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OPPORTUNITIES, CHALLENGES AND SOLUTIONS FOR DIGITAL TRANSFORMATION OF THE EDUCATIONAL PROCESSES THROUGH 3D TECHNOLOGIES

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Abstract. The modern 3D technologies allow the development and visualization of three-dimensional objects and environments in the digital world, as well as the physical recreation of the digital contents through various specialized systems and solutions. The 3D technologies have the potential to catalyse the digital transformation of the education, through the technologies for virtual reality, augmented reality and 3D printing. Using these technologies, the teachers can change not only the way they conduct classes, but also the methods for learning and studying of the students. The integration of the 3D technologies in the educational processes is characterized not only by many new opportunities, which they are offering, but also by the big number of challenges, which they present. For this reason, this publication presents the main opportunities, challenges and solutions for digital transformation of the educational processes through the use of the various 3D technologies.

Keywords: 3D technologies; education, digital transformation; 3D scanning; 3D printing; 3D modelling; photogrammetry; virtual and augmented reality

1. Introduction

In the recent years, the educational domain underwent significant transformations, which were primary driven by the numerous advancements in the area of the digital technologies (Johnson et al. 2015; Redecker & Punie 2017). The three-dimensional (3D) technologies were also part of these digital transformative tools and have emerged as powerful enablers, which have offered unprecedented opportunities to reimagine and enhance the educational processes (Pantelidis 2010). From Virtual Reality (VR) and Augmented Reality (AR) to 3D modelling and printing, the 3D technologies are holding the potential to revolutionize the teaching and learning experience for many of the present-day classes in the schools and the universities (Johnson et al. 2010).

The integration of the 3D technologies into the educational processes is offering a plethora of opportunities to enrich the learning experiences and to foster deeper engagement among the students at all educational levels (Pantelidis 2010). Through immersive simulations, interactive visualizations and hands-on experiments, the 3D technologies can facilitate the experiential and practical learning and can provide the students with the opportunity to explore complex concepts with greater clarity and better understanding (Johnson et al., 2010). Moreover, these technologies can be adapted to the different teaching and learning styles and can be easily used to promote collaborations or to cultivate essential skills, like critical thinking, problem-solving and creativity (Zhu et al. 2022).

Nevertheless, the adoption of the 3D technologies by the educational institutions is facing a specific set of challenges, which are ranging from the infrastructural limitations and the technical constraints to the concerns that are related to the accessibility, equity and pedagogical alignment (Kirkwood & Price 2014; Selwyn 2016). Due to these and many other reasons, the trainers and the educational institutions are encountering various hurdles on their path to harness the full potential of the 3D technologies (Selwyn 2016, Hristov et al. 2023, Hristov et al. 2017).

2. Present technologies for development of 3D models

In the modern digital world, the primary approaches for development of 3D content are three – 3D modelling, 3D scanning and digitalization using he principles of the photogrammetry.

The development of 3D models in computer environments and using specialized software products and powerful computer platforms is known also as 3D modelling. The process itself can be divided in three steps – modelling, texturing and rendering (Fig. 1).

Figure 1. The modelling, texturing and rendering phases of the 3D modelling process

The 3D modelling is the easiest and cheapest approach for development of digital content, as it requires only the purchase of commuter hardware and software, as well as specific knowledge in the area of the 3D modelling processes and the related software products. The method is suitable for the development of 3D models of non-existing or imaginary objects, futuristic environments and remote or unreachable items and locations. The method is also suitable for animation of the developed 3D content.

The digitalization of real-world objects using the principles of the photogrammetry involves the photo shooting of the targeted object with high-resolution digital camera and the postprocessing of the obtained information in specialized image alignment and image stitching software products, the development of 3D point cloud and mesh models for the object and the follow-up texturing of the developed model (Fig. 2).

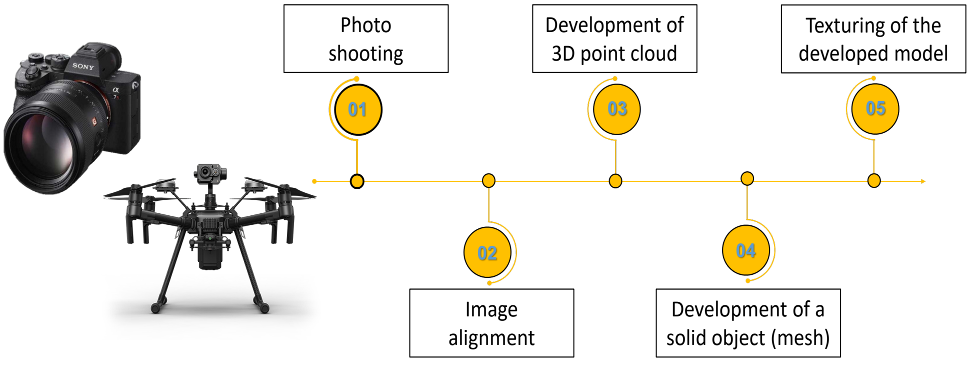

Figure 2. The stages for the digitalization of objects using the principles of the photogrammetry

This method is based on the use of digital cameras and possibly also different camera lenses, which makes it more expensive that the 3D modelling method. However, this method can be also used for the digitalization of large monuments, buildings and even whole cities using unmanned aerial vehicles. This makes it the preferred choice for the 3D digitalization specialists, which are tasked with the digitalization of spacious or voluminous objects and locations or are required to develop a digital twin of a given area.

Last, but not least, the modern 3D scanning solutions can be used for the digitalization of any object or person. This is probably the fastest method for development of digital 3D content, but it is also unfortunately the most expensive one, as the cost of a good 3D scanner is in the range of between 5000 euro and 100000 euro. The 3D scanning of the objects is usually accomplished either using structured light scanners or using laser scanners (Fig. 3). The structured light scanners operate by emitting a grid of light with a specific pattern (Fig. 3), which then gets wrapped around the digitalized object. High-speed cameras on the scanner are then used to analyse the change in the shape of the light grid and to estimate the geometrical shape of the object. Unlike this method, the laser scanners employ laser emitter and rely on the popular laser-based range estimation algorithms to determine the range to each point on the surface of the object and then to reconstruct the geometrical shape of the object (Hristov et al. 2023).

Figure 3. The principles of 3D scanning using structured light scanners (left) and a set of structured light and laser 3D scanners (right), which are used in the educational and scientific activities of the University of Ruse in Bulgaria

3. Application and use of the 3D technologies in the teaching and learning activities of the educational institutions

Once the 3D content is developed using one of the abovementioned approaches, the 3D technologies can be used to enhance and improve the educational processes. For example, the developed digital models can be 3D printed and presented to the students, so that they can analyse them and understand the discussed objects of interest. Further to this, the 3D models can be used for the improvement of the educational materials by their integration in AR or VR applications or by their visualisation in hologram displays (Hristov et al. 2023). The developed digital models can also be used in the development of educational games for mobile devices, consoles and computers (Hristov et al. 2017).

In all cases, the 3D technologies are providing numerous opportunities for visual and sensory learning, they are also simplifying the educational processes and are providing opportunities for visualization of various processes through

3D animations. The educators also can create 3D models of objects or processes, which can be tailored to the individual needs of students. Some of the present applications of the 3D technologies in the educational domain are presented and discussed below:

– Archaeology and Anthropology – various artefacts and objects can be scanned and visualized in the classrooms, which would allow the learners to observe and interact with them without any risks of potential damage. The modern platforms for sharing of 3D models can also help the learners from around the world to interact with the developed 3D models, to explore and to study them. This makes the 3D technologies also a popular tool for use in the Massive Open Online Courses (MOOCs).

– Biology and Medicine – from plant specimens to anatomical models, the 3D technologies can provide the students with the opportunity for immersive 360-degree viewing and studying of the developed or publicly available digital models. For example, a biology or anatomy teacher can use an AR or a VR model of a human hearth to present it to the students. Further to this, the model can also be animated.

– Art and Design – the artists and the designers can scan their sculptures, paintings, drawings, models, etc., so that they can create their own digital portfolios. Moreover, they can also study many famous artworks from every possible angle and without the geographical restrictions, as the 3D models of these art pieces are publicly available in popular online platforms and frameworks for popularization of the cultural heritage.

– Engineering and Architecture – the development and the visualization of digital models of various elements, components, mechanisms and processes can be extremely useful in the field of the engineering sciences. The reverse engineering of products, components or vehicles, using 3D scanning or photogrammetry, is also very popular in the automotive and manufacturing industries. In the architecture, the 3D technologies can help in the presentation of the architectural models or can be utilized to visualize in an attractive way a particular building to the potential clients.

The University of Ruse “Angel Kanchev” has already integrated the 3D technologies in its study programs and is also offering them to Erasmus exchange students (Fig. 4)

Figure 4. Erasmus students at the University of Ruse, studying the 3D technologies course and principles of the 3D modelling (left), 3D scanning (middle) and 3D printing (right)

The course on 3D technologies includes theoretical lectures and practical exercises on 3D modelling, digitalization using photogrammetry, 3D scanning, 3D printing, AR and VR technologies and other trending topic from the world of the 3D technologies (Hristov et al. 2023). The course is offered to all students from the "Computer systems and technologies" and the "Internet and mobile communications" bachelor study programmes, which are available at the Faculty of "Electrical engineering, electronics and automation".

To further spread the importance of the 3D technologies and to popularize them to the public, the Department of Telecommunications at the University of Ruse is regularly organizing local and remote workshops, seminars and trainings on the most interesting topics from the art of the 3D technologies (Fig. 5).

Figure 5. Moments from some of the recent workshops, seminars and trainings about the 3D technologies, organized by the Department of Telecommunications

4. Conclusion

The 3D technologies are the future of the educational processes and within 10 years they will be applied and utilized in all academic disciplines and study processes. Despite their many advantages, these technologies are still not so widely distributed – mainly due to the high cost of the specialized equipment, the lack of trained educators and the insufficient educational materials and textbooks. For these reasons, the higher education institutions have an extremely important role in the digital transformation of the educational processes through the 3D technologies – they must provide the necessary prerequisites, in terms of trained teachers and developed teaching materials, which will guarantee the adoption of the 3D technologies in all educational processes.

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