DISTANCE TEACHING OF 3D MODEL POST-PROCESSING ON THE EXAMPLE OF ARTEFACTS FROM THE SILK ROAD AREA

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Abstract

The current situation with the global spread of SARS-CoV-2 has had a significant impact on the teaching process at all levels of education. This also applies to the training of IT students in 3D computer graphics. Currently, the preferred model is distance learning, which uses various technologies and IT tools allowing for synchronous and asynchronous work. The problem is often their correct selection in order to ensure the continuity of an effective process of educating students. This work concerns the issue of proper selection of technologies and tools for teaching students in the field of 3D computer graphics at the Faculty of Computer Science at the Lublin University of Technology.

The article describes the methodology for the didactic materials preparation, the selection method of technologies and programs needed to conduct classes, individual tasks for students and the method of evaluation of their work. The process of distance learning was presented on the example of post-processing models of archaeological artefacts from the Silk Road area. The post-processing of 3D scanning data includes: (1) initial point cloud processing (2) grid models creation, (3) the received models inspection, (4) texturing and mapping and finally (5) model optimisation. This is an example of practical use of computer graphics technologies to preserve cultural heritage. During the work with the models the following software was used: Artec Studio, MeshLab and Gimp. Microsoft Teams was used to communicate with the students. The Moodle platform was used to exchange and share materials. The material for processing was obtained using 3D optical scanning in Uzbekistan. Post-processing of 3D mesh models was carried out in the direction of their later use in presentations and multimedia exhibitions.

The effectiveness of the learning method applied and students' preferences for distance learning were examined. The implemented concept of remote learning proved to be an effective solution for conducting the process of educating students in the era of the SARS-CoV-2 pandemic. The results of the research on the effectiveness of the learning method discussed confirmed the correctness of such solutions.

Keywords: Distance learning, 3D model post-processing, Silk Road, SARS-CoV-2 pandemic.

1 INTRODUCTION

The pandemic situation, linked to the spread of the SARS-CoV-2 virus practically all over the world, has forced significant changes in the education process including intensive changes in teaching methods and techniques. These changes are being experienced at all levels of education and are challenging for the teaching staff and educational institutions. Many countries have decided to temporarily close down schools and universities while introducing distance learning. The dynamics of these changes has forced a very quick response from teachers, who have often had to adapt the curriculum to distance learning using IT (information technology). Distance learning has been provided at the LUT (Lublin University of Technology), authors' workplace, since March 2020, as a binding form of education in all the fields of study. The relevant principles of distance learning, documentation of classes and verification of educational results are regulated by the rector's orders.

Unfortunately, the use of IT in educational processes is associated with many problems. Particularly difficult to implement is materials content that requires pragmatic information provision. In such cases, appropriate cooperation at learner-teacher level is particularly important. The current situation related to the spread of the SARS-CoV-2 virus worldwide has significantly reduced interpersonal contacts in teaching processes. The use of IT has made it possible to replace real contact with virtual contact. The IT used in such conditions in teaching processes has made it possible to maintain educational processes continuity. This type of process is called remote learning, which strongly correlates with the e-learning process, which, by available technical means, enables the relationship between the learner

and the teacher [1,2,3,4]. Teaching using computers and educational platforms is called in many ways, e.g.: remote education, hybrid teaching, distance learning, e-learning and even online teaching. The regulations concerning distance learning are contained in the Law on Higher Education. According to Article. 164, paragraph 3 "Teaching activities during studies may also be conducted using distance learning methods and techniques".

This is particularly important in areas where teaching involves the use of engineering software with a high degree of difficulty. Educational platforms such as Teams, Moodle, Zoom make it possible to carry out complex learning processes and teaching area such as computer graphics. The diversity, degree of complexity and difficulty of using graphic software determines the use of educational platforms in the teaching process [5,6,7].

The goal of this work is to identify the possibilities and explore the effectiveness of distance teaching of post-processing 3D models using artefacts from the Silk Road area.

2   METHODOLOGY

Education in the field of 3D computer graphics requires the use of many computer programs during laboratory classes. The transition to remote learning has forced the development of a methodology for teaching students using computer techniques. Table 1 contains the programs used during distance learning, their short characteristics and the scope of use in remote learning.

Table 1: Solutions applied in remote learning.

Software	Sort description	Scope of use
Microsoft Teams	A virtual environment with tools for multi-level and multithreaded cooperation between team members	meeting planning, basic voice and text communication and the possibility of videoconferencing with students, providing a remote desktop during classes, recording student attendance
Moodle e-learning platform	an online remote learning environment available in web browsers	making instructions and materials available to students, defining tasks for students, sending students their papers, evaluating papers
Artec Studio 12	Basic software cooperating with Artec 3D scanners	3D scan data acquisition, point cloud processing, data processing and optimisation, folding scans, creating mesh models, overlaying textures, exporting to other programs for further processing
Blender	3D modelling software	texturing and mapping, digital model reconstruction, creating visualisation
MeshLab	a 3D mesh processing software that is oriented to the management and processing of unstructured large meshes	processing and optimisation of mesh models, preparation of models for 3D printing
Gimp	Raster graphics processing software	texture preparation, texture processing.

For the implementation of remote learning it was decided to use two popular solutions: (1) Microsoft Teams for basic communication with students, and (2) Moodle e-learning platform for sharing and exchanging materials. These programs complement each other. The students are provided with access to organisational and didactic information on an ongoing basis. The use of two tools for remote teaching also provides an alternative of choosing one of them in case of other's failure. For example a very large number of active users may cause server overload and communication problems. The occurrence of failure of one tool does not interrupt the learning process, as communication and data exchange can be transferred to the other. The IT tools used allow for synchronous and asynchronous work. The teacher can provide students with the same content at the same time. He can also prepare tasks for students and post them online. Students adapt their solution to their schedule. The teacher defines only the maximum time of sending solutions [8,9,10,11].

The proper selection of technologies and tools for teaching 3D computer graphics in the field of Computer Science is very important from the point of view of maintaining continuity and achieving the assumed educational results. Students should be able to configure their workstations at home. The

selection of tools and tasks should also take into account the parameters of computers. Advanced work with 3D graphics very often forces the use of computers with high computing parameters. Such programs as Artec Studio 12, Blender, MeshLab and Gimp were used to educate students. Artec Studio is a commercial program, however, students can take advantage of a 30-day license for a given product. Other programs are distributed under free licence for use [12,13,14,15].

A survey method has been used to examine the effectiveness of the education method used and students' preferences for distance learning. The research involved 38 IT students. The research was conducted after completing a course in computer graphics in November 2020 via the Internet. Both women and men took part in it. Men constituted 86.8%, while women 13.2% of the research group. The survey process was conducted in an anonymous manner. Then statistical calculations were carried out on the data, and graphs of the obtained results were made [16,17,18].

3 RESULTS

The teaching of 3D graphics should be focused on the practical possibilities of using the skills acquired by students in their future professional work.

3.1 Teaching content in the field of 3D graphics

Due to the dynamic development of 3D graphics and areas of its practical application, it is necessary to implement this subject in the process of teaching IT students. One of such issues is the implementation of the subject of post-processing data from 3D scanning. In this way, realistic 3D digital copies of real objects are obtained. Practical implementation of post-processing requires the students to acquire knowledge and skills in the field of computer modelling and 3D scanning. Students should learn data processing programs in the form of a point cloud.

Due to the existence of the course "Basics of Computer Graphics" at the LUT in bachelor's studies of the Faculty of Computer Science, it was decided to prepare exercises in post-processing of 3D models within available hours. 30 hours of lectures and 30 hours of laboratories have been reserved for this subject. Since the thematic scope includes other elements, there is only 1/6 of the total number of hours effectively to introduce new topics.

The aims of the course are as follows:

1 To familiarise students with the basic issues of computer graphics and its processing methods.

2 To equip students with skills in processing 2D and 3D raster and vector graphics.

Table 2 shows the detailed content of each laboratory class. Apart from practical skills acquired in the laboratories, students have the opportunity to acquire theoretical knowledge during lectures.

Table 2. Course contents of lectures.

Lecture	Content
LAB1	Introduction to raster graphics editing software. Basic exercises with raster graphics: drawing, correction of image parameters, scaling, rotation, trimming, use of filters.
LAB2	Working with layers, modification of 2D image sections, image corrections with area tools, enhancement, collage.
LAB3	Introduction to raster graphics editing software. Raster graphics processing. Implementation and usage of raster graphics filter and enhancement algorithms.
LAB4	Introduction to vector graphics editing software. Simple vector drawing creation and vector object processing techniques. Combining vector and raster graphics.
LAB5	Using the processing environment to define and process vector images. Implementation of vector transformations algorithms.
LAB6	Introduction to 3D graphics editing software. Basic 3D objects creation – parametric and non-parametric modelling, use of primitives and extrusion functions.
LAB7	Complex objects creation using constructive solid geometry methods. Editing the model mesh and making a 3D object from pattern. 3D scenes construction. Basics of automation scripts for 3D scenes fast construction and transformations.
LAB8	UV decomposition exercises and application of textures on 3D objects

3.2 Implementation of the concept of distance teaching of 3D model post-processing on the example of artefacts from the Silk Road area

Research is being carried out at the LUT on the use of 3D technology in terms of protection of cultural heritage. This results in extensive cooperation with museums and cultural centres in the countries through which the former Silk Road (Uzbekistan, Kazakhstan) passed. Researchers are engaged in 3D scanning of selected archaeological artefacts, creating digital models, digital reconstruction and virtual shows. Digital 3D models are a kind of documentation that enables the reconstruction of the real dimensions of shapes and textures of the artefacts. This allows for their reconstruction in case of destruction or oblivion. The practical aspects of these works have been decided to include in the process of educating students of the IT faculty. Students gain knowledge of post-processing of 3D models. This results in the creation of engineering studies and scientific publications.[11,20,21,22,23] Examples of research results are presented in Figure 1.
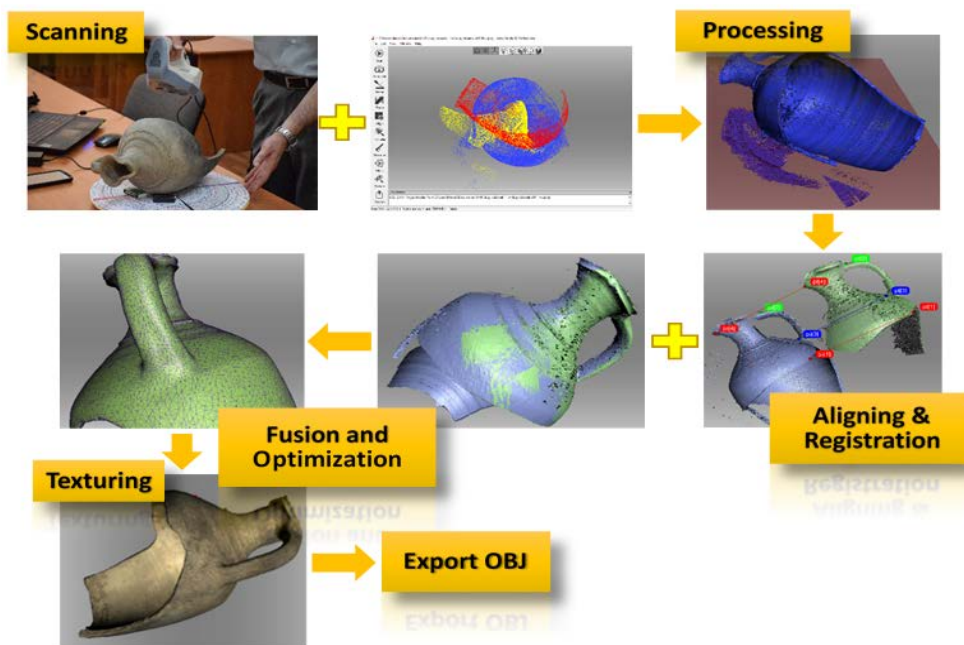

Figure 1. Stages of post-processing [22].

Through remote learning using Microsoft Teams software, students will learn about the individual stages of post-processing 3D models. By sharing a desktop view, teacher can discuss and practically present the subsequent stages, and the students to follow the activities. Data obtained in the 3D scanning process are saved in the form of a point cloud. Each point of this cloud has its coordinates (x, y, z) in the Cartesian system. The 3D scanner also captures the texture of the model by saving it in a bitmap graphic format. A so-called texture map is created.

The first stage is the import and processing of point clouds. It is carried out with Artec Studio software. Point cloud consists mainly in "cleaning the rubbish" in individual scans, bringing them to a common coordinate system and merging them into one whole.

The next stage is to generate a mesh model. Such models consist of vertices, and edges. The greater the number of vertices obtained, the more accurately the model reproduces the volume. The problem, however, is its size after saving. Therefore the next step is to optimise the mesh. Special algorithms are used to reduce the number of vertices without significantly affecting the quality of the displayed model.

The next stage is texturing. The texture is very often initially corrected in Gimp. Overlaying the texture on the 3D model allows to obtain its photorealistic properties. The resulting model can be exported to the Volume format. This format is supported by most 3D graphics programs. If the mesh model requires further optimisation or repair of the mesh, the MeshLab program is used.

Digital artefact models very often show signs of damage or are incomplete. Digital reconstruction can be realised using the Blender program. It allows to carry out complex modifications of the mesh models and their texturing again. Fig. 2 presents exemplary stages of post-processing of a flacon from the 12-13th century (Afrasiyab, Uzbekistan) [23].
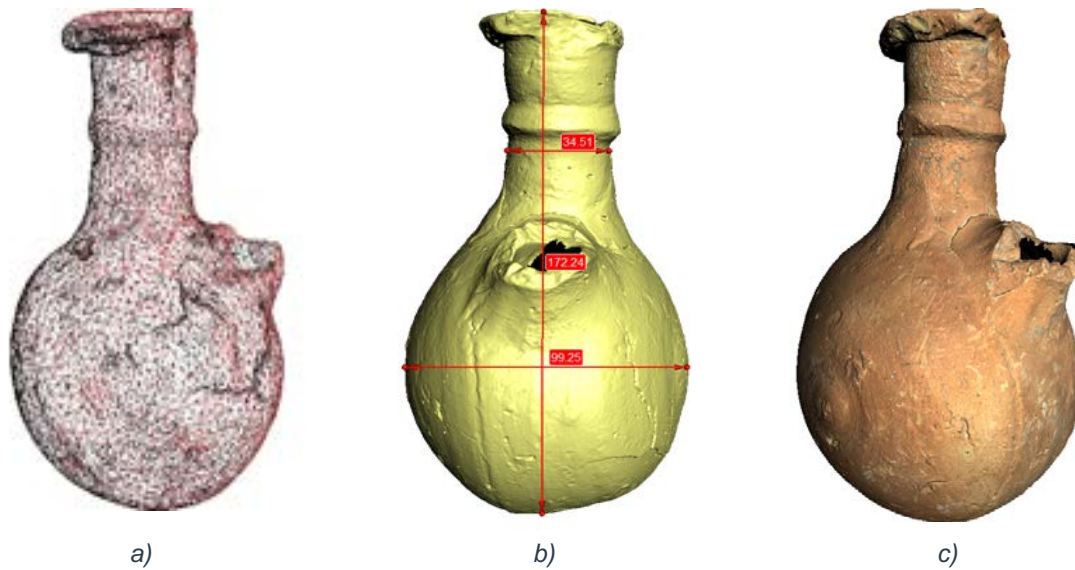
a)   *b)*   *c)*

Figure 2. Example results of the post-processing of a 12-13th century flacon. (Registan): a) mesh model, b) measurement of geometric dimensions, c) model after texturing.

Fig. 2 a shows 3D mesh model of vertex optimisation. Such model reproduces the shape of an object but does not contain information about its texture. It can be displayed as solid which allows to obtain a very realistic appearance displayed in one colour as shown in Fig. 2 b. This figure also shows the possibility to measure the geometric size of the object. Fig. 2 c shows a 3D digital model with texture overlay. The final result is a realistic appearance of the digitally reproduced artefact model.

3.3   Results of research on the effectiveness of the applied method of distance learning for students

After the course on the basics of computer graphics containing content related to the post-processing of 3D models, the effectiveness of the applied distance learning method was examined. When asked which form of teaching students preferred, whether full-time or distance learning, 55.3% of them chose the full-time form. A large number of students pointing to remote learning suggested that a significant proportion of them accepted this solution. During the classes, 80.9% of students did not have any problems with Internet connection. The rest of them indicated occasional problems with connecting during classes, which affected their understanding of the content. The solution is to place materials online, allowing the students to work asynchronously. Figure 3 shows the students' answers to the question "Was it easy for you to understand the content provided by the teacher during the remote classes? Analysing the grading scale, most people had no difficulty in understanding the content presented in the classroom.
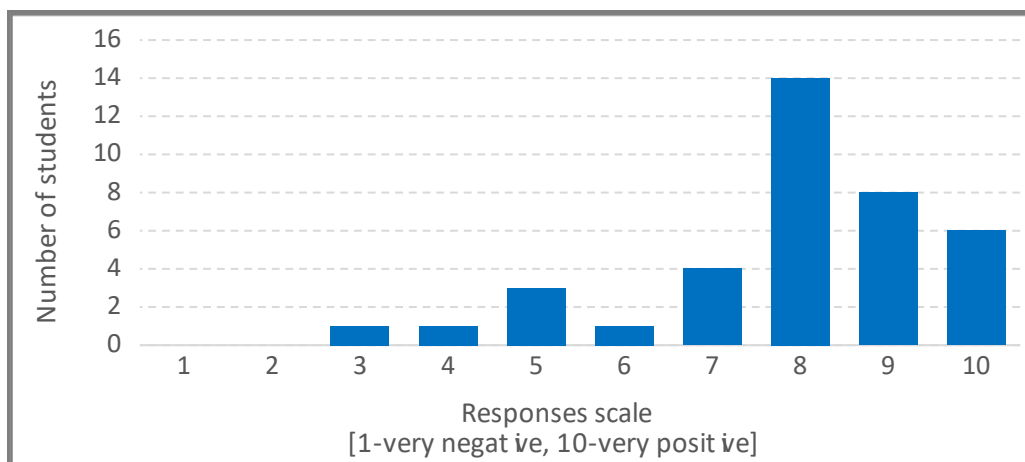

Figure 3. Answers to the question "Was it easy for you to understand the content provided by the teacher during the remote classes?

The correct choice of information technologies used in remote learning (Teams, Moodle) was indicated by 83% of respondents. Similarly, 88% of the students surveyed indicated the correctness of the 3D graphics learning programmes used (Artec Studio, Blender, MeshLab). Such a high percentage of positive answers allows to conclude that the choice of technologies and tools was correct. Similarly, work with materials placed on the Moodle platform was evaluated positively. The use of these materials was positively assessed by 81% of the surveyed students. Figure 4 presents the answers to the question "Whether distance learning was effective in achieving educational results". The answers in this case were more varied. However, the majority of the respondents assessed the realisation of the assumed educational results in the syllabus as effective.
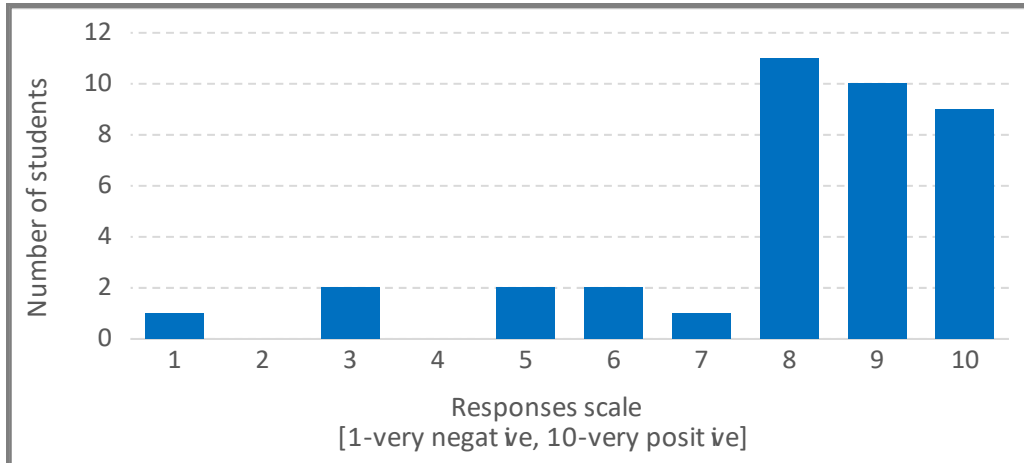

Figure 4. Answers to the question "Assess whether distance learning was effective
in the realisation of educational results".

The latter question was formulated in the following way: "Evaluate the selection of teaching content in the field of 3D graphics". Fig. 5 presents the answers obtained. Here, too, a considerable spread of answers in relation to the average was obtained. However, most of those surveyed assessed the selection of teaching content as positive, which is evidenced by the fact that the maximum mark of 10 (adequate selection and within the appropriate scope of this subject) was indicated by 10 persons.
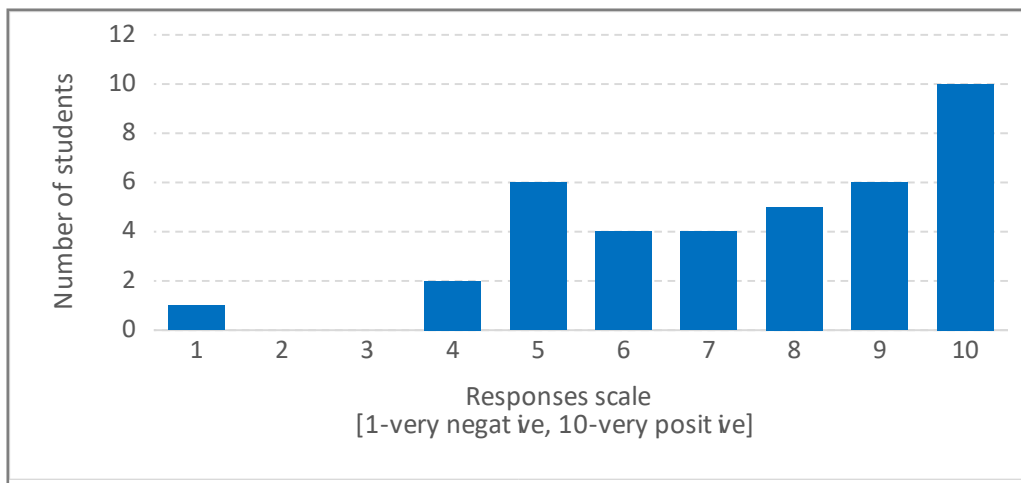

Figure 5. Answers to the question "Evaluate the selection of teaching content in 3D graphics".

Emphasising the practical use of the content taught (post-processing of 3D models of artefacts coming from the Silk Road area) is an important aspect of the educational process and is well received by students.

4   CONCLUSIONS

The choice of remote teaching technology (Teams, Moodle) and 3D graphics tools (Artec Studio, Blender, MeshLab) allowed for the implementation of distance learning post-processing of 3D models on the example of artefacts coming from the Silk Road area, which is presented in Figure 3. Referring to the answers of the respondents, the introduction of e-learning technology to the process of teaching computer graphics gave great flexibility in using information in the form of graphic files. Such training materials are more interesting and easier to understand for students, as shown by the results in Figure 4.

Free Moodle and Teams software packages have allowed to achieve previously assumed teaching goals and can be used in further teaching work. The obtained results of the surveys allowed to confirm the effectiveness of the applied method of distance learning in the field of 3D graphics. The students positively assess both the choice of computer programs and the selection of content offered (Fig. 5).

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