Experience in developing and implementing virtual tours using 360° video technology in the educational environment

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Abstract

The article examines the specifics of such a modern immersive technology as 360° video. Its characteristics, varieties, and possibilities of application in the educational process are considered, including the peculiarities of training specialists in the publishing and printing industry, which requires a combination of theoretical knowledge and practical skills. 360° video technology allows creating interactive and immersive content that provides an immersive effect, demonstration of real production processes, modelling of complex situations and learning technologies. The potential of 360° video technology to increase the efficiency of learning through visualisation of material, interactivity and active interaction of students with content is determined. The experience of developing and implementing 360° video technology in the educational environment within the framework of an educational project on the development of a virtual tour is described. The article presents the methodology for implementing an educational project to create 360° video, which includes theoretical training, mastering software and hardware, and practical work on creating and processing video content. The practical result of the study is the creation of a virtual university tour, demonstrating the application of innovative solutions in the professional training of students.

Keywords

sound design, artificial intelligence, sound creation for music, Suno AI, sound plugins, visual novels, AudioGen

1. Introduction

Changes in society, technologies and the labour market require constant modernisation of educational programmes and teaching methods. Higher education should prepare specialists capable of flexibly adapting to new challenges. The use of modern technologies, which are becoming an integral part of any field of activity, is a key aspect of such training. Among the latest technologies, immersive technologies, which are gaining increasing popularity and widespread use, are of particular interest.

Today, augmented reality technologies are characterised by active implementation in world educational practice [1], bringing education to a significantly new level. They form new approaches to teaching and learning educational material and a new education system in general, acting as one of the indicators of educational innovation [2, 3].

As noted by scientists, immersive technologies are used as a collective nomination for human interaction with space, information, content on the verge between the real and the unreal product of virtual, augmented or mixed realities [4, 5]. That is, immersive technologies are a general name for technologies that provide an experience of full or partial immersion in an alternative space or a combination of it with the real world [6, 7]. Immersive technologies include:

- virtual reality (VR),

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- augmented reality (AR),
- mixed reality (MR),
- extended reality (XR), which combines AR and VR technologies,
- 360° photos and videos.

All these types of immersive technologies provide new approaches to the implementation of educational activities beyond the previous limitations of human perception. They represent innovative methods of creating, demonstrating and human interaction with content. The essence of these technologies is to combine the real world with the virtual one. By expanding human experience and going beyond spatial limitations, they immerse the user in the virtual world and provide an opportunity to perceive immersive content differently: not only to see and hear, but also to touch or connect other sensory sensations, or even to "be" a part of it. Scientists agree that the use of immersive technologies in educational practice has many advantages [8, 9, 10], in particular, interest, increased motivation to learn, visualisation of educational content, personalisation of learning, providing feedback, real experience and communication, development of critical thinking.

Among the immersive technologies used in education, AR and VR technologies are most often mentioned. Their potential for creating engaging and effective learning environments is truly undeniable [11]. However, no less interesting and relevant is the 360° technology (panorama and video), which offers a more accessible and simpler way to immerse users in different contexts.

The directions of application of immersive technologies in higher education are also very wide. In the domestic educational space, there is experience of their use in the training of future specialists in the field of linguistics [12], mechanical engineers [13], teachers [14], etc. However, the possibilities of their application in the training of publishing and printing specialists remain insufficiently studied, which opens new prospects for research.

The aim of the study is to reveal the specifics of 360° video technology, determine its didactic potential and possibilities of application in the professional training of future specialists in publishing and printing in the context of the implementation of educational projects (using the practical experience of creating virtual video tours as an example).

2. Results

The modern educational process, which in today's conditions is forced to move into the digital space, requires a review of approaches to the organisation of the information and educational environment and the formation of educational content. Under such conditions, the use of immersive technologies is not just a tribute to a popular educational trend, but an urgent necessity to involve students in learning and make their activities informative, exciting and effective.

This is especially important in the training of specialists in the publishing and printing industry, which combines technical, production and creative aspects. The training of specialists in this field requires extensive use of visual materials, such as samples of printed products, demonstrations of production processes and equipment. The use of immersive technologies will allow students not only to theoretically master the material, but also to gain practical experience, will provide an opportunity not just to passively observe, but to actively interact with the educational content. This allows for a deeper immersion in the material, consolidation of knowledge and makes the learning process more interesting and effective [15].

However, despite the fact that scientists and educators make significant efforts to implement immersive technologies in educational practice, their widespread use is complicated by a number of factors. In particular, technological, organisational and financial challenges hinder the large-scale virtualisation of learning [16]. In view of this, 360° video technology is a more convenient, realistic and accessible version of VR [17].

360° technology is one of the most recognisable forms of immersion technology that creates a virtual reality experience by which users can immerse themselves in a 360° digital environment. 360° technology

comes in two types: 360° panorama and 360° video. 360° panoramas or videos are visual constructs in which images or videos in all directions are captured and presented simultaneously [18].

Within the framework of this study, the technology of 360° video is of particular interest. It is a specific video format that has the characteristics of virtual reality, but at the same time differs from it in the necessary real recording situation without programmed virtual environments [19]. Unlike traditional flat 2D video clips, 360° video is recorded simultaneously in all possible directions with a viewing angle of 360° horizontally and 180° vertically, giving the viewer expanded access to the video object. In addition, due to its specifics, this technology, when viewing, really gives the impression of being present in the scenes, provides opportunities for the viewer to change the viewing parameters in several viewing angles and from any perspective and interact with the elements of the scene.

That is why 360° video is often called spherical or immersive video. In turn, 360° video can be of several types [18, 20]. Figure 1 shows its varieties, depending on the type of image used, the method of creation and the interactive capabilities that the user receives to interact with the content during viewing.

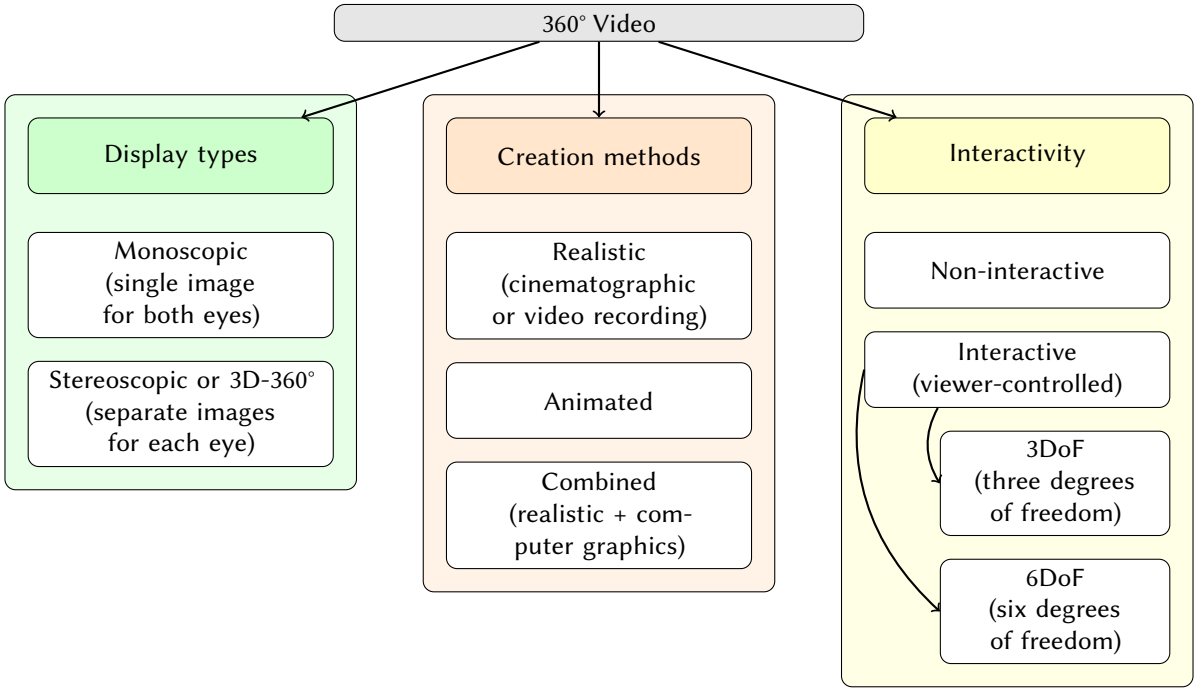

Figure 1: Types of 360° video (based on [18, 20]).

On the one hand, 360° technology is a kind of video, but it differs significantly from the usual video materials, because it provides a feeling of immersion in the broadcast environment, which brings it closer to augmented and virtual reality, because like AR/VR, it conveys a sense of presence and allows interaction with the virtual environment. However, unlike AR/VR, 360° video only creates the effect of presence, allowing the user to freely rotate and view the image from any angle, as if they were directly at the filming location, but does not provide such powerful sensory sensations of full presence.

For example, 360° video that supports 3DoF (three degrees of freedom) gives the user the following capabilities: look forward and backward, side to side, and shoulder to shoulder, that is, in any direction in which the head can rotate. You can also use hand controllers to manipulate some objects or perform certain actions, but 3DoF limits you to being tied to one place, so it is often called fixed virtual reality. 6DoF means six degrees of freedom: the ability to change the position of the head and body while viewing content [18].

For example, VR uses the power of computer technology to create a simulated environment that can be explored and interacted with fully immersed and replaces the “real” world with an alternative one, while AR overlays computer-generated images on an existing space in the real world, complementing

and expanding it and thus providing an exciting learning experience [21, 22]. And although interaction with the created 360° environment is quite limited compared to AR/VR, a great advantage of this technology is its greater simplicity and accessibility in creation and use.

Table 1 shows a comparison of the features of the three immersive technologies in terms of such important characteristics as the properties of the projected environment, the level of immersion and the type of interaction in the immersive environment, the equipment for its use, the design approach and possible directions of application in the educational process.

Table 1
Comparison of AR, VR and 360° video (based on [21, 22]).

Characteristic	VR	AR	360° video
Environment	Completely artificial	Overlaying artificial elements on the real physical world	Real, but with panoramic view
Level of immersion	Maximum	Medium	Medium
Type of interaction	Active, with objects	Active, with objects and the real world	Passive, content viewing, viewing control
Equipment for use	VR headset, controllers	Smartphone, tablet, special glasses	Smartphone, PC, VR headset
Content creation	Complex, requires full computer modelling of an artificial world	Relatively simpler, overlaying computer-generated images on the real world through special devices	Simpler, does not require computer modelling, shooting with a 360-degree camera
Application in education	Simulations, virtual laboratories	Interactive textbooks, virtual excursions	Virtual excursions, tours, process demonstrations, etc.

Given its features, 360° video is gaining popularity in the field of education. Scientists determine the powerful didactic potential of this technology [19, 23, 24]. 360° videos allow students to observe a scene in any direction, giving them the opportunity to virtually explore an imaginary world or view a real recording of the real world. On smartphones, when they move and rotate their devices left and right or up and down, the images they see move in perfect synchronisation; on laptops and desktops, they can easily navigate spherical 360-degree videos by clicking and dragging navigation buttons, or using a mouse or touch screen [23]. Thus, 360° technology allows creating interactive and immersive learning environments that help gain new knowledge and skills in an engaging and effective way.

With the help of this technology, compared to traditional learning, it is possible to create a learning experience that would be impossible or extremely difficult in dangerous or hard-to-reach conditions [25]. Thanks to it, students can visit remote or restricted places, such as historical and cultural monuments, museums, laboratories, industries and distant countries; study complex concepts in a more accessible and interesting way; conduct virtual tours, as if being among the exhibits and explore objects from all sides. In each of these cases, learners act as active participants in the learning process, not passive consumers of information.

Regarding the peculiarities of training future specialists in the publishing and printing field, 360° technology can become a powerful and accessible tool for creating immersive educational materials and building an educational environment. Considering the specifics of the industry, 360° materials can be used to provide the following educational goals:

- demonstration of production processes and functioning of printing equipment (360° video allows to clearly show all stages of production and creates the effect of full immersion in the professional environment);

- modelling of complex, risky production situations, minimising the risks of errors, which is critically important in real production;
- research of printing technologies and comparison of different technical solutions;
- familiarisation with printing materials, demonstration of their properties and peculiarities of use;
- demonstration of interaction of specialists in production, which helps to better understand the coordination of work in the printing shop;
- practical study and analysis of the principles of composition construction, selection of fonts, textures and colour schemes in real projects, carrying out a detailed study of samples of publication design in an extended space;
- study of the history of the industry and its current state;
- development of "visual perception" and formation of creative skills;
- creation of presentations and development of communication skills (360° video is an innovative tool that students can use to create special and visual presentations of their work and research).

In form, such 360° educational materials can be very diverse: virtual excursions and tours to real enterprises / exhibitions / galleries / museums, virtual demonstrations, virtual production quest rooms, simulators, seminars, educational videos. In addition, 360° video can be combined with other technologies (for example, adding AR markers or 3D models). A set of materials on one topic can be structured in the form of an immersive educational module, as a separate completed block of learning, and become an important component of an interactive educational environment.

However, 360° video can be not only an educational technology that helps in the study of certain academic disciplines, but also an object of study and a learning tool. Thus, at the Department of Computer Multimedia Technologies of the State University 'Kyiv Aviation Institute" there are a number of educational disciplines, the purpose of which is to study various interactive and immersive technologies, including 360° video technology. And one of the best ways to master them is not just a theoretical acquaintance with the specifics and features of the technology, but the implementation in practice of a real project using it. In this way, students gain real practical experience working with modern technologies, taking on the functions of creative content developers.

Based on this, at the Department of Computer Multimedia Technologies, together with students, an educational project was implemented and a 360° video tour of the university territory was created. The experience of implementing an educational project showed that it is most appropriate to organise it in several consecutive stages (figure 2).

Before starting to create a real 360° video, it is necessary for students to already have a sufficient set of practical skills in working with a set of tools. They master various programs and equipment necessary for work: they acquire practical skills in the use of hardware (photo and video cameras, PCs, other devices) and software (video and audio editors, editing programs, etc.). In addition, they already have knowledge of composition construction and optimisation of visual content (colour adjustment, light, aesthetics of the frame).

The second stage is theoretical preparation. Students need to be introduced to the specifics of the new technology. This stage involves assimilation of the essence of 360° technology, its capabilities and scope, basic concepts and terminology related to 360° and theoretical aspects of the application of this technology in real projects. It is also important to acquire initial knowledge about the principles of operation of 360° cameras, features of shooting and processing of this type of content.

Having theoretical knowledge and basic skills, the next step for students is to move on to the practical stage: the implementation of a real 360° project. They were given a specific task, which was to create a 360° video tour of the university territory. The project itself was implemented in two major stages. The first was to create video materials, and the second was to process them and compile them into a single material with subsequent publication on the Internet for further viewing.

At the first stage, an analytical review of existing similar materials was carried out, the concept and script of the video were developed, equipment and software were selected, and video shooting and synchronous recording of the sound accompaniment were conducted. The type of video tour

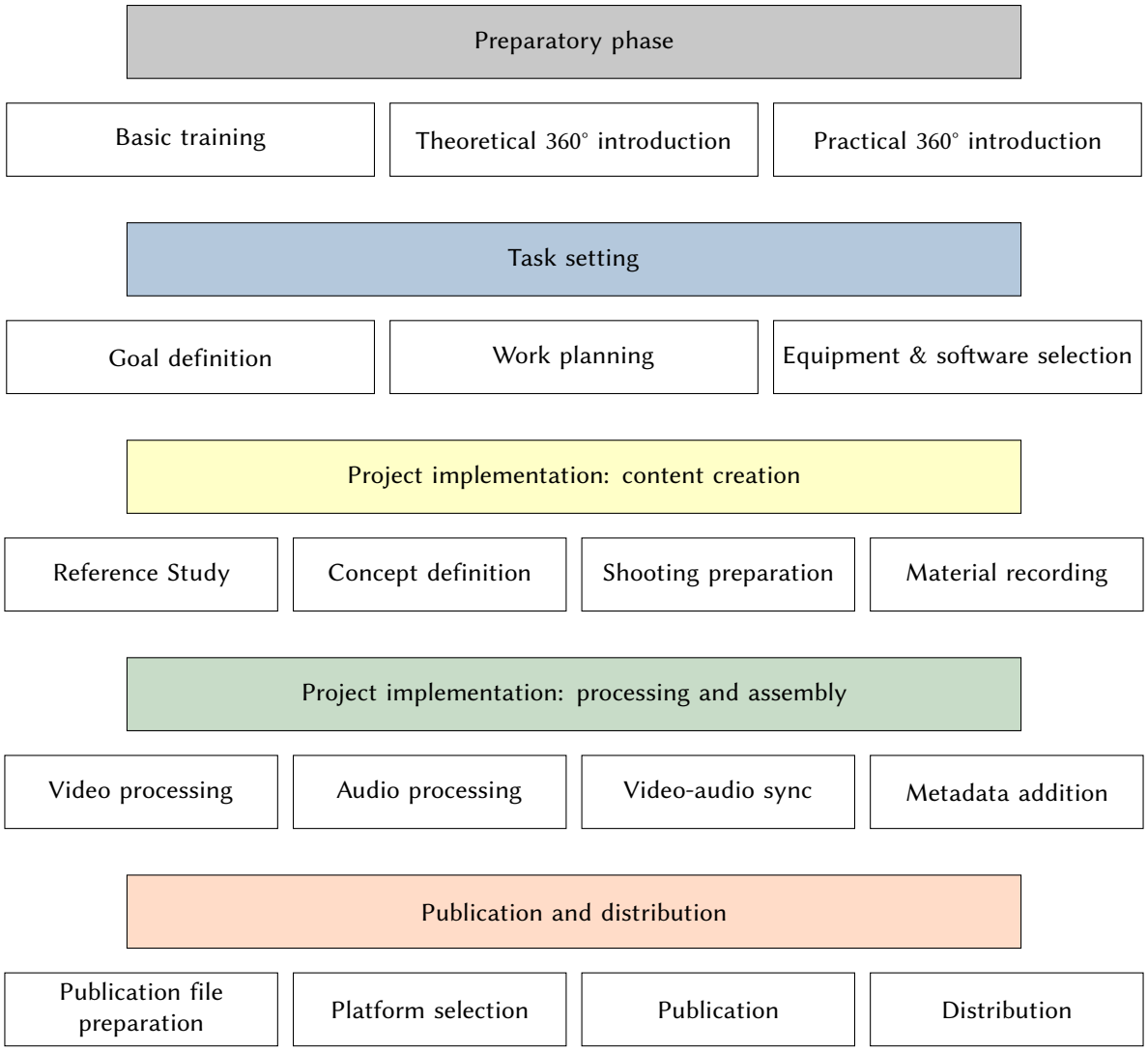

Figure 2: Stages of implementation of an educational project to create a 360° video.

that was created is a review of notable places with a presenter. This format is characterised by high informativeness, is emotional and provides visual contact with the audience.

Technically, the 360° video was created by simultaneously shooting two 180° frames together. That is, two 180° shots make up one 360° frame. To do this, you need to use special 360° cameras that have special characteristics that distinguish them from ordinary video cameras. The main difference is that the 360° camera immediately takes a panoramic image, covering the entire space around without the need to use multiple cameras or take separate frames. This makes the shooting process simpler and more accessible for new users. The user can also easily select the desired parameters for shooting, and the captured material is ready immediately for processing, and the video processing process itself takes less time.

The Samsung Gear 360 camera was used for shooting due to its advantages such as affordability, wide setting options during shooting, compatibility with processing programs, and large memory capacity. A tripod and a smartphone with a downloaded application were also used, where the necessary camera settings were set.

An important task at this stage was the preliminary sketching of frames, which included detailed planning of their compositional construction. Special attention was paid to determining the line of symmetry and the horizon line, which play a key role in creating a balanced and harmonious image. The distance from the camera to the presenter and key shooting elements was also calculated, which allows

the objects to be correctly positioned in the frame, ensuring their optimal visibility and interaction in space. Such careful planning of the compositional construction helps to avoid technical errors during 360° video shooting and ensures a high-quality final result, both in terms of technical implementation (focusing, object placement) and aesthetic perception of the frame. Figure 3 shows the sketching of the frame and the captured 360° frame.

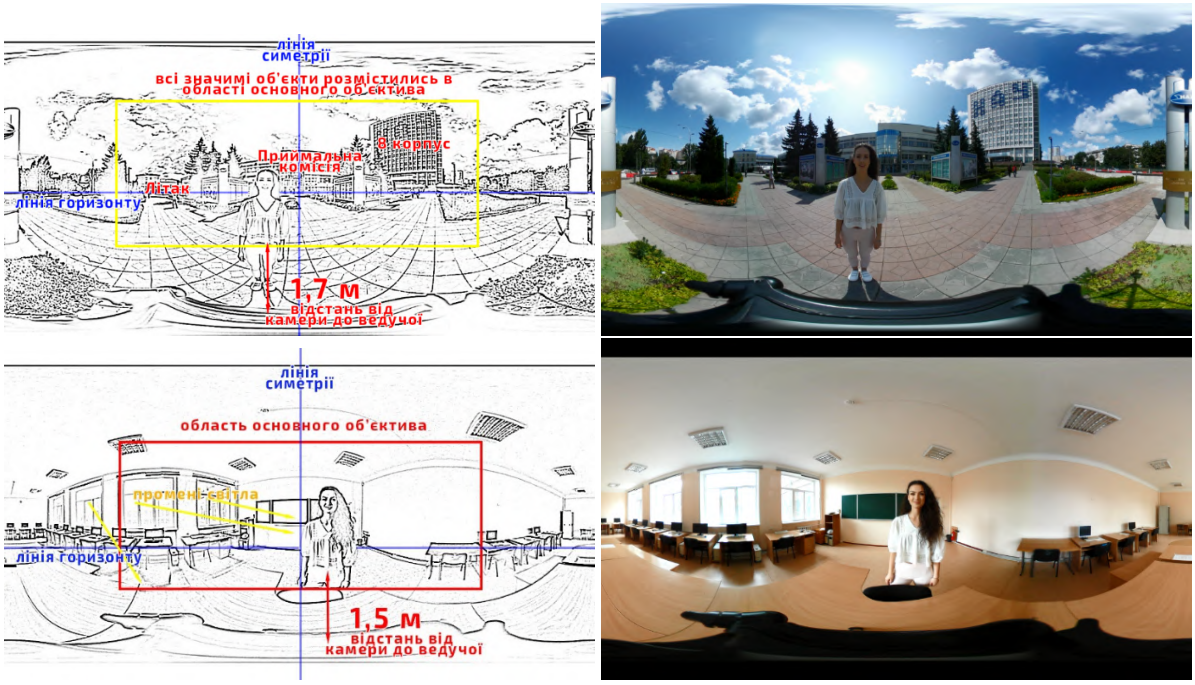

Figure 3: Sketch and captured frame.

At the second stage, all the captured materials were processed (video stitching, frame cropping, colour correction, sound processing, video clip editing) and exported in 360° video format. A set of software was used to process the materials. In Gear 360 ActionDirector, the videos obtained from the two lenses were stitched together into one video sequence, the best frames were selected and the entire video material was trimmed, and colour correction was performed. This program was chosen because it comes with the camera and does not require additional costs for purchase, and it has many additional technical possibilities for post-processing the captured video (setting transitions, overlaying titles, optimisation, etc.) like other well-known powerful applications. Figure 4 shows the video stitching process.

Figure 4: Video stitching.

In Adobe Audition CC, the audio accompaniment was processed, audio tracks were cleaned of noise to improve the sound. In Adobe Premiere Pro, video and audio tracks were synchronised and background music was added.

In order to distribute the created 360° video, the participants of the educational project finalised the metadata of the file so that it would be recognised by video hosting services. For this purpose, Spatial Media Metadata Injector was used. Figure 5 shows the final material of the 360° video tour placed on the website of the Faculty of International Relations.

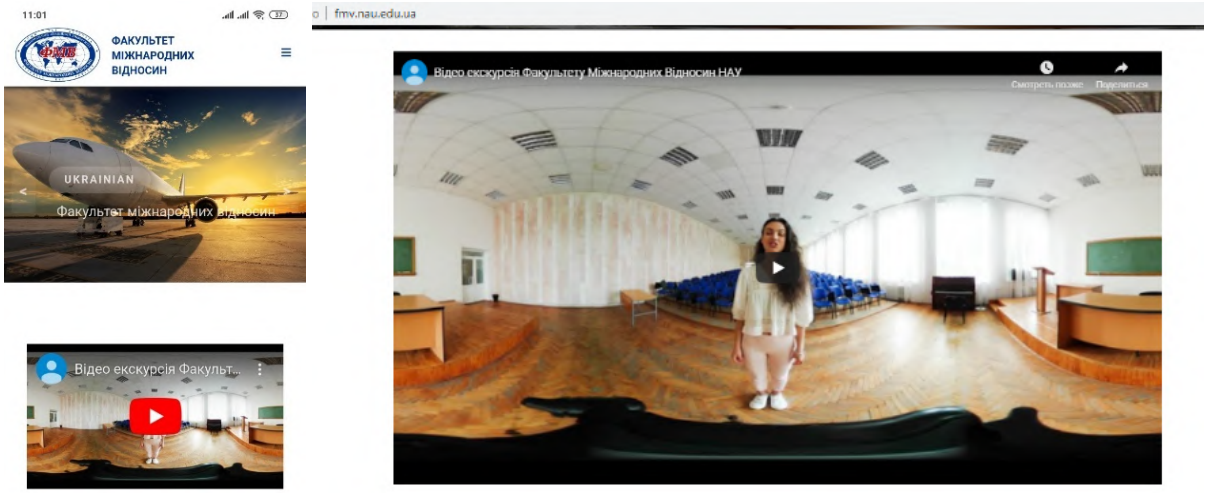

Figure 5: 360° video tour.

As you can see, although 360° video technology is simpler than full-fledged VR, it requires the use of certain hardware and software components and the availability of special knowledge and skills. When it comes to software solutions, special programs and applications are necessary, with the help of which you can create, edit and play engaging content. Appropriate hardware is also necessary, which is used both at the stage of creating and processing materials, and is necessary for viewing immersive content. With their use, you can implement projects that are extraordinary in appearance.

The Department of Multimedia Systems and Technologies of the Simon Kuznets Kharkiv National University of Economics, in cooperation with the Department of Computer Multimedia Technologies of the State University "Kyiv Aviation Institute", is developing another direction of using various interactive and immersive technologies in the educational process. Thus, when creating the content of multimedia didactic complexes for the digital educational space of the educational-professional program 'Technologies of Electronic Multimedia Publications", 360° video technologies are used. This project involves structuring knowledge based on the approach of Nonaka and Takeuchi [26], taking into account the peculiarities of the educational process in pedagogical design.

Of the four types of knowledge (unformalized, weakly formalised, conceptual, systemic scientific-theoretical knowledge), the project selects the first two types of knowledge for a given topic, which provide answers through visual and verbal tools to the questions: "how is it done", "how is it used and why"; "how is it designed and manufactured". The use of 360° video technology allows solving a wide range of didactic tasks: ensuring the perception, memorisation of knowledge, ways of action (including at the level of application in a changed situation), connections and relations in the object of study; establishing the correctness of the assimilation of educational material; ensuring the assimilation of knowledge and methods of action [27]. This approach is advisable to use to create visual content for such disciplines as "Packaging Design", "Illustration", "Computer Animation and Virtual Reality", "3D Modeling".

As part of the international project "Methods of Distributed Development of Computer Games", students of EPP "Technologies of Electronic Multimedia Publications", who are engaged in the scientific circle "Augmented Reality and Computer Games: Methods of Content Development and Animation", took part in the Online Pitching Event at the University of Bayreuth (Germany). The results of such testing showed the feasibility of continuing research and development of immersive technologies in this direction.

3. Conclusions

360° video technology, which is based on the creation of panoramic content, provides the effect of presence and immersion. Its difference from AR/VR is greater accessibility due to lower hardware requirements and a simpler creation process. And although the level of interactivity in 360° video is limited compared to AR/VR, where the user has the opportunity to actively interact with the virtual environment, this technology has significant didactic capabilities, in particular, in the training of publishing and printing specialists. Due to the possibility of visually rich immersion, this technology allows students not only to effectively master educational material, but also to directly approach real professional tasks. The creation of 360° video promotes the development of critical thinking, creative abilities and technical skills in working with equipment and software, which are important components of professional competence. The practical experience of creating virtual tours using 360° video technology in educational projects has shown that this approach in the educational process is extremely effective. On the one hand, students became acquainted with one of the most relevant modern immersive technologies through their own practical experience. On the other hand, the developed methodology for creating 360° video tours has come in handy for other students who can create their own exciting projects. And finally, the created 360° video tour is not just another educational task, it is a real product that is used in practice.

Prospects for further scientific research are seen in the study of other aspects of 360° video development and the possibilities of using this immersive technology in higher education. In particular, it is planned to continue creating 360° videos to enrich the educational environment with high-quality immersive content: video tours shot at real objects, classrooms, university laboratories, at production facilities of stakeholders, as well as video content about the functioning of complex and hard-to-reach objects (inside airplanes, engines, other aircraft systems, etc.). It is also important to continue work on the development of methodological recommendations for their use of 360° video in the educational process. A special potential is seen in the creation of virtual excursions and tours in 360° format, which will allow students to gain practical skills and feel themselves in the conditions of real professional activity, even while being in the classroom.

Declaration on Generative AI: The authors have not employed any Generative AI tools.

References

[1] M. M. Mintii, N. M. Sharmanova, A. O. Mankuta, O. S. Palchevska, S. O. Semerikov, Selection of pedagogical conditions for training STEM teachers to use augmented reality technologies in their work, Journal of Physics: Conference Series 2611 (2023) 012022. doi:10.1088/1742-6596/2611/1/012022.

[2] S. O. Semerikov, M. V. Foki, D. S. Shepiliev, M. M. Mintii, I. S. Mintii, O. H. Kuzminska, Methodology for teaching development of web-based augmented reality with integrated machine learning models, CEUR Workshop Proceedings 3820 (2024) 118–145.

[3] S. O. Semerikov, M. M. Mintii, I. S. Mintii, Review of the course "Development of Virtual and Augmented Reality Software" for STEM teachers: Implementation results and improvement potentials, CEUR Workshop Proceedings 2898 (2021) 159–177.

[4] S. H. Lytvynova, S. O. Semerikov, A. M. Striuk, M. I. Striuk, L. S. Kolgatina, V. Y. Velychko, I. S. Mintii, O. O. Kalinichenko, S. M. Tukalo, AREdu 2021 - Immersive technology today, CEUR Workshop Proceedings 2898 (2021) 1–40.

[5] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, V. N. Soloviev, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, D. S. Shepiliev, Immersive E-Learning Resources: Design Methods, in: Digital Humanities Workshop, DHW 2021, Association for Computing Machinery, New York, NY, USA, 2022, p. 37–47. doi:10.1145/3526242.3526264.

[6] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, O. V. Bondarenko, P. P. Nechypurenko,

S. V. Shokaliuk, N. V. Moiseienko, Designing an immersive cloud-based educational environment for universities: a comprehensive approach, CEUR Workshop Proceedings 3844 (2024) 107–116.
[7] S. Palamar, K. Brovko, S. Semerikov, Enhancing Foreign Language Learning in Ukraine: Immersive Technologies as Catalysts for Cognitive Interest and Achievement, CEUR Workshop Proceedings 3624 (2023) 69–81.
[8] M. A. Kuhail, A. ElSayary, S. Farooq, A. Alghamdi, Exploring Immersive Learning Experiences: A Survey, Informatics 9 (2022) 75. doi:10.3390/informatics9040075.
[9] P. MacDowell, J. Lock, Immersive Education: Designing for learning, Springer, Cham, 2022. doi:10.1007/978-3-031-18138-2.
[10] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, Immersive cloud-based educational environment of the university: Design principles, CEUR Workshop Proceedings 3771 (2024) 126–135.
[11] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, Development of digital competencies in immersive cloud-based educational environment, CEUR Workshop Proceedings 3781 (2024) 203–208.
[12] R. O. Tarasenko, S. M. Amelina, S. O. Semerikov, V. D. Shynkaruk, Using interactive semantic networks as an augmented reality element in autonomous learning, Journal of Physics: Conference Series 1946 (2021) 012023. doi:10.1088/1742-6596/1946/1/012023.
[13] A. Striuk, M. Rassovytska, S. V. Shokaliuk, Using Blippar Augmented Reality Browser in the Practical Training of Mechanical Engineers, in: V. Ermolayev, M. C. Suárez-Figueroa, V. Yakovyna, V. S. Kharchenko, V. Kobets, H. Kravtsov, V. S. Peschanenko, Y. Prytula, M. S. Nikitchenko, A. Spivakovsky (Eds.), Proceedings of the 14th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops, Kyiv, Ukraine, May 14-17, 2018, volume 2104 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2018, pp. 412–419. URL: https://ceur-ws.org/Vol-2104/paper_223.pdf.
[14] S. O. Semerikov, A. M. Striuk, Augmented Reality in Education 2023: innovations, applications, and future directions, CEUR Workshop Proceedings 3844 (2024) 1–22.
[15] S. Denysenko, Pedagogical Design: Study Guides with Interactive Elements, Viae Educationis: Studies of Education and Didactics 3 (2024) 23–31. URL: https://czasopisma.marszalek.com.pl/images/pliki/ve/9/ve903.pdf.
[16] S. Papadakis, A. E. Kiv, H. M. Kravtsov, V. V. Osadchyi, M. V. Marienko, O. P. Pinchuk, M. P. Shyshkina, O. M. Sokolyuk, I. S. Mintii, T. A. Vakaliuk, L. E. Azarova, L. S. Kolgatina, S. M. Amelina, N. P. Volkova, V. Y. Velychko, A. M. Striuk, S. O. Semerikov, Unlocking the power of synergy: the joint force of cloud technologies and augmented reality in education, CEUR Workshop Proceedings 3364 (2023) 1–23.
[17] M. Evens, M. Empsen, W. Hustinx, A literature review on 360-degree video as an educational tool: towards design guidelines, Journal of Computers in Education 10 (2023) 325–375. doi:10.1007/s40692-022-00233-z.
[18] J. Cameron, G. Gould, A. Ma, 360 Essentials: A Beginner's Guide to Immersive Video Storytelling, Ryerson University Library Toronto, 2024. URL: https://pressbooks.library.torontomu.ca/360essentials/.
[19] P. Rosendahl, I. Wagner, 360° videos in education – A systematic literature review on application areas and future potentials, Education and Information Technologies 29 (2024) 1319–1355. doi:10.1007/s10639-022-11549-9.
[20] S. Stumbo, Getting started in interactive 360 video: Download our sample project, 2018. URL: https://unity.com/blog/games/getting-started-in-interactive-360-video-download-our-sample-project.
[21] V. Nolan, Augmented Reality, Virtual Reality, and 360 Video: What's the Difference?, 2018. URL: https://crewscontrol.com/blog-central/augmented-reality-virtual-reality-and-360-video-whats-the-difference/.
[22] S. Gardonio, What's the Difference Between VR, AR, MR, and 360?, 2024. URL: https://www.iotforall.com/difference-between-vr-ar-mr-360.
[23] J. Pirker, A. Dengel, The Potential of 360° Virtual Reality Videos and Real VR for Education—A

Literature Review, IEEE Computer Graphics and Applications 41 (2021) 76–89. doi:10.1109/MCG.2021.3067999.

[24] A. Haimi, M. Adnan, M. Syafiq, Y. Shak, R. A. Karim, M. Haniff, M. Tahir, D. S. M. Shah, 360-Degree Videos, VR Experiences and the Application of Education 4.0 Technologies in Malaysia for Exposure and Immersion, Advances in Science, Technology and Engineering Systems Journal 5 (2020) 373–381. doi:10.25046/aj050148.

[25] S. H. Lytvynova, Methodical aspects of using 360-degree video in blended learning conditions, Scientific Notes. Series: Pedagogical Sciences (2024) 279–286. doi:10.36550/2415-7988-2024-1-213-279-286.

[26] I. Nonaka, H. Takeuchi, The knowledge creating company: how Japanese companies create the dynamics of innovation, Oxford University Press, New York, 1995. doi:10.1080/23735082.2023.2272611.

[27] O. I. Pushkar, The concept of creating multimedia tools for the educational space of dual education, Printing and Publishing 1(85) (2023) 101–122. URL: http://repository.hneu.edu.ua/handle/123456789/30490.