AR/VR apps based on open standards offers an excellent opportunity to encourage the public to become acquainted with our products with no specific investment. There are open technologies to diffuse 3D contents, but they are not widely used nowadays because producers of plugins for visualizing 3D contents on the web are leading this technology. But most used web browsers include native possibilities for visualizing 3D contents; it is only a question of developing special websites or adding the necessary modifications to the actual websites. This is the aim of our project. Basically, we will focus on the CAD programs (Jungjun Park and others 2011) we have at our disposal. These have allowed us to see all the possibilities for the AR/VR environment. Table 1 below shows the software used and the different extensions that we provide for further treatment in AR/VR. From 3D models stored in files with the different extensions provided by CAD programs, we try to transfer them to AR/VR software, making the appropriate changes, rendered application layers, lighting and even movement. Thus, we get the effect of visualization features as real as possible and the users can manipulate them as if they were in their hands. Such supplements are obtained from other specific programs (Kosmadoudi and others 2013) and tools for rendering, animation or illumination of scenes, such as Autodesk 3D Studio (3DSMax 2018), Maya (Maya 2018) or Blender (Blender 2018), the latter Open Source.

Table 1. Software used and the different extensions

CAD Software	Principal extension	Other extensions
CATIA v5	*.part; *.product	*.stp;*.vrml;*.3dmap;*.3dxml;*.cgr;*.iges; .model;*.Navrep;*.stl;*.x3d;*.wrl;*.hcg;*.icem
NX 9	*.prt	*.iges;*.stp;*.step;*.dxf;*.dwg;*.model(catia); .catpart(catia)
Autocad 2014	*.dwg;	*.dgn;*.dxf;*.dws;*.dxx;*.bmp;*iges:*.igs;*.dwf; .3ddwf;*.pdf;*.fbx;*.wmf;*.sat;*.stl;*eps
Solid Edge ST5	*.par;*.asm	*.model;*.plmxml;*.prt:*.dwg:*.dxf; *.xt;*.xgl;*.sat; .jt:*.part;*.igs;*.step;*.stl;*.3dpdf;*.u3d
Solid Works	*.sldprt;*.sldasm	*.stl;*.iges;*.stp;*.proe;3D XML; *.dxf;*.dwg
Sketchup 2013	*.skp	*.mtl;*.obj;*.wrl;*.xsi:*.fbx;*.dwg;*.3ds;*.txt

3. REALITY-VIRTUALITY CONTINUUM

Milgram (Milgram and others 1994) proposed the idea of the Reality-Virtuality Continuum where reality, as we know, is situated at one side and VEs totally generated by computer or VR is situated at the opposite side. Moving from the side of the reality to the side of the VR we could pass by the AR and from the VR towards Reality, we will situate at an Augmented Virtuality, AV. Everything between AR and AV is called Mixed Reality (MR). MR not only allows user's interaction with VEs even allows physical objects from the immediate environment of the user to be elements to interact with the VE.

MR will include everything that is not only VR nor AR applications. For example, an application developed for giving a virtual scene for broadcasting the weather forecast with a real human over it.

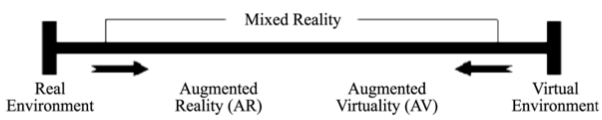

Figure 1. Reality-Virtuality Continuum (Milgram and others 1994)

AR concept involves the combination of different technologies to mix on real-time 3D content computer generated with live video recorded with a device (Azuma 1997). An example of AR could be an application that superposes a synthetic image over a real image; this is done with applications for an indoor design that superpose virtual furniture over images with the buildings. MR would be between AR and VR, concerning to different levels of a mixture of real and virtual world, integrated on one only visualization device, depending on the weight of its contribution to the final result (Milgram and others 1994). An example of AV could be an application that superposes a real image over a synthetic image, the way it is done with virtual stages for weather forecast where the real image of the presenter is superposed over the maps. So, it is on MR where techniques such as using physical objects from the user's environment are used as elements for interacting with the VE. As said in (Olmedo 2013) more and more websites are three-dimensional. This will be generalized when our smartphones and tablets are able to visualize these characteristics. Having specific hardware to do this was the intention of the AR Engine project (AR Engine 2015). Several standards such as VRML and X3D have been designed by Web3D Consortium (Web3D consortium 2018) but there is also work in progress for AR. For example, ARML (Lechner 2010) is a proposal. Also, standardization of a 3D compression format is a must. The big challenge is to compress and stream 3D assets using an effective and widely adopted coder-decoder (codec), in the same way as MP3 is the standard for audio, H.264 is that for video and PNG/JPEG is that for images. In the future, we will see a popular application for 3D transmission on the way as there are popular applications for audio, video and images (see Table 2).

Table 2. Applications for audio, video, images and 3D.

Audio	Video	Image	3D
MP3	H.264	PNG/JPEG	X3D, MPEG4, COLLADA
Napster	YouTube	Facebook	?

Uses of Web3D could be those proposed by John Vince (Vince 1995) in Table 3:

Table 3. Uses of Web3D.

GROUPS	AR/MR/VR applications
Industrial	Visualizing engineering concepts, Training personnel, Evaluating ergonomic issues, Visualizing virtual prototypes, Visualizing virtual weapons, Exploring servicing strategies, Simulating the interaction of assemblies, Simulating the dynamics of articulated structures, Stress analysis, Distributed product development management, Simulating manufacturing processes, Collaborative engineering on large AEC projects, Machining and pressing simulation, Concurrent engineering, Ergonomics, Virtual prototypes, Visual engineering, Spatial visualization.
Training Simulators	Medicine (Soft body modelling, Minimally invasive surgery, Virtual therapy), Civilian flight simulators, Teaching, Learning, Military simulators (Flight, etc.), Strategic simulators, Train driving simulators, Vehicle simulators, Emergency services
Entertainment and Cultural Heritage	Computer and Video Games, Recreational games, Experiences at Thematic parks and Museums, Tourism and Advertisement
VR Centres	Architecture, Indoor Design, Urban Development, Airport Design, Bridge Design, Human Movement Analysis

But, in the field of engineering, we can consider:

- Visualization of product and data, reducing the cost of sending samples to the customers, etc.
- E-commerce and B2B applications, improving detailed information regarding products offered.
- Learning and training, giving a better approach to the three-dimensional appearance to the learners without using authoring tools.
- Web improvement, giving 3D to the web.
- News and Ad improvement, giving 3D to advertising and commercial web-based reports.

Several options have been used to develop Web3D, the most popular are: (i) Commercial Plugins: Adobe Director (Adobe Director 2018), Adobe Flash/Animate CC (Adobe Flash/Animate 2018), Microsoft Silverlight (Microsoft Silverlight 2018), Cortona (Cortona 2018) and others; (ii) Java Plugins, applet based solutions developed with Java or Java based APIs like Java3D (Java3D 2018); (iii) Ajax3D (Ajax3D 2018): X3D based and plugin needed with JavaScript; (iv) WebGL (WebGL 2018): several JavaScript libraries for HTML5; (v) X3DOM (X3DOM 2018): that is our choice because of the ample community supporting this JavaScript and CSS library with no need for plugin and widely implemented natively on most popular web browsers.

4. TEACHING OF ENGINEERING AND THE REALITY-VIRTUALITY CONTINUUM

New technologies must help our students to take an active part in our classes in order that they become more involved in learning, without having to listen to endless lectures or passive PowerPoint presentations. Inductive learning must be continuous. AR/VR can be used in education to show the students models that cannot be seen in the real world. In the field of drawing in engineering, it can be very effective for students who wish to improve their spatial ability on the screen which makes it possible to view objects such as 3D images, which can be handled to rotate, scale or section them in real time. AR systems are an extension of the concept of VE. These systems present the user with an enhanced view of the real world. This view contains virtual elements. The visual augmentation may be accompanied by sound, tactile (haptic) and other types of augmentation. Visual augmentation requires users' movements to be tracked. Tracking computes the position and orientation of the user's head so that the virtual elements can be correctly rendered and displayed. Rendered elements are displayed in the user's view of the real world. By mixing this view, the virtual graphics and text can be done in either of two ways. See-through devices allow the user to see the real world directly. They display the graphics on a transparent screen located between the real world and the users' eyes. The display may be a LED or an OLED like those used in projectors. Alternatively, a camera mounted on the user's head may capture views of the real world. These may then be combined with the virtual graphics and displayed on a head-mounted display (HMD). The main advantage of AR systems over regular VE systems is that they combine virtual and real worlds thus providing a much richer experience. AR systems can be single-user or multi-user collaborative. Single-user systems have been applied to science, engineering, training and entertainment, among others. Collaborative systems have been applied to the same areas with much more valuable results. For example, we can collaborate with other colleagues such as computer technicians, mechanics or mathematicians and use automation or other disciplines around us, to obtain a multidisciplinary work. Many processes, ideas and concepts can be better illustrated by using both images of the real world and graphics. Think for example of a future architect looking at a building. We can let the student look at the floor plans at the same time. A different but much better approach uses AR to superimpose the internal structure of the building so that it can be understood why it does not collapse.

University teaching methodologies have not evolved much over the centuries. The method of attending lectures, taking notes and taking a final exam date back to the 15th and 16th centuries. Recently, new technologies have appeared in the classroom. For example, it is common to see PowerPoint presentations and use networked platforms like Moodle (Foster and Cole 2009). Using these new technologies does not imply an increased interaction between students and the teacher. In fact, information often keeps on flowing in only one direction, from the teacher to the students. For students to learn more and better, education must be both experimental and interactive. We learn more from hands-on experiences than from traditional lectures. Also, collaboration and discussions between students help them with their education by teaching them opinions and methods proposed by their peers. This is more interesting for engineering students. But other disciplines such as law may benefit from new technologies, like teleconferencing to attend or participate in remote trials.

AR is mature enough to be applied to many everyday activities. Education is one of them, especially for the following reasons (Billinghurst 2012): (i) AR supports seamless interaction between real and VEs; (ii) AR makes it possible to use a tangible interface metaphor for object manipulation; (iii) Finally, AR makes for a smooth transition from reality to virtuality. AR can also be used for online education. Project MARIE (Multimedia Augmented Reality Interface for E-Learning) uses AR to present 3D information to the students (Petridis and Liarokapis 2002). The authors argue that AR is more effective than VEs in terms of price, realism and interactivity. They also predict that in ten years AR will be used in many everyday applications.

On the other way, VR is interesting to isolate students from the real world and make them concentrate on 3D models allowing manipulations that are more difficult to do in the real world, this is the case of engineering students.

We intend to use AR/VR to help to teach in several different classes: in the first level of engineering, in a class of expression graphics and advanced graphics and finally in project work. These classes are well suited for this purpose because:

- It can be used in different subjects or departments.
- All of them are based on the knowledge of computer-aided graphics.
- Models and practices are much better understood using 3D models with rendering and tangible interfaces. We will explain the expected benefits of using AR/VR in the classroom. We will describe our objectives, our classroom setup, and the results obtained from our experience with AR/VR and Engineering Graphics. More specifically, we will present the outcome of a satisfaction questionnaire filled out by the student subjects of the experience. And finally, as an example of sharing experiences, the MotoStudent project will be introduced.

4.1. Justification and expected benefits

Not every student has the same 3D spatial perception abilities. Some students have difficulties envisioning 3D objects drawn or displayed in 2D. This is relevant in Engineering where students must analyse the 3D models to see the correct answers to the class problems. 2D produces optical illusions that usually stem from the ambiguity of 2D renderings. Figure 2 shows the Necker cube where two edges of the cube cross (a), the image does not tell which one is at the front and which is at the back: the drawing is ambiguous; (b) and (c) are the two possible interpretations. Figure 3 shows an M.C. Escher drawing, an impossible object, there are just drawings or images with no consistent interpretation. But, one can construct real physical “sculptures” that when viewed from a certain angle look like impossible objects.

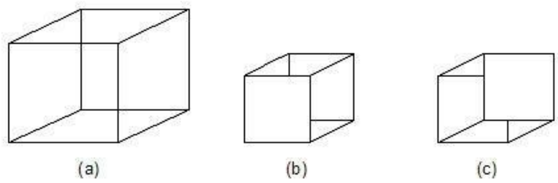

Figure 2. The Necker cube (CSPE 2018).

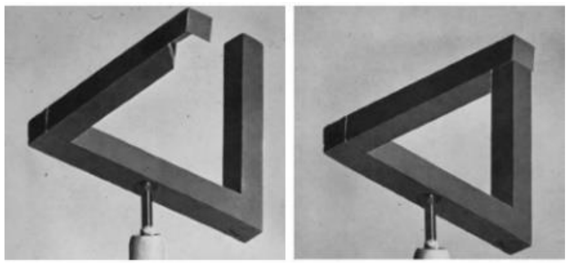

Figure 3. Impossible objects (CSPE 2018).

The ambiguity of 2D models together with the difficulties of 3D analysis and perception implies that very often important concepts are not assimilated. Also, problems that can be easily solved by rotating a model and analysing its face and geometry are almost unsolvable, even for competent students. Therefore, many students end up memorizing models and problem solutions before the exam. A few days afterwards the students have forgotten most of them. Instead, models should be derived from much simpler concepts. This would help the knowledge to settle in their minds. To improve our students’ comprehension of spatial capacity we introduce an AR/VR system. It allows tangible interaction with the virtual models, thus simplifying their 3D analysis. The two main benefits of applying AR/VR techniques to our classes are: (1) Students have a much better understanding of the fundamental concepts and models presented in the classes; (2) A powerful and flexible AR/VR tool simplifies the teacher's task of explaining the basic concepts related to models and spatial capacity.

4.2. Objectives

Overall, we have two objectives: (I) to improve the students understanding of models and assemblies using AR/VR, and (II) to provide the teacher with a tool to better explain those models that require good 3D spatial intuition. Additionally, we have the following specific objectives, including computer-related objectives.
With respect to the students' spatial ability, our intention is to achieve the following objectives: (1) To get them actively involved by introducing a novel technology like AR/VR; (2) To provide them with a tool to view different 3D models in an intuitive way; (3) To increase their 3D analysis and perception skills; (4) During the class we want them to manipulate the models independently or in groups not only with the teacher but also on their own, while working on problem solving; (5) To develop aptitudes such as initiative and class participation by manipulating the structures; we also want them to collaborate in groups; (6) Bringing new computer technologies to the students, increasing their knowledge, their abilities and their communication skills; these skills are critical for the students to later be able to successfully join multi-disciplinary teams with experts from other areas.
With respect to teachers of Graphics Expression we aim to achieve the following objectives: (a) To provide them with a tool that will catch students' attention by attracting and surprising them; so, students' attention and participation will then be maximized; (b) Increasing the teachers options to effectively teach concepts where a good spatial intuition is critical for the students understanding.
Finally, our computer related objectives are: (i) To compile a database of 3D models of mechanical of engineering; (ii) To use it in a collaborative AR/VR system with markers and cameras; (iii) To implement our software system with open-source libraries; (iv) To promote free software usage.

4.3. Classroom setup

To apply AR/VR technology to our classes we first consider our current methodology. We do not want to introduce substantial changes. Instead, our objective is to naturally improve our current methodology using the AR/VR system. To do so we add AR/VR sessions to our current theory, problem, practice and laboratory classes. That is, we alternate between using the blackboard, PowerPoint presentations and other teaching resources, and using structure analysis with the AR/VR system. There are some models that have been built using the VRML modelling language and X3DOM. Figure 4 shows the original 3D model developed with CATIA. Figure 5 shows the same model on the web-based on X3DOM. The system allows students to inspect a set of models by moving a maker or showing the model on the web and moving the mouse. We also have model libraries in the browser allowing easy access and manipulation on AR. Figure 6 shows the same model on the web-based on AR.js with their associated markers. The marker is recognized by AR.js (Etienne 2017), an open-source library for AR application development. Note that the makers easily identify the structures. The 3D models of the material structures are superimposed on the markers when these are recognized. Finally, we allow the students print their 3D models to accomplish their projects totally. Figure 7 shows the same model ready to be printed on 3D.

4.4. First impressions and results

In order to know the students' opinion about this project, a survey was carried out in the Graphics Expression classes. The main objective of this survey was to collect their opinions about the advantages and disadvantages of using AR/VR techniques. We also wanted to know whether it was useful from the point of view of the students as users of this methodology. The survey group was made up of fifteen students randomly chosen from the different classes where our system was used. Note that some of them were in more than one of these classes. The general opinion among them was that using AR/VR to understand models was very useful. All the students surveyed considered that AR/VR was a powerful tool that helped them to understand the 3D arrangement of these models. Besides, the possibility to print their models on 3D was like a prize for their effort developing their projects.

5. THE MOTOSTUDENT PROJECT

MotoStudent Competition (MotoStudent 2018) is a challenge between University students' teams from all over the world. The objective is to design, manufacture and evaluate a racing motorbike prototype, which is then put to the test and final evaluation at the MotorLand Aragón Circuit. The competition itself represents a challenge to the students. They will have to prove their creativity and innovation skills to directly apply their engineering abilities against other teams from universities all over the world during a period of three semesters/terms. MotoStudent brings benefits to the students, to the universities and to the industry and with our proposal also to the society. The challenge to teams is to develop a motorbike that can successfully accomplish with all the tests and events along the MotoStudent Competition. MotoStudent gives the teams the chance to prove and demonstrate their engineering skills, creativity and business abilities in competition to teams from other universities around the world, so there is a need to make the project universally reachable. A group of students of mechanical engineering from the

University of Basque Country desired to participate in this contest. Their idea was using the CAD software at the University to design their prototypes. But there is a need of sharing these prototypes to promote their work to the audience of the contest and maybe to possible investors. The lack of cheap software for 3D on the web is a handicap. Besides, the economic situation nowadays gives the students few chances to develop an initiative out of the official budgets. Thus, the use of software like X3DOM and AR.js allows them to share their 3D designs over the Internet with low costs and, they can enrich their experience collaborating with computing science engineers and web designers. Some examples of pieces developed with CATIA for this project with their conversion for the web allowed the students to share their developments with other students and the general public with no investment for them or for the public. On the next sections, X3DOM, AR.js and 3D printing are introduced. Finally, the workflow used to share our students' 3D models on the web is described.

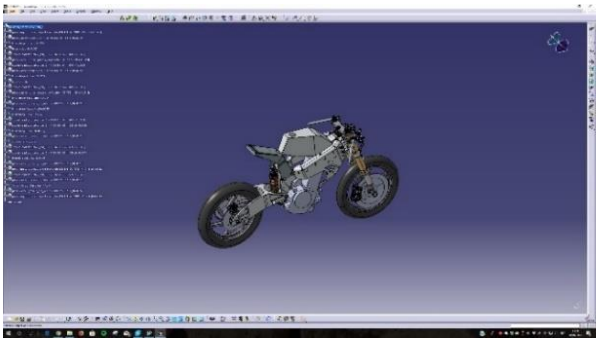

Figure 4. 3D model in CATIA.

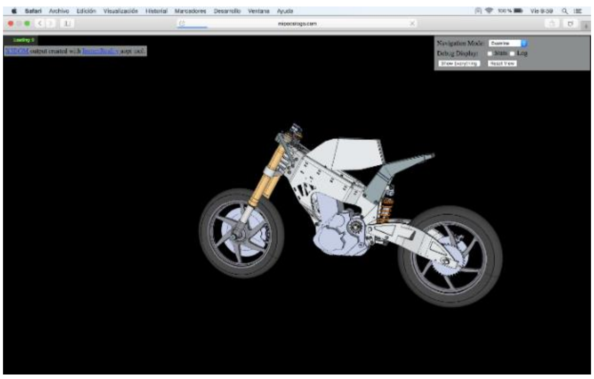

Figure 5. 3D model in a web browser.

6. X3DOM

While X3DOM community is still working hard to make it a reference for Web3D (Web3D 2018), we have tested several desktop and mobile devices in order to see the possibilities of accessing 3D contents using desktop/laptop based systems and mobile-based systems.

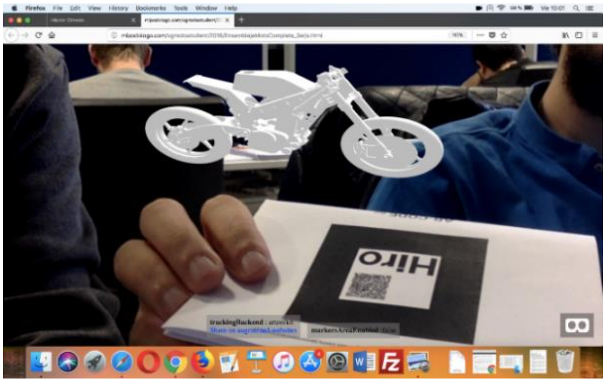

Figure 6. AR application using a trigger.

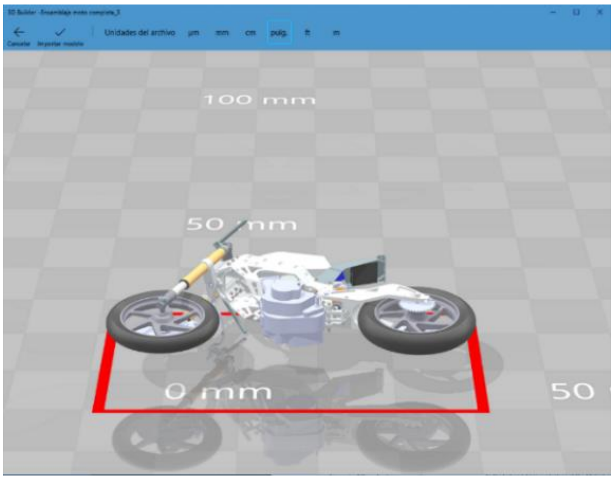

Figure 7. 3D model on Builder 3D ready to print.

6.1. Desktop/Laptop support for X3DOM

Some implementations of the X3DOM model need an Instant Reality plugin (Instant Reality 2015), an Adobe Flash/Animate CC plugin or a WebGL enabled browser. We tested the most usual web browsers on a Microsoft Windows 10, on an Apple Mac OS machine and on an Ubuntu system (Table 4). Both Windows and Mac OS support X3DOM websites on the latest versions of the most popular browsers: Google Chrome (Google Chrome 2018), Mozilla Firefox (Mozilla Firefox 2018), Safari (Safari 2018) , Opera (Opera 2018) and Microsoft Edge (Microsoft Edge 2018).

Table 4. Support of x3dom at web browsers for desktop/laptop.

Web browser	Windows 10	Mac OS 10.10.4	Ubuntu 16.04
Ms Internet Explorer	NO	N/A	N/A
Ms Edge	OK	N/A	N/A
Google Chrome	OK	OK	N/A
Mozilla Firefox	OK	OK	OK
Safari	OK	OK	N/A
Opera	OK	OK	N/A

6.2. Mobile support for X3DOM

We tested the most usual web browsers on an iOS-based device and an Android-based device (Table 5). Latest versions of iOS and Android support X3DOM on most popular web browsers.

Table 5. Support of x3dom at web browsers for mobile/tablet.

Web browser	iOS 11.4	Android 6.0.1
Google Chrome	OK	OK
Mozilla Firefox	OK	OK
Safari	OK	N/A
Opera	OK	NO

7. AR.JS

Based on AR.js (Etienne 2017) we have tested several desktop and mobile devices to see the possibilities of accessing AR contents using desktop/laptop-based systems and mobile-based systems. 3D models developed with CATIA must be converted to .ply files using meshconv program (Meshconv 2018).

7.1. Desktop/Laptop support for AR.js

We tested the most usual web browsers on a Microsoft Windows 10, on an Apple Mac OS machine and on a Linux system (Table 6). Linux testing is more complicated due to the diversity of distributions. Both Windows and Mac OS support X3DOM websites on the latest versions of the most popular browsers: Google Chrome (Google Chrome 2018), Mozilla Firefox (Mozilla Firefox 2018), Safari (Safari 2018), Opera (Opera 2018) and Microsoft Edge (Microsoft Edge 2018).

Table 6. Support of AR.js at web browsers for desktop/laptop.

Web browser	Windows 10	Mac OS 10.10.4	Ubuntu 16.04
Ms Internet Explorer	NO	N/A	N/A
Ms Edge	NO	N/A	N/A
Google Chrome	NO	NO	NO
Mozilla Firefox	OK	OK	OK
Safari	NO	NO	N/A
Opera	NO	NO	N/A

7.2. Mobile support for AR.js

We tested the most usual web browsers on an iOS-based device and an Android-based device (Table 7). Latest versions of iOS and Android support X3DOM on most popular web browsers.

Table 7. Support of AR.js at web browsers for mobile/tablet.

Web browser	iOS 11.4	Android 6.0.1
Google Chrome	NO	NO
Mozilla Firefox	NO	OK
Safari	NO	N/A
Opera	NO	NO

8. 3D PRINTING

Nowadays, 3D printers are easy to buy (Anonymousb) and there are services allowing to print our 3D models easily with no need to acquire a 3D printing (Anonymousc). Most applications to develop 3D models allow exporting these models like .stl files. Once generated models in 3D with any software, either Catia, NX or SolidWorks, the .stl files can be generated. These are needed to be interpreted by the 3D printers. These .stl files are obtained through other specific software, such as open source CURA (Ultimaker Cura 2018), or Microsoft 3D Builder (Microsoft 3D Builder 2018). They are responsible for translating it into coordinates so that it can be printed on 3D additive printers at XYZ coordinates and assign the material and printing characteristics of each 3D printer. If the printers are not open source, the software of the printer itself is used, being able to print with different plastic materials such as PLA, ABS, carbon fibre (see Figure 8), glass fibre or even metals, in which case we would talk about additive manufacturing.

Table 8 Tested 3D printing software tools and supported OS (Anonymousa)

	Windows 10	Mac OS 10.10.4	Ubuntu 16.04
Cura	OK	OK	OK
Netfabb	OK	OK	OK
Meshlab	OK	OK	OK
3D Builder	OK	NO	NO

9. FROM CAD TO THE REALITY-VIRTUALITY CONTINUUM

As mentioned above, the information transfer from CAD (Chang, Kim, and Kim 2007; Altidor and others 2011) models to the AR/VR applications is sometimes carried out in a direct way, through specific AR/VR software or through intermediaries such as could be Sketchup (Sketchup 2018), 3DS Max (3DSMax 2018) or Maya (Maya 2018) which allow models to be interpreted by the AR/VR software. Our proposal allows 3D designers to export their contents developed with the usual author tools such as Catia (CATIA 2018), AutoCAD (AutoCAD 2018), NX11 (SIEMENS NX 2018), etc. to be shown on the Internet inside websites with no need for downloading plugins or any special configuration by the users. This process is shown in Figure 9 (VIRTUAL REALITY). The 3D model developed with the authoring tool (CATIA) must be converted to X3D format using the “aopt program” (AOPT 2018). The code on the obtained X3D file from the .wrl file exported from CATIA must be inserted into our webpage HTML code under the <x3d> tag. Stylesheets x3dom.css and blog-web.css must be associated to this webpage together with the last version of X3DOM’s JavaScript libraries. After this process is done, we have it all to display the 3D content in the usual Web browsers for PCs, laptops, tablets or mobile phones. Thus, users can interact with this 3D content resizing it, changing perspectives, etc. 3D content can be shown also as AR, as seen at Figure 9

(AUGMENTED REALITY). For visualizing as AR more development is needed depending on whether it is location-based, marker-based or even Oculus Rift (Oculus Rift 2018) based but we always use JavaScript and HTML with no commercial plugins. To do this, we convert the .wrl file exported from CATIA to .ply format using Meshconv program (Meshconv 2018). With stylesheets and AR.js library we develop a website capable to show the 3D model when detecting a marker. Once we can show our 3D models through the Web3D, 3D printing is the next step, and this is done by means of a similar process where instead of producing web pages, files formatted for 3D printing are provided for downloading (STL, stereotype layered, etc.). See Figure 9 (MIXED REALITY).

Figure 8 Result of the 3D printed model

10. CONCLUSIONS AND FUTURE WORK

We have introduced an AR/VR/MR system for teaching Graphics Expression at the university level. Our system uses inexpensive cameras, 3D printers and open-source software to set up a collaborative environment that supports several groups of students interacting with 3D models and assemblies. The structures are modelled in 3D using CAD software such as CATIA, SolarEdge or NX and translating to .wrl, x3d, .ply and .stl. AR models with interaction handled using hand-held markers and AR.js. VR websites with the 3D models are done using X3DOM. 3D models are printed on 3D. Our experience with the system shows that students enjoy it and learn more Graphics Expression concepts. In fact, they ask whether they can take the 3d printed model home. We have also observed that they substantially improve their spatial intuition and learn to better understand visual cues better. We aim to apply this system to other areas of Mechanical design, automation, physical or electronic department. We intend to improve the tracking and rendering capabilities of the system and a better support for heavy models. We wish to support more students and we try to have a classroom permanently outfitted for collaborative AR/VR/MR education. As can be seen above, it is clear that the world of AR/VR/MR is very powerful and can have many applications (Chi, Kang, and Wang 2013) in engineering and that this junction can be very beneficial for all parties involved, both the designer and the potential customer, which the information will reach a more realistic and intuitive way, as it can interact with the model in some cases. At other times we may be of assistance information or maintenance (Anastassova and Burkhardt 2009) of equipment, in the aeronautical and automobile fields. In the field of education, we can see that the interaction with the design can be more realistic, although still alignment errors or loss of information are in place, the AR (Olalde and Guesalaga 2013; Olalde, García, and Seco 2013) can provide us a breakthrough in spatial ability student, unimaginable recently time. In the field of aeronautics and automobile production, major companies such as Boeing and Airbus are already making significant evidence for the use of AR in the training of their workers, as well as in the field of maintenance. There is a promising future for these technologies. Despite the investment in training for developing this kind of applications, the solutions that can be reached are less expensive than others, not only with respect to money but also sustainability. So, we will be aware of the CAD Working Group Strategy (Web3D 2018) to improve our developments. Our future work is intended on two lines: (1) we want to add information to the AR/VR models using JavaScript to present metadata exported from the CAD software referred to sizes, characteristics, etc. (2) we want to add interaction capabilities to our 3D printed models using the capabilities of small processors like Arduino (Arduino 2018) and Raspberry pi (RaspberryPi 2018), this way our 3D models will be part of the so called Internet Of Things, IOT (Gabbai 2015). So, as said before, it is on MR where techniques such as using physical objects from the user's environment as elements for interacting with the VE. That is why we called the corresponding part of our proposed work flow "MIXED REALITY".

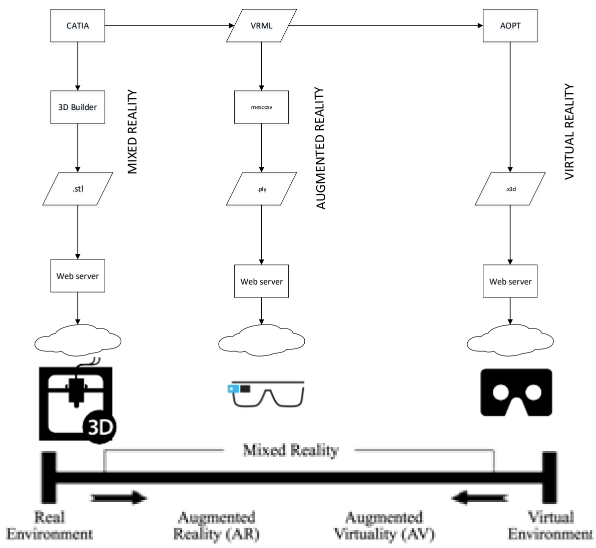

Figure 9. From CATIA to VR, AR and MR

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AUGMENTED REALITY: MODERNIZING RURAL EDUCATION IN INDIA

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ABSTRACT
The rapid evolution of technology has changed the face of education, especially when technology was combined with adequate pedagogical foundations. In this paper we are trying to answer the following question: is Augmented Reality an enhancer for Rural Education in India? For this purpose, we define augmented reality and present a state of the art mapped mainly by studies that focus AR in educational contexts. We also describe our research, including methodological aspects in data collection and the creation of 3D contents in AR for the purpose of education in high school level. This combination has created new opportunities for improving the quality of teaching and learning experiences. Until recently, Augmented Reality (AR) is one of the latest technologies that offer a new way to educate. Due to the rising popularity of mobile devices globally, the widespread use of AR on mobile devices such as smart phones and tablets has become a growing phenomenon. Therefore, this paper reviews several literatures concerning the information about mobile augmented reality and exemplify the potentials for education.

Keywords—Augmented Reality, Three-Dimensional models, Rural-Education.

1. INTRODUCTION

The term Augmented Reality (AR) was created by Tom Caudill, in 1990, while he was working at Boing1, and it translates the integration of virtual images in the real world, i.e. the reality is augmented of virtual elements mentioned in the sections 2,3,4. The integration of such images is made by the use of Information and Communication Technologies (ICT), through a mobile device with a camera (computer, tablet, mobile phone with android or iOS operating systems) which allows the access to the available contents with AR.

One characteristic that AR applications offer is the integration and interaction between the real and the virtual, allowing a huge versatility and creativity in applications. For instance, AR allows the development of contents such as books, instructions or presentations, in a conventional way, yet adding graphical elements that an AR application recognizes and that, when displayed, had been programmed to activate additional elements of explanation (for instance: three-dimensional files, explanatory videos and/or images)(Cardoso Teresa and Mateus Artur 2015).

In the age of digital learning where our cities are getting modernized everyday and the use of mobile phone has developed so much that, bringing AR in education will make the learning process easier for urban students but the problem comes in rural part of India where 70% of the Indian population resides. (niti.gov.in 2011) and still lacks the basic infrastructure and The paper reviews an AR application to ease the learning process in rural India which doesn't have an access to all modern facilities but everyone has mobile phone in their hands. The problem which we are trying to address is how a mobile application can solve or uplift the education in rural India.

1.1. The purpose of the study

Investigating prior research in a field is important, as this reveals the current state of the field and offers guidance to researchers who are seeking suitable topics to explore moreover; such systematic reviews provide a concise reference for policymakers, who must make critical decisions regarding funding and applications. The examination of prior research in a field also helps researchers to determine which subjects are of continuing importance. There are many literature review studies in the fields of global education and technology (Hwang and Tsai 2011; Wu et al.2012). In these studies, researchers focus on topics such as e-learning (Lu, Wu, and Chiu 2009; Shih et al. 2008), mobile and ubiquitous learning (Hwang&Tsai, 2011;Wu et al. 2012), blended learning (Drysdale, Graham, Spring & Halverson 2013), and educational technologies (Hew, Kale, & Kim 2007; Kucuk, Aydemir, Yildirim, Arpacik, and Goktas 2013). But reviews of research on AR technology are less common (Bacca, Baldiris, Fabregat, and Graf 2014) because AR has only recently become very popular in educational settings, the earlier research on AR in education are of were carried on Advantages and challenges associated with augmented reality for education: A systematic review of the literature by

(Murat Akçayır a, G€okçe Akçayır b), Mobile Augmented Reality: the potential for education by (Danakorn Nincareana, Mohamad Bilal Alia*, Noor Dayana Abdul Halima, Mohd Hishamuddin Abdul Rahmana 2013).
Referring to prior research, we find that mobile augmented reality has been used in several ways in the field of education, but our research aims on how can it be implemented in particular case such as in rural areas of India. The major target users for the research will be student in high school level, so the paper reviews a highly important societal challenge, that is mostly important for developing countries, in strategies to enable better learning conditions in rural areas, further the paper review the process of how AR content can be generated and how it can be implemented in rural education.

2. PROPOSED METHOD

The following section reviews the process of creating the pipeline for generation of AR content and implementation of the same in rural scenarios Each process is divided into phases. The pipeline follows a water-fall method in which the phases are cascaded. Figure 2 shows a block diagram of the pipeline for creating AR content.

2.1. Selecting the appropriate users and problems

Before going for the solution, we need to find the users and problems faced by them, and in this context, why are we focusing on rural education? The reason is simple, rural India covers the 70% of total population of India(niti.gov.in 2011) and the student population of 29.9 Cr (mhrd.gov.in). Majority of India still lives in villages and so the topic of rural education in India is of utmost importance. A survey named, Annual Status of Education Report (ASER), shows that even though the number of rural students attending schools is rising, but more than half of the students in fifth grade are unable to read a second grade text book and are not able to solve simple mathematical problems. The reason might be different but the main reason is lack of proper teaching and unavailability of essential technology in education. Not only this, the level of problem solving and reading is further declining. Though efforts are being made, they are not in the right direction. The reason cited for this problem in surveys is the increasing number of single classroom to educate students from more than one grade and decreasing ability of self learning of students shown in phase-1 in figure 2.
Quality and access to education is the major concern in Rural schools as there are fewer committed teachers, lack of proper text books and learning material in the schools. Though Government schools exist, but when compared to private schools the quality is a major issue. Majority of people living in villages have understood the importance of education and know that it is the only way to get rid of poverty. But due to the lack of money they are not able to send their children to good schools providing all the necessary learning materials and internet facilities for the additional learning, hence depend upon government schools for education. Above that, in some of the government schools there is only one teacher for the entire school and if they don't show up at work, then it is a holiday. If the quality along with number of teachers and, that too committed teachers can be improved in these schools, then aspiring rural children and India can fulfil their dreams of doing something great(Kaur Ramandeep 2013).
So the primary users for our study are the high school students in rural India and the problems faced by them is the lack of modernized tools which help them to learn and understand any science concepts in a more practical way with or without the help of a teacher.

2.2. The content generation

Phase-2,3 in figure-2 deals with problems in Content generation in education for AR is an important task which needs to be done before implementation and development stage. The right content in education is must, and creating 3D-models and AR videos for the application is difficult task. A survey has been carried out to find out the topics which are most likely considered as difficult for understanding from student's point of view. To make it easier, we have tried to convert the 2D diagram into 3D models and animations with the help of open source tools such as Blender. The model is a replica of the 2D figure with exactly similar texture, and also added animations like opening and closing of 3D models to view their internal architecture which will be easy for the students to learn in an interactive way and also makes reading more interesting.
Another problem faced during the research was due to the difficulty in making the application more generic and at the same time offline, as the rural part of India lacks internet facilities. So, teacher and student would not able to use it if an application entirely depends on the internet connectivity. Thus developing all essential features of the application offline was a challenge.
The book which we selected for the application is N.C.E.R.T (National Council of Educational Research and Training) by Government of India which is widely used in India especially in Rural India. So the purpose of scaling the application to high amount of users was solved.

2.3. Application working

In this section we will review the working of AR application which are subdivided into marker-based and marker-less AR application , vuforia(PTC software) library is been used to develop the application. Although there are lots of concerns on selection of appropriate AR SDK's for development(Amin Dhiraj and Govilkar Sharvar 2015) but for our research vuforia SDK's was appropriate as its support both marker-based and marker-less AR application development and support of natural markers.

2.3.1. Video Tracking

Vuforia library has been used for most of the AR applications. It uses video tracking capabilities that calculate the real camera position and orientation relative to square physical markers or natural feature markers in real time .Once the real time camera positioned at the same point and 3D computer graphics models drawn exactly is overlaid on the real marker . A fiducial marker is an easily detected feature in proximity to and as a point of reference to an object targeted for tracking.

Fiducial markers can be knowingly and intentionally placed or naturally exist in a scene. Natural Feature Tracking (NFT) is the idea of recognising and tracking a natural scene that is not (seemingly) augmented with markers.

2.3.2. Natural feature tracking

For the detection and tracking of naturally occurring features, the system integrates three main motion analysis functions, in a closed-loop cooperative manner

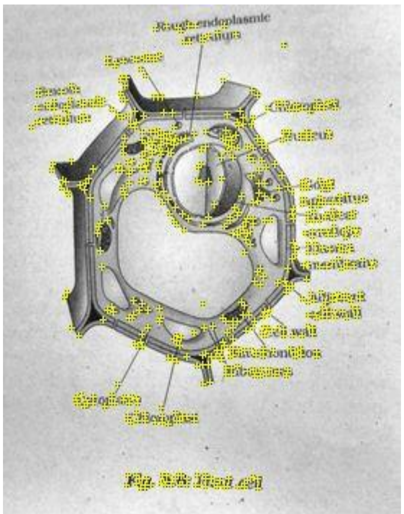


Figure 1: Feature detection of vuforia algorithm

to deal with the complex natural imaging conditions : Feature Tracking, Motion Tracking, Estimate Verification

2.3.3. SLAM (Simultaneous Localization and Mapping)

SLAM refers to the problem of trying to simultaneously localize (i.e. find the position/ orientation of) some sensor with respect to its surroundings, while at the same time mapping the structure of that environment. The majority of modern visual SLAM systems are based on tracking a set of points through successive camera frames, and using these tracks to triangulate their 3D position; while simultaneously using the estimated point locations to calculate the camera pose which could have observed them. SLAM is an optimisation problem, where the goal is to compute the best configuration of camera poses and point positions in order to minimise reprojecting error this algorithm is used when we are are coding for marker-less AR applications.

2.4. Application coding

After creation of 3D elements, content programming has been carried out as mentioned in phase-4 in figure 2. It is classified into two types the

1. Marker based Augmented Reality – In a marker- based AR application the images (or the corresponding image descriptors) to be recognised are provided beforehand. In this case you know exactly what the application will search for while acquiring camera data (camera frames). Most of the nowadays AR apps dealing with image recognition are marker-based. Why? Because it's much more simple to detect things that are hard-coded in your app.most of the library like vuforia uses natural feature tracking to track the image and augment the virtual element(Kumar Satish 2015).

2. Marker less Augmented Reality - On the other hand marker-less AR application recognises things that were not directly provided to the application beforehand. This scenario is much more difficult to implement because the recognition algorithm running in your AR application has to identify patterns, colors or some other features that may exist in camera frames. For example if your algorithm is able to identify dogs, it means that the AR application will be able to trigger AR actions whenever a dog is detected in a camera frame, without you having to provide images with all the dogs in the world (this is exaggerated of course - training a database for example) when developing the application. The other problem when using Marker-less AR is the detection of real world environment because with only RGB camera which are mostly used in mobiles detecting the environment is difficult as need lots of processing power, but with help of advance SLAM algorithm
   which is used in vuforia it possible to place the virtual content in real world without the help of a marker(Kumar Satish 2015).

After creation of 3D element, AR SDK’s are required which can provide basic tracking algorithm and a game editor which can be used to code the application. We have used vuforia and Unity as AR SDK and game editor respectively because of their cross-platform support, Marker based and Marker less capabilities(Amin Dhiraj and Govilkar Sharvar 2015).

The application coding block diagram shows the integration of different phases such as content making to feedback review

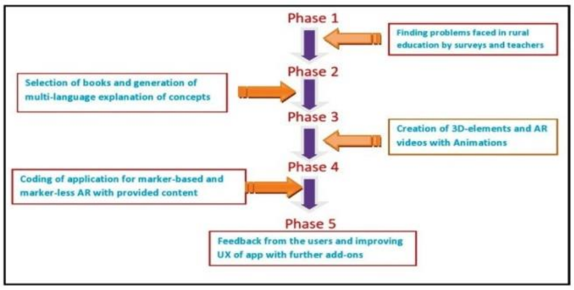


Figure 2. Block diagram of the AR application

During the initial application user testing, the feedback we got was to make the application to work in many languages as India is a country of more than 22 languages (Traveldudes 2010) and in rural India most of the students do not know English so it was a challenge to develop the application in their regional language, we took the challenge and we tried to add the buttons to change the language of explanation. Now it is available in 3 languages: English, Hindi and Kannada. Further feedback was to link an application with more content which is available freely. So we added direct links of Google and YouTube search for that topic.

The final application with marker based AR, we have come out has the visuals

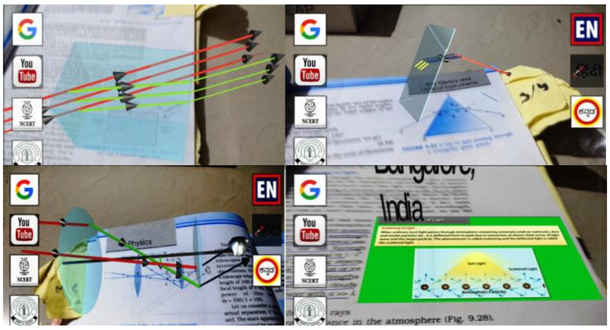


Figure 3: Experimental visuals of AR on NCERT books for class 12

In higher secondary education, Laboratories play an important role in explaining some of the difficult concepts. Laboratory experiences may help students concretely understand the inherent complexity and ambiguity of the concepts rather than reading it from the text books and understand. But in rural education there is lack of infrastructure of labs and sufficient instruments in labs. So there is need to bring AR so that a student can visualize an instrument and able to perform experiment virtually even if the instrument is not present in lab. This can even avoid the common laboratory hazards during the conduction of some chemistry experiment. Posters of the experiment can be stuck in labs and students can just scan the poster and can be able to visualize the instruments and their working.

The final application with marker-based AR in labs, we have come out has the visuals

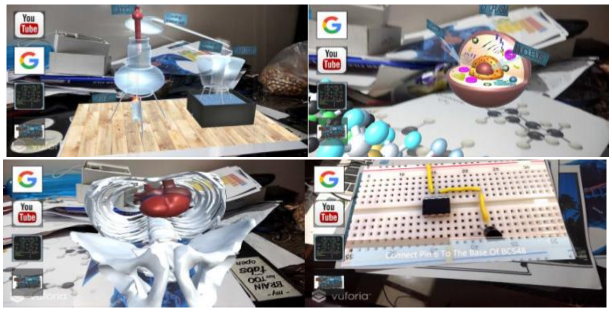


Figure 4: Experimental visuals of AR in labs

Moving forward to marker-less AR, there may exist a situation where students do not have books, and the question arises how AR will be useful for them in such scenarios. So we have come up with an alternate solution of placing the 3D content anywhere like ground or table tops with a Menu driven application in which student can select the topic to study and the mobile camera will find the appropriate surface to place the 3D content. The final application with marker less AR we have come up with, has the visuals.

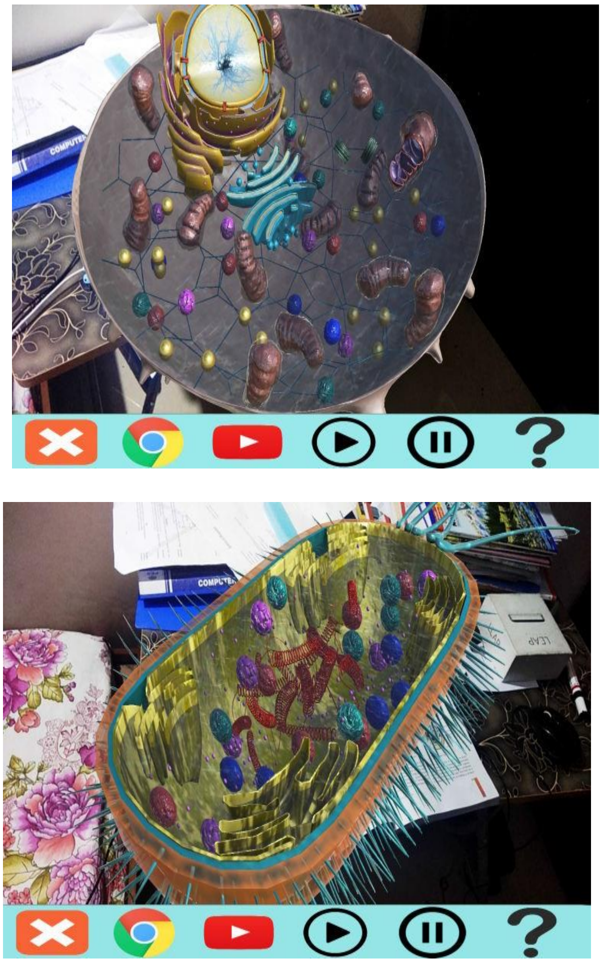


Figure 5: Experimental visuals of marker less AR of animal and fungal cell

Proceedings of the International Conference of the Virtual and Augmented Reality in Education, 2018
ISBN 978-88-85741-20-1; Bruzzone, Ginters, González, Gutierrez and Longo Eds.

3. RESULTS AND DISCUSSION

The application developed has primarily focused on rural education especially at high school level students and the workflow of working model has been made simple and easy to use. The application was developed with such accessible user interface so that it can be easily used by a first time user. The application also provides a tutorial video for the first time users.

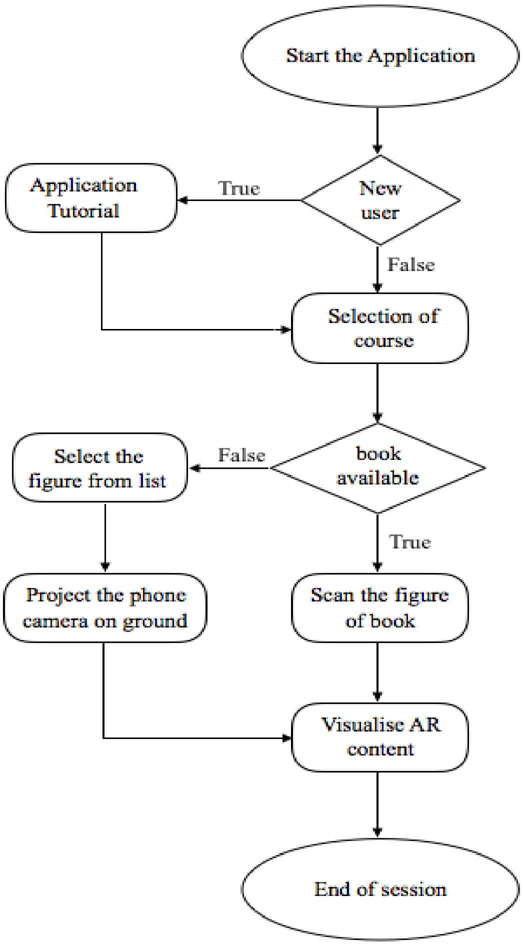


Figure **6**. The workflow of the AR application

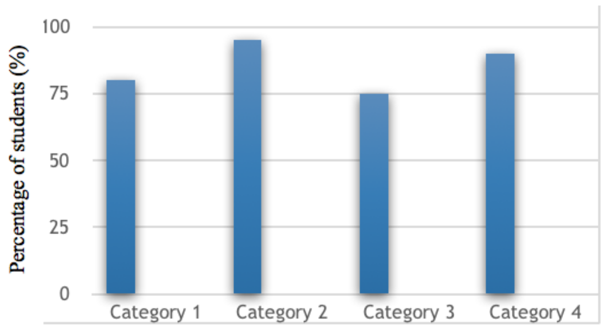
3.1. User feedback

Getting feedback from the application user is last phase in pipeline of AR application development; the application was shared with various students and teachers from different categories ranging from rural to urban schools. The written and verbal feedback were recorded and compiled in tabular and graph format.
The feedback will be considered as learning for future iterations in development cycle.
In direct feedback sessions, it was observed that students who were using AR application for the first time were finding it hard to scan image and use other gestures, hence an initial animation on camera view was added to guide the new users.

Table 1 : Summarized feedback from users

Factors	Feedback
Influencing factor for downloading application	Interactive visualization makes learning easy
Preferred application type-Online/offline/semi-offline	Offline/ ability to update content when connectivity present
User experience while using the application	Good and easy to operate for first time AR users
Can be used as additional teaching tool	Yes, the application helps in explaining complex models

The feedback received was positive and the result was calculated on the percentage of students favored each category.



Category 1 = Accuracy in image detection

Category 2 = 3D models replicate 2D figures

Category 3 = Quality of explanation through animations

Category 4 = App. useful for visualising complex figures

Figure 7: Percentage of student supported categories

Thus the results were positive and most of the students and teachers were in favor of bringing AR in rural education. The another reason why bringing AR in rural education is affordance, although AR is a new technology but the affordances and benefits to support learning were worth as mentioned and discussed (Nincareana Danakorn, Ali Bilal and Dayana Abdul Halima 2013).

3.2. Future research

The problem faced by most of the users was scanning
The correct book as in maker-based AR the the marker/figures should be same as that of the figures provided during development process. So this limits application usage to single book, hence in the future work, we will be primarily focusing on making marker-based AR generic for all the books, so that it identifies the figures using machine learning algorithms and produce the AR content according to identification.
The current version of SLAM which is supported by most of the devices has limited tracking, so placing AR

content at fixed position is hard and it decreases overall user experience of application.

3.3. Authors contribution

The paper faces a quite serious challenge - education in rural India, so authors had provided a pipeline or model on how AR applications can be used at rural education level with limited infrastructure, the results were positive from users which signifies that model presented was useful and can be used in future learning. The example application (scienceAR) illustrates the same. The model is also useful in the processes where learning is involved and assets are limited.

4. USE OF AR IN DIFFERENT DOMAINS

Augmented reality in current state of art has many applications domains which has been successfully implemented, this section reviews the state of art work done in the domains such as in Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context(Longo, F., Nicoletti, L. And Padovano, A. 2017), Augmented reality in healthcare education: An integrative review (Zhu, E., Hadadgar, A., Masiello, I. & Zary, N. 2014), Vision-based location positioning using augmented reality for indoor navigation(Jongbae kim and heesung jun 2008).
Authors are also working on finding a new approach for indoor navigation and positioning through augmented reality using advanced SLAM.

ACKNOWLEDGEMENT

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CONCLUSION

Exploring the potentials of Augmented Reality (AR) and Virtual Reality (VR) concepts and technologies has been a research topic for decades. Research on how to take an advantage of these concepts in the domain of education has brought forward a great number of concepts, prototypes, and working systems. Although, the surveys and studies in this designing area of Augmented and Virtual reality keep diversifying.

We have proposed a virtual approach towards assisting this space by creating special tools which can be helpful in the process of teaching and learning. We have also made some attempts to visualize their real world applications.

Here is link to our prototype app for 9th standard science textbook, the NCERT book is used in all over rural India the name of the application is **SCIENCEAR9** it is available on google play store https://play.google.com/store/apps/details id=com.NIXAR.ScienceAR9

Augmented Reality is a new way of interacting with the world and bringing it in education will be a great platform for students to grasp the knowledge in a better way. Our project could eliminate the overpriced SMART class in schools as this is much more economic method of learning. It could thus be encouraged to implement in government schools through the faculties.

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VR-TECHNOLOGY FOR RISK ASSESSMENT OF AND ACCIDENT PREVENTION AT MACHINE TOOLS

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ABSTRACT

Using Virtual Reality (VR) could allow for a more structured and comprehensive risk assessment (RA) of machines and equipment at an early stage of the machine development process (design phase). Before developing a new method for VR-based RA, it is, however, necessary to first determine if VR is feasible and useful in carrying out risk assessments.

For this purpose we initiated two user studies. In the first study, a column type drilling machine was investigated to evaluate the general usability of VR for RA. In the second study, the modality of information transfer was investigated. A conventional form of safety instruction (SI) was compared with a VR-SI. The results showed that the VR-RA is generally feasible, so we started to develop a VR-RA method.

This paper presents the implementation and results of the two studies, the current status of the VR-RA method and the next steps to be taken.

Keywords: virtual reality (VR), risk assessment (RA), safety instruction (SI), user test

1. INTRODUCTION

The RA is an iterative process that includes a risk analysis and a risk evaluation (ISO 12100, 2010). Machine manufactures are obligated to perform an RA before placing a machine on the market to ensure that machines are safely designed and fulfill all health and safety requirements of the Machinery Directive (Machinery Directive 2006/42/EC, 2006). In the context of machine and occupational safety, VR allows the user to perform the RA at a very early stage of the product development process, based on a true to scale model of the entire machine. In other areas, such as the construction industry, VR visualizations are very useful for planning, risk and safety analyses and realization of large projects (Nickel et. al, 2015).

The SI, in contrast, is used to improve occupational safety and accident prevention, and it needs to be fulfilled by the employer or an expert representative (DGUV, 2013). Based on legal regulations, employers are obliged to instruct their employees on health and safety at work, in particular about the hazards and prevention measures. Regarding this, VR offers a realistic, immersive and true to scale virtual learning and training environment. This environment makes VR a very promising instrument for accident prevention, because the expenditure compared to traditional, real world RA or SI can be reduced, and an early deployment can speed up implementation of safety measures (Nickel et. al, 2013).

VR might be a promising technology to optimize risk and safety analysis as well as occupational safety training and instruction. Nevertheless, several questions have to be addressed before using VR in a real industrial environment. First, it still needs to be explored if VR-based RA and SI can deliver comparable results to traditional, real-world methods.
If VR-based methods are in principal feasible concepts, new methods would need to be developed on how to optimally use VR for RA and SI.

In this context, the paper presents two experimental studies examining the use of VR technology in the context of RA and SI. In addition, the first results of the VR-RA method that is being developed will be shown and discussed. Finally we discuss the next necessary research steps.

2. VR-BASED USER STUDIES

2.1. Questions & Hypothesis

The aim of the first study was to compare two variants of VR-based RA. The initial questions were:

- How can VR productively be used for risk assessment?
- Which forms of presentation (e.g. schematic vs. detailed model), corresponding to different phases of the development process, are suitable in the implementation of VR-RA?

- Which steps have to be taken when creating a specific VR scene?
- How are machine-related risks assessed in the both RA variants?

In the second study, possibilities of the use of VR for SI were investigated. Specifically, the following question was addressed:

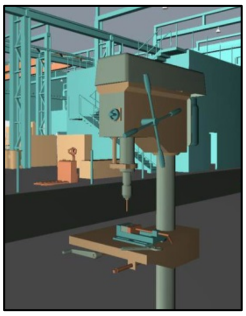
- In which ways do VR-based SI and traditional SI differ regarding knowledge transfer and influence on risk and hazard related decisions?

2.2. Experimental Setup and Implementation

For both studies a column type drilling machine was used as a demonstrator. The advantages of this machine for our purpose are the open working space and visibility of hazards. Additionally, the low complexity of the machine allows for brief user tests. Such tests are of crucial importance: Despite the relatively high awareness level of machine-related risks and relatively low requirements on the operator, accidents with serious injuries still happen frequently (DGUV, 2015).

2.2.1. Study 1: Risk Assessment

The development of the test design consisted of four phases: design draft, pre-test, experimental study and evaluation of results. CAD-data of the column type drilling machine formed the basis of the VR scene creation. More detailed information about the development of the test design and the phases is described in (Puschmann et al., 2016).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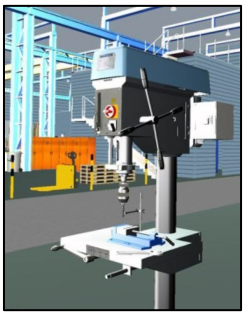
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Figure 1: VR-models of drilling machine (1) schematic model, (2) complex model

Two variants of the machine, which represent the different phases of the product development process, were created (Fig. 1):

1. A schematic model similar to a typical CAD-model with simple colors and missing components or details such as screws or chamfers
2. A complex model, which was graphically processed (realistic colors and textures)

The experimental study was carried out with 27 RA experts (machine tool industry, engineering offices, institutions, individuals), who were randomly assigned to the two different VR machine models. The test procedure included the following steps: reception, personality questionnaire, navigation training in the VR environment, machine briefing, performance of three tasks, presence questionnaire and a final interview. Specifically the following three tasks were performed in this process: 1) identification of hazards according to standards (EN 12717+A1, 2009) without virtual operator and animation, 2) identification of hazards with virtual operator and animation, and 3) risk evaluation for selected hazards (ISO/TR 14121, 2012).

2.2.2. Study 2: Safety Instruction

In addition to the VR model of the column type drilling machine from the first study, a power point (PPT) version, using snapshots of the VR scene of the machine, was tested. The aim of the study was to compare the two methods of presenting a safety instruction. Both variants used the complex model of the drilling machine, described earlier.

121 vocational students participated and were randomly assigned to the VR or PPT safety instruction. For comparability, the content and duration of both variants were the same. Furthermore, identical verbal information was presented via audio track.

In detail, the SI was divided into seven parts: 1) column type drilling machine assembly, 2) general rules of conduct and protective measures, 3) rules of conduct and protective measures in the process, 4) workpiece preparation, 5) workpiece fixing and rotation speed selection, 6) drilling, and finally 7) accident and failure behavior. As control variables various questionnaires were administered to measure immersion and personality factors.

The students were asked to assess a real column type drilling machine before and after the training.

2.3. Results

The results of the first study show that with the complex model a higher number of hazards were identified (Fig. 2). Such hazards included aspects such as the clamping device or the open gear cover of the machine. For certain hazards, such as the completeness of the gear cover or stability of the machine the schematic model was more suitable, however. Furthermore, the integration of a virtual human model and also use of animations for working steps had positive effects on the number of identified hazards.

The evaluation of the questionnaire showed that both variants of the model are suitable to obtain a high level of involvement. In any case, work experience proved to be a crucial variable in identifying hazards (Horlitz et. al., 2017).

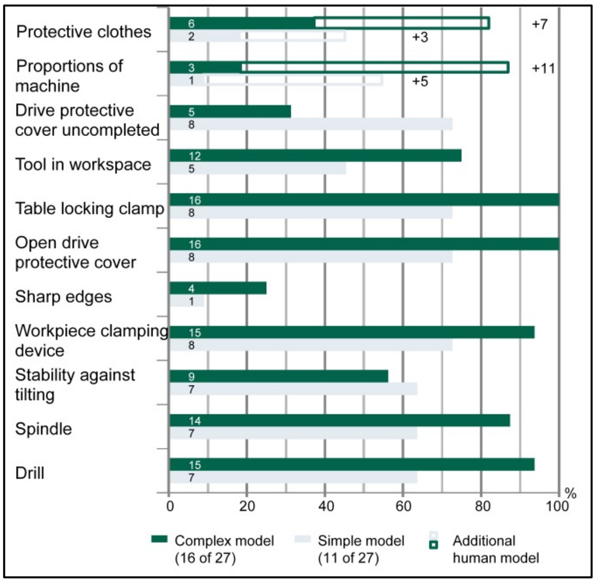

Figure 2: Number and percentage of test subjects, who identified existing risks

Results of the second study show that participants clearly experienced a greater degree of immersion in the VR condition than in the PPT condition. Furthermore, we found evidence that supports the notion that VR presents a more powerful tool for delivering safety training than PPT: In the VR condition participants estimated the probability of accidents higher than those who had received the information via PPT.

Overall, the results suggest that VR is suitable for RA and SI. Consequently the next step is the development of a new method VR-RA.

3. FIRST RESULTS OF THE VR-BASED RISK ASSESSMENT METHOD

3.1. General Aspects

The development of the VR-RA method started with a thorough analysis of existing national and international rules and regulations concerning risk assessment of machines and manufacturing equipment. This was followed by research regarding traditional RA methods, current software tools for RA, and existing quality management methods that might be suitable as basis for the new VR-RA method. Based on that, the study results and an analysis of relevant national and international research projects, several requirements for the VR-RA method evolved.

First, the VR model or scene for the RA has to be created with as little extra effort (time and cost) as possible. Second, hazard factors should be easily and clearly visible (on average better than with just the CAD model of the machine and close to the recognizability at the real machine). Third, future machine operators have to be part of the RA (e.g. as virtual humans or as a user of the VR during the RA process). Fourth, existing results of former RAs, accident reports, etc. have to be integrated. Fifth, during the RA process the user has to have easy access to relevant rules and regulations: pre-filtered based on the current assessment object. Lastly, the method needs to include a documentation function, directly out of the VR.

The chronological sequence of the method can be divided into two main parts – the preparation of the VR scene and the RA in VR itself. For the preparation of the VR scene, several questions have to be answered: 1) Is it the first VR-RA of this machine type? 2) If so, which data (CAD/VR models, documentations, regulations, etc.) is available? 3) If it is the first VR-RA, is it a new design or a modification design? 4) Is the coupling of a real NC control unit necessary (e.g. regarding the analysis of functional safety)?

The general procedure of the VR-RA will be the same as it is for the traditional RA and is currently being researched to determine how exactly the integration of VR in the RA process will optimize the RA itself.

3.2. Categorization of hazard factors

Depending on the existing machine model (CAD model in different development states, VR model or real machine) only some of the existing hazard factors (for a complete list see, among others, ISO 12100) can be detected directly. To carry out a complete RA those hazard factors that cannot be detected directly have to be assessed theoretically using predefined forms. Therefore, it had to be analyzed which hazard factors can be directly detected using a VR machine model.

For this purpose, all hazard categories stated in ISO 12100 were analyzed regarding their perceptibility in VR. For each hazard factor the following categories were analyzed (example: mechanical hazard caused by geometric machine design): 1) source of hazard (sharp parts), 2) possible consequences of hazard (insertion, stabbing), 3) data/information necessary to recognize the hazard (radius of spike or angle between planes) and 4) source of the necessary information (geometry/ CAD/VR data). Based on the aforementioned information, an assessment of the additional effort to include that information into the VR model was carried out. Four effort categories were established: A – no additional effort (information included in standard VR model), B – minor additional effort (enhancements of the static VR model, like simple animations (e.g. movement of main machine axes)), C – middle additional effort (either additional objects (like electrical wires or more complex animations)) and D – large additional effort (all other, especially external measurement data, simulation or calculation models).

If the additional effort to include the necessary additional information was rated A or B, the hazard factors were categorized as “detectable” (meaning they are detectable based on a VR model without enhancing the model with too much additional information). If the additional effort was rated D – the hazard factors in question were categorized as “undetectable”. Those hazard factors rated C were categorized as “maybe detectable”. There it depends on other circumstances if the additional effort necessary to include the information needed to directly detect the hazard in the VR model is outweighed by the additional benefit. For example, if a machine manufacturer has a lot of problems (reported incidents) with electrical hazards (e.g. too small distance to high voltage areas) it might be worth the additional effort to integrate those into the VR model to definitely detect them when carrying out the risk analysis.

Based on the described analysis and categorization of hazard factors, mechanical hazards can be detected best. 10 subcategories were rated “detectable”, the remaining 5 were rated “maybe detectable”. For electrical hazards the additional effort to integrate the necessary information for direct detection is much higher. Therefore, only two subcategories were rated “maybe detectable”, the other six “undetectable”. For thermal hazards, two were rated “maybe detectable”, three “undetectable”. Hazards caused by noise, vibration, radiation and materials/substances were rated “undetectable”. The same is true for hazards connected to the machine environment as well as the combination of hazards. For ergonomic hazards, the recognizability strongly depended on the specific subcategory. Hazards connected to accessibility and body position were well “detectable”, hazards connected to the design and arrangement of user interfaces were “maybe detectable” and all other seven subcategories were “undetectable”.

3.3. Consequences of the categorization for the RA method

As stated before, “maybe detectable” or “undetectable” does not mean that those hazard categories cannot be included into a VR-based RA. It only means that those categories are not directly recognizable when looking at the VR model. That is even truer for an RA based only on the CAD model of the machine. And even carrying out the final risk analysis at the real machine does not always directly detect all hazards.

Therefore, the RA method that is to be developed must consider this and include a procedure regarding how to integrate all hazard categories rated as “undetectable” into the RA process (e.g. using predefined forms).

4. FUTURE WORK ON VR-BASED RA

Now, that the basic structure of the VR-RA exists, several specific research areas have to be targeted. The first area to study is the necessary interaction and navigation concepts with the VR scene, the VR machine model and virtual humans and also with the relevant documents and forms. That includes not only interaction with tablet PCs and navigation with classical VR devices (like Flystick) but also a real NC control unit or a motion capture system as interaction devices.

A second research area to be addressed is functional safety. It still needs to be explored which parts of the functional safety (concerning components but also relevant mathematical equations) can be directly integrated in the VR-RA method.

The last research area to be addressed is knowledge management and documentation. The targeted question here will be how to integrate and intuitively use results from former RAs or accident reports as well as relevant rules and regulations.

5. CONCLUSION

In our first study, the use of VR for risk assessment proved to be an excellent alternative to document-based or CAD-based approaches. In comparison of the two investigated variants of the column type drilling machine, it has been shown that more hazards were recognized using the complex VR machine model. However, certain hazards were better identified with the schematic model. With regard to the evaluation of risks, the two models proved to be comparable. It can be concluded that in a typical assessment situation a schematic model seems sufficient to carry out a realistic and appropriate risk evaluation. Basically, a schematic model should support efficient risk assessment, because too many details actually may distract from crucial hazards. It is however recommended to use an increasing level of detail during the different phases of the machine development in order to identify all kinds of risks carefully.

The second study complements the investigation as it shows that VR-based training as compared to traditional methods increases involvement and risk awareness. A possible explanation for these effects is the higher level of realism and the resulting sense of presence.

Based on the results of the two studies we started to develop a structured method for VR-based RA. The development process is still ongoing but several requirements and first sequences are starting to be found.

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EDUCATIONAL AUGMENTED REALITY SYSTEMS: BENEFITS OF IMPLEMENTATION AND GOVERNMENT SUPPORT

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ABSTRACT
Technology plays an important role in many aspects of day-to-day life, and education is no different. Technology in education can influence students to learn actively and can motivate them, leading to an effective process of learning. In recent years, there has been an increasing interest in applying Augmented Reality (AR) to a wide range of industries. This paper reports a review of recorded successful implementations of AR technology in different industries, from Medicine to Marketing, Military to Education, where the main goal is to reveal the benefits of this emerging technology in educational settings. More specifically this review describes the application of AR in a number of subjects as complex as Biology, Chemistry, Anatomy, Geometry, and Physics. This paper also discusses the intention of several technologically advanced governments to implement forward-thinking AR technology in their national curriculum as it will benefit the learning capabilities of the students leading to a qualified workforce.

Keywords: Augmented Reality, educational technologies, literature review, national curriculum

1. INTRODUCTION

We stand on the very beginning of the Fourth Industrial Revolution, alternatively known as technological revolution, where the transformation of traditional industries in their scale, scope, and complexity will be unlike anything humankind has ever experienced and will fundamentally alter the way we live, work, and relate to one another.

As any other industries technology has become embedded in education and the results indicate a positive impact on learning and teaching techniques. It is obvious, lessons that are supported by technology will lead to more innovative forms of teaching and bring the learning capabilities to a new level.

Augmented Reality (AR) is a new emerging technology where computer-generated digital information is overlaid onto live direct or indirect physical real-world environment, thus enhancing user's perception of reality (Azuma 1997; Zhou, Duh, and Billinghurst 2008). The history of AR technology dates back to 1968 when Ivan Sutherland at the University of Utah, developed the first head-mounted display system. The system used computer-generated graphics to show users simple wireframe drawings and the first use of AR technologies for educational training was in the 1990s when applications were aimed to increase the training results of pilots (Caudell and Mizell D 1992).

Rest of the paper is structured as follow: In section two we briefly discuss the positive impact of AR technology in different fields. Sections 3 describes the current state of the art of the AR educational systems and their applications in different subjects of study. Section 4 presents the governments supporting the augmented reality technologies use in the national education curriculum.

2. CURRENT IMPLEMENTATIONS OF AR TECHNOLOGY

Being a cutting-edge technology there has been an increasing interest in applying Augmented Reality technology in various industries. The flexibility and constant upgrade of open platforms available for developing AR applications with various content allow independent groups and organizations to create field-specific applications thus broadening the use of the AR technology. As the name suggests the actual state of the reality is augmented and the physical environment enhanced with supplemented information, AR has found a wide implementation in such industries where the transaction of a large amount of information to the user within a limited time is critical.

2.1. Healthcare and Medicine

It's no surprise nowadays achievements of modern medical systems are the results of meticulous integration of new, forward-thinking technologies into the healthcare system.

As an emerging technology, integration of specific AR features into existing medical systems will not only enhance medical-surgical and clinical procedures by improving cost-effectiveness, safety, and

efficiency, medical AR systems may also assist in the invention of new surgical procedures.
To minimize tissue damage and improve patient recovery time in (Rashed and El-Seoud 2017) AR camera was integrated into Mobile C-arm machine helping to provide low-dose orthopedic surgery. In (Lee, Yoon, Park, Chung, and Yi 2015), authors suggest power the existing Surgical Navigation System and Endoscope Holder systems with AR to reduce the complications by delivering the location of tissues, organs and important bones to surgeons. Smart glasses such us Google Glass and Meta Pro are useful in the operating room as an adjunct device in screening necessary electronised health records of the patient right in front of the surgeons (Mitrasinovic, Camacho, Trivedi, Logan, Campbell, Zilinyi, Lieber, Bruce, Taylor, Martineau, Dumon, Appelboom and Connolly 2015).
It is clear that there are many exciting opportunities and applications of AR to surgical healthcare.

2.2. Marketing and Advertisement

The marketing industry has been always changing and adapting to consumers' needs in order to capture the selected audiences' attention. In no other field has the AR excitement exploded in such a huge way than in advertising and marketing. Companies seeking new ways to engage and interest potential customers bringing a better brand awareness associated with potential sales.
Research conducted in (Baratali, Abd.Rahim, Parhizkar and Gebril 2016), discusses how companies such as Ray-Ban, Pepsi & Co, Nivea and many others use Augmented Reality Experiential Marketing to stay connected with customers more effectively and associate the customer with a brand.
The authors of (Yazdanifard and Jin 2015) describe the AR as the future great tool for its ability to lead and expand the marketing communication in order to establish a better relationship between consumer and brands.

2.3. Military and Security

Modern combat platforms are powered by new generation weapons and it is very common to refer to them as intelligent units based on the use of advanced technologies. But the critical information of the battlefield is still expressed as graphics, data, text, and voice, requiring commanders to spend more time for a decision making which not always is accurate and may cause a fatal loses.
Stunning advances and rapid development of AR technology have proved to be very helpful in combat platform applications. The authors of (Livingston, Rosenblum, Brown and Schmidt 2011) introduces 2 equally important application scenarios of AR technology in combat field:

- The *Super-Cockpit:* This system overlays collected and already analyzed target information into pilot's heads-up display's visual field accompanied with augmented sounds to assist the user. The concept was to enhance the pilot's visual field by merging the virtual map on the dashboard display.
- *Battlefield Augmented Reality System*: Battlefield Augmented Reality System(BARS) is a Head Mounted Display (HMD) system with a wireless network connection which enhances user's perception of the environment by superimposing graphics onto the user's field of view. This system is designed to be used in urban environments with limited visibility, lack of familiarity with the environment.

3. EDUCATION-SPECIFIC AR SYSTEMS

Education plays a crucial role in the society. It is an investment in human capital and it can have a great impact on a nation's growth and development.
Integration of new educational approaches and technologies into educational programs is one of the most responsible tasks for governments for having an effective and employable society as new technologies provide opportunities for creating a specific ecosystem for learners.
The integration of emerging technologies and advanced techniques such as AR into the curriculum is becoming a part of a good and productive teaching. Below, is the review of several conducted studies describing the current state of the art of the use of the AR technologies for educational purposes.

3.1. Biology, Chemistry, and Anatomy

Biology, Chemistry, and Anatomy are incredibly fascinating fields of study because they are very fundamental to our world, playing an important role in everyone's lives. But mastering these subjects is not always an easy task. Students cannot imagine the actual structure and processes described in the subject of study. The problem is that study materials provide a two-dimensional representation of the chemical molecules, living organisms and life processes.

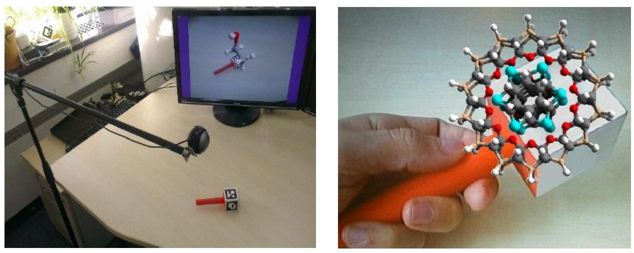

Figure 1: Augmented Chemistry and Augmented Chem. Reactions Systems

To combine the visualization of complex structures and the advantages of direct interaction with physical objects, researchers of the (Maier and Klinker 2013) have developed two Augmented Chemistry and Augmented Chemical Reactions systems. Both systems use Augmented Reality to supply a direct interactive 3D

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user interfaces. Augmented Chemical Reactions application composed of a handled physical cube with black and white patterns on each side. In a typical scenario, the student holds the cube by the handle and placing it in a web-come visible location. A webcam tracks the black and white patterns and by using a direct manipulation of the 3D user interface, students can literally grasp the spatial structure of the complex molecules thus enhancing learning capabilities of complex structures taught during the chemistry class. (Figure 1).
A similar approach was inherited by (Gillet, Sanner M, Stoffler, Goodsell and Olson 2004), where in order to explain the key concept of Molecular Biology, researchers have augmented the 2D diagrams and textual descriptions of HIV protease and Superoxide Dismutase(SOD) viruses. As in this approach visual sensors are fully engaged and the added voice assistance accompanies the 3D visualization, learner easily and faster understand the concept of virus development, damaging and the spreading pace in the living organism.
In (Touel, Mekkadem, Kenoui and Benbelkacem, 2017) study, researchers created e-learning by augmented reality system (Figure 2), which helps students and teachers visualize the course content with 3D models i.e. 3D heart, 3D sine, 3D brain. To have a better understanding of the above-mentioned organs and their interaction, a physical human torso was proposed with specially placed textures that would indicate the correct location of human organs.

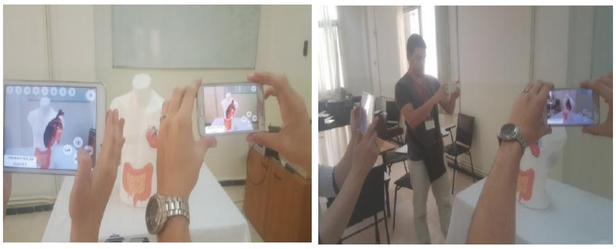

Figure 2: E-learning by Augmented Reality System

By scanning markers using their tablets, laptops and smart-phones, students can easily grasp the idea of the presented course. This integration of augmented anatomy course can dramatically increase the learning level with a small investment in the education.

3.2. Geometry and Physics

Math and geometry are one of the oldest and necessary among the sciences and are the first we interact from the early age of our life. When we understand the relationship between shapes, sizes, and numbers it will then be the basic knowledge to start understanding much complex science as Physics. Physics, the study of matter, energy and their interactions, is an international enterprise, which plays a key role in the future progress of humankind. The support of math and physics education is an essential part of the educational system of any advanced society.

To help students and scholars understand these two equally important sciences and apply them in their daily life and have a better perspective for the future analyses AR applications were introduced.
The research supervised by (Le and Kim 2017) suggests augmenting the 2D shapes of the simple objects i.e. a cube, a cylinder. Besides augmenting the diagrams on the flashcards, researchers developed an application allowing interaction of several augmented objects to create simple constructions (Figure 3). This approach will definitely help triggering students constructive ability.

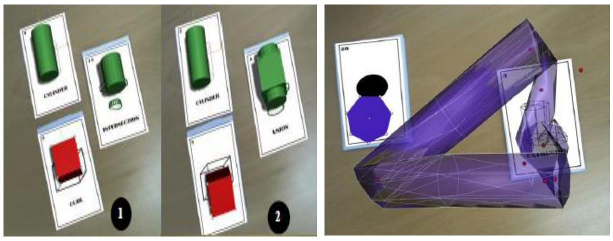

Figure 3: Interactive application for the Geometry learning use.

To develop the spatial abilities and master the manipulating visual patterns of human intelligence, the “Spatial Cube” was introduced by (Liao, Yu and Wu 2015). They expect that the AR function enables students to visualize the process clues while solving a Rubik’s cube. To visualize the hidden part of the object a series of process steps will be provided to students when they use a tablet to scan an object.
Authors of (Dünser, Walker Horner and Bentall 2012) propose to power the existing Physics books with augmented features to teach concepts of magnetism (Figure 4). The augmented content of the book explains 3 topics: magnets and magnetic forces, electromagnetism including Right-Hand Grip convention and the force of the current-carrying (Figure 4). In order to give a correct evaluation of the implemented AR technology, researchers have collected 10 students and divided them into two groups. Those who have learned the content of the book by AR features performed 59.7% higher in average on the same test.

Figure 4: Augmented View of the Physics Book

Similar research was conducted by (Kaufmann and Meyer 2008; Somsak and Prachyanun 2015) where participants instead of students were high-school teachers. The final result collected from the teachers shows that the 14 out of 15 participants strongly suggest the use of the AR technology in the classroom which will expand the learning capabilities as well as the interest of students toward the subject itself.

4. GOVERNMENTS SUPPORT

The remarkable achievements of the AR educational systems potential did not escape the notice of technologically advanced governments. Many of them have moved forward and have taken the initiatives of supporting the use of the advantages of the AR Educational Systems through their departments of Education and Technology.

In November 2015, the U.S. Department of Education first announced the EdSim Challenge in order to explore new technologies that will benefit next-generation learning through the use of forward-thinking technologies such as Augmented and Virtual Reality (U.S. Department of Education 2016). Five projects were selected as finalists as they have proposed simulations that have a higher potential of strengthening academic, technical, and employability skills in students. In the same year, the French Ministry of National Education also expressed their support of Augmented Reality technologies in the classroom (French Ministry of National Education, 2015). In their announcement, the Ministry of Education recommended to include the AR educational technologies in the national education curriculum.

By the end of 2016, the Ministry of Science, ICT and Future Planning in South Korea reported that the South Korean government will invest a total of $363 million in the KoVAC project with 20 campuses to support the AR use in government school nationwide by the year 2020 (Oh 2017). These campuses will enroll 2,200 students symbolizing the success of the Korean education of the year of 2020.

The Ministry of Industry and Information Technology (MIIT) of China, in partnership with over 170 private companies and research institutions established the Industry of Virtual Reality Alliance (IVRA) to grow the ecosystem of both AR and VR technologies and enhance the advanced use of the technology in the university level (Bourne 2016).

5. CONCLUSION

Improvement of the education by bringing new technologies should be considered as the main goal of the today's society. Augmented Reality can become a core of discussions since the technology is new and not used massively.

Calculated to have a market of $78 billion by 2021, AR is expected to invade through multiple industries and many are continuing to realize the impact and value of the Augmented Reality technologies will have on our society in the near future.

One impacted industry will be education. AR, with its ability to combine the digital and physical worlds, will bring new dimensions for teachers and learners with enormous potential benefits for the users.

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As almost as two years of consistent work experience lead to conduct a deeper research on the current implementation and the attention governments place to matter of Augmented Reality technologies in the field of Education.

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DEVELOPMENT AND EVALUATION OF WORK SUPPORT SYSTEM BY AR USING HMD

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ABSTRACT

The serious concerns of rapid aging and very low birthrate are faced in Japan. The aging increases the number of retired employee with work skill, and the declining birthrate decreases the number of employee. Therefore, securing and fostering human resources are social issues in Japan. In particular, the work support system is desired for several companies in rural areas. This is because that they can not secure human resources. By the way, AR technique can add the virtual information to reality space. Therefore, it is possible to show efficient information. Currently, AR technique has been used to education system.

In this paper, AR technique is applied to work support system for laptop computer repair. In this system, the parts of laptop computer are recognized by image recognition technique and the repair procedures are presented to user through HMD. In the experiment, the sensibility evaluation was performed. According to these results, the usefulness of the developed work support system was confirmed.

Keywords: Application of AR, human support system, image recognition

1. INTRODUCTION

Fig.1 shows the estimated future population in Japan. We face the serious concerns of rapid aging and very low birthrate. In 2017, ratio of elderly people at least 65 years old is 27.7%. This means that about one out of every four is an elderly person. Moreover, the ratio of elderly people at least 65 years old will be 38.8% according to the declining birthrate in 2060. The aging increases the number of retired employee with work skill, and the declining birthrate decreases the number of employee. Therefore, securing and fostering human resources are social issues in Japan. In particular, these issues are especially serious in rural areas. Currently, the ratio of elderly people at least 65 years old is 31.1% in Nagano prefecture where our university is located. Moreover, a lot of teenagers finds a job at city areas. Therefore, fostering human resources are serious issue.

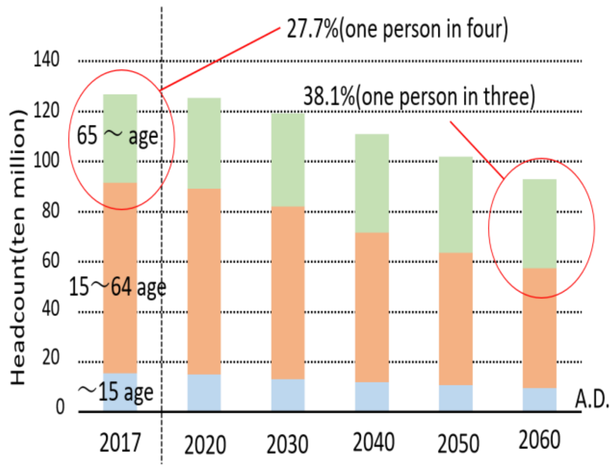


Fig.1 : Estimated future population in Japan

Our university has addressed the technical resolution of this issue in cooperation with medium-sized companies at rural areas. The one of these companies has been running the business of assembly and repair service for personal computer. There are more than 90 repair computers. Therefore, considerable skill is required to judge instantly the repairing procedure. The manuals have been made as the measures. However, it takes quite a while to work under referring the manuals. According to these reasons, the work support system for a beginning employee is desired in the company.

Recently, AR(Augumented Reality) technique has received considerable attention in recent years as a novel method of information communication. In particular, AR technique has become to be widely known to general public because that the “Pokemon Go”, which is game application software for smart phone, had gone viral. AR techniques have been actively developed in Japan. For example, in “Textbook AR”, the 3D graphics to explain the described sentence on textbook are shown in the mobile device when a user holds the device over the textbook. In “IKEA place”, the situation that IKEA furniture is put in the user’s room can be shown when a user holds the mobile device over the user’s room. Thus, AR technique can add the virtual information to reality space. Therefore, it is possible to show efficient information.

In this research, we have developed a work support system for repair of laptop computer by using AR technique and HMD(Head Mounted Display). HMD is the device like big glasses, and lens have a role of display. Therefore, user can see actual world superimposing digital information by using HMD. If the system can present repairing procedures to display on HMD depending on the actual repairing situation, user can work at the same time as recognition of repairing procedures. In this paper, the prototype work support system for repair computer was developed, and the usefulness was evaluated. The developed system was used by students on our university. Then, the questionnaire survey to confirm the usefulness was conducted.

2. DEVELOPED WORK SUPPORT SYSTEM

Fig.2 show construct of the developed work support system. EPSON MOVERIO BT-300 is used as HMD. And Unity and Vuforia are used as software for making AR processing. Fig.3 shows a scene that examinee wears the HMD. EPSON MOVERIO BT-300 has a camera to recognize environment information around him. And object on the environment can be recognized. Moreover, virtual object can be generated by using Unity and Vuforia. In our developed work support system, repair laptop computer, repair areas on one such as CPU and battery, and parts such as screws are recognized, and the repairing procedures are presented in any areas. Moreover, gesture can be recognized by using HMD. Therefore, click function can be also added by using this gesture recognition.

Next, actual process flow by using our system is described. Fig.4(a) shows a menu presentation paper. When the system is used, this paper is kept within shooting range of camera. Then, the repair parts categories and procedure button such as "next" and "back" are presented by using HMD as Fig.4(b) shows. User can click these buttons by using gesture recognition function. Moreover, teaching sentences are also presented in any areas. The scene in Fig.4(b) is start screen in our system.

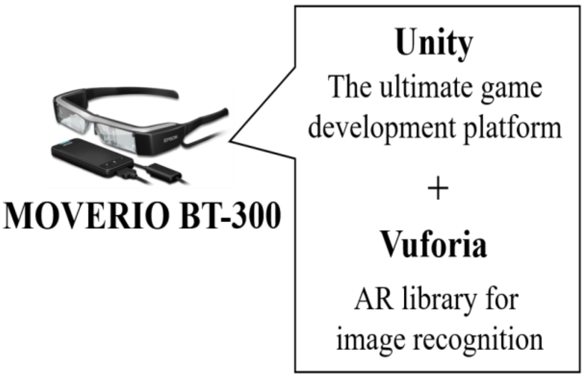
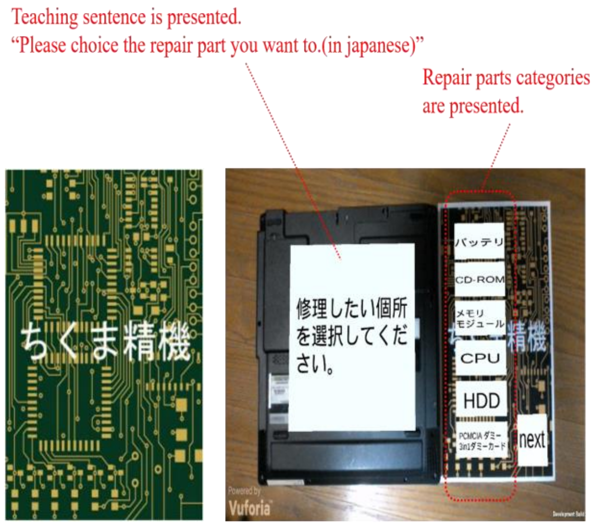


Fig.2: Construct of the developed work support system

In this system, repairing procedures of battery and CPU in repair categories presented in Fig.4(b) are presented as prototype. Note that the presented repairing procedure is the dismount procedure of the selected parts.

Fig.5 shows the presented repairing procedures by using HMD when buttery button selected by user. As Fig.5(a) shows, the teaching sentence to dismount the buttery is presented. Moreover, the lock of the buttery and the pushing arrow to dismount the butter are also presented on display. In this presentation, the detector of the lock of the buttery is used to recognize the one. This detector is generated by using image processing technique to extract the features of the lock and machine learning technique in advance. When user finished the dismount process of the buttery, he click the "next" button. Then the HMD presents the next repairing procedure. As Fig.5(b) shows, the presented

Fig.3: A scene using the developed work support system



(a) Menu presentation paper (b) Start menu scene

Fig.4 : Start menu screen in our system

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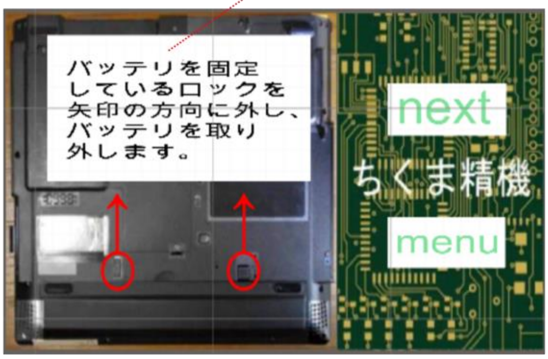
"Completed" sentence means the end of the procedure. When user click the "menu" button, the start menu screen is presented.

Fig.6 shows the presented repairing procedures by using HMD when CPU button selected by user. As Fig.6(a) shows, the way to uncover CPU is presented as first procedure. Here, the screws which should be dismounted are also presented by using image recognition technique. When user finished uncovering the CPU, he clicks the "next" button. As Fig.6(b) shows, the procedure to dismount CPU fan is dictated as next procedure. Here, the screws and connector which should be dismounted are also presented. Next, the procedure to dismount CPU heat sink is dictated as Fig.6(c) shows. Fig.6(d) is last procedure.

In this system, start menu screen, buttery and CPU repairing procedures are presented. The sentence described the way of work and part are presented on user's eye sight. Therefore, it is possible that user can work smoothly.

Teaching sentence is presented.
"Please dismount the buttery."
"Please push the lock of the battery in the arrow direction."
"Then you can dismount the buttery." (in japanese)



(a) First step in buttery repairing procedure

(b) Second step in buttery repairing procedure

Fig.5: The presented repairing procedure of buttery

3. SENSIBILITY EVALUATION

The sensibility evaluation was performed by using questionnaire. Here, an examinee worked the notebook computer repair by using a paper manual and the developed work support system. Then, the questionnaire survey was carried out. In this evaluation, 8 examinee of our college students were performed.

Table.1 shows the result of questionnaire about usability of HMD. As this table shows, it is confirmed that using HMD for a task of notebook computer repair is usefulness. However, the comments that this device give fatigue were given. This fatigue is eye fatigue. In this device, reality space objects and virtual information based on AR technique are shown. Therefore, a user must recognize several information with his eyes.

Table.2 shows the result of questionnaire about usability of button. As the good comments show, it was confirmed that user can operate the presented button intuitively. On the other hand, the recognition accuracy of the start presentation paper was low in this system. Therefore, the button can not be always presented. According to these reasons, it is considered that user felt unsure and ambivalence for button operation. In the future work, it is necessary to improve the recognition accuracy of the start presentation paper.

Table.3 shows the result of questionnaire about comparison between paper manual and the developed work support system. In this evaluation, all examinee evaluated that the developed work support system is better than paper manual. Therefore, the reasons why they selected the developed work support system are described in Table.3. As this Table shows, it is considered that this device has efficacy for beginner.

4. DISCUSSION

According to the results described in previous section, the usefulness of the developed work support system was confirmed. However, there are several problems.

The first problem is the recognition accuracy of objects. As table.2 shows, the low recognition accuracy of menu presentation paper made decreasing the usability of the system. Moreover, several parts such as screw and connector are presented by using image recognition technique in this system. Therefore, the recognition accuracy of objects is important.

It is necessary to select suitability the features of recognized objects. In this system, the feature point is used based luminance value. However, objects can be looked from several direction. Therefore, feature point is changed or disappeared according to the direction. For this problem, it is considered that the deep learning technique is usefulness. In particular, Convolutional Neural Network can select automatically the feature of object to be recognized. Therefore, high recognition accuracy of object can be expected by using object recognition technique based on Convolutional Neural Network. However, this method has demerit that it

(a) First step in CPU repairing procedure

(d) Fourth step in CPU repairing procedure

(b) Second step in CPU repairing procedure

(e) Fifth step in CPU repairing procedure

(c) Third step in CPU repairing procedure

Fig.6 : The presented repairing procedure of CPU

needs amount of training data. Fig.7 shows recognition result of laptop computer and CPU by using Convolutional Neural Network. High recognition accuracy was confirmed. However, it is problem that this technique requires the high computational power for HMD.

The second problem is setting of the presented repairing procedure. In order to construct this system, designer has to set the all procedure depending on the repair laptop computer and repair parts. Moreover, he has to consider what system should present as work support. As mentioned in the first section, there are more than 90 repair computers. Therefore, it is required a huge amount of work for constructing this system. For this problem, it is considered that the automatic generation method of repairing procedures from actual work movie is usefulness. The skeleton model of worker can be estimated by using deep learning technique. Fig.8 shows the estimation result of worker's skeleton model. This means that the time series data about worker's behavior can be obtained from movie. Several methods of time series segmentation have been proposed. Therefore, it is possible that work procedure is extracted automatically by segmenting the time series data about worker's behavior based on their methods.

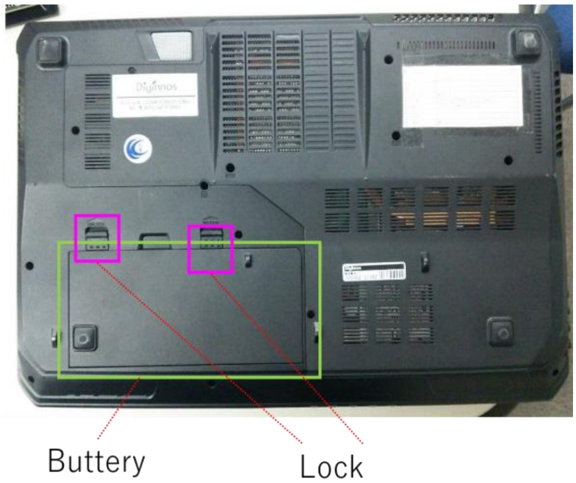


Fig.7: Recognition result of objects based on Convolutional Neural Network

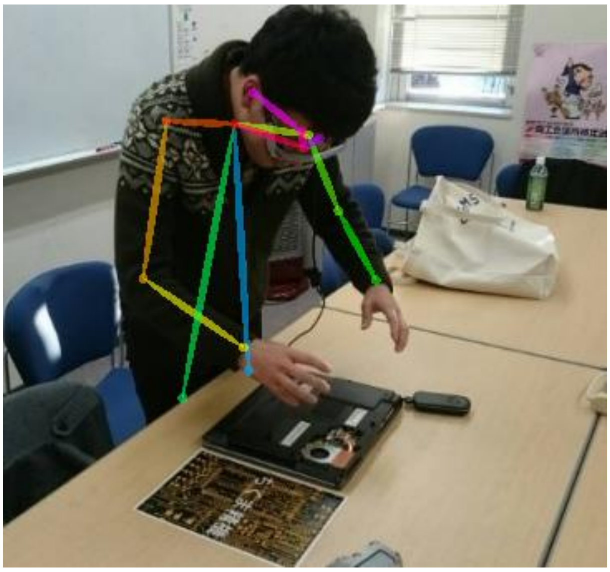


Fig.8: The result of skeleton model of worker.

Table.1 Questionnaire result about usability of HMD

Good comment
-This device is head mounted device. But, I did not feel discomfort.
- I feel that this device is convenience. This is because that user can operation this device seeing reality objects.
-There was a few delay for showing information. But I did not mind it.
Bad comment
-HMD is bad fitting.
-I feel tired for seeing the shown information and operating HMD.

Table.2 Questionnaire result about usability of button

Good comment
-It was easy to understand the presentation way.
-It was easy to operate.
Bad comment
-It took to recognition user's operation. Therefore, I felt unsure for button operation.
-I felt that false recognition will increase when the number of buttons is increase.
-The presented button was disappeared sometimes.
-It needs practice to operate smoothly.
-User can not feel pushing sense. Therefore, they can not understand which button they pushed.

Table.3 Reasons why they selected the developed work support system

Reasons
- This device is easy for beginner to understand compared on paper manual.
- I could work efficiently by the lack of wasted behavior and eye movement.
- It is easy to learn the procedure. This is because I can work with half an eye on actual objects.

5. CONCLUSION

The serious concerns of rapid aging and very low birthrate are faced in Japan. The aging increases the number of retired employee with work skill, and the declining birthrate decreases the number of employee. Therefore, securing and fostering human resources are social issues in Japan. According to these reasons, work support and proficiency support system are desired for beginner of worker. In our university, we cooperate with several companies and develop any work support system. In this paper, we developed the work support system for laptop computer repair by using AR technique and HMD. In this system, repair laptop computer and the repair parts are recognized by using image recognition technique, and the repairing procedures are presented through HMD. In this paper, the sensibility evaluation was performed. Then, the comments that it is easy to use and learn for beginner were given. According to these results, the usefulness of the developed work support system was confirmed.

For the future work, the recognition accuracy of object will be improved firstly. This is because that the usability of this system depends on the accuracy. For this problem, it is considered that the deep learning technique is usefulness. Here, high recognition accuracy of object can be expected by using object recognition technique based on Convolutional Neural Network. Secondly, the automatic detection method of the repairing produce from movie. This is because that a huge amount of work for constructing this system with several repair laptop computer and parts is required. For this problem, it is considered that the proposal of detection and segmentation method of time series data of worker's movement is desired.

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DEVELOPMENT AND EVALUATION OF THE MUSEUM SUPPORT SYSTEM USING AN AR TECHNOLOGY

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ABSTRACT
Recently, museums IT technique have been adopted in the museums as information communication method with the popularization of smart phone and tablet device. In this paper, this AR technique applies to museum. We developed the observation support system by AR technique for a Japanese museum. The developed system can tell their detailed information for the exhibited objects to visitor by AR technique. In this paper, three presentation method of the exhibited-object-information were examined. First is that the simple information is only presented such as name and genus by AR. Secondly, when the exhibited objects are recognized by the system, the screen image is switched. Then the text and movie to explain their objects are presented on the screen. Finally, the button function is added to the system. Then, the explanation about the exhibited objects is presented hierarchically by user's operation the button. In this paper, the usability and effectivity of these methods were examined.

Keywords: Observation support system, AR technique, image recognition

1. INTRODUCTION

The serious concerns of rapid aging and very low birthrate are faced in Japan. In particular, this issue is especially serious in rural areas. For this problem, a revitalization of rural areas is required. In japan, tourism is put effort into. Government set a national goal that the number of foreign travelers is 4,000 ten-millions by 2020. Fig.1 shows the number of foreign travelers to Japan. It is confirmed that the number has been increasing steadily over time. Fig.2 shows the number of travelers to Chino city in Nagano prefecture where our university is located. There are several sightseeing spots such as Sirakaba lake and Kurumaya highland in Chino city. However, it is confirmed that the number of travelers has grown at a sluggish pace. According to this reason, our university has addressed the technical resolution of this issue in cooperation with Chino city government.

Recently, museums IT technique have been adopted in the museums as information communication method with the popularization of smart phone and tablet device. In particular, AR technique has become to be widely known to general public because that the "Pokemon Go", which is game application software for smart phone, had gone viral. AR technique can add the virtual information to reality space. Therefore, it is possible to show efficient information. In this paper, this AR technique applies to museum.

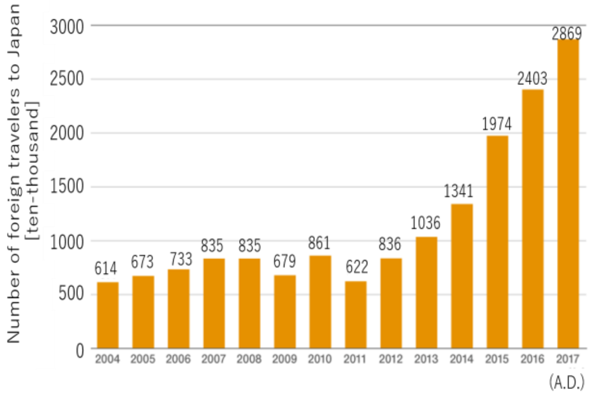

Fig.1 : Number of foreign travelers to Japan

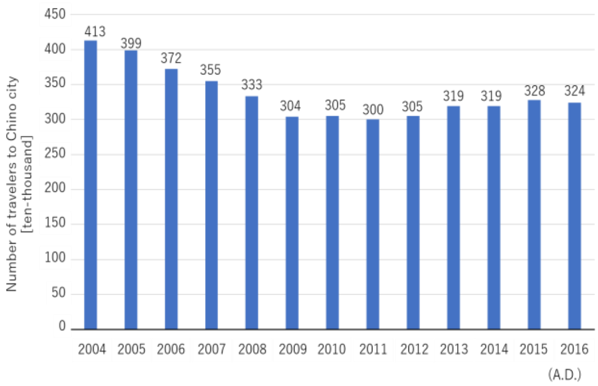

Fig.2 : Number of travelers to Chino city

The several documents and works about industrials and history and culture are exhibited to tell their information to visitor in the museum. However, there is a limit on amount of information which can be told to visitor by installation of the exhibited object and explanation board. On the other hand, it is possible to tell the detailed information about the exhibited objects to visitor by using AR technique. For example, Matthias Greiner has developed the observation support system for museum of art by using AR technique. Here, when the exhibited objects are hold the device, the

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information of the hold objects is told to visitor through the movie and sound.

We develop the observation support system by AR technique cooperatively with staff on Chino City Yatsugatake Museum in Japan. In this museum, the several documents and works about nature, culture, and history of chino city are exhibited. The developed system can tell their detailed information to visitor by AR technique. In this paper, the presentation method of the exhibited-object-information was examined, and the usability and effectivity of the developed system was examined.

2. DEVELOPMENT ENVIRONMENT

In the developed museum support system, when user hold his smart phone to the exhibited objects in museum, the explanation about them is presented to him by AR as Fig.3 shows. Table.1 and Table.2 show the development environment of developed museum support system. On the other hand, Junaio and Metaio Creator are used as AR application in this sytem. Junaio is mobile augmented reality browser. This can make easily application of augmented reality. Metaio Creator is editor for AR content by support Metaio company. This can make marker and scenario for AR content.

3. DEVELOPED SYSTEM

In this system, when user hold his smart phone to the exhibited objects, the explanation about them is presented to him by AR. It is considered that degree of interest for the exhibited objects changes depending on the presentation method of explanation about them. Therefore, we made the following three contents of the observation support system to examine the difference of degree interest for the exhibited objects.

Table.1 : Content development environment(laptop computer)

Type of equipment	HP ProBook 4230s
CPU	Intel(R)Core(TM)i3-2350M CPU@2.30GHz
Memory	4GB
OS	Windows 7 Professional

Table.2 : Support system(Smart phone-GALAXY S5)

Number of camera pixels	16-megapixel
OS	Android5.0
CPU	2.5GHz Quad Core
Memory	16GB
Transmission speed	Max of receipt : 150Mbps Max of send : 50Mbs

Fig.3 : The scene that user uses the development support system

Fig.4 shows an example of explanation-presentation by content 1. In this content, at first, an exhibited object is recognized by using image recognition technique. Then, the simple information is only presented such as name and genus by AR as Fig.4 shows. This content is made as simple content.

Next, Fig.5 shows an example of explanation-presentation by content 2. In this content, when the exhibited objects are recognized by the system, the screen image is switched. Then the text and movie to explain their objects are presented on the screen. Thus, AR technique is not used. This content is made with a goal that user can know the detail of the exhibited objects. The presentation information is consisted of three slides. And this information is presented for about 36 seconds. Moreover, the sound of river as back-ground music is played during browse

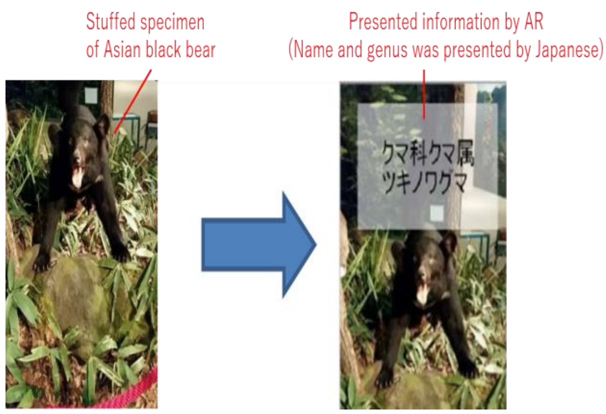

Fig.4: The presentation method of information about target object by using developed content 1.

Finally, Fig.6 shows an example of explanation-presentation by content 3. In this content, the button function is added to the system. Then, the explanation about the exhibited objects is presented hierarchically by user's operation the button. The outline of operation is described as follow.

1. When the exhibited object is recognized, the simple information is only presented.
2. When user pushes the click button, the slide described detail information about the exhibited objects is presented.
3. When user pushed the click button again, the next slide is presented.

In this content, it is possible to present the explanation about the exhibited objects depending on user's will by adding the button operation function.

Fig.5 : Presentation method of information about target object by using content2.

4. EXPERIMENT

In the experiment, the usability and effectivity of the developed system for the above described three contents were examined. This experiment was performed in the department that the stuffed specimens of animals of Yatsugatake area in Chino city in Japan are set. In this system, the explanations of the three stuffed specimens of animals, Asian black bear, Japanese duck-billed platypus, and Japanese Honsyu deer, can be presented.

The number of examinee was 7. They were 22 years old in our university students. At first, the examinee observed the museum by using the developed system. Then, the questionnaire survey was carried out. In this questionnaire, the readability and usability of the developed system are evaluated on scale of 1 to 5.

Fig.7 shows the result of questionnaire for readability of the developed system. Here, the result is shown in histogram for each evaluation value. It is confirmed that high evaluation is given from examinee wholly. In particular, content 2 got high evaluation. In this content, detail information is presented as slides sequence. Their information is presented even if user hold out smart phone from the exhibited objects after the objects are recognized. Moreover, this content is not necessary to operation the system. Therefore, it is easy to use. Fig.8 shows the result of questionnaire for usability of the developed system. It was confirmed that high evaluation was received for all contents.

Fig.6 : Presentation method of information about target object by using content3.

Table.3 shows the comments from examinees. As this results shows, the comments that this system has learning and enjoyable effect for user were given. Therefore, it was confirmed that it is effective to use our developed museum support system. However, any bad comments were given. The pointed stability of this system is depended on the recognition accuracy of the exhibited objects. In this system, this recognition was conducted by image recognition technique. Therefore, it is considered that the future work is the improvement of the recognition accuracy of the exhibited objects. For the presented sentence, it is useful to present the information by sound.

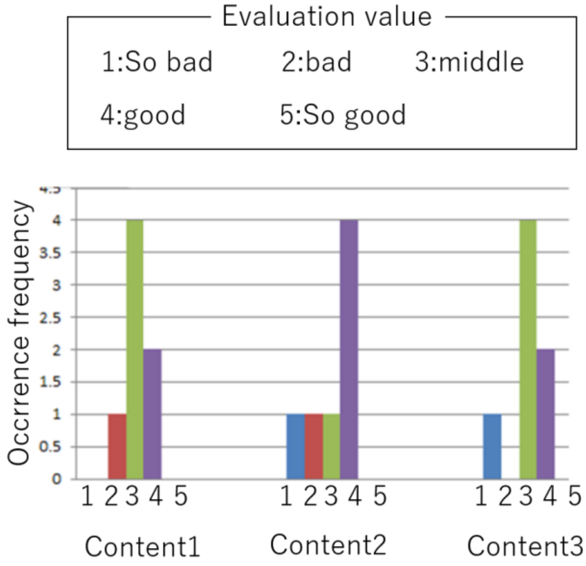

Fig.7 : Result of the questionnaire for readability

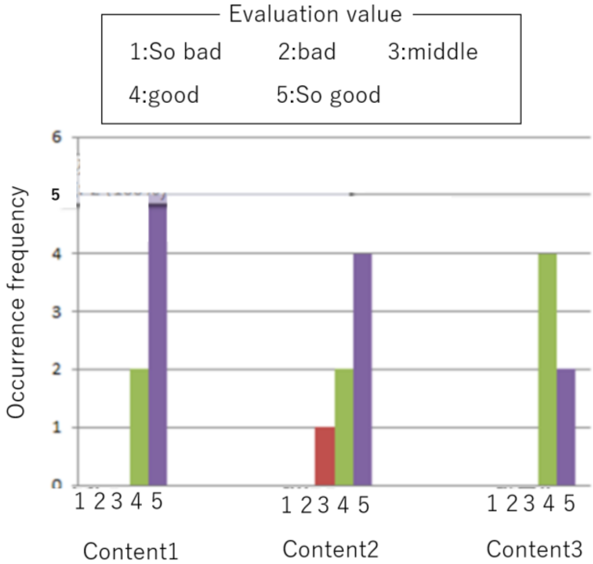

Fig.8 : Result of the questionnaire for usability

Table.3 : Comments from examinee

Good comments
I could understand about the exhibited animals in detail.
I could learn about the targets in an enjoyable format in this system.
It is easy to see the sentence and slide.
This system was attractive. This is because that user can select the presented information about the exhibited objects(content 3).
Bad comments
The presentation of information is not stable.
I do not want to read a lot of sentence.

5. CONCLUTION

Our country puts effort into tourism. However, the number of travelers to Chino city in Nagano prefecture where our university is located has grown at a sluggish pace. According to this reason, our university has addressed the technical resolution of this issue in cooperation with Chino city government.

In this paper, the observation support system of museum was developed, and the readability and usability of the developed system were evaluated. In the experiment, three contents with different presentation method were evaluated. As the result of experiment, high evaluation was received for all contents. Therefore, it was confirmed that it is effective to use AR technique. However, the different of the effect for each content was not confirmed. It is considered that this effect is depended on amount of explanation-presentation and degree of user's interest. Therefore, it needs these evaluations as future work.

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THE IMPACT OF NEW TECHNOLOGIES IN DESIGN EDUCATION

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Conference topic (domain). - Technological, psychological and artistic view of integrating VR, AR, and MR objects with real-world objects and environments

Contribution. - Original Paper.

ABSTRACT

Technology has made profound changes even in education. New educational trends include technology to facilitate the teaching-learning process. The design aims to develop solutions for the needs of the human being. The use of technology allows these solutions to be carried out effectively.

Digital technology has been integrated into visual communication and new digital techniques have emerged for education. It is becoming easier to acquire software to create 2 dimensional (2D) and 3 dimensional (3D) representations. However, this does not mean that by using pure technology effective designs are made, since it is essential to have knowledge of elements and principles of architecture and design in order to make a useful design.

The objective of this article is to demonstrate that an educational design course equipped with digital technologies including Augmented Reality (AR), Virtual Reality (VR) and 3D printing can be proposed for the second-semester students of architecture career to help them develop a better understanding of how different designs relate to the needs of the users.

Keywords: Spatial visualization and design, Virtual Reality, Augmented Reality, 3D printing.

1. INTRODUCTION

Fonseca et al. (2012) state that application of new visualization techniques provides a better spatial understanding. The use of new technologies in education permits a greater influence on learning. Due to the globalization of the computers, the relatively reasonable cost of internet and the availability of numerous applications, the use of technologies in education has become considerably popular. Hsin-Kai Wu at al. (2012) mention that new methods of teaching are emerging due to the application of virtual and/or augmented reality approaches. The simultaneity of virtual and real environments helps students to visualize complex structures in the virtual spaces.

The current article describes the results obtained from the implementation of new technologies such as Virtual Reality (VR), Augmented Reality (AR), and 3D printing for designing structures that would address the needs of the users in a much effective manner. This work was carried out with students in the second semester of the Architecture and Design career who have attended the Design Fundamentals II course. The results of this project are presented with digital tools of Virtual Reality, Augmented Reality and 3D printing.

The structure of this work is organized in the following way: (*i*) students define the importance of the integration of interactive systems in a design process.; (*ii*) Methodology would be explained with an emphasis on the importance of using a process in a spatial design project; (*iii*) developed proposal shows how digital systems are integrated into a design process and are applied in spatial design, (*iv*) results and discussion explains the obtained data and the impact of VR, AR, and 3D printing on the development of the project; and (*v*) conclusions justify the obtained data in the process of the work.

2. PREVIOUS WORK

The current developments in digital technology are introducing reformations in education to address the social changes and needs. As a result of visual thinking and imagination, gathered information by mind recreates one's own visual representation. Therefore, it is essential to improve the visual thinking process of students. In that regard, the application of VR, AR, and 3D printing allows the spatial design to be more dynamic hence creating various functional structures by the designers.

In the area of architecture and design, representation methods are continuously evolving aimed to overcome the barriers of space and time. Conceptualization of the design is a very important process for the development of a project; it integrates principles and elements that any design should contain. The design process is also a way to make the spatial design effective and attractive; a process in which organization and implementation of the visual elements for a creative design take place. It is, therefore, of utmost importance for such representation techniques to provide the final projects within the physical environments they will be built to give a better understanding of personalization options and necessary alterations for the final design. VR and AR hand in hand with 3D printing could provide with such possibility for the designers.

2.1. The effect of spatial understanding on the design

Francis D. K. Ching (2015) states "space constantly encompasses our being." He also tells us "as space begins to be captured, enclosed, molded, and organized by the elements of mass, architecture comes into being." In another word, based on the fundamentals of design, our observation and understanding of objects' shapes vary depending on our interpretation of the components that form the spatial design.

Following Ching's methodology, all spatial arrangements are considered positive or negative elements that create an inseparable reality. Therefore, by visualizing these forms, the students would develop spatial skills that allow them to subsequently develop personal spatial visualization.

2.2. Conceptual and digital process in design

The effect of spatial understanding Saffer et al. (2010) state that an interactive design is more than aligning technologies with human activities and needs. One of the latest developments in this area is spatial exploration under the VR and the AR domains. The interest in implementing space design and interactive design is rapidly growing.

A number of new design concepts were established covering a range of structures from small cities, and street furniture, to the disposition of public signs and digital banners. Architects and designers have begun to use new technologies to create designs that meet the requirements when environment, productivity and information sources are concerned.

Interactive design provides new bases for thinking in different manners including: (i) cognitive thinking that is used to structure and organize the spatial representations; (ii) technological mindset that prepares designers to create novel designs that are benefited from the available technological advancements; and (iii) social understanding to establish a strong connection between the designs and people who will use the structures taking their culture and religious background, among others, into account. Furthermore, Saffer et al. (2010) state that the following capabilities are developed as a result of the interactive design and use of available technology that can assist the designers:

- Creativity
- Problem identification
- Effective use of scale, proportion, and composition
- Decision-making
- Growth and improvement of technical profile

Considering these principles, we begin to develop a methodology that can carry out the integration of new technologies in the teaching of spatial design aimed for second-semester students of the Design and Architecture career at the Tecnológico de Monterrey, Monterrey Campus.

3. METHODOLOGY

3.1. Spatial design education with digital technologies

From forms to their functions, VR, AR, and 3D printing are the technologies that offer great advances in the production of industrial prototypes in respect to their spatial representation. A great advantage of applying such techniques is identifying and avoiding possible errors in the designs at the early stages of the design process. This, in turn, results in reducing the number of physical prototypes thus saving the time and the resources for companies. These techniques are valuable tools that improve and accelerate many industrial processes.

Ma et al. (2011) consider VR and AR as virtual prototyping technologies as such techniques unfold the intended design in a 3D environment in which the designer him/herself can highly interact with the prototype hence manipulating it in a realistic manner. While AR enriches the design by employing a virtual object that permits the designers to locate their structures in the actual time and place and to develop a better perspective. The powerful 3D printing technique assists VR and AR further in reproducing a scaled model of the design made at different stages of the project. This allows a comprehensive understanding of the possible errors or additional considerations as the designer can assess the design from its first conceptualized forms to the highly detailed presentation models.

Howeidy et al. (2017) describe that 3D printing provides designers with a better visualization of any project. It is a rapid technique in comparison to the traditional methods and is highly reproducible for further duplications. For the mentioned reason, 3D printing accompanied by VR and AR create a powerful set of tools that can be applied for spatial understanding and design.

4. PROPOSAL

4.1. Spatial visualization through augmented reality and virtual reality

Space is a vital concept in 3D designs. A teacher can play a great role in developing spatial understanding in students by designing tools that can assist the student in improving their sense of space. Due to the time spent in front of the digital screen, students have not fully developed their sense of dimension. This is teachers task to teach students to observe their surroundings and to explore methods that would allow them to develop their sense of dimension and space. Careful observation of the world also allows imagination development and subsequently enhances the cognitive functions to generate images that, in turn, might even break the limits of reality. This is also named as spatial intelligence, the ability that allows individuals to conceive and to visualize objects in their different faces hence enabling the designers to transform such objects into uniquely different structures. Developing spatial skills allow students to create constructive representations. The project in the current study was performed in two phases that are described in the following section.

4.2. Exploration phase

This phase of the project consists of exploring the spatial theory of Bruno Zevi (1999) considering space as an essential element in architectural design. The challenge in this phase is to bring together all the students the same anti-classical code through the seven invariants with which the author expresses a language of modern architecture of the twentieth century.

Table 1: Invariants of Bruno Zevi's design.

No.	Invariants	Process
1	The catalog as a project methodology	Starting from scratch by unfollowing previous models
2	Asymmetries and dissonances	No use of parallel lines and symmetries
3	Antithetic tridimensionality of perspective	Considering world as geometrized with no curves, deviations
4	Syntax of the quadripartite decomposition	Exceeding the limits between exterior and interior spaces
5	Cantilevered structures, shells and membranes	Combining technique with expression while taking advantage from the design construction
6	Temporality of space	Use of spatiality such as length, width, height that surround the space and the empty space
7	Reitegration building-city-territory	Merging buildings and cities in a urbatectura by integration of all concepts

Modern architectures are becoming more and more plastic-made. There are new materials and technical means for design available for the architecture that encourages the development of plastic structures including organic architecture. Architecture and sculpture both possess dimensional characters; a sculpture satisfies the physical, social and cultural needs within the environment. Sabouri et al. (2015) define urban sculpture "as a 3D volume that has an expression of artistic form and can be seen in different aspects. Its function is to create a sense of identity in an open space and be appreciated by people of different cultures." In another perspective and for Shahhosseini et al., (2015) sculpture is a mean for human and social expression that signifies morals including identity or tradition. Therefore, the theme for the initial phase of the project was to encourage students to design an urban sculpture.

After establishing the theme and the theoretical framework, the sketching process began in SketchUp, turning this representation into a non-immersive VR. One of the advantages of this software was ease of access is (it is freely available or its latest version, SketchUp Pro, has reasonable economic cost). Also, this software is user-friendly and different formats of the images can be exported for AR or 3D printing applications. Yet another advantage of this software is that due to its ease of operation and user friendliness, it generates confidence and interest in students to develop more complex and meaningful designs. Among the proposals that contributed to this project, few were chosen to be demonstrated it in this article.

4.2.1. Proposals in sketchup (non inmersive VR)

In this exercise, through the theory of Bruno Zevi regarding the anti-classical code of architectural design, we began to work on the concept that the student wanted to convey. In this design, the basic elements of visual communication, as well as the message behind the design, were intended to be transmitted.

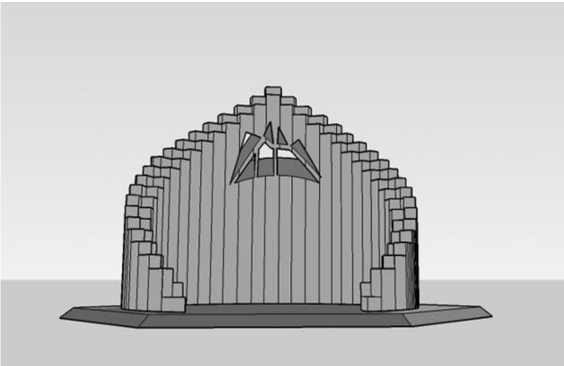

Figure 1: Proposal of urban sculpture in SketchUp by Gustavo Hernández Aranda

In this example designed by the student, Gustavo Hernández Aranda, SketchUp design (Fig. 1) represents the city of Monterrey located in the state of Nuevo Leon in Mexico and the evolution of the city through the industrial and commercial progression of the state.

Known as Sultana del Norte and its key identity, the famous Cerro de la Silla, is shown in the hollowed format in the structure so that the light would be reflected through the design and would project the iconic mountain of Monterrey.

In this second proposal (Fig. 2), the student, Luis Gilberto Rodríguez Sustaita, designs a sculpture that includes the union of individuals forming a harmonious whole characterized by its dynamism, thus combining the invariant of symmetry and asymmetry. The pattern of the elements can be observed to have accommodated a dynamic structure. This proposal tries to express that the viewers can also be part of this sculpture becoming not just passive viewers but active elements in its dynamism.

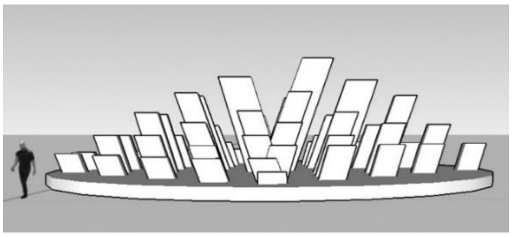

Figure 2: Proposal of urban sculpture in SketchUp by Luis Gilberto Rodríguez Sustaita

4.2.2. Proposals in AR

The design proposals in AR were made with the SketchUp software exporting with the Augment format. This conversation was done through a phone application. Due to its interaction facility, it was very practical for the students to use and to locate the proposal on a real site. The software was downloaded free of charge from Google. The software allowed the students to visualize their design in a more efficient manner by placing them in a real space. For example, in Fig. 3, the student places his design in the Technological Park located at the streets of Philosophers and Chemists of Technology colony in the city of Monterrey, Nuevo León, Mexico. This location is near the Monterrey Campus.

Figure 3: Representation with Augmented Reality by Gustavo Hernández Aranda

As another example made in AR, the student shows his design in the esplanade of the Museum of Mexican History next to the fountain (Fig. 4). The location is on the side of the government palace at Dr. José Ma. Coss 445, at the Macroplaza de Monterrey, N.L., Mexico.

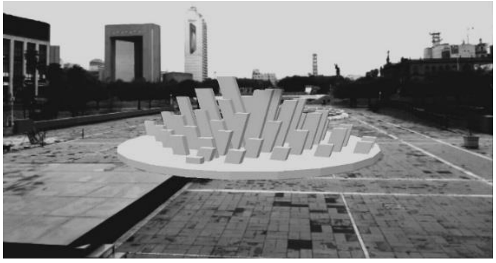

Figure 4: Representation with Augmented Reality by Luis Gilberto Rodríguez Sustaita

4.2.3. Proposals after 3D printing

And finally, a scaled model was made in 3D printing to demonstrate the real dimensions of each proposal taking into account the proposed environment. In this model, the student Gustavo Aranda Hernandez confirms that the proportions of the monument are in accordance with the expectation raised through the creative process.

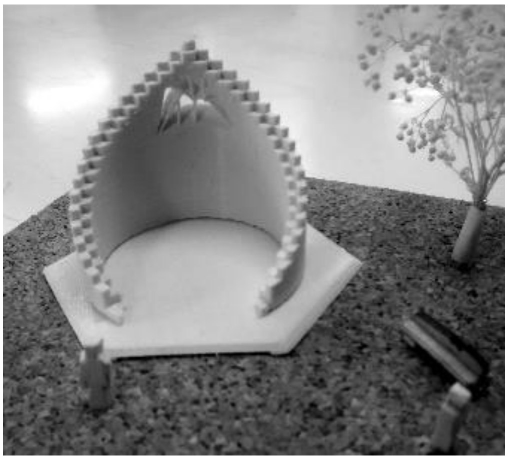

Figure 5: Prototype fabricated by Gustavo Hernández Aranda

In another scaled model, the student, Luis Gilberto Rodriguez Sustaita, represents the location of his sculpture proving that it could be potentially located on the side of the fountain of the museum esplanade (Fig. 6).

4.3. Design of spiritual spaces

It might be the case that the students start a design project without basic principles that support their internal structure. Franco Fonatti (1988) is a writer who demonstrates that "art is equated with sciences for the acquisition of knowledge." The author claims that a human being over time changes his psyche, and his rational and emotional approach hence modifying his environment, architecture as well as the evaluation of its contents. Based upon the idea of the author "the form will be studied in a receptive sense with the help of an analytical spirit for the proposal of ideas and the creation of representations." The confirmation that a component is should not be sufficient for a designer. It is essential to know why this component is, what effects it may or may not produce and from where such effects are originated. According to his theory, all the information must be evaluated, categorized and ordered in a methodological manner. These concepts are what create the form. Therefore, for Fonatti the form explains the qualitative formulation of a component (whether visual or spatial), independent and complete, which can only be imagined.

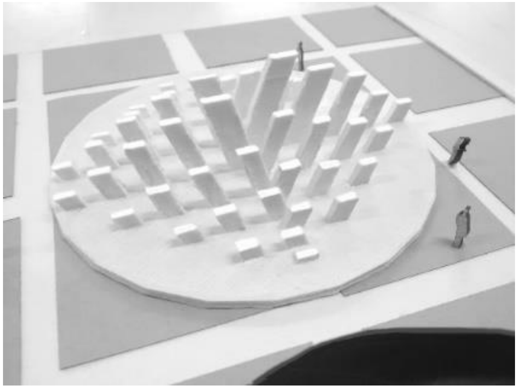

Figure 6: Model by Luis Gilberto Rodríguez Sustaita

The design of spiritual spaces is not unintentional. The man has always looked for a space for contemplation. As a part of this project, students designed places considered the human needs beyond the needs of the physical world, arriving at the conclusion that in design there are no limits. In this project, the designed space was intended to contemplate different levels of meaning. The idea of space must be oriented towards the organization of the environment between outer space and inner space. The exterior space was designed according to the art of building construction, while the interior space was established based upon the man and his spiritual needs.

The two spaces are interconnected and the perception of them requires a visual transition that creates a line of a union. For example, the threshold of a door is a line of union between the two mentioned spaces with visual, cultural, and social signs and symbols. Current generation lives immersed in various technologies and often forgetting about the essence of humanity. Through this project, the students also learn that technologies are not always involved in numbers and calculations, but can play significant roles in generating sensory and symbolic functions.

4.3.1. Proposals for spritual buildings

When carrying out this project, the students were encouraged to identify places that reflect human beings and their needs including those of cultural, spiritual, and social. The students decided to venture into religious buildings including churches. Nonetheless, students have faced a certain degree of disconcerting, as the project has challenged them to discern the laws of visual communication in designs that were meant to symbolize man's interaction with sublime concepts. Therefore, the students began to work on the design of a place of worship in order to create appropriate spaces for introspection and meditation. Many cultures have had great resources for the construction of magnificent temples and religious monuments, which have provided architectural styles throughout history.

The use of signs and symbols were common to all these constructions. Many such signs were evolved throughout the centuries. For instance, the use of natural light, as a transcendental element, played a vital role in the construction of Christian churches. In natural light, designers can symbolize the transcendence of man and the divine presence in a religious place. In the offered course subject to this study, there were several strategies to incorporate interactive design with the religious concepts for creating spaces that can address the spiritual needs of individuals. In the following section, some of them are introduced.

Design #1:

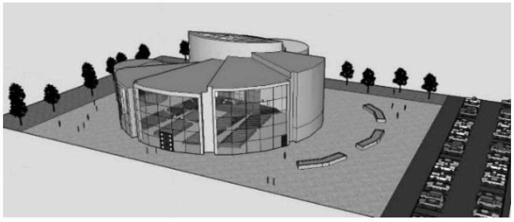

Figure 7: Representation of facade in SketchUp by Brenda Anette Cuéllar Villaseñor

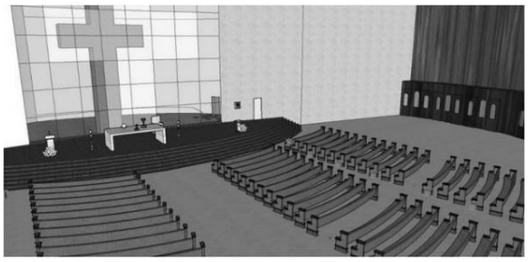

Figure 8: Interior design of the church in SketchUp by Brenda Anette Cuéllar Villaseñor

Design #2:

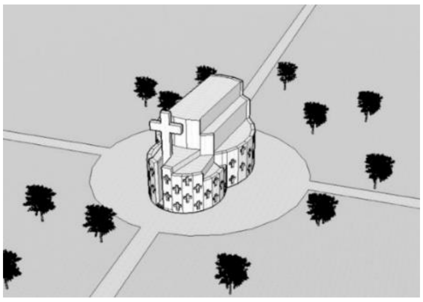

Figure 9: Representation of facade in SketchUp by Kevin Mauricio Pacheco Rendón

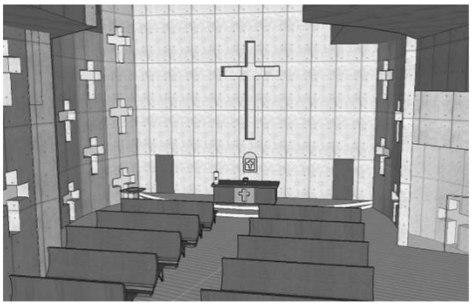

Figure 10: Interior design in SketchUp by Kevin Mauricio Pacheco Rendón

4.3.2. Presentation of scaled models after 3d printing

3D architectural models of these designs were developed at the final stage of this project. These models not only familiarized students with the importance of scale, proportion, space, form, and structure but also allowed them to assess their designs in their actual shapes.

Design#1:

Figure 11: 3D printed scaled model by Brenda Anette Cuéllar Villaseñor

Design#2:

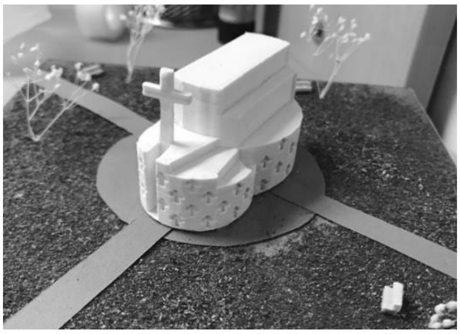

Figure 12: 3D printed scales model by Kevin Mauricio Pacheco Rendón

5. RESULTS AND DISCUSSION

The technologies including AR, non-immersive VR, and 3D printing allowed students and the supervisors to carry out the projects in a pleasant environment while allowing students to learn about different aspects of the design. The themes of urban sculptures and design of spiritual spaces helped students to locate the prototypes in the in spaces that mimicked the actual environment in which the building would be located.

A design is a creative act that meets a need from many needs we human being may have including those of physical, psychological, social, spiritual, and cultural. Therefore, the students of design and architecture have to be equipped with various resources including technological means, and creative thinking that allows them to produce functional designs to address not only the basic needs but also those of deeper levels. The design of the urban sculpture presented in this project helped students to explore the forms and allowed them to change classical theories by creating novel designs using AR, VR, and 3D Printing.

The second phase of this process is to direct the design to a particular cultural system. This project is represented by the techniques of non-immersive Virtual Reality and 3D printing. The following section presents the results of these projects when using non-immersive VR, AR, and 3D printing techniques.

5.1. Urban sculpture

A sculpture is a solid, 3D body that occupies a space. In this project, we have used the concept of urban sculptures to improve the design skills of students. Furthermore, by 3D printing the sculptures and locating them into the mimicked spaces, the students have reflected upon a value that they have identified in their design to address a human need in the context of spirituality. During the exercise, a series of observations were made regarding the reactions and performance of students when using AR, VR, and 3D printing. Table 1 summarizes some of these observations.

Table 1: Results of the observations made in the classroom when conducting the project

100%	The students enjoyed using AR and 3D printing and felt happy with the results of the project
100%	The students have visualized 3D spaces with applied digital techniques
100%	The average performance from the design process to the prototype fabrication was enhanced
90%	The visualization of the design process was improved.
100%	The students enjoyed the projects
80%	These digital techniques were easy to use
80%	The projects improved spatial visualization of the students
95%	The presentation of projects by students were improved
100%	The students found the projects to be pleasant activities
100%	They learned all the concepts in a much comprehensive manner

The observations made throughout the semester have shown that the students have made a better progress in a

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much shorter time. The fact that the student could see the prototypes in their physical presence helped them generated not only a better understanding of the concepts but also resulted in students excitement and subsequent involvement. The students have also learned that powerful digital technologies such as AR, VR, and 3D printing bring pleasure to the design process while being effective tools in interactive design.

5.2. Design of spiritual spaces

The human being is in constant evolution. His knowledge and understanding of the surroundings have changed with the help of technological tools. On the other hand, visual communication is crucial to understand signs and symbols, which are described as the origins of each culture. Various experiences of man and his conception of space and time unfold every day. Religious architecture has also evolved in the context of space and time, becoming a cultural sign and an identity to diverse cultural groups. In this project, space is the main element to be considered in the design. Space serves as a channel to connect man to higher qualities and to his inner self.

The current project allowed the students to consider the significance of the space in their design not only in its physical context but when it concerns spiritual needs. A number of observations were made throughout this project regarding the reactions and performance of students when using AR, VR, and 3D printing. Table 2 summarizes some of these observations.

Table 2: Observations on the performance of the students when conducting the projects

100%	The visualization was improved by using SketchUp (non-immersive VR)
90%	The creative process was faster than expected
100%	The students have shown enthusiasm
100%	The creative process felt more fun when using SketchUp and 3D printing
100%	The students were encouraged when working with novel and uncommon forms
100%	The students took better responsibility for their projects
100%	The students learned the design theory better
100%	Providing feedbacks was easier
100%	The students were very happy with the results

During the project, the students expressed satisfaction to have taken the course. They also have confirmed that they have learned the content in a much more comprehensive manner that without applying digital technologies. In general, the students enjoyed the project and had a pleasant experience throughout the semester.

6. CONCLUSIONS

In design and architecture, there are various elements to be considered before aiming for a specific design. Apart from the basic physical needs that have to be taken into account, a designer must also be aware of other human needs including those of cultural, social, spiritual, and individual. Due to recent advances in software, there are increasingly more sophisticated and commercialized technologies that are becoming very popular. For students who start their professional career, it is important to acquire the software in an accessible way.

In the current project, we have combined the fundamentals of design with important contents such as clear understanding of the space with digital technologies such as virtual reality, augmented reality and 3D printing to help the student develop their skills and interest in designing buildings that address a multitude of needs. These projects allowed the students to see and assess their design in the virtual and real world and to identify the crucial elements of the design in a much detailed manner. The results of this project also allowed students to have a highly interactive working environment that, in turn, brought them great satisfaction.

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ALTERNATIVES GENERATION VIA DATA ANALYTICS FOR DECISION MAKING USING VR

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ABSTRACT
Advances in education, economy, and administration in the areas of science and technology as well as social science disciplines have established a great importance worldwide thus necessity for developing the knowledge-based economies. Due to globalization, the complexity in manufacturing and elaborated processes is continuously increasing. It is, therefore, crucial to develop core business topics related to efficiency and evaluation that incorporate emerging technologies in such areas. Virtual Reality (VR) is known as a computer-generated simulation of three-dimensional (3D) environments that can produce seemingly real images and introduce physical ways of interacting with individuals. VR has become increasingly important in reaching data visualisation for generation of alternative scenarios. Combined with business analytics, VR can offer quantitative models for decision making applied to optimize production and administration procedures. In this study, a case is developed to deploy use of data exploitation and VR for alternatives generation in the decision-making processes.

Keywords: Alternatives generation, Business analytics, Data visualisation for decision making, Virtual Reality

1. INTRODUCTION

Modernization and globalization in many aspects of life have led to the swift expansion of numerous fields, further demanding experts in different enterprises to skilfully control their resources, to benefit from new advantages, to be updated and to be fully aware of future trends. While an organized customer dataset is growing in size and scope, it is unstructured data that is emerging as an even larger and precious source for various industrial fields.

Nowadays, investment and financial advisors, relationship managers, loan officers and other personnel are required to have access to detailed product and service data to make wise decisions.

According to Turner et al. (2013), the demand for more advanced data visualisation and analytics competences rises with the application of massive data. Datasets are expanding too large for business or data analysts to assess and investigate them with their traditional data mining tools. There are advanced techniques designed to analyse text in its natural state. For instance, some analytics consist of the ability to interpret and understand the nuances of language including slangs, sentiments, and/or intentions. Such tools are typically used to relate to the costumers opinion hence understanding needs of individuals while improving the overall customers experience. Other tools are capable of analysing even more complex categories of unstructured data including geospatial location data, voice data, videos, or streaming data.

Data Analytics (DA) is widely applied in various industries to enable organizations to make more-informed business-related decisions and to confirm or disprove on-going models or hypotheses for each business case. DA is particularly promising for financial departments of different industries, as massive sources of information are becoming great assets. With every transaction another row of information is added to the pool of data, which raises the question of: how to harvest, control, and benefit from such load of information in order to obtain competitive advantages?

A main task is to identify the processes that could directly add value to the business. It is of great importance to align the requirements of business users with the chosen information technology (IT) and its necessary implementations. A careful roadmap outlines what organizations want to achieve with big data (BD) to ensure strategic acquisition and well-defined use of resources. Use of technology allows business to identify key challenges involved, strategies through which those challenges can be addressed, and the business processes that define how tools, hardware, software and information could facilitate achieving the business objectives.

This research describes some aspects of DA including the process of examining datasets in order to draw conclusions from the information with the help of computerized systems and emergent technologies. The objective of this work is to generate alternatives to feed a model for optimization of some production and administration processes for core business by using VR and DA technologies. The structure of this work intends to provide a brief explanation for decision making paradigm via modelling of filtered and classified data in order to generate alternatives that may lead to improve use of resources.

2. PREVIOUS WORK

As a result of accelerated technological advancement it is convenient to establish new production and communication practices. Businessmen benefit from new tools and ways of executing their tasks. They take advantage from growing virtual environments and computerized systems. Therefore, it is estimated that decision-making processes significantly improve with technology advancements. McAfee and Brynjolfsson (2012) confirm that for managing various data sources and speed of information procurement, many corporations would need to acquire DA expertise to enhance their performances.

Turner et al. (2013) outline that companies must leverage their information resources to acquire a broad knowledge about markets, customers, channels, products, regulations, competitors, suppliers, and employees among others. Financial departments could estimates the values by managing and analysing the accumulative volume, velocity and diversity of existing data, and by incorporating the right proficiencies and tools in place to better relate to their operations and customers as well as the marketplace. For example, several businesses apply customer opinions extracted from BD to design their marketing missions, conduct campaigns, and attract sales leads across all channels, product lines, and customer sections. This can improve business-customer relationship while reducing the operation cost and increasing revenues. Other firms apply data integration across stations to provide high-quality and consistent user experience, enhance client satisfaction while decreasing the costs.

According to Davenport (2014) and Chen et al. (2012), BD has become a common term representing the fact that generated and available data today is enormous in variety, volume, and velocity. This massive ocean of data, nonetheless, must be used according to the visions of data analyser and the intended applications. Equipped with DA specialists who can convey such perceptions, current managers are expected to perform better at decision-making and to generate creative ideas for product development, pricing adjustment, and improve customer satisfaction. The added value to the corporations, in turn, can bring more opportune, informed, and relevant interactions while improving the primary operations.

Some DA methodologies include exploratory data analysis (EDA), which aims to find patterns and relationships amongst data. Confirmatory data analysis (CDA), on the other hand, applies statistical practices to determine whether hypotheses about a dataset were true or false. EDA is frequently referred to as detective task, while CDA portrays work of a jury; a distinction, which was first, established by Tukey (1977).

Use of DA in processes assisted by technology to generate diverse alternatives for the purpose of creating models for decision making are the centre of attention of the business and corporation. In this study, we propose a strategy aligned with this topic.

3. METHODOLOGY

Predictive analytics are used in this work, which seeks to predict customer behaviour, equipment failures, and other possible events. Several analytical models using predictive modelling tools or other related analytics software such as MINITAB, SPSS, WATSON and QM for Windows, and programming languages such as Python, Scala, R and SQL are available. Such models are initially run against a partial dataset to examine its accuracy. The model is then revised and tested again, a process known as "training" the model that continues until it functions as intended. Finally, it is run in production mode against the full dataset. This step is performed to address specific information need or tested in a continuous manner as the dataset is being updated.

Dhar (2013) explains that analytics methods used in DA contain path and optimization modelling, which from the business praxis point of view, include various significant quantitative models such as Decision Models and Trees, Queuing Models, Markov Models and Simulation Models. This work develops a decision-making model under Risk and outlines a case study of a Decision Model for a Risky VR Aided Assembly.

4. PROPOSAL

Companies engaged in DA activities apply a strong set of analytics strategies including basic queries, predictive modelling, optimization, and simulations. According to Turner et al. (2013), however, it is also crucial to apply fundamental capabilities of text analytics and data visualisation in order to successfully analyse the data. Therefore, firms could potentially concentrate on specific skills that will increase their ability to analyse unstructured datasets and visually represent them to be more accessible to executives.

Aguilera (2017) proposed a design that recognizes lines cognitive for understanding the visual perception of text by developing spatial skills using VR and Augmented Reality (AR). An advantage of this strategy is that such DA activities could reduce costs and increase revenues, a duality that can improve different business cases and balance essential investments. A successful data solution primarily classifies the business needs, and then includes a plan for infrastructure, data sources,

processes, and necessary services that support the needs. By incorporating interactive design concept in the task of disciplines including Managerial Economics, Business Administration and Industrial (and Visual) Design, the effective and functional process designs could be executed with higher order.
Following these strategies, it is conceivable to have a Quantitative Model (as Figure 1 suggests) that is fed by revised data (i.e. purified, analysed, and classified) to further expand the model. Such Decision Model under Risk can manage a business imbroglio case addressing challenges of strategic decisions and solving problems of planning, optimizing and evaluating of technology-based processes.

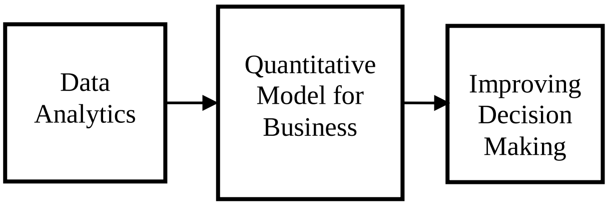

Figure 1: Quantitative Model fed by Revised Data

Stevenson (2018) introduced seven factors in process selection and system design including forecasting, product and service design, technological change, capacity planning, facilities and equipment, layout and work design, from which several factors can greatly contribute to developing a business model.
Olshannikova et al. (2015) discuss about the capabilities of AR and VR that can be applied to data visualisation.
Also, Fan et al. (2009) offer a virtual assembly setting for product design assessment and workplace planning with following previous visualisation focused on process productivity and performance. To foster the model in Figure 2, data are generated via observation, inspection, estimation, measurement, or revision (e.g. filtering, classifying, and arranging) and to design (plan) practicable scenarios or states by evolving an appropriate VR Aided assembly.

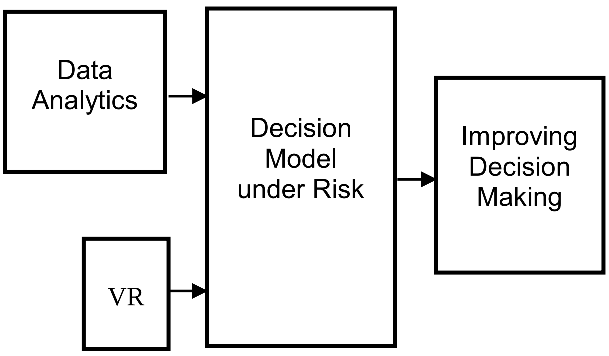

Figure 2: Decision Model under Risk fed by DA and VR

This assembly, supported by technology, may have varied virtual operation environments based upon each relevant company case. The impact of VR technology into the assembly process can be demonstrated through the fact that a short assembly time could be achieved using assembly aided by VR. Table 1 presents a long assembly time, which is obtained by traditional assembly method.

5. CASE STUDY

Logically, an example can deploy the convenient use of this data exploitation to modify relevant elements (or parameter values) into a model and actions that support better decisions. A business problem (decision making under risk) is presented and being solved through a decision theory model.
A difficult business problem is outlined by displaying a decision (payoff) table outlining two payoffs ($) for each possible alternative. This arrangement mathematically constitutes a matrix of 3 × 3 that illustrates a typical Decision Model under Risk (Table 1).

Table 1: Payoff Matrix for Decision under Risk

State of Nature: Assembly time		
Shop Alternatives	Short	Long
1. Big Shop	200	-180
2. Small Shop	100	-20
3. Do Nothing	0	0
Probabilities		
probability data 1	0.6	0.4
probability data 2	0.4	0.6
probability data 3	0.5	0.5

For three alternatives, two states of nature (Short and Long assembly time) were included, and there were three probability data sets to address this quantitative business model (arrangement) under risk.
A payoff is the obtained specific profit (or benefit) when an alternative is selected, and an assembly time (state) occurs in the production area. For example when Big Shop alternative is chosen, and Short time of assembly is considered as the choice, the profit is 200$. As another example, Small Shop in Long assembly time could result in negative profit for the business as Table 1 suggests, while the same size of shop in the short amount of time can be profitable (100$).

6. RESULTS AND DISCUSSION

By using probability datasets, it is viable to construct the Filtered Payoff Matrix for Decision making under Risk. In this case offered analogous arrangement has only one row of average (Av.) probability for each state of nature (probabilities in Table 2). As it can be seen from Table 2, in Short time the Av. Probability is 0.5 = (0.6+0.4+0.5)/3 while in Long time the Av. probability can occupy the same amount (0.5 = (0.4+0.6+0.5)/3). This is while other elements remain unchanged (see Table 2).

Table 2: Filtered Payoff Matrix for Decision under Risk

State of Nature: Assembly time		
Shop Alternatives	Short	Long
1. Big Shop	200	-180
2. Small Shop	100	-20
3. Do Nothing	0	0
Av. Probability	0.5	0.5

This average probability for each state of nature (assembly time type) can dynamically change each month (or each week) so that it may be conceivable to generate various alternatives via DA to support models for decision making.

Correspondingly, by establishing a VR aided assembly, diverse virtual operation environments can be developed to generate a third state of nature (Table 3, 3rd column of the array). Table 3 represents the three Av. probabilities calculations using DA for the corresponding states. This Table shows different average probability values for each case.

Table 3: Payoff Array for a Risky VR Aided Assembly

State of Nature: Assembly time			
Shop Alternatives	Short (state 1)	Regular (state 2)	Long (state 3)
1. Big Shop	200	10	-180
2. Small Shop	100	40	-20
3. Do Nothing	0	0	0
Av. probability	0.4	0.2	0.4

It is noteworthy that according to Decision Theory a better model for addressing these cases can be developed if Minimum Expected Regret criterion is added to the analysis. Subsequently, using QM for Windows©, three Expected Regret values (78, 48 and 88) were obtained for Alternatives 1, 2, and 3, respectively. This case analysis recommended that the best decision was to select Alternative 2 constructing a Small Shop with the Minimum Expected Regret (Figure 3, last column).

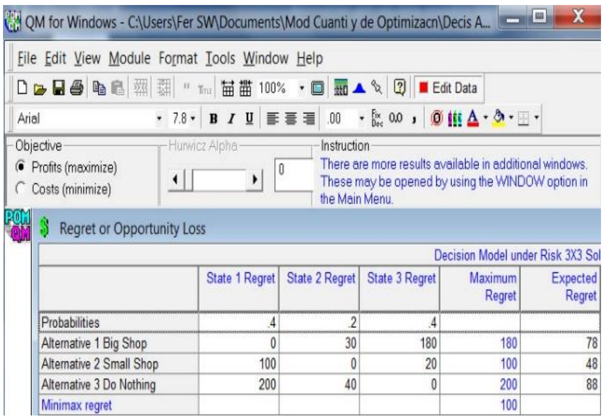

Figure 3: Decision Model for a Risky VR Aided Assembly
Source: obtained by using QM for Windows© software

Using DA, three probability datasets were collected via observation, inspection, estimation, measurement or revision to generate three average probabilities 0.4, 0.2 and 0.4 for the corresponding three states included in the Table named Regret or Opportunity Loss within Figure 3. Three options (columns) could be found in the Table by developing a VR aided assembly, with diverse virtual operation environments. This is similar to that of Fan et al. (2009), which is based on assembly workplace planning to generate scenarios utilized in QM for Windows© for meeting business goals of the corporation. In this strategy the total assembly time for certain workplace (in the production line) should meet the cycle time requirement while the assembly time has a close correlation with workplace facilities, process plans, and assembly tools. Therefore, It is of great importance to initially develop a virtual testing environment to assess the assembly workplace, and according to interactive assembly processes, each assembly plan can be assessed and the workplace layout can be adjusted based upon Short time, Regular time and Long time plans.

By the aim of business analytics each company is able to establish technology-based process, services, plans, and evaluations to fulfil their objectives.

7. CONCLUSIONS

Data utilization and alternatives generation have a great potential for growth. These strategies, in turn, can avoid misconceptions in project evaluation and provide solutions to the existing problems of the corporations via generating enough alternatives. Development of the appropriate business models require data analysts and business holders to learn, understand, and interact with the ever-changing market needs while concentrating on customer satisfaction. Establishing business models with more reliable elements, achieving greater precision for predicted results, increasing the capacity of the evaluative models, learning about model operation and alternative generation are general considerations when a decision-making approach should be conceived under risk-anticipated conditions. Emerging technologies, indeed, provide better solutions and alternatives than traditional methods for such processes.

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A CASE STUDY ON INDUCED MAINTENANCE USING UNITY AND VUFORIA7

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ABSTRACT

The maintenance process is becoming more and more complex due to the complexity of equipment. As a result, maintenance operation time rises and so does error operation rate, which also makes maintenance manuals difficult to write and read. Therefore, induced maintenance rises as there's a need for more reliable ways to reduce the error rate of maintenance personnel, more convenient ways to check the maintenance manuals, and more efficient ways to carry out the maintenance operation. Induced maintenance, by using augmented reality equipment, allows maintenance personnel to receive accurate operational guidance, visual and auditory, overlaid on maintenance object at each step in real time. In this paper, we display a initial induced maintenance case study on augmented reality, using AR software Vuforia7 and unity 2017.3, design and implement a complete maintenance process for a computer cooling fan.

Keywords: Augmented reality, Induced maintenance, Vuforia, Unity, Maintenance operation design.

1. INTRODUCTION

The Augmented Reality Inducted Maintenance System provides the ability to "Be able to complete tasks at the first time(Henderson and Feiner 2009)". In detail, the augmented reality induced maintenance system is a maintenance guidance and training system composed of techniques such as augmented reality, human-machine interaction, and virtual-reality interaction. The technology relies on computer graphics processing and audio processing to superimpose the inducing information into the visual field of maintenance personnel, providing maintenance guidance information to the operators without affecting the field of vision, helping professionals or those who have had little maintenance training to perform maintenance task. Operators can free themselves from paper manuals, and more attention will be focused on maintenance tasks(Reinhart and Patron 2009). What's more, the system also mitigating eyes and head movements(Henderson and Feiner 2009), reducing operational difficulties, increasing work efficiency, avoiding operational mistakes, saving equipment maintenance fees, and making the work environment safe. Nowadays the interactive mode of induced maintenance information is generally provided by text, audio, static 2D/3D models, dynamic 2D/3D models, etc.(Palmarini , Erkovuncu and et al 2018)

In the rest of this paper, we first review the state of the induced maintenance methods. Section3 introduces our method and main process of case-making. Section4 presents the experimental results and Section5 is about the discussions and direction for future work.

2. RELATED WORK

With the advancement of technology, augmented reality technology has become not only one of the research hotspots of universities and research institutes, but also gradually penetrates into fields like medical, education, military, industry, advertising, games, and tourism.

Recent advances in hardware and tracking algorithms have sparked an interest in wearable augmented reality devices. Wearable augmented devices have been successfully been used in induced maintenance such as Microsoft Holoens and other devices. Specifically, Hololens have been in ISS for induced maintenance verification.

Related research on induced maintenance case is still lacking. Especially to Hololens, as an useful tool for AR and induced maintenance, how to present induced maintenance guidance information to operators, how to arrange induced maintenance animations, still need to find optimization methods. This paper introduces a study where way of presenting induced maintenance information have been researched and optimized. It has been proved that the usage of Unity and Vuforia7 can achieve better visual effects for case.

3. METHODS

3.1. 3D recognition model in Hololens

We use unity 2017.3 and Vuforia7 to make induced maintenance case in practice. The maintenance target is a PC CPU cooling fan. As a leading software in

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augmented reality, Vuforia7 has developed many usefully tools for users and now supports 3D object recognizing in unity projects. Unity also develop some SDK to adapt to Vuforia7 and Hololens.
Vuforia7 3D recognition models are special .od files, which need to scan on android smart phone (at least android 4.4).The cooling fan and mainboard as shown in Figure 1. As the feature points of cooling fan that Vuforia needs for tracking are not sufficient, to speed-up the recognition process, we add extra mark on the cooling fan manually.

Figure 1: Target cooling fan and the PC mainboard.

After targets importing and projects building in unity, 3D object recognition project model in Unity as shown in Figure2.

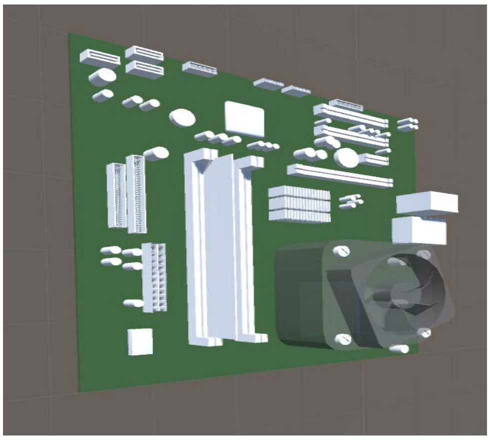

Figure 2: 3DModel in Unity scene.

3.1 Induced maintenance guidance information and UI interface design.

The induced maintenance mainly involves functions such as induce maintenance animation prompts, maintenance operation text narrative, voice interaction control, gesture interaction control. Able to present more intuitive, more types and real-time associated maintenance induction.
UI system is the main interface for maintenance personnel to use and control, to improve the maintenance efficiency, the induce information should be easy to find and read on the UI system.
In consideration of operation efficiency, the UI layout, icon, pointer, menu, color, etc. which can highlight induce information in a complex maintenance environment should be included in the design.
The induced maintenance interface UI system design method are shown in Figure3:

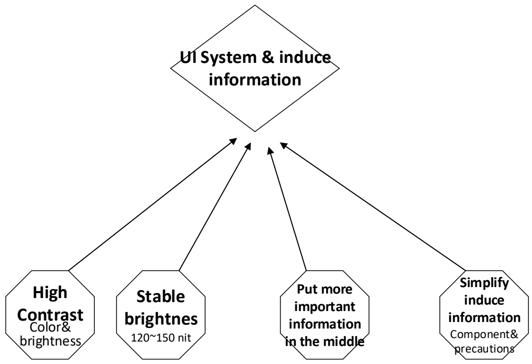

Figure 3: UI system design method.

UI layout: UI layout should adapt to human eyes physiological characteristics. Since horizontal angle of human eyesight is 160° and the vertical angle is 80°, when performing maintenance operations within the distinguishing field of vision(around 15°), the main information can be concentrated in the effective field of view(about 15°-30°), which is convenient for timely inquiry; Auxiliary information is placed within the induced field of view (30°-100°), prompting when forgotten.
Mark: The mark design mainly includes the disassembly part moving direction prompt mark, the disassembly part indication mark, etc., which provide a dynamic prompt and indicates the specific direction or position that needs to be operated. The icon design uses stereo arrows or indicator icons to prompt.
Pointer: Maintenance operators use the virtual UI interface. The pointer can be used as an interactive tool for natural interaction (gesture or voice). The pointer can be placed in the center of the view as an interactive trigger pointer.
Menu: The menu can be set with reference to the physiological characteristics of human eyes, and the information directly related to the work can be displayed in the effective field of view, and the information of the minor maintenance operation parts and the text of the specific maintenance process can be displayed at the edge of the window.
Color: The human eye has a higher degree of recognition for colors with higher saturation, the maintenance animation can be designed with high saturation colors such as green, yellow, and red.
In design process, considering color as the main guiding signal for human eyes, the color of the digital prototype is adjusted to warm colors with high contrast, which can be clearly distinguished from the maintenance environment. At the same time, the model display transparency is adjusted to 40%, so that the highlighted

induce information can be observed in the field of view, and the virtual model has no effect on the operation of the actual object. At the same time, simplify the display model, hiding the part that has less impact on the maintenance operation.

Table 1: Visual design.

Function	Design	On UI system
Visual design	Bright color	Bright color rendering model
	No affection on operation	40% transparency
	Simplify	Simplify the model

Complete maintenance procedures include a variety of information, such as the type of operating tools, the way the operating tools are used, the tools that need to be used, the repairing procedures, the location of the disassembled parts, and the way in which the fasteners are removed. If all the maintenance information is displayed in screen, it will affect the operation, hard for the operator to extract the useful information for maintenance will be reduced due to the cumbersome information. Therefore, we analyzed the layout of the operation environment and the specific maintenance process arrangement in advance, filter the main information of maintenance, extract the types of maintenance information with information importance, display it in a targeted manner.
For maintenance guidance, the "display" method is not only intended to visually dynamic guidance or text, but also to voice. In the combination of visually and audibly, the maintenance guidance could be more efficiency.
Induced maintenance animation needs registration display; Text is generally displayed at the edge of the screen field , so as not to affect the normal field of view; The auditory information is generally played in conjunction with the current maintenance operation.

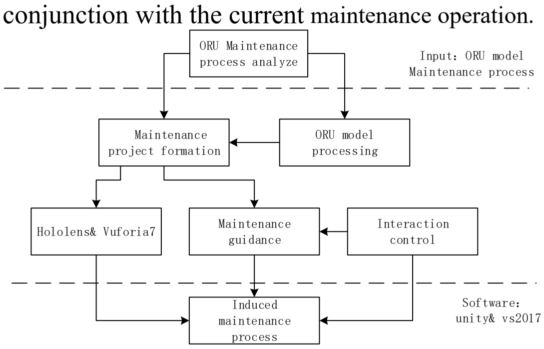

Figure 4: Induce information integration process, ORU refers to operational replacement unit.

UI interface design in unity is as shown in Figure4. In this figure, yellow cubes indicate the screws position, we use pink to label the screws that need to be disassembled. On the left is the prompt information about target and maintenance operation.
The pointer is a blue dot in the middle of the screen, designed to interact with gesture.

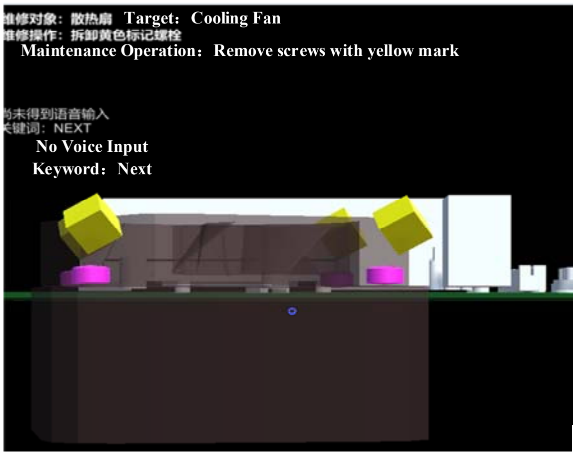

Figure 5: Interface design.

3.2. Interaction controls and maintenance process design.

We use Microsoft voice and gesture API for Hololens to add gesture and voice control into unity scene. Microsoft holotoolkit provides API for air tap and keywords recognition, available on Github, also support unity game engine. All the features are fulfilled in C# script Switching induce animation and text are triggered by air tap and keywords recognition.
In this case study, the cooling fan maintenance process is composed of three steps.
The first step of the maintenance process is object recognition, display the maintenance text information and the induce animation. The UI displays as shown in the Figure5, awaiting for interactive control (air tap) input.

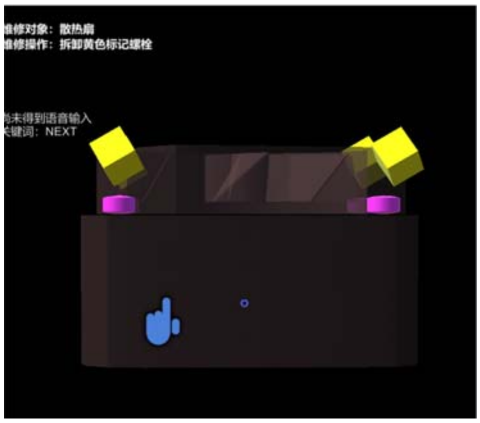

Figure 6: First induced maintenance step.

In the second step of the maintenance process, , the disassembly animation and maintenance text are triggered and updated by the interactive control input.

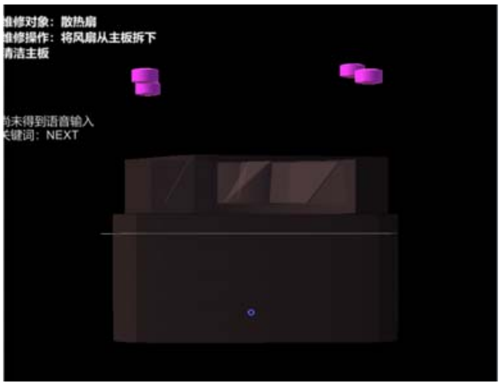

Figure 7: Second induced maintenance step.

The last step of the maintenance process is accomplished by tracking and recognition CPU model, display information to end the maintenance process through interactive control.

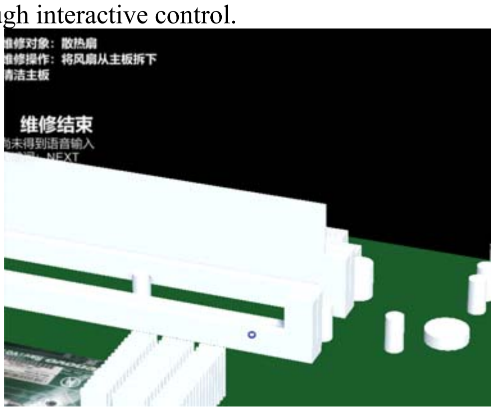

Figure 8: Last induced maintenance step.

The combination of these three steps is the whole induced maintenance process.

3.3. Experimental Verification

The proposed case has been implemented, tested in real maintenance environment.

Firstly, exporting unity project and building on hololens, air tap project icon, start the game scene.

Figure 9: Open the project scene, air tap to start the maintenance process..

Second step, start the induce maintenance process, play induce animation, use the screwdriver to remove the pink rendering screws.

Figure 10: Remove the pink rendering screws.

Finishing disassembly procedure, remove CPU cooling fan, use voice or air tap to switch the induce maintenance information.

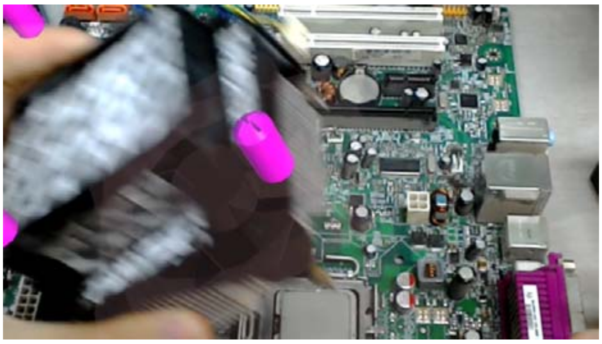

Figure 11: Remove the cooling fan.

Tracking and recognition CPU model, display information to end the maintenance process through interactive(air tap or keywords) control.

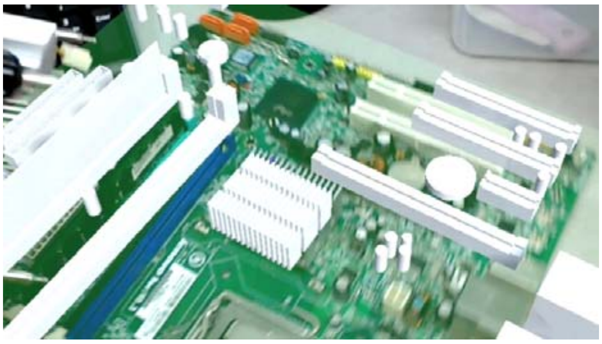

Figure 12: Finish maintenance process.

3.4. Conclusion

This study has shown that Hololens with unity 2017.3 and Vuforia7 are useful for induced maintenance guidance. But the feature points of cooling fan that Vuforia7 needs for tracking are not sufficient, need to add some marks manually.

When recording the induced maintenance process on hololens(Connecting over USB) device portal, the UI system unable to display on screen, stop recording function on device portal can fix this problem.

See through hololens may cause discomfort on eye, as the model is displayed separately in left and right eyes(Like 3D vertigo).

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USING THE AUGMENTED REALITY FOR TRAINING ENGINEERING STUDENTS

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ABSTRACT
Preparation of highly qualified engineers allows solving complex tasks of development, implementation and service of innovative technical systems and technologies, requires new approaches to the educational process. Improving the competitiveness of graduates on the labor market, acquiring and accumulating production experience are needed tasks of higher education system. In the present article, the interdisciplinary relationships between disciplines of specialty “Applied Mechanics” are being presented. Approaches for students’ professional competences for the disciplines “Descriptive Geometry”, “Engineering Graphics”, “Computer Graphics in Engineering” are being proposed. The importance of computer disciplines and their correspondence with professional disciplines were confirmed with regard the necessity of increasing the quality of the educational process. Engineering graphics training for modern engineer is the transfer of graphic information from an idea to manufacturing. The ability to design graphic images is an integral skill of an engineer. Due to limited lecture time, the presenting of material on the relationship between 3D geometry and their 2D projections by means of traditional approach seems to be rather complicated. In the present paper, a mobile application based on Augmented Reality is being proposed and allows representing 2D drawings in 3D models. The program is aimed on improving spatial skills and increase the students’ educational motivation. Implementation of the results in the educational process shows the effectiveness and the possibility of this application to support training activities in other areas of engineering. Mobile application “AR in Engineering Graphics” based on using the technology of augmented reality was developed and implemented into the educational process for overcoming the challenges related to the graphic training of future engineers.

Keywords: engineering, computer discipline, graphics, augmented reality, engineering education, spatial skills

1. INTRODUCTION

The current level of society, equipment and technology rapid development needs a preparation of highly qualified specialists for engineering area. At the same time, this required level of development puts forward higher requirements to higher engineering education. Under the influence of changes which take place in the globalized information environment, the professors of higher education institutions face with the modern challenges associated with the creation of innovative teaching materials.

The experience of developed countries shows that introduction disciplines on computer direction are an integral part of developing higher engineering education system. This approach encourages academic staff to constantly improvement their skills and quality of teaching of disciplines to implement a practice-based approach into the educational process in accordance with the global trends of higher education.

Modern trends in teaching on computer disciplines are inextricably linked with the formation of the students’ competencies using e-learning technologies to expand their self-learning, practical skills and professional competencies. For proper understanding and use of CAD/CAE/CAPP/CAM systems, future engineer must understand the fundamental principles of 3D design.

Different levels of knowledge of graduates of secondary schools and the shortest basic cycle of disciplines on computer direction make its own adjustments to the program of training future engineers, encouraging people for self-learning. Considering the above-mentioned there is a need for developing educational electronic resources and specialized mobile applications for each direction of training, which allow improving spatial skills and increasing the educational motivation of students. The system must be simplified and provide an efficient interaction between the lecturer and students.

2. THE IMPORTANCE OF THE USE OF AUGMENTED REALITY TOOLS

Today modern engineering education opens endless possibilities of using various visualization tools such as virtual and augmented reality (AR) based on the generation of accurate 3D models to improve the perception of the professional environment (Azkorreta 2014, Carretero 2010, Dangelmaier 2005, Rodrigo-

Magro 2011). The main advantages of the AR technology are simplicity, interactivity and high performance in contrast to the use of traditional teaching materials (Sharadchandra 2013).
AR could be treated similarly as the Virtual Reality. The visualization technique, which augments the real-time 3D graphics, computer generated and includes the real videos, develops and enhances the representation by the reality (Martin-Gutierrez 2011a).
The Reality-Virtuality Continuum (Binks 2003; Martin-Gutierrez 2011b) represents interacting components of Mixed Reality Environment, which include Real and Virtual Environments, Augmented Reality and Augmented Virtuality.
There are several types of AR systems, which include Desktop AR, Mobile AR and an Interactive 3D viewer (Azuma 1997, Milgram 1994).
One of the major problem in training students in the field of Engineering is the shortage of lecture hours for the subjects related to disciplines "Descriptive Geometry", "Engineering Graphics", "Computer Graphics in Engineering" that leads to decrease the time for theoretical and practical knowledge and development of spatial skills. Therefore, there is a need for developing of new attractive methodologies for students training.
AR technologies appear to become a useful resource for younger generation which is familiar with the latest developments in science, technology and entertainment. This technology needs a basic computer training to be visualized, forcing the student to develop the ability of reading and representing geometric shapes, which could be necessary for future engineers (Camba 2014).
AR could be better realized in the full cycle of training engineering students, starting with the development of models of products, completing their manufacturing (Chen 2011, Liarokapis 2004, Parmar 2015, Veide 2014). The AR is one of key elements of the so-called Industry 4.0 concept (Zawadzki 2016). It is important for the future engineer to be able developing and recognizing a graphical representation of products. Additionally, AR technology can be implemented for visualization of processes (Sklabinskyi 2019). Development of AR applications for product design and process visualization can be realized with artificial neural networks (Pavlenko 2019a, Pavlenko 2019b). Moreover, in terms of lack of classroom hours traditional methods of training are inadmissible. Given the above, it is evident that AR is the next inevitable step to improve the quality of engineering education.

3. PLACE OF DISCIPLINES ON COMPUTER DIRECTION IN CURRICULUM OF TRAINING OF ENGINEERS

Disciplines on computer directions are reflected in the educational process of preparation of engineers and designed to provide students competencies for using contemporary computer software, mobile applications, etc. for further professional activities. Engineering education program enforces the existence of interdisciplinary connections (Fig. 1) between: computer science (yellow); general engineering (green); professional (blue). This relationship corresponds to the program of BSc students in Applied Mechanics (professional direction "Manufacturing Engineering").
Computer direction disciplines could be divided into two levels – graphical and professional. The first level of study (graphical) includes such disciplines as: "Descriptive Geometry" (1st semester); "Engineering Graphics" (2nd semester); "Computer Graphics in Engineering" (3rd and 4th semesters). The objectives of this level are studying and practical mastering of methods of graphic images, creating the fundamentals on designing the documentation and 3D modeling. The task of teaching subjects is related to bachelor's needs for obtaining the knowledge and skills for effective use of software with the purpose of the following study of professional disciplines.
The second level (professional) includes disciplines: "CAD Systems" (5th semester); "CAE Systems", "CAPP Systems" (6th semester); "CAM Systems" (7th semester); "CAT Systems" (8th semester). These disciplines provide a fundamental knowledge for using automated production systems to improve the efficiency of production planning.

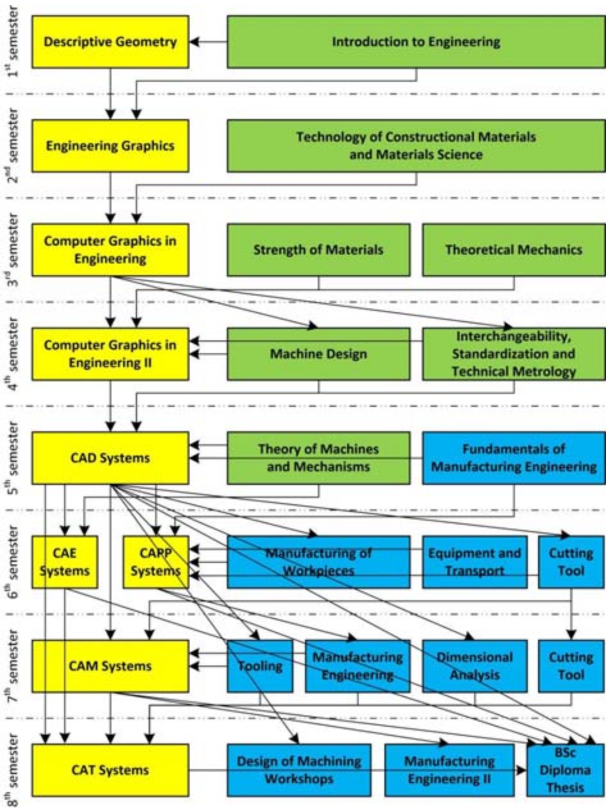


Figure 1: The relationship between disciplines, fundamental computer and professional orientation program of training of engineers

During "CAD Systems" classes students improve their skills in the use of CAD-systems, mastering several software products. Each student receives individual task, projects its own 3D-model of products, on which base develops the associated assembly drawing, detailed workshop drawings, and automatically forms product specification. A parallel study of discipline «Fundamentals of Manufacturing Engineering» allows using of acquired computer skills to develop the technological scheme of product assembling, distributed species and animations of assembly and disassembly.

In the discipline «CAE Systems» students study tools for engineering analysis of products for strength, rigidity, stability, exploring the dynamic state of technical systems by modeling specific production conditions, carry out optimization design. The study of these disciplines is the basis for obtaining the fundamental knowledge in the following disciplines "Technology of Constructional Materials and Materials Science", "Strength of Materials", "Machine Design", "Theoretical Mechanics", "Theory of Machines and Mechanisms".

During studying the disciplines "CAPP Systems", students study designing of manufacturing processes, develop product assembly processes and machining processes for the most complex parts by means of computer-aided tools. This is a practical application of acquired knowledge from the disciplines "Manufacturing of Workpieces", "Fundamentals of Manufacturing Engineering". Rational choice of metalworking equipment and cutting tools for specific production conditions and type of production is ensured by study subjects "Equipment and Transport" and "Cutting Tool". The acquired knowledge and skills are used in the core discipline "Manufacturing Engineering" (7th and 8th semesters) and Bachelor of Science thesis (8th semester).

Study discipline "CAM Systems" is based on mastering several CAM-systems for the implementation of subtractive (machining) and additive technologies (additive manufacturing). The result of this discipline is the development of real parts, which are manufactured on CNC machine tools or 3D-printer by means of use CNC data.

Discipline "CAT Systems" (computer-aided tooling) provides the practical implementation of the theoretical knowledge of subjects "Tooling", "Cutting Tool", "Manufacturing Engineering", "Dimensional Analysis" and practical skills in the use of CAD/CAE-systems.

Following the completion studying the cycle of computer disciplines, student should know:

- tendencies and prospects of development of modern computer-aided technologies for design and manufacturing purposes;
- basic design problem to be solved at the stages of product design and process planning;
- features making design decisions at the stages of developing, machining parts and assembly of the product;
- describe the means of information and presentation of data formats used in construction and technological design;
- mathematical models and means of formalizing technological knowledge.

Because of discipline studying, the student should be able:

- find solutions of the problem on development and technological planning of manufacturing production;
- applying modern computer-aided technologies to solve problems of engineering design.

4. E-LEARNING IN ENGINEERING EDUCATION

General difficulties on professional preparation associated with relentless acceleration of the development of ICT, need permanent solutions in the specific context of engineering education. E-learning environment of Sumy State University is based on the principle that the essential part of a modern education is the availability of all necessary learning tools for communication not only within the audience, but also it is the single information environment for accommodation of teaching materials, interaction with them and learning management. The functioning of the system provides a set of software and information environments: automated system of distance learning, open platform of online courses, the platform for blended learning, OCW, etc.

Basic approaches for the development and implementation of modern information and communication technologies into the educational process of SSU students on engineering training were developed.

Automated system that provides a complete solution for training is implemented by integrating virtual learning environment with the following subsystems management educational material and training process (Fig. 2).

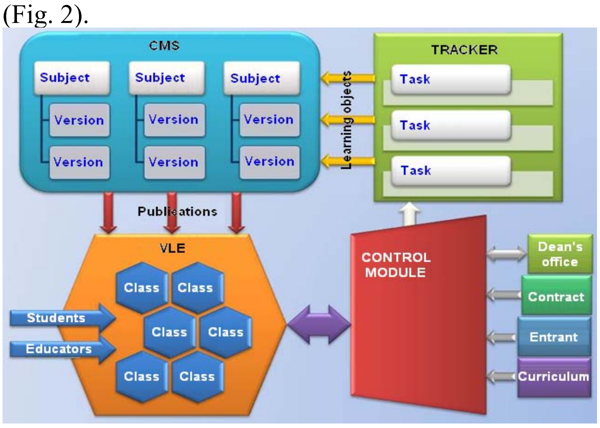


Figure 2: The scheme of automated system of organization educational process

5. CONCEPT AND STRUCTURE OF THE COMPUTER DISCIPLINES (1ST LEVEL)

5.1. Descriptive Geometry

The aim of the graphical level disciplines is the ability to have the perfect knowledge on the design of graphical images that is the index of professional skills of the future specialist. Basic knowledge on nature sciences are always supported by visual graphical images. Methods of descriptive geometry by means of graphical interpretation allows studying the mathematical models, which are used in the following levels of education. Use of modern computer means allow performing complex geometrical constructions by means of simplified procedure and with high accuracy.

As the descriptive geometry is the science that studies the spatial forms and methods of their imagination on the plane, the main task of discipline is the development of methods on designing images and solving of special tasks by means of complex drawing. The present discipline plays a special role in the development of modern engineer during the professional activity. The discipline realizes two types of tasks. The direct task of the descriptive geometry is to build the complex drawing of the object. The inverse task is the rebuilding of the form, size and relative placement of objects per their drawings. Therefore, use of methods of the AR for preparation of engineers is the up-to-date task, especially during the solving of the inversed tasks of the descriptive geometry by the students.

Tasks of the descriptive geometry are also divided into position and metric. Position tasks refer to the implementation of relative placement of geometrical objects (crossroads, parallelism etc.). Metric tasks are related to the determination of numerical characteristics (distance, angle, area, volume).

Knowledge obtaining on descriptive geometry course ensures the following studying of such disciplines as engineering and computer graphics, parts of mechanisms and machines, theoretical mechanics etc., assists the increasing of quality of performing drawings in course and graduate thesis.

5.2. Engineering Graphics

Engineering graphics is one of the most important discipline, which is studied by future engineers. It is the basis for studying of the following disciplines of the engineering direction. The course of engineering graphics consists of the following sections: geometrical drawing, projection drawing, technical drawing.

The aim of the discipline is the formation by student the practical skills on formation at high technical level the engineering drawings with use of educational-methodical and reference literature. On completing the studying of the discipline "Engineering graphics" the student should know the basic provisions of normative base on development of the engineering drawings, have skills to read and compose it by means of use of modern computer programs of automatic engineering.

5.3. Computer Graphics in Engineering

The present curriculum is presented by four thematic sections. The first section is dedicated to the development of working drawings of the plane parts (plates, clamps, brackets, etc.), in particular with use of the applied libraries of constructive elements; and also, designation of form tolerances and surfaces placement, so as selection of rigidity parameters and development of technical requirements to manufacturing of parts and their control.

Development of 3D parts models, material selection, entering of designation information and code assignment are presented in the second section. The associated drawing with the automatic filling in of the main legend of the drawing, with use of the auxiliary formats, simple and complex sectional elevations and remote elements is developed on the basis of this model in automatic mode. The drawing is added by sizes, parameters of surface quality and technical requirements. The mass-centering characteristics of the model could be additionally determined (weight, coordinated of center of weight, centroidal moment of inertia).

The third section is dedicated the process of product assembling from the existing collection of 3D models. The aim is the skills obtaining by students on the efficient application of tools combination between each other. The process is completed by the development of the associated assembly drawing with the automatic placement of the numbers of elements locations, which are parts of assembly, and by the generation of the specification. Depending on the completeness of filling in of the drawing sheet, the specification could be presented either on this drawing sheet or as a separate document. The obligatory element of the assembly drawing is the specified technical feature of the product and the assigned technical requirements. The settings of mated surfaces, also dimensional, location, joining and reference dimensions are additionally specified.

In the fourth section the students develop the assembled unit based on the previous designed parts and with use of the applied engineering libraries of standard products. The next step is the development of the associated assembly drawings and working drawings of the original parts. Development of specifications and formation of drawings are performed on demand, specified in the previous section.

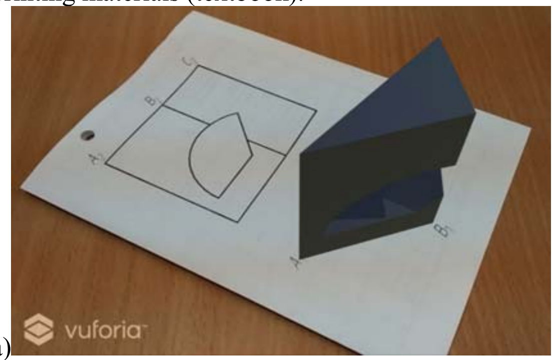
6. MOBILE APPLICATION "AR IN ENGINEERING GRAPHICS"

Mobile application "AR in Engineering Graphics" was developed and can be installed from the Google Play (https://play.google.com/store/apps/details?id=arieg.unity3d.sumdu.edu.ua).

Demonstrating the difference between 2D and 3D objects using AR technology in the context of the study disciplines "Descriptive Geometry", "Engineering Graphics", "Computer Graphics in Engineering" are presented in Fig. 3, Fig 4, and Fig. 5.

AR application is developed based on "Vuforia" software. It was selected as a tool for visualization of learning materials by using Computer Vision Technology for tracking 2D and 3D images which was realized by means of Application Programming Interface C++, Java, Objective-C and could be integrated with Game Engines. This approach allows locating of virtual objects in interaction with real images by viewing through mobile device cameras. This

technology is implemented through the installation of a mobile application on a smartphone or tablet equipped with OS Android. When pointing camera to 2D drawing over it appears the corresponding 3D model. The rotation of the drawing on the desktop, allows viewing 3D model from all sides.
As mobile applications do not allow using the great volume of data, the drawing is loaded from E-learning system of Sumy State University or directly from printing materials (textbook).

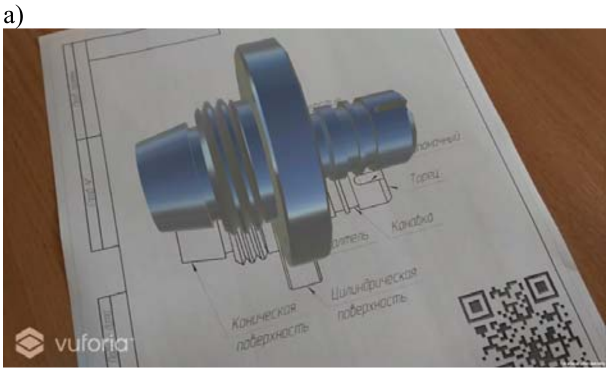


a)

b)

Figure 3: Examples of augmented reality in Descriptive Geometry

a)



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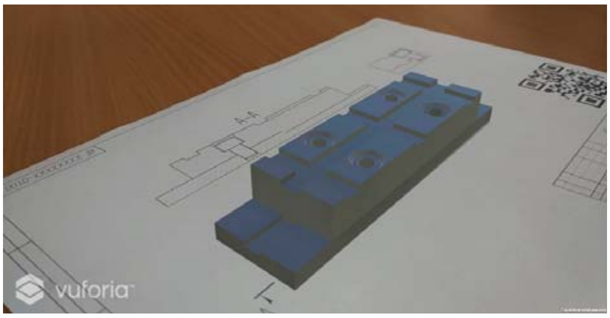
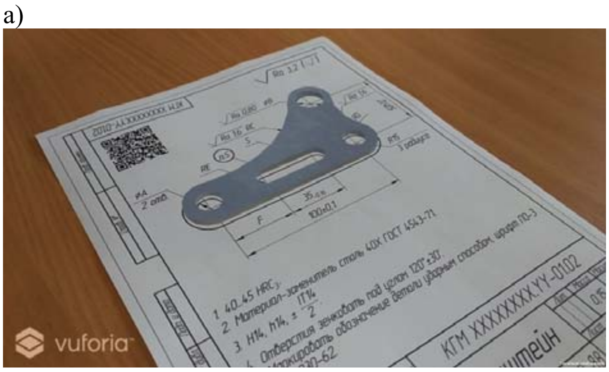


Figure 4: Examples of augmented reality in Engineering Graphics

a)



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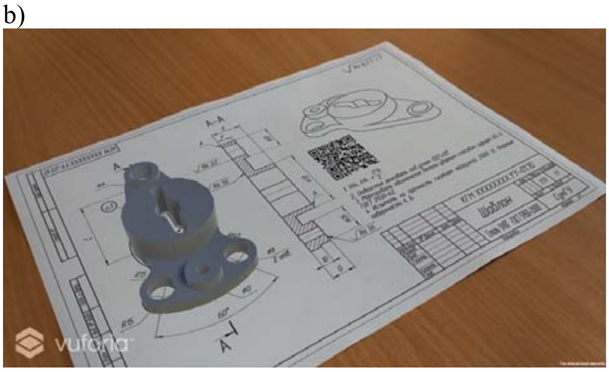

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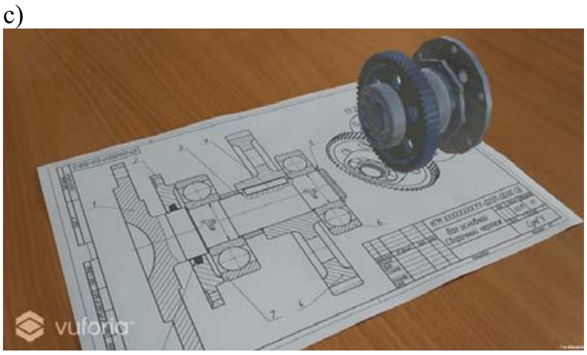

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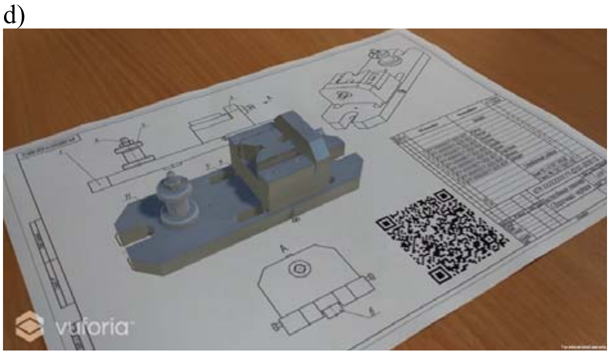

ISBN 978-88-85741-20-1; Bruzzone, Ginters, González, Gutierrez and Longo Eds.

Figure 5: Examples of augmented reality in Computer Graphics in Engineering

This approach is more productive than application of traditional, static axonometric images. The appropriate form of training with information transferring in a virtual environment is useful for students in terms of avoiding the difficulties of perception of graphical information by visualizing complex objects and contributes to a better understanding of educational material. Moreover, AR technology can be implemented to fixture design area (Fig. 5 d) with the aim to visualize the designed solutions (Ivanov 2019). In addition, the use of AR technology that could be easily implemented motivates academic staff to overcome the challenges of lack of classroom hours on computer direction disciplines in engineering education.

7. CONCLUSIONS

Within the globalized educational environment, a modern engineer is an expert able to effectively using of the ICT tools with the aim of applying of knowledge and scientific experience for solving interdisciplinary production problems, finding new scientific and research topics for the improvement of the computer-aided production planning.

It has been proved that AR is one of the most effective approaches of transferring knowledge to groups of students. To overcome the challenges related to the graphic training of future engineers the new mobile application "AR in Engineering Graphics" based on using the AR technology was developed and implemented into educational process of Sumy State University. Such innovation significantly increased the quality of the educational process.

Further research will be aimed at a comprehensive implementation of ICT tools into the educational process for disciplines "Metal-cutting Machines and Systems" and "Tool Production". Furthermore, it is necessary to develop more educational templates and to expand multimedia content to apply the system in practice.

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THE USE OF VIRTUAL REALITY TRAINING APPLICATION TO INCREASE THE EFFECTIVENESS OF WORKSHOPS IN THE FIELD OF LEAN MANUFACTURING

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ABSTRACT
The aim of the research is to check whether the use of VR will allow reducing the time needed to prepare students for workshop classes - simulation of the assembly process. The acquisition of manual skills or procedural knowledge about the manual assembly tasks is not the main goal of the workshop classes, but it is required to efficiently perform the classes. The traditional approach of teaching students how to assemble products during workshops was not time-effective. In order to improve the quality of classes, the authors decided to use new, low-cost VR devices that were recently developed, in a training application, which can be used by students before classes. Initial research carried out among students of the Poznan University of Technology indicate that the use of the VR application for operator training will shorten the time to prepare students for simulation by about 75%, which will positively affect the efficiency of the workshop classes. It should also be emphasized that students who prepare for classes using the VR application are trained to work at all assembly positions, which eliminates organizational problems that arise when changing roles during subsequent rounds of simulation.

Keywords: virtual reality training systems, object manipulation, lean management

1. INTRODUCTION
Until now, the significant limitation for the development of civil Virtual Reality immersive applications was the cost of peripheral devices enabling interaction with the virtual environment. With the emergence of low-cost VR devices on the market (which is sometimes referred to as VR 2.0 (Dann 2017)) and the interest of companies associated so far with the e-entertainment, communication and visualization industries, VR technology is almost universally available. Application that fully uses the potential of new interaction devices can make users feel physically located within the virtual world or feel a sense of presence, which sets VR apart and takes traditional computing interfaces to the next level (Berg 2017). This creates new opportunities for designers of various immersive applications, and at the same time confronts them with a number of challenges related to the selection and adaptation of appropriate equipment, as well as the construction of applications for specific educational applications. Additionally, a significant contribution to the development of VR applications can play artificial neural networks, the comprehensive use of which for solving a wide range of engineering problems is considered in paper (Pavlenko 2019a, Pavlenko 2019b).
In industrial training the use of virtual training simulators in situations where practical experience is important is becoming common. The usefulness of the VR training application depends on the learning transfer - the amount of knowledge acquired during training, which can be applied to a new task (Hamblin 2005). Learning transfer can take place only when there is similarity of tasks or knowledge about a given field, and the person is able to see the similarity (Gick 1987). In order to ensure the greatest possible similarity between the virtual task and the real task that the user should face at the end of the training, it is necessary to ensure the most natural interaction between the user and Virtual Environment. In order to achieve that user must be able to manipulate virtual environment freely. Object manipulation is a fundamental task in several VR interactive simulators and the development of effective metaphors and tools for its practical implementation is extremely important for their success (Caputo 2015).
The purpose of this paper is to describe the results of preliminary tests to check if the use of VR will allow reducing the time needed to prepare students for workshop classes in the field of improving production flow by using the Lean Manufacturing (LM) concept.
Especially in job-shop production system, in which similar workstations are grouped together and flow of processing materials are discontinuous because of needs to transport them from one workstation to another, organization of production flow conduct a crucial role in a company (Lopes 2018). That is why the present work deals with the topic Lean Manufacturing, which

began in the 1950s in Japan, more specifically in Toyota. According to (Womack 1990), it was Toyota's Eiiji Toyoda and Taiichi Ohno who realized that mass manufacturing would not work in Japan and then adopted a new approach to production aimed at eliminating waste. To achieve this goal, techniques such as small batch production, set up reduction, inventory reduction, high quality focus, and others were used. This new approach came to be known as the Toyota Production System (Araújo 2018). Womack and Roos, in 1990 (Womack 1990) defined five fundamental principles for reducing waste:

- Identify value: differentiate activities that add value to the product and differentiate them from waste;
- Value Chain: map the product's processing chain to identify and eliminate waste;
- Flow: work the product at each step of the process to avoid waits and obstacles in the process;
- Pulled production: let the production be "pulled" by the customer, and produce only what is ordered by the customer;
- Continuous improvement: there is always room for improvement, there are no perfect systems.

Lean Management is an organizational production model that focuses on fostering a philosophy of continuous improvement, eliminating wastefulness in the process, reducing unnecessary costs, and thereby increasing productivity and customer satisfaction. In other words, it is a system with fewer inputs to achieve the same objectives as traditional mass production systems, but it offers a greater variety of products (Womack 1996). It allows, according to Liker (Liker 1997), to reach smaller cycle times through the elimination of waste. In this case, the goal is to increase the time value that is added during the production process, reducing the time between the customer order and the final delivery. By eliminating the waste and the added value time, it is possible to reduce the time of process throughput, that is, the time from when the raw material enters until it is incorporated in the final product. Lean manufacturing contains such tools as cellular manufacturing (CM), line balancing, value stream mapping (VSM), Inventory control, U-line system, single minute exchange of dies (SMED), production levelling, pull system, kanban, standard work, kaizen, one piece flow, poke-yoke, visual control etc.

2. MATERIALS AND METHODS

2.1. Lean Manufacturing workshops

The workshop classes in an area of organization and improvement of the production process by using lean manufacturing tools are carried out in the form of simulations. Each student plays a specific role during the simulation, and each role involves the need to perform specific tasks. During the simulation, students perform assembly operations on five consecutively placed workstations and provide to the customer a set of consistent quality finished products at a given time. The workshops include observation of the flow of materials and information between assembly stations, measurement of basic parameters of assembly processes and analysis of results in order to improve the organization of the process. Students, acting as assembly workers, are called operators and play a key role in the workshop. The traditional approach to the organization of simulation activities, consisting of teaching students how to assemble products during the workshops, was not time-effective. During traditional classes, students receive paper instructions containing drawing and information about how to connect blocks, and then more than 20 minutes of classes are allocated to teaching operators the correct performance of assembly tasks. It should be emphasized that in 20 minutes, operators learn to perform only one operation to which they were initially assigned. The correct method of assembling the blocks is crucial for the correct process of workshop simulation, because the purpose of the simulation is to observe the flow of materials and information, and the unqualified operator would artificially disrupt this flow. During workshop classes, from 3 to 6 rounds are realized. It often happens that in subsequent rounds, students, for organizational reasons, change roles. This means that another extra time must be allocated to training "new" operators. Assuming that during one workshop only three simulation rounds are held for the operator training itself, which is not the added value of the classes, up to 60 minutes are spent. Using the VR training application can replace or significantly reduce the time of preparing operators to work at assembly stations, and at the same time increase the available time for process analysis or other activities adding value to the content.

2.2. Object manipulation in virtual space

A defining feature of virtual reality (VR) is capability of manipulation of virtual objects interactively, rather than simply viewing a passive environment (Bowman 1997). Physical interaction is important for realism (Brooks, 1999) and is essential for creating virtual equivalents of real tasks. The most fundamental interactions between humans and environments (both "real" and "virtual") are object selection, positioning and rotating. Manipulation in immersive virtual environments is difficult, partly because users must do it without the haptic contact with real objects, which they normally use to orient themselves and surrounding objects (Mine 1997).

The authors in previous studies have repeatedly undertook the problem of manipulation of virtual objects (Buń 2015, Buń 2017, Buń 2018) and interaction with a virtual environment to ensure the highest possible level of immersion and, consequently, effective transfer of knowledge (Górski 2017).

2.3. Hardware

The prepared solution uses low-cost VR devices with dedicated controllers (Oculus Rift CV1 and HTC Vive) to manipulate objects in a virtual environment. The application has been prepared in the Unity 3D 2017.2

environment. Unity is a game engine that supports Oculus Rift, HTC Vive and other “new” HMDs. It has become a very popular platform that allows to create applications for most of currently available commercial VR devices.

Table 1: Parameters of used HMDs

Parameter	Oculus Rift CV1	HTC Vive
	Value	Value
Resolution	2160 x 1200	2160 x 1200
Refresh Rate	90Hz	90Hz
Platform	Oculus Home	SteamVR, VivePort
Field of view	110 degrees	110 degrees
Tracking	IR LED sensor – 3 DOF positional tracking, 1,5 x 1,5 m tracking space, built-in accelerometer for 3 DOF rotational tracking	Lighthouse – 2 base stations emitting pulsed laser , built-in accelerometer for 3 DOF rotational tracking
Controller	Oculus Touch, Xbox One controller	Vive controller, any PC compatible gamepad
Connections	HDMI, USB 2.0, USB 3.0	HDMI, USB 2.0, USB 3.0

Virtual Reality Toolkit was used along with the appropriate library packages provided by the equipment manufacturers to operate motion controllers.

2.4. Virtual Training Application

Training simulation and a virtual training environment should engage the user and at the same time contain only what is necessary to perform the task, so that the simulated task is consistent with real-world behavior and does not distract the user. Therefore, the application was prepared in two versions, differing in the amount of information provided and the manner of presenting it. In both cases, the user had to properly manipulate virtual objects in such a way as to submit a complete product in the shortest possible time.
The first version of this application offered hints as to the location and orientation of individual blocks in the form of a "shadow". When the user lifted the block using the controller, the translucent copy appeared in the place where it should appear (as shown in Fig 1 A).
The second version of the application limited the hints to the assembly instructions placed around the virtual work station, informing about the correct order of assembly of individual blocks and their mutual position (Fig.1 - B).

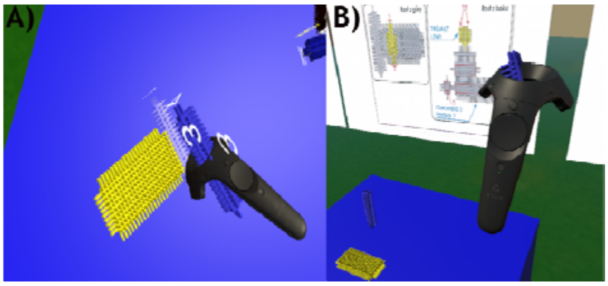

Figure 1: Different versions of tested application.
A) Version with „shadow” of element in target position.
B) Version with assembly instructions around workplace.

In order to lift the block, the user had to put a virtual representation of his hand in the right place (so that he collides with the part) and press the button on the controller. Then he could manipulate the object connected to the controller by moving and rotating the controller in reality. If the wrong part was grabbed or the user had to have a problem with rotating the selected block, he was able to re-place it in the virtual table by pressing the button again. To provide the user with additional information, each time the virtual hand was in the correct position relative to the block (so that it could be grabbed), the controller vibrated. When the selected part was placed in the right place with the correct orientation (taking into account the assumed tolerance), it was automatically disconnected from the controller and connected to another part using Unity Physic system. The amount of tolerance could be adjusted by changing right values in editor, as seen in Fig 2.

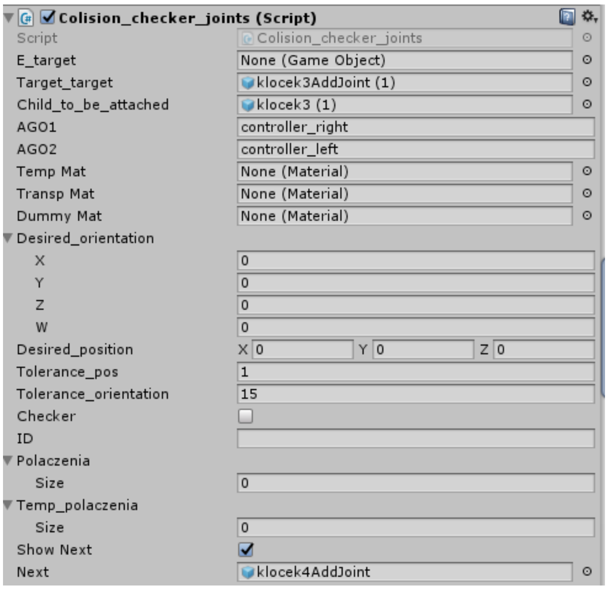

Figure 2: Unity editor Window with script checking positions and orientation of objects entering collision zone.

During application development first users found it difficult to calculating the number of pins on the individual sides of the block. In order to solve this problem, the 2 most important sides from assembly procedure point of view, were provided with additional information on the number of pins in form of floating numbers indicating number of pins. This information could have been helpful in positioning, but in the case of the first of the proposed solutions, this could distract students' attention from the actual task. Some of the test subjects tested this solution only tried to put numbers on themselves so as to correctly position the blocks.

3. USER TASK AND TEST PROCEDURE

The authors wanted to check how the presentation of information about the task was the most effective in terms of knowledge transfer during short sessions in VR. Two methods for the presentation of the correct assembly order and orientation of the blocks have been proposed and tested. In the first of them (VR1) the shadow of the grasped part appeared in the place where it should be placed, giving a clue (information). In the second method (VR2), to learn how to properly assemble the product, users had to look at the boards, placed in a virtual space, showing the next steps. One of the boards with assembly instructions is shown in Fig. 3.

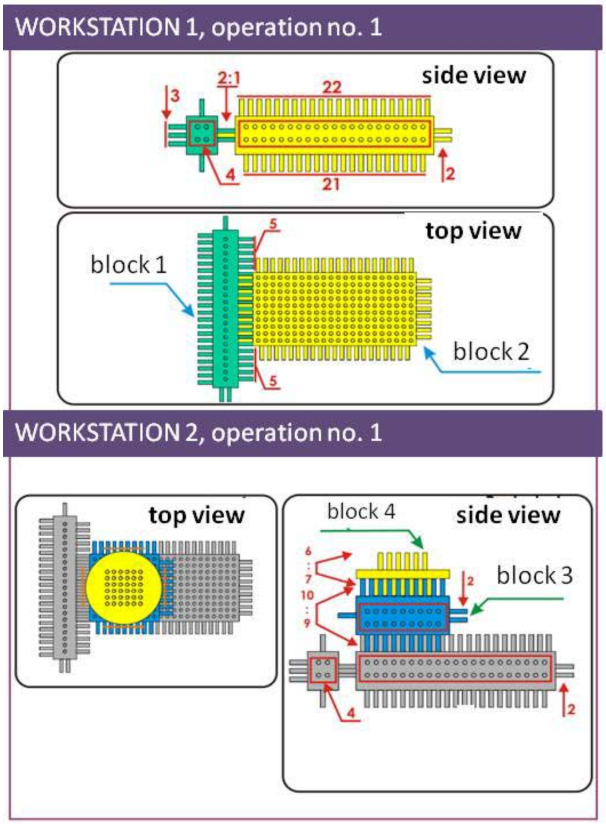

Figure 3: Assembly instruction. Step one – up, step two – down. Numbers indicate number of pins on block side or number of rows of pins.

The task consists of 5 assembly operations. In each operation, the blocks should be properly positioned relative to each other to assemble.

In both cases, students had a few minutes to become familiar with the virtual environment, methods of interaction and moving around in it. Next, users learned for 5 minutes the correct way to assemble the blocks in VR, trying to complete the task as soon as possible.
After virtual training, they continued the Lean Manufacturing workshops in a traditional way, repeating 10 times each of the assembly operations (Fig. 4). The average duration of assembly operations and the number of errors made were calculated. The results obtained by students who had previously received VR training were compared with the results of a group of students (VR0) who did not take part in VR training, but only passed the "traditional" assembly training, which lasts 20 minutes and takes place during the LM workshops.

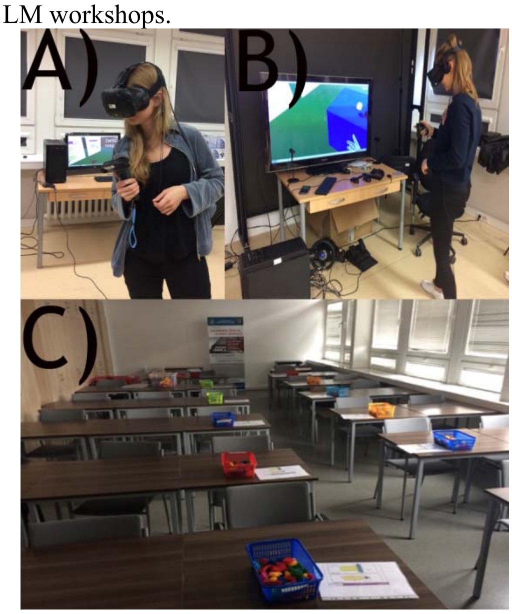

Figure 4: A) VR training using HTC Vive B) VR training using Oculus Rift C) Workstations for test procedure.

4. RESULTS

As a part of the research, the students had to assemble the product correctly after completing the VR training. The correct assembly of the finished product required 5 operations. In case that the research condition corresponds to the conditions during the workshop classes, each student received 10 sets of blocks and 10 times repeated the same operation, i.e. 10 times the first operation, 10 times the second operation, etc. For each student was measured the total duration of ten operations of a given type and the number of errors.
First, the VR1 group (contains 20 students) was tested. VR1 group was taught in the application version, in which, after grasping the element, reflecting the blocks on which students work during the classes, his shadow was shown indicating the place where the block should be dropped.
Next, the VR2 group (also contains 20 students, but different from VR1) was tested, which was taught in the application version, where information on the correct

assembly method was placed on virtual boards placed around the workplace.
The graph (Fig. 5) presents the number of mistakes made by students represents particular groups. The analysis of the graph indicates that students from the VR1 group made 51% fewer errors during assembly, while the VR2 students 40% fewer errors than students from the VR0 group who did not have training in the VR laboratory.

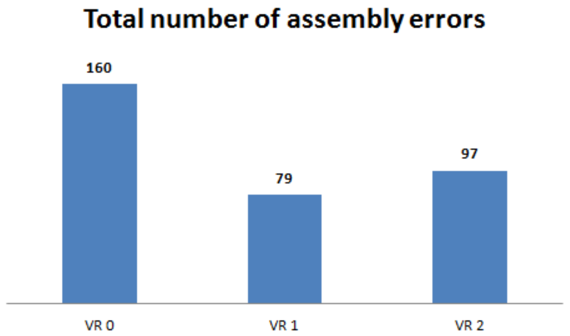

Figure 5: Total number of assembly errors

The graph (Fig. 6) presents detailed results regarding the number of errors made in each operation.

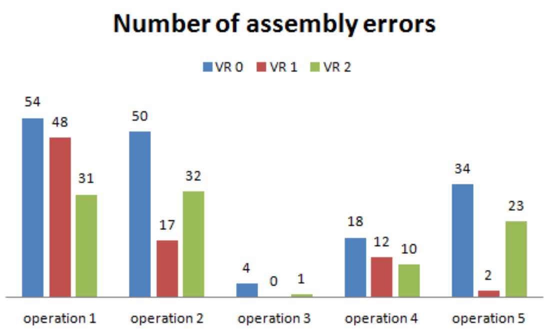

Figure 6: Number of assembly errors

Analyzing the graph (Fig. 6) it should be noted that the VR1 group made fewer mistakes only in operations no. 2, 3 and 5. However, in operations no. 1 and 4, the training made for the VR2 group proved to be more effective. This is due to the fact that operations no. 2, 3 and 5 are much simpler than operations no. 1 and 4. Assembly operations no. 2, 3 and 5 consist only of attaching one block, and its proper positioning does not require too much focus.
In turn, operations no. 1 and 4 are complicated because they require proper positioning and joining of two blocks in case of operation no. 1 and select one of six possible positions in case of operation no. 4. This may indicate that in the case of more complex operations, training is more effective when the student has the opportunity to familiarize with the virtual instruction.
The graph (Fig. 6) shows the average assembly time of one piece of product. It shows that both kinds of training contributed to shortening assembly time, and students from the VR1 group achieved better results by approximately 10% than students from the VR2 group.

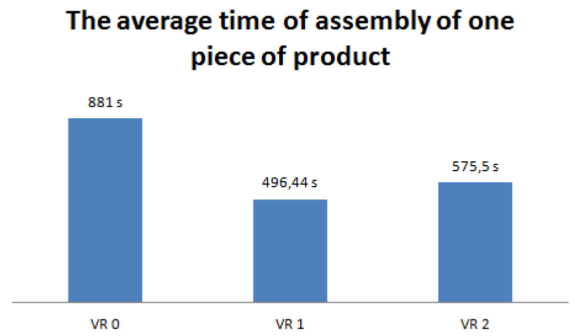

Figure 7: The average time of assembly one piece of product

Whereas the graph (Fig. 7) presents the average duration time of individual operations achieved by students from VR0, VR1 and VR2 groups.

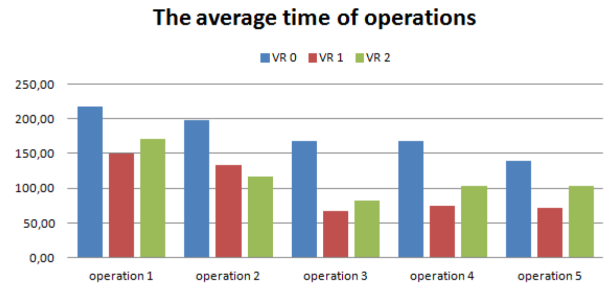

Figure 8: The average time of operations

The analysis of the graph (Fig. 8) shows that regardless of the complexity of the operation, students from the VR1 group in 4 of 5 operations performed their tasks in a shorter time.
The results of the conducted research clearly prove that the use of VR training has a positive effect on the way and time of performing assembly operations. Significant reduction of student training time during LM workshops is also due to the fact that students trained in VR are able to perform all assembly operations, which means that there will be no need to repeat the training before each round of simulation in which the students will change roles.

5. CONCLUSIONS AND FUTURE WORKS

Devices for interaction with virtual reality are becoming cheaper, and as a result, VR becomes public. In the future, if the promotion of low-cost devices for interaction with VR is not halted, HMD to VR will become the standard equipment for every apartment.
Thanks to this and properly prepared applications, similar to those proposed by the authors, students will have the opportunity to prepare for workshop classes, including manual tasks, in their own home. This will allow for the more effective use of time of workshop and more thorough analysis of issues constituting the merits of the course. Potentially, it will also shorten all types of professional training if the student will already know basic manual skills and sequences in procedural tasks in VR. In the future, it is planned to expand the

research by introducing a more complex product that will move on the assembly line. The task of the test group will then be to learn how to perform assembly operations on individual positions.

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AUGMNETED REALITY IN PRODUCTION MANAGEMENT CLASSES

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ABSTRACT

The paper presents preliminary results of research on integrating Augmented Reality in Production Management classes. The aim of the classes in Production Management, carried out for the Mechanical Engineering is to familiarize students with the widely understood organization of production processes. The main goal of the classes, in to which AR application was integrated, is to familiarize students with the rules and stages of the 5S tool. Evaluation of effectiveness of the proposed application was performed based on time of the task, number of errors, number of repetitions without errors, as well as with questionnaire in which students evaluated proposed solution.

Keywords: lean manufacturing, 5S, Augmented Reality

1. Introduction

The use of Virtual and Augmented Reality(AR) in education is becoming more and more common. The AR technology is used for displaying dynamic spatial and flat visualizations overlaid on real-world objects, definition by Azuma (Azuma 1997) includes constant bond between real-world and digital objects as well as an interaction between the user and the virtual objects. The AR solutions can be based on mobile devices, such as cellphones or tablets (Rumiński 2013) or headsets (Hamacher 2016), such as Microsoft HoloLens.
High-end components installed in today's phones make it possible to present 3D content. AR applications can run on almost any modern smartphone. Along with the popularization of AR-based games such as PokemonGO, game engines have begun offering the possibility of relatively simple creation of AR applications. This opens up a number of possibilities, including many educational applications. The authors decided to examine the effectiveness of the AR application in the Production Management classes.
The aim of the classes in Production Management, carried out for the Mechanical Engineering study program is to familiarize students with the widely understood organization of production processes. One of the main issues in this area is the Japanese concept of Lean Manufacturing (LM).

2. Materials and methods

2.1. Lean Manufacturing and 5S

Lean Manufacturing assumes the elimination of all wastage occurring on production, which leads to shortening the time of material passing through the process (lead time). Lean Manufacturing derives from the production system of TPS (Toyota Production System), whose creators are Japanese engineers: Sakichi Toyoda, Ki'ichirō Toyoda and Taiichi Ohno (Liker, 2004; Shah, Ward, 2003).
The name of the method comes from the first letters of the Japanese words: Seiri, Seiton, Seiso, Seiketsu, Shitsuke. Fig.1 shows the stages of this method. They are at the same time the names of the five stages of organization of the workplace (Womack, Jones, Roos, 1990)) Sort, Set in order, Shine/Sweeping, Standardize, Sustain. It is a systematic method for organizing and standardizing the workplace. It's one of the simplest Lean tools to implement, provides immediate return on investment, crosses all industry boundaries, and is applicable to every function with an organization (Kilpatrick 2003). It is also the first stage of strengthening the attachment in the employees and the sense of responsibility for their work position.

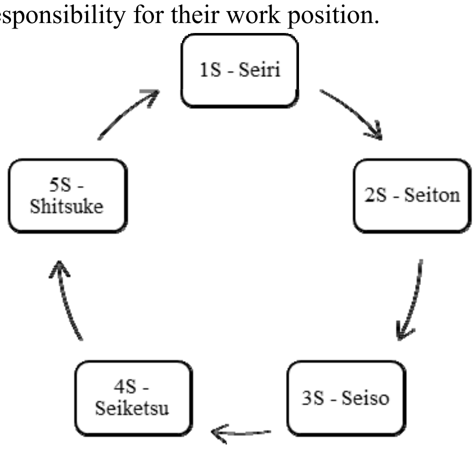


Fig. 1. 5S stages.

Lean Manufacturing tools and techniques are commonly used in many manufacturing enterprises. Therefore, future employers expect students to know the methods and rules for the use of basic LM tools and techniques. In order to meet these expectations, students in the classes on PM realize the topic related to the basic LM tool which is 5S.

2.2. 5S Workshops

The main goal of the course is to familiarize students with the rules and stages of the 5S tool. Students are divided into 9 or 12 groups of 2-3 people (depending on the size of the group). Their task is to assemble one of three products (Fig. 2), in an appropriate color variant. Each product consists of 14 parts (Lego bricks).

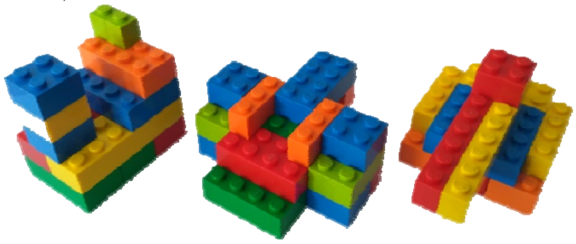


Fig. 2. Products assembled during the classes

In each group, students choose an operator, a quality controller and a process engineer among themselves. The operator's task is to assemble the product according to the documentation provided (by the teacher in the first stage or made by other students in the subsequent stages). The quality controller's task is to inspect the product provided by the operator after completion of the assembly according to detailed documentation, and task of the process engineer is to measure the time of performing operations and to propose improvement actions.

Students perform 3 stages:

- stage 1 - students work in a disordered workplace.
- stage 2 - students work in an organized workstation with a work instruction created by other students, students change job positions.
- stage 3 - students work in an orderly work station with work instructions developed in the AR.

In stage 1, students work in a disordered workplace (Figure 3). They get a mix of different Lego bricks that are not necessarily needed to assemble the right product. They also receive extensive documentation, of which only one picture is useful to assemble the product. The task of students is to assemble the product in the shortest possible time. The biggest problems during the assembly of the product are:

- the lack of parts needed to assemble the product, so that students need to look for them - most often at colleagues' workstations,
- lack of detailed documentation - frequent mistakes, the use of wrong blocks or blocks of a different color.

Fig. 3. Workplace before introducing the 5S practice

After the "production" is finished, there is a discussion. Students indicate the problems encountered and their possible solutions. After the discussion, students perform the first 4 stages of 5S: sorting, systematics, "sweeping" and standardization (Figure 4). At the standardization stage, students create paper instructions for assembly of the product.

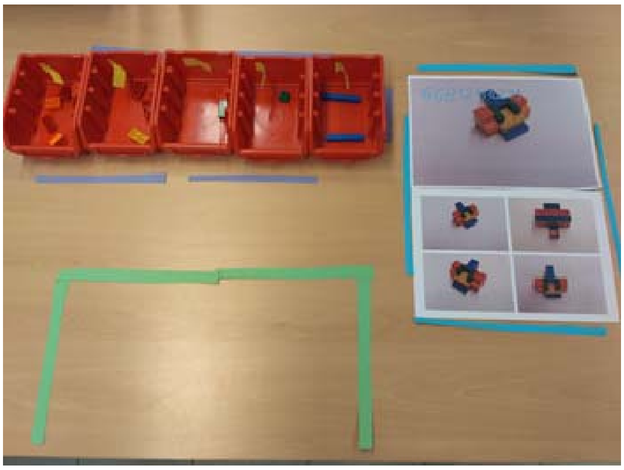


Fig. 4. Workplace after introducing 5S

In passage 2, the students change workplaces (whole group goes to workplace where another product was assembled). They are now working in a work station arranged by the previous group. Their task is to assemble the product as soon as possible, in accordance with the prepared instructions (Figure 5). However, it is not always possible for all the groups to assemble the product. The main reasons are:

- illegible instructions,
- lack of proper parts for production.

After the work is completed, a discussion takes place, which mainly concerns the preparation of the assembly instructions for the product.

Fig. 5. Students during work on a workplace with 5S introduced

In the stage 3, the students change jobs again. They work in organized workstations, but this time instead of instructions for assembly of the product in a paper version, they use the instructions developed using the AR technology. After the work the discussion takes place, which mainly concerns the comparison of the paper assembly instructions of the product with that developed in the AR.

At the end of the course, students prepare conclusions resulting from the use of the 5S tool. The most important of them are: shortening the time of performing operations, shortening the time of preparation, order and the lack of unnecessary items in the position.

2.3. Augmented Reality

The Augmented Reality (AR) technology is used for displaying dynamic spatial and flat visualizations overlaid on real-world objects as a way to "augment" the real-world (Milgramt 1994). Constant bond between real-world and digital objects as well as an interaction between the user and the virtual objects are an inseparable part of the AR definition by Azuma (1997). The AR solutions are gaining on popularity, because they can be based on mobile devices, such as cellphones or tablets (Ramirez 2013; Ruminski 2013). In more specialized approach dedicated headsets (Hamacher 2016), such as Microsoft HoloLens, can be used. Augmented Reality is widely used in engineering processes for example in or maintenance (Palmarini 2017), although there is no common architecture or standards for building AR applications (Palmarini 2018).

Augmented Reality and related technology of Virtual Reality (VR) both use similar visualization techniques and hardware, although VR is focused on obtaining a feeling of immersion – sense of presence in computer – generated environment (Bowman 2007). Immersion and user engagement is especially important in education (Wu 2015). AR interfaces enhance the real world experience, unlike other computer interfaces that draw users away from the real world and onto the screen(Billinghurst 2002).

During the past decade the AR and VR applications became widely used for training and education (Martín-Gutiérrez), in engineering (Torres 2017, Gorski 2015 Trojanowska 2017), medicine (Ha 2016) and standard education processes (Martín-Gutiérrez 2015). Both technologies enable high efficiency in training performed without supervision and self-learning by enclosing of human knowledge inside a computer application and visualization with high level of interaction (Gorski 2017). The VR and AR are also key elements of the so-called Operator 4.0 and Industry 4.0 concept (Zawadzki 2016).

2.4. Object manipulation in handheld AR

Both AR and VR User Interfaces (UIs) have so far been used for a great number of tasks, where they at times have shown great promise for increasing a user's performance compared to traditional mouse-and-monitor UIs(Krichenbauer 2018). In creating an AR interface that allows users to manipulate 3D virtual objects there are a number of problems that need to be overcome (Kato 2001). Bowman et. al. (Bowman 1997) identify three basic object manipulation tasks: selection, positioning, and rotation.

The disadvantages of handheld AR devices are the physical constraints of the user having to hold the device out in front of them at all times as well as distorting effect of classically wide-angled mobile phone cameras when compared to the real world as viewed through the eye (Kesim 2012) . Due to that in most cases user can manipulate object by touching screen and interacting with user interface. The other possibility of interaction is by moving AR marker or moving himself in real space.

2.5. AR application structure

The AR application was developed using the Unity game engine, version 2017.2.0f3, integrated with the Vuforia AR package. Three geometric variants of products have been implemented into the application for the PM classes. Each variant can be made of blocks of specified width and length (geometry) but different colors. After aiming the camera of the mobile device on the marker in front of the user, a product is made up of blocks of appropriate geometry, however, built of elements of the same color (Fig. 6).

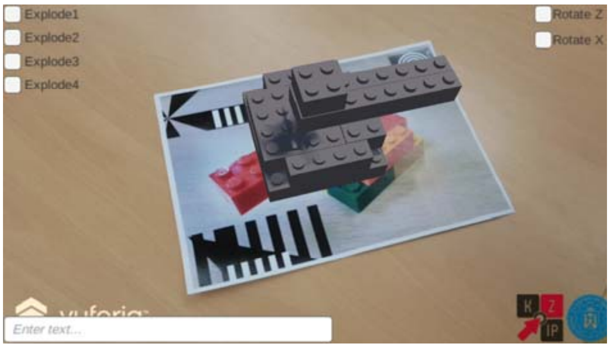


Fig 6. Start view in app after scaning AR marker.

In order to determine the colors of individual blocks, the user is required to enter the appropriate code consisiting 9 digit responsible for the color of the final product. After entering the code into the text field, the string is separated and then interpreted by the script written for this purpose. Each of the digits of the code corresponds to one of the colors found in the pre-defined array at the Unity level (Fig 7).

Fig 7. Color table created in Unity.

In order to introduce the possibility of easier interpretation of 3D content and subsequent steps to be taken during the assembly procedure, the basic navigation functions and the option of assembly / disassembly of the product have been added to the application. They allow users to rotate the object in each of the 3 axes independently of each other, but with a constant angular velocity. The user interface system is visible in Fig. 7.

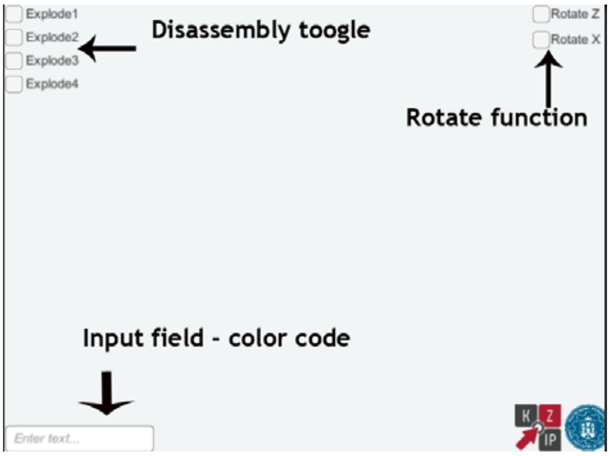
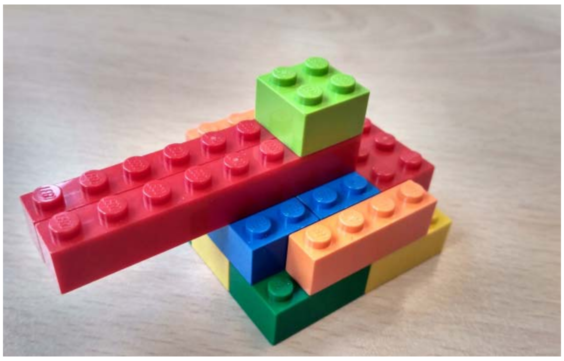


Fig 8. GUI in AR application

The proposed interface was assumed to be simplistic, in order not to draw attention from the contents and allow intuitive interaction at the same time.

3. AR application in 5S classes

The main goal of the classes, where AR application was introduced, is to familiarize students with the rules and stages of the 5S tool. Students are divided into 6 or 9 teams (depending on the number of groups). AR based assembly instruction was introduced as part of classes. The students had possibility to compare usefulness of standard instructions and proposed solution in assembly task – simple product with 14 parts and 4-7 colors depending on product variant. Students perform 3 passes, in each pass the workspace is organized in a better way. In the first pass students get a mix of different Lego blocks and a picture of the finished product(as shown in Fig 1.). Their task is to submit the product in the shortest possible time.


.
Fig.9. Picture of assembled product given to students at the first pass of workshops

After assembling the product, the students perform the first 4 stages of 5S. At the standardization stage, students create paper instructions for assembling the product.

In the second pass, the students change workspaces (and product at the same time). Their task is to assemble product as fast as they can using paper instructions made by previous team. In the last pass, the students use premade AR instructions.

4. Results

Evaluation of effectiveness of the proposed application was performed based on time of the task, number of errors, number of repetitions without errors, as well as with questionnaire in which the students evaluated the proposed solution. The classes were taken by approximately 80 students in total. The students were divided into 9 or 12 groups, 2-3 persons in each group. In each passage, the "process engineer" measured time of the "operator". On that basis, a table of results was created (Table 1).

Table 1. Time for each pass.

	pass 1	pass 2	pass 3
Mean (s)	213	41	55
Standard deviation (s)	90	27	43
Median (s)	187	28	32
Minimum (s)	75	17	13
Maximum (s)	439	123	213
Dispersion (s)	364	106	200

The results show that the assembly of the product during passage 1 took definitely the most time. Students assembled the product in an average of 213 seconds, the shortest time was 75 seconds, and the longest time was 439 seconds. Such a long time resulted mainly from the lack of appropriate elements for assembly (which resulted in long-last searching for appropriate blocks) and inaccurate documentation. In passage 2, after execution of the 5S at the station and preparation of the paper assembly instruction, the students made the product on average 41s, the longest time was 123s, and the shortest 17s. It is worth noting that the two groups failed to assemble the product due to inaccurate instructions. In the passage 3, the students obtained the shortest assembly time and it was 13s. On average, the assembly, using the AR instructions, was 55s, with the longest time of 213s.

After working with the AR application, the students were asked to rate it in the survey (Table 2).

Table 2. Survey given to students after testing application. Mean values in second column.

Question	Scale 1-5
A) How do you evaluate the overall applicability of the application (in the context of the discussed issue)	3.35
B) How do you evaluate the interface's intuitiveness	3.5
C) To what extent the application of augmented reality facilitates the correct execution of the task	3.625
D) How important is the ability to rotate an object using the rotate function	4.125
E) How intuitive was the assignment of functions to the buttons on the screen	2.95

Students indicated that the biggest advantage of the application is ability to rotate the object using additional functions on the screen. At the same time, they rated this solution as not very intuitive.

5. Results analysis and conclusions

The data presented show that students obtained the best results during the pass 2. Slightly worse, they obtained during the transition using AR, and the worst during the pass 1. After the analysis, it was found that the longer assembly time while using the AR instructions (longer using a paper instruction) is primarily due to students being accustomed to paper instructions and lack of knowledge in AR. The survey suggest that improving interface and interactions can improve results.

It is planned to conduct studies with more diverse products. Pre-planned tests envisage the introduction of assembly instructions for 10 geometrically different products moving on the assembly line. Each of the product types will have an individual AR marker placed on the transport tray which, after being scanned by the device, will display its assembly instructions. For each workstation the products will change in an random order or according to predefined production plan.

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KNOWLEDGE EXCHANGE USING HOLOGRAMS IN THE TEACHING FACTORY CONCEPT

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ABSTRACT
Industrial production systems as well as manufactured products are constantly evolving due to new technologies and customer demands. Towards ensuring an optimized co-evolution of both, the concept of Teaching Factory uses advanced ICTs and high-grade industrial didactic equipment to operate as a non-geographically anchored learning "space". In this context, we propose a novel collaborative framework utilizing holograms in aid of exchanging new technologies and manufacturing concepts between remotely located factories and classrooms in real time. The proposed approach will enable for the visualization of a complex CAD model or advanced tool in real dimensions in the laboratory, as well as the interaction with the holograms. From the industrial side, it will enable the use of simple mobile devices to navigate between components and views and display annotations. To support this setup, a prototype has been implemented and integrated involving a holographic system, a low-cost finger tracking device and a mobile device so as to exchange information in real time by intuitively manipulating CAD models during a live session.

Keywords: holograms, teaching factory, knowledge exchange

1. INTRODUCTION

Manufacturing is the dominant sector of the European economy, since each job in manufacturing is linked to two additional jobs in high quality services and also exerts a strong technology pull on research and innovation, so the EU depends strongly on the dynamism of its manufacturing industry (Manufuture 2018). The Industry 4.0 paradigm has introduced a new workflow for production systems by integrating the latest advances in Information and Communication Technologies (ICT), Virtual and Augmented Reality (VR and AR), cloud computing and networking, smart sensors, cyber-physical systems and others (Mourtzis, 2018). Moving forward to this paradigm, novel life-long learning schemes are deemed essential to keep up with the rapid advances in production related technologies, tools and techniques (IMF (International Monetary Fund 2013). Over the last decade, digital manufacturing has been considered a highly promising set of technologies for reducing product development times and cost as well as for addressing the need for customization, increased product quality, and faster response to the market requirements (Chryssolouris, Mavrikios, Papakostas, Mourtzis, Michalos and Georgoulias 2008). In this new era, the skills required by modern engineers are constantly evolving; making life-long education more relevant than ever (Chryssolouris, 2013).

Quality and availability of skilled workforce and its ability to lead innovation constitute the most important factor for manufacturing competitiveness. However, a lack of available personnel, having the required skills, especially digital skills, has been identified in the manufacturing sector. Skill gaps and shortages hinder the industry's innovation performance world-wide. Although Industry 4.0 has begun being integrated into manufacturing, there is still much to be achieved in the domain of educating and attracting young talents in the industry (Antoniou, Rentzos, Mavrikios, Georgoulias, Mourtzis, and Chryssolouris 2016). The employment pattern in the manufacturing industry is changing towards more knowledge and skills-intensive jobs (Mavrikios, Georgoulias and Chryssolouris 2018). Thus, new approaches are required for manufacturing education in order to i) modernize the educational methods and bring them closer to the industrial practice, ii) leverage industrial practice through new knowledge, iii) support the transition from the manual to the future knowledge-based work positions and shorten the gap between resource-based manufacturing (labor and capital) and knowledge-based manufacturing (information and knowledge) and iv) establish and maintain a steady industrial growth. To effectively address the emerging challenges for manufacturing education and skills delivery (Hanushek, Wößmann, Jamison, E.A. and D.T. 2008, Eurostat 2013, Ifo Institute, Cambridge Econometrics, Danish Technological Institute 2012) the educational paradigm in manufacturing needs to be revised. Many educational institutions have tried to bring their educational practice closer to industry (Chryssolouris, Mavrikios and Mourtzis 2013, Dinkelmann, Riffelmacher, and Westkämper 2011, Tisch, Hertle, Cachay, Abele, Metternich and Tenberg 2013, Wagner, AlGeddawy, ElMaraghy and Müller 2012, Abele, Metternich, Tisch, Chryssolouris, Sihn, ElMaraghy, Hummel, and Ranz, 2015) also with the concept of a Learning Factory. A drawback of this approach may be that the dedicated equipment, which is installed on the academic settings, may at some point become obsolete. Consequently, dedicated learning factories have the intrinsic limitation of narrowing down their scope, based on the existing equipment.

The Teaching Factory concept is based on the knowledge triangle notion (Chryssolouris, Mavrikios and Rentzos 2014, Rentzos, Mavrikios and Chryssolouris 2015) and has its origins in the medical sciences discipline and specifically, in the paradigm of the teaching hospitals, namely the medical schools operating in parallel with hospitals. It aims to incorporate the learning and working environment from which realistic and relevant learning experiences arise. In the Teaching Factory manufacturing practitioners "teach" students in Engineering Schools about manufacturing problems, manufacturing issues and manufacturing practice. The concept also involves the other direction, that from a classroom to a factory, where students and faculty "teach" manufacturing practitioners about advances made in manufacturing technology, new trends, results of research and development work. The Teaching factory is a "two-way street", where from the factory, practitioners teach students and from the classroom, students and faculty teach practitioners. This two-way street is realized via internet and is a continuous process over a lengthier period of time, with regular sessions and continuous interaction between the factory and the classroom. The modular nature of the Teaching Factory may suit the needs and limitations of both the academia and industry. Not all manufacturing problems can have their solution worked out via the method proposed in this study. This is the reason why the Teaching Factory asks for a high-degree of modularity when adopted for academic and industrial practice. New ICT technologies may help the concept to be implemented; and there is room for the ICT technologies of the Teaching Factory to be improved in terms of didactic content (Chryssolouris, Mavrikios and Rentzos 2016).

Teaching and training have not kept pace with the advances in technology and skills' shortages are reported to have had a negative effect on innovation performance (Tether, Mina, Consoli and Gagliardi 2005). Although far from mainstream, there has been a lot of interest in the potential of VR applications for learning and teaching in recent years. Simulations are a modern means of providing realistic context in which learners can explore and experiment, with these explorations allowing the learner to construct their own mental model of the environment. The interactivity inherent in simulations allows learners to see immediate results as they create models or try out their theories about the concepts modelled (Rieber 1992). Serious games and VR delivery mechanisms are popular with young people, and in general also tend to be used occasionally in formal education and there are examples, where games used with sufficient support are shown to be motivational and an aid to learning high level or complex skills (Bonde, Makransky, Wandall, Larsen, Morsing, Jarmer, and Sommer 2014, Eseryel, Law, Ifenthaler, Ge and Miller 2014).

The study presents an approach toward realizing a Teaching Factory using holographic technologies implemented under the umbrella of Education 4.0. The combination of traditional methods and Industry 4.0 technologies will create a result that will be highly interesting and at the same time educating for its attendees, aiding and smoothing integration in manufacturing (Mourtzis, Vlachou, Dimitrakopoulos and Zogopoulos 2018). The holograms enabled Teaching Factory approach presented in this study aims at a much broader use of novel learning methods for the introduction of young engineers to a possible wide spectrum of manufacturing problems. The aim is to effectively integrate education, research and innovation activities into a single initiative, involving industry and academia. Towards that end, the proposed Teaching Factory paradigm focuses on integrating industry and academia, through novel adaptations to the teaching / training curricula, achieved by the deployment of holographic technologies.

Regarding the structure of the present paper, after this introductory section, the holograms-enabled Teaching Factory concept is presented in detail in section 2. Section 3 presents the implementation of the proposed system, while section 4 presents the case study for the early validation of the proposed method. Finally, section 5 compiles the conclusions.

2. HOLOGRAMS ENABLED TEACHING FACTORY CONCEPT

The aim of the Teaching Factory paradigm, as previously mentioned, is to involve aspiring young engineers in an environment in close collaboration with experts on the field, in order to familiarize them with its requirements and enhance the collaboration between involved parties with different knowledge and background. Moreover, it is important to update traditional Teaching Factories with emerging technologies and expand their contribution. Shifting from the traditional teaching courses to the framework of Education 4.0 requires a careful design and combination of the traditional manufacturing techniques with the technologies introduced by Industry 4.0.

The proposed method aims to enhance the Teaching Factory experience, by involving the projection of 3D objects in mid-air, as holograms and the intuitive interaction with them, in a collaborative way between academic and industrial partners. The VR technologies utilized, achieve an advanced form of visualizing complex geometries of products or mechanisms and interacting with them, so as to facilitate the knowledge transferring process. The system is capable of importing complex CAD models, rendering them in stereo and implementing user interaction, through both visual and gesture input feedback.

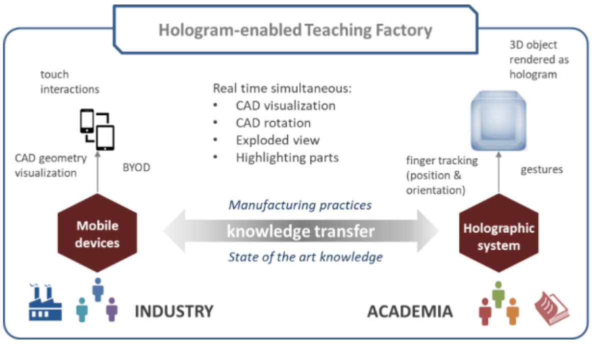

Figure 1: Hologram enabled Teaching Factory concept

As can be seen in Figure 1, from the industrial side, engineers will be able to use their mobile devices to view and interact with virtual models, display information about parts and highlight components by simple touch interactions. Simultaneously, the students will be able, apart from exchanging oral information through teleconferencing sessions, to view the same geometries as the engineers, and inspect the 3D objects projected upon the holographic display in their actual physical volume in their real dimensions. Additionally, using a low-cost finger tracking device, the academics will be able to manipulate the holograms by grabbing and rotating them, explode the view, highlight and assemble parts from their side. The system displays great potential, as it allows for collaboration of actors from different backgrounds and can also provide animated mechanisms for better understanding.

3. HOLOGRAMS ENABLED TEACHING FACTORY IMPLEMENTATION

3.1. Holograms-enabled knowledge transfer end point

The first part of the implementation involves the visualization of the designed product as a hologram and the realization of interacting with it. For the visualization of holograms in this method, a dedicated holographic display that consists of a 3D monitor and an optical see through (half-silvered) mirror has been utilized. The 3D display supports passive stereoscopy; thus, passive 3D glasses are required. To enable motion parallax, a simple camera provides feedback for the user’s head position. The virtual objects are projected upon a nine optical layer glass panel, being perceived as floating in space if the correct depth lighting, shadows and movement are added in the VE engine (Unity 3D). In the physical space, the movement of the consecutive position of the user’s fingers is tracked, with Leap Motion (Leap Motion 2018); a low-cost finger tracking device that is designed to detect and track hands, fingers and finger-like tools. Each update interval, the input of the user’s actions is transferred to the virtual environment (Figure 2).

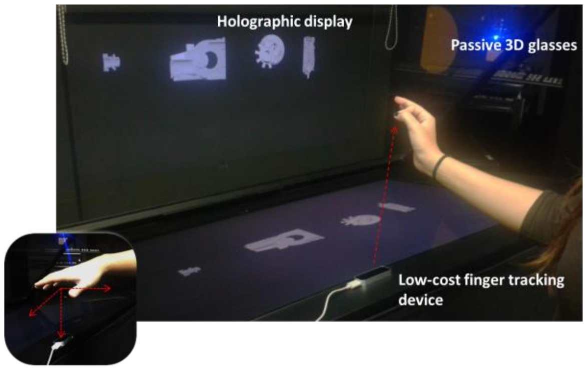

Figure 2: Holographic system configuration

For the acquisition of the position and orientation of the real hand, the Leap motion Unity asset has been imported. The controller recognizes the position of the fingertips and the position and orientation of the palm (x, y, z coordinates for position, roll, pitch and yaw values for orientation. The device also tracks some basic gestures and performs a real-time calibration of the data sent to the virtual environment, so that their position corresponds to the real world. The virtual environment is configured so as to present virtual hands and objects from a perspective stereoscopic view in their true dimensions. The result is a representation of virtual hands and objects in their true dimensions, appearing in mid-air, as holograms. Considering that the CAD geometries have to be represented in the VR environment they are converted from the CAD software used such as CATIA (CATIA 2018) to a format readable from Unity such as .obj. The application of the holographic system is compiled with Unity networking to allow the simultaneous instances on the mobile devices and the holographic system and runs in a single computer in the side of the holographic system.

Depending on the VE engine used, the position of the virtual hands (acquired by tracking the physical hands) and the position of the virtual object in the VR environment serve as input to a grab algorithm that has been implemented to enable object manipulation. Virtual objects in the scene can be grabbed based on the provided SDK available functionality. To enable students to manipulate the holograms, a set of gestures has been defined, that correspond to specific actions. The 3D motion capturing device tracks the actions of the user’s hands and whenever a gesture from a predefined list is detected, a certain id is generated. This id gesture is sent from the instance of Unity executed in the holographic system to the instance executed in the mobile interfaces via Unity networking, so that the gestures of the students also have a visual effect on the industrial side. Thus, the students can perform operations, such as grabbing/releasing the object, translating and rotating it, explode or compact the view of the CAD and highlight specific parts operations such as those of translation and rotation in a natural, intuitive way.

3.2. Mobile device-enabled knowledge transfer end point

For the industrial partners, the Unity scene is compiled for android mobile devices into an .apk and can also be available through a store. As seen in Figure 3, the users, after installing the application, can use it to visualize and interact with the virtual geometries with simple touch operations.

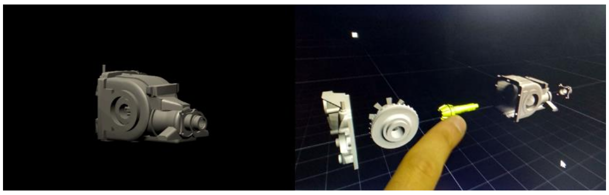

Figure 3: The mobile device-enabled end point of the Teaching Factory

4. CASE STUDY

A test case was conducted on a teaching factory course use case in order to estimate the functionality and usability of the proposed method. The participants, four mechanical engineering students, were familiar with the hardware used and had previous experience with VR technologies. The course was broken down into steps, where the participants, go from the design to the manufacturing and the assembly of a car differential. The proposed method was used to create a holistic experience for the participants, and also providing input for the collaborating engineers regarding the challenges and possibilities offered by the novel technologies.

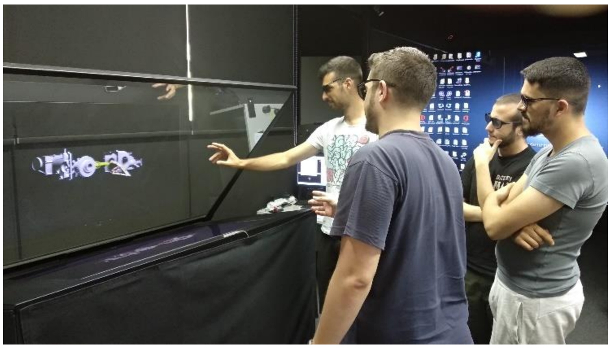

Figure 4: Teaching Factory session in the University

The students utilized the proposed collaborative environment to exchange knowledge on the design of several different CAD designs (Figure 4). The participants benefited from the holographic method in the virtual prototyping of the differential, both by becoming aware of their mistakes in the earlier steps of design, thus preventing errors that may be critical in the next steps, while also better understanding the mechanism.

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DEFINING THE PARAMETERS FOR A HOLOGRAPHIC TELEPRESENCE CLASSROOM EXPERIENCE

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Conference topic (domain). – Holographic visualization.

Contribution. - Original Paper.

ABSTRACT
Through communication systems, human beings have always sought to be able to have contact with others as if they were really in the same place. In our condition as social beings, people need to communicate. Communication allows transmitting information and exchange or sharing ideas, which enriches the human experience. Communication is of vital importance to develop our potential. With holographic telepresence the level of engagement and the exchange of information in a lecture, it flows as natural as having a conversation in the same room even though the speaker is not there. The objective of this project is to demonstrate that by defining the correct parameters for a holographic telepresence setup it will facilitate to reproduce the use of this technology in future university courses.

Keywords: Holography, telepresence, flexible learning, remote assistance.

1. INTRODUCTION

Ever since smoke signals, carrier pigeons, the telegraph to the modern computer and smart phones, the thing that is common among these technologies is the way, it has changed how the human being communicate. Newer advancements like texting and messaging apps have spurred even more efficiency within workplace communication. We have come a long way since the days of written letters and memos. Even email has become a secondary form of communication in the workplace as chat platforms are taking over. This is where the concept of "telepresence" enters, and it consists of a combination of technologies that seeks to represent a person that is in a distant location as if it was there. Although, in telepresence systems it is important for the images to have a real-world scale. In telepresence systems, the goal is to make the user lose the notion that has some intermediate devices with a lot of technology and that can act in a natural way.

Luis Lombardero, author of "Trabajar en la Era Digital" (Working in the Digital Age), very aptly points, regarding this new conception of mobility based in new technologies, that has made technology to evolve towards everyday use, which forces any project of digital transformation to consider mobility as a tool for controlling remote appliances, sensors or applications, for accessing the information in businesses, helping the relationship with clients or coworkers, among other uses. Between these uses professor Lombardero, highlights the concept of "telepresence", and how it can be applied by seeing an image of a user being projected on a screen or in a hologram, or through a remote-control robot (Rojas, 2016).

Moving towards an accessible, personalized and quality education is of great interest to the international community, for this reason there are several alternatives to be able to offer distance education. Based on this premise, the subject of personalized and immediate attention is an area of opportunity that many institutions and companies in technology focused on education have begun to explore. This project it is a telepresence model developed in the University of Tecnologico de Monterrey. The model offers the experience of having a professor in a holographic projection in a classroom, granting virtual mobility from any part of the world with real-time and personalized interaction for students, giving it a social presence in the classroom, even when it is not physically present, thus humanizing long distance education. The objective of this research is to facilitate the assembly for a correct transmission by identifying the factors and parameters involved so that the use of this technology can be replicated with ease.

2. PREVIOUS WORK HOLOGRAPHIC TELEPRESENCE MODEL.

In the education sector, offering an innovative, low-cost, easily scalable and adaptable solution to different learning styles is what constitutes the main benefit of this project. Being able to connect holographic projection in real time to teachers, specialists, mentors, etc., provides the opportunity to generate an advanced communication channel, where any teacher, regardless of the school level or subject, can give personalized attention to their students. A telepresence model can help solve problems such as transportation costs, insecurity, mobility, and geographic dispersion and / or personalized attention in real time at a distance (Luevano & Lopez, 2014).

In the search of making the telepresence experience the best possible the Tecnológico de Monterrey research group has arrived at the Holographic Projection. In this context of new technological resources, in the digital world of constant transformations, where this research group is currently working on. They developed an educational innovation that proposes holographic projections in real time. In which the professor can be seen and heard by the students, through a holographic projection that includes sound and voice in two ways.

Being able to see the teacher in a holographic representation on a real scale, generates a very different set of emotions in the student, having the possibility of interacting in real time with him, as if he were physically present, causes the student to feel really accompanied in the teaching-learning process. Unlike traditional videoconferencing where it is assumed that the teacher is not (Luevano, Profesor Avatar, 2016).

Telepresence with the Holographic Projection applied in a college course will allow the professor to, without limits as far as distance, weather, time difference, etc., to give his class on time and in a form that while he isn't physically there in the classroom. This technology enables cost saving because it won't be necessary to travel to other cities just to give a class, conference or meeting (Luevano & Lopez, Uso de Dispositivo Móvil de Telepresencia en la Educación a Nivel Universitario, 2014).

In the University of Tecnológico de Monterrey, professor Eduardo Luévano from campus Zacatecas has been doing research and working on making the long-distance education process more efficient. His research is centered in the telepresence concept. He and his research team where searching to improve the telepresence sensation given by the professor, so they proposed to integrate a complement to long distance education, which is holographic projection (Figure 1 & 2). They believe that integrating this technology with videoconference and telepresence robot, they can assemble a technological package that will allow supplying, but never to replace, the temporary physical absence of the teacher in the classroom (Luévano, 2015).

The research team launched "Reto i" (i Challenge) that it's a collaboration network that we launched to a group of universities across all over Latin America, with the objective of demonstrating that multiple telepresence technologies can be used as teaching and support tools for multidisciplinary work groups (Luevano, Profesor Avatar, 2016).

Fig. #1 Holographic projection of an engineer professor from Zacatecas campus being projected in Monterrey campus.

Fig. #2 Holographic projection of professor Eduardo Luévano from Zacatecas campus being projected in Monterrey campus.

The one week i Challenge, required students to construct a sustainable electric generator using recycled material useful to solve a necessity of a local community in poverty. Facing a real problem in a community promotes student's social commitment awareness, allows them to relate classroom theoretical learning to practice, work collaboratively, and to develop decision-making, communication, and leadership skills offer sponsorship for the project.

The designed instruments used were surveys, photographic recollection and field notes. Some of the main results of the instruments analyzed to prove the project impact are:

87% perceived the holographic projection as the social presence of their professor
86% of the students were satisfied with the project
88% of the students felt comfortable with the “Professor Avatar”
93% would recommend this model to other students.
97% would participate again in tele-presence projects.

3. METHODOLOGY.

Communication over time has been evolving and improving so that people could have a much simpler and easier access towards the information that they need. Even before the emergence of technology, communication has been at the forefront of relationship building and business development, the exchange of ideas, talent, knowledge and creativity. That is what holographic and telepresence technologies are enabling. The level of engagement and interaction becomes more human and meaningful. Increasing the capability of a team of people, such as approaching a complex situation, gaining comprehension and finding solutions; wherever they are in the world.

The methodology used was Action Research (AR) that is the reflective process whereby, in each problem area where one wishes to improve practice or personal understanding, inquiry is carried out by the practitioner --; first, to clearly define the problem; secondly, to specify a plan of action --; including the testing of hypotheses by application of action to the problem. Evaluation is then undertaken to monitor and establish the effectiveness of the actions taken. Finally, participants reflect upon, explain developments and communicate those results to the community of action researchers. AR is systematic self-reflective inquiry by practitioners to improve practice” (McKernan, 1996).

The process of action research consists of:
1. Unsatisfied with the current state of things (Observe).
2. Identifying the problem area (Observe).
3. Identifying a specific problem to be solved by action (Think).
4. Formulation of multiple hypotheses (Think).
5. Selecting a hypothesis (Act).
6. Executing the action to prove the hypothesis (Act).
7. Evaluation of the effects of the action.
8. Generalizations.

The research methodology used in this project is of a qualitative nature, because it allows the use of different sources of information and produces descriptive data (peoples own words, written or spoken, and observable behavior). Its objective is the description of qualities of a phenomenon, since it seeks a deep understanding about the research topic. This methodology is of inductive character, it helps to understand the context and the people under a holistic perspective, and i.e. they are not reduced to variables, if not considered. It studies people in their context of their past and in the situations, that they are. McNiff, J. (2002)

The qualitative methods used were:
Interviews, action research and observation. In some cases, surveys were used as a quantitative method, with the sole purpose to enrich the investigation.

4. PROPOSING SETUP FOR HOLOGRAPHIC TELEPRESENCE.

4.1. Definition of the setup.

The purpose of this work is to propose a setup and a method that can potentially improve and help so that others may easily carry out their own holographic telepresence communications with ease.

This method will present the knowledge, basic requirements and step by step guide, so that the users can understand and may save time in the installation and setup. It is not intended to replace other forms of communication but the contrary it is a proposal for enhancing the remote telepresence experience, so that its use can be further divulge and be as natural as other mediums of communication as a telephone, instant messaging, social networks, etc. (Quintero, 2017) . The key factors that define the correct setup for this means of communication are listed and described and divided into three categories: Structure/Components, Software and Ambient considerations.
See Fig. 3:

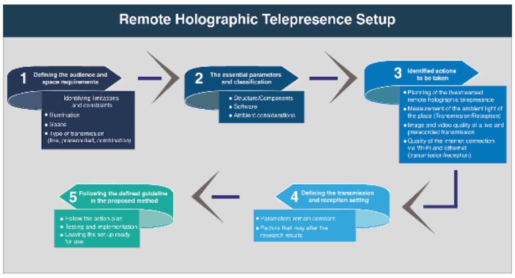

Fig. 3. Proposed solution for improving and accelerating the setting process of a Remote Holographic Telepresence communication system.

The essential structure and components for the parameters that are considered in this study are:

Transparent Glass or Acrylic: The screen is a pane of tempered glass or transparent acrylic, preferable 2 meters high and at least 1.3 meters wide. This transparent pane should be held upright in a sturdy manner and should have nothing immediately behind it.
Holographic film: This is a polarized semitransparent film sticker that adheres to a transparent glass or acrylic screen. The film has crystalline Nano-structures that retain light emitted by the projector.
Computer: with 4GB RAM memory and a faster processor will render greater image stability and quality.

Proceedings of the International Conference of the Virtual and Augmented Reality in Education, 2018
ISBN 978-88-85741-20-1; Bruzzone, Ginters, González, Gutierrez and Longo Eds.

Internet connection: For live transmission, it is critical to have good internet connection, preferably 10 Mbps or greater.

Projector. Another key component is the projector. Here are some considerations:

a. Use a projector of at least 3,500 lumens.

b. Long throw (standard) projectors emit uniform luminosity. When projecting an entire person in life-sized scale the entire body is correctly illuminated. The restriction of long throw projectors is that they require greater distance between the projector and the screen to achieve life-size scale.

c. Short throw projectors have the advantage of reducing the distance necessary between projector and screen to achieve life-size scale. The disadvantage of these machines is that they emit non-uniform luminosity. For example, when projecting an entire human at life-size scale, only the upper half is well illuminated while the legs fade out of sight. We recommend short throw projectors for half-body images. One example would be a person sitting at a desk and visible from the surface of the desk upward.

d. The projector is placed behind the holographic screen shining toward the audience, but at a slight angle so that its light does not hit the audience directly in the eyes. The holograph will appear uniformly visible to the audience.

Audio equipment. The dimensions of your audio system should correspond to the dimensions of your classroom or auditorium.

Black background for transmission, The background can be a paper cyclorama or a fabric with no sheen, such as muslin.

4.2 Setup tests & transmission.

After it was agreed that there was going to be a livestreamed class from RWTH Aachen University to the University of Tecnologico de Monterrey (Monterrey campus). Weekly rehearsal meetings were scheduled with the purpose of planning and rehearsing the setup with the professors that were going to give via holographic telepresence their lecture. During the tests multiple measurements of the ambient light of the transmission & reception rooms were taken, internet connection tests & adjusting the scale of the projector's shot. After following these guidelines previously rehearsed a great improvement was shown in the projection (Quintero, 2017). See Fig.5.

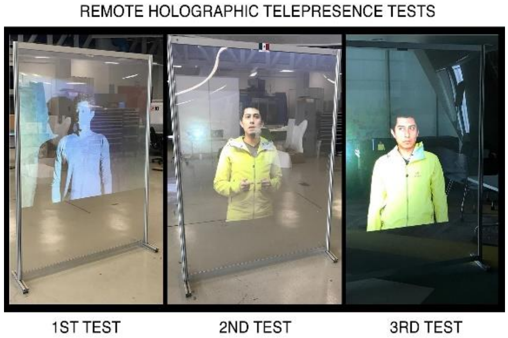

Fig. 5. Comparison between the evolution of the remote holographic telepresence by following the identified parameters and guidelines.

The reception took place in Monterrey, Mexico and the transmission in Aachen, Germany and the duration was of one hour. The remote holographic telepresence setup was put in order according to the identified parameters and guidelines that were previously rehearsed. Thirty students from the university of Tecnologico de Monterrey campus Monterrey (Mexico) attended this class, that was being transmitted from the RWTH Aachen University and Dr. Horacio Ahuett who was visiting Aachen was the lecturer. See Fig. 6a & 6b.

Fig. 6a Holographic telepresence projection presentation of professor’s (from left to right) Dr. Kurfess Dr.Horacio Ahuett and Pedro Orta two different and distant locations Germany/Mexico

Fig. 6b Holographic telepresence projection presentation of an official university class being taught from two different and distant locations Germany/Mexico

5. RESULTS & DISCUSSIONS

In Figure 7 it is illustrated how the proposed Remote Holographic Telepresence Reception should be setup according to the requirements mentioned before. In this case, it will be used a long throw projector that is recommended to be set at 5m behind the holographic screen, so that it will be a lot easier to adjust the image to a full human scale body (as illustrated in the figure). For the position of the webcam the ideal position should be at the eye level of the spectators, but if that it’s not possible another recommendation will be to put it on a location that gives it a broad field of view of the target audience; so that the speaker may be able to see who is he addressing.

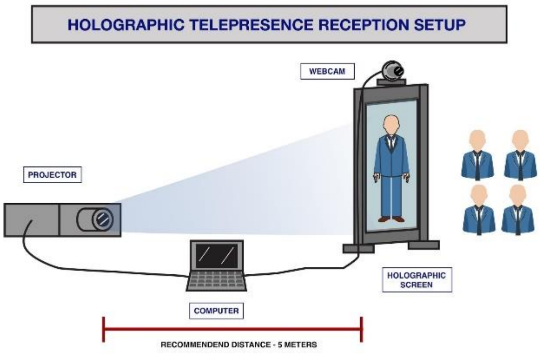

Fig. # 7 Hologram Reception Setup.

The audience should sit in front of the screen, but depending on the power of the projector it is sometimes advisable not to feel at the center but to one side of the screen about 30 degrees approximately, as they can be blinded by the power of the shot of the projection. In Figure 8 is a demonstration of the different perspectives of a holographic screen.

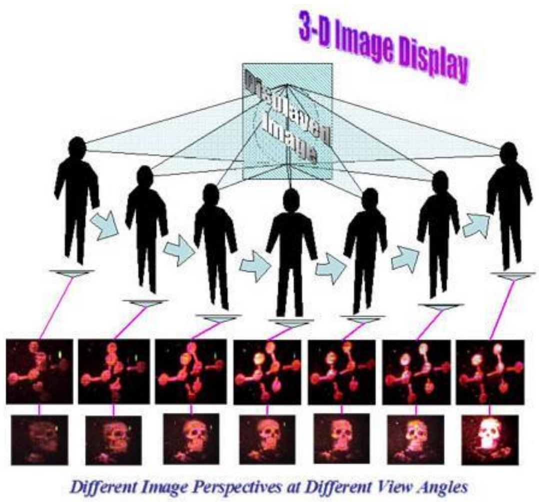

Fig. # 8 Different Image Perspectives of a 3D Image Display.

In the next Figure 9 it is illustrated how the proposed Remote Holographic Telepresence Transmission should be setup according to the requirements mentioned before. In the figure, it is shown that the user needs to be in front of the black background. The position of the webcam needs to be adjusted so that the only thing visible that will be transmitted will be the black background and the user nothing else. Depending on the space where the transmission will be taking place and the type of lighting, it may be necessary to have a couple of fill lights, so that the user may appear well lit. In Figure 10 the setup can be appreciated from a side view.

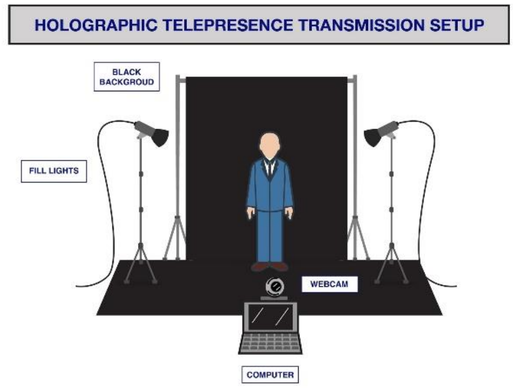

Fig. #9 Hologram Transmission Setup as seen in a front view.

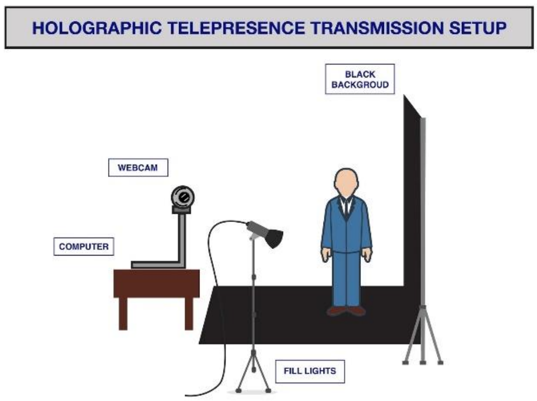

Fig. #10 Hologram Transmission Setup as seen in a side view.

The survey was applied to 20 students who participated in the experimentation of the remote holographic projection of Dr. Horacio Ahuett's class that was transmitted from RWTH Aachen University (Germany) to Tecnológico de Monterrey campus Monterrey (México).

The survey that was applied consists of a total of 8 questions in which the students could choose out of 5 possible answers: Total Disagreement, A Little Agreement, Agree, Strongly Agree and Totally Agree. In the following table 1 are the results and impressions of the students that attended the class.

Question 1: During the interaction in class I perceived the virtual teacher as if he were a real person	
Answers	**Number of students (out of 20)**
Total Disagreement	0 students
A Little Agreement	0 students
Agree	5 students
Strongly Agree	8 students
Totally Agree	7 students

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Question 2:
During class, the holographic telepresence mode allowed me to follow the instructions optimally

Answers	Number of students (out of 20)
Total Disagreement	0 students
A Little Agreement	1 student
Agree	3 students
Strongly Agree	10 students
Totally Agree	6 students

Question 3:
In this mode of virtual teaching can you interact with the teacher as if he were present?

Answers	Number of students (out of 20)
Total Disagreement	0 students
A Little Agreement	3 students
Agree	8 students
Strongly Agree	5 students
Totally Agree	4 students

Question 4:
In this virtual teaching mode, can I express my doubts to the teacher?

Answers	Number of students (out of 20)
Total Disagreement	0 students
A Little Agreement	3 students
Agree	3 students
Strongly Agree	7 students
Totally Agree	7 students

Question 5:
How well do you agree that you have at least one class taught by this method?

Answers	Number of students (out of 20)
Total Disagreement	2 students
A Little Agreement	2 students
Agree	7 students
Strongly Agree	2 students
Totally Agree	7 students

Question 6:
Do you consider this mode of virtual teaching a good option to replace some kind?

Answers	Number of students (out of 20)
Total Disagreement	0 students
A Little Agreement	1 student
Agree	1 student
Strongly Agree	3 students
Totally Agree	15 students

Question 7:
Was I satisfied with this mode of experienced virtual teaching?

Answers	Number of students (out of 20)
Total Disagreement	0 students
A Little Agreement	1 student
Agree	4 students
Strongly Agree	5 students
Totally Agree	10 students

Question 8:
Would you recommend to your classmates this type of virtual teaching?

Answers	Number of students (out of 20)
Total Disagreement	0 students
A Little Agreement	2 students
Agree	5 students
Strongly Agree	3 students
Totally Agree	10 students

Table 1 Questions and answers of the holographic telepresence class survey.

The feedback received by this remote holographic telepresence experience by the students was mostly positive, more than half of the students that answered the survey agreed that this form of communication served its purpose and will ensure that classes are not rescheduled.

6. CONCLUSION

It was verified that by identifying the parameters for a remote holographic telepresence transmission, challenges and complications could be identified, also it was possible to streamline and facilitate the assembly process. Since this series of instructions served and could be replicated easily in another place without major problems. By correcting the parameters, it was possible to change drastically the quality of the image both recorded and live transmission.

As for the transmission, it was possible to do it in a reduced space of 0.5 meters to 2 meters of distance of the camera, although only the projection left in half body. But for the reception of the holographic projection due that the work was made with a long throw projector the most that the space could be reduced space sacrificing human scale was 4 meters of distance between the projector and the holographic screen. Tests with short throw projectors were made but it distorted the proportions of quality and size of the holographic projection.

Holographic projection technology clearly has a big future ahead. As this audiovisual display continues to get high profile credibility, we are likely to see more companies advertising their products or marketing their business in this way. The holographic projectors that are under development will be able to be much smaller and portable than image projectors that rely on conventional, incoherent light beams. Ultimately, holographic projectors may become sufficiently small to be incorporated into future generation cell phones.

Holographic projectors will be able to render sharp projected images from relatively small projection devices (e.g. cell-phones) because they do not require high intensity, high-temperature light sources. Investigators at companies and universities are working toward applied science that could make television with holographic projections that can project moving, three-dimensional pictures outside of the screen (Elmorshidy, 2010).

7. ACKNOWLEDGMENTS

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THE USE OF AUGMENTED REALITY TO PROMOTE TOURISM IN THAILAND

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ABSTRACT
Tourism industry plays an important role in Thailand. But only popular places can attract the tourists. This research is aimed at developing a mobile application using augmented reality to attract the domestic tourists to visit new attractions in Lan Saka District. Fifteen points of interest along the local road were selected, and the AR mascots were designed for these locations. At each attraction, tourists can find the signboard that will be used as a marker. With the downloaded application, tourists can use it to take the photo of the mascot which will then convert to bonus points. They can use the bonus points when purchasing products or service. With the social application software, the tourists can share the photo that they took with their friends. The application has been launched and use in Lan Saka District. From the observation, this application got good feedback from the tourists.

Keywords: augmented reality, tourism, attraction, mobile application

1. INTRODUCTION

Thailand's tourism sector has played an increasingly important role in the economy in recent years. The total contribution of Travel & Tourism to GDP (including broader effects from investment, the supply chain, and induced income impacts, was US$ 92.3bn in 2016 (20.6% of GDP) and is expected to grow by 9.4% to US$ 100.9bn (21.9% of GDP) in 2017. Direct contribution from international arrival in 2016 is US$ 58bn (+11.66%) and US$ 30bn (+5.42%) for domestic tourism. Even though, the numbers seem to be impressive but in fact, it concentrates in some specific area like Chiang Mai, Bangkok, Pattaya, and Phuket. To add a new destination for the tourists, marketing tools should be used, and augmented reality (AR) may be the answer. Augmented reality has been used in edutainment for quite some time but became well known all over the world due to the Pokemon phenomenon. In this research, we are going to use this technology to expand the tourist destination to domestic travelers. The target area for this research is in Nakorn Si Thammarat Province, which is located in the southern part of Thailand not far from Samui Island, the famous tourist attraction in the south of Thailand.

Nakorn Si Thammarat is divided into 23 districts. Lan Saka is a community that is well known for very fresh air (non-pollution area), beautiful scenery, and orchard. Lan Saka itself consists of 43 villages. Local government organization has a plan to promote the tourism industry in this area because there are many points of interest such as caves and waterfalls. Kiri Wong Village is in Lan Saka District. It is famous for the very fresh air and beautiful scenery. Most of the tourists have heard of Kiri Wong Village, but very few know other places in Lan Saka District. During high season there are a lot of tourists visiting Kiri Wong Village, it will be benefits to the nearby villages if groups of visitors also visit other places in that area. Currently, the villagers have set up the business. Some of them offer the accommodation (homestay) for the tourist. Other businesses are restaurants, coffee house, adventure activity (rafting) and theme park. To expand the attracting area for tourism will distribute the expense of tourists to other villages.

This research will study the community businesses and use the technology to promote the business. We will invite the tourists to visit points of interest along the local road, route 4015 and collect their experience with the 3D mascot. The photos taken with the 3D mascot can then be used to get the discount from the local shops that registered in the system.

2. LITERATURE REVIEW

ICT plays a vital role in tourism industry. It can be applied to use in many functions, i.e., sales and marketing, reservation, traveling, catering, housekeeping and so on. Besides using ICT in management and administration by the staff of hotel or traveling agency, it can be applied to provide additional information for the customers or tourists.

AR is a technology that the computer creating object can be displayed over the real-world environment. AR application can be run on a different kind of computer such as a desktop, notebook, tablet, or on the mobile phone.

Many mobile applications have been used in tourism industry such as tourist guide, museum guide, and theme park. (Kounavis, Kasimati, and Zamani 2012; Jung, Chung, and Leue 2015; Kourouthanassis, Boletsis, Bardaki, and Chasanidou 2015) Some applications are marker-based, and some are markerless. It often found that the marker-based AR is appropriate for indoors and markerless AR is suitable for outdoor activities.

From the study on the use of mobile augmented reality travel guide, the feature of the software include providing information of points of interest, direction to the selected points of interest, and recommend the location to friends. The categories of the point of interest include sights, museum, religion, bars, sport, shopping, food, nature, and beaches. The result of the study showed the appreciation from the tourists of information about the places and the navigation that the application provided. (Kourouthanassis, Boletsis, Bardaki, and Chasanidou 2015) One reason for using mobile AR application is it is convenient for obtaining GPS information.

Many mobile applications were developed for tourists. Yovcheva, Buhalis, and Gatzidis (2012) conducted the study based on the given features in 22 mobile applications for tourism industry using AR. The criteria on the functionality of the application included search and browse, context-aware push, m-Commerce, feedback, routing and navigation, tour generation, map services, communication, exploration of visible surroundings, interactive AR view and filtering of AR Content. It was found that the applications did not support every feature. The features that some applications did not support are the context-aware push, m-Commerce, feedback, and routing. They also suggested that the providing information should be improved to suit the tourists.

For tourists, they may require information that based on the outdoor location that they visit. In some case such as the heritage, AR and Virtual reality (VR) can help the tourist to visualize the ancient architecture without touching real ancient artifact. (Noh, Sunar, and Pan 2009)

Keckes and Tomicic (2017) had reviewed the use of AR in tourism to identify the success factor in developing AR application classifying as general requirements, functionality, issues, overlay types, and technology. Many research papers are focused on the augmented visual object, but there was some non-visual input that might appropriate when less distraction is required.

3. CONCEPTUAL FRAMEWORK

There are three things that people in the new generation prefer to do with their mobile phone, i.e., engaging with the mobile phone most of the time; taking photos of everything especially themselves (Selfie) with a mobile phone and buying things with mobile phones. People use a mobile phone to communicate either by calling, texting, chatting or sharing information on Facebook or Instagram. By rough estimation, more than 80% of the new generation of adults have a smartphone, and the rest have a mobile phone. From the behavior and availability of the mobile phone, all activities related to tourism should be on the mobile phone. Another new behavior that arises with a new smartphone is the passion of taking the pictures and shared them with friends or relatives. The last thing that we found about the new generation is that they prefer to buy things online. Combine those things altogether; we have designed the tourism promotion system to support every aspect for tourists in the new generation using AR as the main feature.

As mention earlier that we try to introduce other points of interest that tourist may not know before. To attract tourist to a new destination, we will use AR technology in this software application. We designed the software application to cover the three main features as shown in Figure 1. The first feature is having the mascot with the different characters at the attractive locations along the route 4015 for tourists to take the photo. Besides taking a photo of the scenery, tourists can take pictures of a virtual mascot or take the picture with the mascot. It will be more fun. The second feature, after taking the photo of the mascot, the image will be converted to bonus points for exchange with the discount of the products or services at the community shops or coffee shops in this area. For the third feature, the photos can be shared or tagged on social media for peoples to see and initiate a visit.

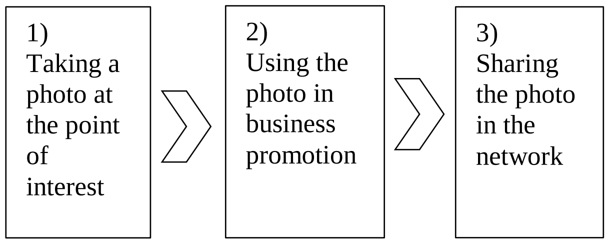


Figure 1: Research framework

4. METHODS AND STRATEGIES

System development life cycle (SDLC) method is used as a guideline in developing a software application. The phases include planning, systems analysis, systems design, developing, testing, implementation, and operation & maintenance. Due to the time limitation, some phases are combined to expedite the whole project.

In planning and systems analysis phase were combined to identify boundary and scope. The locations and mascot were selected. Focus group is used to gather the requirements and make the decision. In Lan Saka District there are thirty-one points of interest that the community wants to promote. These locations can be classified into the category such as historical place and temple, cave and waterfall, shop and restaurant, and farm and theme park. In this project, fifteen points of interest (Figure 2) were selected by the focus group. The chosen locations cover every location categories.

Figure 2: Points of interest along the route 4015

The information of these fifteen locations was studied to set the character of the mascot. The stories of each area were learned to understand the history, culture, belief and business activity. Since we are using the concept of "Pokemon go," so the lead characters should be able to represent this district. This virtual mascot should also be attractive to get the attention from the tourists. Nakorn Si Thammarat is famous for the fruits especially mangosteen, and Lan Saka is the only place that has old mangosteen trees that aged more than 100 years old. The focus group decided to select the character of mangosteen as the mascot. Figure 3 shows the mascot character that comes from the mangosteen.

After the mascot was selected, the details of fifteen virtual mascots were then designed. The systems design and development phase are combined to get the prototype of the application. In the testing phase, a stub test, integration test, and system test were conducted. Fifteen signboards were set at the selected locations in the implementation phase.

(a) (b)

Figure 3: Mascot character (a) and the mangosteen (b)

5. THE DEVELOPMENT OF AR TOURISM PROMOTION SYSTEM

The development of the AR tourism promotion system was combined with the design process. It consists of 4 steps as shown in Figure 4.

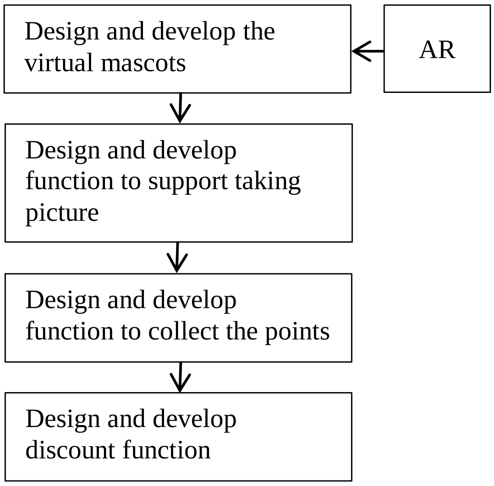


Figure 4: Detailed design and development steps

The first step is to design and develop the mascot. The mascot is the design in male and female character, and in three different ages, i.e., young and old mangosteen. From the information of fifteen points of interest, it is required to design the outfits that are different depending on the location the tourist visits.

In Figure 5, the mascots in the first row from left to right, the first mascot is paying the respect at the house of spirit. The second mascot is having fun at the water theme park. The third mascot is walking to the restaurant. The fourth mascot is at the temple, so he brings the lotuses and food container, and the fifth mascot carries the lamp and wears a headlight to get into the cave.

Figure 5: The mascot outfits for 15 points of interest

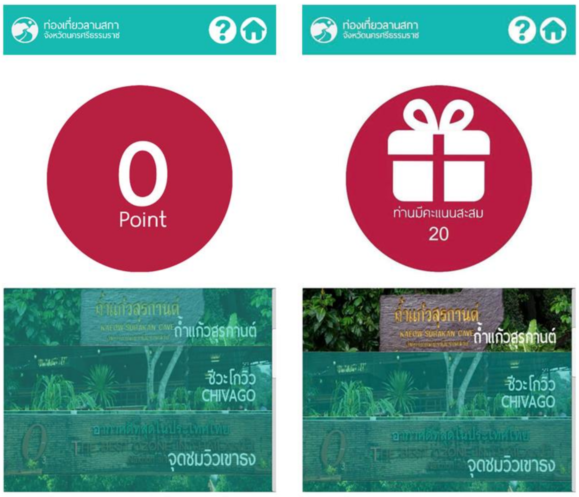
Figure 6: Size of signboard marker and virtual mascot

The second step is about the function that the tourists can take their pictures with the virtual mascot. Since there are two types of AR, i.e., marker-based AR and markerless AR, we have decided to choose marker-based AR due to the stability in use and the marker is the signboard located at every attraction points. Figure 6 shows the size of the signboard and the mascot related to human scale. We designed the mascot with the medium height (90 cm), so mascot's size is not too big when it is compared with the human body, and the height of the signboard is 180 cm. Tourist can download the application and use on iOS or Android platform to take the photo of the virtual mascot as shown in Figure 7 and keep the pictures in their mobile phone. When the signboards are set up at the point of interest, tourists can also take a picture of themselves with the mascot (Figure 8). The photos will then store on their mobile phone, so they can efficiently distribute these photos in their network using social network software. In this setup, we also program the mascot to be interactive with the environment. For example, if the mascot is appearing at the middle of the signboard and the tourist wants to take a selfie with the mascot, so he moves to the center of the signboard, the mascot will move to the side to avoid blocking the tourists. But if the tourist did not block the signboard, the mascot will stay wherever he is standing.

Figure 7: Signboard Marker and Virtual Mascot

Figure 8: Taking a photo with the mascot

Step 3 and step 4 are related to the promotion. In step 3, the application will convert the mascot photo to bonus points. In this model, one image is equal to 20 points. In one location, only one image is allowed to use to collect the point to avoid using the photos from one place to boost the scores and to encourage the tourists to visit other points of interest on the route. From Figure 9(a) is the screen showing the collecting points before taking the first photo of a virtual mascot, so there is no bonus point. Figure 9(b) showing the bonus points that are collected after the picture is taken. And to help the tourists to know the points of interest that they haven't got the bonus point yet, the different color of the icon was used. The location icon with bright color is the location that bonus points were already collected while the dimmed icon was the place that the tourist has not got the bonus yet.



(a) (b)

Figure 9: The collecting points can be displayed on the screen

In the final step of the design is the function that tourists can use the points that they got for the discount. On the screen, there is a list of the local shop that offers the discount when tourists are buying the products or services as shown in Figure 10. The shop's owner provides the information on the discount. Tourists can select the shop by clicking the "use discount" button that located nearby. If the tourists have enough bonus points, the screen will be displayed as shown in Figure 11. The displayed popup will ask the shop assistant to confirm the discount. After the button is pressed, the application will reduce the bonus points according to the amount of the discount.

Figure 10: Screen showing the list of offering discount from local shops

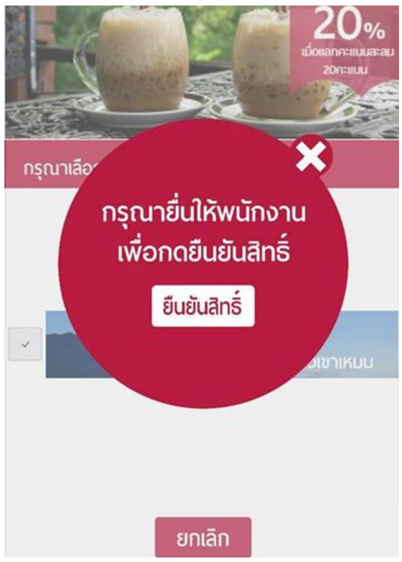
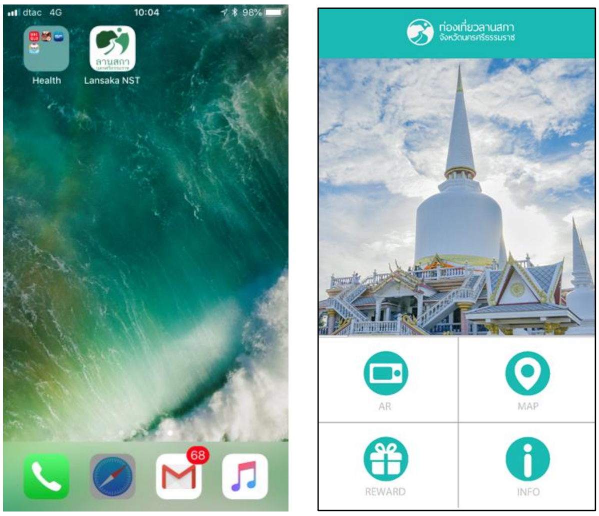


Figure 11: Pop-up for the shop assistant

6. EXPERIMENTAL SETUP

In developing the application, computer graphic software such as Maya is used for creating a 3D virtual mascot. Unity3D and Qualcomm's Vulforia are also required. Unity3D is a cross-platform game engine, used for developing 2D and 3D video games and simulations for computers and Vuforia is an augmented reality Software Development Kit (SDK) for mobile devices that enables the creation of augmented reality applications. After downloading the application, the icon of the application (Lan Saka NST) is then displayed on the screen as shown in Figure 12(a). The main menu in Figure 12(b) consists of 4 command buttons which are AR, map, award, and info. AR button is used to take a photo of virtual mascot, Map button will show the points of interest on the map, and Reward button is used to make the discount on purchasing.



(a) (b)

Figure 12: The Application and main menu

Fifteen signboards were set up in fifteen locations, and on each signboard, there are the pictures those use as markers as shown in Figure 13. The signboard is made of metal, and the base is made of concrete so they cannot fall. Later the community officers will look after the signboard when the project is finished.

Figure 13: The markers on the signboard

Figure 14: Installing the signboard in front of the ancient mangosteen tree

7. EXPERIMENTAL RESULTS

After installing the signboard at the fifteen point of attraction for one month, we have noticed that many people enjoy taking pictures with the virtual mascot and shares with their friends, but not many people use the bonus point to get the discount from the local coffee shop or community store. This may be because they did not know about the promotion.

The application of AR tourism promotion system was also introduced to the potential local tourists in 5 events holding in Nakhon Si Thammarat and Bangkok from January to April 2018 (Figure 15).

Figure 15: Promoting event at the Department Store in Nakhon Si Thammarat

7. CONCLUSION

Promotion to attract domestic tourists to the new tourist attraction using AR is the new way of using technology that everyone can use. Since the system supports both iOS and Android and does not need a high specification for the device, so everyone can enjoy using this application. Judging from the excitement that people showed, we believe that this kind of applications will fulfill our purpose in a short time.

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VIRTUAL AQUARIUM: TOOL FOR SCIENCE MOTIVATION USING AUGMENTED REALTY

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ABSTRACT
During the past decade, there has been some significant drop in the number of Thai students taking sciences class, even though the country is struggling to transform the economy into an innovation-driven one which needed lots of scientists. These may relate to many sources, but the most important one is the lack of inspiration and motivation in science. To fix these problems, we have to get them inspiration for sciences and augmented reality (AR) is the suitable technology to answer this question. In this experiment, children will be guided to learn about fish and build the virtual aquarium using AR. The children can create their 3D virtual fish from the 2D picture and let them swim in the aquarium. Testing this concept, we have found that lots of children start with curiosity about how it has been done and then went to try and finally enjoy the output.

Keywords: augmented reality, virtual aquarium, science inspiration, 3D animation

1. INTRODUCTION
During the past decade, there has been some significant drop in the number of Thai students taking sciences class, even though the country is struggling to transform the economy into an innovation-driven one which needed lots of scientists. The problems may relate to many sources, but the most important one is the lack of inspiration and motivation in science. Usually children, in their early years of education, often say that science is one of their favorite subjects but later on, when teachers introduce more complex concepts, they start moving away. Many researchers are working on the topics of how to motivate students to love science and one thing in common from their conclusion is that study science should be fun. There are many ways to make student enjoy learning sciences, for example, hands-on experiments and games. Today, almost all of the students have either smartphones or tablets, using the applications on those devices may be practical in term of financial and safety. In that case, augmented reality (AR) is the suitable technology to answer this question. AR is the technique that allows the virtual objects created by computer, such as text, 3D model or animation, to be overlaid and tracked atop the real world. The outcome is an illusion that displays as if they are in the same space. In this experiment, we are going to create the system that let the children choose the species of the fish and create the textures of their fish, such as color, birthmark or even put their name on the fish, on the 2D picture of the fish. Then using the algorithm, their 3D fish will emerge from the 2D picture. The last process will involve on letting the fish swim in the virtual aquarium without bumping to the other fishes in the tank. With this concept, children will have a chance to have a hands-on experience and enjoy their work which we hope that will inspire their creativity and motivation in science learning. The reason that we choose fish tank because it can teach the children about nature. Since all the fish are different, children can make them different in color, see different kind of fish behave differently in the virtual aquarium.

2. RELATED WORK
Many researchers are working on the concept of using AR to motivate and inspire children in many areas of study ranging from arts, music, culture, and science (Nielsen, Brandt, Swenson 2016). Rohaya, Rambli, Matcha, Sulaiman and Nayan (2012) presented the development of an engaging method for learning numbers via a highly interactive edutainment children storybook based on AR technology and an old folklore story. Gopalan, Zulkifli and Bakar (2016) did some experiment to determine whether the intervention of the enhanced science textbook using AR contributes to the learning process of lower secondary school students in science or not. The results provide empirical support for the relationship between engaging, enjoyment and fun and students' motivation for science learning. Gopalan, Aida, Bakar and Zulkifli (2017), reviewed some literature, searching for theories and model that could be applied to science motivation and find out that AR is suitable for that purpose. Since science has lots of intuitive processes which is hard to understand, therefore adding new technology like AR is necessary.
For the research on transforming 2D to 3D with color, many researchers are working to perfect this category. Clark, Dünser and Grasset (2011) presented a new type of mixed-reality book experience, which augments an educational coloring book with user-generated three-dimensional content. Users can color in the pages, and these pages are then recognized by the system to produce three-dimensional scenes and textured models reflecting the artwork created by the users. Kwangmoon, Hadong and Youngho (2016) develop an

AR coloring book with a transitional user interface. This AR coloring enables the user to enjoy content by switching between the real world, augmented reality, virtual reality, and networked virtual reality. Magnenat, Ngo, Zund, Ryffel, Noris, Rothlin, Marra, Nitti, Fua, Gross and Sumner (2017), present an AR coloring book App in which children color their favorite characters and then using texture generation algorithm to transform and inspect their 3D model using smartphone or tablets.

In this paper, instead of creating AR atop of the page on the coloring book, we create the 3D model from the coloring book and animate them onscreen in the aquarium so that they can interact with the environment in the aquarium.

3. CONCEPTUAL FRAMEWORK

Setting up the AR experiment on a virtual aquarium that will inspire science learning, three criteria need to consider. The first one is how children can create their identity fish. The second one is, how to create 3D virtual fish from the 2D picture (transform the texture of the coloring fish to the texture of the 3D model) and the last one is how to animate them and let them free in the aquarium without bumping into other fish. Figure 1 shows the conceptual framework diagram while Figure 2 shows the output of the process.

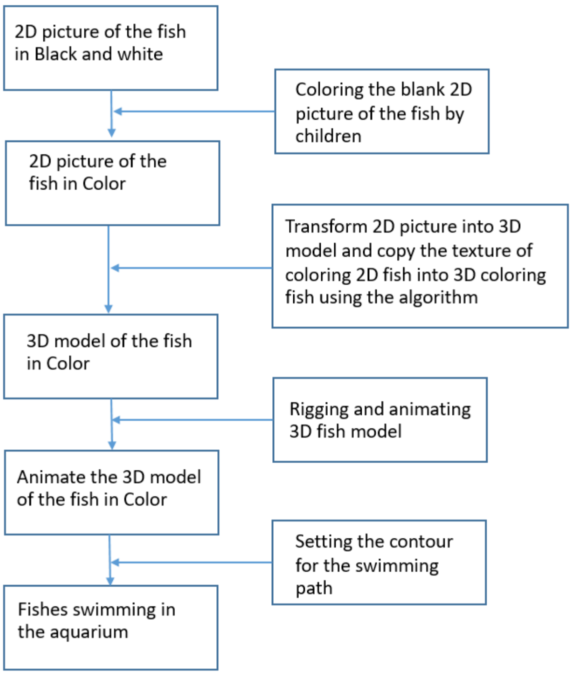

Figure 1: Conceptual framework

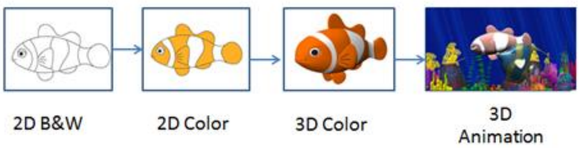

Figure 2: Flow diagram of the output

3.1. Create identity of the fish

For the children to create the identity of the fish, first, we allow them to choose the species of the fish which is a 2D sketch of the fish with the only black line on the white paper. Then we allow them to put on the various color of their choices on the fish and if they prefer, they can put the name of the fish or their name on the fish as well. Figure 3 shows the example of this activity.

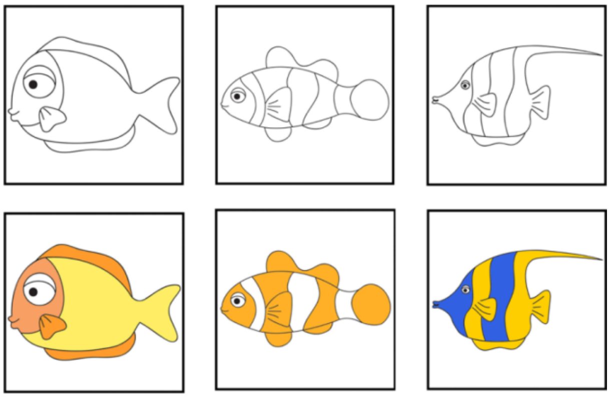

Figure 3: Create the identity of the fish

3.2. Transforming 2D picture into 3D model

Since we want the 3D model to look exactly like the 2D picture, so we are not going to use Direct Volumetric Convolutional Neural Network (CNN) Regression (Jackson, Bulat, Argyriou, and Tzimiropoulos 2017), or texture generation algorithm (Magnenat, Ngo, Zund, Ryffel, Noris, Rothlin, Marra, Nitti, Fua, Gross and Sumner 2017), to transform 2D picture to the 3D model which may give the model differ from what we expect. Instead, we will construct the model of 3D fish from the 2D picture using Maya. In this case, the shape and size of the model will be compatible with the 2D picture. Figure 4 shows the working process of this activity.

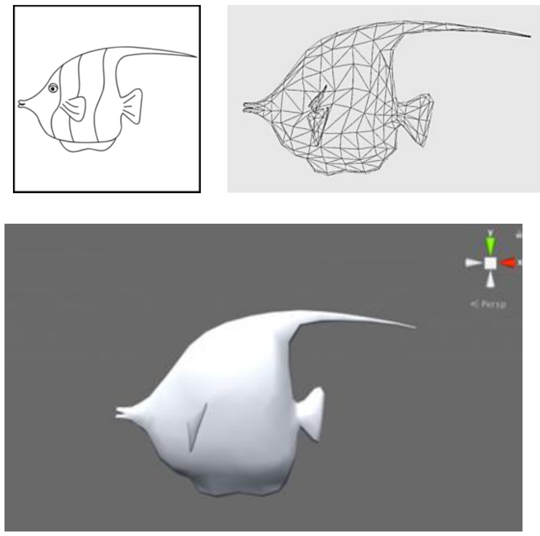

Figure 4: 3D model of the fish created from 2D picture by Maya

3.3. Texture generation for 3-D model

Since 2D colored drawing provides information about the texture, i.e., color and pattern of only one side of the fish, determining the other side of the fish which is the occluded part has to consider. Because the two sides the regular fish is symmetry, then replacing the occluded part with the reversed part the known textured is considered the reasonable choice. Usually the textured of the 3D model is in the form of UV pattern, so the full UV pattern for the 3D fish will look like the one in Figure 5.

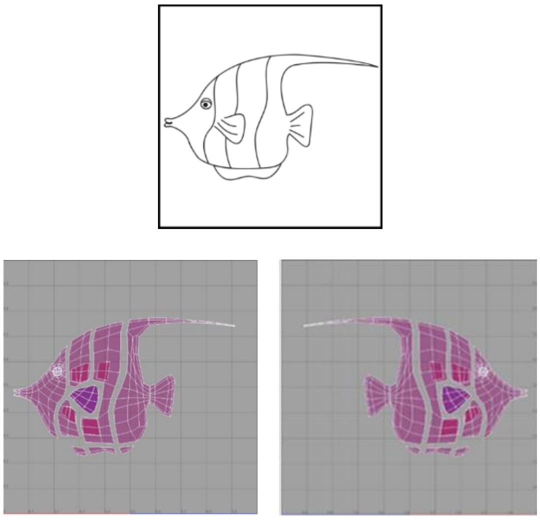

Figure 5: 3D model of the fish and its UV pattern

In real life, the shape of the fish is not flat. Some part of the fish such as the head and the body has volume, while the fin and the tail may be flat (as shown in Figure 6).

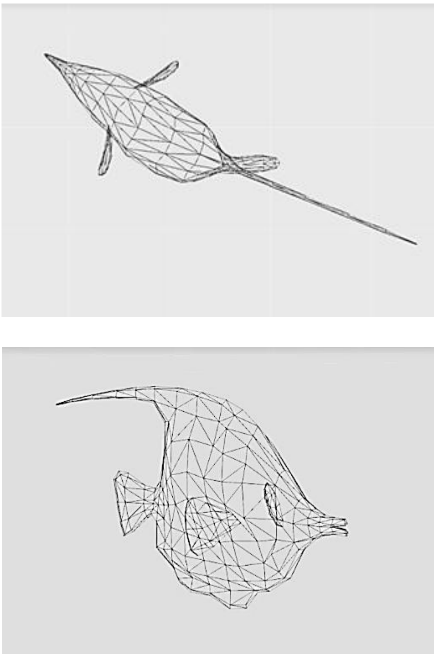

Figure 6: Shape of the fish

To make the texture of the fish look realistic, some parts of the UV patterns must be stretch, while the rest may not change. With this technique, the texture pattern from the colored picture will transfer to the UV pattern of the 3D model. Figure 7 shows the results of this process.

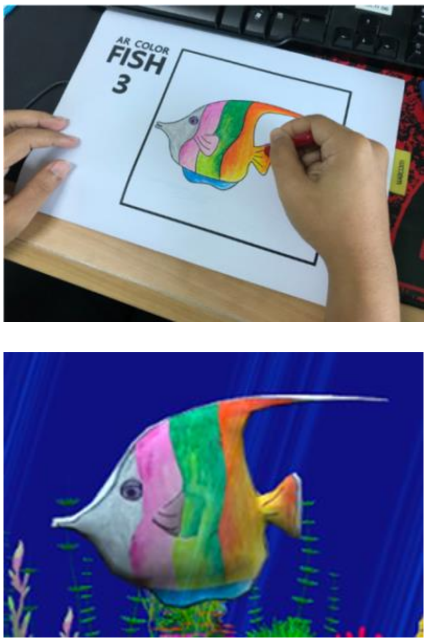

Figure 7: From 2D picture to 3D model of the colored fish

With this concept, all 2D colored fishes will transform into the 3D model of the colored fished as shown in Figure 8.

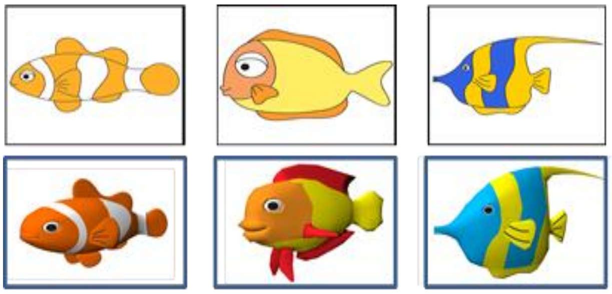

Figure 8: Variety of fishes that has been transformed from 2D colored picture to 3D model

3.4. Rigging and animation

To animate the parts of the 3D model, like fish or any characters, the model must have a skeleton, and the process of creating a skeleton is called rigging. Usually, the characters are rigged before animation because, without the skeleton, they cannot deform and move around. For fish, there are some parts needed skeletons such as body, fin, tail or even mouth, so when animated, it can move. Figure 9 shows the skeleton created by rigging for this experiment. After rigging, then the character which in this case is fish can be animated to swim in the aquarium just like the real fish.

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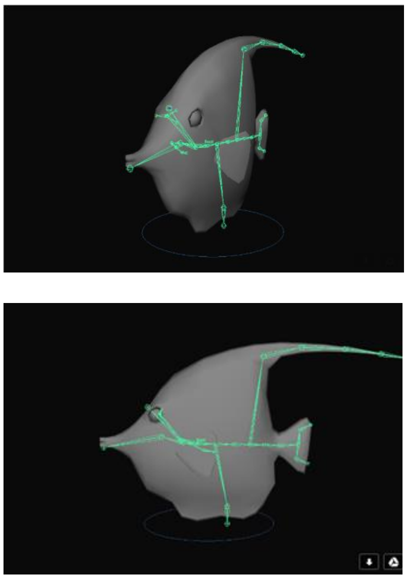

Figure 9: Skeleton of the 3D fish created by rigging

3.5. Setting the swimming path and speed of the fish

The last process for the virtual aquarium is the swimming path since there will be many fishes entering the aquarium. Without setting the path and speed, there is a chance that there will be collisions among the fishes. To avoid this incident, we can use either the artificial intelligent technique or we can set the swimming path for each fish. In this experiment, we want to control the number of fish in the aquarium at one time for example 20 fishes, so assigning the swimming path for each fish is a practical solution. Each fish will be assigned to have their path, taking by random, while entering the aquarium along with speed. In case that collision may occur, the anti-collision detection process will, and change in speed or path will be assigned to avoid the incident. Figure 10 shows the example of the assigned swimming path.

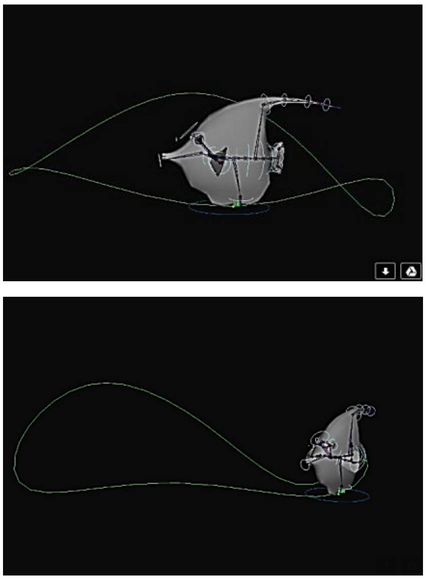

Figure 10: Example of the swimming path for virtual fish

4. EXPERIMENTAL SETUP

The experimental setup for the virtual aquarium requires both hardware and software to fulfill the requirement. For the hardware, besides the computer, the setup required webcam for scanning the 2D coloring picture into the system. With its technical specification, we decide to use the Logitech c920 webcam for this purpose. For the software, we use Maya for creating the 3D model of the fish. Unity 3D and Qualcomm's Vulforia is also required. Unity 3D is a game engine, used for creating the program that converts 2D scanning to 3D model. Vuforia is an Augmented Reality Software Development Kit (SDK) for mobile devices that enables the creation of Augmented Reality applications. Figure 11 shows the experimental setup of the system.

Figure 11: The hardware setup

Releasing the virtual fish into the aquarium, three steps are required. First, the colored 2D picture of the fish must be scanned into the system using a webcam and then the program will convert the colored 2D picture to 3D color model with the skeleton and animate them (as shown in Figure 12). The last step is assigning the swimming path and speed for the virtual fish. Then the fish is released into the aquarium (as in Figure 13). After finishing this process, the next process can start with the next fish. If the number of the fish is more than specific numbers, for example, 20, the first one will be released from the aquarium, keeping only 20 fishes in the aquarium. Figure 14 shows the aquarium with many fishes.

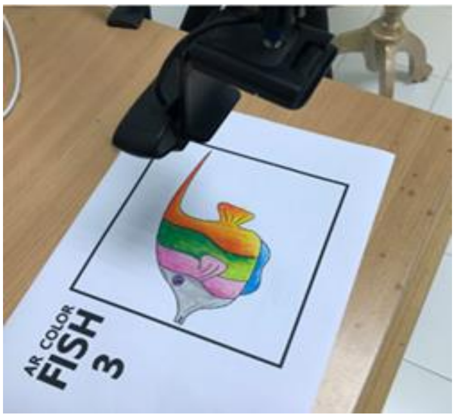

Figure 12: Scanning the 2D color picture of the fish into the system


Figure 13: First virtual fish release into the aquarium


Figure 14: Aquarium with many fishes

5. RESULT

The system testing was done at the shopping mall in the city of Nakorn Si Thammarat for three days from 10:30 AM. To 7:30 PM. There are more than 1,000 children and adults involved in this system testing. For children, they used their imagination in giving the color of their fish and satisfy when their fish start swimming in the aquarium. For teenager and adults, their first impression was how the technology does that. After the explanation, they seem to understand and enjoy creating their fish as well. From the interview, the majority of the tester agreed that this concept gave them the motivation to learn about science especially biology and computer graphics. Figure 15 and figure 16 show some activity from the events.


Figure 15: Coloring activities at the event


Figure 16: People enjoying the virtual aquarium

6. DISCUSSION AND CONCLUSION

This application is different from others in the same categories which also create fish and let them move into the tank. In those applications, the fish is still in the 2D and swim just like flapping paper, so they did not get much attention from the grown up. Using AR technology and computer graphics making them more realistic and will inspire and motivate children and adults to learn more about the topics. This concept can also be used in other topics as well such as astronomy, logistics or smart city.

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DECISION SUPPORT METHOD FOR USING VIRTUAL REALITY IN EDUCATION BASED ON A COST-BENEFIT-ANALYSIS

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ABSTRACT

Virtual reality is becoming increasingly popular, especially for education and training. Many schoolings or training domains can profit from it. Until now, there is few guidance on when and how to employ such technologies. In this paper, we propose a method for analyzing step by step if a course can profit from the use of immersive virtual environments. Specific indicators were identified and compiled into a questionnaire that can be used to assess for which courses the use of virtual reality could be beneficial. An existing course situation is analyzed from different perspectives, as students, educators or the management might perceive it differently. As a further step, the paper contains a guideline on how to carry out the feasibility studies in the context of virtual reality learning environments. The profitability of the investment is investigated from different angles in order to allow a well-founded decision. The procedure is then carried out on sample use cases to validate the method.

Keywords: virtual reality, education, immersive learning environment, benefit analysis, cost-efficiency analysis

1. INTRODUCTION

The gaming industry tries to push virtual reality (VR) into homes and living rooms, the promise to gamers is to be able to immerse oneself completely into a different world and perceive it from new angles and dimensions. As this technology is evolving quickly and becomes more affordable, other industries become more and more interested.

Especially the possibility of greatly enhancing learning and training with software environments able to replicate the real situation as close as possible draws the attention of the education and training sector to this technology.

The main goal of almost every training is learning new skills, improving performance and avoiding or handling mistakes (Gallagher et al. 2005). As the virtual reality offers new ways to impart knowledge or train practical skills, it is increasingly used for schooling and training purposes, building on the digital affinity of the younger generation for transmitting knowledge.

Learning is becoming an adventure. Especially trainings that require a repetition of process sequences for a good understanding can be more easily performed in VR (Bremer 2017).

VR was used for learning as early as in the nineties for training NASA astronauts (Loftin, Kenney and Benedetti 1997). Nowadays virtual reality learning environments are deployed for a broad variety of trainings. Theoretical knowledge and technical details can be transmitted as well as practical skills. The handling of a welding machine can be trained just as risk-free and resource-friendly as the painting of car body parts (Fronius 2017; IWRC 2018). Driving a car can be learned in VR as well as functional algebra (Janz 2018; KVE 2012). The railway company "Deutsche Bahn" uses VR to teach the operation of new trains before they are deployed (Janssen 2017). Safety-critical situations, impossible to train in a real setting, can be simulated and trained in VR (DB Systel 2018). This is especially true for the medical sector. VR allows to blend together the skeleton, muscles and organs to provide unique insights into the complexity of the human body (Betts 2016). Via simulated emergency students can be prepared for the actual application (Oculus 2017). Trainee performance can be automatically tracked and evaluated by the VR system (Mantovani 2001; Maschuw, Hassan and Bartsch 2010).

Hence, the use of VR is not appropriate for every teaching course. It is necessary to gather accurate information and conduct an extensive feasibility study to make a well-founded investment decision.

In the following, the related methods and models to determine when to use virtual reality, how cost benefit analyses are usually conducted and some introductions on didactics are presented. The benefits of virtual reality technologies for teaching are summarized in seven categories in section 4. Then all steps of the decision support method are described in detail, followed by their validation in section 6, a discussion, conclusion and outlook.

2. RELATED WORKS

Several methods for evaluation of VR usability and benefits already exist, especially for specific application areas. Some of the most relevant and useful methods determining the feasibility of using VR technologies one could mention the SWOT models designed by Minocha (Minocha 2005) and Rizzo (Rizzo and Kim 2005) as well as the efficiency analysis methodologies constructed by Dücker (Dücker, Häfner and Ovtcharova 2016) and Kunst (Kunst 2005).

The acronym SWOT refers to the strengths and weaknesses of a company and the opportunities and threats which it faces. It is one of several strategic planning tools that are used by businesses and other organizations to ensure that there is a clear objective defined for the project or venture, and that all factors related to the effort, both positive and negative, are identified and addressed (Ifediora, Idoko and Nzekwe 2014). Minocha makes overall SWOT analysis to study the challenges of applying virtual reality in education. He suggest that the impact of VR is still limited, so it can be used as a complement to traditional classrooms and standard trainings (Minocha 2015). Rizzo and Kim made SWOT analysis for an application of virtual reality in the field of rehabilitation and therapy in 2005. They provided structured examination of the factors relevant to the current and future status of VR rehabilitation as well as a good overview of the key issues and concerns that are relevant for understanding and advancing this application area (Rizzo and Kim 2005).

From high importance for this paper is the work of Pantelidis. She makes suggestions on when to use and when not to use virtual reality and propose a 10-step model that can be used to determine the application of virtual reality in an education or training course (Pantelidis 2010). This model serves as good orientation but is difficult to apply due to missing validation examples.

To make a decision on the profitability of an general investment all advantages and disadvantages should be analyzed and compared in detail using tools for profitability analysis like cost-benefit analysis (Bösch 2016). Several steps are usually applied to achieve a profitability analysis: First an analysis of the actual situation takes place, as well as the requirements and objectives are defined. Subsequently, the identified cost and benefit factors of the alternatives are set in a ratio. Finally, a decision is made and the stability of the result could be checked with a sensitivity analysis.

Kunst developed a methodology for economic analysis of VR technologies in 2005, where he focused on virtual factories (Kunst 2005). He recognized the problem that classic investment calculations are difficult to apply in this context.

The developed efficiency analysis of VR environments by Dücker et al. so called WAVE methodology allows a step by step approximation of the complex decision on technology adaptation without the need of initial knowledge about VR technologies. It also involves many interdisciplinary company divisions in order to obtain comprehensive statements about a future VR usage. In addition to the insights on possible improvements in the company, a concrete VR solution is also identified by a risk-based efficiency analysis optimized for the specific company (Dücker, Häfner and Ovtcharova 2016).

In the field of virtual reality for education, there are few models to determine when to use this immersive technology and no specific methods developed to identify the cost-benefit ratio of using this new media in training courses. This paper describes an extensive method based on nine steps that should guide through the decision support process. The model is based on detailed benefit analysis followed by cost efficiency analysis and key figures for monitoring the results.

3. BACKGROUND ON DIDACTICS AND IMMERSIVE ENVIRONMENTS

The success of every learning environment based on new technology is depending on the design and its integration in the learning process (Mayer 2009). In order to successfully combine both fields one should understand both VR technology and didactics.

There is plenty of literature on learning and teaching, which should help to determine main factors as what is being taught (the subject of learning), how it is being taught (the process of learning), the behavioral outcome (the object of learning) as well as the context and medium.

The word didactics comes from the Greek word "διδάσκειν" (didáskein), which means teaching. The scientific term didactics stems from the German tradition of theorizing classroom learning and teaching (Arnold 2012). Conceptual frameworks, which describe how knowledge is absorbed, processed, and retained during learning, are known as learning theories (Simandan 2013). They are focused on how human beings learn and what exactly happens during learning. The most important learning theories are behaviorism, cognitivism, and constructivism (PELe 2006).

Comparing the learning theories with the didactic models, the latest contain the teaching/learning goals, contents and methods, and are focused on the proceeding during the course and its drivers (Jank and Meyer 1994). There are many didactic models known such as "Berlin Model", "Hamburger Modell", etc., which offer guidance for analysis and planning of single steps for subsequent reflection and evaluation of course units (Furrer 2009). A practical framework for identifying the observable and measurable skills of the students was presented by Bloom's Taxonomy of Educational Objectives (Bloom, 1956). He identified six types of cognitive processes and ordered these according to the increasing level of complexity involved: knowledge, comprehension, application, analysis, synthesis, and evaluation.

Further educators should have in mind that there are different learning styles or modalities like visual, auditory, physical and social learning (Fleming and Baume 2006) that are important for the choice of media to be used. Textbooks, videotapes, films, computer software as well as the internet contents like podcasts, blogs, and virtual environments (Pantelidis 2010) are frequently used media in the courses today.

Virtual reality as interactive media opens new possibilities for instructional approaches like situated learning and methods based on experiential education (Dede 2009). At the same time, teachers can use the flexibility of a virtual learning environment to embed gamification elements in the training (Kapp 2012).

Our understanding of Virtual Reality is based on the human-centered definition of Sherman and Craig described as "... a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation" (Sherman and Craig 2002). According to Burdea and Coiffet, the three most important properties of VR are the so called "3 Is": Immersion, interaction and imagination (Burdea and Coiffet 2003). These are realized through multiple input and output devices, enabling the bidirectional information flow between the user and the virtual world. From the technological point of view, the authors characterize a virtual environment as immersive, if it provides stereoscopic representations of objects, supports user head tracking and offers intuitive interaction. Due to the fast and constant development of virtual reality technology, the authors will proceed without detailed description on this topic.

4. BENEFITS OF VIRTUAL REALITY FOR TEACHING - A CLASSIFICATION

Using virtual reality for teaching purposes implies several advantages, which in this paper are classified into seven categories: Motivation, communication and evaluation, better understanding, adaptability and flexibility, safety and health aspects, environmental aspects as well as time and costs (Schlatt 2018). In the following paragraphs, the seven categories are described in details and some examples are given.

The **motivation** of students/learners can be enhanced by the use of a new technology. Additionally VR makes learning more active and engaging (Häfner 2013). Students deal with the information more intensely and can make their own experiences with the learning material by interacting with the learning environment in real-time (Huang, Rauch, and Liaw 2010). By highlighting important information or slowing down a process, it can be made sure that everyone gets the same picture of a learning matter (Mantovani 2001; Günther, Walch and Wulz 2006). Details that are not visible to the naked eye can be pointed out by easily disassembling a device or zooming in on this special information (Trindade, Fiolhais and Almeida 2002).

Communication is also enhanced as language barriers can be overcome by the use of VR (Pantelidis 1995). In case someone does not understand verbally, information can be shown visually. In addition, the **evaluation** of a learner's performance can often be made more concrete and objectively when using a computer-aided evaluation process (Mantovani 2001). Virtual reality offers new possibilities of visualization. Hidden and difficult to see components and processes as well as consequences of an action can be illustrated better (Pantelidis 1996; Mantovani, 2001). Abstract and theoretical information that are difficult to imagine as the structure of a molecule can be displayed visually (Pantelidis 2010). Even the dynamic behavior and interconnections between objects or processes of the learning environment can be displayed (Jung and Vitzthum 2013). Additionally parameters like electrical current flow or gas pressure can be faded in in order to **improve the understanding** of the learning matters (Broll 2013). Using VR the learner gets the opportunity to repeat costly and time-consuming actions causing only marginal expenses (over and over again) until a solid level of comprehension is reached (Pantelidis 2010). Almost every possible scenario can be simulated in VR, so that the course participants can be prepared for challenging situations without the pressure of an emergency (Linde and Kunkler 2016).

Adaptability and Flexibility. With the help of VR, individual needs can be addressed more easily as processes can be slowed down and learning matters can be supplemented with additional information (Mantovani 2001). As well, single steps can be skipped or repeated according to the learners' abilities without affecting the whole class (Pantelidis 1995). To technological changes or new insights in the learning matters can be reacted with a change in the software code, which sometimes is less time consuming than adapting or creating a new learning environment in the reality (Günther, Walch and Wulz 2006).

Safety and Health aspects. In a virtual reality, learning environment dangerous tasks or scenarios can be trained in advance without the pressure or the danger of the real environment (Pantelidis 1996). As the learners gain a better understanding of the learning matters and are warned by the VR system against potential risks, accidents and injuries can be reduced (Seymour et al. 2002). In addition, the handling of toxic or contaminated material can be practiced in the VR environment without the danger of contamination (IWRC 2018). Thereby accidental damages to the environment can be avoided. Additionally the **environment can be protected** as the use of VR for training leads to a significant lower material consumption than the traditional training (Stambolieva 2017).

The use of VR for training and education also offers monetary benefits as **time and costs** can be saved. As many preparatory and follow-up activities are not mandatory any more, time can be saved. It is for example not obligatory anymore to put on protective clothing before welding or to clean up after every training lesson (IWRC 2018). Also waiting periods can be skipped in VR. In case a learning environment or a specific object is still being constructed or produced, it can be simulated in VR in advance. Precisely the handling of a machine can already be trained in the virtual environment so that it can be put into operation as soon as it arrives and is installed at the production site (Günther, Walch, and

Wulz 2006). Additionally the time to achieve a certain level of understanding significantly decreases as the result of an extended visualization and teaching method (MacGillivray 2017). In further consequence error correction costs as well as operating expenses, decline (Pantelidis 1996). Material consumption as well as machine and process downtime are significantly reduced (Stambolieva 2017). A VR system can be designed as an intelligent tutoring system so that no extra qualified training personnel has to accompany the training session (Psotka 1995).

Nevertheless, VR learning environments are not beneficial in every case. Some drawbacks have to be considered. Firstly, the establishment of such a learning environment can imply relatively high investment costs (Pantelidis 1996). Nowadays some low cost solutions are available but with an increasing demand for quality, immersion and real time capability the price of the VR system rises quickly (Günther, Walch and Wulz 2006).

Another problem with the VR technology is the occurrence of health issues like nausea, dizziness or headaches for some users (VDC 2014). Some VR solutions completely isolate the user from the natural environment. Potential obstacles might be overlooked resulting in injuries (Warnecke and Bullinger 1993). The communication and interaction with other people in the room is partially restricted as eye contact is not always possible.

Especially within the elder generation acceptance, problems concerning VR can be registered. They are generally sceptical about the use of new technologies (Pantelidis 2010). Other people rise concerns that VR is only a temporary hype (Völger Winsky 2014). In the context of education and learning, a major concern is that potential interference parameters or environmental impacts might not have been sufficiently considered. Training participants could overestimate their abilities, which in turn leads to dangerous situations (Pantelidis 2010).

5. DECISION SUPPORT METHOD

In this section, we propose a method that should help stakeholders to decide whether to use or not VR technology in their courses. The method is based on an identification of potential benefits and course optimizations, a cost-benefit-analysis as well as determination of key figures (KPIs) for monitoring the deployment process. The nine steps of the method are described in the subsections below.

Step 1: Recording the Current Situation

The current course situation should be described and it serves as a foundation for the following steps. It can be a new course or an already existing one, which will be advanced by virtual reality technology.

The course description can include the course objectives, the used teaching methods and techniques, the curriculum design and content, a schedule of class meetings, information on requirements, assignments and examinations, grading or evaluation policy, course management policies, used media, materials, and resources.

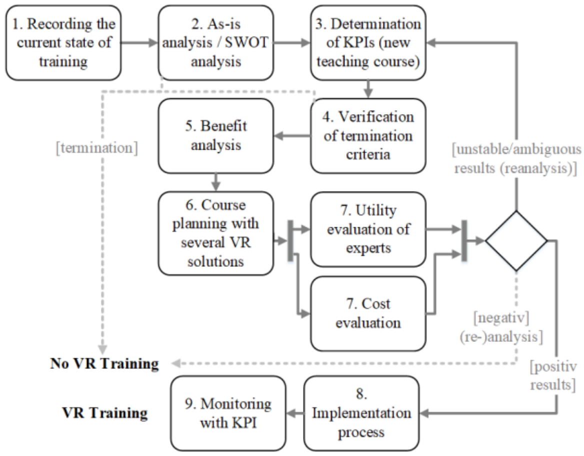

Figure 1: Decision Support Method Sequence Diagram

Step 2: As-Is Analysis using SWOT

The goal of this step is to analyse the actual situation of the training course and identify the general needs and its optimization potentials that come using the new technology. To achieve this step a SWOT analysis is recommended (Hill and Westbrook 1997). With its help the strengths and weaknesses of a course as well as the opportunities and threats which it faces can be described. This can be done according to the collected data for the existing course and the benefit categories we provided in section 3.

Step 3: Determination of Key Figures for the New Teaching Concept

Based on the SWOT analysis results a rough definition of the new teaching concept as well as determination of key figures should be made. The following question should help during this process completely independent of the type of change (no relation to VR): Which are the expected results when we rework the course and invest in it? While determining the key figures based on the expected results it can be distinguished between qualitative and quantitative criteria. Here some examples: the training is to be reduced from 5 days to 4 or to pass the course you need 60 points instead of 50 from 100. A qualitative result can be for instance that the satisfaction of the participants should increase. It is important to convert the expected results in measurable key figures. The key figures are needed for the next steps in order to monitor the course development and implementation. The quantitative results can be easily measured and one should think about how to make the qualitative results measurable. For instance, advancing our example on course satisfaction, giving the students a scale to evaluate the course before and after, can help in better tracking on satisfaction increase or decrease.

Step 4: Termination Criteria

Depending on the specific course and the educational organization there can be different criteria for termination depending on external or internal factors.

Following classification of possible termination criteria deriving from the immersive technology based on authors' experience as well as research publications (Pantelidis 2010; Minocha 2015) are proposed, "Do not use VR for education if ":

Learning Outcomes:

- training with the real subject and in real environment is easy accessible and available.
- virtual reality cannot have the same impact and learning outcome i.e. as an actual visit to a museum, park or historical site or haptics and fine motor skills are important and cannot be substituted with current virtual reality technology (i.e. stitching with needle).
- interaction with real humans, either teachers or students, is necessary, so VR solutions using telepresence meetings are not leading to the same learning outcomes
- VR leads to distraction of the learning matter depending on the target group, instead of focusing on the educational experience; students get excited about the gadgets.

Safety and Health issues:

- using a virtual environment could be physically or emotionally damaging for a course participant i.e. motion sickness and balance issues;
- using a virtual environment can result in "literalization", a simulation so convincing that some users could confuse model with reality.
- addiction to virtual reality or false sense of security;

Technology issues:

- missing knowledge and qualification to operate and supervise the complicated nature of virtual reality hardware as well as to navigate the virtual environment software.
- compensation of qualification and experience is extensive and specific training is necessary.
- insufficient usability and flexibility of software and hardware i.e wires and displays – no free movement;
- insufficient platform compatibility, flexibility and stability;

- Time:
  - not enough time to plan, implement the course and huge effort is required to adjust it to purpose of education.
  - too time consuming to extract and analyze resources and back end data;
  - training on using the technology itself is very extensive and time consuming

Costs:

- virtual reality is at first appearance too expensive to justify, considering the expected learning outcome.
- too small participants number and too low frequency of the training for the investment

Legal issues

- training cannot be redesigned due to norms and laws (i.e. a certificate cannot be issued based only on virtual reality training)
- liability issues can occur caused by e.g. health issues
- law enforcement issues can arise or it may lead to inventory loss of objects in virtual world.

Social issues:

- too much dependency on VR and computers can lead to loss of personal contact with the teacher and loss of social interaction lessons that only a face to face classroom can teach.
- behavior ethics should be learned. For example, how one should behave in a class, a museum or a library
- Too heterogeneous group of participants having different background and age resulting in too complex (and expensive) VR solution.

Other issues:

- there are active rejection of the technology by educators or students
- there are limited awareness and unrealistic expectations.

Step 5: Benefit Analysis

In order to identify potential benefits of the use of VR for a specific training purpose, a questionnaire was developed (see Appendix). Interested investors can answer these questions to obtain a tendency statement on whether VR could be beneficial in his case. The concept of the model implies that three different interest groups should answer the questionnaire: course participants, educators and managers. Course participants often perceive a training differently than a educator or the management does. While the management is responsible for the investment decision on establishing a virtual reality learning environment, it is not always aware of the exact contents and procedure of the training session but it usually has very good knowledge of the incurring expenditures. The instructor knows best which information is most important and what could be potential difficulties or dangers. He is responsible for finding a suitable educational approach on delivering relevant learning matters to the course participants, who need to be motivated and engaged.

The questions are classified according to the previously defined use/benefit categories. Most of them are formulated as statements concerning the different use aspects. The interested party is asked to state his or her consent on a five point Likert scale. The response options are coded, so that in the end a numerical value can be calculated for each category. By depicting the results in a bar chart, areas of high potential can quickly be identified. As the respondents are also asked to rate the importance/relevance of the different use categories for the decision making a total value for the investigated training case can be calculated by summing up the single category values considering these weighting factors.

The result is a value between 0 and 1, where 0 means no benefits attainable through the use of a VR learning environment, while 1 stands for a very high potential for the use of VR. In between five areas are proposed for the interpretation resulting from the previous coding scheme:

0,85-1,00: "Very suitable: The use of VR is especially appropriate for the considered training course and can lead to a very high benefit."
0,625-0,85: "Rather suitable: The use of VR is well-suited for the considered training and can lead to significant benefits."
0,375-0,624: "Medium: The use of VR can be quite suitable for the considered training situation. By selecting an appropriate VR system some benefits can be generated."
0,125-0,375: "Rather not suitable: The use of VR is rather not appropriate for the considered training. By choosing a low cost VR-System sometimes some benefits can still be generated."
0,00-0,125: "Not suitable: The realizable benefit of a VR learning environment is to be rated very low. The investment should be reconsidered. An exception could be that there is already a VR system that could also be used for the training, the establishment of the VR learning environment could still be feasible."

Step 6: Course Planning with VR and Derivation of Alternative Solutions
The potential identified by the questionnaire in Step 5 should be adapted with the help of experts. Experts in the field of immersive technologies should define together with the educators the alternative solutions inclusive all relevant costs because not any VR solution can fulfill all benefits equally. Recommended is to define solutions in different price segments because they will be included in the further economic consideration. Following information for all alternative solutions are necessary to conduct the next step: investment costs for both hardware and software, ongoing cost for maintenance of VR solution per year (support, repair, warranty costs), average operating costs per year (like personnel, machine downtime, consumables, etc.), average cost of an error, frequency of errors; average training time, calculations on time savings (due to preparation or follow-ups, reduction of waiting time, other losses or gains of time), costs per hour.
Here the benefit analysis results from step 5 is taken under consideration again and possible realized potentials are adjusted with the help of the experts to achieve more realistic prognosis for the final potentials.

Step 7: Cost-Efficiency-Analysis
Is the added value after the refinement of the benefit analysis in step 5 high enough, it is worth to conduct a detailed cost-efficiency analysis.
The various alternative solutions are then analyzed using a utility analysis in qualitative areas as well as a static investment calculation, which includes profitability comparison calculation and amortization. To ensure that the calculations are right, a sensitivity analysis is recommended. Since many parameters are included in these calculations, it should be checked to what extent result changes if the input parameters are slightly variated.

Step 8: Decision and Start of the Implementation
Based on the results of the previous steps the educators can decide to maintain the course such at it is or to advance with virtual reality solution and which alternative solution. Two main results are available to support the decision on the alternatives - qualitative based on the benefit analysis and quantitative based on the monetary calculations. There can be the case that one VR solution alternative takes first place for both analysis, if not the stakeholders should decide which is more important. In last case, further ranking techniques that facilitates the decision-making can be applied. The decision for the use of the immersive technology means further extensive steps in planning and implementation of the project, which is not focus of this publication.

Step 9: Monitoring
The defined key figures in Step 3 can be used to monitor the project implementation and to validate if the goals and expected results are achieved.

6. VALIDATION AND APPLICATION OF THE METHOD

The decision support method was validated with several use cases. Here we describe a safety training for milling machine in detail as well as discuss some results of a leather sewing training.

6.1 Safety Training for Milling Machine

During a practical course at the IMI institute of the Karlsruhe Institute of Technology (KIT) the students work with a milling machine to physically produce the products they have previously designed in a 3D-construction software. Before the first use, the students have to take part at a safety training in order to learn the correct handling of the milling machine.

Step 1: Currently the training is conducted 15 times a year with an attendance of 2-3 students at a time. On average, one session takes 20 minutes and is organized by one trainer.

Step 2: To perform a SWOT analysis of the current course first the internal aspects strengths and weaknesses was considered. It was found one the one side that safety training on real machine provides the necessary quality, on the other side virtual reality infrastructure is available and its usage is already a workday life. The weaknesses lie in potential injuries or hardware damages during the training, the material wastes, trainer time and costs as well as the often changes of trainer personal. The opportunities are defined based on the external influences, which in this case was the increasing importance of digitization and the need to prepare students for a digitized world of work. The students also demand today well-prepared learning content and can learn on their own pace. Additionally, development of such training can be profitable for other organizations - companies or universities, where the same machines are used. The conclusion of the SWOT analysis is that standardization of the training could be beneficial and consistent quality can be ensured. As a potential solution VR can be investigated in the further steps.

Step 3: In the immersive learning environment the students should discover the machine on their own at the beginning of the course or repeat the training shortly before using the machine. Some of the qualitative key figures and results should be user-friendly software and hardware operated without supervisor, modernization of training through digitalization, better and safely understanding on the milling process. The determined quantitative key figures were: Reducing trainer time from 5 to 1 hour per year, increase the machine users from 50 to 100 per year, the reduction of material waste, dust and energy consumption of the real machine and others.

Step 4: Only one point was determined as critical during the termination criteria check, the lower number of students per year. Despite a decision to proceed with the benefit analysis was taken.

Step 5: In order to decide about the adequacy and the profitability of the establishment of such a learning environment, the previously introduced benefit analysis step was applied. Eight students, who have already taken part in the traditional training, as well as the teacher and the managing director of the institute, were asked to answer the questionnaire in order to assess the current situation. Potential benefits, that could be derived, can be seen in fig. 2. In total a weighted value of 0,43 (without weighting 0,45) stands for quite a potential that could be realized by establishing an immersive learning environment.

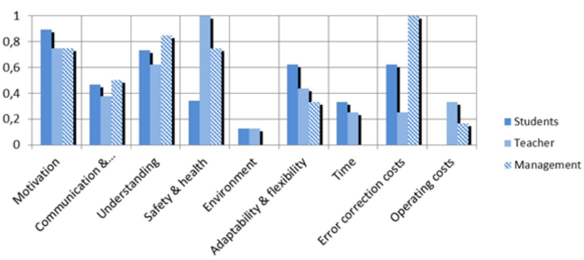

Figure 2: Potential Benefits resulted from the Step 5 for the Milling Machine Safety Training

Step 6: Therefore, two solution alternatives, using the internal available VR hardware, were proposed by the in-house VR experts. The first solution includes a HTC Vive HMD with the corresponding controllers and tracking system. The second solution consist of a passive 3D-TV complemented with a Smarttrack optical tracking system and flystick2 of the ART company as interaction device (see fig. 3).
A suitable software needs to be implemented containing the virtual twin of the specific milling machine model, which allows realistic interaction and features to explore, but also consecutive steps introducing the safety instructions and automatic evaluation of the training.

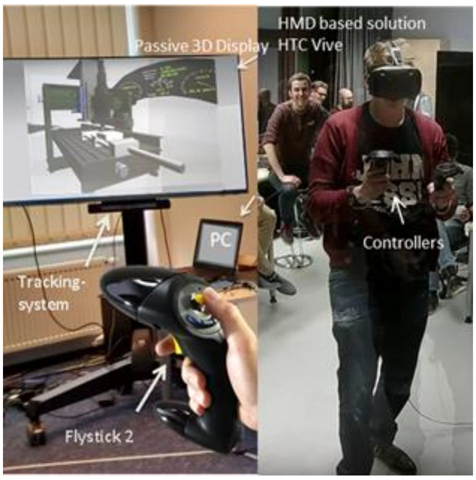

Figure 3: Suggested VR Hardware Alternatives

Step 7: The results of the detailed cost-efficiency analysis showed less difference between the two alternatives (0,423 for the first vs. 0,416 for the second weighted with the ranking of the management perspective). Here the difference is resulted mainly by the higher costs of the second hardware setup, because the software solution costs remain the same. All other details are insignificant and not discussed in detail.

Step 8: The results did not show conclusive evidence that the potential benefits from step 5 will come true after the investment in software development. The management took decision to do not implement the VR training for the safety training.

6.2 Sewing Training with Immersive Haptic Setup

The second use case aims teaching of the sewing process in the leather goods industry using haptic force-feedback next to the immersive setup (Heinzelmeier 2018). Due to the confidential information about this use case, authors will focus only on validation of steps 5 and 6. After the conducting of questionnaire in step 5 high potentials in the field of time, error correction and operating costs were identified (see fig. 4), which was total value of 0,41 according to the management weighs and stands for quite a potential.

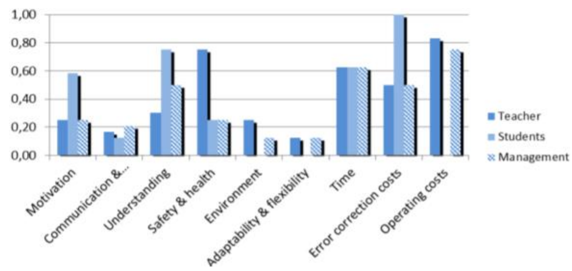

Figure 4: Potential Benefits resulted from the Step 5 for the sewing training

At this point the stakeholders decided to create a prototype in order to test the feasibility and to better estimate the alternative solutions (jumped to step 8). This is good example how the proposed method can be modified or refined in smaller steps based on prototypes. The current prototype of the sewing training can be seen on fig. 5. The focus lies on the haptic feedback during the sewing process and how to create perfect seam on a leather bag. As haptic device the Virtuose 6D from Haption company was used as well as a pedal from Logitech for the sewing machine. The hardware alternatives created for step 6 and evaluated in step 7 lied only in the visual output devices - 3D display in form of projection vs HMDs, because no other alternatives could be tested for the haptic feedback and the software requirements and development costs stay the same for both solutions. The prototype is still in development, so no further validation on step 8 decision on implementation in practice and step 9 monitoring with key figures ware be possible at this time.

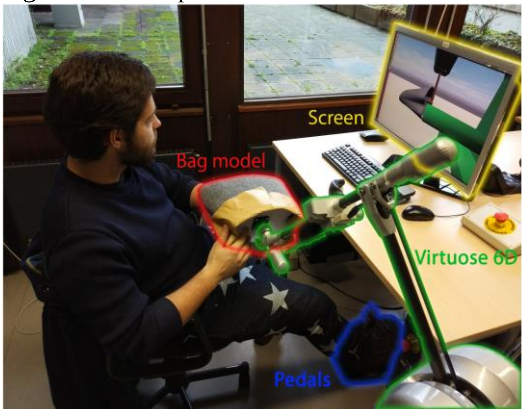

Figure 5: First prototype of the sewing hardware setup with force feedback, no immersive visual output device.

7. DISCUSSION

The practical application of the methodology steps confirms that it is a quick and easy way to identify the potential for the use of Virtual Reality for the considered training. By the subsequent detailed analysis of the discovered potentials using concrete alternative solutions, a sound basis for decision-making could be created. During the validation only the first 8 steps could be performed. The real potential after the implementation of the project could not have been monitored and evaluated at this time.

During our work with the questionnaire of step 5 we noticed that many definitions like “abstract or complex contents”, “level of details of a virtual scene” and others, despite of provided additional explanations, could not be evaluated by the users and the interpretation of these words varies significantly.

Creating a generic questionnaire with fixed questions was quite challenging task and it will not match all issues for all organizations, especially in such fast developing field. That is why additional individual steps were embedded in the methodology where additional expertise is needed.

One of the disadvantages using questionnaire for decision making, if and when to use VR for education, is that the stakeholders (educators, students or management) have never experienced immersive technologies before and cannot judge correctly. Reading or watching reports about virtual reality does not substitute the real experience, which is crucial for the understanding of the technology. Once experienced and understood its possibilities and potentials, educators can use their expertise in pedagogy and will be more creative how and when to use VR in their courses, just like the tablets, PCs and projectors today. For the solution of this problem, teachers should get better access to the different virtual and augmented technologies and applications through laboratories, universities, companies or fairs visits etc. In the future, the higher education should be advanced preparing experts in both fields – multimedia (with background in information technology and computer graphic) and pedagogy simultaneously.

Defining alternative VR solutions in Step 6 is today still challenging task. Various hardware is after all available in different price segments, but the interaction features for a specific hardware setup can be strongly restricted and adjustments like integration additional hardware elements can be costly.

Virtual reality is in his nature individual experience and this is still a problem for the course design with large number of participants like a school class, when it comes to hardware selection.

The question is less if virtual reality is beneficial to the learning process, but instead if the added value of training in an immersive environment justifies the costs of creating the training applications and maintaining the technical installations necessary to deploy them. There are various trends, which make this kind of technology more accessible, further and further reducing hardware investments, but this is not reflected in software developments. Training applications are as costly to make as modern computer games; they share the requirements for real-time performance, interactive and rich virtual environments, usually made by designers. The problem is that learning applications still do not have access to a marked as big as computer games.

CONCLUSION

Training is a repeated execution of specific tasks, aggregated in skills and domains. This usually involves a huge investment in time, from the trainee and the potential trainer, as well as an investment in resources, materials, consumables. Learning applications try to support the learning process and reduce the investments. This paper analyzed the use of virtual reality technologies for learning applications, and presents a methodology to assess the potential on a per use-case basis. The method application was demonstrated on two use-cases: A virtual milling machine and a virtual sewing with haptic feedback. The results are mixed, but clearly show the strength and weaknesses of such an assessment.

In general, one has to keep in mind that the success of a VR learning environment is depending on the design and integration in the learning process. Therefore, it is necessary to develop an overall consistent teaching concept that supports the learning habits of the students that are supported by the VR technology.

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APPENDIX
The questionnaire from Step 5 designed to determine the potential benefits of a VR compared to a traditional learning environment could be found under following link: *https://goo.gl/ocx2tR*

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ACOUSTIC AR-TA AGENT USING FOOTSTEPS IN CORRESPONDING TO AUDIENCE MEMBERS' PARTICIPATING ATTITUDES

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ABSTRACT
We propose an acoustic AR-TA agent (AATA) that reacts to the audience members' participating attitudes in a lecture. In one-to-many communications such as lectures with over 100 audiences, some do not focus on the lecture. In such cases, it is difficult to make them pay attention to the lecture. To improve such audience members' attitudes, we propose an AATA expressed by moving localized sounds of footsteps using a direction-controllable parametric speaker. Based on the hypothesis that the footsteps approaching to an audience member will indirectly notice the audience her/his problematic attitudes, we conducted two experiments. From the results, the participants felt as through someone walked around them when they perceived the movement of footsteps, as if the walk of the lecturer or TA was the source of the footsteps. Accordingly, we discuss the possibility of the AATA's movement to warn to the audiences.

Keywords: One-to-many communication, acoustic AR-TA agent, lecturer support, audience attention

1. INTRODUCTION

1.1. Backgrounds and Purposes

There is a concept called "audience interaction" which considers trends in multiple audience members' participating attitudes and audience participatory interaction between multiple people (Maynes-Aminzade, Pausch and Seitz 2002).

We have also considered the idea of "audience interaction" based on an idea of bidirectional interaction between one speaker (e.g., teacher or lecturer) and many participants. As a matter of particular focus, we hypothesized that it becomes more difficult for the lecturer to grasp audience members' participating attitudes (e.g., they are interested, listening earnestly, talking with friends, etc.) as the number of audience members in one-to-many communications such as university lectures and conference speeches increases. For example, it becomes difficult to grasp the audience members' attitudes if the number of audience member increases beyond 100. In such situations, the lecturer becomes difficult to change the speech content based on the grasped their attitudes. Therefore, efficient interaction between the lecturer and the audience is not possible unless the speaker understands the audience members' attitudes.

To solve such problems, we proposed a system that supports the lecturer's intuitive understanding about the audience members' participating attitudes by estimating their attitudes and showing the estimated attitudes using a color map to the lecturer in a one-to-many communication (Kitagishi and Yonezawa 2017). The lecturer would be able to explain the contents according to their attitudes by realizing her/his intuitive understanding of their attitudes. Also, the individual or group whose attention wanders away from the lecture and who needs help (e.g., they have some questions) becomes clear to the lecturer, and she/he can correspond to such audience members. However, it is not realistic that the lecturer corresponds separately with such individual or group because it would interrupt the flow of the lecturer's talk, and the distance between the lecturer and the audience is too wide to talk across.

We focus on the university lectures that involved more than 100 audience members where not everyone listens to the lecturer's speech seriously. It is necessary to draw their attention to the lecture while some audience members' attention wanders away from the lecture content, and sometimes lack of attention can hinder the lecture. However, when the lecturer makes her/his efforts to solve such problems, the lecture's flow should be interrupted.

To improve the audience members' attitudes without stopping the lecture's flow, we propose an acoustic AR-TA agent (AATA) that behaves semi-autonomously based on audience members' attitudes or the lecturer's operation. In a broad sense, a TA (teaching assistant) assists the teacher (i.e., lecturer). The position includes many roles such as asking students questions, confirming class attendance, warning students against side discussions, and marking student's reports. Among such roles, the AATA expresses the attention toward the audience members who pay attention to something other than the lecture content. Corresponding to such audience members, the AATA expresses its attention corresponding to the direct/indirect operations from the lecturer. Among them, we aim for indirect interaction and an ambient auditory stimulation approach through moving the footsteps.

The movement of an AATA is expressed through moving localized sounds of footsteps using a parametric speaker, which direction is controlled by two servomotors. The AATA "walks" toward the audience members based on their estimated attitudes toward the lecture (Kitagishi and Yonezawa 2017). We expect that it will encourage audience members to unconsciously pay attention to the lecture contents without requiring the lecturer to stop or taking her/his time.

1.2. Presence and Attention of AATA

Using the AATA, we aim to portray an invisible, ambient presence (e.g., someone's movement and attention) using the movement of localized sounds of footsteps. We considered that we could give audience members the senses of an invisible presence (i.e., the AATA) that exists, walks, and pays attention, by moving the localized sounds of footsteps close by them. We define such senses as "the presence of AATA."

The AATA is expressed by only the footsteps. The presence of AATA is weak compared to a virtual agent, which consists of multiple elements such as visual and auditory stimulations.

It is possible to express the walker's emotion, physical features, and gender by changing the tone, pressure, direction, and speed of the footsteps (Giordano and Bresin 2006; Visell, Fontana, Giordano, Nordahl, Serafin and Bresin 2009). We considered that it can also express the walker's attention with walking. Therefore, we hypothesized that the AATA can express the attention and emotion of someone who is assisting the lecturer simply through the movement of footsteps.

A benefit of expressing the AATA with only movement of footsteps is its indirect and ambient interaction with audience members. They may lose their motivation to the lecture if the expressions are aimed at them directly because such a direct expression may be discouragingly strong for audience members. Also, it is possible that a direct expression would draw audience members' attention to the expression itself. We considered that we can solve this problem by using indirect expressions.

The drawbacks of expressing the AATA with only the movement of footsteps are 1) the expression is simple because the expression is only footsteps; 2) the AATA is not able to clearly interact with a particular person or group. However, we plan to use the AATA to unconsciously draw audience members' attention to the lecture contents with indirect and ambient interaction. We believe the indirect and ambient movement of footsteps will suit our purposes.

2. RELATED WORKS

2.1. Generation of Localized Sound

There are the methods (Sugibayashi, Kurimoto, Ikefuji, Morise and Nishiura 2012; Shi, Nomura, Kamakura and Gan 2014) by which localized sounds are generated at the particular position using parametric speakers that emit localized sounds by using amplitude modulation by the ultrasonic wave (Westervelt 1963). Also, there is a method (Yonezawa, Ino and Kitagishi 2016) by which localized sounds are generated using synchronized personal smartphones or tablets. The purposes of such studies and our study are to generate localized sounds at the particular positions.

Such studies that generate the localized sounds by DBAP (distance-based amplitude panning) (Lossius, Baltazar and Hogue 2001) could cause the listener to feel wrapped in the sounds. In order to prevent this problem, we use one directional-controllable parametric speaker whose height and position are set by two servomotors.

2.2. Movement of Virtual Agent

An ITACO system that expresses the movement of the virtual agent among multiple media in order to keep attachment to the agent from the system user (Ogawa, and Ono 2008). In contrast, our proposed system expresses an AATA by the movement of footsteps to interact with the audience members. The purposes of expressing the movement of a virtual agent with ITACO system and of our research are different.

2.3. Lecturer Supporting System by Anthropomorphosis

2.3.1. Anthropomorphized Virtual Agent

A TA system was proposed (Goel, Creeden, Kumble, Salunke, Shetty and Wiltgen 2015) using Watson, which is provided by IBM. This system interacts with the audience through text; for example, it may answer questions from the audience and assist the audience members with their work. This system and our purpose system are the same in terms of assisting the lecturer by creating a virtual agent in the real world.

However, this system can only correspond passively because it is designed to respond to audience input. In contrast, an AATA does not require input from the audience members or the lecturer to interact with the audience members. Thus, the AATA can interact with audience members who pay attention to things other than the lecture.

2.3.2. Anthropomorphized Robot Agent

Some researchers have proposed the use of robot-TAs in education (You, Shen, Chang, Liu and Chen 2006; Meghdari, Alemi, Ghazisaedy, Taheri, Karimian, and Zandvakili 2013; Sun, Li and Nishimori 2017). The purposes of their research and ours are the same in terms of assisting the lecture. However, the robots are physical entities, unlike the virtual agents, and they interact directly with audience members. Also, the robots are visual stimulations for the audience and draw audience members' attention away from the contents of the lecture. In contrast, an AATA ambiently expresses its presence and interacts indirectly with the audience members using only the footsteps. Also, the AATA does not attract attention from audience members because it is not a physical presence. We considered that the AATA would not draw attention away from the lecture contents.

2.4. Drawing Audience's Attention

In educational settings, there are ways to draw the audience member's attention to a particular point using overlapped visual stimulations. These are usually achieved by emphasizing the particular point using the visual stimulations' vibration, switching, and color changing etc. (Ueno, Yoshida and Yonezawa 2017; Koning, Tabbers, Rikers and Pass 2010; Hagiwara, Sugimoto and Kawamoto 2011; Hata, Koike and Sato 2016). These methods are completed easily, however, they do not have an effect on audience members who are not paying attention to the contents of the lecture because the premise is based on the audience paying attention to the contents of the lecture. Also, it is possible that an audience member would pay attention to the visual stimulations rather than the lecture contents (Hata, Koike and Sato 2016).
In contrast, our research aims to draw audience members' attention from the surrounding elements to the lecture. We express the ambient presence of an AATA to the audience using the footsteps as auditory stimulation. We considered that the AATA could interact with an audience member regardless of what she/he was paying attention to. Also, we considered that such an indirect and ambient stimulation would not draw the audience member's attention away from the lecture contents.

3. SYSTEM

3.1. Overview

Our proposed system expresses an AATA in one-to-many communication by moving the localized sounds of footsteps.
Figure 1 shows the system's flow. The AATA that walks toward the target audience members is expressed by moving the localized sounds of footsteps. The target is decided based on the estimated their participating attitudes (Kitagishi and Yonezawa 2017) or the lecturer's operation.
The system hardware consists of a laptop (Mac OS X, 13-inch display, Intel®Core™i5-3427U CPU, 8 GB RAM) to control the system, a web camera (2592 × 1944 pixel resolution) for face detection, a parametric speaker (frequency characteristic: 400 Hz to 5 kHz, using FM frequency modulation) to generate the localized sounds of footsteps, two servomotors for movement of the localized sounds of footsteps, and an AVR (Arduino Uno) to control the servomotors.
This system was implemented using Python 3.5.3[1] for face detection through OpenCV 3.1.0[2] and dlib19.10[3]. The sounds of the footsteps are controlled via PyAudio 0.2.11[4], serial communications to the AVR, and ARDUINO 1.6.13[5] to control the AVR.

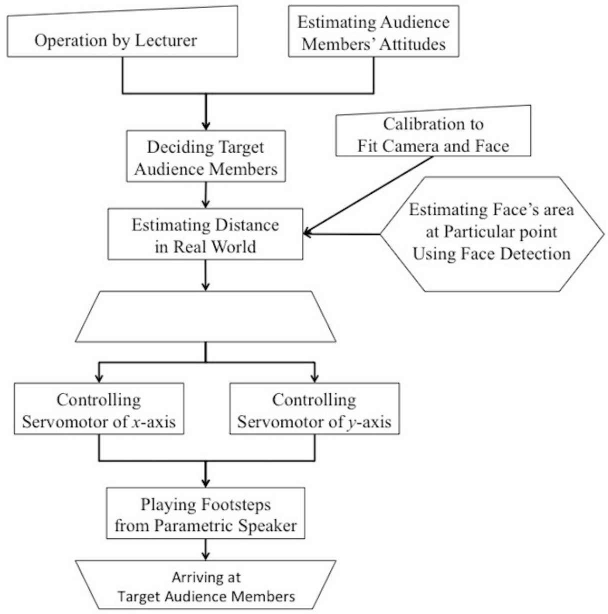


Figure 1: System's Flow

3.2. Configuration of AATA

First, we configured the AATA's height to calculate its stride and walking speed. The AATA was set supposing a male graduate student in early twenties. Accordingly, we set the height to 170.00 cm (Ministry of Internal Affairs Statistics Bureau and Japan Communications 2015; Roser 2018).
Next, we designed the AATA's stride and walking speed based on its height. The AATA's stride was set 76.50 cm corresponding to the general equation, height × 0.45 (Science Buddies 2013), and its walking speed was set 80 m/min, that is 1.74 sec. for one step, corresponding to the average of human's walking speed (Mohler, Thompson, Creem-Regher and Warren 2007) and Japanese Real Estate Fair Trade Council of Federation's agreement (Japan Real Estate Fair Trade Council of Federation 2015).

3.3. Estimation of Distance to Audience

To decide the AATA's walking position, the system estimate the distance between the camera and the audience using face detection. 1) The user (lecturer) first set the target region of the participants in the captured video by removing walls and ceiling from the video to prevent error face detection; *width* = the width of the captured video after the regional configuration (by pixel). 2) The system gets the length and area (by pixel) of audience members' faces using face detection in the captured video. 3) The system calculates an equation ($area = f_s(y)$) using three or more face areas. This equation estimates the face's area (*area*) at a particular y-coordinate in the captured video. The system can estimate the real end-to-end width (w) at a particular y-coordinate in the captured video using $f_s(y)$ and the general face length (14.90 cm)

[1] https://www.python.org/
[2] https://opencv.org/
[3] http://dlib.net
[4] https://people.csail.mit.edu/hubert/pyaudio/
[5] https://www.arduino.cc/

(FaceBase 2015). Equation 1 shows the calculation process.
Equation 2 shows the calculation that estimates the real distance (h_y) between the camera and real position. The coefficients S_{pre} and d in Equation 2 are configured based on the preliminary survey: a position 500 cm (d) away from the camera, the square of 221.01 cm^2 is displayed as 3,969 pixels (S_{pre}).

$$w_y \text{ (cm)}=\frac{width}{\sqrt{f_s(y)}}\times 14.90 \quad (1)$$

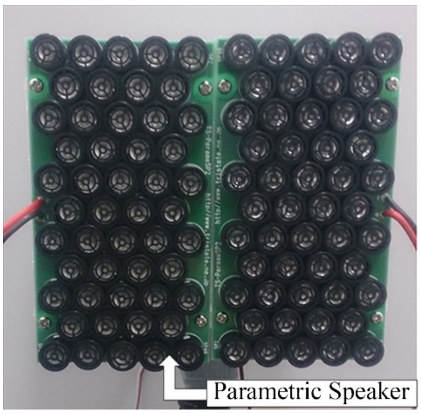
$$h_y \text{ (cm)}=\sqrt{\frac{area}{S_{pre}}}\dot{d} \quad (2)$$

3.4. DCPS: Direction-Controllable Parametric Speaker

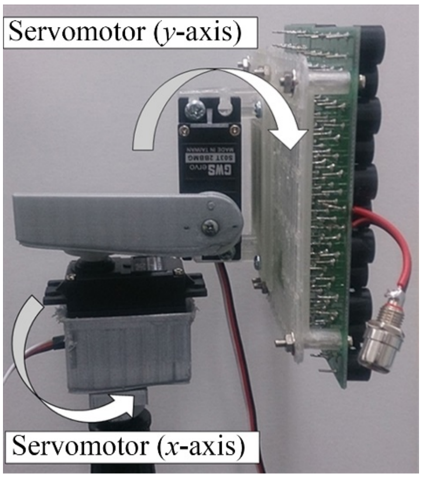
Figure 2 shows a DCPS (direction-controllable parametric speaker, W11 × H10 × D10 cm). The DCPS's height is established to prevent the ultrasonic wave emitted from the parametric speaker from hitting obstructions.
We attached two servomotors that correspond to the *x*- and *y*-axis to the parametric speaker in order to move the localized sounds of footsteps on the floor. The system expresses the movement of the localized sounds of footsteps like a human's walking speed by controlling the angle of each servomotor.
The DCPS position is *O*, the localized sound's position is *P*, the point just below the DCPS is *Q*, and the orthogonal point of *Q* and *P* is *R* (Figure 3). The angle of the servomotor in relation to the *x*-axis ($\angle PQR$) is controlled according to Equation 3. $\angle PQR$ corresponds as follows: 0° = just left, 90° = just front, and 180° = just right. The angle of the servomotor in relation to the *y*-axis ($\angle POQ$) is controlled according to Equation 4. $\angle POQ$ corresponds as follows: 0° = just below the axis, 90° = just front, and 180° = just above the axis. Thus, the parametric speaker faces front when $\angle PQR$ and $\angle POQ$ equal 90°.

$$\angle \text{POR}=\arccos\left(\frac{\text{OR}}{\sqrt{\text{OR}^2+\text{RP}^2}}\right) \quad (3)$$

$$\angle \text{QOP}=\arccos\left(\frac{\text{OQ}}{\sqrt{\text{OQ}^2+\text{QP}^2}}\right) \quad (4)$$



[a] front-view



[b] side-view

Figure 2: DCPS: Direction-Controllable Parametric Speaker

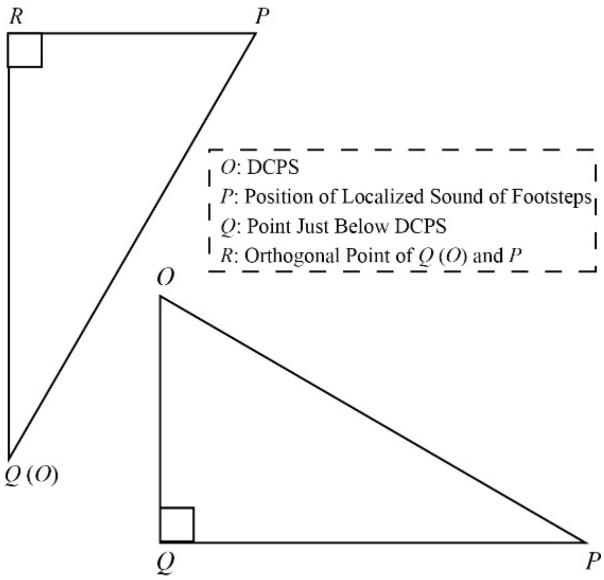


Figure 3: Calculation of Each Servomotor's Angle

4. EXPERIMENTS

We conducted two experiments series. Before describing each detail, the common elements in these experiments are following.

4.1.1. Participants

The participants are 32 Japanese university students between the age of 19 and 24 (20 males and 12 females, mean age = 21.66, standard deviation = 1.42). All participants have normal hearing because we use auditory stimulations in the experiments. We believed that if any of the participants had a hearing impairment, the auditory stimulations could go unheard, possibility affecting the results.

4.1.2. Environment

We performed the experiments in a classroom (W7.19 × H2.94 × D8.60 m) at the university. Figure 4 shows the environment of the experiments. The classroom's noise level during silent period was about 37 dB. In these experiments, we set the DCPS height to 2.38 m using a microphone stand on the desk.

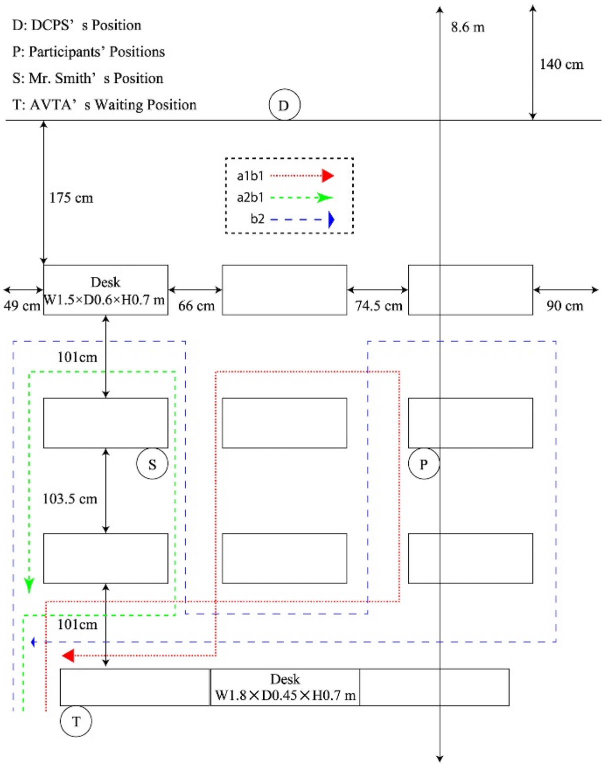


Figure 4: Environment of Experiments

4.1.3. Stimulations

Footsteps: We used "Standard Footsteps, " which is available to the public in "Sound Effect Lab. "[6] to express the AATA's presence. We adjusted the volume of the footsteps so that it would reach about 45 dB regardless of conditions when the AATA got closest to its target member. The positions of the footsteps were set in advance, and the sounds were processed through a high-pass filter to cut off the lower 400 Hz.

Videos: We prepared the videos of "Sudoku" for each condition as the simulated lecture contents. The videos were silent to prevent interference with the footsteps.

4.2. Experiment 1: Presence of AATA by Localized Sounds of Footsteps

4.2.1. Purposes

In this experiment, we verified whether our proposed system can express the someone's presence by moving the localized sounds of footsteps without any visual expression. Also, we verified how the participants recognized as the subject of the footsteps.

4.2.2. Hypotheses

1. It can express the presence of an invisible person by moving the localized sounds of footsteps.
2. The person who hears the moving footsteps feels that the subject of the footsteps is a TA.

4.2.3. Conditions

They are two conditions with one factor: with or without sound localization; a1: with the localized sounds of footstep using the parametric speaker (i.e., using the DCPS), a2: without the localization of footsteps using the loudspeaker (frequency characteristic: 180 Hz to 20 kHz).

4.2.4. Methods

Before the experiment, the experimenter instructed the participant 1) to sit at the fixed position in the classroom, 2) to behave as an audience member attending the lecture, 3) to consider each chair is filled by each audience, and 4) to expect a noise like the Mosquito because the experimenter use a device that emits an ultrasonic wave. The experimenter also informed them that there is no adverse effect on the participant's health.

In the experiment, 1) the participants watch the stimulation video as the contents of the simulated lecture, which is started by the experimenter with a cue of start. 2) Five seconds after the video starts, the footsteps are expressed from the speaker that corresponds to the conditions. 3) After five seconds from the end of the footsteps, the stimulation video is stopped. 4) The participants answered the evaluation items according to the experimenter's instructions.

This experiment was a within-subjects design and the conditions were randomly arranged for counterbalance. Before the experiment sessions, the participants experienced the practice sessions. We did not inform the participants that the footsteps were played from the speaker. The footsteps are expressed as the AATA walks around in the classroom by our proposed system (Figure 4-b2). In order to regulate the experiment's environment with the sound of servomotors, the servomotors were rotated in every condition.

4.2.5. Evaluation Items

The participants answered the following evaluation items.

Q1. You felt something that makes sounds has moved in the classroom
Q2. You felt something that makes sounds has existed in the classroom.
Q3. You felt someone has existed in the classroom besides you and the experimenter.
Q4. You felt someone has walked in the classroom besides you and the experimenter.
Q5. You felt someone has walked toward you.
Q6. Who do you think that the subject of the footsteps was?; α: teacher, β: TA, γ: other student, or δ: other.

The participants evaluated Q1 to Q5 using a five-point relevance rating (5: very relevant, 4: somewhat relevant, 3: even, 2: somewhat irrelevant, 1: irrelevant), and Q6

[6] https://soundeffect-lab.info/

Table 1: Experiment1; Results of Votes and Chi-squared Test (Q6)

	measured value				$\chi^2(3)$	p	Multiple comparison with Ryan's method
	α: teacher	β: TA	γ: other student	δ: other			
a1	17	11	4	0	21.250	*	α > γ, α > δ, β > δ
a2	16	9	5	2	13.750	*	α > δ

$p < 0.05$ = *, all expected values = 8.0

using choices α to δ. In addition, there was a free response section.

Q1 and Q2 are for verifying the participants felt something that makes sounds existed in the classroom. Q3 to Q5 are for verifying the participants felt the presence and movement of an invisible presence. Q6 is for verifying who the participants felt the subject of the footsteps. We set up the choices α to δ as the possible people who walked in the classroom.

4.2.6. Results

First, we mention to the results of Q1 to Q5. Figure 5 shows the means and SEMs (standard error of the mean) of the responses, and the results of the paired t-test with a significance level of 0.05. There are significant differences in all evaluation items. In the results of Q2, the mean of the a2 level is significantly higher than that of the a1 level. In the other evaluation items, the means of the a1 level are significantly higher than that of the a2 level.

Next, we mention to the results of Q6. Table 1 shows the number of votes for each choice and the results of the chi-squared test with a significance level of 0.05. In the chi-squared test between two conditions (2 × 4), there was no significant difference ($\chi^2(3) = 2.431$, $p = 0.505$), thus we used the chi-squared test between four choices (1 × 4) in each condition. In the a1 level, there were significant differences: α > γ, α > δ, β > δ. In the a2 level, there was a significant difference: α > δ.

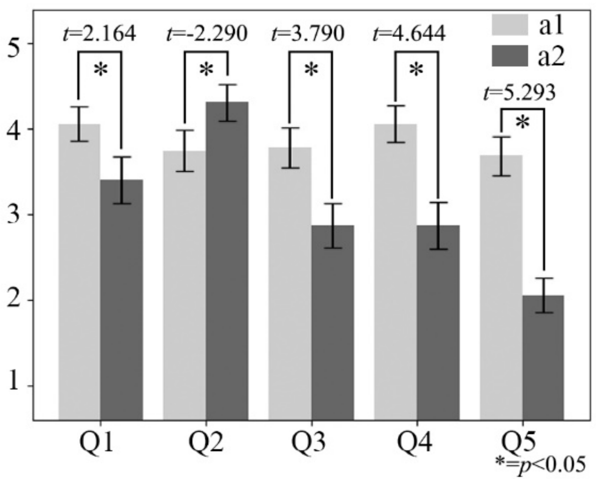


Figure 5: Experiment 1; Means and SEMs of Responses, and Results of T-test (Q1 to Q5)

4.2.7. Discussions

First, we discuss the results from Q1 to Q5. In the results of Q1 and Q3 to Q5, the participants tended to feel the presence of an invisible person by movement of the localized sounds of footsteps created via the DCPS. These results support Hypothesis 1. Therefore, we consider that our proposed system can express an AATA simply by moving the localization of the sound source of footsteps, and the interaction between the AATA and the audience members has potential to be achieved in the lecture.

About the results of Q2, we considered that the mean of the a2 level, the use of the loudspeaker without the sense of movement, is significantly higher than the means of the a1 level because Q2 asks about the presence of the sound source regardless of the sound localization.

Next, we discuss the results of Q6. From the result of the chi-squared test between the a1 and a2 levels, we considered that the sound localization does not affect participants' recognition of the subject of the footsteps. From the results of Q1 to Q5, we consider that the effectiveness of the a1 level (i.e., our proposed method) is shown, and the a2 level is set up to compare with the a1 level. Thus, we discuss the results of the a1 level only. According to the results of the chi-squared test of the a1 level, the participants tended to believe the subject of the footsteps was not a student but the teacher. These results do not support Hypothesis 2. However, the participants significantly selected "α: teacher" than "γ: other students" as the subject of the footsteps, that is, the AATA was recognized as a person who is a person in the lecture-administration side. From the results, we consider that the AATA can fulfill its roles such as warning audience members.

4.3. Experiment 2: Influences by AATA's Movement toward Audience Members who do not Concentrate on Lecture

4.3.1. Purpose

In this experiment, we verified the influences of the AATA's movements toward the audience members who do not concentrate on the lecture.

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4.3.2. Hypotheses

When the audience members do not concentrate on the lecture,

1. the audience members feel as though the AATA pays attention or has negative impressions toward them by a) the AATA's walking around the audience members, b) its stopping at the place close to the audience and c) its fast walking toward the audience members;
2. the audience members pay attention and get negative impressions toward the AATA by its actions from a to c in Hypothesis 1;
3. the audience members feel that the AATA pays attention and has negative impressions toward a third person (*the other person*) by a) the AATA's walking around *the other person*, b) its stopping at the place close to *the other person* and c) its fast walking toward *the other person*;
4. the audience members pay attention and get negative impressions toward *the other person* by the AATA's actions from a to c in Hypothesis 3.

4.3.3. Conditions

They are 16 conditions with four factors, as follows.

A. The target that the AATA walks toward (a1: the participants, a2: *the other person*).
B. The routes of the AATA's movement toward the target (b1: the shortest routes, b2: a long route walking around in the whole of classroom regardless the other conditions).
C. The AATA's stop at the place close to the target (c1: for three seconds, c2: without stop).
D. The speed of the AATA's walk toward the target (d1: faster than usual speed (100m/min.), d2: unchanged).

Figure 4 shows the walking routes of AATA that are changed based on Factor A and B.

4.3.4. Methods

After Experiment 1, the participants experienced Experiment 2 with the following instructions: 1) the participant behaves as an audience member attending the lecture, 2) she/he should consider as though there are audiences for each chair in the classroom although there is nobody besides the participant and the experimenter, 3) the presence of an audience called Mr. Smith (i.e., *the other person*) is expressed by an illustration signboard put on a chair in the classroom, and 4) an invisible TA may sometimes walk in the classroom. We did not inform the participant of Mr. Smith's participating attitudes.
In this experiment, 1) the stimulation video was started by the experimenter with a cue of the start. The participants read the comics (Sasaki 1995) without watching the video as a task simulating the audience who does not concentrate on the lecture. 2) Five seconds after the video starts, the AATA walks in the classroom corresponding to conditions. 3) After five seconds of the end of the walking of AATA, the participant answered to the evaluation items according to the experimenter's instructions. This experiment was a within-subjects design and the conditions were randomly arranged for counterbalance. Before the experiment sessions, the participants experienced the practice sessions.

4.3.5. Evaluation Items

The participants answered the following evaluation items.

Q1. You felt that the TA has existed in the classroom.
Q2. You felt that the TA has walked in the classroom.
Q3. You felt that the TA considered as you had concentrated on the lecture.
Q4. You felt that the TA has paid attention to you.
Q5. You paid attention to the TA.
Q6. You felt the negative impressions to the TA.
Q7. You felt that the TA had a negative impression to you.
Q8. You felt that the TA considered Mr. Smith as concentrating on the lecture.
Q9. You felt that the TA have paid attention to Mr. Smith.
Q10. You felt that the TA had the negative impressions to Mr. Smith.
Q11. You felt that Mr. Smith had concentrated on the lecture.
Q12. You paid attention to Mr. Smith.
Q13. You felt the negative impressions to Mr. Smith.

The participants evaluated all evaluated items using a five-point relevance rating as same as Experiment 1. In addition, there was a free response section of the experience.
Q1 and Q2 are for verifying the presence of AATA. Q3, Q4 and Q7 are for verifying the AATA's impressions toward the participants. Q5 and Q6 are for verifying the participants' impressions toward the AATA. Q8 to Q10 are for verifying the AATA's the impressions toward *the other person*. Q11 to Q13 are for verifying the participants' impressions toward *the other person*.

4.3.6. Results

Figure 6 shows the means and SEMs of the responses, and Table 2 shows the results of the four-factor repeated measures ANOVA with a significance level 0.05.
In the results of Q1 and Q2, there are significant differences at Factor A with the b1 level and Factor B with the a1 and a2 levels.
In the results of Q3, Q4 and Q7, there are significant differences at Factor A with the c1 levels of Q3, Q4 and Q7, Factor A with the c2 levels of Q3 and Q4, Factor C with the a1 levels of Q4 and Q7, and Factor B with the a1 level, Factor B with the a2 level and Factor A with the b1 level of Q7. Therefore, Hypothesis 1 was supported.

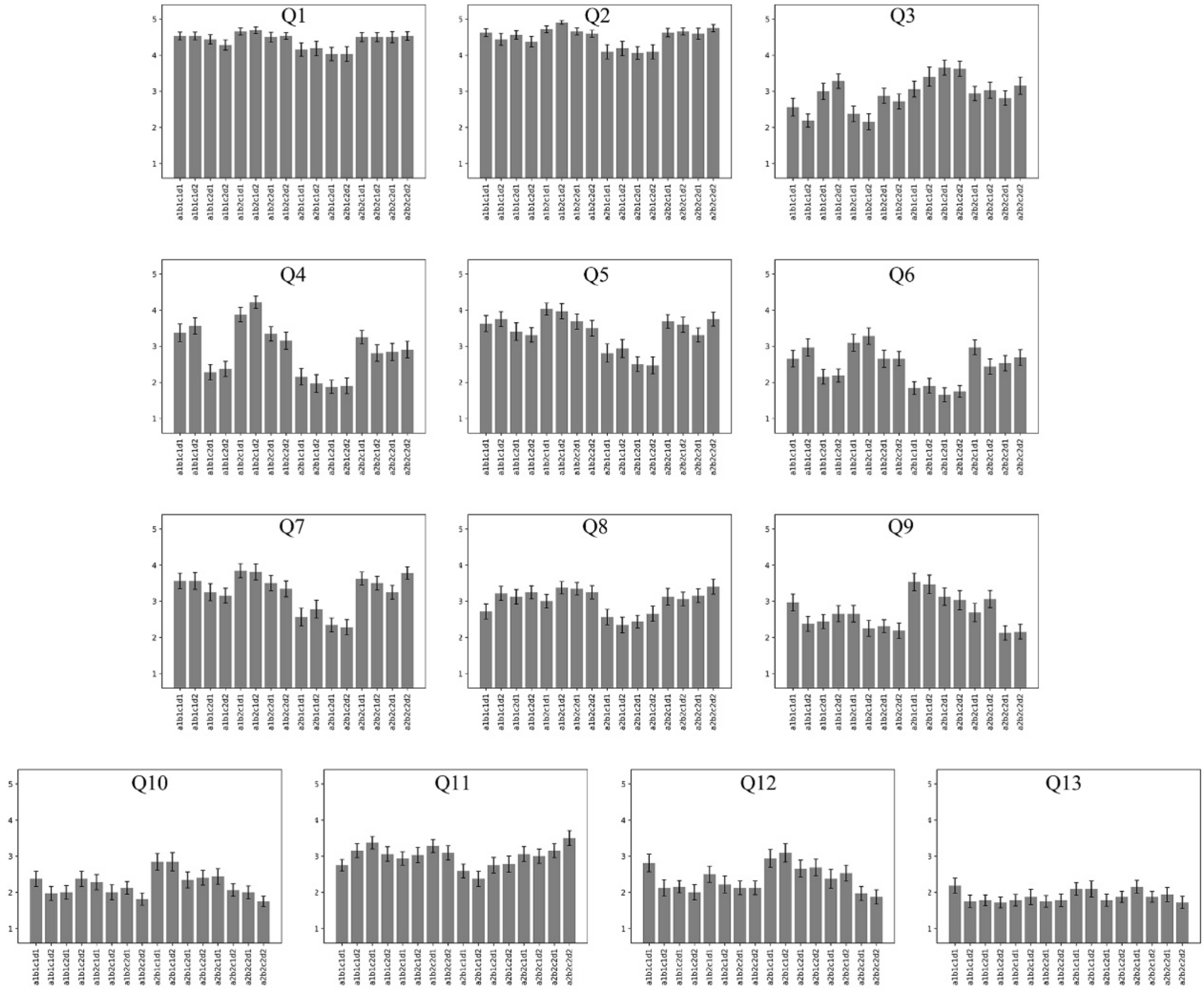

Figure 6: Experiment 2; Means and SEMs of Responses

The significant differences in Q5 and Q6, at Factor A with the b1 levels and Factor B with the a2 levels, supported Hypothesis 2.

In the results of Q8 to Q10, there are significant differences at Factor A with the c1 levels and Factor C with the a2 level of Q9 and Q10, and Factor B with the a2 level and Factor A with the b1 level of Q9. Thus Hypothesis 3 was supported.

In the results of Q11 to Q13, there are significant differences at Factor A with the b1 level and Factor B with the a2 level of Q11, Factor A with the b1 level of Q12, and Factor A with the b2d1 level and Factor D with the a2b2 level. Thus Hypothesis 4 was supported. On the other hand, there is a significant difference that dismisses Hypothesis 4 at Factor D with the a1b1 level of Q13.

4.3.7. Discussions

First, we discuss the presence of AATA. All mean values of Q1 and Q2 are significantly higher than 3 (the expected mean value) by the results of the one sample t-test (all *p*-values less than a significance level 0.05). We consider that the presence of AATA by the footsteps is already strong, so it is not changed by its behavior as a ceiling effect.

Next, we discuss the AATA's stopping behavior. From the results of Q3, Q4 and Q7 to Q10, the participants tended to perceive the change of direction of the AATA's attention. On the one hand, from the results of Q5, Q6 and Q11 to Q13, the participants' impressions toward the AATA was not changed by its stop at nearby. We consider that the AATA without any action after stopping near the participants cannot affect the impressions. Accordingly, it is necessary to make some action after the AATA's stop to enhance the attentive behaviors.

Next, we discuss the AATA's walking speed. From the results of Q3 to Q7, the participants' impressions toward the AATA was not affected by changing the AATA's walking speed. On the one hand, the participants seemed to perceive the change of AATA's walking speed from the results of Q13. It is conjectured that the change of the AATA's walking speed does not change the AATA's impressions from the audience members but changes the impressions of interaction among the other audience members and the AATA.

Table 2: Experiment 2; Results of Four-Factor Repeated Measures ANOVA

	Factor A		Factor B		Factor C		Factor D		simple and simple-simple effects of significant interactions
	F	*p*	*F*	*p*	*F*	*p*	*F*	*p*	
Q1	8.976	*	15.883	*	2.966	0.095	0.014	0.906	b1(a1>a2), a1(b2>b1), a2(b2>b1)
Q2	10.284	*	27.866	*	1.826	0.186	0.028	0.868	b1(a1>a2), a1(b2>b1), a2(b2>b1)
Q3	13.932	*	8.018	*	12.793	*	0.206	0.653	c1(a2>a1), c2(a2>a1), a1(c2>c1)
Q4	46.537	*	64.929	*	27.600	*	0.012	0.913	c1(a1>a2), c2(a1>a2), a1(c1>c2)
Q5	24.746	*	22.950	*	6.934	*	0.164	0.688	b1(a1>a2), a2(b2>b1)
Q6	20.658	*	7.047	*	7.047	*	0.246	0.623	b1(a1>a2), a2(b2>b1)
Q7	11.642	*	10.205	*	10.205	*	0.150	0.701	b1(a1>a2), a1(b2>b1), a2(b2>b1), c1(a1>a2), a1(c1>c2)
Q8	14.125	*	11.467	*	2.379	0.133	2.742	0.108	b1(a1>a2), a2(b2>b1)
Q9	17.084	*	11.656	*	13.148	*	0.683	0.415	b1(a2>a1), a2(b1>b2), c1(a2>a1), a2(c1>c2)
Q10	5.754	*	8.190	*	9.403	*	5.126	*	c1(a2>a1), a2(c1>c2), d2(b1>b2), b2(d1>d2)
Q11	3.603	0.067	5.122	*	5.855	*	0.021	0.885	b1(a1>a2), a2(b2>b1)
Q12	5.012	*	6.129	*	13.486	*	1.280	0.267	b1(a2>a1), a2(b1>b2)
Q13	3.380	0.059	0.385	0.540	4.714	*	4.106	0.051	b2d1(a2>a1), a1b1(d1>d2), a2b2(d1>d2)

$p < 0.05$ = *

Finally, we discuss the impressions toward *the other person*. From the results of Q11 without any preceding instruction of *the other person's* attitude, the audience may perceive that the other audience members approached by the AATA are not concentrating to the lecture.

5. GENERAL DISCUSSION

In this paper, we proposed and verified that the AATA was expressed by moving only the localized sounds of footsteps. While the expressiveness of the AATA is limited (e.g., walking, running, stopping, changing direction) if the system uses only footsteps, it is obviously necessary to add more stimulations such as sound effects, voice, BGM, and projection mapping of a virtual sound source to promote further interactions between the AATA and the audience members. On the other hand, the interaction between the AATA and the audience members becomes direct if the AATA's elements are increased too much. Accordingly, it is desirable to add selective/effective elements that would not draw the audience members' attention too much in order to maintain indirect and ambient interaction between the AATA and the audience members.

As related works (Giordano and Bresin 2006; Visell, Fontana, Giordano, Nordahl, Serfin and Bresin 2009), they have shown that the tone, pressure, direction, and speed of human footsteps expresses her/his presence. We consider that the multiple AATAs with different roles can be realized by changing its walking patterns; for example, one AATA warns the audience members while another AATA supports them.

From the results of the experiments, we confirmed that the participants felt the invisible presence (i.e., the AATA) presence expressed by our proposed method. We confirmed that the AATA can express its presence to the audience members regardless of what they pay attention to. Additionally, the AATA can also express its emotion and attention to audience members simply by walking. Correspondingly, it is conjectured that the AATA can draw the audience member's attitudes to the lecture by these results.

In future work, we would like to verify whether the audience members' impressions of the AATA change by their participating attitudes toward the lecture. In addition, the system does not consider control of the footsteps' volume from the parametric speaker based on attenuation of the ultrasonic wave with the distance and surrounding noise level in a real lecture. We consider it is necessary to control the volume based on such a case not in a simulated lecture but in a real lecture. We would like to conduct the experiment in a real lecture using such system improvements.

6. CONCLUSION

We proposed an acoustic AR-TA agent (AATA) to support lecturers by semi-autonomously drawing audience members' attention to the lecture in one-to-many communication. The AATA is expressed by moving the localized sounds of footsteps on the floor using a direction-controllable parametric speaker. The experiment results showed that the presence of AATA can be expressed using our proposed system, and the AATA can show its attention to the audience members who do not concentrate on the lecture by its approach. Therefore, we consider that the AATA can appropriately warn to the audience members.

In future work, we would like to achieve and verify the interaction between the AATA and the audience members using footsteps along with other modalities.

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VIRTUAL SPACES FOR COLLABORATION AND LEARNING CONSTRUCTING MULTI USER VIRTUAL ENVIRONMENTS FOR LEARNING

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ABSTRACT
In this paper we present a way of use of virtual environments as Virtual Reality (VR) to conform multi user virtual environments for collaboration and learning, allowing students and professors interact within a virtual space in real-time, reviewing and presenting topics and materials, coaching and tutoring to enhance learning process.
We review three technologies on the market who facilitate constructing this kind of spaces and share our experiences on our pilot implementations. This is a research in process and other implementation and evaluations will be done in future works.

Keywords: virtual reality, multi-collaboration systems, student engagement, distance assistance.

1. INTRODUCTION

Tecnologico de Monterrey is a geographically dispersed institution of higher education in Mexico. It has 32 campuses organized in 5 regions (North, South, Pacific, Center, Mexico City), because of this organization most of the course are offered in a local way, some efforts are doing using technologies such as video-conference to facilitate interactions with limited benefits.
We explore the use of VR technology in a distributed form, taking advantage of telecommunications and networks to enrich the interaction of students and professors in activities where the learning process are present and can be enhanced using VR technologies.
Other important consideration for development of this project is the cost reduction of VR technology, new products development (HMDs, GPUs, VR Ready computers, and controls), new software platforms who facilitate the integration and publishing of those kind of experiences (5 reasons why virtual reality is booming, not waiting 2016).
On this work we present our experience of use of virtual environments (VR) to conform multi user virtual environments for learning. We review tree technologies on the market who facilitate constructing this kind of spaces and share our experiences on pilot activities.
This is a research in process project part of Tecnologico de Monterrey Novus projects (Novus 2018) and other implementation and evaluations will be done in future works.

2. DEVELOPMENT

2.1. Method

We follow these steps for development:

1. Problem definition
2. Technology review
3. Pilot 3D virtual spaces for teaching
4. Data gathering and analysis
5. Conclusions

Description of those steps are at next sections of the paper, general method is based in Action Research Framework as an interactive process balancing problem and solving implemented actions to understand causes and enabling future predictions about personal and organizational change (Reason & Bradbury, 2001).
As we mention this is a working in progress paper, and the pilot testing and data collection will be doing on fall semester 2018, August to December. Our plan is collect data using qualitative tools as observation and interviews, and according to action research framework collected data will suggest adjustments to the plan to resolve identified issues and plan next interaction.

2.2. Problem definition

Tecnológico de Monterrey has taken the decision to evolve towards a new educational model that allows its students to become leaders prepared to face the challenges and opportunities of the 21st century (Tec21 2018). New education model is based in 4 main components:

1. Challenge based learning
2. Flexibility
3. Inspiring professors
4. Memorable experience

Inspiring professors are the main pillar of the model to provide academic quality education, they have the responsibility to create an active learning environment, captivate the student's attention, challenge, guide and potentiate the development of the student, as well as It has to stands out as an academic and leader in its discipline, it should be innovative and takes advantage of technology.

One of the great elements of classic education at classroom, is that it allowing students and professors interact at the same time, same space, interchanging ideas, questions, having a direct communication considering social and affective elements on an interactive way. Unfortunately, current educations models use this time and space for lecturing presenting theory, concepts, expositions, etc., and one of the main challenges at the classroom at present time is maintain student attention, here the importance to use modern digital technologies as VR to increase attention and knowledge retention as a vivid experience.
But include VR as an education technology needs to be analyzed to develop a better understanding. VR is human centered as Sherman and Craig (Sherman WR, 2003) describe as "that physical immersion and highly interactive simulations are key components of the medium", this empathize three characteristics of VR or 3-I's of VR as Burdes (G. Burdea, 2003) describe: Immersion, Interaction, Imagination. These elements are important features in a local learning environment, but combining it with networks and telecommunications evolution, to conform distance virtual learning environment, were students are active participants of the learning process collaborating with partner students and guided by professor.
Marwa (Marwa 2014) present a great analysis about VR education, on figure 1, we present the seven challenges of learning on three dimensional worlds to support and enhance learning.

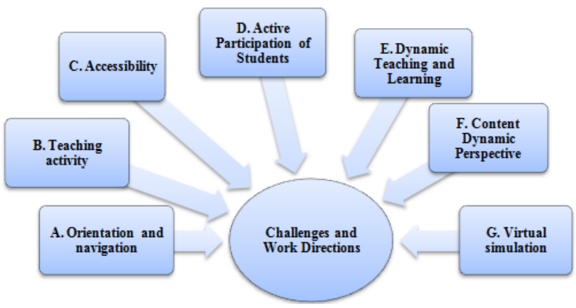

Figure 1: Challenges and work directions

Some of those challenges are professor (or educator) and student related such as:

- Teaching activity
- Active participation of students
- Dynamic teaching and learning,

Here the importance to include instructional designs and experimented professors to design the learning experience. Unfortunately, only a small amount of universities 148 on 2003, and 273 on 2008 according to Burdea (Burdea 2008) offer courses with VR and most of them are part of computer science topics, here the importance and need to develop content and activities for different learning areas for example: physics, math, engineering, among others.
Because professors design these activities and most of them are not technology experts or software programmers, software tools must be easy to use and facilitate the integration of media elements (video, images, animations, etc.) in an intuitive and friendly interaction.
Other challenges are technology related such as:

- Orientation and navigation
- Accessibility
- Content dynamic perspective
- Virtual simulation

The technology evolution and market is addressing them, because of that we have low cost HMD's (Head Mounting Displays) as HTC-Vive and Oculus Rift devices, and also from software perspective we have new kind of VR tools to simplify the creation and integration of virtual learning spaces with a rich media contents.

2.3. VR Tools

We review three tools available on the market for collaboration in virtual environments, our main objective is not to make an exhaustive evaluation of platforms to select one, we only present general features of platforms and can be used to create interactive multiuser environments, to better understand the impact on the learning process. Revised tools are: Vizible, Rumii, and Engage. Table 1 resume general features of respective tools as a comparative view.

2.3.1. Vizible

Developed by Worldviz (Worldviz 2018) and released on February 2018 after a beta testing period on 2017, works under Windows OS, the complete solution has a tool for design virtual spaces: Presentation Designer, and tools for runtime presentation: Client Attendee and Client Presenter.
Presentation Designer, Figure 3, allows the use of tools to construct virtual spaces (scenes) from scratch or using available templates, is a simple drag and drop tool, and allows integration of diverse set of media such as: images, sound, pdf files, standard videos and 360° videos, also allows selection of avatars, teleports, proximity sensors and interaction with the space, it allows to setup session IDs for presentation. Client Presenter is the moderator of the session, Figure 3.
Client Attendee for student or participant on a session.
At moment of review it allows to select only two kind of avatars representations, allows the use a set of tools for interaction: pencil, laser pointer, object grabber, space navigation, teleport, Slide clicker for scene navigation and remote control for multimedia.

Figure 2: Vizible Designer

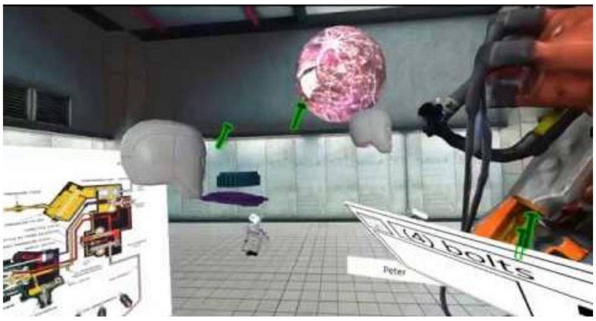

Figure 3: Vizible Client

2.3.2. Rumii

Developed by Doghead Simulations in 2016 (Rumi 2018), it is a company that its leadership team is respected in the virtual reality industry. Their CTO Co-Created the HTC Vive & the CCO Co-founded Infiny Ward. Rumii uses VR to Amplify Communication and Collaboration, VR to Increases Fidelity and Immersion. In its current version 1.1 it allows use variety of customizable avatars and present a set of preconfigured spaces for interaction with limited customization, allows distribution via Steam, iTunes and Google Paly, integrate media content (presentations, videos, images) and 3d Objects, another feature is to share PC screen. Figure 4.

Figure 4: Rumii platform

2.3.3. Engage

Developed by Immersive VR Education (VR immerse education, 2018), is a social education and corporate training platform designed from the ground up to support virtual and augmented reality devices, allows to hold meetings, classes, private lessons, events and presentations with people from all around the world in a safe virtual multiuser environment and allows to setup password for private sessions. ENGAGE allows you to record and create your own lessons, presentations using 3D preconfigured spaces such as the surface of Mars, sea and marine space, a science museum style space, or classic auditorium space for teaching.

Figure 5: Engage platform

Table 1: VR tools for multiuser virtual environments

Feature:	**Vizible:**	**Rumii:**	**Engage:**
Platform	Windows	Windows and Mac OSX	Windows
VR System	HTC-Vive, Oculus, PPT (Precision Position Tracking), and Desktop	HTC-Vive, Oculus and Oculus Go, iOS, Android, and Desktop	HTC-Vive, Oculus, and Desktop
Tools	3D navigation, laser pointer, pencil drawing, object grabber, remote control for play-pause-stop media, bidirectional audio.	3D navigation, laser pointer, whiteboard, 3D object manipulation, screen sharing, file sharing, bidirectional audio	3D navigation, bi directional audio, record of sessions
Media Resources	Audio, video, image files, PDF, 3D models, 360º photo and video	Video, 3D models, presentation and image files	Video, 3D models, sounds,2d images
Participants	4	25	35
Other features	Full editor for 3D space and configuration. two avatar types. teleports and proximity sensors. recording of virtual interactions for posterior reproduction.	Limited customization of 3D spaces. Rich customizable avatars.	At present no customization of 3D space, no avatar selection, recording of virtual interactions

2.4. Pilot 3D virtual spaces for learning

In this section we present some of the scenarios designed for pilot these tools.
First one is based on Vizible, it allows you to customize in full the 3D virtual space, we design a space that will be used for Math teaching, Figure 6. On Figure 7, we present other two spaces designed to teach Physics and Figure 8 a space designed for Arts teaching.

Figure 6: Designed 3D space for Math

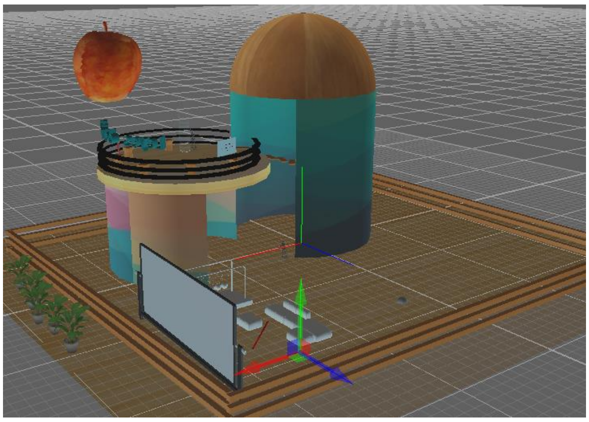

Figure 7: Designed 3D space for Physics

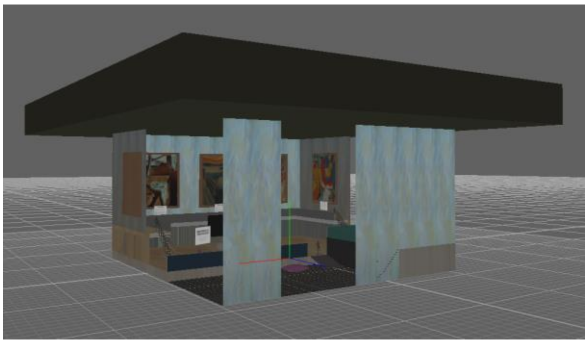

Figure 8: Designed 3D space for Arts

Second space is Rumii, it offers a limited option to customize a 3D space, but this apparent limitation, can be a feature for professors with limited capabilities to use modeling tools to design his own 3D space. We present on Figure 9, and Figure 10, 3D spaces reviewed with professor interest on use on his own class.

Figure 9 3D space used with Rumii

Figure 10: 3D space with Rumii

Engage offer pre-constructed 3D spaces you have to select one for, at review moment it does not allows customizations, Figure 11.

Figure 11: 3D space with Engage

3. CONCLUSIONS

As a working in progress project, we have some preliminary conclusions, we organize in three perspectives: Professor, Student, and general.

Next semester Aug-Sept 2018 (fall semester) we will have instruments to collect data considering qualitative elements to precise project conclusions.

3.1. Professor perspective conclusions

Most of the professors never have used before VR and got impressed about immersion and required minimum support to get ready to use the platforms.

Younger professors showed more interest in use this VR collaboration technology to teach and measure the impact on students on his class, but they have the concern about the experience needed to design learning activities for students.

Professors expressed concerns about the learning curve needed to learn the use of these technologies, and the equipment required to practice and design learning activities.

Another concern was related to student attention, although we hope these technologies capture student's attention, we have to be careful, so it is not being another distractor.

3.2. Student perspective conclusions

Most of the students does not used before VR, but they are used to using video games, so they learn to use these technologies in a shorter time as professors.

Many students have not used before HMDs, so in a similar way as professors, they got impressed about immersion, this a good sign to catch their attetion.

3.3. General perspective conclusions

One important element to consider is the infrastructure needed for project implementation, in general students and professors does not have VR ready computers and HMD and controls for personal use, for that reason Tecnologico de Monterrey is the process to acquire equipment to work in this pilot project.

Networks and telecommunications infrastructure are other element to consider, at present time we do not have numbers to quantify these requirements.

We need to generate instruments to measure the impact on learning as well as the technical requirements for the correct implementation.

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CONCEPTUAL MODEL OF AUGMENTED REALITY USE FOR IMPROVING THE PERCEPTION SKILLS OF SENIORS

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ABSTRACT

If we believe in statistical data, unless skilled labour resources in EC will not be updated on migration, the problems expect pension beneficiaries' and other socially protected groups that are jointly supported by workers. It is important to be aware of the challenges that are expected and to keep skilled professionals in the labour market as long as possible, compensating for loss of job capacity and enabling skills development through the use of ICTE and the global area of information.

The study aims at establishing a conceptual set of requirements for augmented reality (AR) applications for the preservation and development of older communications capabilities.

The human physical body is aging with time, i.e. worsening memory, perception and functionality. Virtual and augmented reality (VR/AR) applications are associated with the first two elements: memory and perception. Data search and recall functions are associated with memory, but with sensory organs - vision, hearing, touch and taste. The article looks at, above all, vision and memory related issues.

Today, there is a diverse, complex and poorly adaptable, as well as functionally limited but relatively expensive VR/AR equipment, whose sustainability is debatable. The analysis of the situations covered by the article makes it possible to design a conceptual model for the logical structure of the application, which is the justification for further selection of technical equipment and the construction of the physical structure of the socio-technical system.

Keywords: augmented reality, augmented reality reference model, communication skills enhancement, Google Glass

1. INTRODUCTION

Abstracted from a series of different factors that determine the challenges of the development of labour resources in today's digital society, we will only mention three major impacts: aging, migration and digital technologies.

The western civilization is aging. The curve of the changes in labour force is indicative of the constant aging of the working population (see Table 1). Employment rate by age groups (%) in the EU from 1997 includes 19 countries, but from 2001 – the data on all 28 member countries (Eurostat 2018). In certain member countries such as Germany, relevant statistics have been processed since 1993, therefore, for the purpose of clarifying the nature of the curve in the earlier period, these individual data can also be used, the analysis of which confirms the general trends to be analyzed in the future.

Table 1: Employment Rate by Age Groups (%) of Total Population (Eurostat 2018)

Age	1997 (EU-19)	2001 (EU-28)	2016 (EU-28)
15-24	33,4	37,6	33,8
25-54	72,8	76,2	78,8
55-64	33,5	37,7	55,3

The aforementioned Table 1 can be transformed in a more visible form, referring to the number of employees in general (see Table 2).

Table 2: Breakdown by Age Groups (%) of Total Employment

Year	Age (15-24)	Age (25-54)	Age (55-64)
1997	23,91	52,11	23,98
2001	24,82	50,30	24,88
2016	20,13	46,93	32,94

As skilled labour is unlikely to be imported, labour collectives are expected to undergo major changes (see Figure 1). Conducting the linear approximation by labour force age groups, it can be roughly predicted that in the EU countries in 2020, in the labour collective, on average, from every 10 employees, 2 will be under 25 years old, 5 under 55 years old, and 3 will be older.

Whereas in 2030, already 40% of the workforce will be over 55 years old. Since the problems associated with the physical aging of the body are objective, almost half of the workforce will need various support measures to ensure work capacity, which will increase the cost of production.

People having deteriorated memory tend to typically forget both names of facts and visual objects and the related to them information. Especially awkward situations are the ones when a user sees a person as if well-known before, but cannot remember either the name of the person or the related events. One of the functions of AR equipment would be to recognize the object, find the information related to it in the information space, and inform the user in real-time. In addition, the aforementioned functions would also be useful if a previously unknown person was encountered or another object was seen, which was previously unknown, but visually identifiable (a landscape, a building, an animal, a drawing, etc.) can be found in the information space. In this case, the informational function could be accompanied by the learning/training function or the guidelines for further action can also be provided. For example, AR equipment enables a car mechanic to visually recognize a specific technical unit that differs in car models and provides guidelines for its repair. This way, new additional qualification skills are ensured. It would also be useful to provide an opposite alternative. There may be a situation where an object is identified using other types of recognition (documents, biometrics, technical implants etc.), but after that its visual image and the related information are passed to the AR user. In this case, additional verification options are provided. For example, by reading the biometric implant code of a stray dog, remote search of the data can be conducted in the pet's register, but the received information with the dog's photo is given to the user displaying it with AR equipment, which allows comparing existing data with the real object.

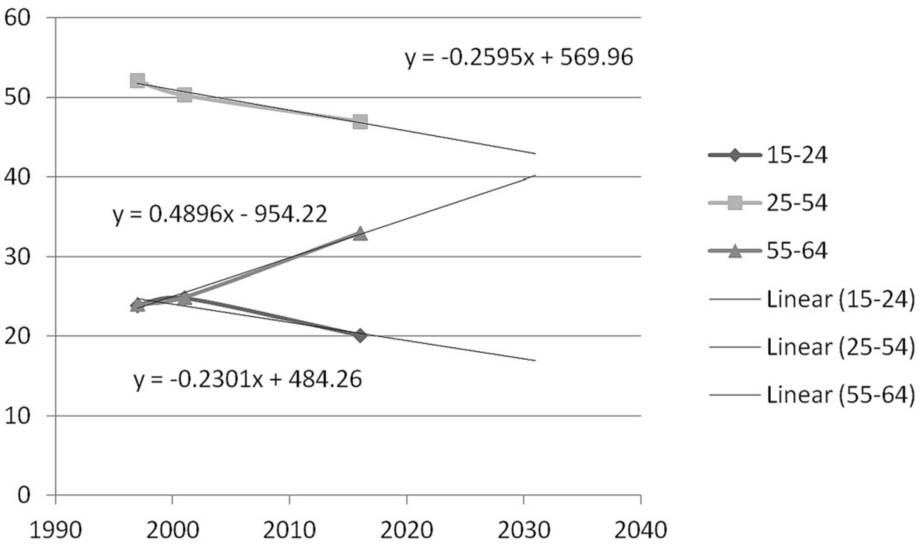

Figure 1: Breakdown Forecast by Age Groups (%) of Total Employment

The advanced visualization capabilities make it possible to pre-process the read information by simplifying and/or improving the representation of the objective reality and/or increasing the size (scaling) of the identified object, for example, a text and images.

The wave of migration is continuing and no changes are expected in the near future, as they are mainly determined by socio-economic factors. Migration and business globalization, and the same time interaction between different social and cultural systems as well as religions, inevitably call for the emergence of multi-language work collectives. In addition to this, it refers to not only the office environment that also becomes multi-language, but also the customer structure becomes analogous. This means that the employee must be able to communicate freely enough in at least three different operating languages. Respecting aging and the ever-tense rhythm of work, it is not always possible for the successful tuition of the work collective members. The peculiarities of perception of a person must also be respected. A visualist and a kinaesthetic will learn the language with difficulties, as other channels of perception dominate. Often this is typical of the representatives of the exact sciences. If this characteristic is accompanied by the gradual deterioration of memory and hearing typical for seniors, the opportunities for acquiring new skills become even more problematic. However, translation software is becoming more and more complete today, but in this case, a perfect translation into the mother tongue is not necessary. It is enough to be able to understand and visualize using AR equipment the content and the nature of the information provided by the member of the conversation, which could be provided in real-time mode.

Digital technologies development increases the efficiency of work and facilitates social life, however, as any process, it also has its own side effects. The

introduction of mobile telecommunications facilitated communication, but the use of SMS service, complemented by the streamlining of social networking resources, transmission of audio-visual data and creation of the developed virtual entertainment environment, step by step offset individuals in the society. People are gradually losing their literary language and natural communication skills.
More and more people are spending time struggling on the screen of a computer or a smart phone, which sooner or later will inevitably affect the quality of vision and, in particular, peripheral vision. Of course, in a civilized society, an individual does not have to constantly care if he is tolerated or attacked by anyone, however, the driver's loss of peripheral vision would be a significant problem.
Sedation is also increasing, which causes decrease of muscle mass and other problems associated with overweight.
It remains to respect the existing situation and develop digital technologies that can at least minimally compensate for the basic problems of memory and perception deterioration mentioned above.

2. AUGMENTED REALITY SOLUTION – SOCIOTECHNICAL SYSTEM AND DIGITAL TECHNOLOGY

The existing regularities of objective nature (OR) are in the process of inquiry simplified, thus forming a researcher's idea of the research object (see Figure 2). Then the concept is translated into a model using different specification methods with varied semantic capacities.
In digital society practically all the models are sociotechnical (S_{TS}) respecting interoperability of both parts – technical (T_S) and social (S_S).
Technical systems usually are closed and determined, but social systems are open and stochastic. The architecture of the model (abstract or physical) is determined by the existence of logical (L^S) and physical (Ph^S) structures and the interaction of these structures (Ginters and Aizstrauta 2018).
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 (Ginters and Aizstrauta 2018).

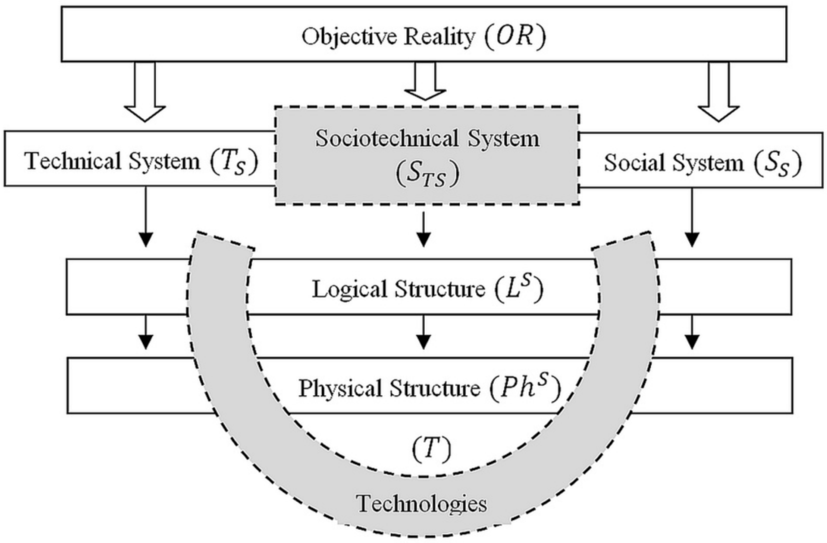

Figure 2: Systems Architecture in Digital Society (Ginters and Aizstrauta 2018)

A common manifestation of physical and logical structures is a variety of technologies (*T*). New technologies are emerging as a product of interaction of engineering and society. If the social factor is not respected, the technology will be destined to fail. At present, the driving force behind technological development is the needs of society.
AR solution is typical sample of sociotechnical system and the same time digital technology.
The development of sustainable AR solution must be directed from requirements to logical and then to physical structures designing under the framework of regular social validation.

3. CONFERENCE CASE – GENERAL REQUIREMENTS MODEL OF AR SOLUTION

Let's consider the case of a conditional typical AR conference application. The case described below is a traditional situation that is characteristic not only of conferences, but also of daily communication that is not only in the office but also in everyday life. Practically the conference case is voice and image processing subsystems interoperability presentation and the same time requirements model for AR solution.
First of all, certain problems can be caused by finding a conference venue. Something that seems to be very easy for the organizers is often difficult for the participants

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of the conference. Of course, in this case, we are not talking about identifying a country or a settlement, but finding the right building and entrance is often a problem. The participant is not always able to communicate in the language of a particular country. The assumption that, at the right time, there will be available residents who will at least speak English, or will be able to explain whether a particular building is sought, may be unreasonably optimistic. So there must be technologies that will not only determine the location but will also be able to recognize the specific buildings and inscriptions on them. GPS and digital map will not be enough here. You need to recognize both the landscape and the object and translate the inscriptions into the desired language.

During the presentation, the author is observing the audience and sees a number of previously met people who are waiting for the report with interest, and may also ask clarifying questions and make remarks in the future. Who are these people? The situation may become particularly awkward if it turns out that the author knows some people very well, but cannot remember either the names of these people or the events associated with them. Recognition will become more complicated if identifiable persons move in the auditorium. For example, a person is approaching the author to start a conversation. The author has to understand if competent questions are expected or they will be asked because the conversation partner does not have enough background knowledge on the particular topic. It is important to create a presentation style using a specific industry slang, or to substantially simplify the content, making it understandable to the audience without preliminary knowledge. Since the audience is not just a couple of front rows, but the author's vision is no longer so great, it is desirable to also recognize the people sitting farther in the hall. So you need the scaling capabilities of the display. Possibly, opponents with already-prepared posters and flags that are placed in the hall, or raised and flipped during the presentation, are also present. It is very good if their content is favourable, but the opposite is also possible. So not only the recognition of textual information is desirable, but also the understanding of virtual objects. Questions are often submitted in writing during the presentation. This means that at least minimal handwriting recognition and translation capabilities must be ensured.

The aforementioned requirements are binding not only for visual but also for audio information processing. Of course, it is not necessary to recognize a particular person by his/her voice, this is not a routine task. However, it is necessary to regulate the volume of the sound, as well as define the language of the conversation and provide real-time translation. This alternative form of perception is also important for people who have a significant deterioration of vision. In turn, the conversation and/or its translation must also be able to be printed, as the author may have a deteriorated hearing.

It would be important to decide if the set of the AR requirements should include the need to translate and reproduce the audio information provided by the author? Perhaps, this would not be advisable because it would require significant data-processing resources, which would not be outweighed by the expected benefits. In this situation, the existing and sufficiently cheap portable translation devices that will be sufficient in everyday communication could be used since the author can use a limited vocabulary to explain his point of view.

Looking at the aforementioned requirements, it can be seen that a set of operations, such as face recognition and/or language translation, require significant resources that cannot be provided by portable AR solutions available to a wide audience. That is followed the requirement for the real-time Internet access and cloud support service provision. For the sake of saving resources, VR functions will not be provided there. For example, the functionality will not involve rendering and new virtual object design operations. The object of AR solutions is the objective reality, and the support of VR is only so much that AR must be able to recognize previously created virtual objects.

The conference case described above further serves for the following visual recognition and voice processing subsystems logical structure designing.

4. THE LOGICAL STRUCTURE OF AR SOLUTION FOR PERCEPTION SKILLS ENHANCEMENT

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, where, based on the software engineering concepts, depicted in the UML diagram breakdown in the six main functional subsystems:

- Application - placeholder for all application code,
- Interaction - processes any deliberately input,
- Presentation - displays 3D output for the user,
- Tracking - computation the user’s pose,
- Context - collects and converts different types of context data,
- World model – stores the data about real-world objects.

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.
The reference model of AR solution in conformity with conference case requirements involves two interoperable subsystems for visual recognition and voice processing.

4.1. Visual recognition subsystem

Visual recognition subsystem (see BPMN2 diagram on Figure 3) must give the answers on three basic questions:

- What is this – what is the content of the eyesight, how much objects are on the scene,
- Who it is – each visible object must be identified by its type and recognized,
- Where it is – location of the objects could be recognized.

Visual recognition BPMN2 model comprises some basic activities corresponding to the set of requirements formulated before: identification, recognition, tracking and visualization.

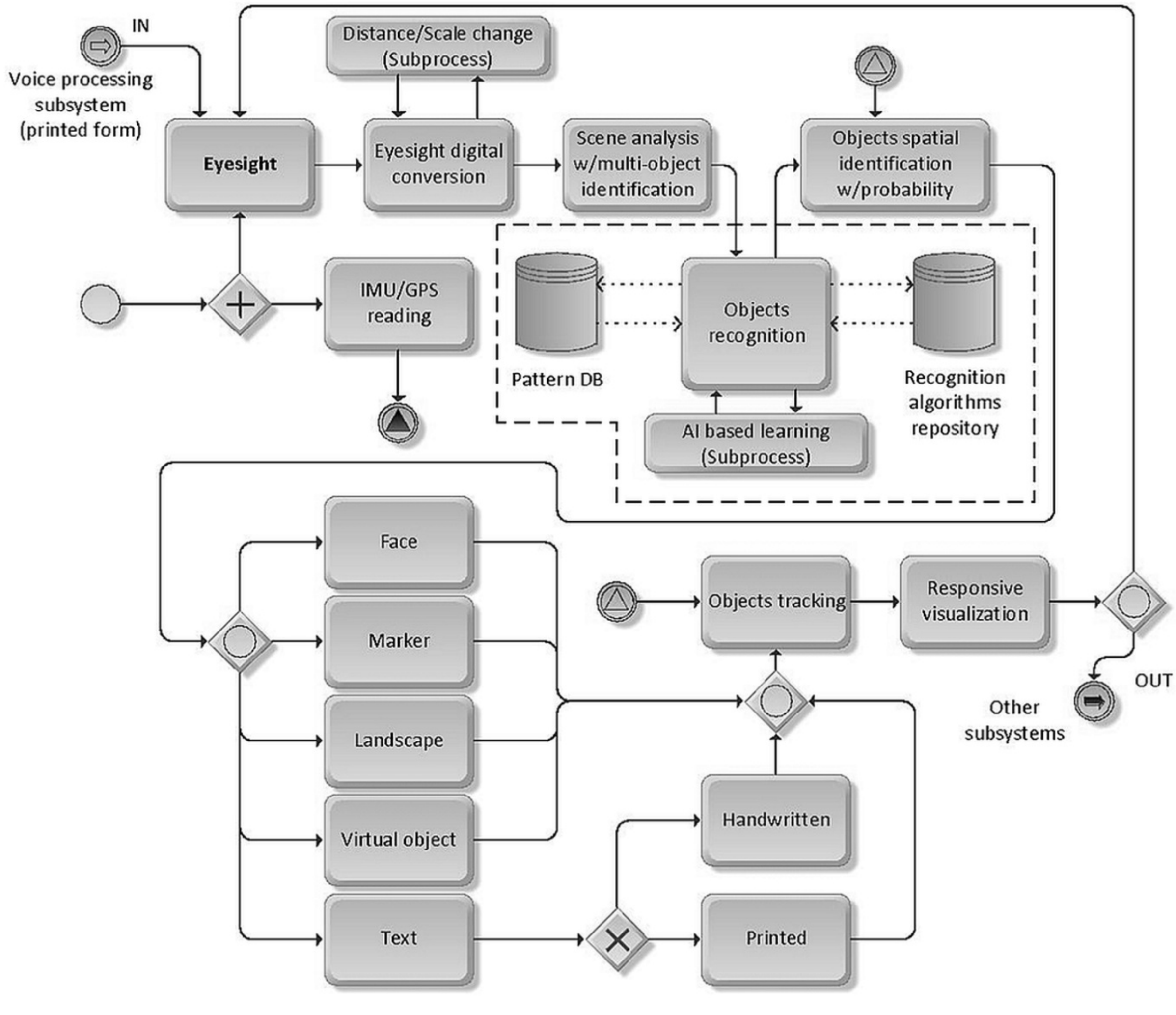

Figure 3: Reference Model of Visual Recognition Subsystem

At the same time, two processes are paralleled: eyesight processing and inertial measurement unit (IMU) data reading. IMU measures a body's specific attitude using a combination of accelerometers, gyroscopes, magnetometers etc. IMU allows a GPS receiver to work when GPS-signals are unavailable (Colin 2011). Of course, GPS data are also read at the same time as the IMU flow. In some cases, RFID solutions are also used to identify specific objects (Ginters and Martin-Gutierrez 2013). These data are needed to detect the presence of the identified objects in the space and to ensure their tracking. The system visually identifies five different object types: face, marker, landscape, virtual object and text. All these objects form a common scene. This means that it may be necessary to simultaneously identify and recognize different objects. If in the simplest cases, such as the marker type object, the analyzer performs matching patterns in pattern DB, then facial or text recognition is a labour-consuming process, which may require analyzer training using artificial intelligence (AI) techniques. Image recognition will be affected by resolution and lighting as well as facial mimics and accessories (a hat, glasses, scarves, etc.). Problems can be caused by the object distance and the camera angle. It is not expected that the portable and widely used AR solution, the basic computing resource of which is a smart phone, will be able to provide the appropriate capacity and memory resources for recognition, which is why the essential requirement for each subsystem is the efficient Internet connection. Therefore, the chart (see Figure 3) features with an interrupted line the functions that are implemented as the outsourced service on the cloud.

The processed data are visualized on head-mounted display (HMD), replicated to other devices, or become available to other subsystems, including voice processing. The visualization must be responsive. It is automatically matched to the resolution of the imaging device and other technical parameters. It is also advisable to use the visual analytics and to adapt the eyesight image on the HMD to the person's professional domain (Nazemi, Burkhardt, Ginters, and Kohlhammer 2015).

The visual recognition subsystem serves requests for voice processing, since the recognized and / or translated voice content sometimes must be displayed in printed form. This is important if the user has deteriorated hearing, or he does not remember the audio information.

4.2. Voice processing subsystem

The main tasks of voice processing are translation and reproduction (see Figure 4). At time also you need to amplify the signal. The source of an input signal can be both an environment and a visual recognition subsystem. Reproduction of the input signal or translation can take place both in audio form and in writing. Written replication in turn serves as input data for the visual recognition subsystem.

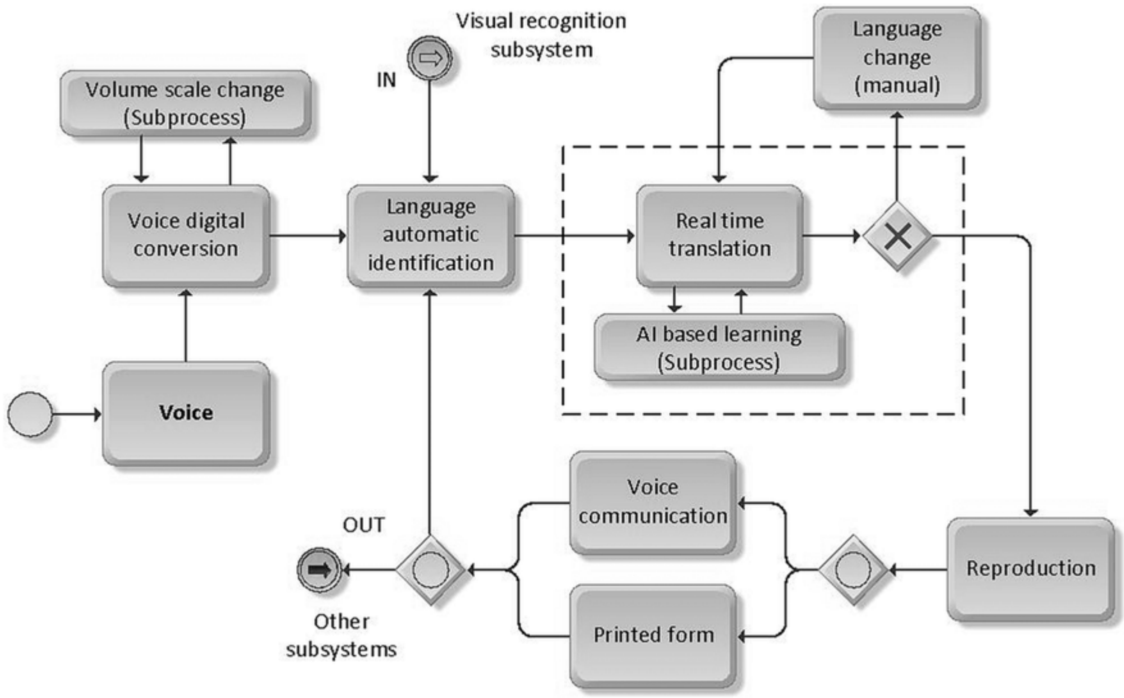

Figure 4: Reference Model of Voice Processing Subsystem

Also translating process requires significant computer resources, therefore in Figure 4 the interrupted line highlights the functions that are not implemented directly on the AR equipment, but are outsourced.

5. AR PHYSICAL STRUCTURE – ENVIRONMENT FOR REQUIREMENTS IMPLEMENTATION

The physical structure has two components: hardware and software. Software consists of operating system, systemic components and AR application. However, hardware in this case is first choice object.

An appropriate AR solution hardware must consist of a portable HMD and data processing equipment that, while respecting the requirement towards the size of the users' audience, cannot be anything other than a smart phone compatible with the visualization device.

5.1. Smart glasses selection

Smart glasses contain a variety of functionality that can ease the user's everyday life. They must meet the following criteria: convenient use, size and weight limitations, sufficient battery life. In the author's conducted study, each model is characterized by a set of parameters: weight, operating system, Wi-Fi, resolution,

RAM, built-in memory, processor, Bluetooth, battery capacity and price. Several smart glass models have been analyzed: Recon Jet (Glass 2015; Random 2018), Telepathy Walker and Jumper (Telepathy 2015), Vue (Vue 2018), Moverio BT-200 (Epson 2018), Jins meme ES, ODG R9 (ODG 2018), SED-E1 (O'Reilly 2018), HoloLens (Rowinski 2013) and Google Glass (Selmanovic 2018; Salton 2017). The authors did not review the HMD models that did not meet the logical structure requirements and are focused on the implementation of the VR functions, such as Oculus Rift VR, Samsung Odyssey and etc. HoloLens is the only model viewed.
Comparing the capacity of RAM, the leader with 6GB was the ODG R9, but HoloLens with 2GB RAM lagged behind. Other competitors can be found within RAM 1GB area. The aforementioned solutions are also the leaders in built-in memory volume estimation, respectively reaching 128GB ODG R9 and 64GB HoloLens. The third place belongs to Google Glass with 16GB built-in memory.
Complicated and disputed is the question of using multi-core CPU. It is logical that the existence of multi-core would allow parallel processing of data and achieve a higher overall performance. However, multi core operating will cost faster battery consumption, but the software will have to be able to use the benefits of these multi-core CPU. If we assume that the software will handle it, then the leader among smart glasses will again be ODG R9, which has 8 cores, but HoloLens has 4, while the rest of the bulk have only 2 cores. The more significant parameter than the amount of CPU cores is the clock speed. The winners in this evaluation are SED-E1 with 2.5GHz and OGG R9 with 2.45GHz, while Google Glass reaches 1.2GHz, but HoloLens has only 1GHz.
An important parameter is the resolution that determines the image quality, although the use area of AR solution is important here. If the AR equipment is used in surgical operations, then the increased requirements are understandable, but in everyday applications it will inevitably affect not only the price of smart glasses, but also the size and the consumption of the battery. The horizontal and vertical aspect ratio of the screen is usually 16: 9. The resolution leaders are ODG R9 and HoloLens, which provide 1080 light points vertically, while the Recon Jet reaches 720 points.
The essential compatibility issue is operating systems support. Undeniably, Android versions predominate, and only some smart glasses models are capable of working with iOS or MS Windows. Vue and Google Glass work on both Android and iOS environments, while HoloLens, of course, is provided for MS Windows mainly.
Operative use time depends on both the battery resource and the intensity of use, so this parameter is relative. However, the leader in this parameter assessment is Google Glass, with a running session of up to 15 hours, while BT-200 model can operate 6 hours, but HoloLens - only 2 hours. However, with respect to battery aging and the operation of smart glasses in real applications, we can assume that operative real use time will be substantially shorter.
Smart glasses prices are relatively stable, so there is no specific reason to expect a significant decrease during the life-cycle. The most expensive solution is HoloLens, which costs around $3,000, followed by Telepathy Walker and ODG R9 with $2,000, while the price of the Google Glass basic version is at around $1,500. And finally the weight of smart glasses. The meaning of this parameter will be understood by anyone who is compelled to use glasses every day. So HoloLens weighs 579g! Who is ready to carry half a kilogram on his nose? Whereas, the OGG R9's and Google Glass achieved just 180g.
It is seen that Google Glass, ODG R9 and HoloLens are significantly superior in several categories. The most powerful is the ODG R9 model, however, respecting the daily requirement for battery life, Google Glass is the most appropriate device out of these visualization devices.
In 2018, actually a visually slightly improved prototype of Google Glass Vuzix Blade AR (Statt 2018) was created. However, while respecting the need for outsourcing functionality related to image recognition and translation, it would not be right to cherish expectations about the successful use of this prototype.
Google Glass appeared on the market in 2014 (Savov 2017). Since smart glasses was equipped with a camera, they were criticized due to the reasons of privacy threat. In 2015, Google Glass public trading was stopped, but the project was continued, and in 2017 a new version of Google Glass was created (Salton 2017).
Google Glass is equipped with a touch-screen, which is located on the side of the glasses. With its help the user is able to control the device. Different commands can be initiated with varied gestures. Google Glass has 5 mpix camera for video recording with 720 pix quality (Jackson 2015). Smart glasses are equipped with liquid crystal on silicon (LCoS) un LED display with backlight. It also has 16 GB built-in memory, 1,2GHz dual core CPU, microphone, Bluetooth and Wi-Fi, 2 GB RAM, 570 mAh embedded battery with micro USB socket (Technopedia 2018). Last version has IMU, GPS and GLONASS support, 32 GB built-in memory, Intel Atom CPU and 780 mAh battery (Hall 2017). Google Glass has compatibility with Android 4.3 and later and iOS operated equipment.

5.2. AR application software designing framework

The AR application software improving communication skills and abilities is a part of the AR physical structure. Its functionality is determined by the set of logical structure requirements and the selected Google Glass AR device. The development environment must be valid for the designing of the AR application and further exploitation. If the costs of the development process are not fundamentally important, operating costs may be a critical factor in determining the acceptance and sustainability of the AR solution.

Development software set must be compatible. It consists of operating system, development environment/kit (SDK) with AR engine, additional libraries, third part remote services and AR application to be designed, while the hardware involves Google Glass and compatible smart phone.

AR engine must ensure the main functionalities – objects tracking, real and virtual objects identification, reaction on context changes and interoperability. The ability of the engine to provide collaboration with cloud services is important. Engines were compared by authors in accordance with their functionality, license types, operating systems and/or platforms, markers generation methods, tracking and content (images, video, 3D animations) covering possibilities.

The authors' conducted study included analysis of several development environments, in particular, Metaio SDK (Srah 2014), Vuforia SDK (Mykola and Gleb 2018), Wikitude SDK (Siltanen 2012), D'Fusion (Srah 2014), ARToolKit (Siltanen 2012) and ARmedia 3D SDK (Salenko 2018).

Metaio, D'Fusion and ARmedia support the development of AR software on the platforms of Android, iOS, MS Windows and Flash. Vuforia supports the development on the platforms of Android and iOS, whereas Wikitude supports the development on the platforms of Android, iOS and BlackBerry OS. ARToolKit supports the development on the platforms of Android, iOS, Linux, OSX and MS Windows.

Metaio has no marker generation options like Vuforia, however, Metaio has 512 different free markers built into it. Vuforia can upload an image that the user wants to use as a marker, and the generator will create the necessary patterns. ARmedia SDK does not support marker generation, so the user needs to install Google SketchUp in the ARmedia plug program, which will provide the required function. D'Fusion SDK can provide around 500 sets of image-labels. Wikitude provides both marker generation and image usage in the form of markers. ARToolKit SDK is capable of handling only square markers that allow 2D bar codes to be used as markers.

Metaio and D'Fusion can process GPS data, IMU, face, landscape and 3D objects. Wikitude cannot process a face and 3D objects. ARmedia cannot process a face, but Vuforia can process just a landscape and 3D objects. ARToolKit and Vuforia does not support GPS and IMU. All the engines more or less support 2D/3D content.

Metaio, Vuforia, Wikitude and ARmedia are available both free of charge and commercially. ARToolKit is available as a commercial SDK with open source license.

Traditionally, the AR engines use Open Source Computer Vision Library (OpenCV). The library can be used by C++, Java un Python, and it works on MS Windows, Linux, iOS and Android environments. The library contains over 2500 different algorithms, which can be used to recognize faces, to identify objects, to identify people's gestures, to follow objects and the movements of eyes, as well as to recognize the landscapes and etc. OpenCV has over 47 thousand users in total. The approximate number of downloads exceeds 14 million (OpenCV 2018).

The authors have developed a model that contains 17 questions suitable for the SDK choice. Answers to questions are a prerequisite for a reasonable choice of AR engine. With no additional difficulties, you can select Metaio or D'Fusion, which provide a set of necessary functionality for conference case implementation.

However, in this case there are both limitations and benefits of the use of Google Glass. Google Glass software development differs from the traditional applications development. Google Glass works with cards that are in the glasses time zone and displays various information for glasses users. Although, it is possible to personalize the visualization and processing of information using the immersion approach (Savov 2017).

Google Glass supports Python, PHP and Java languages. Basic development platform comprises some of Android SDK where Google Glass development kit (GDK) must be installed. In MS Windows, iOS or Linux platforms Android SDK emulator can be used. There are exist also specific on Android platform-oriented software development environments as Eclipse, Android Studio, IntelliJ IDEA, NetBeans, Xamarin.Android and JetBrains Rider (Slant 2018). The authors tested IntelliJ IDEA environment because it uses computing resources in economic way and has a wide set of supported languages.

Right gentlemen's set selection which consists of operating system (Android) with development environment/kit (SDK) (Metaio or D'Fusion or Intellij IDEA) and GDK will ensure usable AR solution designing which will correspond to the requirements of logical structure defined above. It will provide information visualization, object type identification, objects tracking options and even more recognition the objects.

However, translation, handwritten text recognition and some advanced simultaneous multi-face recognition operations are out of this menu. Third-party computing services are required there.

When choosing a third-party service, you must respect the compatibility with the Google Glass technical features and the existing drivers. Google Glass benefits determine the more convenient abilities of the Google services use, for instance, Google translate service (Rubino 2016) and voice conversion into textual information with Google Cloud Speech API (Google Cloud 2018). It is based on computer learning and allows developers to convert audio into text using neural network models. The Google Cloud Speech API recognizes more than 110 languages provided by the global user base. The text can be prepared from the microphone, but you can also use audio files.

The most common problem is the voice itself. Differences between different accents and pronunciations may lead to inaccurate translations. Another negative feature is the background effect. For control purposes, the voice translation text can be displayed on Google Glass using Captioning on Google Glass (CoG 2014). It will help people with hearing impairment or language difficulties. The opposite direction is also important when textual information is to be recognized. Google Word Lens offers real-time translations of 6 languages for textual information into English and vice versa (Broida 2010).

The authors carried out testing of Captioning on Google Glass and Word Lens software and found that the translation of sentences caused difficulties for both products, although the accuracy of Captioning on Google Glass is higher, though.

The testing of the collaboration abilities of Google services and Google Glass conducted by the authors has approved that the development of a truly AR-compliant solution that meets the requirements mentioned in the conference case can be a complicated and highly labour-consuming task.

6. ACCEPTANCE ANALYSIS OF AR SOLUTION FOR COMMUNICATION SKILLS ENHANCEMENT

Smart glasses are not popular in society, because people are not only unaware of existence of these glasses and obtaining options, but also do not see their real use. In the spring of 2018, the authors conducted a potential audience survey to find out the potential acceptance of the AR solution in the society. Anonymous poll was published on Facebook. The aim of the survey was to find out the awareness of different age groups about smart glasses and their views on the use of smart glasses for improving communication skills.

The majority of the respondents age group 72.1% were between 18 and 25 years old, perhaps, because social networks are more often used by the representatives of this group. The second largest group was 17.3% aged from 26 to 35 years old, followed by a 6.7% age group below the age of 18 years old, while people aged over 35 years old only provided 3.8% of the answers. The most responsive respondents, 64%, were females.

More than 30% of the participants of the survey had not heard anything about smart glasses. In turn, from the respondents who were aware of the existence of smart glasses, 11.5% considered that they are impractical, 41.3% thought that they are expensive, 18.3% did not see their implementation, 8.5% believed that they could relieve their everyday life, but 37.5% believed that they could be practically useful in various applications.

The question "Could smart glasses improve communication skills and capabilities?" received the confirming answer from 70% of the respondents, but 30% gave a negative answer.

In turn, the question of how then communication skills could be improved, the answer to the "Translate texts" was chosen by 41.3%, the answer "Translate what the respondent or another person said" was chosen 34.6%, the answer "During the conversation you can look into the pre-made notes" was chosen by 50%, 37.5% chose the answer "Improve language learning", but 19.2% of the respondents did not respond.

The question of whether the respondent would use such glasses on a daily basis if they improved their communication skills, 70% gave positive answers. In addition, 60% of the respondents confirmed that they had previously faced a situation where smart glasses would have been useful.

The main issue, of course, was the cost of the glasses. 46.2% of the respondents would like to pay less than 200 Euros, 24% would buy smart glasses at 200-500 Euros, 4.8% would be willing to pay from 500 to 1000 Euros and only 1% would buy them if the price will exceed 1000 Euros.

104 respondents participated in the express survey, but the audience were not targeted selectively. It turned out that acceptance rates are not so bad. Because, about 6% of the audience that do not belong to the most solvent age group, nor is it endowed with communication problems, could be the potential users of the appropriate AR solution.

7. CONCLUSIONS

In 2030, already 40% of employees will be over 55 years old. As the problems associated with the physical aging of the body are objective, almost half of the workforce will need various support measures to ensure work capacity, which will increase prime costs. It remains to respect the existing situation and develop digital technologies that can at least compensate for the basic problems of the memory and perception deterioration mentioned above. AR application is one of the possible solutions.

In digital society practically all the solutions are sociotechnical respecting interoperability of both parts – technical and social. AR solution is typical sample of sociotechnical system and the same time digital technology. The development of sustainable AR solution must be directed from requirements to logical and then to physical structures designing under the framework of regular social validation.

The reference model of AR solution involves two interoperable subsystems for visual recognition and voice processing. Visual recognition model comprises some basic activities corresponding to the set of requirements formulated in the article: identification, recognition, tracking and visualization. The main tasks of voice processing are translation and reproduction.

An appropriate AR hardware consists of a portable HMD and a smart phone that is compatible with the visualization device.

Smart glasses contain a variety of functionalities that can ease the user's everyday life. They must meet the following criteria: convenient use, size and weight limitations, sufficient battery life. The study conducted by the authors characterized each model in accordance with the following set of parameters: weight, operating system, Wi-Fi, resolution, RAM, built-in memory, CPU, Bluetooth, battery capacity and price. 10 smart glass models were analyzed, of which Google Glass was the most promising.

The communication skills and capabilities improving AR solution software design are determined by the set of logical structure requirements and the selected Google Glass AR device. AR engine must ensure the main functionalities – objects tracking, real and virtual objects identification, reaction on context changes and interoperability. The engines were compared according to their functionality, licence types, operating systems and/or platforms, markers generation methods, tracking and content (images, video, 3D animations) covering possibilities.

Usable AR application development and exploitation software set must be compatible and consists of operating system (Android), development environment/kit (SDK) (Metaio or D'Fusion or Intellij IDEA) with AR engine, Google glass development kit (GDK), additional libraries (like OpenCV), third-party remote services (perhaps, Google) and AR application to be developed. However, for handwritten text analysis and simultaneous multi-face recognition operations more advanced third-party services would be required there.

The survey conducted by the authors showed that, at the moment, AR solutions are not popular in the society because people are not only unaware of such existence and possibilities for obtaining, but also do not see their real use. However, the part of the informed audience is positive. This confirms the need to continue working on the development of real and functionally useful AR applications, although respecting the financial capacity of the potential users.

The further direction of the work will involve the development and validation of a real conference case, in an effort to reduce the use of remote third-party services, which significantly affects the real-time use of the AR solution.

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3D Scenery Learning on Solar system by Using Marker Based Augmented Reality

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***Abstract*— Augmented reality (AR) is the technology that works on computer vision based recognition algorithms to augment sound, video, graphics and other sensor based inputs and real world objects using the camera of your device. AR applications can become the backbone of education industry. Apps are being developed which are embed text, images and videos, as well as the real-world curriculums. With help of AR, travellers can access real-time information of historical places just by pointing their camera viewfinder to subjects. There are two major forms of augmented reality, marker-based AR and markerless AR. A marker based AR works on concept of target recognition. The target can be 3D object, text, image, QR Code or human-face called markers. Whereas marker-less AR, also known as location-based AR, uses GPS of mobile devices to record the device position and displays information relative to that location. Few drawbacks in marker-less AR like house resolution, size variation and time delay can be solved using marker based algorithms such as marker detection, triangle similarity for marker to camera distance and corner detection**

Keywords- Augmented reality, Marker, Camera, education technology, tracking.

I. INTRODUCTION

In Traditional way of teaching the grasping capability, concentration is less as the voice scatters due to acoustic effect [3]. Therefore the students lack focused learning, emphasis on critical thinking, process oriented learning and interactivity [6]. These drawbacks can be overcome by Augmented Reality teaching method which gives a visual experience for the students which increases their concentration, grasping ability and ability to understand things better.

The Augmented Reality is considered as a deviation of Virtual Reality. It allows users to experience the real world with virtual objects superimposed with real image. This technology supplements the real world with composite 3D virtual object [4]. In order to achieve this goal one has to obtain the relationship between the real world and camera's view point. As the user's moves their view point, the computer generated object should remain aligned with the real object [10]. The track viewing pose is used to define the projection of the 3D scene into the real world images. Therefore tracking accuracy greatly affects the accuracy of alignment [5]. Assume a case that the working space of an augmented reality application is as large as a room, one has to place markers all [1] over to make sure that he can see the marker anywhere. Moreover, study of the planets with AR assisted technology can provide learners with perceptual feedback and interaction, allowing them to understand the content better and reach the learning objectives more easily [6] [7].

II. LITERATURE SURVEY

Aw Kien Sin et al [1] has proposed an idea in tangible interaction in Learning Astronomy through Augmented Reality and this paper highlights the interaction in live solar system (LSS). LSS is an augmented reality book based educational tool. They have not used the traditional computer input devices such as mouse or keyboard but they have used visual information seeking Mantra principle to give a better exploration experience in the field of education. Dayang Rohaya Awang Rambli et al [2] has proposed an idea on Fun Learning with AR Alphabet Book for Preschool Children by using superimposed virtual alphabet in a fun and interactive manner using the pattern markers as an interaction tool and this paper tells about that the children reaction in AR Teaching is positively more compared to traditional teaching and reported that they enjoy using AR book. Sylvain Bernhardt et al [3] has proposed an idea on Automatic localization of endoscope in intraoperative CT image which is a simple approach to augmented reality guidance in laparoscopic surgery and this paper highlights the use of augmented reality in minimally invasive surgery that has been the subject of much research for more than a decade. The endoscopic view of the surgical scene obtained is augmented with a 3D model extracted from a preoperative acquisition. It is the first AR method in Laparoscopy based on optical tracking. Jorge Martin-Gutierreza, Manuel Conterob, Mariano Alcaniz [4] has proposed an idea on Augmented reality to training spatial skills which was introduced to improve the spatial ability of students developed using a spatial skill training course based on augmented reality and graphic engineering contents through computer vision techniques for incorporating visual objects through fiducial markers in the real world.

Gue won Rhee et al [5] has proposed an idea of supports adaptive, accurate visual based tracking in AR environment and proposed a context-adaptive tracking method which can not only remove the jumping effect of rotating virtual objects when their reference is changed from one marker to another but also adjust location of invisible tangible markers by interpolating the locations of existing reference marker. Danakorn Nincareana et al [6] has proposed an idea of improving the quality of teaching and learning activity using mobile phones and AR. Mobile Augmented Reality learning based systems are focused on games or simulation and with the ability of mobile devices which has portability, social interactivity, individuality, context sensitivity and connectivity have make a learning experience more meaningfully. Antonia Cascalesa, David Perez-Lopez et al. [7] has proposed an idea of AR technology has important positive effects on the students' academic outcomes, according to the parents. The families believe that the students who use the AR technology improve their reading and writing skills, so important in preschool education, therefore children could obtain better final grades. Suyang dong et al. [8] has proposed an idea of Technology advancement in the classrooms for exposing engineering students using 3D visualization tool. AR Vita a software program is developed to validate the idea. where the multiple users wearing head mounded display and sitting around a table all can to observe and interact with dynamic visual stimulations. Thus it coexists with real and virtual object in a augmented space.

Javier Fombona Cadaviecoa, et al. [9] has proposed an idea of the application of mobile devices and augmented reality in the context of education. The main idea is the combination of these technologies to provide data can be overlapped with images detected by the mobile device in real image. The technology of teaching method and innovative initiatives may have on learning output of students. Wannisa Matcha, Dayang Rohaya Awang Rambli [10] has proposed an idea of the technology has been used to enhance group learning. The aim of the exploratory research to investigate the possible AR technology as a computer supported collaborative learning interface for supporting collaborative process in group learning. Physical interaction among group learners can create joyful and engaging learning environment. Jorge Martin-Gutierreza, Egils Guintersb, David Perez-Lopezc [11] has proposed an idea of student's interaction with modern technological gadgets and computers. The aim of AR in laboratory is creating an environment where real life is enhanced by virtual elements in real time. We use AR manual the electric machine practices are optical for implementation of AR techniques. Hirosuke HORII, Yohei MIYAJIMA [12] has proposed an idea of developing various educational materials for teaching hand-drawn mechanical drawing the virtual educational material constructed by 3D-CAD are superimposed to a real time camera image as AR object. Students can watch the object from various directions by using a cubic marker intuitively.

III. PROBLEM DEFINITION

A. *Technical Issues*

The Recognition rate is a major issue in which camera takes a lot of time to detect the marker and so the output is delayed. The Lightning condition in the test environment also affects Target detection and Tracking if the scene details and target features are not visible in the camera view. The Resolution of Target (Marker) is also an important factor in which the Tracking is affected by the size of the Marker and Distance from the Camera.

B. *Social Issues*

Socially acceptable systems also need to consider a natural way of interaction between the user and the device. The most challenging aspect of teaching and learning is paying attention. A large number of students does not pay attention in the classrooms due to the scattering of voice caused by the acoustic effect of the classroom conditions. The traditional teaching method does not provide the expected knowledge to the students as they get disturbed and bored of the subject.

IV. PROPOSED WORK

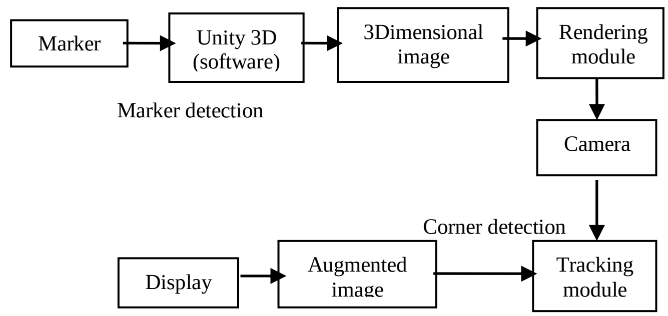

Fig. 1 Outline of the proposed work

Synthetic Markers are the squares which have a white surface surrounded by black region. There are many numbers of markers used generally, e.g. 2D barcodes, Hiro marker, Kanji markers, and multiple markers. Unity 3D is nothing but a 3D Development software. It is a kind of easy to making scenes, dragging and dropping elements to different views, using predefined scripts. It has a large asset store from which we can download assets. 3Dimensional image is nothing but the image can view from all directions by changing the orientations. 3D photos show every detail in a credible manner. 3Dimension photo consists of high resolution from different angles. Sometimes rendering process takes a long time, even on very fast computers. Because the software is essentially picture making each pixel of the image, the calculation of color of each pixel can contain a great deal of calculation, and the tracing rays of light as they would bounce around the 3D scene. After rendering the camera searches for the imported marker and tracking will be takes place. Once we track the marker we get the augmented image as an output. Corner Detection is to extract the features and infer the contents of the image.

A. *Corner detection*

Corners are image locations that have large intensity changes in more than one direction. Corner Detection is the first step to track the markers. This algorithm picks one line out of the set and tries to find a corner by intersecting the chosen line with the right one among all other lines of the set. The suitable second line is found by using several tests. First of all the two lines must not be nearly parallel such that the adjacent lines are chosen to find a corner point. By doing so our algorithm omits extremely distorted markers where the neighboring sides are approximately parallel. But this is not a problem since the interior of such markers cannot be sampled reliably anyway. The next step is to test and check the smallest distance between the two lines end points. If the minimum value among these distances is smaller than a certain threshold, then these two lines are further examined. The two corresponding end points thus obtained mark the line ends where it gets intersected. Then the last test is done to check the orientations of the two lines once more. This time the algorithm detect the markers alone, i.e. black regions surrounded by white background. And at this point it is known that at the end of each line the intersection point and the corner, will be located. We can also use this information to check whether the two lines encloses a dark region by checking their orientations. It is noted that the orientation of a line depends upon the intensity values, and lines of same direction differs at about 180◦ in their orientations. But just finding corner points by simply intersecting suitable line pairs is not sufficient to identify markers. We must also find four corners belonging to the same marker and also their sequence should be arranged to eliminate the cross-sequences, which means that if we follow the corners according to their sequence we should not coincide the marker's interior. Hence the corner detection algorithm is recursive. It starts with a first line and tries to find a corner by intersecting the first line with the second one. If it finds the corner point, the algorithm continues with the second line. It then tries to intersect this line with any of the remaining lines in order to find a second corner point. If successful the algorithm starts to find the newly attached line and searches for a third corner point. This procedure is continued until all the four corners are found or all the corner has not been found in the current detection run. In the eventual case the corner detection process continues at the second, yet unprocessed end point of the first line of the recursion.

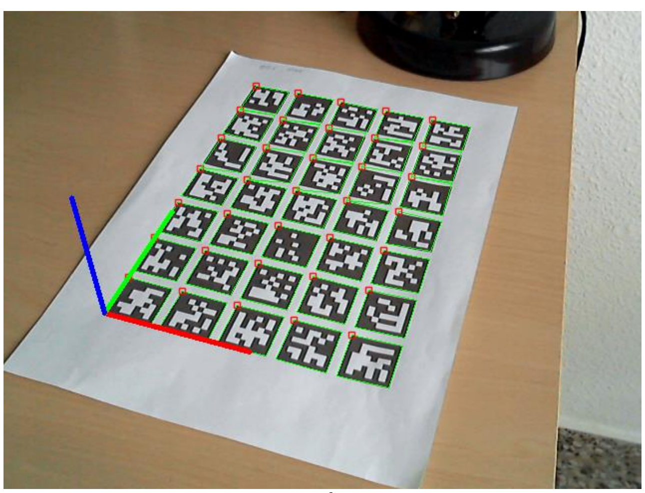

Fig 2. Detection of corners

B. Triangle similarity for marker to camera distance

In order to determine the distance from our camera to a known marker, we are going to use the triangle similarity.

In triangle similarity we take a marker with a known width *W* and placed at some distance *D* from the camera. Then the apparent width in pixels *P* is measured. This algorithm allows us to derive the perceived focal length F of the camera

$$F = (P*D) / W \qquad (1)$$

Triangle similarity can also be applied to calculate the distance D by moving the camera both closer and farther from the marker and by the formula given below

$$D' = (W*F) / P \qquad (2)$$

a) To measure the distance from camera to marker

C. Marker detection

The line detector used to find a marker edges accurate so that their intersection the markers corner points can be located marker's corner points can be located. Furthermore the proposed marker detection front end should allow an AR application to run in real time .so, a very fast line detector is required. False positive removal and template matching.

1) False positive removal: This technique is used to remove the false positives. False positive regions are the one which can satisfy any one of the following conditions:

a) Skewed aspect ratio is beyond 1.4 or 1/1.4

b) Area is greater than 10k pixel.

2) Template matching: This technique is identifying a markerThe template radius of 9.5 must be equal matched with the binarise image from the previous stage.The cross correlation is obtained by the cross correlation pseudo image by the binary image is considered as an grey scale as an value more than 15% of maximum value .It obtain the whole marker is highlighted and the marker doesn't merge with the surrounding region.It does not eliminate noise and irrelevant detail from an image.

D. Figures and Tables

TABLE I. SPECIFICATION OF MARKER

Serial No.	**Marker Specification**		
	Planets	***Size(kb)***	***Dimension***
1.	Mercury	2.84	228*227
2.	Venus	3.07	228*227
3.	Earth	3.00	228*227
4.	Mars	3.69	228*227
5.	Jupiter	3.04	228*227
6.	Saturn	3.98	228*227
7.	Uranus	2.66	228*227
8.	Neptune	3.12	228*227
9.	Pluto	3.08	228*227
10.	Sun	2.78	228*227
11.	Moon	3.04	228*227

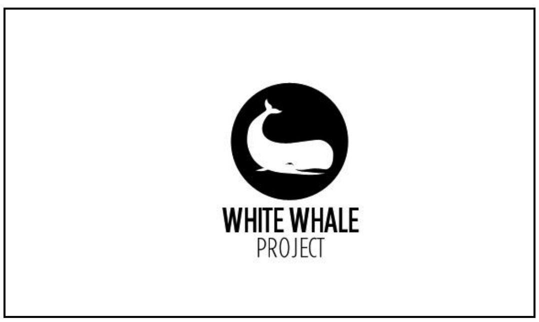

Fig. 2 Uploaded Marker

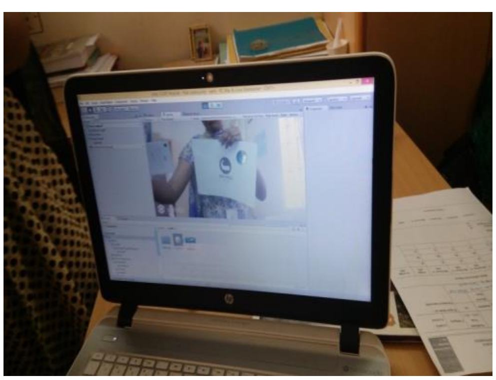

Fig. 3 Distance = 30 cm

Fig. 4 augmented output of the solar system

V. RESULT

In this paper we use Unity 3D and Vuforia to create an augmented output of the solar system. The 2D marker is given as input to the Unity 3D. To convert the marker into Unity 3D format it is uploaded into target manager and the database is downloaded and the corresponding license key of the marker is taken. Vuforia is imported into Unity 3D and the license key is entered in it. The downloaded marker database is now imported into the Unity 3D. A 3D model of the solar system is created using Unity 3D software and parented with the uploaded marker database. The solar system is animated so that the planets move around the sun in elliptical orbit. The marker database is activated and the AR camera is switched on to obtain the augmented output of the solar system.

CONCLUSION

The preferred This paper aimed to discuss the advantage of AR learning over the traditional teaching method. Thus it provides the effective learning of the solar system and to analyze the learner's experiences when using AR markers. As a result the students are able to gain more knowledge from the visual experience from the augmented image with more concentration, focused learning and interactivity.

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JUXTAPOSING VISUAL LAYOUTS – AN APPROACH FOR SOLVING ANALYTICAL AND EXPLORATORY TASKS THROUGH ARRANGING VISUAL INTERFACES

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ABSTRACT

Interactive visualization and visual analytics systems enables solving a variety of tasks. Starting with simple search tasks for outliers, anomalies etc. in data to analytical comparisons, information visualizations may lead to a faster and more precise solving of tasks. There exist a variety of methods to support users in the process of task solving, e.g. superimposing, juxtaposing or partitioning complex visual structures. Commonly all these methods make use of a single data source that is visualized at the same time. We propose in this paper an approach that goes beyond the established methods and enables visualizing different databases, data-sets and sub-sets of data with juxtaposed visual interfaces. Our approach should be seen as an expandable method. Our main contributions are an in-depth analysis of visual task models and an approach for juxtaposing visual layouts as visual interfaces to enable solving complex tasks.

Keywords: Information Visualization, Visual Analytics, visual tasks, visual interfaces

1. INTRODUCTION

Interaction with visualizations enables the dialog between user and the visual representation of the underlying data. The interactive manipulation of the data, the visual structure or the visual representations provides the ability to solve various tasks and uncover insights. The term "task" in the context of information visualization is often used ambiguously. Often, interactions and tasks are not distinguished for visualization design, whereas the knowledge about the task to be solved with the visualization is of great importance for its design. Commonly visualizations are designed to enable solving a certain task. However, there exist a number of visualization tools that provide different visual layouts for a variety of tasks. These systems and tools show promising results and found their way already to real application scenarios not only in research. The main shortcoming of these systems still remains that they allow just one database or dataset to be visualized. This leads to limitations in those tasks that require higher cognitive processing, such as exploration or analysis.

We present in this paper an approach that allows to solve such analytical and exploration tasks by combining different databases with different visual layouts that leads to different visual interfaces. Our approach enables to visualize different databases, datasets, or different sub-sets of the same data and combine different visual interfaces for the different types of tasks. Our main contributions are two-fold: an in-depth analysis of different task models and task classification that should enable users to create such interfaces and a model with different "perspectives" to different or the same data that allows to solve analytical and exploration tasks.

This paper starts with the introduction of taxonomies and classifications of tasks in visualization systems. The classifications will enlighten the heterogeneous view on visualization tasks and enable getting an overview of the differences. The classifications will enable to define and differentiate in particular simple search tasks and exploratory analytical tasks that are the main focus of this paper. After classifying tasks, we introduce exploration in context of search with the assumption that analytical tasks are commonly starting with a kind of exploratory search. In this context we differentiate between a bottom-up search paradigm and a top-down search and illustrate that several combinations of these two abstract paradigms exist. Thereafter we introduce our model juxtaposing visual layouts as visual interfaces with the main difference that several databases can be visualized at the same time and enables analytical comparison tasks. In this context we will outline that the following six perspectives give already a good starting point for more complex visual tasks: *perspective view*, *perspective-comparative view*, *comparative view on level-of-detail*, *comparative view on data sub-sets*, *comparative view on data*, *non-linked view*.

2. CLASSIFICATION OF TASKS IN INTERACTIVE VISUALIZATIONS

Shneiderman (1996) provided one of the most popular task classifications, the "Task by Data Type Taxonomy". With the assumption that users are viewing collections of data with multiple attributes, he proposed that a basic search task is the selection of items that satisfies the search intents. This classification enhances Shneiderman's "Visual Information Seeking Mantra"

(Shneiderman 1996) with the tasks relate, history, and extract. The Visual Information Seeking Mantra of Shneiderman proposed a three-stepped task model. Each visualization should start, according to Shneiderman, with an overview followed by zoom and filter and details on demand.
The following Table 1 illustrates the classification of Shneiderman including the seven main visualization tasks.

Table 1: Task by Data Type Taxonomy (Shneiderman 1996, p. 337)

Task	Description
Overview	Gain an overview of the entire collection.
Zoom	Zoom in on items of interest.
Details-on-Demand	Select an item or group and get details when needed.
Relate	View relationships among items
History	Keep a history of actions to support undo, replay, and progressive refinement.
Extract	Allow extraction of sub-collections and of the query parameters.

The overall tasks in this classification can be abstracted to the high-level tasks exploration and search and leads to finding (relevant) information.

Buja, Cook and Swayne (1996) proposed a classification concept that investigates the interaction with visualizations (view manipulation) and the tasks that are supported by these interactions. They supposed that the purpose of the view manipulations is to support the search for structures in data. For this search they identified three fundamental tasks for data exploration, namely finding gestalt, posing queries, and making comparisons. Finding certain patterns of interest, e.g. clusters, discreteness or discontinuities, are classified in the task finding gestalt. Posing queries is the next step after gestalt features of interest were found and further information are desired to get a comprehensible view on the chosen parts of the data. For the task making comparisons they distinguish between two types of comparisons. First the comparison of variables or projections and second the comparison of subsets of data. The comparison of variables enables the "view from different sides", which illustrates the data from different perspectives, whereas the data subset comparison provides a "view of different slices" and thereby of different subset of data (Buja, Cook and Swayne 1996).
Further they proposed that the identified tasks are optimally related to three manipulation views. For gestalt finding they identified the focusing individual views. Here, focusing provide any operation to manipulate the subset of data or view. The choice of projection, for viewing or the choice of aspect, ratio, and zoom are examples of focusing. For posing queries, they identified linking multiple views. The linking contains view manipulation as brushing or query issuing by highlighting. Making comparisons is related to arranging many views. They propose that the arrangement of large numbers of related plots for simultaneous comparison is a powerful informal technique.
With this tasks and manipulation views they further proposed a set of low-level interaction techniques that are related to each high-level task. Table 2 provides an overview of the proposed tasks, manipulation views and interactions that are related to each other.

Table 2: Task Classification by Buja, Cook and Swayne (1996, pp. 80)

Task	Manipulation View	Interaction
Finding Gestalt	Focusing individual views	Choice of projection, aspect ratio, zoom, pan, order, scale, scale-aspect ratio, animation, and 3-D rotation
Posing Queries	Linking multiple views	Brushing as conditioning / sectioning, database query
Making Comparisons	Arranging many views	Arranging scatter plot matrix and conditional plot

This classification introduces not only a linking of multiple layouts for solving search tasks (query posing), but also arranging many views, which enables performing comparisons and therewith analytical tasks.
Another approach, which correlates low-level interactions with visualization tasks, was proposed by Chuah and Roth (1996). They summarized their "basic visualization interactions" as a set of low-level-interactions with the attributes input, output, and operation and abstracted them to three basic visualization tasks (Chuah and Roth 1996, p. 31). At the lowest level they propose "Data Operations", which contains interactions affecting the elements within visualizations, e.g. add, delete or derive attributes. The higher level considers "Set Operations", which refers to operations on sets, which may have group characteristics. The highest level investigates "Graphical Operations", which are divided into encode-data, set-graphical-value, and manipulate-objects. While the classes encode-data and set-graphical-value change graphical attributes or the mapping between graphical objects and data, the class manipulate objects operates on graphical objects as a unit of manipulation. The investigated tasks in this classification focus on comparison and finding patterns as graphs or in data. The high-level task of this classification can be abstracted as "analysis". The aspect of analysis was investigated in various works. One early example is the classification of Wehrend and Lewis (1990). They proposed a taxonomy with ten analytical tasks: location, identity, distinguish, categorize, cluster, distribution, rank, compare within entities, associate, and correlate.

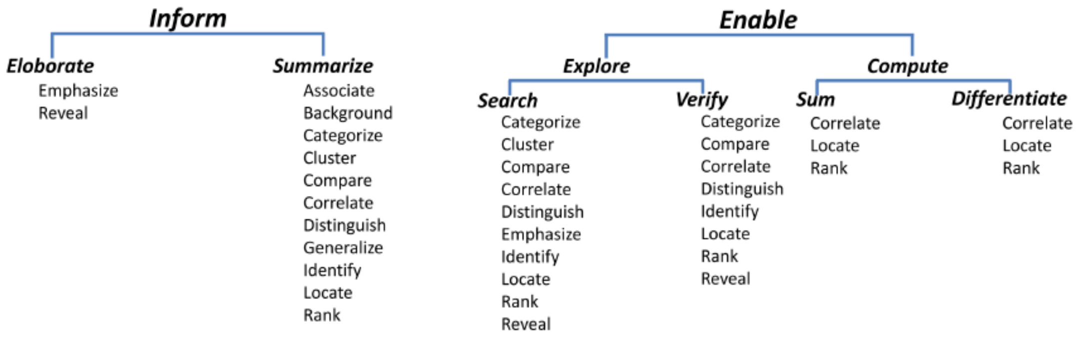

Figure 1: High-level taxonomy of presentation intents and visual tasks (adapted from Zhou and Feiner (1998))

Zhou and Feiner (1998) proposed an approach by considering not only the interaction and manipulation abilities of visualizations.

They investigated the human perception and the intended task of the visual presentation method in their classification to provide a more user centered task-classification.

Based on various existing classifications, they characterized visual tasks along two dimensions. In the dimension Visual Accomplishments, the focus lies on the intention of the visual presentation (Zhou and Feiner 1998, p. 394). They assumed that a presentation intends either to convey the presenter's message or to help user solving a perceptual task. Based on this assumption, visual tasks are distinguished at the highest level between tasks that inform users by elaborating or summarizing and those, which enables users to perform a visual exploration or computation. Their second dimension Visual Implications considers research outcomes of the human visual perception.

Based on these outcomes they summarize three types of visual perception and cognition principles: (1) the visual organization principle investigates how people organize and perceive a visual presentation, (2) the visual signaling principle investigates the manner how people interpret visual cues and infer meanings and (3) the visual transformation principle explains how people perceive visual cues and switch their attention. This incorporates the outcomes of the pre-attentive visual perception too (Treisman and Gelade 1980). Zhou and Feiner (1998) use these principles to infer visual tasks and assign them to the first dimension of Visual Accomplishments. Figure 1 illustrates their classification and the identified tasks in correlation to the Visual Accomplishments. Here the presentation intents (Visual Accomplishments) are bold and italic.

A more user-centered approach for classifying task was proposed by Keller and Keller (1994). Their classification considers the goals and intentions of the users and suggest based on these certain visual representations (Ward, Grinstein and Keim 2010, pp. 164 and pp. 380]. They classify the user-intended tasks in nine task categories (see Table 3). The main characteristic of their classification is that only analytical aspects play a role for users interacting with visualizations. Previous general tasks like exploration or search does not play any role.

Table 3: Visual task classification by Keller and Keller (adapted from (Ward, Grinstein and Keim 2010, p.380])

Task	Description
identify	recognition of objects based on the presented characteristics
locate	identification of the position of an object
distinguish	determination the difference of objects
cluster	grouping of objects based on similarities
rank	ordering objects by intended relevance
compare	examination of similarities and differences of objects
associate	drawing relationships between two or more objects
correlate	finding causal or reciprocal relationships between objects

A comprehensive classification of users' tasks based on user intentions and the interaction role in information visualization was provided by Yi, Ah Kang, Stasko and Jacko (2007). Their classification attempts to abstract the most used interaction possibilities with users' intentions to provide categories of interaction. They classify the user tasks based on the role of interaction in information visualization in seven categories (see Table 3).

Although the identified categories are abstract views on the interaction roles, the level of abstraction differs enormously. The category "select" for example, can be defined as simple and low-level interaction. Here a user marks an object of interest to be able to follow this object in changed views (Yi et al. 2007). In contrast to "select" the category "explore" provide a real abstraction of interaction to a user task. Here the user is able to view on various subset of data to see different characteristics and perform a various number of low-level task e.g., comparing subsets or identifying relevant objects.

Here the first tasks of "identify", "locate", "distinguish" can be ranked as simple search tasks.

Thereby the following tasks of "cluster", "rank", "compare", "associate" and "correlate" refer more to more complex analytical tasks that refer to higher cognitive processing.

Table 4: Visual task categorization by Yi et al. (adapted from (Yi et al. 2007, pp. 1226)

Category	Description
select	mark something as interesting to enable the following of the object
explore	show something else, e.g., different subset of data
reconfigure	provide a different view or arrangement of the underlying data
encode	provide a different fundamental view by selecting another visualization technique
abstract / elaborate	provide a different level of detail on the data e.g., by details-on-demand techniques
filter	provide a view with certain (predefined) criteria
connect	provide a visual connection (e.g. by brushing) between the same objects on different views

The introduced approach makes use of different juxtaposed visual views to enable solving more complex analytical tasks. In particular the tasks explore and connect make use of the visual arrangement, whereas the main tasks can be solved with single views.

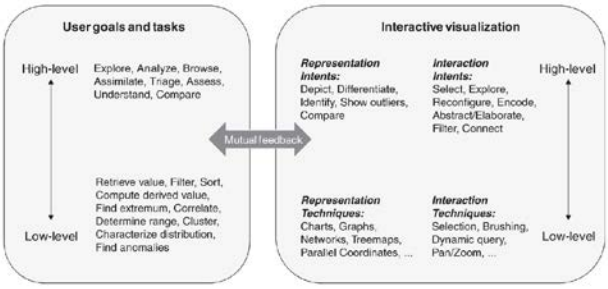

Figure 2: High- and low-level task and interactive visualization of Pike et al. (Pike, Chang and O'Connell 2009, p. 266)

Pike, Chang and O'Connell (2009). extended the proposed approach of Yi et al. (2007) by differentiating between low-level and high-level interactions intending to meet high- and low-level user tasks and goals and proposed a mutual feedback between user goals and tasks and the affordance of interactive visualizations (Pike, Chang and O'Connell 2009). They defined seven categories of high-level tasks, which can be achieved by a number of low-level tasks and interactions respectively. Further they relate the representation and interaction intents of interactive visualizations, similar to the proposed classification of Zhou and Feiner (1998) to low-level representation and interaction techniques. The proposed approach relates the classifications of user goals and tasks with the abilities and goals of interactive visualization in a "mutual feedback". The relationship of the proposed techniques and the user's goals and tasks is the "analytical discourse", which investigates the low-level interaction and user goals to form a feedback between them (Pike, Chang and O'Connell 2009, p. 265). Figure 2 illustrates the classification of high- and low-level user tasks and interactive visualization with the proposed mutual feedback.

The classification of Pike et al. considered the interaction value and user's goal and tasks from both perspectives, information visualization and Visual Analytics and gave a good overview of the high-level tasks intended by users and provided by interactive visualizations. Nevertheless, the differentiation of high- and low-level tasks is not clearly defined. A "compare" task could be a part and therefore a low-level task of "assess" or "analyze", while important tasks like "decision making" (Kohlhammer 2005) are not considered at all.

Fluit, Sabou, and van Harmelen (2004) proposed a very simple classification of visualization tasks in the special domain of ontology visualizations in the categories Analysis, Query, and Navigation. Therefore, they defined the Analysis task for getting a global view on data, the Query task for finding a narrow set of items, and the Navigation task for graphically navigating through the data. In their revised work (Fluit, Sabou, and van Harmelen 2006) the last category Navigation was replaced by "Exploration". They proposed that "Analysis" can be performed within a single domain with various perspectives, in various sets of data, and by monitoring the changes of data over time. The category Query is divided into the processes of query formulation, initiation of actions, and review of results. The task category Exploration is defined as finding information that are loosely of interest for the users. Here a further subdivision is not proposed.

A more recent visual task classification or framework was proposed by Munzner (2014). She proposed based on the main assumption that visualization should enable humans to solve different tasks that leads in best case to a more efficient and effective way of problem solving in two main categories: "Actions" and "Targets". Each task can be described as tuple of actions and targets and leads to a more efficient way of solving tasks. The model of Munzner can be used to create and generate interactive visualization systems that consider the task to be solved as a main attribute of interactive visualizations.

The Actions are subdivided in three main levels of "Analyze", "Search" and "Query".

In the analyze category users may want to produce information or consume information, whereas commonly users are consuming information. The analyze category contain six goals, whereas three are assigned to consume and three to produce. The search category is a process that is required for the analysis tasks. The search category contains four goals based on the target location (either known or unknown) and the search target (either known or unknown). This categorization already includes the differentiation between exploration and targeted search as proposed by Marchionini (2006) or White and Roth (2009). The last category of actions is "Query" that

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contains three goals, starting from a single target (identify) to a set of multiple targets (compare) and the full set of possible targets (summarize). (Munzner 2014, pp. 43-55) The following table illustrates the "Actions" according to Munzner (2014).

Table 5: Actions according to Munzner (2014)

Actions		
Analyze		
Consume		
Discover	Present	Enjoy
Produce		
Annotate	Record	Derive
Search		
	Target known	*Target unknown*
Location known	Lookup	Browse
Location unknown	Locate	Explore
Query		
Identify	Compare	Summarize

As Actions are defined by Munzner as verbs, targets are the nouns. Each target refers to some aspects of data that is of interest for the user. Munzner proposes three high-level of targets are of great interest for the user: trends, outliers and features. 'These three targets can be derived from any kind of data. Further targets are prosed that may rely on the number of attributes: "distribution", "dependencies", "correlation", "similarity" and "extremes", or to the type of data: "topology", "paths" and "shape".

One main aspect of Munzner's work is that she addresses that a visualization idiom can be constructed out of a set of design choices. These design choices also include juxtaposing visualizations, partitioning and superimposing visualizations. (Munzner 2014)

We investigate in this work in particular the juxtaposing design to enable solving analytical tasks that commonly start with a search task as Munzner proposed.

3. EXPLORATORY SEARCH

Commonly analytical tasks start with a search task (Munzner 2014). The main intention is to reduce the amount of visualized data or to focus only on targets of interest. We consider in this paper only exploratory tasks based on the assumption of Marchionini (2006). Locating outliers or identifying certain items are not considered, thus these commonly leads to faster interpretation, where the analytical tasks are rarely needed.

Exploratory search (Marchionini 2006; White and Roth 2009) enables with the different stages of exploration the acquisition of in particular implicit knowledge or information. Implicit in this context refers to that kind of knowledge or information that is not explicitly known or may not be formulated by the user explicitly, e.g. due to lack of knowledge. From the visualization point of view, implicit knowledge or information refer to that knowledge that is not explicitly modeled in the data but can be enlightened through the visualization of the modeled data (Nazemi 2012).

Different disciplines provide technologies, systems, and approaches to enable the acquisition of implicit knowledge or information. For simplifying the investigation of these approaches, we classify the methods into bottom-up and top-down approaches. The standard search process (Hearst 2009), e.g. is a simplification of a bottom-up approach (see Figure 3: left illustration). The approach attempts to formalize the iterative search process a three-stepped model of Query Formulation, Query Refinement and Result Processing. This model assumes that the search begins with the formulation of query of known knowledge. During the search process the subject gets more knowledge about a certain topic to refine his query and gather more knowledge about the certain topic. The main aspect of this model is that the search process starts with the ability to formulate a query and to reformulate the query during the search. During the search process new knowledge is adopted, which leads to a reformulation of the query. A more complex example for a bottom-up information gathering and search process is the information-seeking process Marchionini (1995). This process includes eight phases and encloses the internalized problem solving of subjects too. Marchionini's model consists of eight phases in information seeking: Recognize and accept an information problem, Define and understand the problem, Choose a search system, Formulate a query, Execute search, Examine results, Extract information and Reflect/iterate/stop (Marchionini 1995, pp. 49-58; Nazemi 2012).

The exploratory search approaches are commonly bottom-up approaches that start with a search term and enable in different stages the investigation, reformulation, learning, and refining. The process of information exploration in information visualization is contrary to the bottom-up approaches of search interface. Commonly in this context a top-down approach is proposed (Sheiderman 1996). The most famous example for a top-down information exploration or gathering model is the already introduced Visual Information Seeking Mantra (Sheiderman 1996). This model proposes the opposite of the bottom-up approach and is designed for the visual information seeking. The three-stepped model propagates to Overview the data first, then Zoom and Filter the relevant parts and finally gather Details on Demand. Beginning with the overview of data, this model premises not the verbalization ability, here the focus is on the recognition ability. If a subject detects in the overview step an area-of-interest, he can zoom into the area or filter this information out. After he gets enough information to recognize a seeking problem, details about the information can be fetched. The top-down model of search and information acquisition based on Shneiderman's work is applied to many visualization environments and is the main approach for gathering information in visual environments (Nazemi 2012). The investigation of the search process in a bottom-up manner plays an increasing role in visualizations. van Ham and Perer (2009) for instance proposed a bottom-up search approach in visual environments that starts with search, by means of querying the data-set followed by show context that enables the contextual view on data and expand on demand that provides a detailed view on demand (see Figure 3).

The described seeking approaches require different human abilities required for solving a seeking problem. In a bottom-up approach the formulation of the searched topic is important, whereas the recognition ability plays an important role in the top-down approaches. The mentioned top-down approaches are primary information visualization approaches thus, the overview of information and recognition of area-of-interest can be more supported with visualization systems. Figure 3 illustrates the two approaches. Thereby the left schema refers to the standard search process, the mid one illustrates the process as proposed by van Ham and Perer (2009), and the right one is a simplified illustration of Shneiderman's model (Shneiderman 1996).

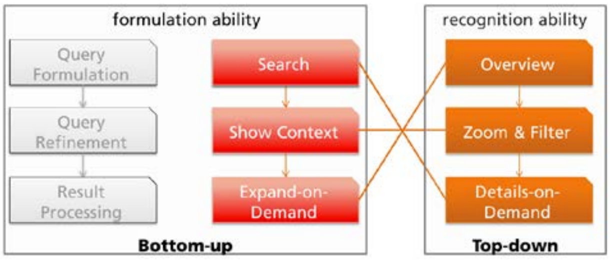


Figure 3: Top-down versus bottom-up search (Nazemi 2014, p. 216)

4. MODEL FOR JUXTAPOSING VISUAL LAYOUTS FOR ANALYTICAL TASKS

Most of the visual layouts specialize upon one feature of data. This is because the visual layouts have advantages for a special data type, but disadvantages for others. We can easily show the relations between instances in an arbitrary graph-layout, which provides interaction methods for expanding or collapsing a node to gain a better overview, but we can hardly display a textual article, a picture or properties like geographical or temporal data in arbitrary graphs. On the other hand, geographical visual layouts support the view and search for geo-related properties, but their enhancement with relational or hierarchical layouts may lead to overcharging users and non-comprehensible visualizations. To face on the one hand the visual overflow and support on the other hand the solving of analytical tasks, we introduce a model that reduces the information overload by separating the visualized information in a visual interface of juxtaposed visual layouts.

Our model separates data models with their attributes and visualizes this information in separate visual layout without losing any information and without overcharging the user by complex visualizations. The advantage of the separation of complex information units is obvious; the user of is able to perceive the same information from several perspectives by the placed juxtaposed visual layouts. With this approach both, bottom-up and top-down approaches are supported. A bottom approach starts with the query formulation. If the formulated query is precise enough, a data instance and the modelled neighborhood is presented. Otherwise, if the query is not specific or the user wants to have an overview, the abstracted schema of the data is presented. The different perspectives on data enable more comprehensible view.

Thereby the visual layouts are linked with each other and make use of a brushing and linking metaphor to support the comprehensible view and changes on users' interactions. Figure 4 illustrates a screenshot of the same data with different perspectives, where the visual layouts are linked with each other.

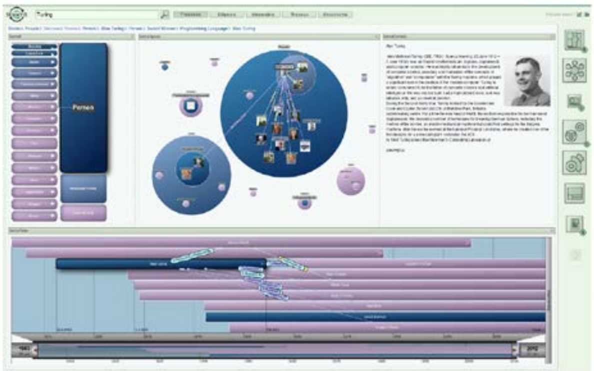


Figure 4: Perspective view: Different perspectives on the same data (Nazemi 2014, p. 217)

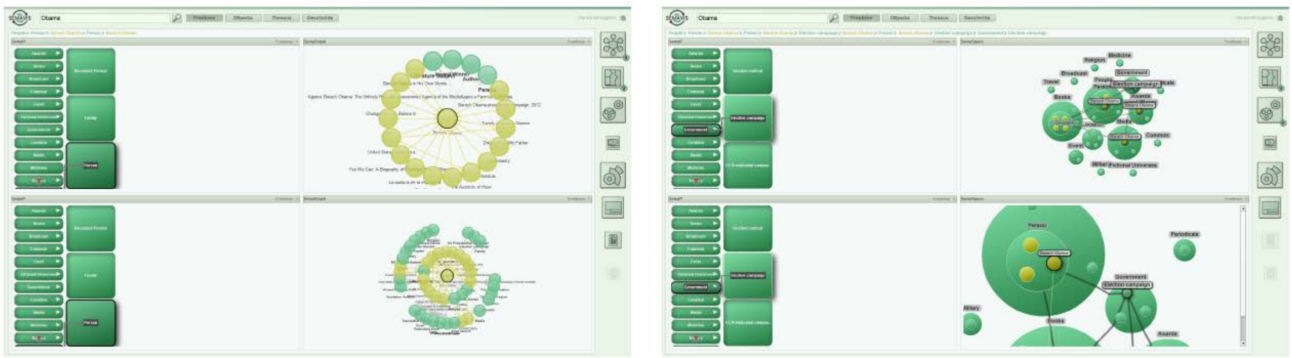
The visual layouts can be integrated in the visual interface to provide different perspectives on the same information in abstracted and different ways. Users are able to rearrange or add visual layouts on the screen or dismiss the placed visual layouts. The view on different perspective or aspects on the same data and data-set with different visual layouts allows to arrange different visual interfaces and solve analytical tasks. The main purpose remains the support of exploratory search. In order to support this search, we identify following styles for our model:

- Perspective view: Visualization of the same data with different visual layouts.
- Perspective-comparative view: Visualization of different sub-set of data from the same data-base with different visual layouts.
- Comparative view on level-of-details: Visualization of the same data using the same visual layouts with different parameters.
- Comparative view on data sub-sets: Visualization of different data sub-sets from the same data-base with the same visual layouts.
- Comparative view on data: Visualization of different data-bases with the same visual layouts.
- Non-linked view: Visualization of different data-bases with different visual layouts.

With the different adjustments of the visualization interface, different goals can be achieved and different requirements fulfilled. As introduced the perspective view (Figure 4) enables the exploration of a queried sub-set of data from different perspectives with different visual layouts. The layouts are linked with each other and the user is able to navigate through the different visual layouts and gather required information from other visual layouts. The perspective-comparative view allows solving comparative tasks by providing the free choice of visual layouts for different data-subset form the same data base. Here only one data-base is queried, e.g. by different search terms. The results for each sub-set of data are linked with each other, whereas the visual layouts are just linked through the data. If a user interacts within a visual layout, only those visual layouts react to the interaction that visualize the same data-subsets. Adding a visual layout leads to a coupling of this with the data sub-set of the last user interaction. The user is able to change the linking each visual layout. Figure 5 illustrates a screenshot of this interface style.

Figure 5: Perspective-comparative view on different data sub-sets (Nazemi 2014, 2018)

The perspective-comparative view enables to compare tasks with the freedom to choose the visual layout for each data-subset. This view is in particular efficient if the data sub-set has different characteristics. Thus, this view is not providing at each level the same visual layout, it goes beyond comparison tasks and enables a more investigative view on various topics of the same data-set.
A comparative view on a low-level is provided by the comparative view on level-of-detail. This view enables the visualization of the same data with the same visual layouts, but different parameterization for gathering on the one hand an overview and on the other hand a detailed view on the data.
The parameterization of certain visual layouts allows controlling the level of detail as part of the zooming. The zoom levels may vary from visual zoom, to semantic zoom with semantics-based filtering. For example, the level of detail can on the one hand be used to show a greater part of the semantics or information space for showing the structure of the information and on the other hand with small numbers of elements of interest to show detailed information.
There are two main ways to combine the same visualization technique duplicated in a cockpit for providing more information. First the level of details can be provided as a zoom on a specific area of the semantics while the entire search results is displayed too (Figure 6 (b)) and second the semantic neighbors of a particular focused elements can be enhanced and reduced due to enabling an overview and detailed view (Figure 6 (a)). A reduction of the numbers of entities can be achieved by filtering the information, e.g. based on relevance metrics. With this kind of information visualization, a similar effect can be achieved. Many information elements give an overview about the whole structure of the data and the information about the focused element can be revealed with a visual layout that visualizes a small number of elements.
A similar approach with a more focus on comparative tasks is provided by the comparative view on data sub-sets. This view enables the visualization of different search or interaction results with the same visual layouts that are commonly placed upon each other. The usage of same visual layout supports the comparison and analysis process thus, a direct visual correlation is built. Visual layouts visualizing the same content or query result are linked with each other, while visual layouts that visualize another subset are not affected. The interaction coupling of visual layouts is depending on the data that are visualized. If a user interacts with the visual layout that visualizes a certain data-set, only those are changed by users' interactions that are visualizing the same content. With this procedure and the visualization through the same layouts, the users are able to navigate independently through the different sets of data and get insights, compare results, and investigate deeper search tasks on each data base. Figure 7 illustrates a screenshot of the visualization interface with the comparative view on data sub-sets.
The comparative view on data sub-sets enables solving comparative and analysis tasks in one domain of data. With the growing data sources on Web, the combined search on different data sources gets more and more relevant. We mean with the combined search, a simultaneous search in different data bases on Web with the same search term. This enables a deeper search and investigation of certain entities or information of interest by considering not only one data base. One main side effect of this search is that the visualization of the results enables to validate and proof the quality and information value of a data-base.



(a) Different Levels-of-Detail (b) Different Levels-of-Zoom

Figure 6: Comparative view on Level-of-Details (Nazemi 2014, p. 2018)

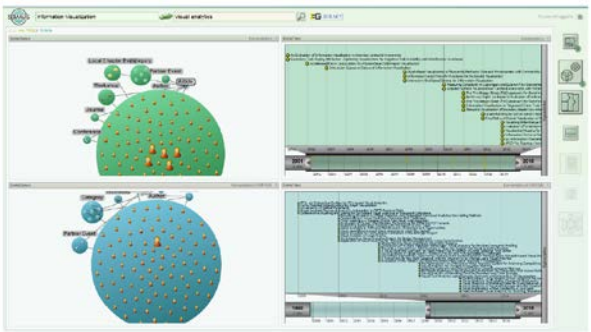


Figure 7: Comparative view on data sub-sets visualizing different data (Nazemi 2014, 219)

Our main goal remains the support of exploratory search and analytical tasks by providing appropriate visualizations that enables an adequate and comprehensible result retrievement. Our comparative views on data enable the simultaneous search and visualization of search results from different data sources. Thereby the search results from each data base are visualized with the same visual layouts to enable a more comprehensible view on data. The visual layouts that are visualizing data from the same data base are linked with each other and enable the independent navigation in various data sources.

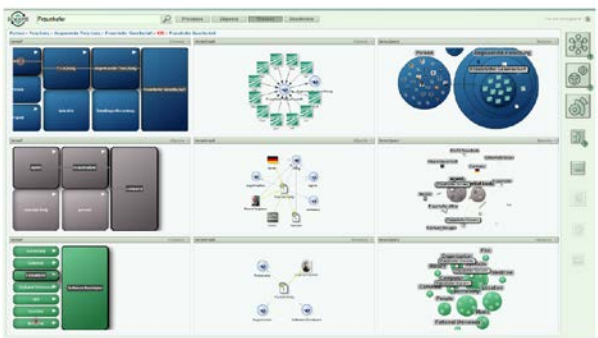


Figure 8: Comparative view on data visualizing different data-bases with the same visual layouts (Nazemi 2014, p. 219)

Users are able to add, rearrange or dismiss certain visual layouts. This effects the entire visual interface, e.g. if a user adds a new visual layout on the screen, the same visual layout appears twice for two data bases.

The model is not limited to certain number of data bases. Therewith the user is able to view retrieved results from various data bases simultaneously. Although the number of the data bases is not limited, the system limits the number of visual layouts based on the user model to not overcharge the user with visual information. The comparative view on data enables analysis tasks without querying different data-bases and changes the view. The results are presented in the same way, so that the process of investigation in analytical tasks and exploratory search can be supported in one visual interface. Figure 8 illustrates a screenshot of the visualization interface with the comparative view on data. Thereby a searched term was found in three different databases. The same visualization enlightens different information on the same search term and enables a clear comparison of the search result.

The comparative view on data has the advantage that all results from all data-bases are visualized in the same way and enable therewith an easy comparison. The view is limited to the fact that only the same visualization can be used in this context for the various resulted data. These resulted data may have different attributes that cannot be visualized with the certain chosen layouts. In these cases, information about the results are lost. To face this aspect, we introduce the non-linked view that has no limitations at all. It enables the visualization of data from different data-bases with various visual layouts. The main idea is to provide a nonlimited view for the deeper exploratory search steps as proposed by Marchionini (2006). Thereby we use the visual layout linking for the data-bases too, as in other views, but the user is able to disable this linking even for the same data-base. This procedure enables the freedom of retrieving the search results from different perspectives and different data-bases according to the assumption and theories of constructivism. The user gets guidance for the visual layout when he selects a data-base. Figure 9 illustrates a screenshot of a non-linked visualization cockpit. Thereby different visualizations are selected for the different data-bases.

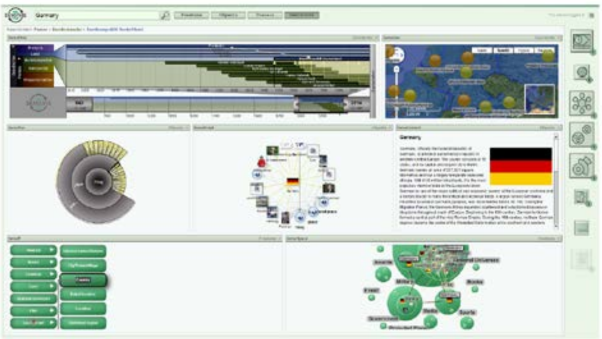


Figure 9: Non-linked view: Visualization of different data-bases with different visual layouts (Nazemi 2014, p. 220)

The visualization interface arrangements enable to view data from different data-bases or different sub-sets of the same data with the same or various visual layouts. With the juxtaposed arrangement and linking of visual layouts the approach supports the entire process of exploratory search. We introduced six different styles or views how the visualization interface can be used for the different stages of exploratory search or the given tasks. These six views should be seen as examples how the visual layouts can be arranged and what kind of tasks and in which process they support the user. Although the juxtaposed arrangement of visualization can be performed manually and provide therewith a more 'adaptable' character, we focus on automatic adaptation that generates the adequate visual interface through machine learning methods. Previous works on visual interface arrangements allowed us to enhance the model and provide a sufficient interface collection that is based on industrial requirements and tested in real situations.

5. CONCLUSION

We introduced in this paper our model for arranging visual layouts and combining them with different databases, datasets and sub-set of data to enable solving exploratory analytical tasks. We first introduced different classifications, taxonomies and models for visualization tasks. This should enable identifying the most relevant analytical and exploratory tasks. In context of exploration, we will introduce two different views on the search process, the bottom-up search that starts with the formulation of a query and provide the result processing in an iterative manner of query refinement. In contrast to that the top-down search process starts with an overview on a knowledge domain and provides various interaction abilities to process the required detailed information. It is important in context of visualization to differentiate between these two search processes, thus the bottom-up search requires formulation ability and the top-down search relies more on the human recognition ability. Based on these assumptions, we introduced our visual interface model that makes use of the visual layout arrangement to provide various views on the same or different data for exploratory and analytical tasks. Overall, we identified six different views that interconnect visual layouts and data with each other or disconnect them. The approach enables different perspectives or the same view on different data or the same data. We thereby differentiated in our model 'data' as a data-set of the same data-source and from different data-sources. The identified six views on data as visual interfaces were described and illustrated exemplary.

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VISUALIZING LAW - A NORM-GRAPH VISUALIZATION APPROACH BASED ON SEMANTIC LEGAL DATA

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ABSTRACT
Laws or in general legal documents regulate a wide range of our daily life and also define the borders of business models and commercial services. However, legal text and laws are almost hard to understand. From other domains it is already known that visualizations can help understanding complex aspects easier. In fact, in this paper we introduce a new approach to visualize legal texts in a Norm-graph visualization. In the developed Norm-graph visualization it is possible to show major aspects of laws and make it easier for users to understand it. The Norm-graph is based on semantic legal data, a so called Legal-Concept-Ontology.

Keywords: Norm-graph, Law Visualization, Decision Support Systems, Policy Modeling, E-Government, Information Visualization, Semantic Data

1. INTRODUCTION

Innovative enterprises, in particular in the ICT domain, regularly deal with innovations where no experiences in form of best practices could be used as reference. Well known examples are UberPop, autonomous driving systems in cars or services for smart (energy) meters, who have in particular in Europe hard challenges in perspective of the legal situation. Starting a new business model or service is always a challenging situation due to uncertainty about the market potentials, but it can become an extreme risk if also the legal situation is still unclear. In particular the data privacy in Europe is one point that was and is a quite complex situation, due to high barriers on what agreements and terms the user needs to accept or what is prohibited in general (Raabe et al. 2013). The problem of new small and medium size enterprises is the miss of legal experts, and even if they have lawyers, it is often difficult for them due to lag of technical experience. In fact, a number of services start without clarity about the legal validity.

As known from many other domains, visualizations can help to understand complex context much better and identify errors, problems or critical aspects. It seems logic that even for laws visualizations could help to understand the context much better and easier either for legal experts such as lawyers or casual users, similar to the other public affairs in policy modeling or e-government (Burkhardt et al. 2013, Nazemi et al. 2014). But, it still would help, if the complexity of laws could be simplified with “graphical sentences” that clearly could outline what each term has for definition or how it intended to use by law.

In this paper we introduce a new approach to visualize laws in a so named Norm-graph in an easy and commonly understandable manner, to support legal experts as well as casual users in understanding laws. As a major purpose we aim to support users in developing business models or services so that these could be validated against the law to ensure validity.

2. RELATED WORKS

Visualizations are rarely represented in the legal domain (Kleinhietpaß 2005), although visualization techniques offer a high potential for the easy understanding of complex issues. Schematic representations of references between legal texts, facts or relationships between different legal norms are everyday use cases. Nevertheless, there are some examples that demonstrate the potential of visualizations for the legal domain. For example, Röhl et al. (1995) uses the radiance of fundamental rights with the distinction between the conceptual kernel and the term court (Röhl 1995, p.26) to visualize legal knowledge. They also use a pyramid of terms to convey legal methods (Röhl 1995, p.51). These didactic representations of legal knowledge serve to impart legal knowledge and can be found in textbooks on methodology. However, these representations are designed for lawyers and legal experts, but not the end user who needs legal support or a legal expert of legal norms. In addition, these representations are static and not driven by ICT. The use of ICT in the legal domain is still a relatively young discipline. Nevertheless, there are already a few approaches that integrate the potential of visualizations in interactive applications. The following sections introduce some of these systems to give an overview of today's visualization approaches in the legal domain.

Most systems focus on managing legal cases, such as the case navigator (Fallnavigator 2013) by Faktor Logik, which is a computer-aided case processing system. The innovative approach supports the application of legal norms, contractual conditions and work instructions that are loaded as an ontology-formalized knowledge base. After a regulation (legal norm) has been loaded, the legal texts are presented in a structured way. In contrast to the previously presented approaches, the case navigator also allows a visual description of the facts in a graph-based visualization.

Beside the strong visualization-driven approaches, there are also ICT solutions that include basic visualization metaphors. One representative is the Legal Information Retrieval and Focused Semantic Search (LIRFSS). The main focus of Legal Information Retrieval (Gaur 2011) focuses on finding information in legal sources. These include ordinances, legal texts and historical sources such as judgment databases and precedents. The system takes account of various metadata such as date, place of action and IPC (Indian Panel Code). The downside is that the approach only integrates rudimentary visualization techniques to visualize and present the results obtained for a better overview.

Another approach in Legal Information Retrieval is Parallel Tag Clouds (Collins et al. 2011). The aim of this visualization technique is to present court decisions facetted and thus to graphically communicate a comparison between different courts. For this purpose, Parallel Tag Clouds uses the faceting approach in which the set of documents (judgments) is grouped according to a given facet (category). Each facet then extracts a set of keywords that are displayed vertically in a column. The keywords are sorted alphabetically by column and the font size is adjusted to the relevance values identified by the analysis. By combining the same keywords between the search results, this approach allows comparison of different courts and allows conclusions about the topics and judgments dealt with there. For a selection of key terms, a second view shows the corresponding documents and the relevance of the key terms in the respective documents. Thus, in addition to the overview of the judgments, the lawyer also has the opportunity to verify hypotheses based on the textual sources found.

Another approach that goes beyond the mere search for information in the legal domain is a demonstrator for visualizing legal rules on tungsten (Seth 2007). In an interactive graph representation of logical rules are visualized which connect a legal norm based on different legal arguments. In this way it is possible to visualize a fact to judge a legal consequence. The approach demonstrates in a flexible way how visualizations in the legal domain can be used to establish relationships between legal norms and facts. Although the demonstrator is a first example of automated legal education using visualizations, even if the system is still rudimentary.

Another example of Legal Information Retrieval is LexisNexis (LexisNexis 2013). The company specializes in information search for lawyers and legal experts and offers various solutions for identifying relevant information. The company offers several platforms for the search of legal facts. Among other things, the solutions enable search in case databases. The search results are usually presented in textual form, but rudimentary approaches to visualization are also integrated.

3. DATA PREPROCESSING

On the basis of raw texts of existing laws, it is actually not possible to generate effective law visualizations on the fly. For that reason, it is essential to preprocess the data for the final visualization purpose. In our use case we use supervised methods to manually generate the data basis, but for the wide use it is definitely recommended to enhance the approach by the use of semi- or non-supervised methods. As data fundament, we aim to generate a Legal-Concept-Ontology, where all law elements are represented in a semantic schema.

The process of legal modeling includes the systematic transformation of legal texts into a formal ontological description language, which can be processed by a machine. This process is divided into the following sub-steps (the steps are described in more detail in the following sections too):

- Normalization of legal texts: The normalization corresponds to an editorial adaptation of the legal texts. Implicit references within a legal clause are explicitly mapped to ensure correctness for the formalization.
- Legislative modeling (conceptual level): Starting from the normalized legal textual text, legal concepts that need to be modeled are identified, annotated and formalized as classes or relations in legal conceptual ontology.
- Legal sentence modeling (symbolic level): The legal terms formalized in Legal-Conceptual-Ontology (LCO) form the vocabulary for machine-processable definitions of legal sentences. For this process step, the identified legal terms for the extraction of a complete header are logically linked.

In addition to the formal depiction of legal concepts and legal principles, another task for the lawyer is the enrichment of the legal knowledge base with additional materials. In this step, for example, the modeled legal terms are supplemented with references to definitions, which are interactively integrated into the development environment for the client in order to provide a more detailed insight into the applicable legal situation.

3.1. Normalization and Selection of Legal Terms

In the first step of legal notion modeling, the legal texts are editorially adapted to explicitly represent implicit relationships within a legal sentence. This normalization modeling of legal norms is a necessary step in the legal methodology to ensure the correctness of the formalization. For the support of the modeling lawyer, the original legal text is displayed as a modeling object (see Figure 1, left box). In this opinion, the lawyer can make an editorial adaptation of the legal text and insert further characteristics that are necessary for the modeling.

After the resolution of all implicit references in the legal text, the view for legal texts allows the selection of candidates in need of modeling for the following modeling of legal terms. This step may be supported by the use of automatic pre-processing methods from the NLP area for transparency. Since the automatic identification of legal terms requiring modeling is a non-trivial NLP and information extraction challenge,

the annotation of the legal terms in the normalized legal text in the first version is done manually in order to avoid possible errors of automatic recognition.
For the annotation of legal terms requiring modeling, the view for legal texts provides appropriate tools with which the lawyer can mark the candidates intuitively by drag and drop. The selected terms are then displayed in an overview (see Figure 1, right box). In this presentation, the lawyer can see whether a legal concept to be modeled already exists on a symbolic or conceptual level. Furthermore, this view is used for the selection of legal terms and the selection in the other views.

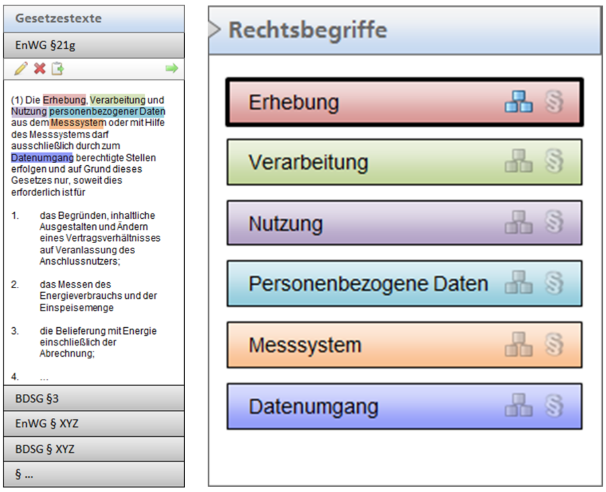

Figure 1. Selection and Normalization of Legal Terms (on the basis of the German Law EnWG §21g – more explanation in Raabe et al. (2015))

3.2. Modeling of Legal Terms (conceptual level)

On the basis of the identified legal concepts, the next step in legal concept modeling is to formalize the identified concepts as classes and relations in the Legal-Concept-Ontology.
This modeling at the conceptual level consists of two sub-steps: (1) creating and editing the classes and the taxonomy and (2) editing the class relations (see (Raabe et al. 2012). These tasks correspond to editing the schema-level ontology. The schema of an ontology can be derived as a tree structure over the *subclassof* relation. Thus, a tree visualization for display and editing by the lawyer is best suited to represent the taxonomy of the concepts and to make it navigable by the user. With the help of Expand/Collapse interactions, this approach enables the collapse and collapse of subtrees and thus also for large trees a clear layout (Figure 2). The hierarchy consists of the concepts of basic ontology (Dolce) and general conceptual ontology, which are color coded for differentiation. For the modeling of the identified legal concepts, drag and drop interactions are used which allow the modeling lawyer to classify legal terms into ontology. In addition to creating the inheritance hierarchy in the Legal-Concept-Ontology (LCO), the visualization also allows the creation of relations within the visualization.

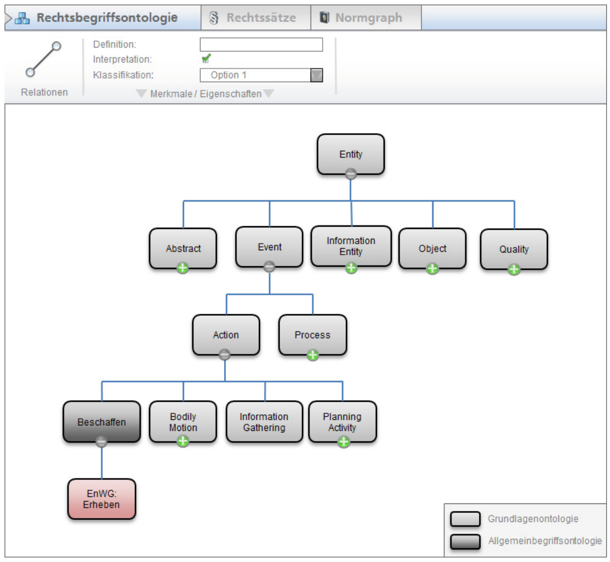

Figure 2. Modeling of Legal Terms

3.3. Definition Support

The interpretation aid provides the modeling lawyers with additional materials to assist in the interpretation. In the process, different materials are integrated into the development environment for the individual legal terms, which facilitates the interpretation and provides textual, systematic, historical and teleological support on the argumentative levels (Figure 3, top tab names). The interpretation aid also serves as a tool for creating a lexicon and allows the lawyer to annotate legal terms with additional materials such as word definitions from a lexicon (Figure 3, text area).
In detail, in the definition support at the following levels, materials are provided to assist the lawyer in interpretation:

- Wording Argument: Provides materials for interpretation at the word-level. For example, dictionaries or dictionaries are conceivable.
- Systematic Argument: For the systematic level, the definition support provides, for example, keyword searches in legal texts.
- Historical Argument: Supports the lawyer in the definition of a legal term on a historical level. For example, search functions for historical examples and accompanying lessons are included.
- Teleological Argument: Provides materials to assist the modeling lawyer in defining at the teleological level. Here, the change of language is in the foreground.

Until this stage, only the general legal aspects where defined on a conceptual level, but no law or sentence/paragraph is modelled. This major 2nd stage is done in the next sections.

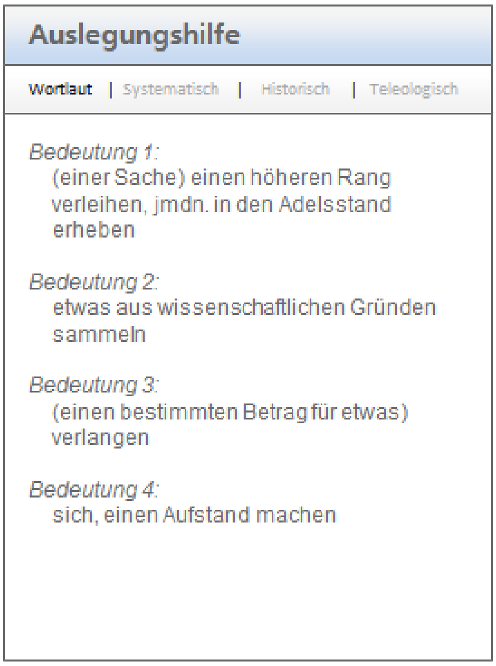

Figure 3. Definition support for the modeling of Legal Terms

3.4. Modeling of Laws (symbolic level)

The right editor provides visual methods used to map legal norms into logical rules. The legal concepts previously stored in legal ontology form the vocabulary for the representation of legal norms on a symbolic level. Therefore, we use an adapted form of the semantic-editing approach that originally was designed for non-ontology experts (Burkhardt et al. 2010).
The editor (Figure 4) makes it possible to link the symbols with different operators (AND, OR, XOR, NOT, ->, etc.). The mapping of the rules to the elements of the previously modeled LCO is implicitly done by the inserted symbols in the rule which all correspond to a concept or a class from the LCO.

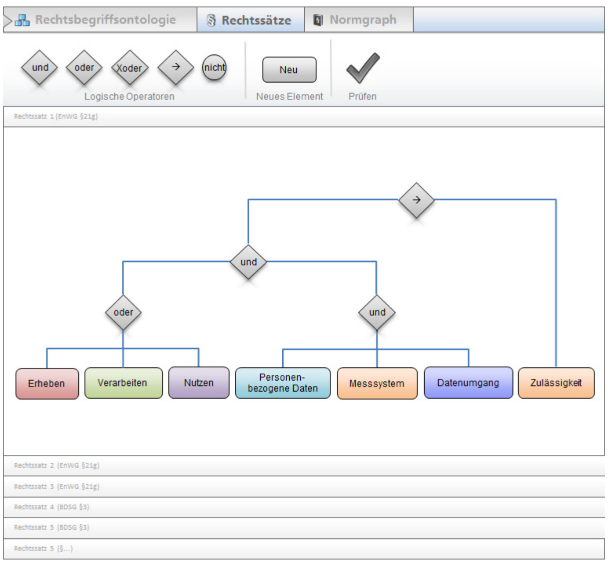

Figure 4. Editor Laws for mapping Legal Norms to Logical Rules

It is to mention that the definition scheme looks similar to a decision tree, but it is not. The expression tells only what legal artefacts in what combination are lawful. There is no opposite expression available, what is a common definition of a decision tree.

3.5. The Lawyer Development Environment

The lawyer development environment consists of four areas (Figure 5) that provide tools to formalize legal concepts and the modeling process; and help lawyers to map legal knowledge. The individual components are in turn divided into further tools which cover specific subtasks of the formalization: (1) *View of Legal Texts and Candidate Selection*: In the view for legal texts, the legal texts to be edited are displayed, and corresponding tools for the selection of models of legal subjects in need of a model and normalization tools are integrated. (2) *Overview of Legal Terms and Candidates*: The selected candidates and already modeled terms of a selected legal text are presented in the overview of legal terms. (3) *Definition Support*: For a more precise interpretation of legal concepts, the interpretation aid provides further additional material to support the definition of legal concepts and integrates further tools for the annotation of legal terms with third-party materials (such as lexicon entries, cross-references, etc.). (4) *Modeling Area*: The modeling area contains the following visual tools for the formalization of the selected legal candidates: (4.1) *Visualization of Legal Conceptual Ontology*: The visualization component on legal conceptual ontology represents basic ontology and general conceptual ontology and provides tools for the formalization of legal concepts on the conceptual level. (4.2) *Legal Editor*: Provides a visual environment for logical linking of legal sentences. Based on a logic language, this view allows formalization on a symbolic level. (4.3) *Representation Norm-graph*: The Norm-graph represents the result of the modeling and is used in the development environment lawyer for testing and validation purposes.

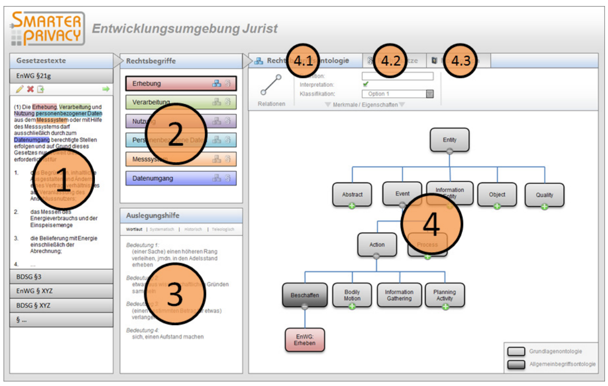

Figure 5. The Lawyer Development Environment

4. NORM-GRAPH TO VISUALIZE LAWS

In following sections, we explain how the Norm-graph is generated.

4.1. Data Principles and Structure

The fundament for the Norm-graph visualization is the generated LCO as described in section 3. In the LCO all terms are defined as sketched in Figure 6.

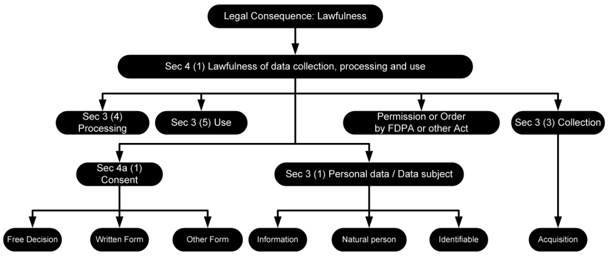

Figure 6. Norm-graph for the legal consequence of "Lawfulness" in the Sec. 4 (1) FDPA. (Oberle et al. 2012)

Next to the structure of the semantic data, also the data provision is important. We use a SPARQL server that enables us to retrieve the required elements with predefined queries. In general, this will also work with alternative technologies, but due to the flexibility of requesting a fine structured data-source, it is easier by using SPARQL.

4.2. Norm-graph Template

To outline better how the Norm-graph is generated, it is important to understand the principle structure that is something like a template. On this basis any kind of norm can be visualized.

As already described in section 3.4, a concrete norm or law consist of a number of constraints that connected with different operators (AND, OR, XOR, NOT, etc.). It is to indicate that there is also a logical structure (see Figure 7) of how certain aspects correspond to each other, such as objects like 'personal data' or actions like 'processing of'.

Followed on a number of connected constraints there is always a clear consecution (indicated with '->'). This consecution indicates if something is valid, in particular if a certain action is allowed or prohibited.

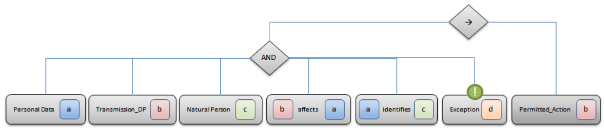

Figure 7. Template for a single Norm on the basis of the underlaying semantic structure

An example, how to request the concrete elements for a Norm-graph, on the basis of the sketched schema in Figure 7, is shown in Table 1.

Table 1. Semantic Query to retrieve the Norm-graph components from the LCO

```
[ Paragraph_21g Abs._1:
(?a rdf:type http://localhost/example_rbo.owl#Personal_Data)
(?b rdf:type http://localhost/example_rbo.owl#Transmission_DP)
(?c rdf:type http://localhost/example_rbo.owl#Natural_Person)
(?b http://localhost/example_abo.owl#affects ?a)
(?a http://localhost/example_rbo.owl#identifies ?c)
noValue(?d rdf:type http://localhost/example_rbo.owl#Exception)
->
(?b rdf:type http://localhost/example_rbo.owl#Permitted_Action) ]
```

4.3. Concept for Norm-graph and Data Cockpit

The Norm-graph represents the central navigation component of the surface lawyer and the subsumption in the narrower sense. The norm-graph visualizes a section of the complete premise of the modeled legal concepts (see section 3.2), the legal sentences (see section 3.4) and the entered facts during subsumption in the narrower sense meaning is presented graphically and thus represents the applicable legal norms (Figure 8). The root is always a legal consequence (e.g. admissibility). In the following nodes, the graph contains further legal norms that are marked as rules. The factual characteristics follow in a further level in the graph which shows which legal terms are involved in the facts. Thus, the client can see which "parts" of a legal norm apply to the facts. In addition, the assignment of factual instances to legal concepts is shown in a further level.

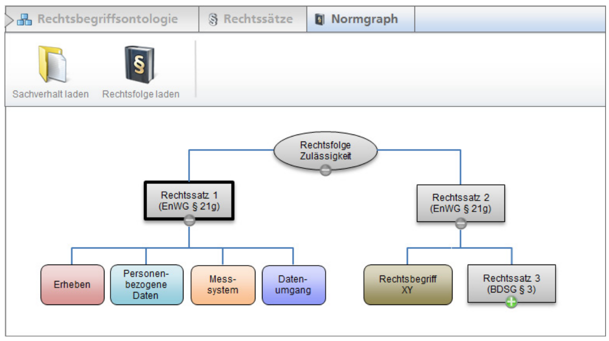

Figure 8. Norm-graph Mockup

In addition to the standard graph, further information is displayed in the client interface which further clarifies the legal situation on the facts and contributes to clarifying the legal basis. Figure 9 shows the data cockpit for the client when selecting an attribute (legal term).

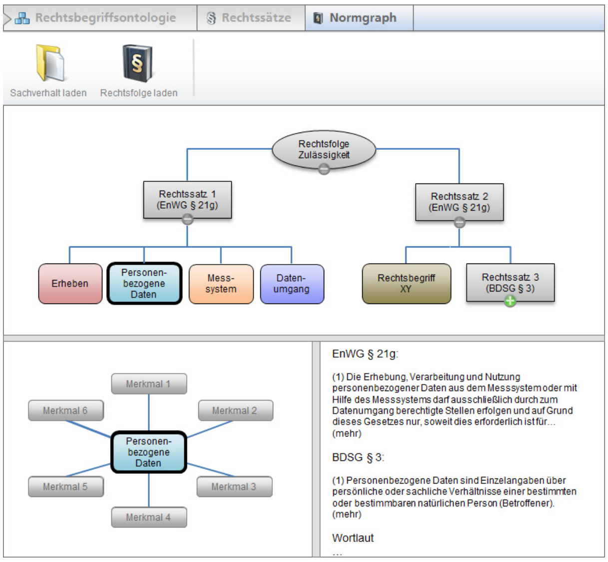

Figure 9. Data Cockpit Mockup including the Norm-graph

As data cockpit we orient on the so-called visualization cockpit as defined by Nazemi et al. (2010). In addition to the standard graph, the characteristics of the selected constituent element are also displayed in a graph visualization (bottom left) and the legal texts in which the constituent element occurs (bottom right). When selecting a legal clause, the logical structure is also displayed in a legal sentence visualization. In the norm graphs presented so far, a completely transferred state of affairs and thus a dynamic norm graph have been assumed.

4.4. Norm-graph to visualize Legal Text

The Norm-graph shows the major aspect of a law in one line (Figure 10, top line) with the consecution at the end – this is different to original concept but was necessary for the following interaction ability where further explanations are shown below. The show aspects in the top line is different to the text of laws, where now only the major aspects as annotated before (see section 3.1) are considered, but even on this level the message is easy to understand when read by humans.
Since a number of aspects are not defined in a single paragraph and sometimes references to terms from other statutes, the major advantage is the interactivity.
Through clicking on a concrete aspect, it shows underneath where an aspect is further explained, defined or where is derived from.
Since some referenced paragraphs or term definitions are representing an own norm, a second line is opened (Figure 10, second line). Based on this recursive approach, the user is able to elaborate the full bunch of underlaying laws to understand e.g. what "personal data" are and how they are defined. This simple overview about legal aspects and how each single aspect and term resolves to all kind of law sources enablers a fast and clear understanding.

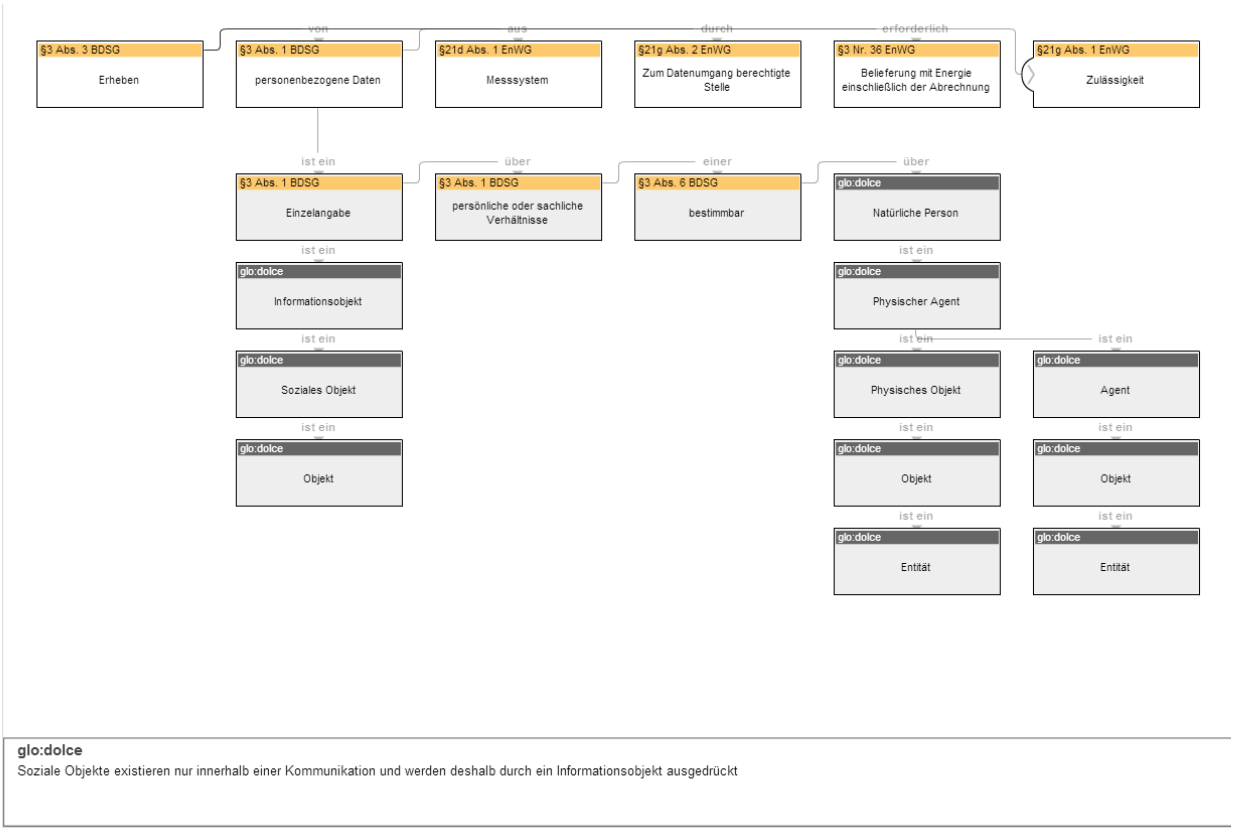

Figure 10. The final Norm-graph visualization

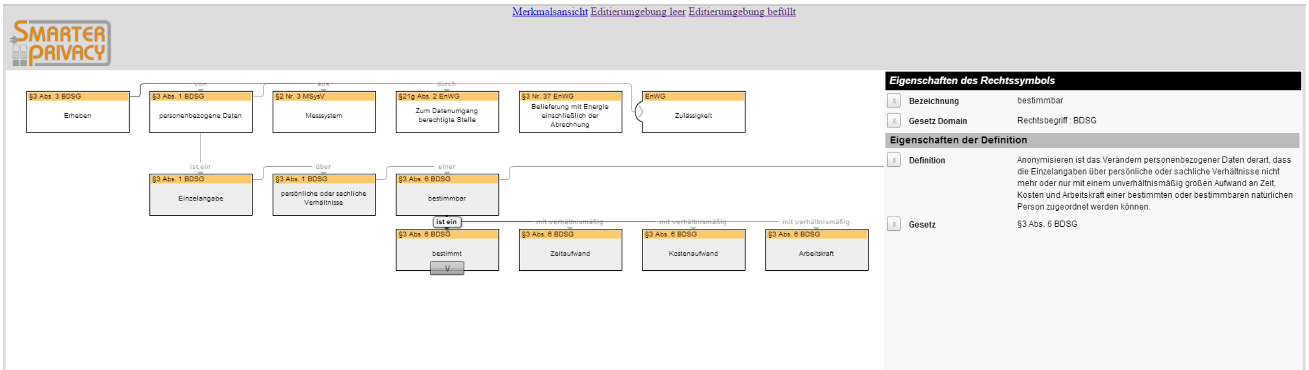

Figure 11. The Legal Data Cockpit

4.5. Law Data Cockpit for Legal Experts

The main goal was to create a data cockpit for legal experts that helps them to check business models or planned services against existing laws, in particular if they are conform with them. In a first round we prepared therefore a scenario toward the privacy of personal data in the field of the German Energy Industry Act (more information in Raabe et al. (2015)) and new services that needs to cover the regulations that are explained in it. The intention is that legal experts can validate business models and service purposes against the German Energy Industry Act (more information in Raabe et al. (2015)) to identify complications early (Figure 11).

The challenge of lawyers in checking validity of business model requires a complete understanding of the corresponding laws as well as how certain terms are defined. This connection to other laws, law books or legal (term) definitions can become quite complex that our visualization can easily show in one overview, and therewith decreases the efforts that needs to be investigated. An example could be, what are "personal data", e.g. is the title (such as Dr./PhD.) also part of personal data? A full tree that shows, how this term can be derived on the basis on laws, legal books on legal definitions is a helpful lawyer support that makes finally the decision making much easier.

We used a generic approach that can be easily applied also on other domains and scenarios of legal aspect. The major requirement for this purpose is the data preprocessing as explained in section 3.

5. USE-CASE: A SEMI-AUTOMATED INTERPRETATION SUPPORT

The Norm-graph visualization is one of the major results to provide a simplified access to law data and support decisions toward legal conformity. However, the original intention is going a step ahead, where even the interpretation of legal issues should be supported via reasoning for enterprise services (Oberle 2014, Burkhardt et al. 2017).

Figure 12 shows a norm graph with markings that emerged as a result of the subsumption algorithm. In this example, the question of the admissibility of the facts was asked and the corresponding standard chains identified. By marking the user recognizes which parts could not be detected automatically during subsumtion. The red marked branches show the way to the criteria for a user interaction. In this example, the individual details of the personal data and the supply of energy could not be resolved. These elements are marked in red. With the selection by the user, these conflicts can be resolved. For this purpose, further graphical tools are provided, as the case may be, in order to facilitate the user's interpretation or the assignment of the instances from the situation to the unrecognized factual features of the LCO. So far, the following cases have been identified which are successively integrated into the surface: (1) layout at the schema level - teleological reduction (e.g. personal data), (2) interpretation of a relation (e.g. necessity, mean & purpose) and (3) schema interpretation - teleological extension (e.g. elevation).

After the interpretation in the strict sense and after all elements of the Norm-graph could be assigned to instances of the facts, the Norm-graph indicates the fulfillment of the norm. The standard fulfillment is indicated in the standard graph by further markings. By unfolding further subtrees and the view of additional materials, this concept allows the graphically interactive navigation and exploration of the applicable law to the inputted fact.

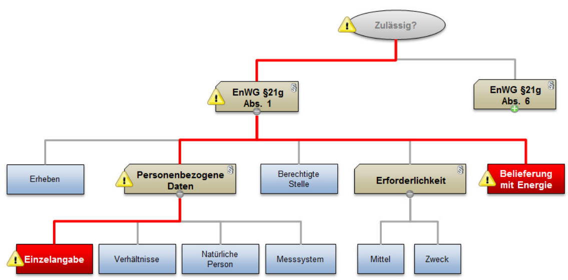

Figure 12. Concept for a Norm-graph that supports interpretation

6. DISCUSSION

Due to the strong collaboration with the target users as well as legal experts, we got constructive feedback and even positive feedback in perspective of productivity and added value. However, a major challenge is the empirical evaluation of this approach. We actually deal with a number of challenges. First the target group is very special and even there, lawyers are most often specialized, so the setup of an evaluation scenario is difficult – in particular to acquire a significant number of participants. The second challenge is the lack of similar visualizations, which would be necessary to perform a comparative evaluation. The third challenge is how to come to a general statement to the benefits of this kind of visualization algorithm. Since an evaluation can only cover a specific scenario, it is unclear how with that a general statement regarding the efficiency or effectiveness could be derived.

Next to the evaluation, there is also a challenge of how to preprocess data (semi-)automatically. Indeed, LDA algorithm are in general appropriate for this purpose, but it is to mention, that legal texts are very special than e.g. text from normal documents such as reports. In fact, the annotation is almost impossible to process that step completely automatically. Furthermore, legal books contain big amounts of contents that needs to be considered and additionally there are regularly changes that needs to be considered too. There is still further investigation required how to handle these data preprocessing stage almost autonomously.

7. CONCLUSION

The paper describes a new approach how to visualize laws graphically in a Norm-graph. The major benefit is that the complexity of norms and their legal aspects could be decreased so that also normal users can easily understand it and see all the relating facts. The major purpose is to finally support users in finding critical aspects, in perspective of existing laws, for new planned business models or services. The approach was practically implemented and tested on the basis of laws toward the German Energy Industry Act. The result received positive feedbacks from lawyers and legal experts.

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EXPLORING DIMENSIONALITY REDUCTION EFFECTS IN MIXED REALITY FOR ANALYZING TINNITUS PATIENT DATA

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ABSTRACT

In the context of big data analytics, gaining insights into high-dimensional data sets can be properly achieved, inter alia, by the use of visual analytics. Current developments in the field of immersive analytics, mainly driven by the improvements of smart glasses and virtual reality headsets, are one enabler to enhance user-friendly and interactive ways for data analytics. Along this trend, more and more fields in the medical domain crave for this type of technology to analyze medical data in a new way. In this work, a mixed-reality prototype is presented that shall help tinnitus researchers and clinicians to analyze patient data more efficiently. In particular, the prototype simplifies the analysis on a high-dimensional real-world tinnitus patient data set by the use of dimensionality reduction effects. The latter is represented by resulting clusters, which are identified through the density of particles, while information loss is denoted as the remaining covered variance. Technically, the graphical interface of the prototype includes a correlation coefficient graph, a plot for the information loss, and a 3D particle system. Furthermore, the prototype provides a voice recognition feature to select or deselect relevant data variables by its users. Moreover, based on a machine learning library, the prototype aims at reducing the computational resources on the used smart glasses. Finally, in practical sessions, we demonstrated the prototype to clinicians and they reported that such a tool may be very helpful to analyze patient data on one hand. On the other, such system is welcome to educate unexperienced clinicians in a better way. Altogether, the presented tool may constitute a promising direction for the medical as well as other domains.

Keywords: immersive analytics, dimensionality reduction, mixed reality, covariance graph

1. INTRODUCTION

Recent developments of smart glasses offer new perspectives in the field of immersive analytics. The latter is a research field that investigates new display technologies for analytical reasoning (Chandler 2015). In many cases, augmented reality approaches use a three-dimensional representation of data, which enables the user to recognize spatial contexts of data more easily.

In this context, Figure 1 presents our categorization of different approaches in the field of augmented reality for smart glasses. Note that there exists a variety of other categorizations, such as the so-called *Reality-Virtuality Continuum* (Milgram 1994).

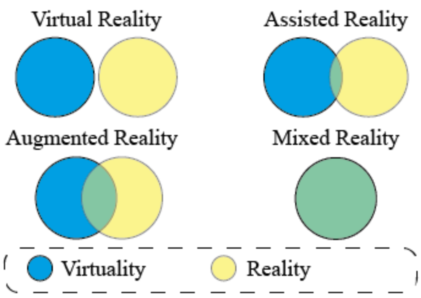

Figure 1: Types of 3D Approaches

In our categorization, the augmented reality approaches are defined by the degree of overlap between reality and virtuality: First, *virtual reality* (VR) separates the user from the real world by the use of a headset that simulates an environment that is similar to the real world. Second, *assisted reality* (ASR) constitutes the concept of appliances (e.g., again headsets) for which the augmented information is not directly in the user's field of view. Consequently, the augmented information must be actively focused on to obtain further insights. For example, an industrial maintainer is repairing a machine and needs a clear field of vision. Though, he should be able to check the current machine state with a sideways glance to the edge region of his smart glasses. Third, in contrast to assisted reality, *augmented reality* (AR) displays the information directly in the user's viewing area. Fourth, and most importantly for the work at hand, *mixed reality* (MR) must be distinguished.

Thereby, the displayed information is integrated into the real world by using the concept of spatial mapping, also denoted as 3D reconstruction (Izadi 2011). Hereby, a room is scanned, usually by the use of depth-sensors, and the resulting, generated model can be used as an interface between holograms and the real world. Note that this concept enables new interaction possibilities in the context of immersive analytics as diagrams to be analyzed can be placed nearly anywhere in the real world. In this context, we discuss the following research question along a high-dimensional data set of tinnitus patients: *How does mixed-reality allow quick insights into the effects of dimensionality reduction in large data sets?*

To answer this question, first of all, we selected from a variety of dimensionality reduction techniques (Van Der Maaten 2009), the principal component analysis (PCA) (Wold 1987). This Euclidean distance-based technique, in turn, is often used for classification purposes in combination with other approaches, such as neural networks. Thereby, the PCA transfers all values into a *subdimension*, which allows for displaying a three-dimensional plot for data sets of arbitrary size. However, since information can be lost in this transformation process, our approach particularly addresses this issue during the dimensionality reduction. In addition, we focus on two other major aspects:

- Identification of clusters in dimensionality reduced data sets
- Recognition of correlations between variables of the data set

To practically evaluate our approach, we implemented a proof of concept based on the Microsoft *HoloLens*, a head-mounted display for mixed-reality, and the *unity* game engine (Technologies 2015). The data set that is used for the prototype stems from the TrackYourTinnitus platform (TYT). Note that the latter is a mHealth crowdsensing platform that enables iOS and Android users to gather everyday life data with their own smartphones to understand their individual tinnitus situation better. Tinnitus can be described as the phantom perception of sound. Note that symptoms for tinnitus are subjective and vary over time. Therefore, TYT was developed to reveal insights on this patient variability. Moreover, depending on tinnitus definitions, the duration as well as on the patient age and birth cohort, between 5.1\% and 42.7\% of the population worldwide experience tinnitus at least once during their lifetime. Moreover, tinnitus is a chronic disorder and its general treatment is challenging as well as costly. Especially in the context of chronic disorders, a comprehensive and quick access to patient data is of utmost importance. On one hand, clinicians and researchers want to obtain the required patient information (e.g., what are the characteristic variables of an individual patient) as quick as possible in order to conduct studies with promising hypotheses or to start a proper patient treatment. On the other, by sharing information on patient data in a proper way, unexperienced clinicians can be educated more efficiently. Therefore, the presented approach and the developed prototype shall support clinicians and researchers in this context.

The remainder of the paper is structured as follows: Section 2 discusses related work, while Section 3 introduces the mathematical background for the pursued dimensionality reduction. In Section 4, the developed prototype is presented, in which the data set, the *Graphical User Interface* (GUI), and the backend are presented. Threats to validity are presented in Section 5, whereas Section 6 presents a summary and Section 7 concludes the paper with an outlook.

2. RELATED WORK

The usefulness of the third dimension for data analytics has been tested in various scenarios. In a study based on loss of quality quantification (Gracia 2016), the authors found that three-dimensional visualizations are superior compared to two-dimensional representations. The authors compared the tasks point classification, distance perception, and outlier identification in two ways. First, they evaluated a visual approach and, second, they applied an analytical counterpart. Furthermore, they conducted a user study and compared 2D and 3D scenarios on a display. However, they did not use smart glasses to evaluate their models. A second user study (Raja 2004)), specialized on scatter plots in an immersive environment, indicated that a high degree of physical immersion results in lower interaction times. This scenario included a large field-of-regards, head-tracking, and stereopsis, but was limited to only a few number of subjects. Another study supporting the theory of improved performance in a three-dimensional space (Arms 1999), compared 2D and 3D visualizations by using interaction (i.e., time measurement) and visualization tests (i.e., correct identification). The subjects were asked to identify clusters, to determine the dimension of a dataset, and to classify the radial sparseness of data. Similar to our work, a prototype for dimensionality reduced scatterplots was developed and examined in (Wagner Filho 2017). The subjects had to identify the closest party, party outliers, and the closest deputy in a data set. Therefore, a desktop-based 3D and an immersive 3D visualization were tested on the defined user tasks. Interestingly, the immersive approach generated the best outcome concerning classification accuracy. The differences to our solution are missing components to visualize correlations and information loss, the lack of voice commands, and a different representation of data points. Here, the data points are displayed using solids circles or spheres, which is unsuitable for large data sets we are focusing on. In contrast to the previous works, (Sedlmair 2013) recommends 2D scatterplots. In a study in which users had to compare the class separability of dimensionality reduced data using 2D and 3D scatterplots, the three-dimensional approach generated higher interaction costs.

Teaching abstract data analytical concepts, such as dimensionality reduction, was tested in an exceptional project called *Be the Data* (Chen 2016). Persons were embodying by data points, while the floor represents a 2D projection. This idea relies on findings, where bodily experiences, such as gesturing, body orientation, and distance perception support the cognitive process (Bakker 2011). Note that the concepts of bodily experiences are an important part of mixed reality and, hence, can be associated with our work.
The Microsoft HoloLens was profoundly evaluated in (Evans 2017). The authors underline the advantages of working in a hands-free manner, yet they criticize the spatial mapping mash to be unprecise in their industrial environment.
Finally, a platform for immersive analytics was proposed by (Donalek 2018). Effective data visualization for high-dimensional data is described as "a cognitive bottleneck on the path between data and discovery".
Altogether, the introduced literature shows the potential of immersive analytics, though indicate potential weaknesses in our pursued context.

3. PRINCIPAL COMPONENT ANALYSIS

The principal component analysis (PCA) is a technique to find patterns in high-dimensional data. Common use cases in this context are face recognition (Yang 2004) and image compression (Clausen 2000).

In general, PCA is based on the *covariance* measure, which expresses the connection between the dimension *x* and *y*, and which is denoted as

$$cov(X,Y) = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{(n-1)} \qquad (1.1)$$

Most importantly for the interpretation of the covariance is it' sign. First, if the value is positive, *x* and *y* increase together. Second, if the value is negative, then if one dimension increases, the other decreases accordingly. Finally, a covariance of zero indicates independent variables. When representing more than two dimensions, then a covariance matrix is needed:

$$C^{nxn} = (c_{i,j}, c_{i,j} = cov(Dim_i, Dim_j)), \qquad (1.2)$$

where *n* is denoted as the number of dimensions and each entry in the matrix is a result of the calculation (1.1). Next, we need the eigenvectors and eigenvalues (Hoffman 1971) of the covariance matrix. Note that all eigenvectors of a matrix are perpendicular. The highest eigenvalue (eig_1, *cf.* Figure 2) is denoted as *principle component* and can be seen as the most important axis of a new coordinate system. Thereby, each eigenvector is identified by a *significance*, represented by an eigenvalue. This, in turn, is the decisive point of the dimensionality reduction. If we leave out some components, we will lose information.

The remaining eigenvectors form a feature vector as follows:

$$FeatureVector = (eig_1, eig_2, eig_3, ...eig_n) \qquad (1.3)$$

Finally, the feature vector is multiplied with the transposed and mean-adjusted data to receive the final data set.
In summary, the complete steps of the PCA are as follows:

1) Subtract the average across each dimension
2) Calculate the covariance matrix
3) Calculate eigenvectors and eigenvalues of the covariance matrix
4) Define number of components
5) Calculate the new data set

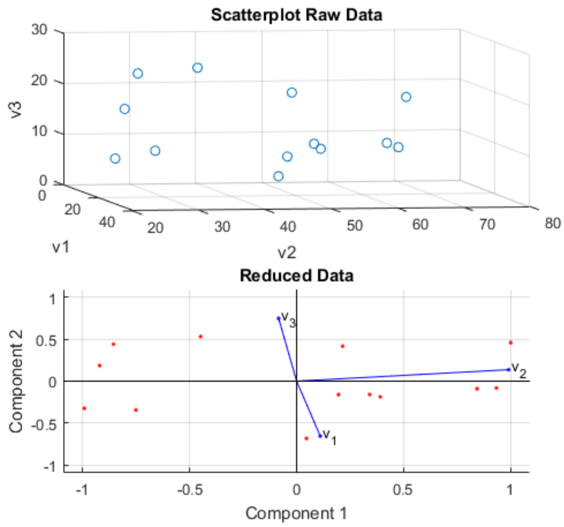

Figure 2: PCA Example

To conclude, by excluding eigenvectors, we reduce the information in the data set. The information loss can be calculated using the percental significance of the erased component. Correlating dimensions, as expressed by the covariance measure, can therefore be well reduced by using the PCA approach.

4. PROTOTYPE

The client-side of the prototype is developed using the Unity game engine and the Microsoft HoloLens, a mixed reality smart glass. When starting the application, the hologram can be placed in the current room and it is further on placed in a static manner, so that the user can walk around the hologram and inspect it from different positions.

4.1. Data Set

The prototype was developed based on data from the TrackYourTinnitus project (Schlee et al. 2016; Probst et al. 2016; Pryss et al. 2018). Included variables are patient data that recorded via mobile applications and which represent, inter alia, the tinnitus loudness or the patient's mood during the occurrence of tinnitus. Each data point in this data set represents the users condition at a certain point in time. In a first preprocessing step, the data set was cleaned from missing values, which might occur if the data is stored incompletely due to missing user inputs or errors caused by the used smart mobile devices (cf. Table 1). Next, each column is normalized to ensure comparability between the dimensions. However, we lose information about the absolute values of each dimension on one hand. On the other, a uniform representation for three dimensions becomes possible (cf. Figure 2).

Table 1: The Data Set

Size	41 892
Size After Cleansing	36524
Variables	17
Data Format	.csv

A common task for this medical data set is to find connections between dimensions and to derive hypotheses such as "*the current mood of the patient influences the perceived tinnitus loudness*".
In this context, three major requirements concerning the developed application are derived from this TYT patient data set:

REQ1: High-dimensional data needs to be displayed and for existing clusters it should be easily possible to identify them.
REQ2: A simple data representation is essential since the application users are not necessarily data science experts.
REQ3: The relation between the data sets dimensions is a core function and needs to be displayed using a quick overview feature.
REQ4: The exchange of dimensions and the visualization of more than three dimensions must be possible.
REQ5: High computational resources must be provided as each permutation, generated by REQ4, needs to be computed on demand.
REQ6: Due to the complexity of the data set, the user needs precise application feedback and easy input possibilities during the data analysis workflow.

4.2. The HoloLens

The HoloLens offers a variety of sensors to improve the user interaction and user feedback (cf. Table 2). The *Inertial Measurement Unit* (IMU) contains a combination of accelerometers and gyroscopes, which stabilize the visualization of holograms by providing the angular velocity of any head movement (LaValle 2013). Concerning REQ6, a promising way for a user interaction in this context constitutes the use of *voice commands*, as they allow for a hands-free interaction principle. Interestingly, the HoloLens provides a microphone array, which can distinguish between vocal user commands and ambient noise. Furthermore, due to the microphone array's positioning, the identification of the direction of external sounds is easily possible. Moreover, using *spatial audio*, the in-app audio comes from different directions, based on the user's relative position to a virtual object. This can be used to guide the user through a room and direct his field of view to relevant diagrams or information.

Table 2: Technical Data HoloLens

Sensor Overview	
Inertial Measurement Unit (IMU)	1
Environment Recognition Camera	4
Depth Sensor	1
RGB Camera	2MP * 1
Mixed Reality Capture	1
Microphone	4(2 * 2)
Ambient Light Sensor	1

Furthermore, real-world 3D projections can be anchored onto real-life objects and are visible to the user in a distance from about 60 cm to a few meters. Therefore, infinite projections are not possible, neither to the actual distance nor to the actual proximity. Moreover, the HoloLens offers gesture- and gaze recognition. In our work, we solely utilize the tap-to-place-interaction via gestures (cf. Figure 3).

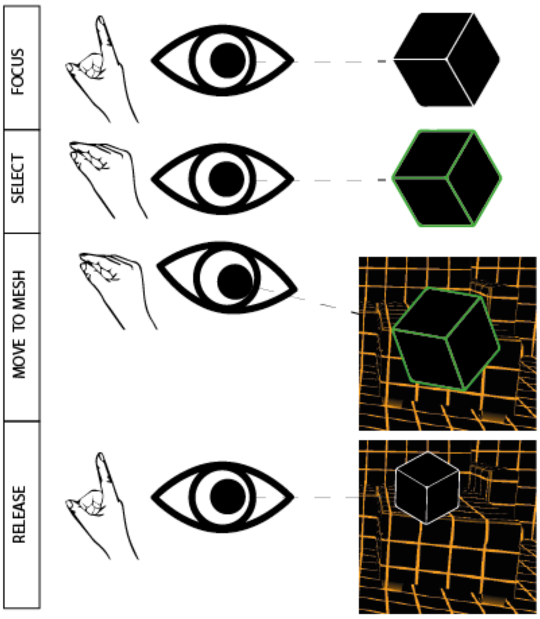

Figure 3: *TapToPlace* for Holograms

With a weight of 579g, the HoloLens usually needs a longer period for getting familiar with the appliance. Note that longer wearing periods are not recommended in the beginning, due to the unnatural head positioning. Theoretically, the power consumption of the HoloLens allows for a usage of 2.5 hours during intensive use, though it is unlikely a user will wear the HoloLens that long for an immersive analytic task.

4.3. Graphical User Interface

The first introduced graphical component is a particle system as shown in Figure 4. Most importantly here is the increasing brightness for particles in the same position as configured by a shader. This effect simplifies the detection of *clusters* as regions with a high particle density appear brighter than those with only few contained data points (cf. REQ1). Furthermore, the particle system is labeled with the corresponding dimension name on each axis. It is possible to plot the same variable on several axes. When these axes are *overloaded*, meaning that there are more than three variables to be displayed (cf. REQ4), the visualization changes and the plot switches to the dimensionality reduction view. Here, in Figure 4, the PCA result is shown and the axes are renamed to the three principal components with highest significance.

Voice commands allow for the plot manipulation, where a hologram scalation by predefined values can be realized using the keywords *plus* and *minus*. As introduced in Section 4.2, a *natural zoom* by approaching the hologram is only possible to 60cm, therefore the scalation of the hologram replaces this use case and allows the detailed inspection of data points. Furthermore, the variable assignment to each axis can be edited using voice commands and the resulting changes in the plot are animated, so that the user can understand occurring state changes. Note that the voice commands work fine until a certain degree of background noise exists. Our prototype was demonstrated at the TRI/TINNET Conference 2018 and, depending on the number of visitors in the exhibition hall, the voice recognition failed to detect voice input. Still, the voice commands are intuitive and fulfill REQ6.

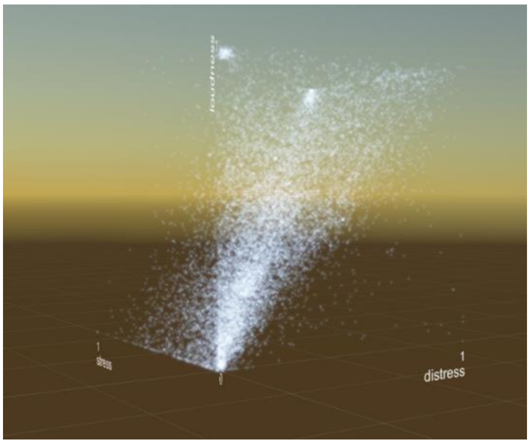

Figure 4: Default Particle System Plot

The number of variables to be displayed is further on denoted as *variables collection*. All items in the variables collection are shown next to the particle system, as well as in a correlation coefficient graph (cf. Figure 5). The latter is a variant of an existing approach (Peña 2013) using the concept of color coding. Negative variance is marked as a red edge, while positive variance is displayed as a green edge. The strength of the variable connection is visualized using the opacity of each color, where the covariance intervals [0,1] and [-1,0] are mapped to the new opacity value in the range [0,100%]. In Table 3, therefore, a sample correlation matrix for five variables is shown. Note that, although the covariance is used for the PCA calculation, we visualize the correlation as a normalized form of the covariance.

The correlation is denoted as

$$corr(X,Y) = \frac{cov(X,Y)}{\sigma_X \sigma_Y} \qquad (1.4)$$

As can be obtained from Eq. 1.4, covariance and correlation depend on each other.

Table 3: Correlation Example

	Variables				
	loudness	distress	mood	arousal	stress
loudness	1.0000	0.0676	0.0373	0.0372	-0.0022
distress	0.0676	1.0000	0.0282	0.0302	-0.0012
mood	0.0373	0.0282	1.0000	0.2874	0.0311
arousal	0.0372	0.0302	0.2874	1.0000	0.0370
stress	-0.0022	-0.0012	0.0311	0.0370	1.0000

Figure 5 shows the resulting graphs based on Table 3. The covariance plot is solely shown to underline the difference to the graphical variant. The covariance graph marks only the strongest edges, while the introduced correlation graph fades irrelevant values. The user of the prototype can obtain this information from the graph to improve the dimensionality reduction by removing variables that don't fit well into the graph; if they a) correlate negatively or b) correlate very weakly.

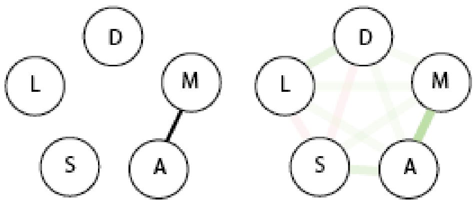

Figure 5: Covariance (left) and Correlation Graph (right) with abbreviated features presented in Table 3

The last GUI component explains the information loss caused by the Principal Component Analysis. A bar plot shows the percentage of the three most important components for the overall variance. Figure 6 presents the variance of each component in a stacked bar. Due to the transparency, the user is able to recognize the importance of each component, while the red cube represents the discarded information.

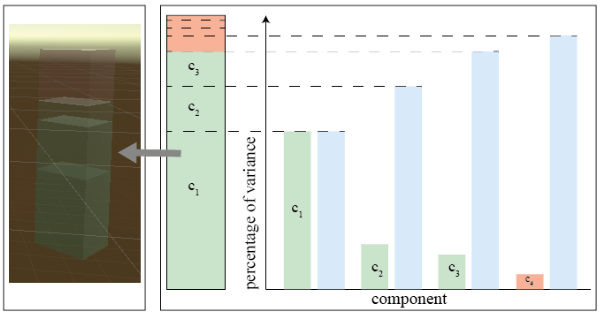

Figure 6: Information Loss Component

Altogether, these three GUI Elements combined allow for an intuitive way of dealing with the dimensionality reduction. First, the difficulties of interpreting a covariance matrix are translated into a graph, for a quicker visual registration of connections between features. Second, the particle system allows for the visualization of high-dimensional data and a simplified detection of clusters through the brightness. Finally, the stacked bar of the PCA components variance allow for a quick estimation of each component's importance and the information loss.

4.4. Backend

The core concept of this application is to separate the algorithm implementation from the visualization to reduce the required computational resources on the smart glasses (REQ5). Therefore, we implemented a python backend server for dimensionality reduction and data exchange possibilities through a Representational State Transfer (REST) Interface (cf. Figure 7). The server relies on the web framework *Flask* (Grinberg 2018), which communicates with external applications using the *Web Server Gateway Interface* (WSGI). Moreover, the PCA implementation is realized by the free machine learning library *scikit-learn* (Pedregosa 2011), and the numerical and scientific library *NumPy* (Walt, Colbert, and Varoquaux 2011). The pursued workflow, in turn, is as follows: Via voice commands, variables can be selected or deselected from the data set, which is stored on the server.

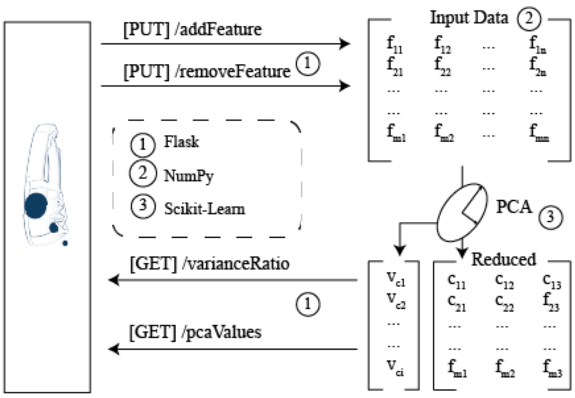

Figure 7: Backend Workflow for the PCA

Based on the number of selected variables *n*, and the number of entries in the data set *m*, a matrix is generated. This matrix serves as the input for the PCA. The PCA is executed twice, by varying the number of components. First, to receive a three-dimensional reduced data set, only the three components representing the highest variances are used. The original data set can now be transformed into the new *subspace*. Second, the PCA is computed with the maximal number of components to show the distribution of components concerning their variance. The mixed reality application is then able to access - via a REST call - the computed variance ratio vector and the transformed data set.

5. THREATS TO VALIDITY

This section discusses threats to validity when using the prototype in practice. First, the split into two parts of the application (i.e., GUI and Backend) complicates the installation and therefore intuitiveness of the application. On one hand, the presented application shall enable simplified insights into methods of dimensionality reduction, which could be technically shown. On the other, the developed application design for the backend and its required installation procedure are currently inappropriately designed for large-scale practical scenarios. Moreover, the need for an Internet connection disqualifies the current approach for local working environments like the ones that can be found in a production environment when working with machines. A second crucial aspect is the missing integration of numeric values. Neither in the correlation graph, nor the stacked bar, and the particle system are concrete numbers used. Therefore, this application is not meant to perform exact analytics. Moreover, all values in the particle system are normalized, which distorts the impression of the real range of values and instead only represents a relative view on the data set. Finally, the prototype has not been evaluated in a psychologic study yet. Therefore, amongst others, insights on the cognitive load for users when using this application in practice is currently unexplored and must be evaluated in an empirical study.

6. CONCLUSION

This work presented an interface for a mixed reality application with the goal to obtain insights into dimensionality reduction effects. Use case specific components (i.e., for analyzing tinnitus patient data) were developed and optimized for the principal component analysis method. Furthermore, it was shown how these components fit together in order to gain quick insights into large data sets like the one for tinnitus patients. We have presented that interactions with the application can be executed by the use of voice commands. Furthermore, the application is enriched by a state of the art machine learning backend including a web interface, which allows future modular extensions. Since the overall algorithm execution is outsourced to a remote server, the required computational resources on the smart glasses could be decreased. Overall, the three introduced components provide a comprehensible function overview with respect to the major goal pursued by a PCA and can therefore be used for immersive analytics in the context of large-scale healthcare data like the one shown for tinnitus patients. We regard such technical opportunities especially in the context of healthcare scenarios as an enabler to analyze patient data more efficiently. However, many other domains crave for such appliances that can be used to perform immersive analytics (e.g., in the context of predictive maintenance).

7. FUTURE WORK

The developed prototype is currently evaluated in a user study, in which the users need to solve cluster-based tasks, such as the assignment of occurring data patterns to the correct cluster and interpreting the effect on a cluster when removing a dimension. The study is accompanied by stress measurements to get more insights on the required mental load when using the prototype in practice. The study users, in turn, are put into two groups, which are built on a pre-test that evaluates the spatial imagination abilities of the participating users. Furthermore, the prototype will be improved by integrating the concept of spatial sounds. As the HoloLens offers a feature for directional sounds, the user may be guided to promising clusters in the particle system. A prerequisite for this approach constitutes a suitably large particle system size, so that a user is enabled to distinguish between clusters. Finally, recommendations will be added to the prototype. So far, a user has to select the dimensions of the data set by himself or herself and, hence, must reveal the most effective dimensionality reduction for the data set by a trial and error method. In a further development, we plan that the variables, which must be selected by an user in this context shall be suggested by the prototype in a more data-driven manner.

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VIRTUAL SKILL TEACHER – PLATFORM FOR EFFECTIVE LEARNING OF TECHNICAL SKILLS

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ABSTRACT

The paper presents development and test procedure of a Virtual Reality system for training of hard, technical skills necessary in an industrial company. The prototype system allows learning of theory and practice of forklift operation. Basic ideas, methodology of system creation, concepts of a virtual course and its test procedure are presented, along with obtained results.

Keywords: virtual reality, industrial training, technical skills, learning

1. INTRODUCTION

One of the most prevalent professional VR application is education and trainings – in engineering (Abulrub et al. 2011, Grajewski et al. 2013, Gorski et al. 2015), school education (Martín-Gutiérrez et al. 2017) or medical training (Escobar-Castillejos et al. 2016, Gorski et al. 2017). In industry, VR is quite often used for support of design processes (Ye et al 2007), simulation of machines and devices (Pandilov et al 2016) or for decision-making (Colombo et al 2014). VR is also used for industrial training purposes (Blümel et al. 2009, Torres et al. 2017), some authors point out its importance in the Industry 4.0 concept and factories of the future (Gorecky et al. 2017, Żywicki et al. 2017). VR is especially well suited to assembly process training (Grajewski et al. 2015, Wan et al. 2004). The VR training allows increasing effectiveness of knowledge transfer. It is far easier to repeat activities in VR, as well as train undesired or dangerous situations. VR applications are also easily scalable and they can be created in a way to allow adjustment of its content for a given user. Blümel and coauthors pointed out advantages of using VR training in their review work (Blümel et al. 2009).

The VR systems are currently readily used for industrial training, e.g. in automotive (Langley et al. 2016) or in aeronautical field, allowing time reductions even up to 75% (Kishore 2017). There is a very broad scope of various equipment, with VR goggles (Head Mounted Devices, HMDs) being the most widespread, allowing user look and move around a virtual environment. Other systems allow direct interaction with elements inside a visualization (haptic devices, systems for tracking and gesture recognition), intensifying feelings of immersion. By integrating specific hardware with a properly prepared VR application, a specialized simulation environment can be obtained, in which the training is performed according to conditions present in reality.

The aim of the work was to prove that VR can be used by shop floor workers of industrial production companies, usually not familiar with advanced systems, such as professional VR used in engineering. As such, the presented system is considered as a social innovation. The paper presents basic concepts, building methodology and testing results. The selected case of a technical skill is operation of a forklift – a common skill necessary for employees of production companies.

2. MATERIALS AND METHODS

2.1. Concept and research overview

The Virtual Skill Teacher (VST) is a VR platform for learning practical, technical skills, usually related with operating working vehicles (such as the forklifts, which are the main case), machines, realizing tasks in a certain production process, etc. The key ideas are as following:

- the course is the main entity, it is divided into lessons and exercises, which are further divided into blocks,
- lessons are theoretical and contain a number of graphical, text, audio and interactive 3D info presented in immersive space,
- exercises are sets of practical tasks – they require certain actions in a specified time (such as: drive from place A to B or bring object from one place to another and use it properly) in order to be passed,
- each course has a set of questions, the exam mode is in-built and also performed in the immersive space (Gorski 2017).
- The contents of lessons have the following form:
- text – descriptions of problems, especially regarding information difficult to present in a visual form (names of standards, formulas etc.), as well as instructions,

- audio – complementary to the text content, read by a lector and launched by interaction with a character of virtual teacher, who is always present in the virtual space,
- 2D graphics – pictures, schemes, diagrams, infographics illustrating blocks,
- 3D content – interactive models of objects (machines and devices, elements of work environment etc.), along with animations, illustrating a current block.

The most important constant elements of the lesson scene are:

- virtual teacher – an animated character helping the user, replacing a living teacher,
- flipchart – space in the center of the scene, where 2D content is displayed,
- environment – e.g. a hall – 3D background space, that the user can navigate.

Figure 1 presents a screen from the ready application, showing the most important elements of a lesson.

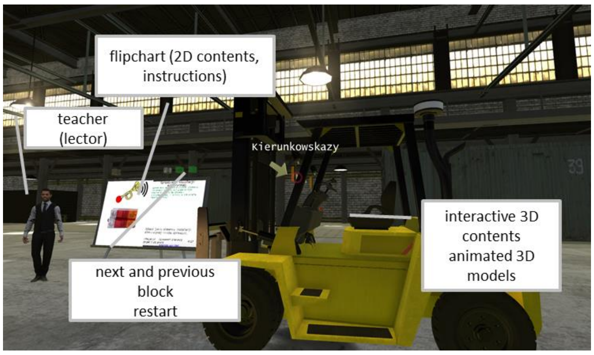

Figure 1: Basic lesson elements in virtual environment

The user can move freely using three means: on own legs (only short distances, due to HMD cable length and workspace limitation), by use of joystick and by use of teleporting points, located in the environment. Interaction in the application is performed by two mechanisms:

- gaze & click – this mechanism is used prevalently in the application, to select lessons, exercises, switch between content blocks, interact with 3D models etc.; a joystick or one-handed pilot is used for that purpose; firstly, user looks at an object, it is highlighted and label is sometimes presented, then a button can be clicked to activate the object,
- drive – for that purpose, driving wheel is used or a regular joystick – controls are assigned to specific elements of a vehicle (steering wheel, acceleration, brake, hand brake, klaxon etc.), user enters the vehicle by gaze & click mechanism, is seated and can only look around (not walk), until he leaves the vehicle.

The application is thought of as a platform, meaning that it can be complemented with other courses. The current version contains only one course (forklift) but other courses are planned (welding, gantry crane operation etc.).

2.2. Software and hardware

The prototype system was created using the Unity 3D software, version 5.6. The authors used a test stand equipped in a VR system, consisting of a computer with Intel Core i7 processor, nVidia GTX 980 graphics card and 12 GB of RAM, as well as Oculus Rift CV1 Head-Mounted Display (HMD), with a gaming driving wheel set and a 50” TV for preview. The application was also proved to be working on a mobile setup, using a gaming laptop MSI GT72 6QE. The whole setup (Fig. 6) was thought as a low-cost one, using solely standard computer equipment readily available even for individual consumers.

2.3. Build methodology

The system was built using a special approach, based on Knowledge Engineering and Design Thinking approaches (Gorski 2017). The main stages of development are presented in Fig. 2.

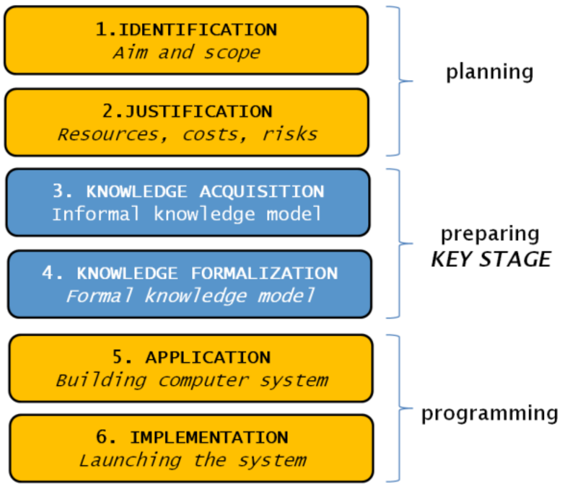

Figure 2: Methodology of building the system (Gorski 2017)

The identification stage consisted in selection of target groups of users (two were selected: instructors and young employees seeking easy learning of skills) and performing deep interviews with their representatives. Then, problems of target groups were defined and a value stream was proposed.

In the justification stage, the knowledge sources were found, human resources were assigned to the project and the whole building and testing process was divided into stages – three prototypes were proposed (Fig. 3). The building team consisted of three persons – one 3D designer and two VR programmers. The risk calculation was also performed, with positive results.

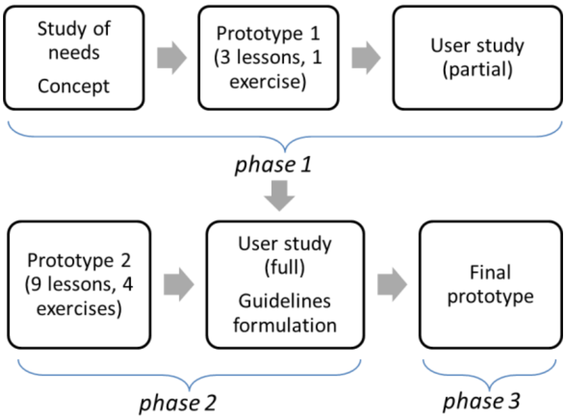

Figure 3: Phases of building the system

The knowledge acquisition and formalization stages allowed the system to gain its unique capability of flexibility. The VST system allows flexibility in content management – it allows easy edition and adding new knowledge, i.e. new courses, lessons etc. with minimal or no programming skills necessary. The access to most knowledge is open and metadata are stored in form of text files of open structure. Exemplary structure of an exercise block is presented in Fig. 4.

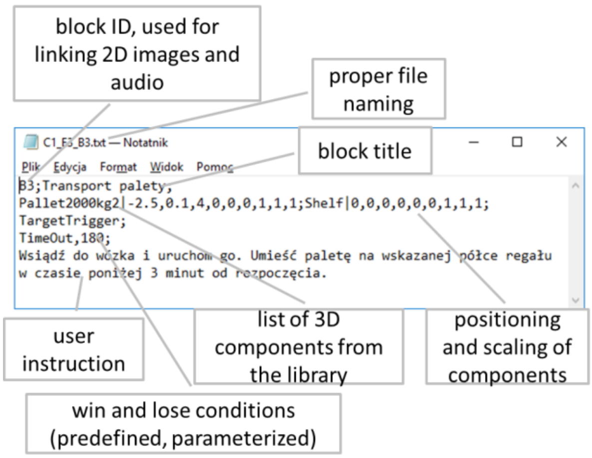

Figure 4: Structure of formalized knowledge

The last two stages consisted in development of subsequent prototypes and testing them with representatives of target groups. For the first two prototypes (phase 1 and 2 in Fig. 3), stages 3 to 5 were repeated. Phase 3 was done after the final testing and did not include knowledge acquisition – it consisted solely in introducing improvements on the basis of guidelines formulated by test users.

The last stage of implementation (launching the system – stage 6 in Fig. 2) is yet to come, potential companies interested in implementation have been selected and the system will be improved from the final prototype and introduced in their daily practice.

2.4. Test methodology

Testing of the system (second prototype – phase 2, described in this paper) involved 20 people from the target group (employees or would-be employees of production companies, seeking new skills), as well as an "expert" group of 5 people (forklift instructors or experienced operators). The test was performed in cooperation with a local company dealing with regular trainings of machine operators. The participants were asked to go through the full course in the system, without time restrictions. Their performance in the test and times of tasks was measured. Then, they were asked to fill two surveys: an evaluation survey with a set of open and closed questions and a simulator sickness questionnaire. The evaluation survey consisted in rating the virtual experience, awarding 1 to 5 points to the following aspects:

1. The HMD comfort of use and adjustment
2. Quality of 3D content
3. Quality and comfort of reading of 2D content
4. Quality and usefulness of audio content
5. Fluency of looking around the virtual scene
6. Fluency and intuitiveness of object interaction
7. Comfort of movement using the pilot (joystick)
8. Comfort of interaction with 3D objects by gaze and click mechanism
9. Animations
10. Realism of presented situations and objects, feeling of immersion

3. RESULTS

3.1. Building results

The finished system contains 9 theoretical lessons (such as: types of forklifts, construction of a forklift, operator duties, safety of work, driving basics etc.) and 4 exercises (preparation for work, easy and advanced driving), as well as a "sandbox" lesson with no goal, but a full hall of objects and obstacles to train advanced maneuvers. The exam mode is in-built and the system also contains a logging mode, with achievement collection. Times of particular exercises and a list of completed lessons are assigned to a given account, created and managed directly in the application.

The whole system was created using the knowledge-oriented methodology, what allowed to do it in a relatively short time. Additionally, an external tool was created for content management (Fig. 5). Table 1 presents a summary of working hours – advantages of open access to knowledge are clearly visible when comparing times of stages 2 & 3 with stages 4 & 5 (twice more content done in three times shorter total time).

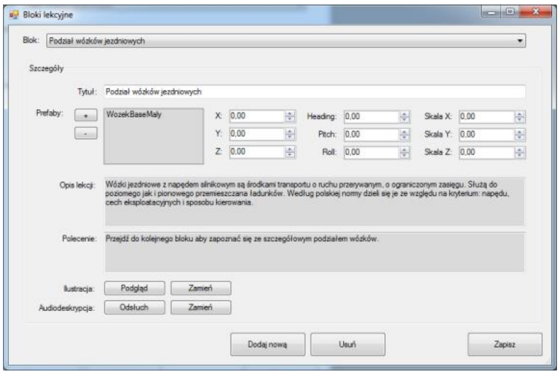

Figure 5: Knowledge management tool

Table 1: Time consumption of system build

Stage	Activity	VR programmer days of work	3D graphic specialist days of work
1	Knowledge acquisition (9 lessons, 4 exercises)	5	20
2	**Knowledge formalization (3 lessons, 1 exercise)**	**10**	3
3	**First prototype implementation**	**60**	2
4	**Knowledge formalization (6 lessons, 3 exercises)**	**15**	3
5	**Second prototype implementation**	**5**	2
6	Final prototype programming	10	-
	Total:	105	30

3.2. Test results

The test results are positive and bring promising results. Most of the participants have finished the whole course, except one case of minor cyber sickness. All the participants passed the final exam, gathering necessary knowledge and skills in under 4 hours (no participant took longer than that). Each participant behaved differently in the virtual system, some doing pauses after 45-50 minutes, some going through 1,5 hours with no break.

A standard forklift operator course, which was the base for building the case in the application, lasts 39 working hours (full week), the yield can be estimated at 90%, which is a very promising value in economic terms. However, the experts' opinion is that there is still a need to supplement the virtual course with a short practical real-life lesson, no longer than 2-3 hours. Therefore, a total yield in the course time can be estimated at approx. 80%, with a realistic course organization of 2 days, 4 hours daily (day 1 – most theory and some practice, day 2 – final theory, virtual and real practice, exam).

Figure 6: Testing the system on stationary (a) and mobile (b) setup

In the evaluation study, the application was rated positively. Average scores of all aspects are above 4.5. Most users were interacting with the VR for the first time. There was no observable difference between the stationary and the mobile setup (Fig. 6a and b), except the workspace size. The most important observations were as following:

- the VR training is far more attractive and compelling than a traditional one,
- interactive 3D models and animations were rated very high, skilled operators observed some mismatches between application and actual physics,
- possibility of safe, no-risk practice was praised,
- experienced operators and instructors were able to perform advanced tasks in the application much faster than its creators each single time, thus proving correctness of the driving simulation (real skills are translated into the virtual world)
- there is a clearly visible learning effect, as each consecutive task in the practical exercise was performed more and more effectively by the participants,
- final exam grades are on average better than grades obtained by students of a traditional, 39-hour course, although the sample is too small to conclude this definitely,
- amount of driving (i.e. practice) is higher in the virtual course – most users took between 1-1,5 hours of pure driving, as opposed to only 1 hour in the real course; however, performance of virtual course trainees was not verified on a real vehicle (it is planned in future studies).

4. CONCLUSIONS

The tests have confirmed high effectiveness and attractive form of VR in learning hard, technical skills. Advantage of virtual training over a traditional one has been proved, for a specific skill presented in the paper. From the viewpoint of an industrial company management, implementation is worthy of consideration, also in economical aspect (low-cost, consumer devices used, much shorter time of course). There is still much to do in terms of content polishing, as some theoretical contents may still be presented in a better, more compelling way. Practical aspect also needs to be improved, especially in terms of virtual world physics.

The proposed methodology of creating flexible, open VR applications has been proved to be very useful in practice, resulting in efficient implementation of most of the virtual training contents, as well as possibility to add more contents (courses and lessons) at a later stage. However, the knowledge formalization and openness is not full yet, as the animated 3D contents still need to be created in Unity and are stored internally (can be only assigned in the knowledge management tool, not added, edited or removed). The authors have prepared a set of predefined object behaviors, so this task is easy to do and does not require script writing. Still, in order to add more contents besides 2D, audio and logic, Unity engine and access to source code is required. Future versions will include full formalization, proved possible in other systems, such as in (Gorski et al 2015).

The users frequently raised a question about a mobile (cellphone based) version of the system. This has been tested extensively in a separate study, with discouraging results – severe reduction of graphics quality and complexity would be required to obtain fluent performance on even the most powerful smartphones equipped with mobile VR glasses. Besides, mobile VR was found to cause much more cases of cyber sickness than the stationary, Oculus Rift based version. As such, it has been dropped from further development, until computing power of smartphones increase to allow fluent operation.

Future work will focus on improving technical aspects of the solution and preparation for industrial implementation in daily use in selected companies.

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VIRTUAL QUALITY TOOLBOX – LEARNING OF QUALITY MANAGEMENT IN IMMERSIVE ENVIRONMENT

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ABSTRACT
The paper presents development and test procedure of a Virtual Reality system for training of soft skills necessary in a production company. The prototype system allows learning of seven basic quality management tools in immersive environment, which is a revolutionary, experimental advancement from the traditional teaching methods. Basic ideas, concepts of a virtual course and its test procedure is presented, along with obtained results.

Keywords: virtual reality, industrial training, quality management, learning

1. INTRODUCTION

In a modern production company, appropriate strategy of quality management is a key factor to competitive advantage. The Total Quality Management is a widely known approach (Carnerud 2018) of viewing processes in the whole company from the viewpoint of quality. The quality management in practice is realized by a set of tools, for obtaining and processing data and information from various processes (Tague 2005). There are many such tools, which are usually a set of "common sense" ways of conduct, often aided by a mathematical (statistical) apparatus.

The quality management tools are naturally used by quality staff (engineers), but they are not easy to acquire by the shop floor workers, especially in smaller companies, although practice shows that they would benefit from their use. The authors decided to take a closer look on the problem of ineffective methods of training of these tools, aiming to use the immersive Virtual Reality technology for learning of selected tools and methods in quality management.

As VR is concerned, its application in education and trainings is very popular - in engineering (Grajewski et al. 2015, Żywicki et al. 2018), school education (Martín-Gutiérrez et al. 2017) or medical training (Gorski et al. 2017). In industry, VR is also used for training purposes (Blümel et al. 2009, Gorecky et al. 2017) or for aiding decision-making processes (Colombo et al. 2014), also often in product design (Jezernik and Hren 2003, Gorski 2017). Blümel and coauthors pointed out advantages of using VR training in their review work (Blümel et al. 2009).

The aim of the work was to prove that VR can be used for learning of soft skills – basic methods of quality management – by shop floor workers of industrial production companies, usually not familiar with advanced systems, such as professional VR used in engineering. As such, the presented system is considered as a social innovation. The paper presents the basic concept and testing results.

2. MATERIALS AND METHODS

2.1. Concept and research overview

The Virtual Quality Toolbox is a VR solution that allows employees of small and micro production companies to easily gain knowledge about application of quality management tools in practice, by use of immersive VR (Starzynska et al. 2018). Each quality tool is represented by a single lesson – a scene in virtual production environment, with a sequence of events and/or tasks for the user. There is also a possibility of getting a recommended tool for a set of defined criteria (for advanced users, for example quality engineers), as well as possibility of testing trainee's knowledge. The system therefore consists of the following modules (selected from the immersive menu):

- the lesson scene for a selected tool,
- the virtual advisor for selection of a proper tool,
- the exam scene (similar to the VST system).

The system prototype contains 7 quality tools (of several dozen existing), namely:

- Pareto diagram,
- Shewhart control chart,
- histogram,
- fishbone (Ishikawa) diagram,
- affinity diagram,
- why?-why? diagram,
- force field analysis.

The contents of lessons have the following form:

- text – descriptions of problems, especially regarding information difficult to present in a visual form, as well as instructions,

- audio – usually a basic form of knowledge, read by a lector and launched by interaction with a character of virtual production master, always present in the virtual space,
- 2D graphics – pictures, schemes, diagrams, infographics illustrating blocks,
- 3D content – interactive models of objects (machines and devices, elements of work environment etc.), along with animations, accompanying a current block.

The most important constant elements of the lessons are:

- virtual production master – an animated character helping the user and giving him orders, replacing a living teacher,
- flipchart – space in the center of the scene, where 2D content is displayed, with instructions for the user,
- environment – e.g. a hall – 3D background space, that the user can navigate,

The lessons are of two general types. In the first type, the knowledge is gained by a trainee by performing a series of practical tasks, such as bringing a certain object or performing a set of actions with it (e.g. measuring, sorting objects, calling other virtual workers etc.). These lessons employ a "learning by doing" paradigm. In the second type of lesson, trainee has a task to observe a sequence of activities performed by virtual employees (animated characters), usually it is a kind of team meeting with various methods employed for various goals. These lessons employ a "learning by observing" paradigm. In both types of lessons, some parts are randomly generated. For example, measurements of products are randomly selected, meaning that in the Shewhart control chart, the obtained diagram will always be slightly different. In the affinity diagram, employees' ideas are randomly drawn from a general pool and their later votes on the best idea are random. That makes it more compelling to repeat the lessons.

The environment contains interactive elements necessary for realization of a given lesson scenario. The most frequently used elements are:

- a virtual production line – a machine realizing an abstract (metaphorical) production process, transforming raw material (cubes) into finished products (spheres),
- animated characters – virtual employees,
- the meeting room, with a white boards, a round table, post-its etc.,
- the "quality corner" – a place in the production hall, where production master usually resides, with a desk, a board, a display and other objects,

Learning of a tool selected from the menu requires trainees to go through a sequence of tasks / events. The simplest task, performed always in the beginning and in the closing of a lesson is listening to an audio instruction from the master. The other practical tasks have been mentioned above, some universal tasks (regardless of lesson type) may also include paying attention to a scheme, diagram or other set of visual knowledge displays, one-click interaction with a machine or a product etc. Performing a given task makes a "next task" 3D button to appear, allowing trainee to proceed with the lesson. When all the tasks are done, the lesson is over and the user is free to go back the menu. The lesson can be started over anytime and the time spent in a single lesson is neither limited, not recorded. However, users log in to the system and their advancement is saved after each lesson is finished. Figure 1 presents the most important elements of a lesson scene.

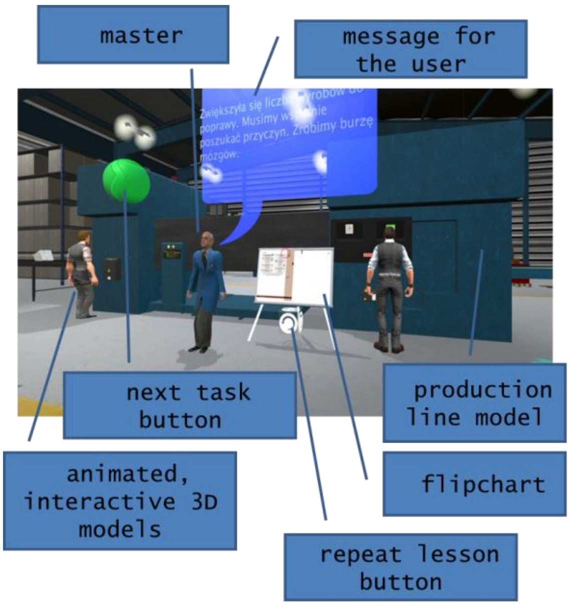

Figure 1: Basic elements of virtual learning environment

The user can move freely using three means: on own legs (only short distances, due to HMD cable length and workspace limitation), by use of joystick and by use of teleporting points, located in the environment. Interaction in the application is performed by "gaze & click" – this mechanism is used to select lessons, go to next task, interact with 3D models etc. A joystick or a one-handed pilot is used for that purpose; firstly, user looks at an object, it is highlighted and label is sometimes presented, then a button can be clicked to activate the object.

2.2. Software and hardware

The prototype system, named Virtual Quality Toolbox, was created using the Unity 3D software. The authors used a test stand equipped in a VR system, consisting of a computer with Intel Core i7 processor, nVidia GTX 980 graphics card and 12 GB of RAM, as well as Oculus Rift CV1 Head-Mounted Display (HMD), with a 50" TV for preview. The application was also proved to be working on a mobile setup, using a gaming laptop MSI GT72 6QE. The whole setup (Fig. 4) was thought as a low-cost one, using solely standard computer equipment readily available even for individual consumers.

2.3. Quality management tools

In modern production companies, a common approach is to involve all the employees to care about quality of products – that is a part of Total Quality Management, known since 70s of XXth century (Carnerud 2018). However, while delegating privileges and inviting employees to get involved in „quality issues", management staff not always remembers that the shop floor workers may be helpless when a decision has to be made. Often they are not sure if their decision is right, or if it data supported to justify it are accurate. On the other hand, they often see necessity of making decisions on the basis of data and hard facts, not only on personal experience and intuition.

In the quality management, obtaining and processing data and information from various processes is done by the quality management tools (Asaka and Ozeki 1998, Tague 2005). Their application allows supporting the decision-makers with information, necessary for the decision-making in field of solving the quality problems, as well as introducing corrective and preventive and improving measures in the production processes. Examples of these tools are Pareto diagram, Shewhart control chart or Ishikawa diagram (Starzyńska and Hamrol 2013).

For the Virtual Quality Toolbox system, seven tools were created, including the very basic ones (Pareto, control chart, Ishikawa), as well as the modern ones (Force Field Analysis). The statistical tools were selected to be presented in a more practical way, allowing users to perform measuring, sorting and comparing, as well as interactively creating diagrams. The other tools, which usually require meeting of a team, were created in a way that requires user only to observe what is going on and proceed to subsequent stages after he is acquainted with all the knowledge at a present stage. Figure 2 presents an overview of tools included in the system.

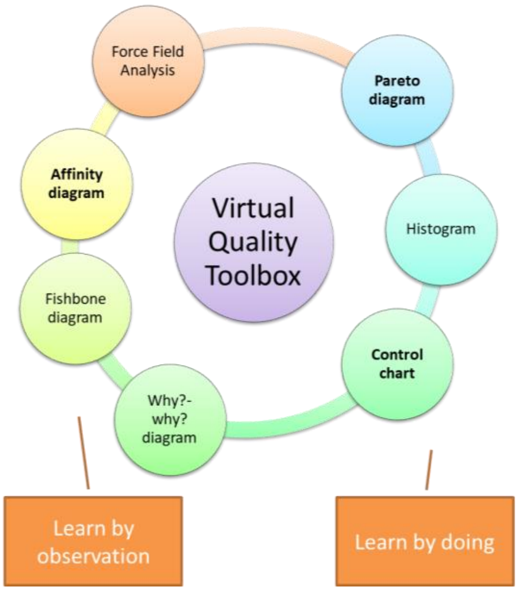

Figure 2: Tools selected for the application

2.4. Build methodology

The system was built using an approach based on Design Thinking methods. Firstly, groups of potential users were selected (4 groups, later reduced to 2: production workers and quality management staff). Their representatives were invited for interviews, basing on which basic functions of the system were proposed – personas were constructed, needs were specified and concepts of values were proposed.

After studying needs of users and formulating a concept, three prototypes were created in an iterative manner (Fig. 3). The whole system was created by a team of three persons (2 programmers, 1 graphics designer), with aid of 2 quality management experts. Before programming, scenarios of interaction in all the lessons were written down and all the 3D models and animations were created and imported into the Unity engine.

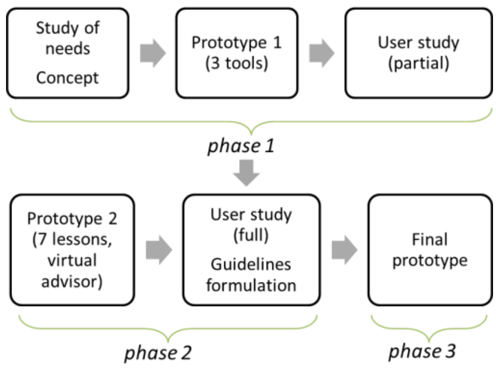

Figure 3: Phases of building the system

The first prototype contained only approximately 40% content (3 lessons and menu), the second prototype containing full contents assumed for the basic version of a ready system (7 tools, menu, virtual advisor and exam mode). First and second prototypes were tested with representatives of user groups – this paper presents results of testing of the second prototype. After the tests, guidelines for improvement were formulated and the final prototype was created, with no significant increase of contents, but rather improvement of user experience, elimination of errors, improving clarity and quality of presentation.

2.5. Test methodology

Testing of the system involved 20 people from the main target group (employees or would-be employees of production companies), as well as an "expert" group of 5 people (quality management experts – representatives of the second group). The test was performed in cooperation with local production companies – their employees were delegated for the tests, which were performed in the laboratory conditions, on a stationary (Fig. 4) or mobile (laptop-based) VR setup. The participants were asked to go through the full course in the system, without time restrictions. Then, they were asked to fill two surveys: an evaluation survey with a set of open and closed questions and a simulator sickness questionnaire. Their performance in the final knowledge test was also measured.

Figure 4: Testing of the application, stationary setup

3. RESULTS

3.1. Building results

As planned, the finished system contains 7 lessons for quality tools. The lessons are selected from immersive menu (Fig. 5a). Three lessons are done with the "learn by doing" paradigm and are performed in the virtual production hall (Fig. 5b), while the other four employ the "learn by observing" paradigm and are performed mostly in the virtual meeting room (Fig. 5c).

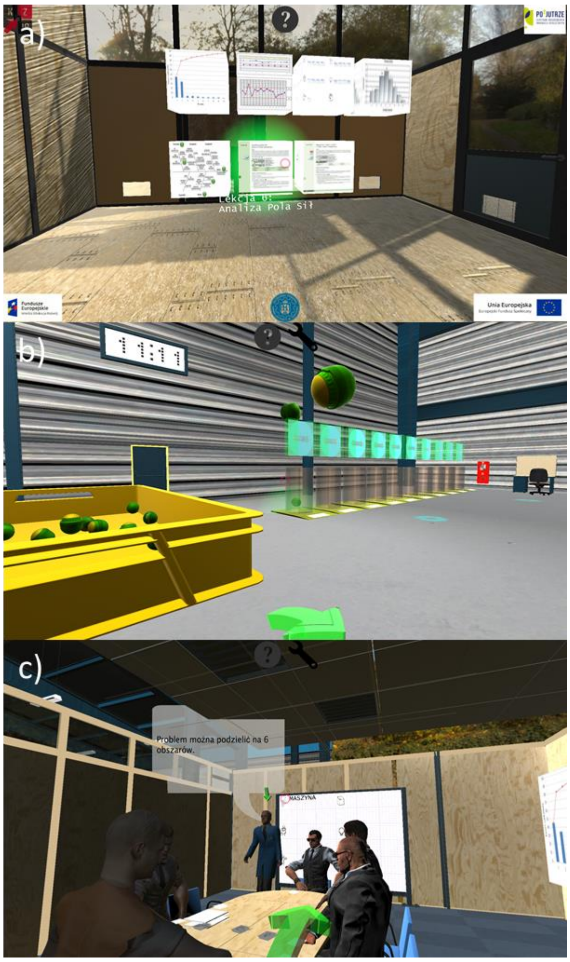

Figure 5: The lessons in final prototype: a) menu for selection of 7 tools, b) "learning by doing", c) "learning by observing"

The system also contains the exam mode and a virtual advisor – on the basis of introduced partial criteria (aim of use, qualitative or quantitative results, difficulty of use etc.), a recommendation is prepared. This functionality (Fig. 6) still works only as a demonstration mode, as the basic library of 7 tools is too small to bring any valuable results. This will be developed to a greater extent at the implementation stage, when introducing the system in particular production companies.

Figure 6: Virtual advisor

3.2. Test results

The test results are positive and bring promising results. All the participants have finished the whole course, despite some cases of minor cyber sickness. Most of the participants (90%) passed the final exam. The time spent in the system for all the seven lessons was various, between 1 and 3 hours in total for different users. Shortening of time in comparison with a standard course is approximately 50%, as a standard course assumes, on average, one tool per one lesson hour (45 minutes), while in the application, single tool can be learned in approximately 20 minutes, depending on the tool. The less extensive lessons (such as the "why-why?" diagram) can be learned in 10 minutes, while more advanced sequences (as the Shewhart control chart) last longer, up to 30 minutes, depending on the user. Most users took pauses after each consecutive lesson, some did 2 with no break.

The experts pointed out high usefulness of the Virtual Quality Toolbox as a method of training and communication with shop floor workers.

The most important observations were as following:

- the VR training is far more attractive and compelling than a traditional one, based on lectures, slides and written exercises,
- the production workers praised increased concentration in VR and feeling of being "surrounded by knowledge",
- interactive 3D content was rated high in both "learn by doing" and "learn by observing" lesson types,
- possibility of learning soft skills by simply observing virtual characters was also rated quite high,
- although the interaction is based by a simple "gaze and click" mechanism, for some users it was difficult to pass through some tasks, especially related to repeated object use (e.g. changing a tool in the machine); in the final prototype, a simple tutorial of moving and interacting in VR was introduced,
- some contents have to be polished, both by means of better graphics and improved intuitiveness and clarity,
- general application evaluation was positive, all production workers agreed that they would gladly participate in such a training at least once or more per week, if given opportunity.

4. CONCLUSIONS

The tests have confirmed attractive form of VR in learning soft skills. Advantage of virtual training over a traditional one has been proved, although some participants were skeptical towards daily use of such a system in its present form. From the viewpoint of an industrial company management, implementation is worthy of consideration to replace traditional training, although contents and methods of interaction must be improved. The main disadvantage of the Virtual Quality Toolbox is the VR user interface and ways of interaction. It was programmed to be as easy as possible, but some participants found even simple tasks of moving around difficult, let alone more complex challenges of measuring, sorting etc. The main challenge in creating the VR systems for education of usually unwilling adults (in this case – production workers) is to maintain tasks easy but not too trivial, while ensuring a proper level of presented knowledge. That is why in the final prototype, some improvements towards better intuitiveness have been introduced, such as the VR interaction tutorial (very basics covered), or an automated guidance arrow that shows users where to go next.

The future work will focus on improving technical aspects of the solution and preparation for industrial implementation in daily use in selected companies. The production companies require such a solution to be tailored to their needs, so library of tools will have to be prepared according to specifically formulated requirements. More efficient ways of quick content creation will be then sought and evaluated.

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VIRTUAL REALITY APPLICATION FOR PRESURGICAL SUPPORT IN UROLOGY

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ABSTRACT

The paper presents results of tests on applying Virtual Reality in presurgical planning in procedure of partial nephrectomy (removing a tumor while leaving the rest of the kidney). The aim of studies was acquainted surgeon to the virtual anatomical model of patient's kidney with a tumor and also familiarized doctors with relation between parts of the organ (blood vessels, body of kidney (kidney cortex) and tumor). For better support, application included manual adjustment of transparency and option of separation selected part. Surgeon could scope the organ out, look inside of kidney and estimate chances for partial nephrectomy, plan the procedure and learn about patient's individual anatomy of the organ. The main issue in this studies is presurgicaly support which until now based on medical imaging and diagnostics. Virtual Reality and Augumented Reality created a completely new view at preparing before operations.

Keywords: biomedical engineering, presurgical support, VR in medicine

1. INTRODUCTION

Progressive development of Virtual Reality (VR) and Virtual Prototyping have a significant influence not only in the industry or military, but also in the medicine (Górski et al. 2017). Thanks to effect of immersion, which is a feeling of being present inside an artificial environment, despite physical presence in the real world (Bowman 2007), VR is effective in creating situations that would be difficult, risky or costly to reproduce in physical reality, in order to gain educational, therapeutic or other effect. VR can be used both for patients and doctors, in various applications. For the patients, one of the most popular usages is phobia treatment supported by Virtual Reality application (also known as VRET – Virtual Reality Exposure Therapy (Bun et al. 2017)). Phobias like arachnophobia, aerophobia, acrophobia can be treated by exposing patient on the thing causing anxiety (Garcia-Palacios et al, 2002). Virtual Reality applications for therapy step by step tame patients with presence of fear inducing triggers, teach them how to function in reality and help changing their thinking. Thanks to that, patients feel safer and there is a chance for faster recovery (Botella et al., 1998).

VR found use also in education and surgeon's support. A VR environment can be used for learning knowledge and skills. The positive educational effect of VR has been observed and reported in literature as early as in the 90's (Bell & Foegler 1995) and proven in further studies (Getchell et al. 2010). There are many possibilities of use of VR in medical education, from simple virtual anatomical atlases (Hamrol et al. 2015), to more complex applications for simulation of surgical procedures (Vankipuram et al. 2014). For realistic simulation, haptic devices with force simulation are frequently used, they allow trainees to develop required abilities before first contact with a real patient (Escobar-Castillejos et al. 2016). Low-cost VR devices can also be used effectively in medical education (Glatter 2015). Presurgical preparation is a very important aspect in urology, as well as in cardiology or neurology. Human anatomy is not always the same, subtle differences can change course of surgical procedures. Furthermore, pathological changes are in many specific places in organs, that is why it requires planning before operation, especially in complex cases.

Basing on knowledge from medical imaging, today's standard procedure is planning operation using only 2D pictures from MRI or CT. Thanks to segmentation of CT/MRI scans, engineers can create a 3D virtual model. There are numerous examples of this approach in literature. For instance, a group of Canadian scientists devised virtual model of kidney with cancer, which could be manipulated in an application for a laptop computer. It created a possibility for using it in an operating room during surgery. This application has also an option to perform a simulated operation of partial nephrectomy. Both models enable doctors collect information about relation between pathological parts and the rest of the kidney. The application decreased probability of unexpected injury during operation (Martinez et al., 2009). Precise visualization of structures inside a human body in VR could help surgeons calculate the potential risk even in this phase of planning. University Hospital UZ Leuven tried implementing application like this in cardiology, urology and radiology. During trainings, doctors must assess type of treatment and procedures on the basis of virtual models (Fig. 1). Applying this type of application in hospitals and universities can contribute to increasing quality of education, for students as well as for residents. Extended presurgical planning can also increase patient's safety (De Buck et al., online). For presurgical planning, 3D printing technologies are often used (Zukowska et al. 2018).

Figure 1: A surgeon during training (left) and presented simulation (right); (De Buck et al., online).

2. MATERIALS AND METHODS

2.1. Case and problem definition

One of primary methods of treatment oncologic modifications in kidneys is nephrectomy – surgical removal of a kidney. Depending on the size of the tumor, type of cancer and localization of modification, procedure of partial nephrectomy is possible (Stajno, 2013). Known also as the kidney-sparing surgery, it is a delicate procedure of removing tumor and leaving rest of the kidney intact. The operation can be performed in open or as laparoscopic (also robotic-assisted) and it requires surgeons to be well trained. Every surgery like this needs individual approach, because not all partial nephrectomy procedures are the same. That is why presurgerical planning and preparation is so important and why Virtual Reality applications could be useful in supporting surgeons' work. (hopkinsmedicine.org, online).

The presented case of a patient with a kidney with tumor was part of a wider studies, where both virtual and real, physical models were developed, tested and compared, in terms of usefulness in surgeon's work. The physical model was built for simulated surgery and low-cost 3D printing was used for it.

The patient's case pertain to abnormal growth of tissue at the top of the left kidney, which formed into a tumor. The tumor was 5,5 cm diameter and it qualified for partial nephrectomy.

The aim of studies was to develop a methodology and create a customized anatomical model of a kidney with tumor, using virtual prototyping techniques. The model with additional options was compared to the 3D printed model and tested by a surgeon, who later expressed opinion about its usefulness and future development possibilities. Furthermore, the VR application helped to define cases in which it can be an important element of presurgical support.

2.2. Methodology

Methodology of creating this types of application is twofold. The first part is creating a model based on individual human anatomy, with the use of special programs for segmentation and generation of a 3D mesh from medical imaging. As a result, a digital 3D model of patient's specific organ with its pathological modification and other elements (depends on early arrangements between doctors and engineers) is received. The second part is importing the model into a virtual environment and then programming relationships and interactions between the model and the user. The whole process is presented in Figure 2

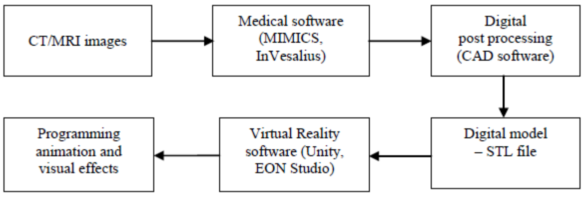

Figure 2: Methodology of prototyping virtual reality application of anatomical model; (based on: K. Gonera et al., 2010, Gorski et al. 2017)

Images from the Computed Tomography are in an international format – DICOM *(Digital Imaging and Communications in Medicine)*. Process of model design starts with scans of patient's body (for example an abdomen). Images are imported to medical software that enables segmentation, like InVesalius or MIMICS. Segmentation is a procedure of dividing a digital image into segments (sets of pixels). In case of medical objects, the most popular type of segmentation is thresholding – method based on selecting pixels in the same level of gray-scale and turn it into a binary image. The procedure consists in superimposing "masks" layer by layer and creating a 3D digital model of organ and other elements, based on the 2D masks. All the parts are saved as an STL (mesh) file. The files are then imported to a CAD software for digital post processing – removing compression artifacts and improving model quality (K. Gonera et al., 2010). Prepared digital model is imported to a software for creating Virtual Reality applications, like Unity 3D or EON Studio. It is the step where relations between objects, as well as visual effects are programmed. Culmination of whole process is performing the tests and evaluate the application by a surgeon. When creating advanced medical applications, like surgical simulators, consultations between application developer and a medical doctor are necessary during the whole process of development (Gorski et al. 2017).

3. PROGRAMMING WORK AND TESTS

3.1. Images segmentation and digital post processing

Segmentation was performed in a free medical software – InVesalius. Imported CT scans were divided in groups of photos, depending on type of scanning process and layer thickness (Fig. 3). After the analysis, images without contrast and with 1.25 mm thick layer were chosen. Small layer thickness enables performing segmentation not only for the kidney's body (renal cortex) and tumor, but also for the main veins and arteries.

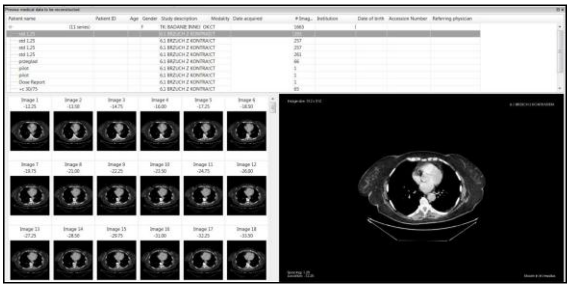

Figure 3: Library of folders with different type of images

After level of grey-scale was set for kidneys, tresholding and brush options were used to mark voxels of kidney's tissues layer by layer. The process was performed manually, because of lack of option of automatic segmentation. All the elements of the model have other levels in grey-scale which is a feature of computed tomography. That is why the whole process was repeated 4 times, for every tissue separately: renal cortex, tumor, veins and arteries. After transforming into 3D models (Fig. 4), the structures were imported to a CAD software – GOM Inspect 2016 and fixed/smoothed.

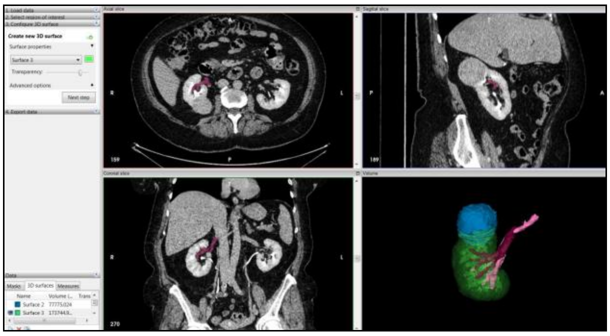

Figure 3: View at CT images and prepared 3D Model

3.2. Programming VR application

The VR application development was performed in the EON Studio 8 – software for object-oriented programming. The process was as following:

- Importing elements to EON Studio 8 (renal cortex, tumor, veins, arteries);
- Applying navigation and its parameterization (moving in application);
- Applying lights and its parameterization;
- Adding textures;
- Visual finishing;
- Adding animation of putting in structures and taking them out with the use of a mouse button;
- Adding manager transparency of kidney's body (renal cortex).

During the process of segmentation, all the elements keep their original zero point in a fixed coordinate system (the same for each part). Thanks to that, geometrical relation between the elements was exactly the same as in the human body, despite separate 3D mesh generation and processing.

In the beginning, type of navigation was selected – object rotating, zooming and zooming out was introduced. It is associated also with applying lights and its parameterization, because correct analysis of relation between a tumor and rest of the kidney depends on it. Lights should show clearly every structure and its placement. To improve visual realism, textures were added (Fig. 5).

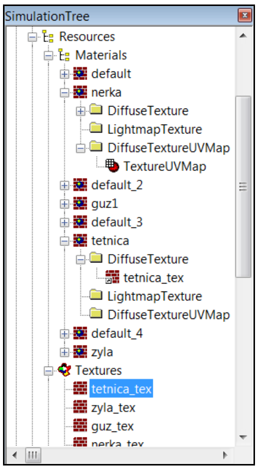

Figure 5: Simulation Tree with added textures

The most important function of application, besides virtual inspection, are animations of objects. For better recognition of relations in the model, two options were created: adjustment of renal cortex transparency to analyze position of tumor in relation to blood vessels and an animation of removing-putting back every structures, also for better understanding of their mutual relation.

Used software helped in easy creation of relations between sensors like mouse buttons, keys and textures and objects, earlier added to the simulation, thanks to use of rapid visual programming techniques (Fig. 6).

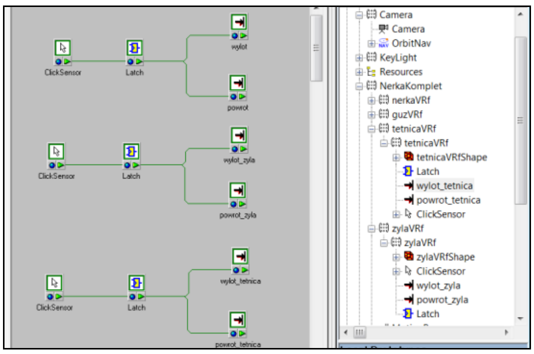

Figure 6: Programming relationship between parts of kidney and mouse button

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Application include simple animation which help surgeon in planning before operation. The finished model was presented to the cooperating surgeon (Fig. 7,8). At this moment of application development, no immersive equipment (such as goggles) was used, although the application fully supports that possibility, which will be considered in future work.

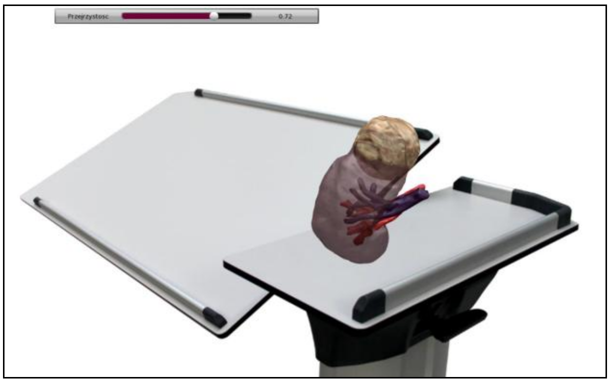

Figure 7: View at finished model and transparency option in use

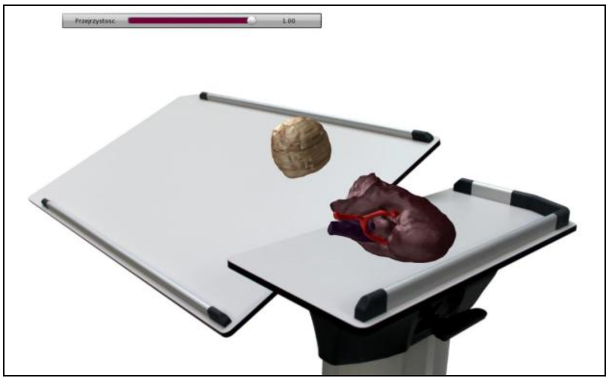

Figure 8: View at finished model during animation

3.3. Tests

The application was part of comparison between Virtual Reality and 3D Printing in preoperative support and planning. The virtual model was presented to the doctor in the programmed application. After a short instruction (how to navigate and explaining options), the surgeon was able to analyze the kidney and its modification, as well as relations between structures: inside and outside. Different levels of transparency during rotation of the kidney were also checked.

After tests on a virtual and a physical model, an interview was made with the doctor. He indicated that a virtual model is a type of preoperative planning which he prefers over a physical model, even without immersive or haptic capabilities.

4. DISSCUSSION

After interview with the surgeon, it can be clearly stated that Virtual Reality applications are helpful in preoperative planning, especially in cases which need special, individual planning before operation. Combination of image segmentation and virtual application programming give a chance to make a functionally and personalized product for preoperative support. Even very simple applications are useful to doctors, who usually do not have such possibilities in their daily work and can only rely on biomedical engineers to develop such applications for them. During the test, it was pointed out, that application like this helped to familiarize with case, modifications and relations in organ and extended previous way of planning. Due to easy type of programming and simple animation, the whole process of creating application was short and fast for the biomedical engineer, what is very important in medicine (usually surgeries are performed shortly after medical imaging, if need arises). At this point, VR is better than 3D printed model, also presented to surgeon – it is cheaper, faster and does contribute to better planning. However, the current version does not allow performing simulated operation, which is possible in a physical model. Full immersion is also not possible.

Next stages of development of this type of application will consist in adding more structures in organs and new types of interactions – for example animations that will enable perform simulative operation. This will require introducing support for haptic manipulators and head-mounted displays. Moreover, possibility of loading data of different patients would be required, as well as automated generation of 3D mesh on the basis of CT scans. More studies on that matter are ongoing and will be continued with full cooperation with surgeons.

5. CONCLUSION

Virtual Reality is an important part of progressive development in medicine. It creates a new way of thinking about preoperative planning and also education of students and residents. Positive feedback from surgeons provide hope that this particular application of VR will help and increase the safety of patients and efficiency of their treatment.

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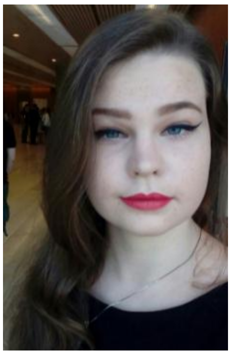

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DISCUSSING THE APPLICATION POTENTIALS OF MICROSOFT HOLOLENS™ IN PRODUCTION AND LOGISTICS: A LITERATURE REVIEW AND CASE STUDY

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ABSTRACT

The Microsoft HoloLens™ is an augmented reality (AR) head-mounted display (HMD) with the capability to enrich the user's perceived environment with virtual information. The HoloLens is considered as state-of-the-art device and provides some new features, which enhance the AR experience. The first part of this paper presents the current state of research concerning the application of Microsoft HoloLens in the field of production and logistics. In the second part, we present a small HoloLens application, which we have developed to evaluate the capabilities of the device. In addition, we asked several visitors of the Open House at our university to test our application and to give us feedback. An evaluation of the user experiences and future research challenges are provided at the end of the paper.

Keywords: Microsoft HoloLens, Augmented Reality, Mixed Reality, Production, Logistics, Manufacturing

1. INTRODUCTION

With the release of Microsoft HoloLens™ (hereafter just referred to as HoloLens) in 2016, a broader part of the research community and industry received access to a new generation of Augmented Reality technology. Azuma (1997) defines Augmented Reality (AR) as the supplementation of reality with virtual objects, which either superimpose or composite with the real environment. Simply described, AR technologies are able to project virtual information to the user's perceived real-world environment. The HoloLens, however, offers some additional features. According to (Taylor 2016), Microsoft describes the HoloLens as a stand-alone, fully untethered, holographic computer. In this context, the attributes "stand-alone" and "untethered" indicates that the execution of a HoloLens application does not require an additional connection to an external computer or other device, which is a big difference to modern VR glasses. The term "holographic" addresses the capability of the HoloLens to generate virtual 3D objects in the user's environment, which the user can inspect from any view angle. In addition to other AR devices, the user is even able to interact with the virtual objects and vice versa. Particularly because of this feature, Microsoft does not classify the HoloLens as AR device. Instead, the company claims that the HoloLens presents the first Mixed Reality (MR) device on the market (Microsoft 2018). However, Microsoft's classification of the HoloLens as well as their definition of "Mixed Reality" (MR) have to be critically assessed, since most researchers rely for the term "Mixed Reality" (MR) on the definition of (Milgram et al 1994). The authors consider MR as a reality-virtuality continuum, which encloses a large number of augmented reality and augmented virtuality displays. Regardless of this discussion, the HoloLens is an innovative and interesting device, which may offers some interesting opportunities for applications in the field of production and logistics. Especially for the training or support of operational tasks on shopfloor level, the possibility to use the HoloLens independently from any other external device provides a lot of potential for new applications.

In this paper, we want to give an overview about research concerning the application of the HoloLens in the field of production and logistics. In addition, we present a HoloLens application settled in the field of production and logistics, which we have developed to evaluate the technical capabilities of the device. Based on our application, we want to discuss the benefits and still existing drawbacks of the HoloLens. Furthermore, we want to state the future research challenges, which are in our opinion most significant to improve the users experience with MR.

2. LITERATURE REVIEW

In order to get an idea about the current state of research on HoloLens applications for production and logistics, we conducted a systematic literature search. Before presenting our findings, we briefly summarize our methodology.

We searched in four online libraries for publications:

- Springer Link
- ScienceDirect
- ACM Digital Library
- IEEE Xplore Digital Library

Furthermore, we only reviewed publications, which are classified as journal article, conference paper or book chapter. We considered the term "Microsoft HoloLens" as only search string in order to enlarge our search space. A publication was included, if...

- ...it presents an AR application which is designed for HoloLens or was at least already tested with HoloLens
- ...the presented application addresses the field of production, logistics, manufacturing or an area which is closely related to the first three mentioned (for instance quality management)

The definition of exclusion criteria was not necessary, since the number of search results, matching our inclusion criteria, was not large. The following table presents a quantitative view on the search results

Table 1: Quantitative analysis of the literature search results

Database	# Publications	# Included
Springer Link	144	6
ScienceDirect	54	4
ACM DL	50	2
IEEE Xplore DL	40	2
Total	**388**	**14**

During our investigations we noticed that most of the paper describes HoloLens applications addressing the field of medical research. Above all, we found a lot of paper in which the HoloLens was utilized to teach or assist in surgery operations. Furthermore, a great number of papers are dealing with HoloLens applications in the field of civil engineering. Many excluded works even present AR applications related to production and logistics, but do not address the application of HoloLens. In this papers, the HoloLens is, for instance, only mentioned in an accompanying literature review or in the outlook as a future milestone. Overall, only 14 papers fulfilled our inclusion criteria. Figure 1 gives a first impression of the application fields addressed in the included papers. We clustered each HoloLens application according to its field of application and its task to fulfill. The following subsections describe briefly how the HoloLens can be utilized in the identified fields of application.

2.1. HoloLens Applications for Assembly

As the results of figure 1 (a) indicates, assembly belongs to the application areas for which we found the largest number of publications. Three of the assembly applications can be classified as assistant systems. In this scenario, the user receives information about the next assembly step over the HoloLens display. More precisely...

- ...the application generates a digital path between the source of the next component to be assembled and the assembly spot at the main product (Blankemeyer, Wiemann and Raatz 2018) or...
- ...it shows a 3D image of the component at the assembly spot, in the right position (Blattgerste et al. 2017) and provides additionally an animation which indicates the direction of the assembly process (Radwoski and Ingebrand 2017).

The main challenge of both approaches is to ensure that the HoloLens displays the assembly instructions at the correct position. Thus, the application has to consider different assembly states of the product as well as different locations for the component sources and for the workspace. To identify the initial position of the component sources and the product to be assembled, every publication describe the usage marker tracking.

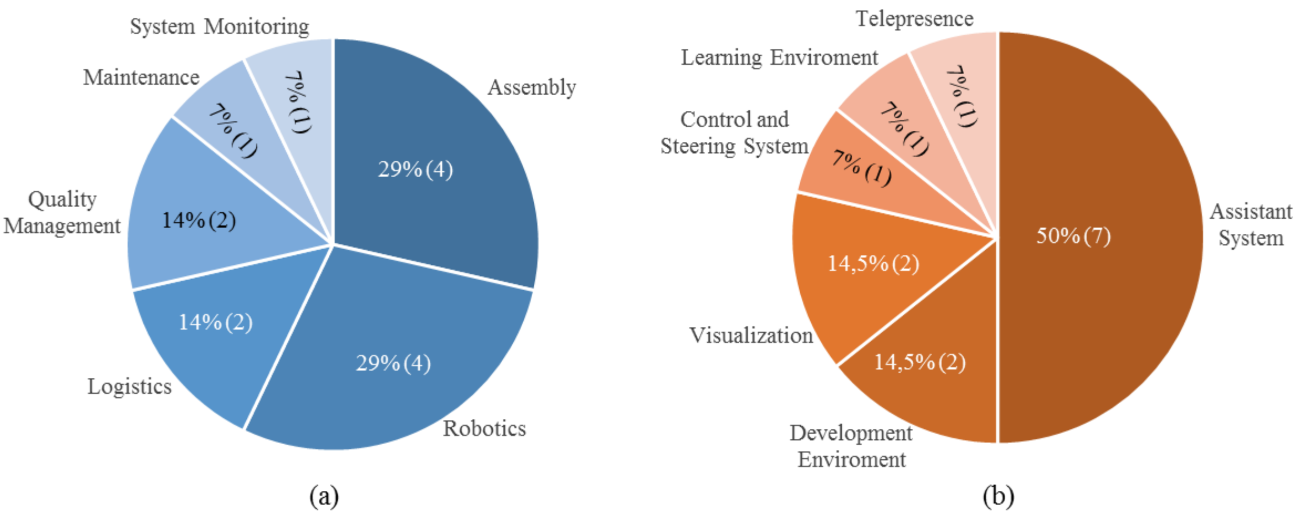

Figure 1: Classification of investigated HoloLens applications according to their (a) field of application and (b) task to fulfill

In addition, (Radwoski and Ingebrand 2017) apply the HoloLens together with a Microsoft Kinect camera to enhance the recognition of location and position changes of the product to be assembled. To consider different assembly states, (Blankemeyer, Wiemann and Raatz 2018) import the CAD models of the assembly components and every intermediate product. As soon as the user completes a step of the assembly process, he needs to give a voice command to receive the assembly instructions for the next step. The authors of the other two publications do not provide detailed information about how they consider different assembly states.

Furthermore, (Radwoski and Ingebrand 2017) and (Blattgerste et al. 2017) evaluates the usability of their applications with a survey. Radwoski and Ingebrand (2017) describe that 32 students have used the HoloLens to complete an assembly task. The feedback from the test persons is generally positive. All users state that the assembly instructions were easy to understand. Furthermore, all users strongly agree that they have enjoyed the experience with the HoloLens. Most of the test persons think that the HoloLens is comfortable to wear. Only a few number of persons have an indifferent or negative attitude regarding the wearing comfort.

Blattgerste et al. (2017) compare the utility and usability of AR based assembly instructions with conventional pictorial presentations. Beside the HoloLens, the authors also test the Epson Moverio BT-200 smart glasses and a smartphone as AR device. However, the authors claim that the AR application performs only sufficient on HoloLens and smartphone. In the consequence, the authors did not utilize the Epson Moverio for their AR application. Instead, the authors consider the Epson Moverio to present the pictorial instructions for the assemblage as alternative to a conventional paper sheet. Overall 24 candidates (16 male, 8 female) participate at the experiment, in which a given assembly task with 32 assembly steps should be completed. The authors evaluates the utility and usability of the assembly support by measuring the task completion time and the number of performed errors. To evaluate the subjective mental workload, the authors additionally measured the NASA Task Load Index (TLX), which considers the mental demand, physical demand, temporal demand, performance, effort, and frustration level of the test person. The results show that the test persons completed the task the fastest, if they used the paper based assembly instructions. However, the test persons achieve the lowest error rate, if they utilize the HoloLens. In terms of the cognitive load, the HoloLens performs significant worse than the paper based assembly support and the Epson Moverio. A reason for this result could be that a lot of test persons complain about the small view area of the HoloLens to project digital information. The smartphone as AR based assembly support receives the lowest utility and usability score. Most of the participants criticize the worse handling of the smartphone which interferes with processing the assembly task.

In accordance with figure 1 (b), we classify the application of (Werrlich, Nitzsche and Notni 2017) as learning environment. In this paper, the authors want to detect the most demanded requirements for AR based assembly training. For this purpose, they implement a simple HoloLens application to give the study participants a first idea about features and capabilities of current AR devices. The application displays predefined work instructions to assemble a product. The user can navigate with gestures through the single assembly steps. The authors present the application to the test persons as a first idea for AR based assembly training. After the presentation, the study participants should rate their level of agreement to 40 statements. Afterwards, the authors interpret the answers of the test persons to identify the requirements. In summary, the assembly staff demand AR based illustration of the complete assembly process. In addition, the device should markup components in the shelf to be assembled. The stuff prefers, if the AR device can be used for training offside the line. In terms of the usability, a lot of participants criticize that the gesture control of the HoloLens is too difficult to use and that the field of view, which represents the virtual information, is too small. Furthermore, the participants think that the HoloLens could be too heavy, when they have to wear the device for several hours.

2.2. HoloLens Applications for Robotics

Besides the field of assembly, the majority of relevant papers describe HoloLens applications in the field of robotics. In terms of their task to fulfill, we classify two of the presented applications as development environments. The first paper of (Rückert, Meiners and Tracht 2018) present an AR environment for HoloLens to program operation sequences for robots, which assist the worker in assembly processes. The HoloLens application is connected to the virtual twin of the robot and the station controller, which is responsible for the monitoring, coordination and processing of interfaces, databases and the operations of both worker and robot. Starting the application, the HoloLens projects an image of the digital twin. By interacting with the 3D object with gestures and voice commands, the user is able to create custom operation sequences. Every interaction with the system is stored in the database of the station controller, in order to quickly and easily apply new created workflows to the real robot. The second paper of (Guhl, Tung and Kruger 2017) describe a nearly similar concept. However, the paper suggests an early state of the research, since some of the described features are considered as future milestones. In the current state, the application supports reading and setting of angle position coordinates and further the visualization and evaluation of existing robot programs.

The third robotics application, presented by (Guhl et al. 2018), can be classified as visualization tool and is probably a side feature of the proposed development framework in the publication described above. In this paper, the authors test a HoloLens and other AR technologies for the visualization of robotic trajectories created by a sampling-based path planning algorithm. Although the utilization of HoloLens is not the core of the paper, the authors mention some interesting benefits when using HoloLens for visualization instead of other devices. First, the HoloLens does not require additional marker to correctly project changes in positioning and rotation of the robot, since the HoloLens utilizes the internal tracking system for this purpose. Second, The HoloLens projects changes of the robots position and rotation without any latency. Third, the user is not forced to carry the AR device with its hands, since the HoloLens is a head-mounted display. Furthermore, first tests indicate that using the HoloLens to adjust the waypoints of the robot trajectory provides a higher spatial accuracy than, for instance, interacting with a tablet screen.

With respect to figure 1 (b), we categorize the fourth identified robotics application, proposed by (Kot, Novák and Babjak 2017) as control and steering system. More precisely, the authors present a digital control panel to steer a mobile robot. The control panel is implemented as HoloLens application. The authors argue that complex steering tasks require an enhanced visual feedback which can be achieved by stereovision camera. In a previous work, the authors implement the control panel as VR application for Occulus Rift to provide a suitable and comfortable presentation of the stereoscopic view. However, the VR implementation had still some drawbacks. First, the operator does not receive any visual feedback from his surrounding environment. Second, the VR goggle require a connection to the graphic card of the PC. Since the processing of a VR scene is computational expensive, a high-end PC with a high performance GPU is necessary. Thus, the connection to a laptop with onboard graphic chip is not sufficient. In addition, the authors state that even a laptop with an additional high performance GPU cannot be utilized, since the processor's onboard graphic chip and the high performance GPU shares the same HDMI interface. When connecting the VR goggle with the laptop, the software is not able to address the GPU to compute the VR scene. Instead, the laptop utilize the onboard graphic chip. Therefore, the VR goggle requires a desktop PC to achieve a sufficient performance. Both drawbacks impede a flexible usage of the control panel. The HoloLens application overcomes the mentioned drawbacks and offers some other benefits, such as the ability to arrange the elements of the panel as the user prefers. Here, walls and other environmental objects can be used to fix the position of the single control panel elements. The main drawback of the HoloLens is its photosensitivity, since too much ambient light interferes with the legibility of the projected information and images.

2.3. HoloLens Applications for Logistics

Two of the papers presents HoloLens applications, which we assign to the field of logistics and to the field of assistant systems. In both publications, the authors consider the HoloLens to support order picking processes. The way of support is comparable to the described assistant systems in the assembly, since the applications display the user the sequence of products to pick and place.

More precisely, the first application proposed by (Hanson, Falkenström and Miettinen 2017) support the preparation of component kits for mixed-model assembly lines. For this purpose, the application displays a virtual path, pointing to the right bin, where the person has to pick components. In addition, the application images the number of components to pick. The application supports the preparation of single kits and kit batches. If one needs to prepare a kit batch, the application markups the right kit container to place the picked component. The authors evaluated the usability and performance of their picking system by an experiment series, in which test persons needed to prepare assembly kits according to a picking list. For comparative purposes, the test persons performed every experiment twice, whereby in the first experiment, the person had to use a standard paper-based picking list. Overall four male and one female person participated at the experiment. Every participant stated to has any experience in picking processes1. For the preparation of kit batches using a HoloLens, the results show that the time for a single picking operation improves in average about more than 12 %. However, when users apply the HoloLens to prepare single kits, the time for a single picking operation increases in average by more than 10 %. Regardless whether a user has prepared single kits or kit batches, the HoloLens application helped in any case to reduce the total number of picking errors. For single kit preparation, the number of errors reduces from seven to one. Looking on the preparation of kit batches, the test persons did in average only five picking errors compared to 11 picking errors, when they used a conventional paper list.

The authors of the second paper evaluate the usability of the HoloLens to support palletization processes. The corresponding application projects the user the sequence of products to pick and place on the pallet. The authors compare the usability with a standard paper-based and a tablet computer based picking list. The usability is measured based on two indicators: The NASA Task Load Index (TLX), which is also utilized by (Blattgerste et al. 2017) and shortly described in section 2.1, and the System Usability Scale (SUS), which rates the general suitability of each picking list representation method. The SUS considers for instance the need for support and training to sufficiently apply the method. Overall 18 test persons participate in the study. The results indicate a low usability of the HoloLens, since the paper list and tablet computer achieved a higher SUS. In terms of the TLX, the process time to complete the whole task and the error rates, the authors cannot identify significant differences. In conclusion, the authors certify the

HoloLens to be suitable for palletizing, but the usability still needs to be improved.

2.4. HoloLens Applications for Quality Management

The two applications settled in the field of quality management are quite different. (Canepa-Talamas, Nassehi and Dhokia 2017) present a research framework for the development of an AR based metrology tool, which allows to perform quality measurements during the assembly of a product. The authors plan to implement the tool for HoloLens and the AR goggle Meta 2. The paper only presents the research methodology and planned milestones, since the research project is still in its infancy. However, the authors give already some insights into the planned features of the metrology tool. First, the tool should guide the user through the assembly process of a given product. In addition, the tool shall support the quality control by informing about appropriate metrology methods and best practices. During the assembly process, the tool should provide real time feedback on the assembly quality. Every assembly and quality control activity should be automated reported and saved. The authors hope that those functions will reduce incorrect measurements and procedures. Based on the planned features, we classify the application as assistant system. Although the features points to assembly as the field of application, we decided to assign the application to the area of quality management, since the paper sees the focus of the tool on the support for quality measurements.

Gupta et al. (2018) apply a HoloLens within an aircraft production to provide the customer remote access to his aircraft during the assembly process. Thus, the customer obtains the possibility to give directly feedback to the manufacturer and is able to communicate additional requirements. To deal with the product complexity, the authors consider for the aircraft a modular product structure. Before a remote inspection begins, the customer needs to inform the responsible employee which module of the aircraft he wants to check. Afterwards, the employee creates the AR model by defining the inspection items and locating them inside the aircraft to enable AR visualization features. The authors state that this model creation is a manual process. However, the paper contains no information about the required time to create a customized AR scenario. During the remotely walk-through, the AR application highlights important spots to inspect and projects necessary information to single components. In addition, the customer is able to inform the employee in real-time, if he is satisfied with an inspected component and how he assess the importance of the component. For this purpose, the AR application provides two rating scales with which the customer can remotely interact. Concerning our categorization in figure 1 (b), we see the interactive remote access as the main feature of the application. Therefore, we classify the software as telepresence application.

2.5. HoloLens Applications for Maintenance

The only publication addressing maintenance is from (Eschen et al 2018). The authors present a method to evaluate the potential of applying MR systems for inspection and maintenance processes in the aviation industry. In this context, they discuss different use cases, dealing with the application of AR or VR devices. Three of the use cases are of relevant for our study, since they utilize the HoloLens hardware. However, a closer look reveals that the described use cases do not necessarily address maintenance as field of application. In the first case, the HoloLens is used for robot programming. The description of how to program the robot with HoloLens is quite similar to the descriptions in section 2.2. In the second case, the HoloLens assists the user in the ground test of an aircraft. The ground test is the final quality check for an airplane before the company delivers it to the customer. During the test, the user has to carry out a sequence of manual operations, for instance testing the functionality of control elements and evaluating the legibility of displays. The author state that the procedure of the ground test is comparable to an assembly process, which also requires the performance of a set of task in a certain sequence. Therefore, the authors adapt the concept of AR supported assemblage, described in section 2.1, to inform about upcoming test procedures within the aircraft cockpit. The third use case is quite similar to the second. In our opinion, it is the only use case which obviously presents a maintenance application. Here, the authors apply the HoloLens to guide through a maintenance process. Here, the methods to support the execution of a maintenance process are similar to those applied to support a ground test or an assembly process. More precisely, the HoloLens application shows the user every necessary activity in advance to carry out the maintenance process correctly. In addition, the HoloLens is able to monitor necessary information about the state of the system and can provide directly feedback regarding the success of maintenance measures.

2.6. HoloLens Applications for System Monitoring

Karlsson et al (2017) apply the HoloLens to transform the visualization of a simulation model to a stereoscopic view. Moreover, the application gives for different model elements information about bottleneck causes and their importance for the system performance. The authors argue that an AR visualization for complex and large models can improve the understanding of the behavior and processes of a system. The simulation model is not executed on the HoloLens itself. In order to run a simulation and to visualize the model activities with the HoloLens, the authors use a self-developed web service to transfer data between the database which contains experiment parameter, the discrete-event simulation engine and the HoloLens itself. We classify the last application as tool for visualization, because it seems not to utilize the features for interacting with virtual information and objects in a remarkable way.

2.7. Discussion of the Findings

From a scope of 388 publications, we identified 14 research papers, which describe applications for Microsoft HoloLens settled in the field of production and logistics. We classified the applications regarding their field of application and their primary task to fulfill. From a technical point of you, we believe that only 10 out of 14 applications, i.e. the applications classified as assistant system, development environment and control and steering system, utilize the exclusive features of the HoloLens in a remarkable way. Surprisingly, most of the publications indicate that the enhanced ergonomics is the main motivation to apply the HoloLens, since the user has both hands free, when executing an AR application, and the device does not require a cable connection to a computer. Furthermore, the authors consider the internal tracking system as one of the most beneficial features, because it reduces the number of optical markers to visualize position changes of virtual objects. However, the possibility to interact with the virtual information and vice versa, which Microsoft highlights as the primary and most innovative feature of the HoloLens, seems to be only considered as an interesting but still not mandatory gimmick. Considering the publications, which additionally analyze the usability of the HoloLens, the feedback of the test persons indicate an increased stress level, if the user needs to apply the HoloLens for a serious task. Two reasons for this could be the gesture control, which a significant number of test persons felt as complicated, and the display area presenting virtual information, about which a lot of users think that it is too small.

3. CASE STUDY: CONCEPTION AND IMPLEMENTATION OF AN ORDER PICKING GAME

A game for order picking was developed to demonstrate different picking techniques that are common in logistic warehouse processes. The main function of the application is to support the user to navigate between the start location, where he has to pick a virtual product, and the destination location, where he has to place the virtual product. There were several reasons for us to design and implement this application: First, we wanted to receive a first impression about the capabilities of the HoloLens. Second, we wanted to collect knowledge about how to develop HoloLens applications. Third, we required an application to give students an idea about AR technologies and how they could be utilized for logistics purposes.

3.1. Application Concept

In this section, we want to give a detailed description about the scope of functions of the application and the scenarios the user is guided through. The user can select between four scenarios representing different picking processes:

- **Single Picking / Piece Picking:** The user should pick and place a specific number of single items. The application displays only one virtual object at the same time.
- **Multiple Picking / Batch Picking:** Unlike single picking, the application displays all objects to be picked simultaneously in the scene. The objects are dispersed across a larger area. Henceforth the user needs to travel to some objects for picking. In addition, the HoloLens places a virtual box in the scene, which the user should apply to consolidate the objects. If objects are too far to pick, the user is able to carry the box to origin point of the object. As soon as the user has collected all objects, he needs to transport the box to its destination point.
- **Item Sorting:** Several spherical objects appear in three different colors. The user needs to sort the spheres in three different real-world boxes according to their color. To figure out which sphere color a specific box demands, the user needs to scan an optical marker related to this box.
- **Zone Picking:** In this scenario, the HoloLens divides the area in a defined number of zones. The user has to travel to every zone where he needs to collect several objects and place them into a box. After the user has picked and placed every object within a zone, the application considers the zone to be completed and the user has to move to the next zone. The HoloLens identifies a specific zone by scanning the zone's name written on a sheet of paper.

After the user have decided for a scenario, the application needs to be initialized. Depending on the selected scenario, the program generates a single 3D object or a set of 3D objects, which it randomly distributes in an area with a specific radius. Afterwards, the application randomly determines a picking order. As soon as the application is initialized, an arrow appears which indicate the position of the next object to pick. The user has different options to interact with the 3D objects:

- Changing the object's position in all directions by using the tap feature on the position symbol and moving the hand in the desired direction
- Rotating the object by using the tap feature on the rotation symbol and moving the hand radially.
- Increasing and decreasing the object's size by using the tap feature on the resize symbol and moving the hand forwards or backwards.

The different interaction options are necessary to adjust the object's position and size in order to make it fit in the real-world or virtual box.

3.2. Description of the Implementation

We implemented our application with Unity3D 2017.3.1 for the frontend programming and Visual Studio 2017 for the backend programming. Unity3D is a cross-platform game engine developed to create three-dimensional games and VR/AR applications. Within Unity3D, we especially utilized the libraries Vuforia and HoloToolkit-Unity, which offer all necessary features to design an AR application. The interface elements, such as buttons and cursors, and the 3D objects, such as cube and spheres, are from Unity3D. The logic behind each object function is implemented in C# with Visual Studio.

Figure 2 gives an impression of our application. The pictures shows the second scenario "Multiple Picking / Batch Picking", i.e. the virtual box, which already contains some 3D objects, and the next object to pick can be seen. Additionally, one may recognize the icons in the middle of the illustration to move, rotate, and resize an object.

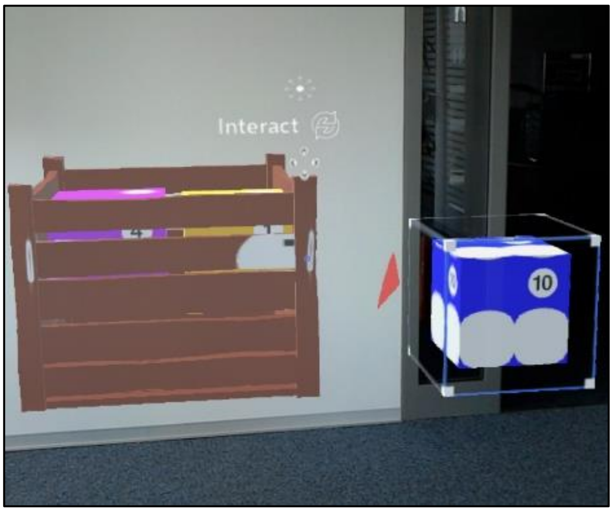

Figure 2: Impression of the "Multiple Picking / Batch" Picking scenario of the HoloLens application

3.3. A Short Survey about the User's Experience with Microsoft HoloLens

Beside our interest in the technical features, we wanted to know how users evaluate the utility and usability of the HoloLens. Hence, we conducted a survey at the Open House of our university. Overall 19 male and 8 female participants took part at the survey and tested our HoloLens application. Most of the participants were in the age between 20 and 26. Six participants were in the age between 17 and 19 years. Another six participants were 27 years or older.

The survey consisted of two parts. Before a visitor has tested our application, he was asked to answer a pre-survey. The purpose of the pre-survey was to identify the participant's knowledge about VR/AR technologies, especially about Microsoft HoloLens. Furthermore, we wanted to know about the participant's attitude to HoloLens based on some first explanations by us and the first impressions of the participant from observing other test persons currently using the HoloLens. Figure 3 summarizes the results of the pre-survey.

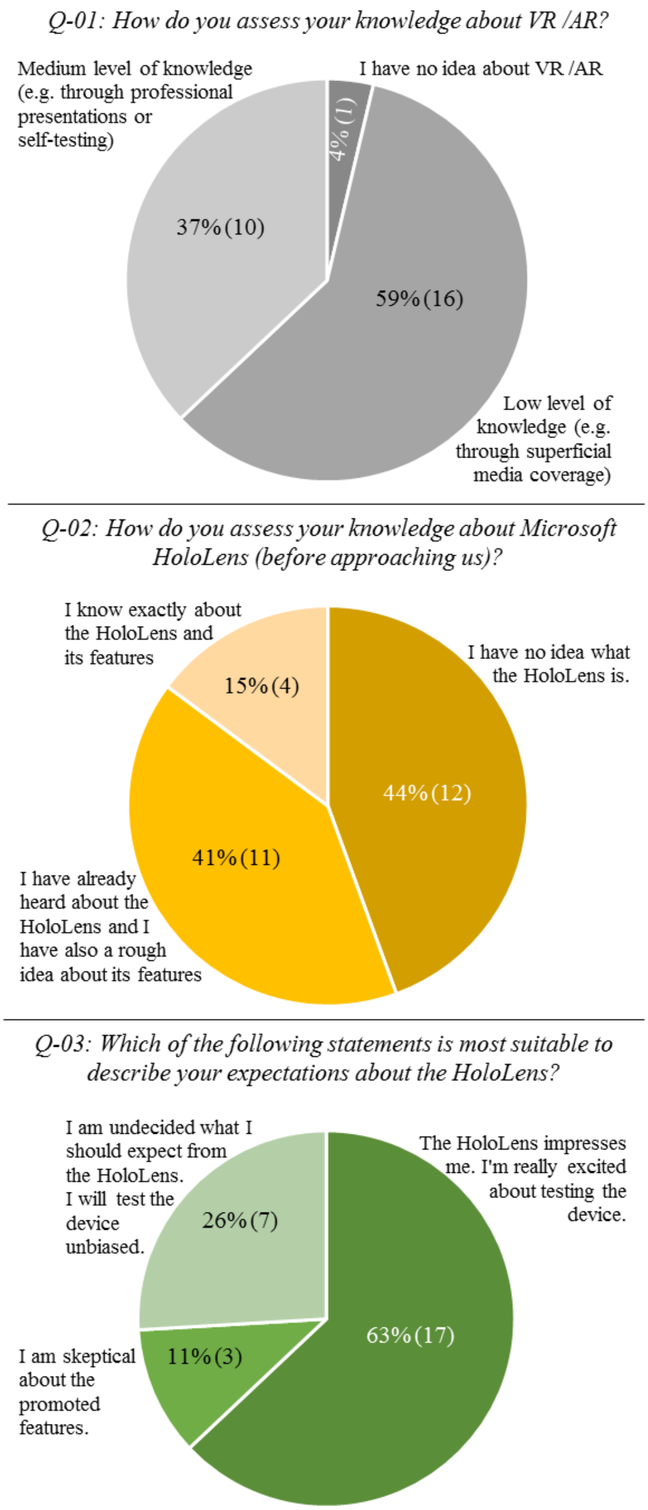

Figure 3: Results of the pre-survey

The results show that most of the participants had at least a general idea about VR / AR technologies. No one of the attendees stated to have a high or a very high knowledge in VR / AR technologies. Furthermore, over the half of the participants already heard about the HoloLens or even had a precise imagination about its technical features. However, no participant has answered that he has already worn and tested the HoloLens. As the third chart in figure 3 shows, most of the participants had already a positive attitude towards the HoloLens before they even tested the device. A quarter of the participants were uncertain what to make of the HoloLens and three attendees were skeptical about the promoted features.

After a participant tested the HoloLens application, he was asked to answer a second survey in which he should evaluate the utility and usability of the device. The follow-up survey mainly consisted of eleven statements, presented in table 2.

Table 2: Question 04 till 14 of the follow-up survey

ID	Statement
Q-04	The virtual objects generated by HoloLens were realistically projected into the user's environment.
Q-05	The presentation and visibility of the virtual objects were always fine.
Q-06	Interacting with the virtual objects was easy and intuitive.
Q-07	The HoloLens were comfortable to wear.
Q-08	The HoloLens fitted very well.
Q-09	It was fun to test the HoloLens.
Q-10	The HoloLens impressed me.
Q-11	The HoloLens could be valuable as complement for teaching at schools or universities.
Q-12	Through the HoloLens, I understood what Augmented Reality is.
Q-13	By testing the HoloLens, my interest in AR technologies has increased.
Q-14	In the future, AR technologies will play a significant role in our everyday life.

The attendees had to judge on a scale of 1 to 5 about their position to each statement, whereby the value 1 equals to "total agreement" and the value 5 to "total disagreement. The following figure illustrates the distributions of the given answers.

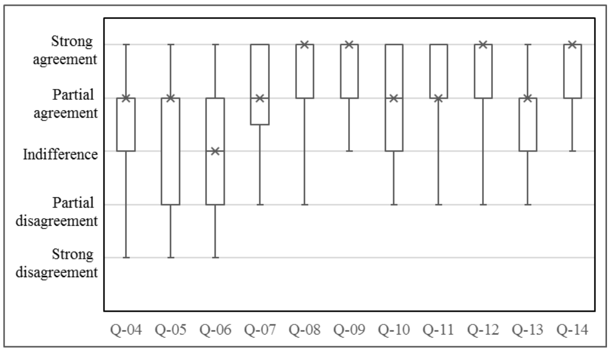

Figure 4: Boxplot diagram representing the distribution of the given answers on the statements Q-04 until Q-14

While the feedback on the quality of the virtual objects representation were quite positive, the field of view and the handling regarding the interaction with the virtual objects were criticized by a significant part of participants. In terms of the ergonomic properties, the test persons rated the HoloLens better than expected. This result is surprising, since the findings of the literature review indicates a low wearing comfort of the HoloLens. In summary, most of the attendees stated that they enjoyed the experience with the HoloLens and that they think the device could be a useful teaching resource in schools or universities. The statement that AR technologies will play a significant role in our future lives received also strong approval from the test persons.

Finally, we wanted to figure out, if the attitude of the participants towards the HoloLens has changed after testing the device. As Figure 4 shows, most of the expectations were fulfilled or even exceeded. Only three participants were disappointed from the capabilities of the HoloLens.

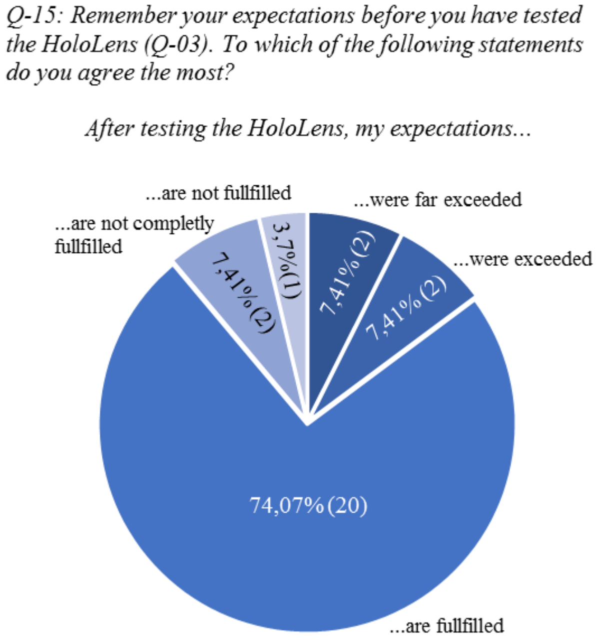

Figure 5: Evaluation of the participants' attitude towards the HoloLens after the test

4. FUTURE RESEARCH CHALLENGES

In our opinion, the most important research challenges concerns both hardware developers and application developers. In terms of hardware, a minor shortcoming is the gesture control, which is not as simple to use as we expected. Only after a short period of training, we were able to easily work with the gesture commands. A more intuitive gesture control would be desirable, for instance to quickly perform experiments with test persons having no experience with HoloLens. Another main weakness of the current HoloLens model is the small projection surface, since some virtual objects cannot be completely recognized from just a single point of view. Thus, the user often has to turn his head or change his position in order to get an impression of the whole scene. However, research and industry are already developing concepts to enhance the experience with AR. For instance, (van der

Meulen, Kun and Shaer 2017) implement an eye-tracking feature for the HoloLens, which enables the device to update the presentation of virtual information in dependence on the user's eye movement. First tests indicate an improvement of the usability. One of the most promising announcements is the release of the AR goggle "Meta 2". The device shall be capable to create high-resolution photorealistic holo-projections on a 90 degree field of view (Meta 2018).

Concerning the development of applications, we currently do not see any challenges in programming and implementation. Moreover, we believe that as a first step, the development of application concepts should be focused, which...

- ...provide significant benefits for the industry and...
- ...utilize the exclusive features of the HoloLens in a meaningful way.

Although the literature review of section 2 uncovers several useful applications, it remains the fact that many of those applications only benefits from the HoloLens, because of its superior ergonomics compared to tablets and other hand-held devices. On the one hand, we think that from the papers presented only the application of (Kot, Novák and Babjak 2017) meets the two requirements. On the other hand, we also think that it is a nontrivial task to develop concepts for industry-relevant applications, which fulfil the postulated requirements. Especially for the most innovative HoloLens feature – the possibility to interact with virtual objects and vice versa –, it is difficult for us to think about convenient applications to support operational tasks on shopfloor level. From our point of view, this feature could be only relevant for industrial training and planning applications.

In the near future, we want to connect our HoloLens with an Industry-4.0 learning laboratory, which we currently develop. The laboratory consists of several conveyors, turntables and other logistics resources, which can be arranged in any preferred structure. This enables an easy and quick setup of various production layouts. The idea of the laboratory results from a previous research project. Details are given in (Hofmann et al. 2017). However, since our laboratory does not contain any production resources, we plan an extension with virtual workstations and manufacturing processes. In order to present a realistic process flow, it is necessary to implement an appropriate behavior for the logistics resources on how to react to the execution of virtual processes. For instance, let us consider a virtual manufacturing process at the center of a conveyor. In that case, the conveyor shall stop the conveyor belt as soon as the position sensor at the center point recognizes a product. Furthermore, the signal of the position sensor informs the HoloLens application to start the animation of the virtual process. The end of process animation indicates that the conveyor can continue the transportation of the product. Hence, the main challenge of our idea is to synchronize the program logics, controlling the sensors and actuators of each logistics resource, with the processes of the HoloLens application. The development of an integral concept will be subject of subsequent projects.

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VIRTUAL REALITY AND AUGMENTED REALITY LOW COAST: AN EXPERIENCE OF HERITAGE EDUCATION IN PRIMARY SCHOOL

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ABSTRACT
Preserving the historical and cultural heritage is one of the ways to safeguard the memory of a period of history, especially regarding to architectural monuments.
Throughout the world there are cities with historic buildings or monuments to visit and one of the great challenges is to make residents aware of the value and representativeness of these constructions for the preservation of the local culture. In this context heritage education should start early with initiatives involving elementary school children. Nowadays children have access to technological devices such as smartphones or tablets from a very early age, and therefore, the use of these resources can be valid to aid in heritage education.
That is why some alternatives have been researched to offer virtual visits through some device or technological resource. Several companies have developed equipment capable of simulating virtual environments or superimposing information in the real world with great quality, but with very high prices.
Undergraduate students in Architecture of the University Center of João Pessoa - UNIPÊ and public elementary school students worked together on this project, developed considering the use of low cost equipment, printed on 3D printers and using free software.

Keyword— Virtual Reality, Augmented Reality, Virtual Heritage, Virtual Historical Monuments, Panoramic 360, Photography, Virtual Reality Glasses

1. INTRODUCTION

One of the main doubts of students when studying cultural heritage is the importance of studying the past and the purpose of preserving old buildings, houses and churches. Students several times do not understand the need to preserve history and memory, precisely because these young people and children do not see themselves as an integral part of the history of their own city.
The purpose of this study is to awaken students' interest in cultural heritage through techniques ranging from puzzle games to the use of Augmented Reality.

2. CULTURAL HERITAGE

The term cultural heritage [1] refers to the manifestations and expressions of society accumulated over the generations.
Basically, we can divide cultural patrimony into two categories, tangible patrimony and intangible patrimony. Tangible heritage consists of private properties, churches, urban stretches, natural environments of landscape importance, as well as handicrafts, utensils and other movable property. The intangible heritage is composed of cultural manifestations, such as dances, testimonies of the elderly, parties, music, etc.

The study of tangible and intangible heritage has been a didactic resource used in schools. In general, only as illustrative elements serving as a resource to generate questions, hypotheses and find possible answers about the memory of a people.

2.1 PRESENTATION OF CULTURAL HERITAGE FOR STUDENTS

The first stage of this project involved primary school students and aimed to present the theme cultural heritage. The project was developed for students between 10 and 14 years old.

The study consisted of bibliographical research about the history of João Pessoa city, highlighting some points of the city wich were discussed in classes with sources including historical documents, texts, images, games and guided visits (Figures 1).

Figure 1: Puzzles with photos of historical monuments and cultural events. Material produced by IPHAN-PB in partnership with the João Pessoa city government in the scope of the project "João Pessoa my city".

The main objective of the work was to get students to know the History of the City through the material presented by the teachers (photos, texts, puzzles) and from these studies produce texts and think about the personal and collective memory of the city. In addition, the students were prepared to identify the places analyzed in the classes during the physical visit and to be able to describe them to the other students (Figure 2).

Figure 2: Students at São Francisco Cultural Center presenting the history of João Pessoa city.

Each student selected a point in the city and produced a text that was presented orally during the visits. In this way when the students arrived at the monuments, they were able to identify the objects and had the autonomy to describe them. The students took photographs to produce a small book about the monuments visited.

Table 1: The study schedule

	Goals
I	Selection of texts, articles about the history of João Pessoa city
II	Production and systematization of a theoretical reference, through the production of texts by students.
III	Selection of places that each student would explain during guided tours
IV	Application of puzzles about the cultural heritage of João Pessoa city
V	Creation of a script for visits to the historic center
VI	Visits to the historic center
VII	Production of written material with pictures taken by the students themselves

2.2 USE OF TECHNOLOGICAL RESOURCES

With the popularization of Smartphones and Tablets, children are entering the technological world at an earlier age, as shown in the Kaiser Family Foundation[1] study, which found that 7 out of 10 American children have smartphones and tablets.

Interactivity and games have always been present in our daily lives awakening creativity and enabling interaction between people been a fundamental part of the history of human evolution [2].

Nowadays, we can observe that the young people are "digital natives" [3], speaking in the mobile phone, communicating in social networks, listening music, etc, all this simultaneously, assimilating the interaction in this applications very quickly.

In general, games have always fascinated people over the years regardless of the format or technology employed.

Following this thought, we began to research recreational applications that favor the teaching of heritage education. Not exactly with the format of electronic games, where there are challenges and a clear goal to be achieved, but making use of interactivity as a tool of interest to students.

Virtual Reality has existed for over three decades and in recent years has become popular with the evolution and cheapness of smartphones. Because of this popularization, we started using Google Cardboard and developing interactive content.

3. VIRTUAL REALITY AND PANORAMAS

Panoramic photographs are a good alternative for remote place presentations and it is the basis for Google Cardboard. A panorama is a type of image in which a wide angle of the scene is visualized, being able to even rotate 360° around the point of view chosen by the photographer.

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[1] http://www.kff.org/disparities-policy/press-release/daily-media-use-among-children-and-teens-up-dramatically-from-five-years-ago/

360º panoramic photographs or minor variations have been made since the beginning of the photographic process. Still at the time of the 35mm film some cameras were specialized in this type of photography with rotation around its axis.

In digital photography the effect is obtained in image processing in softwares known as *stitchers* that deform the image by adapting them to each other until they form a single image. In the process of sequential acquisition of images the software that renders the panoramas verifies which points in a photo are corresponding in the other and joining until having the complete scenario.

In this project we used a Ricoh Theta S camera, capable of making the spherical photograph (360º) in a single shot, generating the finished file in a few seconds with 14MP resolution (Figure 5).

Figure 3 - Ricoh Theta S Camera

With the dynamization of the process in the image acquisition, the group chose a monument in the city (Church of São Francisco - João Pessoa - 1589) and mapped the points that would be digitized in 360º (internal and external). With the photographic records finalized, the group began the linking phase between the images to create the virtual tour using a free virtual tour application (Meu passeio virtual[2]).

The product generated by the digitization of the monument was adapted for the Virtual Reality Glasses whose operation is based on a smartphone.

To give the sensation of immersion, the smartphone is coupled in the glasses and its screen is divided in two parts where each eye perceives a different image. The images change according to the movements of the user's head in any direction.

Students were able to test the application with the Google Card Board, and then with a similar plastic glasses (Figure 6). Both were chosen because they presented low costs (Figure 4).

Figure 4 - Virtual reality glasses with attached smartphone

4. AUGMENTED REALITY

Comparing the non-technological methods (puzzles, books, photographs, physical visit), with the use of Virtual Reality we obtain the following data:

Table 2: comparation

With the glasses it was possible to enter all the environments of the physical visit and more that were closed in the day or were difficult to access.	100%
With the glasses it was possible to explore the environment regardless of the time	92%
Increased interest in getting to know the place physically	100%
The glasses can replace a physical visit when it is not possible	75%
With the glasses it was possible to see details not observed in the physical visit	60%
Glasses can replace a physical visit	40%

Students enjoyed the experience of using virtual reality, but some reported that they preferred to physically visit the monument because of the possibility of walking freely. In this sense we developed an application using Augmented Reality, so that the student could physically visit the monument while having virtual information through a device similar to virtual reality glasses.

A feature of Virtual Reality is that the environment is totally synthetic and the user is immersed in the scene. In Augmented Reality, the user sees the real environment through a camera and information is added to the scene (images, 3D objects, etc).

As a definition, some authors point out that Augmented Reality improves the real world by incorporating texts, images and virtual objects, or blends

[2] www.meupasseiovirtual.com

the real and virtual worlds by connecting them [4]. It can even supplement the real world with computer-generated objects coexisting in the same space and presenting properties like interactive execution in real time and using audio, touch, force and smell features [5].

5. DEVELOPMENT OF THE AUGMENTED REALITY DEVICE

Some Augmented Reality devices perform fairly well, such as Microsoft Hololens (Figure 5), etc, which includes hand tracking and voice interpretation, but with values as high as three thousand dollars.

Figure 5 – Microsoft Hololens

(www.microsoft.com/en-us/hololens)

Our goal was to develop a low cost solution or to adapt an existing solution to make the project viable.

The design was based on Google Cardboard, however, with the Pepper's Ghost principle, where a mirror reflects the image of the smartphone by projecting it onto a transparent surface allowing the user to see the real world with overlapping virtual elements (Figure 6). Later we used a pair of 3D printed glasses because it was more resistant (figure 7).

Figure 6 - modified google cardboard

(https://holokit.io/)

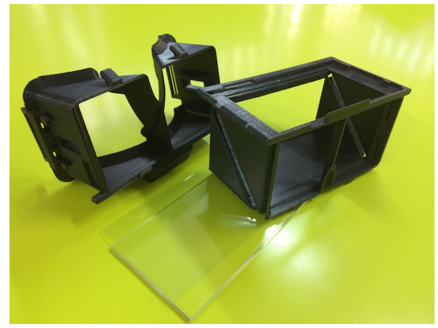

Figure 7 - 3D printed glasses

We chose the Aurasma[3] app to use on the smartphone because it's free.

The augmented reality basically depends on a camera that films the real scene and substitutes some pattern previously mapped by some animation, or digital information. In some cases, markers that are recognized by the camera serve as a trigger for overlapping virtual information. In our project we used the image recognition pattern, rather than markers.

In this case, photographs were taken inside the monument and mapped in the aurasma application. Using the glasses, when viewing a previously mapped image, an animation would be superimposed on the actual view with video and audio information.

In this way the students were able to physically visit the monument and through the augmented reality glasses, see text, audio and 3D animations with information about the details of the art and architectural elements.

Figure 8 – kids using virtual reality device

[3] www.aurasma.com

6. CONCLUSION

Learning through visual information is not necessarily simple. Developing the ability to observe and interpret what surrounds us helps us understand the world. This requires time, practice, and conscious effort that needs to be developed through exercises and tasks [6].

During the visits to the monuments we noticed that the students got directly involved with the proposed themes. They were able to question and point out possible answers related to cultural heritage and learn about the importance of the contribution of different cultures in the construction of the cultural identity of the city.

The visit to the monuments and the contact with technologies contributed to the realization of a critical awareness of the responsibility in relation to the cultural preservation besides the strengthening of the feelings of identity and citizenship.

With this experience, we could see that the interaction provided by virtual environments, or overlapping of virtual elements in real space, proved to be excellent allies in the task of heritage education. We intend on future projects to improve the augmented reality device and expand the digitized area.

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