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Constantine the Philosopher University in Nitra
Faculty of Natural Sciences
Department of Computer Science

and

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Extended Reality in Education

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Abstract

The scientific articles have been recently enormously devoted to the issue of augmented, virtual, and mixed reality and are already being fully established in our normal life. They infiltrated into gaming, industry, medical, manufacturing, etc. However, the area of education (especially in Slovakia) is still lagging behind and is influenced by the fragility of the underfunded system and the inability to respond quickly to today's needs. Educational gaps need to be sought and filled with meaningful projects, which can not only show the potential of all realities in IT, but also attract more young IT enthusiasts (or new future IT teachers or IT students in general) to Slovak education.

That is why we have been trying in recent years to look for a specific focus, where the area of education could be helpful and, at the same time, would shift our knowledge base a little further. 6 years ago, we started working with a psychotherapist to create models and applications for the treatment of various phobias and then we created an optional subject where students can learn how to create these virtual environments themselves. In the last year, we have managed to set up the important hardware for these ideas and currently we are fully engaged in the research, creation and education in this area. In the article, we also present the possibilities of our newly established laboratory, the aforementioned subject, as well as the outputs of student works that have been created over the past few years.

Keywords

Virtual Reality. Augmented Reality. Mixed Reality. Extended Reality. Education.

INTRODUCTION

The problem we are trying to discuss in our article is focusing on different kinds of realities, their understanding, the ability to create them and the possibilities of their use. In this article, we will look at the different resources that deal with all these aspects and we will focus also on the methods we use in education to bring this issue closer to students. Next, we will describe our work together with the presentation of results. Finally, we will evaluate the fulfilment of previously set goals and discuss today's problems as well as our vision for the future.

The rapid development of digital technology is forcing teachers to consider how new technologies, methods and practices can be applied to teaching to achieve higher quality of education. One such dynamic and prospective area seems to be the virtual and augmented

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reality and their various combinations. The border between the virtual and real world continues to break down, providing breath-taking experiences that a short time ago could only be found in the imagination of sci-fi writers.

The basic concepts include the reality-virtuality continuum as can be seen in the Graphic representation of The Virtuality Continuum. Milgram et al. introduced this concept in the 1990s in their work (Augmented reality, 1994). Based on their idea, there are following forms of reality:

- Real Environments (RE),
- Augmented Reality (AR),
- Mixed Reality (MR),
- Augmented Virtuality (AV),
- Virtual Reality (VR).

Here are individual characteristics of each of the aforementioned terms.

By **Real Environment** (RE), we mean unchanged, unadjusted reality. A real environment is any environment consisting exclusively of real objects, including everything that can be seen when viewing the real scene directly or displaying it with some type of video display. Observing the real world through a phone or tablet does not make it virtual (Abdullahi, 2016).

Augmented Reality (AR) is a system that complements the real world with computer-generated virtual objects existing in the same space, combining real and virtual objects in real-time environments and allowing real-time interaction (Schmalstieg, Hollerer, 2016) (Bimber, Raskar, 2005) Azuma (Azuma, 1994) defines AR as a system or visualisation technique that fulfils three main criteria: a combination of real and virtual worlds; real time interaction; and accurate 3D registration of virtual and real objects. It is commonly accepted as a real-time technology whereby a physical environment has been augmented by adding/embedding virtual information in it (Enyedy et al., 2012).

Mixed Reality (MR) is the merging of real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real time. Mixed reality does not exclusively take place in either the physical or virtual world, but is a hybrid of reality and virtual reality, encompassing both augmented reality and augmented virtuality via immersive technology (Milgram and Kishino, 1994).

Augmented Virtuality (AV) is a type of environment in which the main task is to display real, physical information (objects or resources) to the virtual world. The task is situated in a virtual world and the user works with digital information by manipulating physical objects (Arnaldi et. al., 2018).

In Undertsanding Virtual Reality Sherman and Craig describe **Virtual Reality** (VR) as a medium consisting of computer simulations, giving the user a sense of presence in the simulations (Craig, 2013). In other words, it is a completely virtual world made by a computer in which the user interacts only with virtual objects. Virtual Reality technology has traditionally consisted of cumbersome created environments and has often required complex sensors worn on the body of an individual in order to interact with the environment. The emergence of head mounted virtual reality devices is shifting the

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technology into the commercial consumer area. In 2014 Facebook purchased the Oculus VR Company, and Mark Zuckerberg has stated that this form of virtual reality is the social platform of the future (Carter, Potter, 2016).

There is one more term, referring to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. It includes representative forms such as AR, MR and VR (Gownder et. al., 2016) and the areas interpolated among them. It is called **eXtended Reality** (XR). The levels of virtuality range from partially sensory inputs to immersive virtuality. XR is a superset which includes the entire spectrum from "the complete real" to "the complete virtual" in the concept of reality–virtuality continuum introduced by Paul Milgram. Still, its connotation lies in the extension of human experiences especially relating to the senses of existence (represented by VR) and the acquisition of cognition (represented by AR). With the continuous development in human–computer interactions, this connotation is still evolving. XR is a rapid growing field being applied in a wide range of fields, such as entertainment, marketing, real estate, training and remote work (Hui-Wen, 2018).

Mixed and virtual realities support in the immersive environment our feeling of presence and recreate our sensorial apparatus in the fictional featured space in which our entire body can interact with digital objects or assets (Intel, 2019).

VR has been the “next big thing” for several years, but its time has finally come as a way to generate realistic images, sounds and other sensations that put you directly in the middle of a spectacular imaginary world. AR, which adds virtual stuff to your real-world environment, is contributing to the buzz, and both technologies should become a big part of our future. With MR, you can play a virtual video game, grab your real-world water bottle, and hit an imaginary character from the game with the bottle. Imagination and reality have never been so intermingled (Gouveia, 2016).

WHAT BENEFITS BRINGS EXTENDED REALITY IN EDUCATION

All these technologies have an exciting impact also on education. They make the education system more attractive and entertaining. Students learn new things very fast as compared to traditional education system (Bernardo, 2017). Let us see what benefits XR technology brings to education.

Virtual reality in education

Steve Bambury produces new graphics detailing what he feels are the 10 Key Benefits of VR in Education (Bambury, 2019).

Global Teleportation – breaking down geographical boundaries. For a school this can be priceless as it means that students can virtually visit places that are beyond their means in the real world – whether that be on the other side of the globe or even on The Moon!

The Time Machine Effect – allowing students to travel in time and experience the past first hand.

Contextualised Learning – allowing students to actually see what cannot be seen in the real world (objects of micro and macro world, objects of the past and the future).

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Multi-Sensory Experiences – being able to move within a virtual space and engage with elements, manipulate various objects and engage learners like never before.

Extraordinary Abilities – allowing students to break the laws of physics and to do the things they do not or cannot do in the real world. It opens up new learning possibilities in the classroom.

Active Autonomy – letting students go on their own journey, with a great deal of autonomy in how to engage with the content. This starts with the simple fact that they are able to choose where to look and expands when they are offered experiences which allow them to explore freely.

Empathy Agent – VR can be used to foster self-respect, evoke empathy and influence emotions.

Virtual Rehearsal – using VR to practice and hone skills without fear of failure. This is incredibly powerful and can help students build confidence in new areas of learning. It could mean for example using VirtualSpeech to practise public speaking.

Focused Immersion – The very nature of VR being framed inside a headset means that the learners are less prone to distractions in their physical surroundings. For some students this can be immensely beneficial as they may be prone to distraction leading to loss of focus and ultimately loss of learning.

Remote Presence – using VR to connect with other students as well as attend lectures and lessons delivered by educators across the globe. Multi-user, social VR platforms like Engage, AltSpace and more will become thriving hubs for educational content as the entire concept of what a school is and can be begins to morph into something truly new.

Augmented reality in education

Many development companies build commercial, educational and entertainment AR applications, which depict real life scenarios. They achieve this using improved and enhanced computer-generated sights and sounds. This is a huge multi-billion dollar industry with massive potential for the future. There are also many ways to use AR in education to achieve better learning process. The integration of AR into lectures and classrooms drives unparalleled attention from students. Here is a list of some of the benefits of AR application development in education (Harnil, 2018).

Nurtures the learning process – The introduction and use of AR in education creates fun and excitement for students. It stirs up their motivation for the learning process and pushes them into a learning place where they become critical in dissecting new ideas. Students improve their imaginative and thinking ability, they discover and get to know more about themselves through the learning process.

Increases student participation in classes **– AR applications** help students grasp concepts faster and easier through the provided models. They are eager to learn with a high level of curiosity. This results in active class participation increases student motivation and curiosity in the learning process.

Improved and increased memory – Students can access educative and learning AR models through scanning. AR apps helps students improve and retain their knowledge over time. This is possible due to the level of curiosity that comes with learning via AR. AR

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stimulates high level of learning passion and inspiration in students. Thus, improves imagination which results in improved and increased memory.

Interactive lessons – The use of AR in education provides interactive lessons for students. They have full access to educative and interactive models on their devices. On the long run, this propels clear and better understanding of educational concepts.

Increased sensory development – The use of AR in education will enhance the mental and physical dexterity of students. AR gives students the privilege to see, observe, and feel at the same time while learning. In the long run, this results in increased sensory development.

Less expensive – The cost of acquiring educational materials, supplies, nature of 3D physical models, etc. is high. Difficulty is not only with buying, but also maintaining these materials. They can be damaged by years of use, lost or stolen. Some get worn out and others become outdated. AR once acquired does not need a lot of money to maintain, they do not get damaged, lost nor stolen. Students have access to AR learning models on the go, at home, and in the classroom. This reduces the expense of repetitive buying of learning materials. Thus, makes learning less expensive over time as there is no need to invest in physical materials.

Enriched ways of telling a story – The use of AR in education brings about enriched ways of telling educational stories. Through augmented reality, educational storytelling has become powerful thanks to visual models, which help bring to life educational concepts and the learning process. This all creates the impression of originality and realness for educational concepts.

Increased learning activity – Technology has become part of education. Today, students rely more on technology in everything which has contributed to the laziness noticed among students. Fortunate enough, AR apps in education cover the various lapses in educational technology because of their interactivity, learning process and fun experience.

Visiting the past, present, and future – AR in education exposes students to knowledge of the past, present and future events, giving them the opportunity to use the knowledge acquired to solve problems. Therefore, improves understanding and increases curiosity in the learning process.

Mixed reality in education

MR blends real-world and virtual content to create compelling interactive experiences. It offers fully immersive experience that requires students to wear an HMD (head mounted display) and a motion controller, through which they can interact with an environment produced by a mix of real and virtual worlds. Here, the physical and digital objects co-exist. Students can touch and manipulate objects generating a greater understanding of them, and they can interact with data sets, complex formulae and abstract concepts, which could be more difficult to understand through teacher's verbal instructions. For many students, in fact, learning by doing is easier than learning by listening. MR provides a more engaging, fun and effective learning experience than all the other traditional educational methods. MR gives professional educators new innovative possibilities to explore with their learners thanks to its features (Acer and Education, 2017):

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Engaging – direct experience generates an effective way to captivate those students who struggle, or it can just provide another opportunity to boost the engagement during lessons at school.

Universal – regardless of social, economic or geographic disparities, MR at school brings people together and encourage human interaction.

All-purpose – MR can be used to teach any topic, because it is easier to see and hear something instead of having it explained, above all with abstract concepts.

Faraway worlds – using MR devices, students and teachers can go back in time, interacting with objects, animals or human beings that are no longer existing, for example dinosaurs and primitives, and get a new, more realistic image in learners' minds.

No geographical limitations – it is not always simple to plan the perfect school trip to pyramids or coral reef. Thanks to MR, the class has no more limits. Everything is possible wherever and whenever we like.

OUR METHODS OF TEACHING MIXED REALITY

Since 2016, our department has been teaching the subject "Virtual Reality", where students become acquainted with the area of VR. In the following years, when other related areas appeared, we also implemented information about AR and MR into our teaching. To support the subject, an electronic course in LMS Moodle is offered, in which students can find presentations, tasks, links to various websites and learning materials. Using video tutorials for each task, they build VR applications in Unity 3D, panoramic video and photography, to combine models and panoramic video, and to create AR applications too.

We decided to use Unity 3D software or Unreal Engine to create VR applications. We use Unity 3D with Vuforia framework to create AR applications, Action Director to edit and create videos captured by the panoramic camera, and GoProPlayer to play them.

As an example, we present a few applications in which the methodology of creation is briefly described and which students can follow during the learning of the subject, as well as in the creation of their final theses.

Methodology of creation VR applications helping with phobias

Clinical psychology describes phobias as an anxiety disorder, characterized by an intense irrational fear of specific objects or situations. This excessive amount of fear does not correspond to the potential amount of danger of stimulus. Despite the fact, people suffering from phobias experience intensive psychic symptoms (anxiety, loss of control, fear) and physiological symptoms (increased heartbeat, fainting, sweating, problems with breathing) etc. Within the subject of VR, students get acquainted not only with the process of creating such applications, but also with the demands that are required for them. Therefore, it is good if these applications are designed so that they can be controlled not only by the patient but also by the therapist. Thus, the therapist has the whole process under control. (Voštinár et al., 2019)

The methodology of creating applications most often consists of the following steps: specification of requirements and selection of hardware and software tools (we prefer to have a methodology that uses our purchased hardware and free software, which we

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provided), creation of interactivity and application management. Here we take into account not only the comfort of patient control, but also the complete management of the treatment process by the therapist. Once the application is ready, it is tested. First in a school environment, where students debug each other's mistakes and improve their applications, and then the therapist himself has the opportunity to try the application. The last application he tested was the one of Arachnophobia with his daughter, who suffers from this disease. Experience with this application will be mentioned in the next chapter on learning results.

Methodology related to implementing MR to learning process

Another example is from the area of combining panoramic video, captured in the real world, and an animated model of an object. The process of creating a MR depends on circumstances, but in general consists of several steps. First, markers must be placed on the contrast points in the movie - the number of them depends on the video capture technique. After placing enough tags, we can track them. An important step is to set the camera parameters. We must ensure that the virtual camera in the program has the same parameters as the camera with which we record the video. Then the program calculates the movement of the real camera based on the amount and quality of the traced tags. The calculation result in information on the size of the deviation. In the next step, the scene should be prepared so that the 3D object could be placed in the video, which included dividing the scene into the foreground and background. Then the 3D model should be imported into the scene and placed in the desired position, rotated correctly, and resized to fit the video exactly. The lighting for the scene is provided using two lighting methods, which are combined to create the same lighting conditions as in reality. The first method is IBL (Image-Based Lighting), which uses image information from real photography to illuminate. As a second method, the virtual illumination found in the program is used. Finally, the scene is rendered into the resulting panoramic video enriched with an artificial 3D object. (Voštinár et al., 2019)

Methodology of creation AR applications

The third methodology captures the process of creating AR applications (Horváthová, Blšák, 2019). To create AR applications, we use the Unity3D game software with the Vuforia library, which has been directly integrated into Unity3D since Unity 2017.2.

First you need to create a hierarchy of scenes. We insert GameObjects (2D or 3D) into each scene, which form the content of the scene. These are various graphic elements that can be visible and invisible. For buttons and other objects to work, we need to assign them an action that we program in C#. These are scripts that have different functions - view, activate, print, save, check. We must assign a method contained in the script to each GameObject. The final step is to complete the data needed to run the program such as application name, application icon, operating system version, and other specifications, and subsequent compilation.

LEARNING RESULTS

Over the past six years, a number of applications have been developed at our department aimed at using various realities (VR, AR, MR) in multiple areas. We began in the field of phobia treatment with VR, for which we were inspired by expert psychotherapist

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Ján Záskalan. Based on his inspirational ideas, we started creating applications, object models and environments to treat agoraphobia, hypsophobia, claustrophobia, arachnophobia, etc. We gradually analyzed various methods of creating objects and phobia environments, such as: 3D modeling, animation, photography and filming with a 360º panoramic camera and adding (combining) such an environment with animated objects, creating a virtual environment, or enriching the real environment with digital objects and so on. (Horváthová, Siládi, 2016) The laboratory that we have built in recent years contains for example a set of HTC Vive glasses with drivers or previously mentioned other devices. In addition to immersion into the virtual environment, it also enables various interactivity with virtual environment objects.

Results of treatment with support of VR

Testing of the application Arachnophobia was carried out in the laboratory of virtual reality and exploring the user experience at our department on a sample of 33 respondents, who completed our electronic questionnaire. The largest group of respondents were secondary school and university students and also some teachers of the department and faculty staff participated. A very important volunteer was the psychotherapist himself and his 12-years-old daughter, who suffers from arachnophobia. Of these 33 respondents, 24 were men and 9 were women between 12 and 65 years of age, with the highest age share between 21 and 25 years. This was a relatively well-balanced sample of respondents suffering from arachnophobia (21.21%), claustrophobia (9.09%), social phobia (3.03%), unspecified phobia (6.06%), and totally healthy people (60.61%). Nearly half of them (45.45%) have experienced some type of VR technology before. On average, the duration of testing an application in a virtual environment was approximately 16 minutes (ranging from 8 to 80 minutes). More detailed feedback from this research is described in our next paper (Voštinár et. al., 2020)

Here are some examples of environments and applications that were created within the course Virtual Reality or as final theses of students of applied informatics.

Figure 2 Arachnophobia VR application

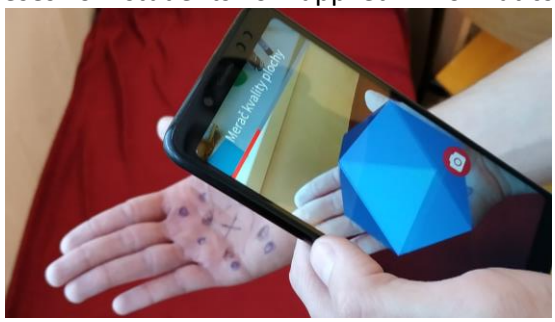

Figure 3 Platonic bodies AR application

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Figure 4 Example of MR environment

Figure 5 Basketball VR application

DISCUSSION

We use the field of XR in education mostly because we are an educational institution, which wants to keep up with modern emerging technologies and has the ambition to closely link the process of education with practice. It is the education that supports our efforts to create applications for various areas. Today, XR applications for education transform the educational sector. The benefit of these technologies in education could be tremendous. We just have to grasp it well in our hands. We believe that XR will continue to transform education and the learning process itself.

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Scope

The scope of the conference includes:

Section: Information Technologies Supporting Learning

- Authoring Tools and Content Development
- Web Based Learning, Wikis and Blogs
- E-learning Platforms, Portals
- Digital Libraries for E-learning
- Multimedia and E-learning
- Mobile Learning
- Massive Online Open Courses
- Ontologies and Meta-Data Standards
- Emotional State in Education Process Identificated using IoT

Section: Learning/Teaching Methodologies, Assessment and Learning Environments

- Blended and Collaborative Learning
- Modeling of Educational Activities
- Personalized and Adaptive E-learning
- Assessment Methods in Blended Learning Environments
- Education Supported Smart Technologies
- Pedagogy Enhancement with E-learning
- Ubiquitous Learning Environments and Applications
- Technology Enhanced Learning
- Virtual Labs and Virtual Classrooms
- E-learning Success Cases

Section: Intelligent Computing

- Web Information Filtering and Retrieval
- Web Data Mining
- Knowledge Discovery and Data Analysis
- Meta-Knowledge Discovery and Representation
- Personalized Web Sites and Services
- Natural Language Processing
- Information Retrieval and Extraction
- Educational Data Mining
- Learning Analytics
- Text Mining
- Internet of Things and Intelligent Systems
- Artificial Intelligence and IoT
- Machine Learning for Internet of Things

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