Benefits of Interactive Augmented Reality in Education

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***Abstract*— Globally, the Fourth Industrial Revolution is a means of pushing boundaries, providing support for development and research in every aspect of life, and education is one of them. The augmented reality learning system is an effective key to an overall understanding of the lectured content, as it allows you to interactively enter, view, enlarge or otherwise process the displayed data. The interaction evokes increased attention and a naturally growing curiosity to explore the details, which the participant learns and at the same time has the experience of the depicted holograms. Reality as such cannot in fact be spread, only its perception. The possibility of achieving an extended space of digital illusions depends on several factors, the basic ones being the observation phase and the image reconstruction phase. The space in which it is to be displayed also plays an important role in creating augmented reality. The most used AR display methods include QR code display, which is enabled by all display devices with a built-in camera and HDM devices such as HoloLens. In education, both have their strong representation, which results in innumerable advantages but also certain disadvantages. Interactive Augmented Reality should also be applicable as supporting technology for UAV path visualization in various scenarios.**

I. INTRODUCTION

In the current digital age, there is a significant differentiation of scientific disciplines under the influence of a huge increase in new knowledge. Scientific disciplines integrate and coordinate the issues of other scientific disciplines, which naturally contributes to their connection.[1] Today, computers are not only a part of our daily lives, but they have also become an irreplaceable part, especially for the alpha generation, which, according to experts, is the best-equipped generation. The pedagogical sector thus faces the challenge of effectively leading teaching for a generation that is no longer built for the outdated way of teaching that has been used so far. As a result of insufficient education of the younger generations in a fully digitized world, there may be a huge shortage of labor in the labor market soon. For this reason, too, the introduction of state-of-the-art technologies, such as augmented reality, is essential for healthy and beneficial population growth. The introduction of new teaching models is expected to make a positive contribution to the innovative growth of the level of education at different levels of education.

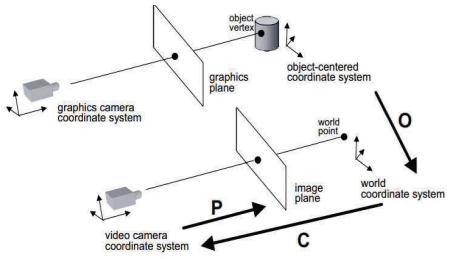

Figure 1. Relationships - object-to-world, world-to-camera and camera-to-image plane

II. AUGMENTED REALITY

Augmented reality was created on the basic principles of virtual reality. Unlike virtual reality, which immerses the participant in a simulated computer-generated environment, AR combines the observed phenomena of the real world with graphically added information [2].

The main principle of AR technology is focused on man and his perception, as reality cannot be spread. The purpose of widespread digital information is to enrich the original phenomenon with information that is useful in many aspects, including studies. Enrichment is through graphics, simulation or a 3D model that could improve understanding. What is remarkable about this study is the fact that augmented reality teaching applications are still minimal, although the trend towards augmented reality in various sectors is still growing [3]

Ronald Azuma and his team, who have conducted valuable surveys with numerous data since 1997, have made a significant contribution to augmented reality. These dated surveys formed an important aspect for the various possibilities of using augmented reality regarding the numerous applications of mobile technology and opened application possibilities in various industries [4]

Although AR is considered a modern technology, the first mention of augmented reality dates to 1950, cameraman Morton Heilig considered fulfilling his vision of the future, called "Sensorama", and less than 15 years to build his prototype [5]

Subsequently, in 1962, Ivan Sutherland, a well-known scientist in computer science and graphics, began to consider the interaction of alternative, innovative forms with computers. So, he developed Sketchpad - the first drawing program with an algorithm for cropping and enlarging images [5]

The basic challenge of augmented reality is the right combination of the physical world with the digital illusion so that there is a consistent perception of the newly

created expanded space. *Figure 1* shows the relationships between the object, the camera, and the environment.

These relationships are the object-to-world, O, world-to-camera, C, and camera-to-image plane, P, transforms (Figure 1). The object-to-world transform specifies the position and orientation of a virtual object with respect to the world coordinate system that defines the real scene. The world-to-camera transform defines the pose of the video camera that views the real scene. Finally, the camera-to-image plane transform specifies the projection the camera performs to create a 2D image of the 3D real scene. [6]

A: AR computer vision method

Augmented reality uses a complex of different methods for the possibilities of computer vision, but the basic principle consists of two phases, namely the observation and reconstruction of the image.

In the first phase, the reference marks are optical images or points of interest recorded by technology like photography. The second phase uses the data obtained in the first phase to achieve the reconstruction of the real image [7]. Tracking can use various principles and functions to detect and interpret an image from a photograph, and with computer vision, most of the available tracking techniques can be divided into two basic classes: [7]

- Model
- Functional

Model methods: They represent the connection between 2D and 3D coordinates of monitored objects through CAD models or through 2D templates in a more extended version of tools. After connecting the 2D and 3D coordinates, it is then possible to find a suitable rotation of the image by minimizing the distance to their corresponding two-dimensional function. Possible limitations are detected by point functions.

The second phase uses the data obtained in the first phase to achieve the reconstruction of the real image. If the camera (sensor) is calibrated and the perspective model has coordinates (x, y, z) ^{T}so the result is displayed in the plane [7]

$$\left(\frac{x}{z},\frac{y}{z},1\right)^{T} \quad p_i(x_i,y_i,z_i)^{T} kde$$

$$i = 1, \dots n$$

$$n \geq 3 \quad q_i = R_{p_i} + T$$

$$h_i = \frac{1}{r_3^T p_i + t_z}\left(R_{p_i} + T\right)$$

$$R = \begin{pmatrix} r_1^T \\ r_2^T \\ r_3^T \end{pmatrix}$$

Functional methods: They use data assuming the presence of functional markers in the environment or scanned 3D objects with known geometry [7].

Spatial Augmented Reality (SAR) is an example of functional AR surveillance methods that use video projectors, optical elements, holograms, radio frequency markers and other surveillance technologies to be displayed in space without the need for HMD. (head mounted display) [8]

Simultaneous Localization and Mapping- SLAM is a simultaneous localization and mapping of 3D objects in a previously unknown environment. [9]

Structure from Motion- SFM is a technique of locating and mapping the environment by monitoring functional points and estimating camera parameters [7]

B: Display of AR content using QR codes

AR QR code is a type of barcode that usually redirects the user to a web or mobile application that allows the display of interactive content. It is a communication tool that forms a bridge between digital technologies and traditional communication media [10].

The process of creating a unique AR QR code with today's open-source capabilities is not a complicated or lengthy matter.

Freely available applications allow the creation of unique codes in a few points, which do not visually repel, but the information can be hidden in markers such as a logo or image when the basic condition is met, and this is a high contrast between the marker and the environment. Interpretation of augmented reality through literature it is widespread especially in children's books, architecture, and medicine.

C: Basic properties of QR codes in AR

Transmedia links One of the important features of AR codes is transmedia links. This means that they provide an experience from simple printing on paper to 3D models, simulations in augmented reality.

Passivity Another feature of the AR QR code is that its marker is fully passive. No external power supply is required for start-up. They come to life, almost immediately after scanning with a smartphone or tablet, using the camera's built-in accessories.

Durability They are also resistant to possible damage, even if approximately 30% of the QR code is damaged, it can still be scanned.

User-friendly The launch is not financially or technically demanding, which allows you to reach a wide range of users.

III. USING AUGMENTED REALITY AS AN EDUCATIONAL TOOL

Augmented reality is used to develop students' understanding of science, including environmental science. [11] From a pedagogical point of view, the benefits of augmented reality can be considered as an effective tool for constructive assessment of either basic or complex teaching units, as by adding digital objects to

the real environment, the learning content can be understood in more detail.

We live in a tangible physical world and are subject to the laws of physics. Therefore, augmented as well as virtual reality is very intuitive for a person and identification with it is natural. It offers humanity a new perspective on the use of digital tools. Studies show an increased interest of students in learning by implementing simple applications [12].

showed that the use of AR in education can make 87% of students more likely to attend classes and 72% of students are more likely to attend classes. Thus, it can be evaluated that from a statistical point of view, the interest in innovative approaches in hybrid teaching is the interest of students, which can be considered a credible factor in considering the change of pedagogical practices in practice.

The quality of education also depends on the way the content is interpreted. During the study, it is possible to come across educational material that requires imagination and augmented reality through simulation allows visual display of unobservable concepts through 3D models that can help students understand the concepts they struggle with and prevent them from misunderstanding information about these subjects.

In medical science, augmented reality based on the principle of role-playing for motivation and a sense of authenticity is used to improve understanding [13]. It is no exception to link game games to achieve better educational results in other areas

A: Distance learning

The Covid-19 pandemic has severely affected the teaching method on a global scale, so helping to work with challenging concepts can be seen as a positive benefit of AR applications.

Useful, especially for remote classrooms or online classrooms, where students often do not benefit from a level of connection and support with their peers than students in traditional classrooms.

Hybrid teaching that combines the established and proven concept of education with the innovative means that the digital world offers brings opportunities to meet the qualitative development of basic and digital skills of students, necessary for successful assimilation after graduation.The rapidly developing trend of AR application development often complicates the possibilities of their practical introduction into a well-established teaching system. Although it can be deduced that the curriculum is subject to change slightly, developments in information and communication technologies are growing dynamically. It therefore becomes costly or burdensome for educational institutions and they choose a more convenient alternative with simple applications based on reading QR codes, which will bring to life, for example, simple models or simulations in books.

There are already countless free applications on the market, such as LearnAR, which uses a marker-based principle to provide free courses in mathematics, physics, biology, religion, and languages. [14] The Fetch lunch rush available through the portal [15] helps students develop basic math skills by they ask questions and require them to find the augmented reality brand with the right answer.

B: Interactive augmented reality

Eastman describes the use of interactive opinion-asking technology (where any answer was correct) to introduce topics and highlight classroom views in open-ended questions with students selected at random (using a random system function) to participate and in multiple choice questions to measure student knowledge about the substance and determine if the class is ready to move on to the next topic. Then these questions were in the exams, so the students had the motivation to make sure they learned the material [12].

The digital interface of augmented reality in physical space and the application enabling complete user interaction with the projected hologram, enables a special approach to obtaining new information, respectively understanding the technology and the principle of its operation. Each user can ultimately take away their own experience and fill in the gaps of unknown learning content in a distinctive and unique way.

The educational environment immerses the participant in a partially virtual world, which allows him a safe, comprehensive, and highly realistic background of the issue or work environment. The moderator in such an interactive educational space can be a teacher or even a virtual character who accompanies, navigates, or advises the user during the course.

Field training can also be considered as field training of specialized employees, technicians, assembly line workers and within IoT and IoP the lessons can be adapted to their specific requirements and unique tasks. Currently, smart glasses are used mainly in industry, but in addition to maintenance and remote support, they are used for training. It turned out that the training of new employees through interactive augmented reality brings several benefits, from the elimination of costs to the adequacy of the selection of candidates in monitoring their prerequisites for fulfilling the job task. Microsoft, along with software solution partners, delivers regular and valuable case studies as technology goes into practice. In collaboration with Microsoft, Vectrona has created an Augmented Cognitive Environment - Extended Reality (ACE-XR) solution that has enabled an immersive 3D training experience created with Vuforia Studio. Vuforia is a PTC product that allows you to turn CAD data into augmented reality. It is one of the two most used software for this purpose. The ACE-XR user interface and user experience (UI / UX) is designed to not only improve training and operations, but also speed up and reduce the cost of developing Extended Reality content. This case study for the US Air Force to ensure safe and effective training of new members was published on its website by PTC [23].

Animation and X-ray vision functions in augmented reality training allow participants to look inside, visualize hidden components and better understand how systems work. As these trainings are not linked to actual equipment, the training may take place even when

physical aircraft and equipment are not available, which allows continuation of training when aircraft are required for air operations, are decommissioned or are obsolete.

During the COVID -19 pandemic, Henkel also considered the need to find new digital opportunities to provide expertise where and when it is needed for its partners and employees and began looking for a remote reality solution that uses augmented reality. When their Digital Business department researched potential solutions, they opted for a software solution through an application, which they rated as the most financially beneficial as no investment in new equipment was required [24].

Education through qualification or retraining, especially in the industrial environment, has a strong presence as it leads to demonstrable cost optimization.

Augmented and mixed reality training can significantly improve the quality of training in the academic classroom and task training, thanks to simple elimination tools such as:

- Reduce time spent on passive training in a PowerPoint-based classroom.
- Allowing students to train even when physical equipment is not available.
- Allowing students to take preliminary training exams before live training on physical assets.
- Preparing students to make the most of the rare practical training opportunities they need most.
- For this purpose, HDM devices such as HoloLens are preferably used so that the user has his hands free [23].

C: HDM HoloLens

HoloLens *Figure 2.* is an HDM holographic computer that allows you to see, hear and communicate through holograms. Microsoft is still one of the leaders in the production of holographic glasses for interactive augmented reality, without the need to connect the device to a computer, as HoloLens are themselves computers. Microsoft has already come up with a second line of these devices, which are preferably used in industry, design, architecture, and medicine.

Recent studies during the COVID -19 pandemic have also made a positive contribution, with second line Hololens2 devices being used for many studies and research, whether to monitor the virus or as a tool to improve and afford access to healthcare. Perspective, observational, nested cohort assessment HoloLens2 was performed in three different clinical groups at a teaching hospital in the United Kingdom. Deployment of HoloLens2 resulted in a 51.5% reduction in exposure time for staff caring for patients with COVID-19. [16]

Optics

HoloLens uses layered thin glass plates, which form the lenses of glasses in several layers, which combines, diffracts, and layers the image so that it can be displayed in space.

The glasses are fitted with a support frame, which relieves the total weight of the glasses and distributes it evenly around the entire circumference. For their trouble-free use, it is necessary to illuminate the room and it at least partially is not yet possible to use them practically in an open space such as the street. Although the device is wireless, the company said that glasses in the interior of factories, offices and the like have a higher potential than on the street to fulfill their purpose [1].

It is the overall concept of HoloLens holographic device optics that makes them the leading and most widely used HDM device.

The overall optical imaging system consists of the following basic components: [7]

- micro display,
- imaging optics,
- merger unit,
- expansive grilles,
- wave conductor.

The entry and most important point for the optics of the functioning of holographic glasses is the human eye, specifically the pupil of the human eye.

Interpupillary distance further IPD is the distance of the pupils measured from the center of the first to the center of the second pupil of the human eye, which is given in millimeters. The second option is to measure the IPD from the center of the pupil of one eye to the root of the nose, and from the center of the other pupil to the root of the nose. In the second case, the measured value in millimeters is given in two numbers. [17]

The measured value is different for each individual and the standard determines the range in the range from 54 to 74 mm in adults and from 26 to 29 mm in children. As this information is essential in optics and different for each person, for the resulting sharpness of the image, it forms the most problematic point of development of any universal glasses, binoculars, or microscopes.

IPD resolution is an important technological data resulting from an anthropological study for the specification of the optimal range of output optics as well as the design of a wide range of binocular devices. [18]

HoloLens use total internal reflection, hereinafter referred to as TIR (total internal reflection), which is a phenomenon that occurs when the propagated wave strikes the middle boundary at an angle greater than a certain critical angle with respect to the normal surface. the incident angle is greater than the critical angle, the wave cannot pass and does not completely bounce in. We define the critical angle as the angle of incidence above which total internal reflections occur. material for making waveguides in lenses, but Microsoft decided to apply thin layers to the lenses as a surface treatment, creating a series of diffraction gratings. Several types of grids can be used to obtain RGB holograms. HoloLens uses layered thin glass plates that form the lenses of several glasses. [19]

Sensors

For each device, one of the most important parts of the device is the sensor, which records head movements, eye sensing, room mapping and allows photo documentation of the displayed content or video recording, whether HDM or other smart glasses.

Their quality and depth of processing is essential for the overall user interaction. By sensor we mean a camera and

in general there is a direct proportionality in the number of sensors to the quality of the overall user interaction with the image of augmented and virtual reality.

Hardware

HoloLens have their own system motherboard that works on the principle of mobile hardware with 64 GB for eMMC SSD and 2GB LPDDR3 RAM (1 GB for SoC and HPU) based on x86 running on Windows 10. [18]

The device battery is situated in the hoop and not subject to the need for secondary cooling. Power is via USB mini for HoloLens 2 and USB for HoloLens 2. [18]

The Holographic Processing Unit HPU 1.0 currently forms the in-depth infrastructure of all data

HPU 1.0 TSMC 28nm HPC has 65 million logical gateways, 8 MB SRAM and the above 1 GB LPDDR3 memory, for a 12x12 mm BGA package.

It has its own inputs and outputs, as well as PCIe and MIPI and 12 computing nodes. The resulting component is manufactured on a high-performance compact TSMC mobile computing process with a power of 28 nm, which is optimized for low performance and more compact distribution. It has dimensions of 144 mm² and contains ~ 65 million logical gates. [18]

The interconnect between the computer nodes is 8 MB of SRAM and, like CherryTrailSoC, the Microsoft HPU has 1 GB of LPDDR3 in the package. All around the HPU, serial interfaces allow communication with the subsystems that enter the HPU. For example, the CSI of the MIPI alliance is used to collect inputs from a depth camera and four cameras to understand the environment. MIPI-DSI connects both screens. The HoloLens Inertial Measurement Unit (IMU) is connected to the HPU via the SPI. The temperature sensor is activated via the I²C interface, like the CherryTrail chip. [18]

Figure 2. HoloLens interface.

CONCUSION

If we consider all previous studies dealing with the use of augmented reality in education, we come across an overall positive benefit. The current world-class challenge is to sustain or increase production capacity of a higher quality with fewer inputs to reduce time, cost, and equally enhance planning productivity.

Bacca et al. developed a systematic review of the literature analyzing 30 works. These systematic reviews examine the occurrence of AR-mediated learning processes and the progress of AR in the educational context. He listed the advantages of AR in educational processes, among which the growth of learning, motivation, interaction, and cooperation stands out. The study confirms that augmented reality is an ideal technology for the development of educational processes. [20]

The disadvantage is the dynamically growing development of application technologies, which is reflected in the high price, and many times until the service is procured, the service is obsolete. It can therefore be assessed that interactive augmented reality applications using HDM devices such as Hololens are not suitable for public educational institutions subject to lengthy tenders. Today, schools support non-formal education and non-formal education centers create formal education programs. All this leads us to the fact that between formal and non-formal education there is continuity in what pedagogical architecture would be, and complementarity in terms of its practical development. [22] On the contrary, for the private sector they can be an adequate attraction for acquiring new clients, for example in the field of retraining and qualification professional courses.

IV. AUGMENTED REALITY FOR UAV EXPERIMENTS

One of the areas where research and experimental activities are currently underway is the use of AR in the field of intra building logistics. As many companies deal with drone navigation in manufacturing industry (within production lines or hangars) – usage of Augmented Reality seems to be promising technology as part of the design process.

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REFERENCES

[1] Robert Tomšik, Introduction to Methodology and Statistical Processing, Nitra. 2017. pp. 16. ISBN 978-80-558-1206-9

[2] Ronald T. Azuma; A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments 1997; 6 (4): 355–385. doi: https://doi.org/10.1162/pres.1997.6.4.355

[3] Andujar Marquez, Jose & Borrero, A. & Marquez, Marco. (2011). Augmented Reality for the Improvement of Remote Laboratories: An Augmented Remote Laboratory. Education, IEEE Transactions on. 54. 492 - 500. 10.1109/TE.2010.2085047.

[4] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier and B. MacIntyre, "Recent advances in augmented reality," in IEEE Computer Graphics and Applications, vol. 21, no. 6, pp. 34-47, Nov.-Dec. 2001, doi: 10.1109/38.963459.

[5] Craig, Alan & Sherman, William & Will, Jeffrey. (2009). Developing Virtual Reality Applications: Foundations of Effective Design. 10.1016/C2009-0-20103-6.

[6] J. R. Vallino. 1998. Interactive Augmented Reality. Technical Report. University of Rochester, USA.

[7] I. Jančíková. Využitie rozšírenej reality v strojárenskej praxi Diploma thesis, Technical University of Košice

[8] Park, Min & Lim, Kyu & Seo, Myoung & Jung, Soon & Lee, Hiu Kwan. (2014). Spatial augmented reality for product appearance design evaluation. Journal of Computational Design and Engineering. 21. 10.1016/j.jcde.2014.11.004

[9] Wang, Zhan, Shoudong Huang, and Gamini Dissanayake. Simultaneous Localization and Mapping: Exactly Sparse Information Filters. Vol. 3. World Scientific, 2011.

[10] Celalettin Aktaş, The Evolution and Emergence of QR codes, 114 pp. ISBN: 9781443850650

[11] Kuei-Fang Hsiao, Nian-Shing Chen & Shih-Yu Huang (2012) Learning while exercising for science education in augmented reality among adolescents, Interactive Learning Environments, 20:4, 331-349, DOI: 10.1080/10494820.2010.486682

[12] Eastman, Jacqueline & Iyer, Rajesh & Eastman, Kevin. (2011). Interactive Technology In The Classroom: An Exploratory Look At Its Use And Effectiveness. Contemporary Issues in Education Research (CIER). 2. 31. 10.19030/cier.v2i3.1084.

[13] Rosenbaum, Eric & Klopfer, Eric & Perry, Judy. (2007). On Location Learning: Authentic Applied Science with Networked Augmented Realities. Journal of Science Education and Technology. 16. 31-45. 10.1007/s10956-006-9036-0.

[14] URL: https://learninglovers.org/2015/05/06/learnar/

[15] URL: http://pbskids.org/mobile/fetchlunch-rush.html

Martin G, Koizia L, Kooner A, Cafferkey J, Ross C, Purkayastha S, Sivananthan A, Tanna A, Pratt P, Kinross J, PanSurg Collaborative Use of the HoloLens2 Mixed Reality Headset for Protecting Health Care Workers During the COVID-19 Pandemic: Prospective, Observational Evaluation, Med Internet Res 2020;22(8):e21486

[16] URL: https://en.wikipedia.org/wiki/Pupillary_distance.

[17] URL: https://www.tomshardware.com/news/microsoft-hololens-components-hpu-28nm,32546.html

[18] Szajna A, Stryjski R, Woźniak W, Chamier-Gliszczyński N, Kostrzewski M. Assessment of Augmented Reality in Manual Wiring Production Process with Use of Mobile AR Glasses. Sensors. 2020; 20(17):4755. https://doi.org/10.3390/s20174755

[19] Raynel Mendoza, Silvia Baldiris, Ramon Fabregat,Framework to Heritage Education Using Emerging Technologies,Procedia Computer Science,Volume 75,2015,Pages 239-249,ISSN 1877-0509

[20] Javad Navaei & Hoda ElMaraghy (2018) Optimal operations sequence retrieval from master operations sequence for part/product families, International Journal of Production Research, 56:1-2, 140-163, DOI: 10.1080/00207543.2017.1391417

[21] Colom Cañellas, Antoni Joan, Revista de educación. Madrid, 2005, n.338, p.9-22.

[22] URL: https://www.ptc.com/en/case-studies/vectrona-immersive-augmented-reality-training-with -us-airforce.

[23] URL: https://www.ptc.com/en/case-studies/henkel-real-time-remote-support-augmented-reality.