https://doi.org/10.53656/str2023-4s-2-pos

Education in the Information Society
Образованието в информационното общество

A STUDY ON THE POSSIBILITIES TO INTEGRATE THE MODERN 3D TECHNOLOGIES IN THE SCIENTIFIC ACTIVITIES OF THE HIGHER EDUCATION INSTITUTIONS

Prof. Dr. Georgi Hristov,
Assoc. Prof. Dr. Ivan Beloev,
Assoc. Prof. Dr. Plamen Zahariev,
Assist. Prof. Dr. Diyana Kinaneva,
Assist. Prof. Georgi Georgiev
"Angel Kanchev" University of Ruse

Abstract. The technological advancements in the last three decades have led to many innovations in the area of the Information and Communication Technologies, which in turn have fuelled the rapid development of the modern 3D technologies. This collective term is used to describe both the methods for the development of the digital content and the solutions and devices, which provide means for the attractive, interactive and innovative visualisation and popularisation of this content. The 3D technologies have provided many possibilities and never-before-seen opportunities, but they have also presented many new challenges. The high cost of the equipment, the complexity of the digitalization processes and the unexperienced staff are just few of the reasons for the slow adoption rate and the delayed integration and use of these technologies by the higher educational institutions.

Currently, there are many different ICT solutions and systems in use in the colleges and universities in Europe and in the world. Nevertheless, only few of them are related to or use the modern 3D technologies. In this article we present and analyse some of the most popular methods and approaches for development of digital models, as well as how this content can be visualised, presented and popularised using different platforms and solutions. Last, but not least, we discuss the possibilities to integrate the modern 3D technologies in the scientific activities of the higher education institutions in Bulgaria.

Keywords: 3D technologies; 3D scanning; 3D printing; digitalization; hologram displays; higher education institutions; scientific projects; scientific activities

1. Introduction

The Information and Communication Technologies (ICT) provided solutions for improvement of many different aspects of the everyday human life. With the

help of different technologies and devices, the modern-day person can perform faster and better many of his regular activities, like working, studying, shopping, communicating, trading, entertaining and many more (Wastiau 2013). The huge potential of the present and emerging ICT solutions was quickly noticed by industrial, business and non-commercial organizations from different domains (Forcheri 2000; Wastiau 2013). Many colleges and universities have also quickly realized that the ICT systems are among the modern solutions for gaining popularity, for attraction of students and for getting additional funds from grants and sponsors. Unfortunately, many of the educational institutions were not familiar with the functionality, the requirements and the needs for the proper operation and use of the modern ICT systems, and this has led to a very slow acceptance rate of these solutions in the area of the higher education (Foutsitzi 2019). While some of the more conservative higher educational institutions (HEIs) withheld from the intensive use of the modern ICT systems, others were more open-minded and decided to proceed with the steady integration of new information platforms, kiosks, virtual guides and other ICT tools and solutions (Wastiau 2013; Foutsitzi 2019).

The COVID-19 pandemic led to significant transformations in almost every aspect of the human life and highlighted the importance of the Information and communication technologies and the vital part that they play in the future of humanity. The educational domain was no exception to this and the institutions, which had already embraced the new technologies and the advantages they offer, have only benefitted from the situation. With the help of social media, video and image sharing platforms and other tools, these schools, colleges and universities have managed to keep the link with their students alive, while the more-conservative educational institutions had to urgently catch up (Foutsitzi 2019).

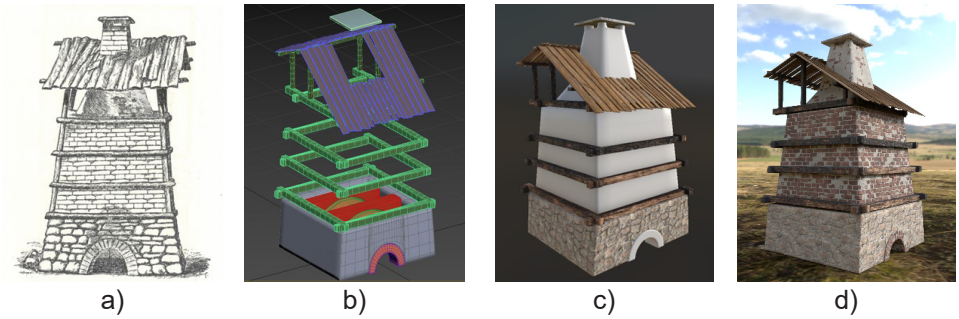
2. Methods for development of 3D models and digital content

In the modern digital world, the traditional means for visualisation and presentation of photos, images and videos, which were widely used in the last decades, are slowly being replaced with new solutions, like platforms for visualization of 3D models, holographic displays and Virtual Reality (VR) systems. The main methods used for the development of the content for these solutions are the 3D modelling, the 3D scanning and the photogrammetry.

2.1. 3D modelling

Many computer games, movies, engineering processes, architectural schematics and designs, advertisements or brochures, as well as numerous other services, products and processes around us and in our daily activities are somehow connected to the 3D technologies or involve the use of 3D models, surfaces or environments. One of the most popular ways to create these digital assets involves the use of specialized software products for 3D modelling and powerful computer platforms. The process itself can be divided in several steps – modelling, texturing and

rendering. During the modelling step, the shape and size of the object are being defined using basic geometric forms or sets of points. These individual points are then interconnected with lines to form polygonal shapes (polygons) with different number of sides. In the next step, textures are applied on top of the available surfaces to provide the model with the needed colours, patterns and visual details. The last step involves the rendering of the prepared model in an environment with light sources, shadows and other visual effects. The result from the implementation of these processes is a photorealistic 3D model, which can be used in any virtual environment. The most significant advantage of this method is the possibility to create 3D models of non-existing items, places, creatures or characters, like the kiln in Fig. 1, which was developed from historical drawings (Hadjiev 1954).



a) b) c) d)

Figure 1. 3D modelling of a kiln – conceptual drawing of the kiln (a), 3D modelling of the individual components and sections of the kiln (b), texturing of the individual shapes (c) and final rendering of the model in a virtual environment (d)

2.2. Photogrammetry

The creation of digital models from real-world objects by localization and positioning of every point from the surface of the object in 3D space is called photogrammetry. The process involves the use of high-resolution digital cameras for the taking of multiple partially overlapping photos of the targeted object, as well as the subsequential use of special software products for the processing of the photos, based on the triangulation principles (Fig. 2).

The creation of digital models using photogrammetry requires not only skills for 3D modelling, but also knowledge about image processing, photography and cameras. The process is also dependant on extra equipment, like cameras, lenses, filters, flashes, etc. Despite all of this, the photogrammetry remains one of the most widely used method for digitalization and can be used to create 3D models of objects with different sizes. This method can also be used together with drones for the digitalization of large building, locations, etc., as shown in Fig. 3.

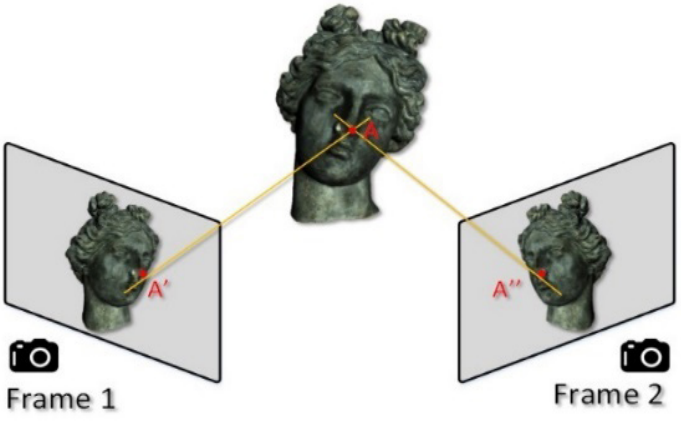


Figure 2. Triangulation of the position of a point on the surface of the object from two photos

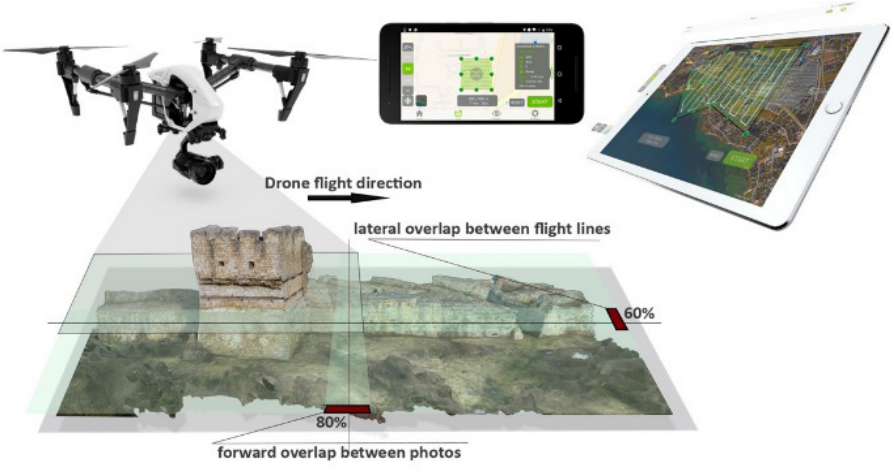


Figure 3. The principles of the photogrammetry can be used to create 3D models of buildings, geographical locations, historical sites and monuments by using drones and aerial photos

2.3. 3D scanning

Several different methods for 3D scanning of real-world objects are currently widely available and used in different industrial applications. However, only two of these methods are considered to be non-invasive and thus are suitable for digitalization of all types of objects.

The first of these methods is based on the use of a laser light for the determination of the distance to each point on the surface of the object. This laser scanning method can be used for the creation of extremely detailed and accurate 3D models of any object. Nevertheless, the unmatched precision of the method comes for a price – the laser scanners cannot capture any details about the textures of the objects and can produce only high-quality 3D geometry models.

When it comes to high-resolution 3D scanning with texture, the scanners with structured light are the only feasible solution. These devices project a pattern of light on the surface of the object and then capture and analyse the deformation of this light pattern, which allows them to calculate the distance to every point in the field of view (Fig. 4). The 3D scanners with structured light are well known for their faster speed of scanning and their high level of precision.

The creation of digital models using 3D scanners is the most expensive from all of the discussed methods, as the specialized devices can cost from several thousand to several hundred thousand Euros. The 3D scanners with structured light are also susceptible to specific issues due to the used optical technology and in some cases can experience difficulties when digitalizing dark, shiny, reflective or transparent objects.

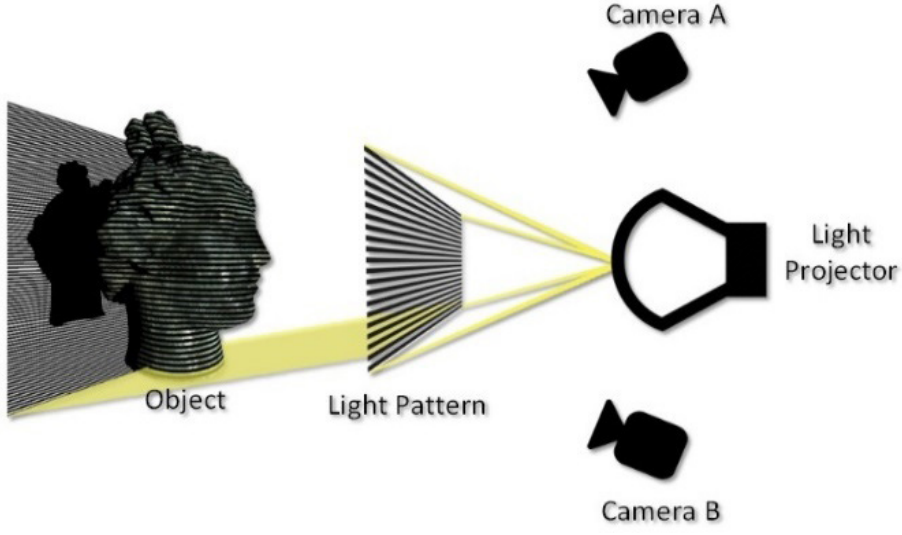


Figure 4. The principle for creation of a digital model using 3D scanner with structured light

3. Technologies and solutions for visualization and use of 3D models

The modelling of the digital assets or the digitalization of the physical objects are just prerequisites for the visualisation and popularisation of the digital content.

Each of the different technological solutions for visualisation of the developed 3D models has its own specific requirements for their use, like the file size, the level of the quality, the number of polygons, the resolution of the textures, etc.

Currently, there are several technologies and solutions, which are very popular and widely used for visualisation, popularisation and use of the developed 3D models. The most popular of them are described in the next parts of this section.

3.1. Additive and subtractive technologies

The modern 3D printing technologies can be used for the creation of exact or scaled replicas of the digital models (Fig. 5). The purposes for the 3D printed models are numerous – from replacement parts to custom souvenirs and keepsakes. The 3D printing technologies are used primary in the different industrial domains, mainly for rapid prototyping purposes. Nevertheless, they also have applications in other domains, like in the area of the cultural heritage, where the printed 3D models can be touched by visually impaired people, providing them with the possibility to feel and explore the heritage.

The subtractive technologies, like CNC milling, can also be used to produce physical objects from plethora of different materials, like wood, stone, metal, etc., which are also based on the developed 3D models. Usually, the final results are more reliable than these produced using the additive technologies, however, the 3D printing technologies are evolving quickly and the new generations of 3D printers can easily compete with the devices that employ the subtractive technologies. Nevertheless, the advancements in the area of both technologies have resulted in the development of new solutions, which can use different types of materials and are characterised with higher accuracy of the produced end products and reduced production costs.

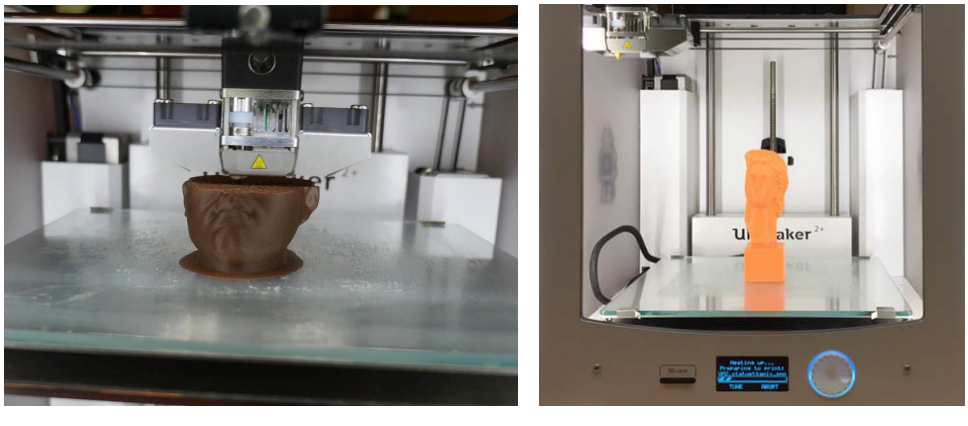


Figure 5. 3D printing of a model (left) and a finalized and ready to collect model (right)

3.2. Promotion of the heritage with holographic displays and systems

Hologram projectors are offering the spectators a modern, highly technological and fun way to see the digital content. Over the years, many different hologram technologies have been developed and used. Some of them use reflective surfaces for visualisation of the holographic content (Fig. 6), while other use projection screens and even laser beams. In terms of the view area of the hologram projectors, the 270-degree and 360-degree systems are most widely used.

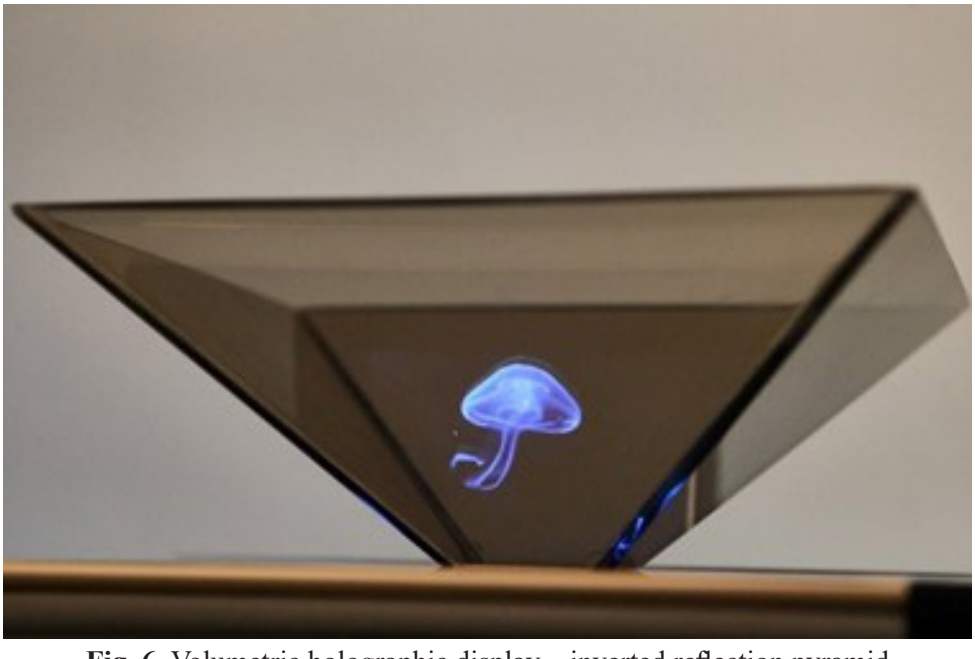


Fig. 6. Volumetric holographic display – inverted reflection pyramid with an underlying tablet as image source

3.3. Online platforms for content sharing and visualisation

The people from the digital generations are constantly chatting, watching videos or playing games on their computers and phones. The development of online platforms for sharing of 3D models can thus be a powerful tool for the dissemination of the digital content and for reaching wider audiences.

At the present time, there are several platforms that allow the sharing of 3D models. Each of these platforms is offering various level of services, with some offering the download of the models for free, while other require monthly subscription or download fees. A well-known online platform for public sharing of 3D models is Sketchfab[1] (Fig. 7).

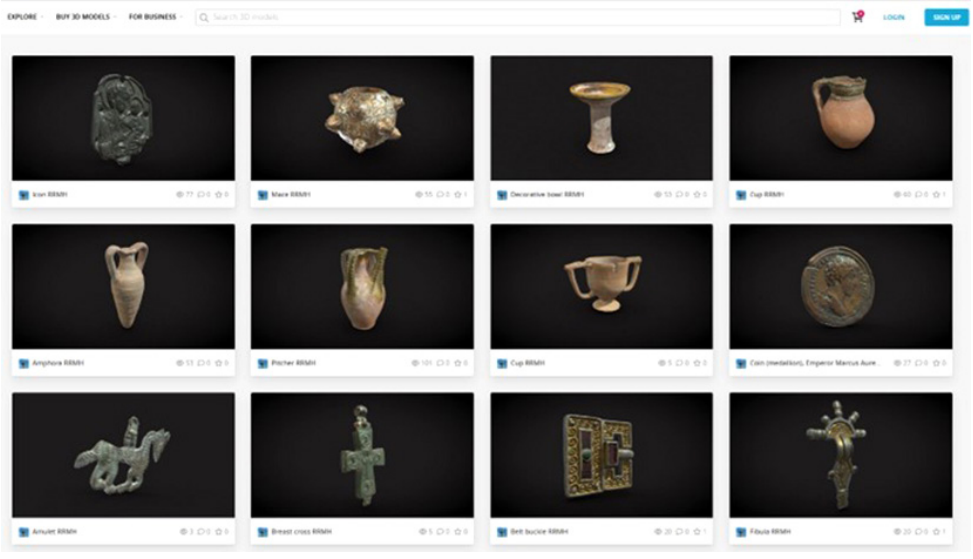


Figure 7. A digital library with artefacts and objects of the cultural heritage in the online platform for sharing of 3D models Sketchfab[1]

3.4. Virtual, mixed and augmented reality applications

Augmented Reality (AR), Mixed Reality (MR) and Virtual Reality (VR) are modern ICT solutions, which can provide interesting and highly attractive ways for popularization of the digital content and the developed 3D models. With the help of VR, the users can visit virtual facilities (Fig. 8), reconstructions of long-forgotten or no longer existing places and locations, etc. Unlike the VR, which requires specialized equipment and tools, like VR glasses and joysticks, the AR and MR solutions can be utilized with the help of a standard handheld device, like a smartphone or a tablet (Fig. 8).

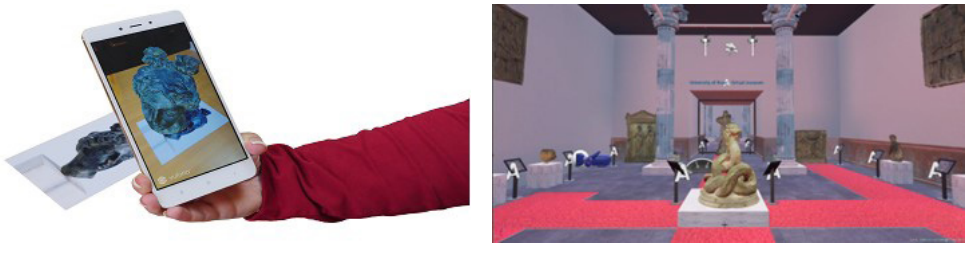


Figure 8. Augmented reality application (left) and a virtual reality environment (right)

4. Integration of the 3D technologies in the scientific activities of the HEIs

The advancements of the 3D technologies have led to a great number of studies and surveys about their potential use for and in different scientific processes, as well as for their use in various applied, industrial and entertaining activities and processes. One of the most widely discussed and studied application area for the 3D technologies is for preservation, visualisation and popularisation of the cultural and historical heritage.

Following this trend, a team of researchers from the University of Ruse "Angel Kanchev"[2] started working on the topic. Their results and activities led to the implementation of several national and international project, including Projects ROBG-9 ARCHIVE and ROBG-499 LIVE, financed under the Interreg V-A Romania-Bulgaria Programme 2014-2020 and the ongoing project BG05M2OP001-1.001-0004 UNITe, funded by the OP "Science and Education for Smart Growth", co-funded by the European Union.

Project ARCHIVE was implemented in the period between 2016 and 2017 and was aimed at the evaluation of the possibilities to use the modern Information and communication technologies for the dissemination and the popularisation of the joint cultural heritage in the cross-border area between Bulgaria and Romania. The leading partner in the project was the University of Ruse[2], while the consortium of the project included also the Regional History Museum in Ruse[3] and the Museum for National History and Archaeology in Constanta[4].

The project implementation period lasted for eighteen months, during which the researchers from the project partners visited more than a dozen of museums in the cross-border area between Romania and Bulgaria and had the opportunity to digitalize more than 150 Roman artefacts and objects with cultural and historical significance (Fig. 9). The remains of more than sixteen Roman fortresses were also visited and digitalized (Fig. 9). The fortresses were specifically selected by the museums in Bulgaria and Romania and were equally divided between both countries – eight in Bulgaria and eight in Romania (Fig. 10).

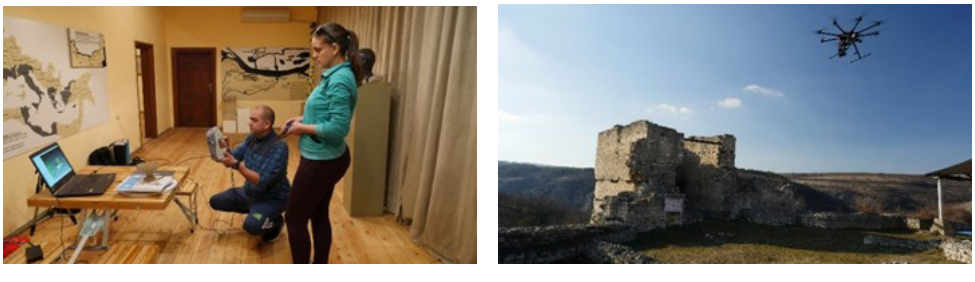


Figure 9. Digitalization of Roman artefacts and objects in the museums from the cross-border area between Romania and Bulgaria (left) and digitalization with a drone of a fortress near Ruse (right)

The implementation of Project ARCHIVE led to the development of several solutions for the popularization of the cultural and historical heritage. Some of these results include the RomanForts[5] online platform and two identical applications for mobile devices, which allow the users to explore for free the digitalized fortresses and artefacts (Fig. 11).

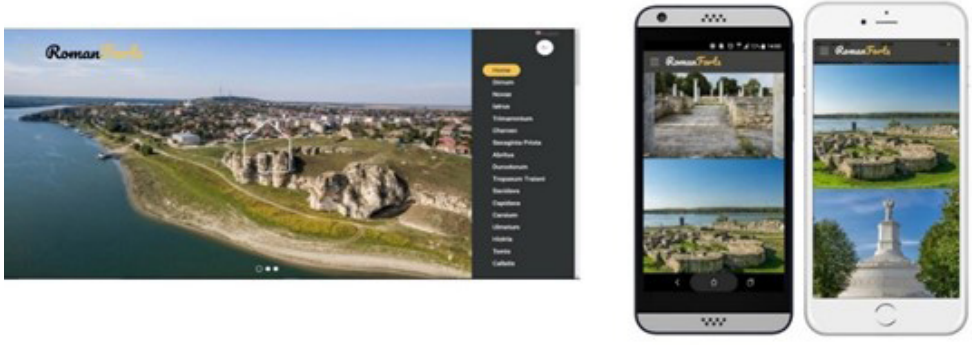


Figure 10. The RomanForts platform (left) and the RomanForts applications for mobile devices (right)

To further present the advantages and the benefits from the use of the modern 3D technologies in the area of the cultural and historical heritage, the consortium of the project produced more than 150 3D printed miniature replicas of the digitalized artefacts and objects. These models were then organized in two exhibitions and are available at the premisses of the museums in Ruse and Constanta (Fig. 11).

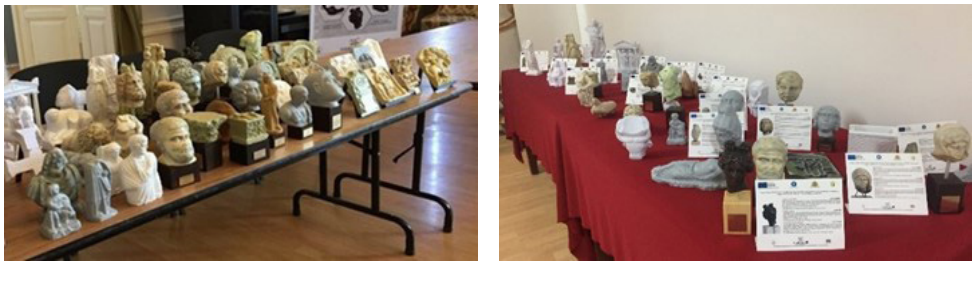


Figure 11. 3D printed miniature replicas of the digitalized artefacts on display in Ruse (left) and Constanta (right)

Project ARCHIVE also explored the possibilities to use the modern Augmented Reality technologies for the needs of the cultural and historical heritage. Specialized applications for visualisation of the digital models on top of the photos of the

digitalized artefacts were developed (Fig. 12). The project resulted also in the development of two interactive books (Hristov 2017 - 1; Hristov 2017 - 2), which utilize these applications and present the readers with a new and interesting method for exploration of the cultural heritage (Fig. 12).

Figure 12. The developed AR application for visualisation of the 3D models and objects (left) and a demonstration of the application in combination with one of the interactive books (right)

Empowered by the successful implementation of Project ROBG-9 ARCHIVE and the obtained results, the scientists from the University of Ruse proceeded forward in their efforts to evaluate the possibilities and the advantages of the implementation of the 3D technologies for the digitalization and popularisation of the cultural heritage between Romania and Bulgaria. These efforts resulted in another cross-border project – ROBG-499 LIVE, which was again led by the University of Ruse. Partners in the project were the Regional History Museums in Ruse[3] and Silistra[6], as well as the museums in Calarasi[7] and Drobeta – Turnu Severin[8].

The activities under Project ROBG-499 LIVE included the digitalization of artefacts at the premisses of the four project partners (Fig. 13), as well as the development of products and services for the visualisation and popularisation of the digital content using advanced ICT systems and the emerging 3D technologies.

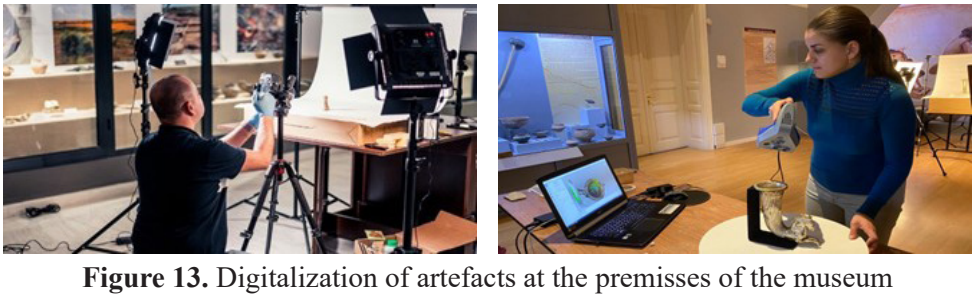


Figure 13. Digitalization of artefacts at the premisses of the museum of Lower Danube Museum – Calarasi (left) and the Regional Museum of History in Ruse (right)

Project LIVE resulted in the development of an interactive online information system[9] that provides access to text-based materials, photos and 3D models of more than 70 digitalized artefacts and objects from the cross-border region between Romania and Bulgaria (Fig. 14).

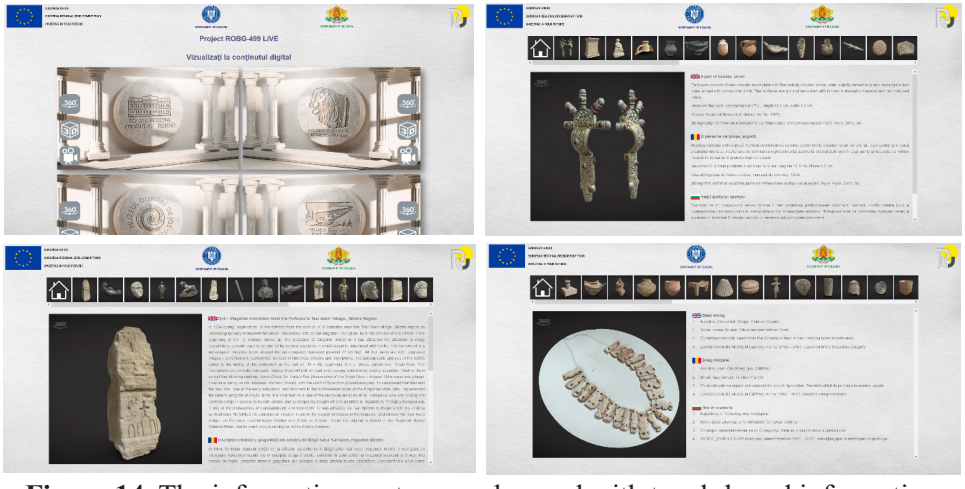


Figure 14. The information system can be used with touch-based information kiosks or can be accessed by mobile devices, which makes it a portable tourism guide for the artefacts in the museums

To attract more visitors to the cross-border area between Romania and Bulgaria, the team of the project established five digital corners, which are located at the

Figure 15. The digital corner at the University of Ruse "Angel Kanchev" in Bulgaria

premisses of each of the project participants. These corners contain a total of 18 information kiosks with touch screens, 5 photobooths, 10 digital TVs, 10 multimedia projectors and more than one hundred visitor chairs (Fig. 15).

To further improve the experience of the visitors, the team of the project developed content for visualisation of artefacts and objects in holographic pyramids. A total of 13 hologram displays with 270-degree view angle (Fig. 16) and the 5 hologram displays with 360-degree view angle (Fig. 17) were installed and are in use by the project partners. The content for the hologram pyramids includes visualisations for 40 artefacts or objects – 10 from each museum in the project.

Figure 16. Hologram displays with 270-degree view angle

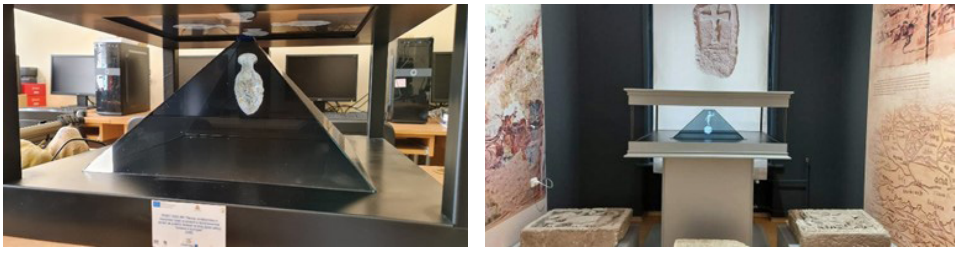


Figure 17. Hologram displays with 360-degree view angle, which are located in the University of Ruse and the Regional Historical Museum in Ruse

The constant use of mobile devices by the modern generations can contribute significantly for the dissemination of materials and information and can even have added value by presenting the users with additional useful or educational content. This can be achieved using entertaining applications and even games. The development of 3D games with historical or educational focus is presenting the museums and their heritage in a new light and is attracting more visitors to their exhibition halls. The scope and genre of the educational games can be different – from puzzle solving to quizzes with different questions and even a 3D quest. Further to this, the games might require an actual visit to the museums for certain quests to be completed or for specific levels to be unlocked.

An educational game for mobile devices was also developed under Project ROBG-499 LIVE. The game includes the digitalized models of the artefacts and objects from the cross-border region and presents the players with interesting historical facts about them (Fig. 18).

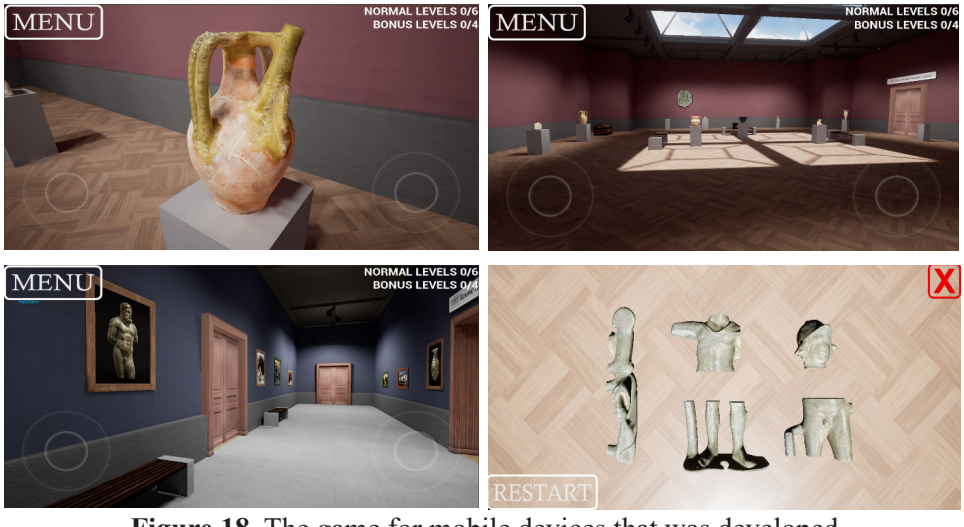


Figure 18. The game for mobile devices that was developed under project ROBG-499 LIVE

Probably the most mesmerizing and impressive result from the implementation of the project were the two-days long 3D mapping projections, which were presented to the citizens, visitors and guest of the City of Ruse in Bulgaria and the City of Drobeta-Turnu Severin in Romania (Fig. 19).

Figure 19. Moments from the two 3D mapping shows – in Ruse (top row) and in Drobeta-Turnu Severin (bottom row)

To make both 3D mapping show reality, the team of the University of Ruse had to digitalize the buildings of the Iron Gates Region Museum and the Courthouse

in Ruse. The digitalization processes were conducted using a combined approach using 3D laser scanners and drones (Fig. 20).

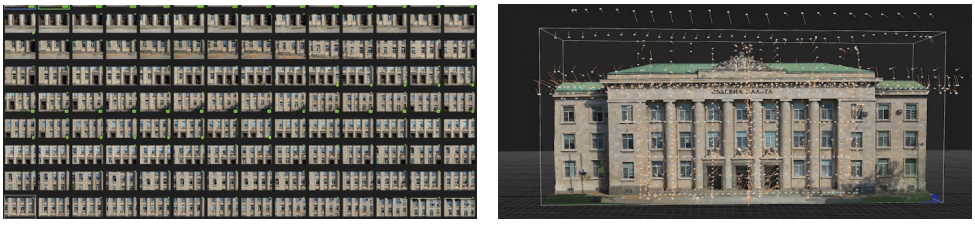


Figure 20. A set of images from the drone (left) and the stitched texture on top of the high-quality 3D model of the Courthouse in Ruse, which was made with laser scanner (right)

Projects ROBG-9 ARCHIVE and ROBG-499 LIVE were huge success and provided the necessary foundations for the University of Ruse to continue its work in the world of the 3D technologies. In the present time, the university is partner in Project BG05M2OP001-1.001-0004 UNITe, funded by the OP "Science and Education for Smart Growth", co-funded by the European Union. The focus of the activities of the university within this project are also directed on the 3D technologies (Fig. 21), with the scientific team being responsible for the activities under Working Package 5 "Visual Search, Image Recognition and 3D Printing" of the project.

4. Conclusions

The modern 3D technologies are a powerful tool, which can help transfer the physical objects in the digital world and vice versa. There are several different methods for the development of the digital content, which were presented in details in the article, as well as numerous present and emerging solutions for the visualisation and the use of the 3D models.

The modern 3D technologies are presenting huge opportunities to the scientific institutions, which are yet to fully acknowledge, accept and use these new systems and solutions. Nevertheless, as presented in the paper, the proper implementation of the 3D technologies in the scientific activities of the HEIs can significantly boost the popularity of the institutions and can result in the acquisition of modern equipment, production of scientific papers and the involvement of the organizations in national and international project.

Acknowledgments

Some materials and results in this article are produced as partial fulfilment of the activities under Projects ROBG-9 ARCHIVE and ROBG-499 LIVE, financed under the Interreg V-A Romania-Bulgaria Programme 2014 – 2020.

The work presented in this publication is completed as partial fulfilment of Project BG05M2OP001-1.001-0004 UNITe, funded by the OP "Science and Education for Smart Growth", co-funded by the European Union.

This article was prepared with the support of Project 2023-FEEA-03, financed under the Scientific and Research Fund of the "Angel Kanchev" University of Ruse.

NOTES

1. https://sketchfab.com – official webpage of the Sketchfab online platform for sharing of 3D models.
2. https://www.uni-ruse.bg/ – official webpage of the University of Ruse "Angel Kanchev".
3. https://www.museumruse.com/ – official webpage of the Ruse Regional Museum of History.
4. https://www.minac.ro/ – official webpage of the Museum for National History and Archaeology in Constanta.
5. https://www.romanforts.eu/ – official webpage of the RomanForts online platform.
6. https://www.museumsilistra.com/en - official webpage of the Regional Museum of History – Silistra.
7. https://mdj-calarasi.ro/ – official webpage of the Lower Danube Museum in Calarasi.
8. https://muzeuldrobetaturnuseverin.ro/ – official webpage of the Iron Gates Region Museum in Drobeta-Turnu Severin.
9. https://info.robg.eu/ – official webpage of the interactive online information system developed under project ROBG-499 LIVE.

REFERENCES

FORCHERI, P., MOLFINO, M.T., 2000. ICT as a tool for learning to learn. *Communications and Networking in Education*. IFIP, vol 35. USA: Springer. DOI: 10.1007/978-0-387-35499-6_16.

FOUTSITZI S., CARIDAKIS, G., 2019. ICT in education: Benefits, Challenges and New directions, *10th International Conference on Information, Intelligence, Systems and Applications (IISA)*, Patras, Greece, pp. 1 – 8. DOI: 10.1109/IISA.2019.8900666.

HADJIEV, P., 1954. *The pottery in Troyan*. Sofia: Publishing house of BAS. (In Bulgarian).

HRISTOV, G.; ZAHARIEV, P.; KINANEVA, D.; RAYCHEV, J.; BENCHEVA, N.; RUSEVA, Y.; TSVETKOVA, I. & ILIEV, M., 2017.

Ancient Roman Fortresses from the Cross-Border Region between Bulgaria and Romania. Ruse: Parnas. ISBN 978-954-8483-52-0.

HRISTOV G.; ZAHARIEV, P.; KINANEVA, D.; RAYCHEV, J.; BENCHEVA, N.; RUSEVA, Y.; TSVETKOVA, I. & ILIEV, M., 2017. *Ancient Roman Artefacts and Monuments from the Cross-Border Region between Bulgaria and Romania*. Ruse: Parnas. ISBN 978-954-8483-51-3.

WASTIAU, P.; BLAMIRE, R.; KEARNEY, C.; QUITTRE, V.; GAER, E. & MONSEUR, C., 2013. The Use of ICT in Education: A survey of schools in Europe. *European Journal of Education*, vol. 48, no. 1, pp. 11 – 27. DOI: 10.2307/23357043.

✉ **Prof. Dr. Georgi Hristov**
Web of Science Researcher ID: R-7414-2016

Dr. Ivan Beloev, Assoc. Prof.
Web of Science Researcher ID: AAT-7382-2021

Dr. Plamen Zahariev, Assoc. Prof.
Web of Science Researcher ID: B-9260-2016

Dr. Diyana Kinaneva, Assist. Prof.
Web of Science Researcher ID: R-6385-2016

Georgi Georgiev, Assist. Prof.
Web of Science Researcher ID: HZK-6575-2023
8, Studentska St.
"Angel Kanchev" University of Ruse
7004 Ruse, Bulgaria
E-mail: ghristov@uni-ruse.bg
E-mail: ibeloev@uni-ruse.bg
E-mail: pzahariev@uni-ruse.bg
E-mail: dkyuchukova@uni-ruse.bg
E-mail: gdgeorgiev@uni-ruse.bg