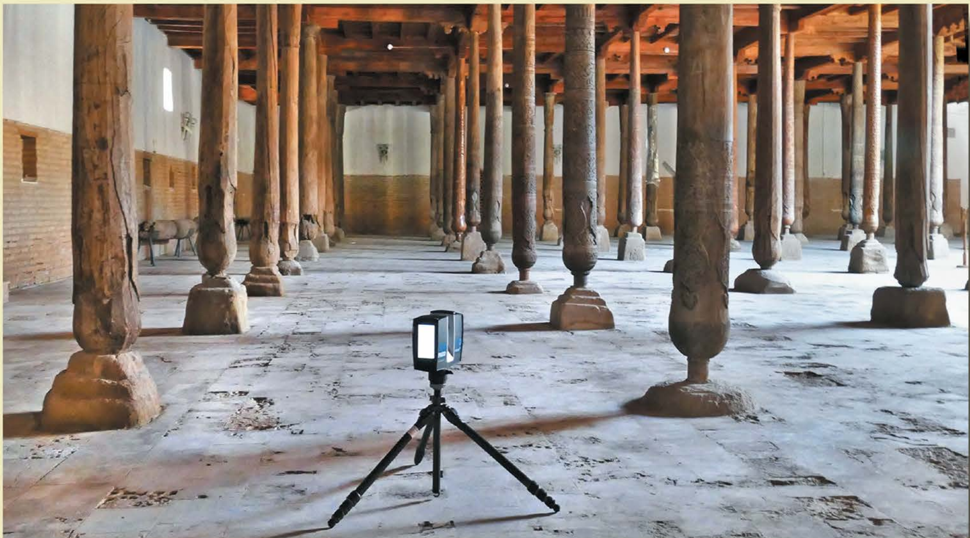
Politechnika Lubelska

Computer technologies in sharing the cultural heritage and education of the Silk Road from Uzbekistans

edited by
Jerzy Montusiewicz
Utkir Abdullaev



MONOGRAFIE

Lublin 2022

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Monografie – Politechnika Lubelska

POLITECHNIKA
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I INFORMATYKI

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LUBLIN UNIVERSITY
OF TECHNOLOGY

Lublin 2022

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This monograph has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00004 titled „3D DIGITAL SILK ROAD". The printing of the monograph was financed from the Lublin University of Technology Scientific Fund No FD-ITIT-001.

Publication approved by the Rector of Lublin University of Technology

ISBN: 978-83-7947-516-2

Publisher: Wydawnictwo Politechniki Lubelskiej
www.biblioteka.pollub.pl/wydawnictwa
ul. Nadbystrzycka 36C, 20-618 Lublin
tel. (81) 538-46-59

Printed by: Soft Vision Mariusz Rajski
www.printone.pl

The digital version is available at the Digital Library of Lublin University of Technology: www.bc.pollub.pl

Circulation: 60 copies

Spis treści

Preface

The fourth volume of the monograph is a continuation of two volumes published by the Lublin University of Technology Publishing House in 2021: Tangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan and Intangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan and one in 2022: Cultural Heritage of Uzbekistan – from Petroglyphs to the Present Days. The first contacts of the employees of the Department of Computer Science with partners from Uzbekistan took place in 2014. In the following years, the first agreement was signed, the first joint articles were prepared, and in 2017, scientific expeditions were organised, the main goal of which was the three-dimensional digitisation of the cultural heritage of the Silk Road. An additional goal was to transfer knowledge about 3D technologies to academic communities by conducting several scientific seminars in Uzbekistan, Kazakhstan and Kyrgyzstan. During the expeditions, small museum artefacts and large architectural objects were digitised in 3D technology. The cooperation resulted in the preparation of joint conferences in Lublin (Poland) and Samarkand (Uzbekistan): International Conferences on Information Technology in Cultural Heritage Management (IT-CHM) and allowed for the preparation of many scientific publications for international conferences and for journals.

In 2019, the cooperation between the Lublin University of Technology and Uzbekistan allowed us to obtain a project financed by the Polish National Agency for International Exchange (NAWA), under the name "3D Digital Silk Road" (project number PPI/APM/2019/1/00004). The new source of financing made it possible to significantly expand the existing cooperation. The Lublin University of Technology and the partners – 4 universities from Uzbekistan: National University of Uzbekistan (NUU) in Tashkent, Samarkand State University (SamSU), Chirchik State Pedagogical Institute (CSPI) and Urgench State University (USU) participates in the project.

This monograph is the result of the International Conference "IT in Cultural Heritage of the Silk Road (IT-CHSR'2021)", which took place on December 13–15, 2021 at the Lublin University of Technology (Lublin, Poland). There were over 20 people from Uzbekistan among the participants of the conference, of which 15 people came to Lublin, and the rest had speeches at the on-line session. The participants represented the most important university and museum circles in Uzbekistan. The monograph contains works that, due to the subject matter covered in them, can be classified into the following groups: preparing museums with the use of computer technologies, including 3D museology, the use of IT to protect cultural heritage, both tangible and intangible (3D scanning of small artifacts, 3D modelling with reconstruction architectural objects and 3D dance recording, modelling of vibrations of historic buildings), educational applications of various computer graphics technologies, the use of IT technology in the broadly understood service of tourist traffic, as well as the use of automatic translation of literature.

We owe the publication of the monograph, first of all, to the authors and co-authors of the texts, collaborators involved in the implementation of the "3D Digital Silk Road" project and the reviewers who assessed the articles accepted for conferences, and the reviewers of the entire monograph. We would like to thank everyone who contributed to the preparation of this volume, despite numerous other duties.

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THE "3D DIGITAL SILK ROAD" PROJECT AS AN EXAMPLE OF THE USE OF 3D COMPUTER TECHNOLOGY TO DIGITISE THE SILK ROAD MONUMENTS IN UZBEKISTAN

Abstract

The paper presents the results of cooperation between scientists from the Department of Computer Science of the Lublin University of Technology with universities in Uzbekistan in the field of 3d digitization of small museum artifacts and architectural objects from the Silk Road area. Various aspects of activities carried out mainly during the implementation of the "3D Digital Silk Road" program (PPI/APM/2019/1/00004) in 2019–2021 are presented: training in 3D digitization, scientific expeditions in Uzbekistan and joint conferences conducted in remote mode and in real life. The content of the silkroad3d.com portal presenting the implemented activities was also described.

Keywords: Silk Road, 3D scanning, access to cultural heritageritage, protection of cultural heritage

1. Introduction

Since 2015 the Department of Computer Science of the Lublin University of Technology has conducted research based on 3D technology within its Laboratory of Inteligent Systems Programming and Computer 3D Technologies (Lab 3D).

The object of study is mainly the digitisation of museum and architectural objects and the application of 3D technology in the field of museology and digital sharing of exhibits.

In December 2019, the Polish National Agency for Academic Exchange (NAWA) awarded funding for the "3D Digital Silk Road" project (PPI/APM/2019/1/00004) under the Academic International Partnerships program. The project's value amounts to PLN 1,043,900. The initially planned project period, October 1, 2019 to September 30, 2021, was extended by a year until September 30, 2022 due to the global Covid-19 pandemic. The project is carried out by the Lublin University of Technology (PL) in collaboration with 4 universities in Uzbekistan: Uzbekistan National University (NUU), Samarkand State University (SamSU), Urgench State Pedagogical Institute (USU) and Chirik State Pedagogical Institute (CSPI). The aim of the project is to carry out scientific and research works on the digitisation of the Silk Road in the territory of modern Uzbekistan. This takes place during the LUT's scientific expeditions there, and in collaboration with our Uzbek partners. The results of these works are shared at international conferences, in scientific publications, on the LUT and partner university websites, as well as the www.silkroad3d.com portal in 4 languages: English, Russian and Uzbek [14].

2. Historical and organisational aspects of scientific expeditions to Uzbekistan

The cooperation of the LUT with universities in Central Asia, including Uzbekistan, has been carried out for over 10 years within various projects. Digitisation of the Silk Road monuments is part of the tasks of the "3D Digital Silk Road" project, but is also a continuation of the previous cooperation between museologists from Poland, Uzbekistan, Kazakhstan and Kyrgyzstan with IT specialists from the LUT. On the territory of modern Uzbekistan, through which the legendary Silk Road passed, there are many architectural monuments: madrasas, mausoleums and mosques, and Uzbek museums are full of interesting artefacts. The project includes scientific trips to digitise the monuments of the Silk Road. The selection of 3D scanning objects was made jointly by the project participants, based on the proposals of Uzbek partners presented at the starter meeting at the LUT. The presentation of historical aspects of the regions and the proposal of objects to be scanned were presented by the Partners at the web-conference "The Silk Road – a cultural heritage of Asia and Europe" in January 2021. The Lublin University of Technology, in return, presented the activities of the 3D Laboratory in the area of the possibility of using information technologies in museology. As a result, 4 scientific and research trips to Tashkent, Samarkand, Chirchik and Urgench, as well as additionally to Bukhara, were planned. Uzbek universities provide the logistics and organisational support for participants of expeditions from Poland. The Lublin University of Technology provides equipment and specialists for 3D scanning and supports Uzbek museologists in solving their problems.

3. Technical aspects of digitisation of monuments

The Department of Computer Science has technical facilities in Lab 3D [15] for the implementation of project tasks and scientific potential in the skills of its experienced employees. The laboratory of 3D scanning and printing (or Lab 3D) has mobile equipment for 3D scanning in the form of Artec Eva and Artec Spider handheld scanners working in structured light technology, and Faro wide area scanners working in laser technology. Lab3D also has stationary 3D replication devices at its disposal: MarkedBot Z18 FDM (Fused Deposition Modelling) 3D printer, and DWS 020X 3D printer in SLS (Selective Laser Sintering) technology. The research equipment includes an interactive 3D zSpace monitor with specialised Quazar 3D software, VR helmets: Oculus Rift DK2, Samsung Gear VR, Vizzmo, LeapMopion human-computer communication system, and 5DT Data Glove 5 Ultra gloves.

Lab3D employees have several years of experience in the field of 3D scanning – before the project, they scanned selected exhibits at the Zamoyski Museum in Kozłówka, at the Scientific-Experimental Museum-Laboratory of Samarkand State University, and at the Afrasiab Museum in Samarkand. They scanned large architectural objects in the Old Town in Lublin, the former Granary on the LUT campus, the Academic Church at the Catholic University of Lublin and other objects. The group of employees experienced in both digitisation and 3D modelling and processing techniques, as well as dissemination of scanning data, has significantly increased during the implementation of scientific and practical trips to Uzbekistan as part of the "3D Digital Silk Road" project.

The partners from Uzbekistan – university employees and museum workers did not have such experience and equipment base. As part of the preparation for joint research work, they were theoretically and practically trained in the use of 3D technology in the field of digitisation of monuments during the web training "3D scanning of small objects using low-cost scanners" in April 2021 and during the stationary training "3D scanning of small objects" in November 2021 Participation of the Partners in scientific expeditions enabled their further practical training in the field of 3D scanning and deepened international scientific cooperation between the LUT and universities in Uzbekistan.

4. Scientific expeditions and processing of 3D scanning data

Before the project, from 2014 to 2017, LUT employees conducted joint scientific and research work with SamSU mainly in remote form – the result was the publication of 5 articles at conferences in Spain, Kazakhstan and Poland. The next stage was the implementation of 3 scientific expeditions to Uzbekistan, Kazakhstan and Kyrgyzstan: in 2017, 2018 and 2019. Objects, petroglyphs and artefacts were scanned in the museums of Samarkand, Tashkent, Shahrizab of Turkestan and in the area of Lake Issyk-Kul. The expeditions resulted in panoramas, 3D models and VR (Virtual

Reality) images of scanned objects, as well as 15 scientific articles published in indexed journals. The list of articles is available on the website https://silkroad3d.com/?page_id=304&lang=pl. As part of the "3D Digital Silk Road" project, 4 more scientific and research trips to Uzbekistan were planned and carried out jointly with partners from Uzbekistan. The aim of the expeditions is to gain practical experience in 3D scanning and data processing of interesting architectural and museum objects of the Silk Road, obtaining research material for scientific publications, helping to solve the problems of Uzbek museologists by exploiting the possibilities of modern IT technologies, as well as transferring 3D scanning experience to partners from Uzbekistan. As part of the "3D Digital Silk Road" project, a 3D scanner was loaned to SamSU and shipped to Samarkand. With the use of the zoom.us platform, a successful training in the use of a simple 3D scanner was conducted in order to be able to carry out scientific and research work together with partners from Uzbekistan.

In the face of the global Covid-19 pandemic and the inability to travel to Uzbekistan in 2020, the first expedition was carried out in May 2021 in remote form as a virtual expedition. A remote scanning experiment was carried out – under the distance management of a specialist from Poland, who had an identical scanner, the samSU scanned ceramic vessels and figurines as well as Uzbek hats – tubeteikas. The acquired 3D scanning data was sent to Poland, where specialists from Poland made digital 3D models. The representatives of partners from other Uzbek universities passively participated in the experiment. More than 50 GB of raw data was obtained. The result of the virtual trip are 2 mini digital collections placed on the project portal: 12 works by the artist-ceramist H. Baturov and 12 Uzbek tubeteikas.

In August and October 2021, there was an opportunity to travel to Uzbekistan – two more (second and third) scientific trips were carried out. The purpose of the expeditions was not only to obtain scanned data for new architectural objects and artefacts of the Silk Road in Uzbekistan, but also to strengthen scientific and research cooperation. 3 scientific seminars were conducted (at NUU, CSPI and USU). Measurements of the deviation of the dome of the Golden Mosque in Registan were also carried out as a continuation of previous research according to the developed methodology, at the request of the directors of the Registan Complex in Samarkand. 3D scanning of architectural objects and artefacts was carried out in the museums of Tashkent, Chirchik, Samarkand, Urgench and Chiwa. Over 270 GB of data was collected during these two expeditions. After the expeditions, specialists from the LUT processed the scanning data, which resulted in the creation of 3D models, panoramas and VR images, later placed on the silkroad3d.com project portal.

5. Practical and scientific achievements of the project

The "3D Digital Silk Road" project enabled the implementation of 3D computer scanning technologies in practical and scientific tasks of digitising Silk Road objects in Uzbekistan.

The practical results of the project so far have been the acquisition of 220 GB of data, on the basis of which 24 3D models were made during the first virtual expedition, 48 3D models, 12 3D panoramas and 6 VR images presenting Silk Road objects from the areas of Tashkent, Samarkand, Chirchik, Urgench and Chiva. They have all been made available on the multilingual silkroad3d.com community portal. By scanning so many objects, LUT employees acquired or improved their practical scanning skills with the use of their equipment. Uzbek museums where the scanning works were carried out received virtual 3D models from the Lublin University of Technology to be placed at multimedia exhibitions, as well as selected copies of the scanned artefacts printed on 3D printers. Employees of Uzbek universities, as well as employees of museums and other facilities, also gained practical experience in the field of scanning and ideas for implementing 3D computer technologies in museums and partner universities in Uzbekistan. The practical results of the projects include the solution of engineering tasks by IT specialists from the LUT, set by museum specialists from Samarkand. The tasks required the development of a scientific methodology and were described together with solutions in scientific publications.

The most valuable results of the project are the results of scientific cooperation. As part of the project, scientific seminars were conducted at the LUT and partner universities in Uzbekistan, so far two international conferences have been organised: one on-line, the other on site at the Lublin University of Technology (with one remote session), during which scientists from the fields of computer science, history and social sciences could exchange experience, undertake joint research work and disseminate its effects in the form of scientific publications.

As part of the project, six joint scientific publications were published in 2020, in which:

- The possibilities of using virtual reality technology were presented on the example of Samarkand museums [1].
- A methodological approach to scanning and visualisation of large monuments in Central Asia was presented [2].
- The problem of calculating the size of ceramic tiles in the given colour range for the renovation of the Sher-Dor madrasa portal with tigers in the Registan Complex in Samarkand [3] was resolved, which was widely echoed in the local Uzbek press: "Scientists from the Institute of Computer Science help save tigers in Uzbekistan" [14]. Based on 3D scanning, an exact copy of the portal with tigers in a 1:1 scale was printed, which will significantly improve the conservation work.
- The application of information technology for the creation of a virtual and interactive Afrasiyab museum in Samarkand was presented [4].
- A series of seminars for museum employees devoted to the implementation of 3D information technologies in the protection and popularisation of the cultural heritage of the Silk Road was organised [5].

- The website silkroad3d.com, currently developed as part of the NAWA project "3D Digital Silk Road", was presented as an example of disseminating the material heritage of the Silk Road in contemporary Uzbekistan in the global community of Internet users [6].

In 2021, as a result of the international web-conference "The Silk Road – a cultural heritage of Asia and Europe", two scientific monographs were created: "Tangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan" and "Intangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan "[7, 8]. In addition to the monographs, in 2021 international scientific cooperation between the LUT and partner universities in Uzbekistan resulted in 5 publications in which:

- a scientific approach was presented to assess the degree of inclination of the dome of the Golden Mosque in Registan (after its renovation) with the use of 3D scanning technology – the research was carried out twice in 2019 and 2021 [9];
- methods and examples of cooperation between Polish IT specialists and Uzbek museologists in the field of digitisation of the cultural heritage of the Silk Road in Uzbekistan were discussed [10];
- the first ever methodical approach to 3D scanning of historical clothing exhibits was presented, and the application of this approach in scanning the robes of the last emir of Bukhara with a 3D scanner operating in the structured light technology was discussed [11];
- a comparative analysis of digital 3D models of various objects was carried out, which were created using two methods: 3D SLS and SfM [12];
- the method of decomposing architectural objects in order to develop virtual 3D models and replication was presented [13].

6. Silkroad3d.com portal – publication of digitisation results

All works related to the digitisation of cultural heritage monuments in Central Asia, reports on the tasks carried out under the "3D Digital Silk Road" project, the results of cooperation between the LUT and universities in Uzbekistan were presented on the website www.silkroad3d.com [14]. The portal works in 4 languages: English, Polish, Russian and Uzbek, occupies 3.46 GB and was visited by 2,494 Internet users from 105 countries (as of December 31, 2021, data based on Google Analytics). The most important role of the portal is to disseminate the digitised monuments of the Silk Road to a wide community of Internet users in the form of 3D models, 3D panoramas and images for VR glasses.

7. Summary

Modern information technologies make it possible to document monuments of the world's cultural heritage in a digitised form and save them from oblivion. 3D scanning technologies allow to create accurate 3D virtual models of architectural objects and artefacts, create interactive 3D panoramas and images for virtual reality glasses. Internet technologies make it possible to place digitised monuments on the web, popularise and share them with a wide community of Internet users, encouraging actual tourist exploration of Uzbekistan, or participation in virtual expeditions for those who cannot travel physically. The "3D Digital Silk Road" project is a real example of the use of 3D computer technologies to digitise cultural heritage objects.

This article has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00004 titled "3D DIGITAL SILK ROAD".

References

[1] Kamil Żyła, Jerzy Montusiewicz, Stanisław Skulimowski, Rahim Kayumov. VR technologies as an extension to the museum exhibition: A case study of the Silk Road museums in Samarkand. *Muzeologia a Kulturne Dedicstvo (Museology and Cultural Heritage)*. 2020, no. 4, pp. 73–93.

[2] Marek Miłosz, Jacek Kęsik, Jerzy Montusiewicz. 3D Scanning and Visualisation of Large Monuments of Timurid Architecture in Central Asia – A Methodological Approach. *Journal on Computing and Cultural Heritage*. 2020, vol. 14, no. 1, pp. 1–31.

[3] Marek Miłosz, Elżbieta Miłosz, Jerzy Montusiewicz. Determination of ceramic tile colour surface areas on the medieval Sher-Dor Madrasah mosaic in Samarkand – Problems and solutions. *Digital Applications in Archaeology and Cultural Heritage*. 2020, vol. 16, pp. 1–6.

[4] Marek Miłosz, Stanisław Skulimowski, Jacek Kęsik, Jerzy Montusiewicz. Virtual and interactive museum of archaeological artefacts from Afrasiyab – An ancient city on the silk road. *Digital Applications in Archaeology and Cultural Heritage*. 2020, vol. 18, pp. 1–12.

[5] M. Miłosz, J. Montusiewicz, J. Kęsik. 3D Information Technologies in Cultural Heritage Preservation and Popularisation – a Series of Seminars for Museologists Made by Computer Scientists. [in]: EDULEARN 20: 12th Annual International Conference on Education and New Learning Technologies, Walencja, Spain 6–7.07 2020: conference proceedings. 2020, pp. 544–549.

[6] Elżbieta Miłosz, Marek Miłosz. Worldwide education of culture heritage using new technologies – "3D Digital Silk Road" portal case study. [in]: INTED 2020: 14th International Technology, Education and Development Conference. 2020, pp. 1812–1818.

[7] Elżbieta Miłosz, Dilbar Mukhamedova (eds). *Tangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan*. Lublin: Politechnika Lubelska, 2021. 134 p. ISBN 978–83–7947–459–2.

[8] Marek Miłosz, Gafurdjan Mukhamedov (eds). *Intangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan*. Lublin: Politechnika Lubelska, 2021. 180 p. ISBN 978–83–7947–463–9.

[9] Jacek Kęsik, Marek Miłosz, Jerzy Montusiewicz, Khonkul Samarov. Documenting the geometry of large architectural monuments using 3D scanning – the case of the dome of the Golden Mosque of the Tillya-Kori Madrasah in Samarkand. *Digital Applications in Archaeology and Cultural Heritage*. 2021, vol. 22, pp. 1–11.

[10] Marek Miłosz, Rahim Kaûtov, Honkul Satarov. Cooperation in the Digitisation of Cultural Heritage. *Moziydan sado (Echo of history, Ekho istorii)* 2021, vol. 89, no. 1, pp. 20–24.

[11] Jerzy Montusiewicz, Marek Miłosz, Jacek Kęsik and Kamil Żyła. Structured-light 3D scanning of exhibited historical clothing – a first-ever methodical trial and its results. *Heritage Science*. 2021, vol. 9, no. 1, pp. 1–20.

[12] Marcin Barszcz, Jerzy Montusiewicz, Magdalena Paśnikowska-Łukaszuk and Anna Sałamacha Comparative Analysis of Digital Models of Objects of Cultural Heritage Obtained by the "3D SLS" and "SfM" Methods. *Applied Sciences*. 2021, vol. 11, no. 12, pp. 1–20.

[13] Jerzy Montusiewicz, Marcin Barszcz, Krzysztof Dziedzic, Tomasz Nowicki. The Method of Decomposition of Architectural Objects for the preparation of 3D Virtual Models and Replication. *Advances in Science and Technology Research Journal*. 2021, vol. 15, no. 2, pp. 247–257.
[14] Internet portal silkroad3d.com
[15] Website of the Department of Computer Science https://cs.pollub.pl/lab-3d/

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INFORMATION TECHNOLOGIES FOR STUDYING THE HERITAGE OF THE GREAT SILK ROAD

Abstract

The Great Silk Road is an important part of our history. It had a significant impact on the development of civilisation. Its study is connected with progress in information technologies that have been developing rapidly in recent years. The work also briefly presents such a scientific direction as historical informatics. Some information technologies are shown that are used in the study of history and can be used in the study of the Great Silk Road.

Keywords: Silk Road, information technology, cultural heritage.

1. Introduction

Since ancient times, people have sought to travel to see new lands, meet other people and exchange goods, skills and new ideas with them. Travellers risked meeting unseen animals or being captured by robbers who might have been met during their travels. However, the chance to get more through intellectual and cultural exchange made the potential dangers to be ignored.

Traders were looking for new markets for their goods, while they themselves were actively involved in obtaining new wares. They brought from other countries new cultural values in the field of art, literature and science, exchanging knowledge about crafts and technologies, shaping the development of languages and the penetration of new religions. The first brave wanderers were Chinese travelers, who risked their lives on the routes of the Great Silk Road.

Traders did carry all kinds of goods: textiles, myrrh and incense, jasmine water, nutmeg, ginseng, jasper, amber, corals, precious stones, ivory and pearls, gold, silver, furs and weapons, earthenware and porcelain dishes, Indian elephants and purebred Arabian horses, camels, hunting falcons, peacocks and talking parrots, etc. As well as oriental sweets, spices and decorations. Silk, along with gold, was a kind of international currency. It paid for goods, settled tribute, squared debts. Silk clothes could once only be afforded by the "powerful of this world". One of the longest sections ran through the territory of Central Asia and present-day Kazakhstan.

It took a year to traverse the entire Silk Road, so merchants began to use sea routes as a faster and less risky way to travel. In addition, one ship could take on board as many people as a large caravan. Therefore, by the 16th century, only short caravan routes between China and Central Asia were used.

We owe a lot to the Great Silk Road. This road spawned and developed many institutions, including international trade, labour distribution, international banking, property and consumer protection. In addition, there was an active exchange of technologies, ideas and art along the Silk Road, which stimulated the development of culture. Wealthy Europeans discovered the beauty, strength and positive effects on the body of silk fabric, and Chinese and Central Asian paper made typography accessible. But most importantly, diverse peoples learned about each other's culture, religions and way of life.

These routes have existed since ancient times, but despite this, the name "Silk Road" is a relatively recent concept. It was proposed by the geologist Baron Ferdinand von Richthofen in the middle of the 19th century, who called the system of communications and trade *Die Seidenstrasse*, the German for The Silk Road.

2. Historical informatics and its tasks

Somewhere in the 1960s, a new direction in information science was born – historical informatics. This subject is a scientific discipline that studies the specifics and features of the informatisation process in the field of historical science and education. It is based on a set of theoretical and applied knowledge necessary for the use of modern information technologies in research practice and historical education [1–5].

In 1986, the International History and Computing Association was established. Historical informatics is actively developing in Germany, Great Britain, Austria, Holland, USA, Norway and many other countries. In these countries, scientific centres have been established that conduct theoretical and applied research in this area.

Scientific research focuses on the development of theoretical and applied problems and the informatisation of historical science and education. Particular attention is paid to the problems of digitisation, preservation, documentation, visualisation and the study of historical and cultural heritage, primarily historical sources, based on the creation of full-text history-oriented information systems. Such projects are actively supported by various international and local foundations (for example UNESCO).

Particular attention is paid to the creation of high-quality three-dimensional photogrammetric models of objects of historical and cultural heritage, the digitisation of literary sources, books, art canvases, etc.

Thus, this direction is a synthesis and mix of humanitarian disciplines with information technology and is one of the ways to preserve historical heritage.

3. Methods of information technology

3.1. Database

One of the methods I would like to start with is the method of creating various databases. As is known, a database is a way to combine various types of information related to any source, and which can have a significant volume, including, in addition to text, also various drawings, photographs, videos and other materials [6–8]. Let us briefly consider what a database is and how it can be used in relation to the purpose of our work.

To begin with, we need to formulate the goal of our work, for which we need to make a database and determine what information will be stored in our database and in what volume.

Let us start with what a database is. Imagine a bookcase that holds various items. These can be printed books, manuscripts, reference books, photo albums, figurines, stamp albums, video and audio materials. They are all in the closet, but are usually placed according to the material to be stored. That is, the books will be stored on one shelf. Directories will be in another part of the cabinet. Video and audio materials will be placed in a separate place in the cabinet, maybe even in a special box for storing such materials. And so on. In this way, all of our stored information will be stored in its place so that it can be easily found. This is one of the ways to post information.

Another storage method is thematic direction. Let us say we have a certain set of different information, categorised according to certain topics. For example, in relation to our historical heritage (the Great Silk Road), information can be arranged in relation to different time intervals, e.g. BC, the first centuries of our era, etc. You can collect information on a territorial basis, for example, the European part of the Silk Road, Central Asia, etc.

The third method can be tied to specific areas, for example, trade goods, what goods were in demand in certain cities or states, how the exchange took place. Or you can make a database on scientific areas, how science developed in different areas, taking into account the influence of different cultures on its distribution. For example, how mathematics (algebra) developed, starting with the very first scientist who became the creator of its foundations and how it developed later (Muhammad bin Musa al-Khorezmi became the founder not only of general rules for solving equations, but also laid the foundations of the key concept of computer science – algorithm). In the future, it will be interesting to trace, thanks to the created database, how his teachings were able to penetrate Europe and become an important subject in education.

Thus, the creation of a database is one of the ways to apply information technology to the study of history in general, and the Silk Road in particular. This method is not a complex technology and does not require any special knowledge. The main difficulty can only be in creating the base itself, choosing a software package or programming language. Anyone can fill the database.

3.2. Digital technologies as a way to preserve information

Another way of using information technology is a list of digitising various records, archival materials, manuscripts, paintings for the purpose of preserving them in electronic form [9–11]. As is known, historical archives contain tens of thousands of handwritten sources and historical documents. Often, these documents are available in a single copy. To study many of them, it is required to spend more than one year, since often these manuscripts are written in old, already defunct dialects that cannot readily be understood, since the terms used in them are no longer found in modern languages.

In order to preserve such literary monuments with the help of special equipment (scanners), they are digitised and stored in digital media [12–16]. In addition to preserving manuscripts by digitisation, the circle of their readers is expanding: more and more people will be able to use such an electronic archive in order to more freely and conveniently study such sources. For example, there are manuscripts that are kept in closed storerooms of libraries or archives, because they are in very poor condition and it is impossible to give them out for study to everyone who wants to do it. Once digitised, the library will be able to provide readers with a digital or printed copy of the digitised book or manuscript, making it easier to study.

With regard to the topic of our work, it is possible to digitise literary sources that were created during the functioning of the Great Silk Road and were disseminated through trade and travel.

Examples are shown in Figure 1–2.

Figure 1. External view of an old manuscript (taken from open source)

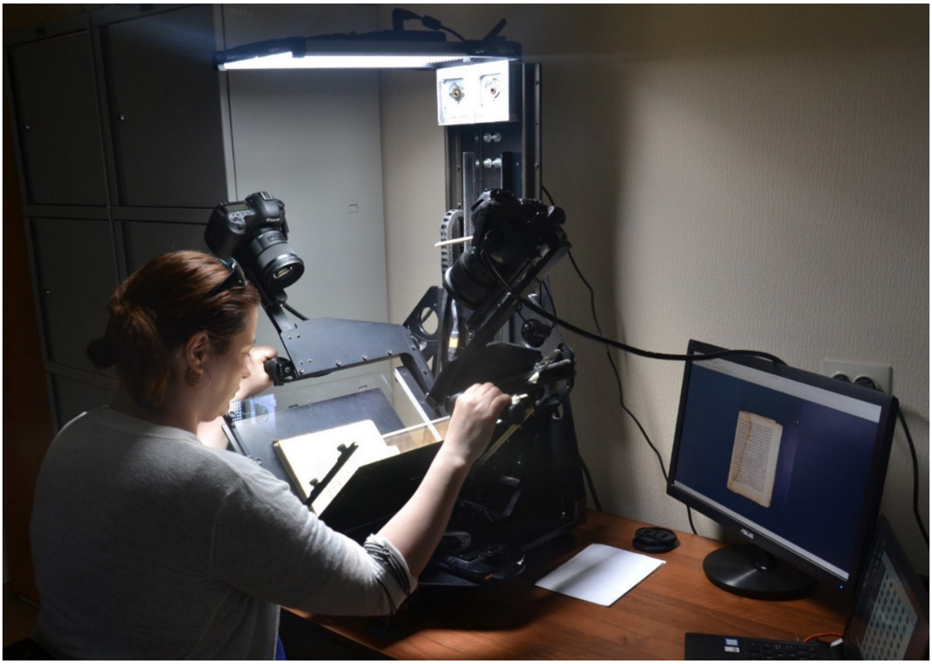

Figure 2. Scanning and digitising a historical book (taken from open source)

3.3. 3D scanning of objects of historical value

Professional 3D scanning of historical objects allows to save them for further study or reconstruction. These objects include ancient artefacts – items of archaeological excavations, as well as old buildings and other items of scientific and historical work. Many of them have been severely damaged or are threatened with extinction. Various technologies can be used for scanning with 3D scanners, each with its own limitations, advantages and disadvantages. Today the main ones are optical and laser 3D scanning technologies.

Laser scanning allows to preserve the existing appearance, and then, using computer modelling, restore the most likely original appearance. Limitations in scanned objects are present in each of these technologies. 3D laser scanners are mostly not suitable for scanning moving objects, since scanning takes a long time. Therefore, their use is difficult if the object is a person. The advantage of using this technology is the high accuracy of the resulting 3D model and a large range.

Optical 3D scanners find it difficult to scan shiny, specular, or transparent surfaces. The advantages of such devices are high scanning speed, which eliminates the problem of distortion of the resulting model when the object moves, and the absence of the need to apply reflective marks. For laser scanning, terrestrial laser scanning and related instruments are used. One of these tools is shown in Figure 3.

The 3D scanning technique consists in building a point cloud during scanning. In each case, a certain number of points is required, along which a three-dimensional model is then built using application programs. Using a computer, you can control the scanning process, select the resolution and the necessary areas to refine the detail, save and modify the data obtained with a three-dimensional laser scanner.

Figure 3. Panoramic digital camera Trimble V10

Digitising with 3D scanning allows to store objects in digital form and then create 3D models from them. A 3D scanner is used for this technology. It can be either manual or ground. Figure 4 shows such a handheld scanner.

Figure 4. Hand-held 3D scanner

After creating a virtual 3D model, this model can be printed on a 3D printer, which creates a three-dimensional object based on a virtual 3D model. Unlike a conventional printer, which displays information on a sheet of paper, a 3D printer allows to display three-dimensional information, i.e. create certain physical objects. 3D printing technology is based on the principle of layer-by-layer creation (growth) of a solid object.

Fig. 5 shows one of these printers.

Figure 5. 3D printer RAISE3D N2 PLUS DUAL

Figure 6 shows architectural 3D models created on a 3D printer. The models obtained with the help of a 3D printer can later be assembled into various compositions, for example, historical structures and presented in museums as model objects of historical places.

The information technology that can be used to study the Great Silk Road in a particular case depends on various factors. However, all of them in one way or another serve as a way of preserving and studying historical heritage.

Figure 6. Models of architectural objects created on a 3D printer

4. Conclusion

In this work we have considered only a few information technologies used to study and preserve historical heritage in general. These technologies can also be successfully used to study the Great Silk Road. In particular, creating a database and populating it with information pertaining to the history of the Silk Road can help in exploring specific questions arising from any scientific research. The database can help answer some questions from researchers without resorting to reasoning. Digitising manuscripts and objects in 3D and then studying from them, for example, what architectural structures looked like in a particular period, as well as how such styles could have spread through travel and trade routes is another information technology that can be used for other tasks. Another way to study history is to create a virtual museum based on objects scanned by a three-dimensional scanner, and then turn them into 3D virtual models. And as a result, we can get virtual museums and exhibitions. You can study history using such virtual museums in much the same way as real museums. The advantage here is that you can do this without leaving your home and looking up from your computer. The result of all this can be answers to some questions, of which there are a huge number in history. And it is possible that it is virtual information technologies that will help to answer them.

5. Contribution of authors

Dilmurod Ahmedjonov – problem statement, discussion of materials, final processing of the article material. Olga Karpova – analysis of the material, , discussing the results writing up the article. Bekjan Akhmedov – collection of material and its technical.

References

[1] Povroznik N. (2020). Digital History of Virtual Museums: The Transition from Analog to Internet Environment. In: Proceedings of the Digital Humanities in the Nordic Countries 5th Conference Riga, Latvia. pp. 125–136.

[2] Povroznik N.G. (2018). Virtual museum exposition based on the antique collection of the Museum of History of the Perm University: creation and use of 3D models. Collections of the Presidential Library. Ser. "E-library". Issue 8: Digital projects in the modern information environment. p. 70–83.
[3] Povroznik N. (2018). 3D models of Ancient Greek Collection of the Perm University History Museum: Creation and Use. Digital Cultural Heritage. M. Ioannides (Ed.): ITN-DCH 2017. LNCS 10605. Springer International Publishing AG, part of Springer Nature. Pp. 1–11.
[4] Povroznik N. (2018). Virtual Museums and Cultural Heritage: Challenges and Solutions. Proceedings of the Digital Humanities in the Nordic Countries 3rd Conference Helsinki, Finland. pp. 394–402.
[5] Gagarina D.A., Kornienko S.I. (2017). "Digital Humanities Concepts and Approaches" as a training course. Materials of the international scientific and methodological conference "Teaching Mathematics and Computer Science in Higher Education". Permian.
[6] Kornienko S.I., Gagarina D.A. (2017). Historically-oriented information systems: from preservation of sources to new methods of their study. Information technology in the humanities: abstracts. report scientific-practical Conf., Sib. Feder. un-t. Krasnoyarsk: Sib. Feder. un-t. pp. 86–87.
[7] Povroznik N.G., Schmoller E. (2017). Material culture of Islam in the post-Soviet space: opportunities for study based on the resources of virtual museums. Digital Humanities: Resources, Methods, Research: Materials of Intern. scientific. conf. at 2 pm Perm: Perm. state nat. issled. un-t. Part 2. pp. 196–199.
[8] Kornienko S.I., Gagarina D.A., Povroznik N.G. (2017). Information systems in the digital environment of historical science. Istoriya, electronic scientific and educational journal. No. 7 (51). DOI 10.18254 / S0001638–0–1.
[9] Povroznik N.G. (2016). Increasing the potential of virtual museums for information support of historical science. Historical research in the digital age: information resources, methods, technologies. Materials of the XV International Conference of the Association "History and Computer": Moscow; Zvenigorod, MAKS Press. (Newsletter of the Association "History and Computer" No. 45. Special issue). pp. 213–214.
[10] Gagarina D.A., Kornienko S.I. (2015). Methods of mathematical modeling in the professional training of historians. Information bulletin of the Association "History and Computer". No. 44. pp. 85–87.
[11] Kornienko S.I., Gagarina D.A. (2015). "Historically-oriented information systems": the possibilities of the Internet resource. Information bulletin of the Association "History and Computer". No. 44. pp. 30–32.
[12] Dmitrieva A.I. (2019) .Photos in Research Practices: Experience in Developing the Architecture of a Photographic Documents Database Based on a Researcher's Request. Historical informatics. No. 2. pp. 9–18. DOI: 10.7256 / 2585–7797.2019.2.29897.
[13] Yumasheva Yu.Yu. (2019). "The Most Important of the Arts" on the Internet (digitized collections of newsreels and documentaries, presented online). Historical informatics. No. 2. pp. 19–105. DOI: 10.7256 / 2585–7797.2019.2.29919.
[14] Borodkin L.I., Vladimirov V.N. (2019). Digital technologies and resources in concrete historical research: discussions and experiences. Historical informatics. No. 2. pp. 1–8. DOI: 10.7256/ 2585–7797.2019.2.30239.
[15] Ivakin Ya.A., Potapychev S.N., Ivakin V.Ya. (2019). Rational algorithm for testing hypotheses of spatial historical research based on geochronological tracking in GIS. Historical informatics. No. 2. pp. 147–158. DOI: 10.7256 / 2585–7797.2019.2.28612.
[16] Thorvaldsen G. (2019). Linking entries in the historical population register of Norway. Historical informatics. No. 2. pp. 212–231. DOI: 10.7256 / 2585–7797.2019.2.30126.

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CREATION OF VIRTUAL MUSEUMS IN KHIVA: PRINCIPLES AND APPROACHES

Abstract

The article discusses the principles and approaches to the creation of virtual museums in Khiva. In particular, the issues of preventing the destruction of historical sites in Khiva under the influence of various influences or their sale for various purposes and their virtual transfer to future generations are highlighted. It also informs about historical informatics associated with the development of virtual reconstructions of objects of historical and cultural heritage (based on the use of 3D modelling technologies), implemented over the past decade, presents the main trends and problems.

Keywords: virtual museums, historical information technology, history modulation

1. Introduction

A person of the 21st century feels the need to use various kinds of electronic entertainment facilities, which prompts technology specialists to gradually improve and introduce qualitatively new technical solutions that allow them to open access to the demanded services of the virtual world. It is actively used by society in order to obtain information for subsequent use in various fields of activity. The virtual world has not bypassed museology. On the contrary, the concept of "virtual museum" was introduced in the 1990s. And the first personal website-museum appeared already in 1994. Initially, virtual museums consisted of slides of museum pieces. The latter could be seen in videos about museums such as the Louvre and the Hermitage, the largest museums in the world. Then they moved on to creating a virtual world based on the reconstruction of museum exhibits in 2V and 3D formats. In the modern world, it is becoming more and more relevant to refer to virtual space Virtual reality is becoming an integral part of human life. In European countries, virtualisation has accelerated in every field. However, in Central Asia, these advances in science and technology are only now being put into practice. The 3D Silk Road is one of the first projects in this area. Of course, this project will play an important role in the virtualisation of Khiva museums.

2. Literature review

There is no scientific research on the principles of creating virtual museums in Khiva. However, the development of modern technologies and the dominance of the market economy require some work in this direction. Of course, museologists are working on this in the future. Therefore, during the study of this topic, we have studied and used a number of works by European and Russian historians. A special place in the study of this issue is occupied by the work of A. V. Lebedev. In his articles, the author considers the phenomenon of network culture in general and the virtual museum as its concrete embodiment in the context of the development of multimedia technologies (Lebedev A. V. 2009). T. P. Polyakov also focuses on the use of new technologies in museums in his works (Polyakov T. P. 2003). V. V. Gvazova in the article "Virtual museum in university education" defines the concept of "virtual museum", and Yu. Yu. Katalura speak in their research about the current trends in the development of virtual culture on the example of a multidimensional phenomenon, the website of the museum. The art critic M. Abdullaev also analyses IT in museums in his articles.

3. Analyses and results

Khiva has the official status of an "open-air museum". It is known for its unique historical and architectural monuments and is included in the list of world cultural monuments among a 100 other cities on the globe. This magnificent museum-reserve is located in the "Ichon Qala" part of Khiva. It is surrounded by a high brick cotton-filled wall and its four gates – the Father Gate, the Polvon Gate, the Stone Gate and the Garden Gate – built on four sides. Some sources state that it had 10 gates [1].

Ichan Fortress is built in the form of a rectangle, 650 meters long and 400 meters wide, covering an area of 26 hectares [2]. It houses 56 historical sites. Khiva's Ichon Qala State Museum-Reserve has 19 permanent expositions located in various madrasahs and other historical buildings.

1. Department of Ancient Khorezm History (Old Ark Palace)
2. Department of History of Khorezm shahs (Old Ark Palace)
3. Department of History of Khorezm khans (Muhammad Rahimkhan II Madrasah)
4. Museum of Fine Arts (Kutlug Murad Inoq Madrasah)
5. History of music (Kozikalon Madrasah)
6. Khorezm Department of Applied Arts (Islamic Khoja Madrasah)
7. Khorezm Department of Public Education (Russian School)
8. Calligraphy department (Matpanoboy Madrasah)
9. Khorezm Department of Nature (Abdullahan Madrasah)
10. Department of Monumental Architecture (Stone Palace)
11. Pottery Exhibition (Stone Palace)
12. History of German Mennonites (Polvon Qori Trading House)
13. Permanent exhibition of the life and activity of Khudoibergan Devonov (Russian school)
14. Dorul Hikmat Val Maorif (Muhammad Amin Inoq Madrasah)

There are also newly established museums in Urgench, Khorezm. Among them are Al-Khwarizmi (Al-Khwarizmi Street in Urgench) and Al-Beruni Museum (Al-Khwarizmi Street in Urgench), as well as the Museum of the Victims of Repression.

Figure 1. UrDU Museum of Repression Victims, [9]

Figure 2. Museum of Al-Khwarizmi, [10]

In addition, there is the Khiva State Museum-Reserve "Ichon Qala" (Arab Muhammadkhan Madrasah). It houses a total of 52,000 unique exhibits [3]. These museums are the main sources of increasing the potential of domestic and foreign tourism in Khorezm. It is visited by several thousand foreign and local tourists every year, and the income from them provides a large part of the population with income.

The question arises, what are the advantages of virtualisation of museums, what are the disadvantages and in what way do they make changes to the work of the museum? Websites will be created to virtualise museums. A website can be designed to present museum exhibits to Internet users. As a distinctive feature of virtual museums, we can show that the virtual site of the museum has no restrictions and can accommodate a huge number of people who want to visit it and get acquainted with the virtual exhibits. Many scholars have speculated about the virtualisation of museums and their post-virtualisation functions. Their work will be quoted below to make it easier to learn more about the functions of virtual museums [4–7].

Figure 3. General view of Ichon Qala castle, [11]

If virtual museums are built in Khiva, they need to be like their real predecessors. A virtual museum performs the following main functions:

1. The social function of virtual museums (by providing on their platform free, open access to cultural heritage sites, the format of organising a museum site allows to use it for all segments of the population and all categories of citizens, regardless of their physical capabilities, geographic location and economic status. This is the consolidating function of virtual museums (introduction of creative contacts, network communities, etc.).
2. The socially transformative function of virtual museums (creative activity, one that is transformative in nature, influencing changes in society)
3. Cognitive – cultural and leisure function of virtual museums. Spiritual needs, which include self-education and creative development, encourage a person to acquire new information in contact with beautiful surroundings, which are easily accessible and contain a large amount of information, a combination of graphics, text, sound elements, animation, panoramic and 3D images.
4. The communicative function of virtual museums (guest books, chats, integration with social networks, etc.)
5. The economic function: the activity of virtual museums is a factor in the development of tourism.
6. The function of the preservation of modernity (exhibitions, conferences, as well as reproduced images of museum items).

Finally, we can say that the user does not need to choose a convenient time to visit and come in advance to buy a ticket. A virtual museum can be visited at the very moment such a desire arises – just open the search box and find the desired website. On the other hand, a virtual museum is an information resource that has the characteristics of the media. The virtual museum acts as a means of mass communication.

If we virtualise the expositions of 19 museums located in 56 historical sites in Khiva, it will be possible to divide them into the following types. Traditional virtual museums – in terms of the content of their sites, such museums follow the traditions of real museums. Virtual museums of this type also have a traditional approach to understanding the functions of a museum. Transitional virtual museums – virtual museums of this type use both the traditional museum product and the latest advances in computer and information technology. In their activities, they also rely on new approaches to understanding the functions of museums. Virtual museums of innovative type – virtual museums of this kind practically do not resemble traditional museums. They actively use innovative technologies in their work, and also actively operate with a new approach to the functions of museums, which is qualitatively different from the traditional approach to understanding museum functions. They interpret the concept of a museum product as broadly as possible – any cultural product is considered as a museum product. The opinion of experts about the breadth of a virtual museum is as follows: "flat" virtual museums resemble an electronic catalogue, "three-dimensional" virtual museums offer visitors the opportunity to take a virtual tour – walk through the halls of the museum, view exhibits from different angles, see panoramas, view individual elements through a magnifying glass [8].

4. Conclusions

The expositions in the virtual museums in Khiva can be arranged in the following order: The visitor has the opportunity to visit all the halls in free movement mode, inspect their interior and the exhibits presented in them. Thus, with the help of computer technologies, virtual museums of the first type create the illusion of an ordinary museum visit. And the second type allows visitors to both freely move around the museum halls, examining the exhibits, and in real time to independently select only those collections that are of greatest interest to him.

In many countries, work is currently underway to complete a database of objects and objects of the cultural heritage of the country, of the entire civilisation. In the future, this database will make it possible to place all cultural monuments within one virtual cultural centre. Khiva museums have not yet been virtualised. However, after this project we can see a lot of museums in virtual form, and we believe this direction of the project allows us to reach a qualitatively new level in the issue of preserving and transferring cultural heritage to future generations.

We know that the creation of virtual museums will allow us to restore and demonstrate our ancient historical heritage, not only that in need of repair, but also what became completely lost, on the basis of sources. 3D reconstructions play an important role in the creation of virtual museums. Scientifically based 3D reconstructions of architectural complexes can be used as a fully-fledged historical source with a high level of aesthetic and historical authenticity, which allows you to create a basis for the design of archaeological open-air nature reserves, to popularise archaeological heritage of antiquity, adapting scientific materials for presenting them in an accessible form.

3D labs are available at universities and research centres in many countries. However, it is not yet present in Khorezm. We hope that in the future on the basis of this project there will be a laboratory that will create a virtual version of the magnificent museums in the ancient city of Khiva in Khorezm.

The question: what will happen to the workforce of museum staff if all museums are virtualised in the future? We hope that the number of jobs will increase, they will study in a new direction. The knowledge of museum staff in the field of IT will become more complex. Of course, the virtualisation of museums also serves as an advertisement. After all, humanity wants to see everything with their own eyes and touch it with their hands.

Acknowledgements

The authors express their gratitude to Elżbieta Miłosz, General Coordinator of the "3D DIGITAL SILK ROAD" Programme within NAWA (Poland's National Academic Cooperation), and the project of the Ministry of Innovation Development of the Republic of Uzbekistan P3–2020102950 "Creation of a modern virtual museum Dorul Hikmat Val Maorif".

References

[1] Pugachenkova G. A., Rempel' L. I. Vydayuŭiyesya pamyatniki arkhitektury Uzbekistana. Tashkent. Fan. 1958. pp. 156. (in Russian)
[2] Khiva ming gumbaz shaẋri. Toshkent, Shark̦. 1997. p. 56–69. (in Russian)
[3] Annual report of Khiva State Museum-Reserve "IchonQala". 2021.
[4] Lebedev A.V. V. Muzeynyye predstavitel'stva v Internete. Rossiyskiy i zarubezhnyy opyt. Muzey i novyye tekhnologii. M.: Progress, 2009. p. 108–110. (in Russian)
[5] Polyakov T. P. Mifologiya muzeynogo proyektirovaniya ili «Kak delat' muzey?». Muzey i novyye tekhnologii. M., 2003. pp. 209. (in Russian)
[6] Gvazova V. V. Virtual'nyy muzey v vuzovskom obrazovanii. Mir russkogo slova. № 3. 2014. p. 99–100. (in Russian)
[7] Katalura YU. YU. Sovremennoye razvitiye yestestvennoy kul'tury na osnove mnogoaspektnogo fenomena veb-samuta. Nauka i sovremennost'. № 5. 2010. pp. 182. (in Russian)
[8] Smirnova T. A. Tsifrovyye tekhnologii v muzeynoy ekspozitsii: tekhnicheskiye, kontseptual'nyye i kommunikativnyye. Kul'tura: upravleniye, ekonomika, pravo. 2010. № 1. p. 16–18. (in Russian)
[9] https://urgamch.wikimapia.org/en/photos/
[10] https://www.traveluzbekistan.uz/tour/index.php/en/sights-and-tourist-attracions/sighrs-ofkhiva
[11] https://www.tourprom.ru/pressrelease/9102/

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VIRTUAL RECONSTRUCTION OF MEDICAL PLACES ON THE GREAT SILK ROAD (ON THE EXAMPLE OF THE HISTORICAL MONUMENT THE ANUSHAKHAN BATHROOM)

Abstract

This article discusses the issues of virtual restoration of local medicine facilities on the Great Silk Road. Indeed, the socio-economic, political and cultural processes taking place in society today show that the modern way to preserve and pass on to future generations the material and spiritual heritage created by our ancestors is to virtualise them. The article discusses the causes and importance of the Anushakhan bath and its virtualisation (3D), located in the historical city of Khiva in Uzbekistan and considered a place of local medicine during the Khiva khanate. There is also information about the healing lakes, salt mines and mediaeval medical schools that existed in the khanate and the advent of modern medicine.

Keywords: local medicine, Anushakhan bath, massage, virtualisation.

1. Introduction

Local (folk) medicine is an important and invaluable part of the health sector. In many countries it is called "folk medicine" or "non-traditional medicine". The concept of the World Health Organisation proposes to call it "complementary medicine" (WHO Strategy in the field of folk (local) medicine 2014–2023, 2014). The World Health Organisation takes into account the effective use of folk medicine in many countries, especially in the treatment of chronic diseases, as well as measures to control the use of folk remedies and practices, and accelerate the integration of world experience in such areas [1].

In this regard, the conduct of scientific research on various aspects of the forgotten folk (local) medicine, the restoration of products, instruments and facilities of folk medicine will serve to develop knowledge in this area. The Khiva khanate also had a large number of traditional medicine facilities. The salt mines of Sultan Sanjar, Qumlik, Chiqirchi, Yangiariq, Qalajiq, Khazarasp, Khiva as well as ancient lakes served as a hospital for patients (during the summer months). The Khiva khanate also had the Shergozikhan madrasah, which trained doctors, and the Anushakhan baths, which served as a hospital.

Modern medicine, on the other hand, began to be used only in the twentieth century. The first modern medical buildings and equipment were commissioned by Islamkhoja in 1913 and employed Russian doctors [2].

2. Literature review

A number of sources, historical works and scientific studies and experiments in the field of 3D rendering of historical heritage, decisions of the World Health Organisation and the Republic of Uzbekistan on folk (local) medicine, as well as items of legislation have been studied. We get information about local medicine in the Khiva khanate from the work "Manofe-ul-inson" ("Useful things for human health", 1657) written by Abulgazi Bahodirkhan at that time. It is a medical manual for khanate physicians, and Chapter 28 contains scientific information on the symptoms of 124 of ills and more than 700 medicines used to treat them. We also find more detailed information on local medicine in the book of Jafarhoja ibn Nasriddinhoja al-Husseini al-Karvaki al-Khazarasp, written in 1823, "Multoqid-al-tib" ("Collection of Medical Information"), consisting of 67 chapters. Muhammad Yusuf Bobojonbek ibn Hasanbek oglu Bayani's work "Shajaraiy Khorezmshahiy" describes the methods of verbal treatment. Historical facts about the history, construction and structure of the Anushakhan bath, Shergozikhan madrasah and Qalajiq Qala are available in the works of foreign historians and modern research historians in addition to the above authors. N. Muravev, Blankennagel, Vamberi are examples of this [3]. The works of medical researchers R. Soburov, M. Goyibov and Sh. Jumaniyazov are also among them [4]. Information about the Anushakhan bath and its function as a medical centre can be found in all sources related to the history of Khiva. In their works, they recommended the treatment of rheumatism, skin and nerve diseases using sunlight, sand, local water and salt deposits, and said that this was the basis of their medical activities.

3. Analysis, results and discussion

History of the Anushaxon bath. Three thousand years ago, in ancient Rome, the bath was considered a place to cure various diseases. The healing function of the bath is well known in Iran, China, India and Turan. The Anushakhan bath in Khiva was built in 1657 during the reign of Abulgazi Bahodirkhan. The origin of these baths has its own interesting history, amazing and extraordinary. Abulkazikhan was a happy father of nine adorable boys, eagerly desiring the birth of a beautiful daughter. When the time came for the birth of the tenth child, he was deceived, saying that a girl was born, whom he happily named after his beloved Armenian concubine, Anushi. Many years later, Abulkazikhan, a participant in many successful battles, was captured by the emir of Bukhara. The sons did not react in any way to the need to save their father's life, but Anusha, without hesitating a minute, went to rescue her beloved father from trouble. The Emir of Bukhara was amazed when he saw the daughter of the khan – he expected to meet her nine brothers, who rushed to rescue their father. But Anusha showed ingenuity, offering the emir an agreement: if she manages to surprise the emir, he will let her father go safe and sound. The Emir of Bukhara agreed, anticipating what a young girl could surprise him with. Then Anusha threw off her clothes, under which was the body of a young man. The surprised emir could only keep his word and let Abulkazikhan go. Upon returning home, Abulkazikhan said: "As it turned out, I have not nine sons, but only one – Anusha." [5]. Abulkazikhan's gratitude for the saved life was the construction of a mosque and a bath-hospital in honour of his tenth son. The owner of the throne will build this oriental-style building, which is a unique architectural monument in recognition of the resourceful son. The bath is radically different from other baths in the East in terms of construction. Part of the building is underground. The bathrooms are arranged in a similar way. From the outside, the domed roof of the building is visible.

Figure 1. Side view of Anushakhan bath, [own sourse]

Figure 2. Entrance door to the Anushakhan bathroom [own sourse]

There are about twenty rooms, five of which are served in the bathroom. Two baths, a golah, and two water-carriers worked. The barber shop inside also served customers. On Thursdays, when the order for bathing was strictly established, the nobles and their relatives were washed, on Friday the scribes and clergymen, and on other days the townspeople and villagers. The bath was in the hands of the khanate, to which the lands of the waqf (a charitable endowment under Islamic law) were also allocated. Women, children, non-believers and people with skin diseases were not allowed in the bathroom [6].

In order to heat the bathroom, various wastes from the city were used to burn the excess waste from horse and donkey dung and from the yards. This served to keep the city and the air clean. The rooms were heated by special pipes under the floor, and water was taken from the well in front of the heating room as a precaution. The large room around the centre all served a function of the surrounding rooms. In some it was possible to wash, to recover from hot steam, in others medical massage sessions were held.

In the East, the benefits of hot steam for bodily and joint diseases were known thousands of years ago. It is no secret to our doctors that massage helps with pain in a number of nervous and vascular parts of the body. Anushakhan's bath had a special room for massage, which was considered a medical treatment, not just to relax the body, and this work was done on a regular basis. There was also a separate room in the bathroom where you could brush your teeth. Removal of painful teeth has been practised in Khiva for centuries. In rural areas, this work was often done by blacksmiths. They knew that breaking a tooth that had begun to erode would often relieve the pain. If this method did not work, the diseased tooth was completely removed. In addition to brushing teeth in the Anushakhan bath, blood was also taken from patients with choking. The practice of stabilising blood pressure by taking excess blood from people with epilepsy has long been known in the East. We know from history that when he went to Herat to meet Hussein, Boykaro, who was returning from another victory, had his blood pressure raised due to excessive excitement and they tried to improve his condition by taking blood from him.

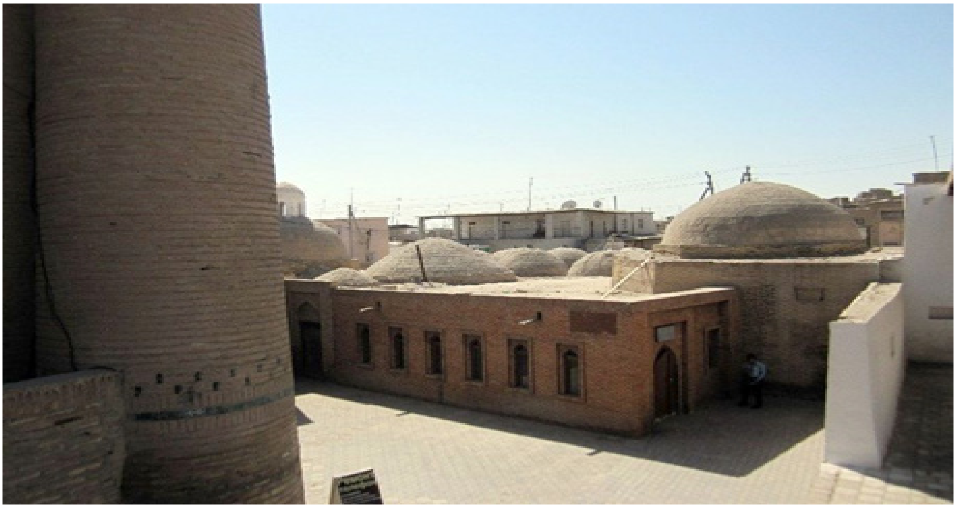

Figure 3. General view of the Anushakhan bath [own sourse]

Figure 4. The look of the bathroom in the 1980 [own sourse]

Hazrat Navoi lost consciousness. However, it was not possible to save the life of the great poet because the doctors took this measure too late.

The Anushakhan bath has all the conditions for customers to drink tea, talk and relax. In a special room, which serves as the same teahouse, in addition to ordinary tea, tea made from the roots, stems, leaves, fruits and flowers of medicinal plants and other medicinal liquids are prepared. The bathroom is a herbal store.

Taking into account all the above services, it can be concluded that Anushakhan bath was a specialised hospital of its time. This bathroom has served the people of the city for centuries. Only some years later its walls started breaking and it became abandoned [7].

Figure 5. The look of the bathroom in the 1980s [own sourse]

Renovated in the 1980s, it once again began to serve the city's residents and visitors.

Figure 6. The bathroom is now operating as a tearoom [own sourse]

Khiva also had healing springs, sacred shrines, and trees (worshiped as a cure for measles and other wounds). However, the shrine of Pahlavon Mahmud and the bathhouse of Anushakhan remained the most visited places of rehabilitation and healing. Mental and neurological patients were cured as well as those with typically bodily ailments.

4. Conclusions

Historical objects will be difficult to preserve for many reasons:

1. Natural erosion (as a result of time, rain, snow and earthquakes).
2. Destruction by people (looting of construction materials, demolition for house construction).
3. Sale by the state (for use in any cultural, commercial and organisational project).
4. Not being reconstructed due to lack of funds.

For the above reasons, it will be much more difficult to pass on and preserve historical monuments to future generations. Technological solutions are able to preserve historical monuments for generations or restore the appearance of partially destroyed structures. Thus, the modern way to preserve historical buildings is to virtualise them on the basis of 2D and 3D technology. The question might be asked: what about photos, archival documents or written sources? The answer must be that it is better to see once than to hear a hundred times. It is more productive to see a vivid image than to animate history in the imagination. There are other advantages to 3D rendering of the Anushakhan bathroom. There are many souvenirs in Khiva, but there are no souvenirs among them that reflect folk (local) medicine. If souvenirs reflecting the medicinal functions of the Anushakhan bath are created, the shelves will be filled with a new gift. This in turn provides any customer with information about that object in a quick and easy way. Of course, nothing is equal to going and seeing historical monuments with one's own eyes. However, virtualisation will be a convenient option for those who do not have the above opportunity.

References

[1] WHO Traditional Medicine Strategy 2014–2023, WHO, Geneva. 2014. WHA62.13. Traditional medicine. Sixty-second World Health Assembly, Geneva, May 18–22, 2009. Resolutions and decisions, annexes. Geneva, World Health Organisation, 2009, pp. 20–22 (apps.who.int/gb/ebwha/pdf_files/WHA62.../WHA62_REC1-ru-P1.pdf)

[2] Umid Bekmuhammad. Qilichga almashtirilgan kasalxona. http://xorazmiy.uz/oz/pages/view/121.

[3] Muravev N. N. Puteshestviya v Turkmeniyu i Xivu v 1819–1820 gg. Taszkent: 1822. cc. 138–139. (in Russian)

[4] Goyibov M., Jumaniyozov Sh. "Medycyna chiwa". Taszkent: Światło Niepodległości, 2013. s. 58–59. (in Russian)

[5] Khorezm medicine; yesterday and today. Urgench. 2015. 15 b. (in Uzbek)

[6] Duschanov E. Khorezm medicine: past, ecology, disease. Urgench: Khorezm, 1997. (in Uzbek)

[7] Abdullayev A. A. Khorazmda meditsina. Toshkent: Bilim,1971. b. 10. (in Russian)

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RESEARCHING THE EMERGENCE OF THE GREAT SILK ROAD WITH COMPUTER MODELLING METHODS

Abstract

The work briefly examines the history of the Great Silk Road and provides a short analysis of its impact on the development of intercultural relations. The technique of computer modelling using applied programs is described. Some preliminary results from both the authors and from additional sources are presented as examples.

Keywords: cultural heritage, the Middle Ages, computer modelling, the Great Silk Road.

1. Introduction

The development of world civilisation cannot be separated from the development of each state or individual culture. Just as a house is built from individual bricks, so history is formed from each individual area, which represents a separate culture or a separate state in a certain period of time.

Now it is impossible to imagine how history would have developed without such an important means of communication as the Great Silk Road. This path connected countries of different civilisations and cultures, a large number of linguistic groups and peoples. It was used to exchange goods and cultural values, music and literature, science and art. Its impact on the development of cities and settlements is impossible to assess.

The Silk Road became the first connecting bridge between East and West. It was not just a network of trade routes, it became a connecting link, a kind of first information channel through which the latest news and scientific achievements were exchanged. It influenced the development of diplomacy, the formation of special historical and cultural landscapes and infrastructures. Along the Silk Road, large markets for the most popular goods and specialised facilities (caravanserais) emerged, combining the functions of hotels and warehouses.

Let us briefly consider what the Silk Road was and which countries it influenced.

2. Development of the Great Silk Road

Around the middle of the second century BC, in ancient China, the need arose for the development of foreign trade. From this period, one can begin the countdown of the emergence of the land route to the countries of Central Asia [1]. The Silk Road began in Chang'an (China), went along the northwestern territory of China through the Tien Shan mountains, then through the Central Asian and Middle Eastern states and ended on the shores of the Mediterranean Sea. In addition to the development of individual objects along the way, new prosperous cities were created, such as Turfan, Kashgar, Khorezm, Bukhara and many others. Trade along the Silk Road was of great historical and cultural importance. It demanded the creation of a complex infrastructure, the construction of places of rest and parking, the organisation of river crossings, etc. [1,2].

The result of the functioning and development of the Silk Road over a long period of time influenced the creation of a base for intercultural exchanges, communications and the formation of special historical and cultural landscapes. The route itself ran mainly through the countries of Central Asia, the Middle East, China and Southern Europe. The Silk Road was active until the 15th century. Its decline is associated with the development of merchant shipping along the coasts of the Middle East, South and Southeast Asia.The main period in the development of the architecture of the Great Silk Road can be considered the time from the middle of the 7th to the beginning of the 14th centuries. Bukhara is one of the large cities of Uzbekistan that emerged on the Silk Road. To date, several large covered markets have survived here, which are unique buildings of the past history with their own special architecture.

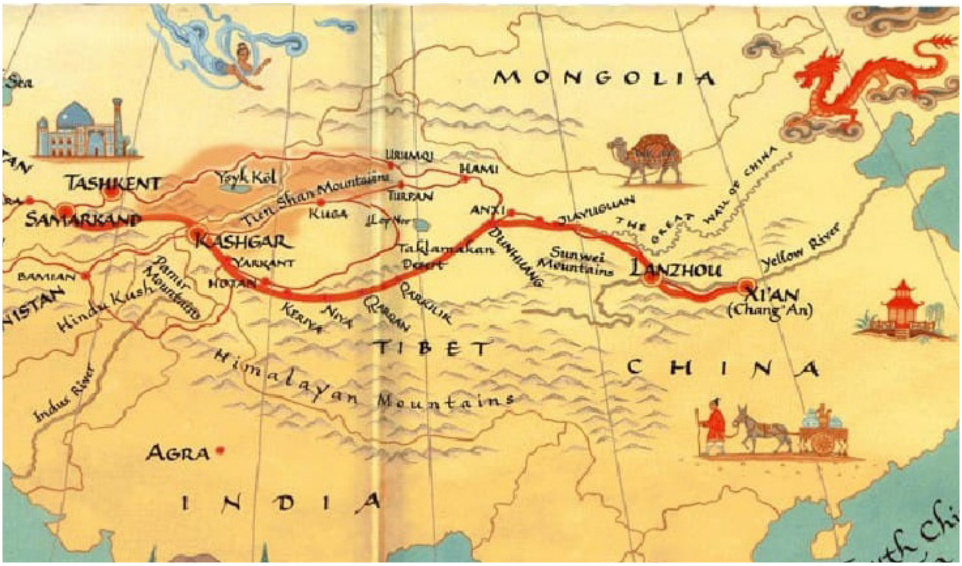

Figure 1. Image of the main part of the Silk Road route on the map [10]

Figure 1 shows the main direction of movement of caravans along the Silk Road. However, there were several roads along which traders moved, these routes also depended on the direction in which the movement took place (from East to West or vice versa). Today, there are more than 40 countries on the territory of the land and sea routes, which still testify to the influence of the Silk Road on their culture, traditions and customs.

Recently, at the initiative of China, in order to strengthen political, friendly and trade ties, it was proposed to form a single system of ties, including integrated transport communications, a pipeline network to connect different regions and strengthen ties between Asia, Europe and Africa both in the region and beyond, and thus revive the Silk path as a way of new cooperation between peoples.

Figure 2. Movement of caravans in the desert [11]

3. Modelling methods

It is known that at the present time it is very difficult, almost impossible, to study the architectural objects that existed in the past, but at present are actually lost or significantly changed as a result of their destruction and restoration. Some site, for example, were lost quite recently, as a result of their targeted barbaric destruction (for example, historical objects in Syria or giant figures in Afghanistan). And, unfortunately, there are more such objects.

However, at present, modern technologies have appeared [3–8], such as computer modelling, which make it possible to preserve, at least in the form of three-dimensional objects, the cultural heritage of the past, and thereby attempt restoration, in whole or in part, of such destroyed objects. In addition to saving, the created three-dimensional models can be used to study historical events that happened in the past, or try to simulate probable events that could have an impact on the development of events that already occurred in the past.

Modelling is a powerful tool for understanding the surrounding world – nature and society. Man has been using modelling to study objects, processes, phenomena in various fields for a very long time [5–6]. The results of these studies are used to understand the essence of phenomena and to develop the skills to adapt or manage them; for constructing new objects or changing old ones. Simulation helps to make decisions and anticipate their consequences. There are various types of modelling and, accordingly, different representations of models, each of which is used at a certain stage of the study and helps to study an object or phenomenon with a certain approach. By their nature, models are divided into material and informational. Material models represent the physical representation of an object. For example, a globe model is a miniature copy of the globe, aircraft models are miniature copies of airplanes or rockets, etc.

Among the various methods of modelling [7], one can conditionally highlight analytical and simulation modelling. The analytical type consists in building a model based on the description of the behaviour of an object or a system of objects in the form of analytical formulas. Simulation modelling involves building a model with characteristics that are adequate to the original, based on some of its physical or informational characteristics. When modelling, the degree of correspondence between the model and the real object is important, but too much similarity is not necessary, since usually the model is built to study certain parameters or phenomena, but very rarely do we need a model that is completely faithful to the original.

Among the large number of different types of models, we will focus only on those that can be used precisely for those cases that are considered in this work.

3.1. Information Modelling

Information modelling represents the model of an object in the form of information describing the parameters and variables of the object that are essential for it, the connections between them, giving information when changing the input values to simulate the possible states of the object. Information models can be created at the initial stage of modelling. Sometimes this is enough, especially if you only need to describe the connections between some objects. An information model can be created as a description, in a table, or as a diagram.

For example, in relation to the topic of our work, such a simple information model can be created to describe the initial information model of the Silk Road in the form of a table (Table 1):

Table 1. The Silk Road in the timeline

City or settlement	Current location (state ownership)	Period of origin (existence)	Main functions	Major historical events during the existence of the Silk Road
Bukhara	Uzbekistan	Mid-1st millennium BC	• trade; • religion; • housing; • defense.	• 709 – captured by Arab conquerors. • The capital of the Samanid state (IX–X centuries). • X century – a center of high culture. • XII century – the centre of Sufism. • etc.
Samarkand	Uzbekistan	VIII century BC	• trade; • religion; • housing; • defense; • center of science and culture	• 567–658 – the center of Sogdiana. • 712 – captured by Arab conquerors. • 875–892 biennium – the capital of the Samanid state. • 1370–1499 – the capital of the Temurid state. • etc.

Table 1 provides a basic summary of the cities that were located along the Great Silk Road and which are currently located on the territory of the Republic of Uzbekistan. However, to study the history of the emergence and functioning of such a major historical means of communication, this information is clearly not enough, since this information does not give us anything about the development of the Silk Road and its connection with life and the development of ties between peoples and the state. In general, this information poorly reflects the story itself. In this case, it will be necessary to use modern tools such as computer simulation.

3.2. Mathematic modelling

The mathematical model [7–8] uses the mathematical apparatus to create an ideal model, which is in some objective correspondence with the cognised object, which is able to some extent replace the original object and gives the researcher information about the modelled object itself. An example of such modelling is, for example, a harmonic oscillator, which describes the behaviour of not only a weight suspended on a spring, but also various oscillatory processes, such as a change in the current strength in an oscillatory circuit, or an oscillation of the liquid level in a U-shaped vessel.

The versatility of mathematical models lies in the fact that one and the same mathematical model can describe completely different real phenomena.

For numerical calculations within the framework of mathematical models, there are computer mathematics systems, for example, Mathematica, MathCAD, MATLAB, Scilab and others [3]. They allow to create mathematical models of processes and devices and easily change the parameters of the models during the simulation.

4. Implementing computer modelling

How can you use computer modelling in the study of historical heritage in general? History is a dynamic structure that cannot stand still, and for the study of which the same dynamic methods are required. However, in some cases it is possible to study some historical moments in a static form as well. For example, this is done when historians study the costumes of art canvases written in the corresponding period of time. Or when studying architectural monuments that could also be depicted on such canvases in their original form.

However, artistic paintings are a two-dimensional image that does not make it possible to understand and feel fully what the historical object was like during its creation or existence. In addition, this is again a completely static image with only one point of view.

In such cases, modern computer methods come to the rescue. To create volumetric information models, various three-dimensional modelling programs are used. One of the most famous, perhaps, is 3DsMAX. This program has a complex interface, a large set of different modifiers and is used to create perspective images of buildings, modelling landscapes and interiors, and when using special effects, animation modelling, lighting, as well as finalising images in Photoshop, it allows to create various complex architectural and design projects.

To create complex 3D-objects, other software systems can also be used [7], as well as programming languages, with the help of which the dynamic characteristics of the created objects can be described. Whole cities and states can be reconstructed on a three-dimensional scale, populated with living objects, and the development of events is shown. At the present time, even such a new subject as "Historical Informatics" has appeared, in which computer methods are studied that make it possible to recreate historical objects of the past.

The modelling process consists of several stages. To create a three-dimensional model, in addition, an appropriate computer and software are required, since such a model requires good visualisation. Let us consider the main stages of this process in relation to our task.

Stage 1. Statement of the problem and its analysis (collecting information about the problem; determining the ultimate goals of solving the problem).

Depending on the form in which the studied model is planned to be built, the corresponding information is collected. As we have already said, the Great Silk Road was a very long route, which existed for more than fifteen centuries, it passed through many settlements and countries, so here it will be necessary to determine which period of history we will be most interested in and through which states and settlements the model is built. Thus, at this stage, it will be necessary to determine what initial data and in what form they need to be obtained to build a model. For example, if you are going to build a 3-dimensional model, you need to determine the study time period and how much of this route will be built at the beginning of the model development.

Stage 2. Building an information model (data description, i.e. a descriptive information model is built).

It will be necessary to collect certain information, determine the relationships between them and build a descriptive information model. The simplest information model has already been presented in Table 1. It is required to determine which information will be used without fail and which part will not.

Stage 3. Development of a method for implementing a computer model.

Since for our task we are supposed to create a model in a 3-dimensional projection, it will be necessary to consider exactly those methods that relate to 3D modelling. To create realistic models, you need to choose the right photos of the corresponding scenes and textures for each object. At this stage, it is necessary to collect all available graphic, written and narrative sources on which the reconstruction of three-dimensional models depends. 3D design is almost an artist's job! Here it is necessary to search for photoreferences and fix scenes of natural nature and the environment. It is useful to compare the realism of the scenes with these examples. It is beneficial to select samples for modelling and positioning even before starting the main work.

The choice of technology for 3D modelling of objects depends on the software used. Each program has its own specifics and its own set of tools. The variety and specificity of programs for creating a three-dimensional model is simply impressive. When performing a project in 3D, correlate the features of the implementation and the functionality of the software. This will help to initially make the right choice of tools. Complex projects are always carried out with a division of labour into modelling and visualisation. This is due to the need to have a large amount of special knowledge and skills for these works.

Stage 4. Development of a computer model. The model can be written in any programming language, or it can be created in any application program.

To build a three-dimensional model, first it is created in two-dimensional form, and then continues to be built in 3D [3–5]. To create a scientific reconstruction in a historical perspective, the joint work of historians (researchers) and specialists in modelling is required. The result is a highly accurate model by combining historical, scientific and research procedures. In such work, the researcher relies on historical sources, applies a historiographic analysis of the results of historical and archaeological researchers, and uses the methods and techniques of the humanities. At the same time, the researcher must consider the consequences of each method of virtual reconstruction of historical and cultural objects.

Over the past decade, various projects for the restoration of historical objects using three-dimensional modelling have been implemented on this principle. Among such objects: 1) virtual reconstruction of disappeared objects of historical heritage based on archaeological and historical sources; 2) virtual reconstruction of modern historical monuments with the possibility of virtual visits; 3) virtual reconstruction of the historical landscape; 4) virtual reconstruction of historical events (war, resettlement, etc.); 5) recreation of lost items, etc.

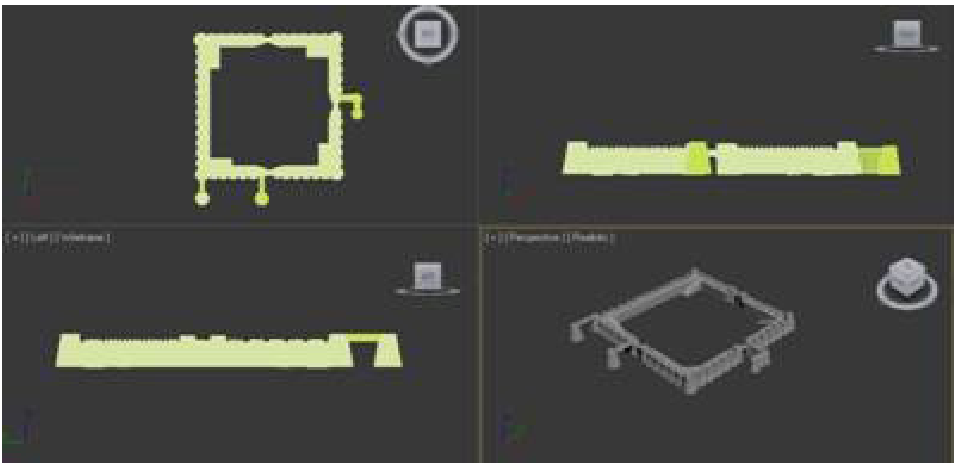

Figure 3. Reconstruction stage [9]

Methods presented, for example, in work [9] can be used to restore historical monuments. Those who are constantly working with 3D models know that there are various ways to model architectural buildings in 3D (Figure 3–5). Using 2D architectural plans using CAD is the most time consuming method.

Figure 4. Reconstructed object [9]

Figure 5. The reconstructed object and the real historical object at the present time [9]

As described above, the process of creating a historical model takes a fairly long period of time. And for such work, it is necessary to involve specialists in the relevant fields, in particular, historians and archaeologists. However, the result that will be obtained after the completion of the work is an important part of the preservation and study of the historical heritage.

5. Conclusion

The process of reconstructing historical sites helps us to better understand history by seeing everything from the point of view of eyewitnesses of those events. Computer technology can then become an excellent tool, the use of which can greatly help and simplify this task. The simplification of the task is that we can create a model without spending material resources, which, in some cases, is much more profitable. In addition, using computer technology, you can create an interactive model which can become an additional tool in modelling real situations, and seeing historical events and studying history using (almost) live examples.

6. Contribution of authors

Dilmurod Ahmedjonov – problem statement, discussion of materials, final processing of the article material. Olga Karpova – analysis of the material, writing up the article, discussing the results. Bekjan Akhmedov – collection of material, analysis of sources, technical processing of material.

References

[1] Khitrina, A.O., Zadvernyuk, L.V. (2017). Historical and cultural landscapes of the Great Silk Roads. New Ideas of New Century, 1, pp. 370–376.

[2] Garnaga I. O., Zadvernyuk L. V. (2013). Impact of the Great Silk Route to the formation of the cities and their architecture, trade and service. New Ideas of New Century, pp. 25–29.

[3] Chevrier, C., Maillard, Y., Perrin, J.P., (2009). A method for the 3D modelling of historic monuments: the case of a gothic abbey. In: International Archives of Photogrammetry, Remote Sensing and Spatial Information Science, 38 (5/W1), (Cd-rom).

[4] Chevrier, C., Charbonneau, N., Grussenmeyer, P., Perrin, J.P., (2010). Parametric documenting of built heritage: 3D virtual reconstruction of architectural details. International Journal of Architectural Computing, 8 (2), pp. 131–146.

[5] Dhont D, Luxey P, Chorowicz J (2005) 3-D modelling of geologic maps from surface data. AAPG Bull 89(11):1465–1474.

[6] Groshong, RH (2006) 3-D structural geology, 2nd edn. Springer, Berlin

[7] Mayer, R.W. (2015). Computer modelling: teaching aid for students of pedagogical universities. Glazov: Glazov. state ped. in-t.

[8] Khusanov, K., Karpova, O., Niyazov, F. (2019). Development of computing centre on mathematical engineering. Erasmus+ in Uzbekistan. 8(1), pp. 23–28.

[9] Batyrbaeva, S.D., Soltobaev, O.A., Tursunova, E.T. (2017). Virtual Reconstruction of the Medieval Settlement of Koshoy-Korgon – a Fortress of Nomads on the Great Silk Road. Istoricheskaya informatika. (1)10, pp. 63–74. https://doi.org/10.7256/2306–0891.2017.1.22452.

[10] https;//pl.pinterest.com/pin519602875764473793/

[11] https://www.tapetus.pl/68932,wielblady-pustynia-karawana.php

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RECONSTRUCTION OF THE MONUMENT OF KHAZARASP AND ITS MODELLING USING 3D TECHNOLOGY

Abstract

Khazarasp is one of the oldest cities in Central Asia, located on the southern border of the Khorezm oasis. The early period of the city's history is represented by local cultural layers, the ceramic materials of which date back to the 1st half of the 1st millennium BC, and by the remains of fortress walls with towers.

The walls are cut with arrow-shaped loopholes and decorated with rectangular pilasters. The outer walls and corners of the fortress are reinforced with quadrangular and square towers and pilasters.

The purpose of this project is to identify the characteristic features of the principles of construction and architecture of the Khazarasp archaic and antiquity era, to create 3D (three-dimensional) models of this unique archaeological site. It is substantiated that the reconstruction of Khazarasp based on three-dimensional modelling technologies opens up a wide opportunity for the preservation, study and promotion of historical and cultural heritage, as well as the creation of virtual museums.

Keywords: Khazarasp, Devsalgan, archaic, antiquity, archaeological research, information technology, GPS (Global Positioning System), GIS (Geographic Information System), 3D modelling, conservation, reconstruction, virtual museum.

1. Introduction

Khazarasp is one of the five major cities of Khorezm. It is located on the right bank of the Amudarya River and was of great strategic importance for the Khorezm oasis.

This eastern city-fortress is one of the fortified outposts of Khorezm. No wonder this fortress is called the "Golden Gate of Khorezm", "Solomon's Fortress" or "Fortress of a Thousand Horsemen". *Khazarasp* is the Persian for 'a thousand horses' (*khazar* – 'thousand', *asp* – 'horse'). The Khorezm rulers always attached special importance to this fortified city and kept a select detachment of horsemen and infantry there. In addition, this fortress played a significant role in the trade and economic development of the region [1].

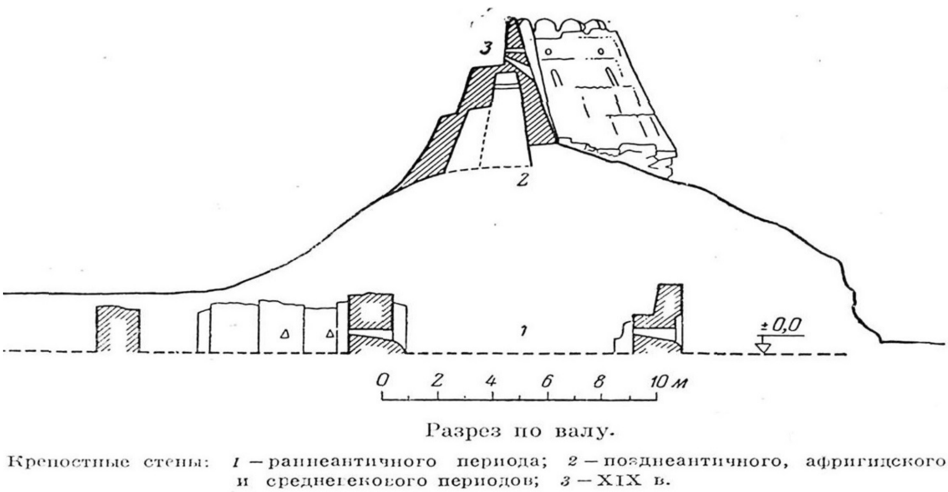


Figure 1. Shaft section. Fortress walls: 1. early antiquity; 2. late antiquity, Afrigid and mediaeval; 3. 19th century. [6]

Figure 2. Khazarasp fortress walls of early antiquity. Reconstruction. [6]

Archaeologists believe that the fortress was built in the 5th century BC.

At this time, the study of the history of the emergence of the city and the determination of its age continues. Archaeological excavations have been going on for several years now. According to the discovered finds and cultural layers, it can be preliminarily concluded that the city is at least 2700–2800 years old. The work continues and soon, according to the conclusions of archaeologists, historians and other specialists, it will be possible to accurately determine the age of this unique fortress city [2].

In order to establish the age of the city of Khazarasp and the stages of its development, to study objects of material culture, to determine the design of defensive walls, the thickness of cultural strata at different stages (1958–1960, 1996–1999), stratigraphic excavations and pits were laid in 9 places. In the process of excavations, several construction periods were identified[3].

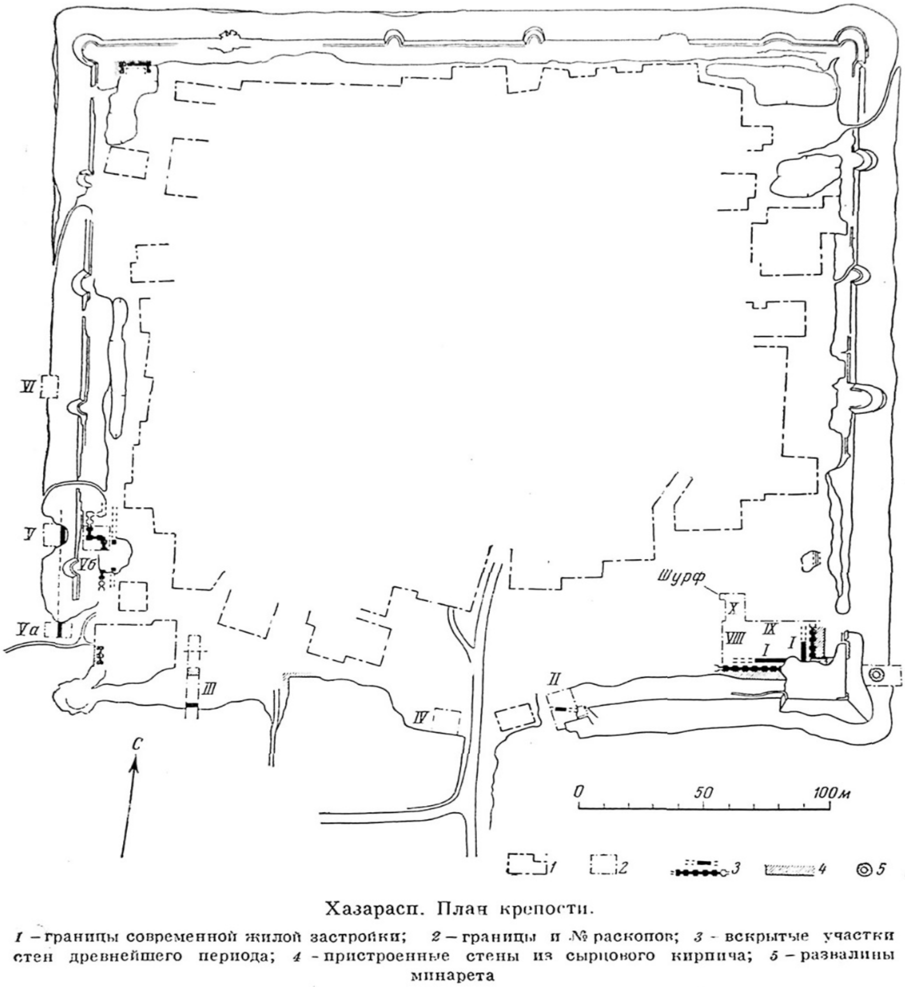


Figure 3. Khazarasp. Fortress plan. 1. boundaries of modern residential development; 2. boundaries and excavation numbers; 3. opening wall sections of the ancient period; 4. built-in walls made of raw bricks; 5. minaret ruins. [6]

First period: represented by local cultural layers, the ceramic materials of which date back to the first half of the first millennium BC, and the remains of fortress walls with towers. The excavation was not brought to the mainland due to the appearance of groundwater. The walls are cut with arrow-shaped loopholes and decorated with rectangular pilasters. The outer walls and corners of the fortress are reinforced with quadrangular and square towers and pilasters. The oldest visual evidence of Khazarasp is represented by several locations with a rich cultural layer and the remains of city fortifications.

Second period: in the second period, the entire fortress was surrounded from the outside by a powerful brick wall-shell, thanks to which a powerful plinth was created, on top of which, as can be seen, a mud-brick wall was erected. The barrier wall continued to function. The material ceramic materials found in the course of work in the cultural layers on this horizon allow us to date it to the 1st–4th centuries AD. The surviving fortress walls contain fragments of the fortification of the ancient period. Archaeological finds contain artefacts from the time of the Achaemenid Empire and the Greco-Bactrian kingdom.

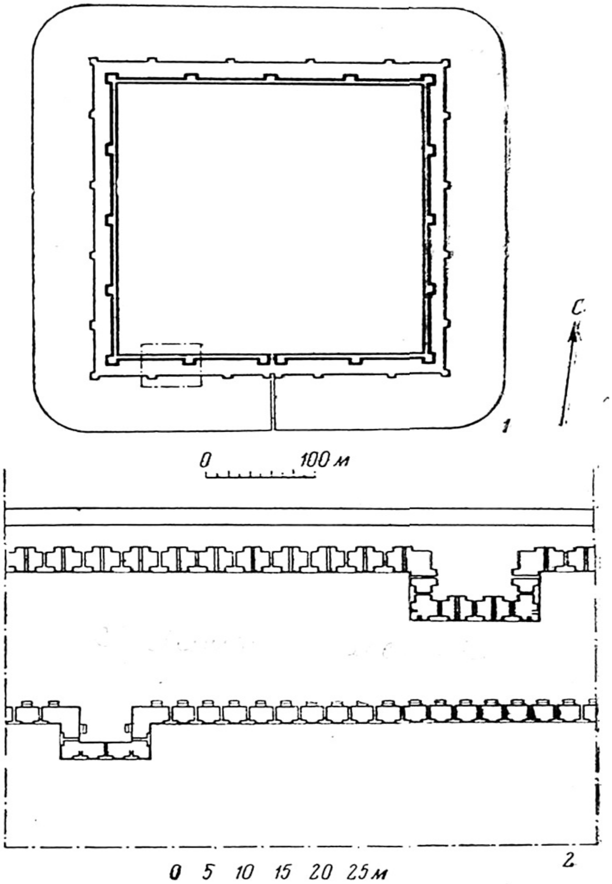
The third period: in the 4th–5th centuries the city continued to exist, and in some of its parts, as can be judged, for example, from the materials of the gate area, life proceeded quite intensively. In the 4th–8th centuries, a new wall was erected over the ancient wall. At the beginning of the 8th century, Khazarasp was known as one of the three most fortified and large cities of Khorezm. Mediaeval Khazarasp protected a rectangle of adobe and raw city walls, a significant part of which was destroyed. However, 12 towers survived. Of these, the southeastern corner stands out – the 12-meter Dev-Solgan. The city walls are surrounded by an open square moat, still filled with water in some places. This is practically all that remains of the ancient canal system of mediaeval Khazarasp.

Excavations have shown the presence of several streets dating back to the 11th–12th centuries. They connected the western and eastern gates, where there were small workshops and trading buildings of street artisans, jewelers, merchants and small traders, as well as the central market. The market occupies more than two hectares of land. Archaeologists have discovered the remains of various buildings: palaces and houses of citizens, caravanserais, craft workshops, baths, etc. [4].

Surrounded by fortress walls built of beaten clay and raw bricks, reinforced with towers, the city of Khazarasp also served as a reliably protected craft centre that developed here at that time, as evidenced by pottery kilns inside the fortress wall. These specific urban functions make it possible to speak of a tendency for the settlement to grow into an urban organism. Thus, Khazarasp is one of the few urban centres of Central Asia that did not cease to exist for many centuries.

Every year, Khazarasp is visited by a large number of tourists, but the tourist and, above all, the historical potential of Khazarasp is not fully disclosed and is waiting in the wings. It is striking that for many centuries Khazarasp grew and developed not chaotically, but systematically. On the territory of the ancient city, the old layout of the streets is still visible [5]. The construction of the fortress dates back to the time when Zoroastrian traditions became one of the main spiritual values of the locals.

Currently, scientists are working on the preservation of this historical monument, a fortified city located in Khorezm. As such, it has become part of the treasure trove of cultural heritage and has been included in the UNESCO World Heritage List.



План крепости раннеантичного периода (*1*) и деталь плана (*2*). Реконструкция

Figure 4. Fortress plan of early antiquity (1) and plan detail (2). Reconstruction. [6]

3. Analysis

In the analysis of issues of interdisciplinary areas (historical geography, paleoecology, ethnic geography and cartography, historical demography) on the history of Khazarasp, as well as in the reconstruction of the history of the city of the archaic, antiquity and Middle Ages, especially in the restoration of historical and cultural processes not covered in written sources, it is important to use the achievements of modern information technologies. Given that the historical monuments of the city of Khazarasp of various periods have not been preserved due to the high level of groundwater, the task of restoring the ancient architectural appearance of the monument, the fortification system and individual structures, as well as the anthropogenic landscape of the agricultural microoasis of Khazarasp on the basis of the 3DsMax program is of current importance.

The significance of the application of 3D modelling methods, especially in the preservation of the historical and cultural heritage for the future generation, is enormous. In this regard, there are separate problems associated primarily with the insufficient use of modern technologies in archaeological and historical research, as well as in the educational process.

Based on the analysis of scientific information and a 3D modelling program, temples, walls, caravanserai, as well as estates around the city of Khazarasp as Sandiklitepe and other objects of the historical microoasis of Khazarasp from the archaic to the mediaeval period will be restored in the future. Software tools create the possibility of reconstruction in full measure of the cultural landscape, natural environment and issues of anthropogenic impact of the ancient city and microoasis.

4. Conclusion

The use of 3D models of the monuments of the city of Khazarasp of the archaic and mediaeval times as museum exhibits, the creation of a virtual museum in the education system and in new textbooks, in the process of enriching knowledge and views on the history of urban planning and architecture, as well as in the study and promotion of historical-cultural heritage.

Taking into account the development of modern technologies and methods of innovation in the field of historical reconstruction of the city of Khazarasp, it is recommended to develop a fundamental scientific project to create 3D models of ancient monuments of the historical microoasis of Khazarasp.

References

[1] Iskhoqov M. Is Khazorasp a “thousand horses” or…? Uzbek language and literature, 1997. 1-dream. B. pp. 72–75. (in Uzbek)

[2] Mambetullaev M. M., Abdirimov R. Research of Khazarasp. Cultural Heritage of Central Asia. Tashkent, 2002. pp. 165–167. (in Russian)

[3] Vorob’eva M. G., Lapirov-Skoblo M. S., Nerazik E. E. Archaeological work in Khazarasp. M., 1963. Issue. 6. pp. 197–200. (in Russian)

[4] Sobirov K., Abdirimov R. Khazarasp and issues of periodisation of the early stages of development of the settled agricultural culture of Khorezm. Civilizations of ancient Khorezm in the context of the history of world culture. Nukus-Buston, 2000. pp. 34–35. (in Rusian)

[5] Baratov S. Archaeological work in South Khorezm. Archaeological research in Uzbekistan. 2003. Tashkent, 2004. pp. 46–51. (in Russian)

[6] Figures from the book: Vorobyova M. G., Lapirov-Skoblo M. S., Nerazik E. E. Archaeological work in Khazarasp. MHE. M., 1963. Issue 6. pp. 197–200. (in Russian)

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DIGITISATION OF SCULPTURES USING 3D SCANNING AND MODELLING: THE EXAMPLE OF THE BUDDHA STATUE FROM OLD TERMEZ IN SOUTH UZBEKISTAN

Abstract

The areas through which the Silk Road ran were influenced by various religions. Before their Islamisation it included Buddhism. At the beginning of A.D. or our era, there were large religious centres of Buddhism in Central Asia. One of them was Fayaztepa (located in Old Termez in Uzbekistan). During the excavations there in 1968, a statue of Buddha carved in sandstone was found. The statue is now in the State Museum of History of Uzbekistan in Tashkent. During one of the research expeditions to Central Asia by the Lublin University of Technology, it was scanned in digital 3D technology. As a result of processing the obtained data, a digital representation of the statue was created, which was used for its presentation in the Internet and for creating copies on 3D printers. The article presents the history of the excavations in Termez, the 3D scanning process in the museum and the post-processing of the data, as well as the results of digitisation.

Keywords: 3D scanning, Silk Road, 3D mesh models, point cloud post-processing,

1. Introduction

Making copies of cultural heritage artefacts is a tool for popularising them, and in many cases also for preserving their appearance for future generations. In the era of dynamic development of digital technologies and their universal access, the best form of making copies of museum artefacts is their digitisation.

For seven years, the Department of Computer Science has been implementing various projects related to the digitisation of artefacts in 3D technology, resulting in the creation of 3D models presenting the appearance of objects, virtual museums and panoramas of larger architectural objects. They are presented on the Internet on the Lab3D laboratory website (https://cs.pollub.pl/lab-3d/?lang=en) and the 3D Digital Silk Road portal (https://silkroad3d.com/). The portal has been developed as part of the Polish National Agency for Academic Exchange (NAWA) called "3D Digital Silk Road" project.

During the work on the 3D digitisation of cultural heritage monuments, scientists from the Department of Computer Science developed a number of methodologies related to the acquisition of data in the field, their processing and preparation for presentation. Some of the works were of a pioneering nature on a global scale. The achieved results are regularly published in high-class magazines: [1]-[10].

2. Fayaztepa – an outstanding monument of Buddhism

Uzbekistan is one of the richest centres of civilisation. In the course of nearly a hundred years of research, characteristic centres of Bactrian, Horezmian and Sogdian civilisation were discovered here, which are not inferior to the level of development of other world hubs of ancient cultures.

Since ancient times, the territory of modern Uzbekistan has been the site of the intersection of not only many roads and caravan routes, but also the cradle where various religions peacefully coexisted in antiquity: Zoroastrianism, Buddhism, Manichaeism. Today, in the country's southernmost region, the Surkhandarya region, several Buddhist temple complexes from that era have been preserved. Among them, the most famous are Ayrtam, Karatepa and Fayaztepa. They served as outposts for the spread of Buddhism by Indian missionaries in the Kushan empire.

The monuments of Buddhism in Central Asia have been known to the contemporaries since the beginning of the 20th century. The Russian orientalist V. V. Bartold [11], who made a great contribution to the study of the history of Central Asia, noted on the basis of testimonies from Muslim and ancient Chinese sources that Buddhism played an important role in shaping the culture of the peoples of Central Asia.

The Fayaztepa complex has been discovered in 1963 by the archaeologist L. Albaum [12] and named in honour of R. Fayazov, the Director of the local Termez museum, who supported the excavations. The construction time of Fayaztepa was determined by experts on the basis of the coins found here, minted by such kings as Kushan Heliokles, Soter Megas, Vim Kadfiz, Kanishka and Huvishka. The time has been defined as between the 1st century BC and the 1st–2nd century AD [13].

The complex impresses with its panache and surprises with design solutions. It is located 5 km to the west from modern Termez, between the shores of the Amu Darya and the ancient Silk Road caravan route. The complex was supplied with water from the Amu Darya river along a 2.5 km aqueduct.

This stately complex is clearly divided into three parts: the temple, the monastery and the farm buildings with a refectory. Each part consists of a courtyard and the rooms around it. The earliest stupa with a perfectly round dome and a cross-shaped foundation was erected on a special pedestal outside the main part, where ritual ablutions were performed. The stupa, which is one of the attributes of Buddhism, dates from the 1st century BC and is considered the oldest building in the complex.

The central part consists of a courtyard around which the rooms are located, and the adjoining ayvana. A specific feature of Buddhist buildings is the separation of the main rooms and their arrangement in an enfilade. The main building materials, as in other Central Asian structures, are clay and brick.

Fayaztepa is not only a cult monument of Buddhism in Central Asia, but also has great value as one of the few examples of Buddhist painting. The walls of the complex were covered with murals of different poses of Buddha. Moreover, the walls of the sanctuary are decorated with stories, one of which is the image of two Buddhas, around whom figures of women are drawn. On the opposite wall are images of monstrosities in Kushan costumes. Of particular importance is the fact that the Buddha images in Fayaztepa are considered to be some of the oldest surviving to this day and date back to the 1st century AD. Data from archaeological excavations have shown that the entire evolution of the Buda image can be traced in the Fayaztepa, from symbol to portrait.

The study of Fayaztepa by L. Albaum [12] has been carried out until 1976. Since 2000, the Ministry of Culture of the Republic of Uzbekistan and the UNESCO Representation in Tashkent launched the international project “Protection and restoration of the ruins of Fayaztepa” (Termez) [14]. The final stage of the project was to open a Science Centre for research. In recent years, a joint Uzbek-Japanese expedition led by Academician E. Rtveladze and the famous professor K. Kato has been working here successfully.

Considering the historical importance of the monument for research into the Buddhist era, the Ministry of Culture and Sports of the Republic of Uzbekistan, UNESCO and the Japanese Trust Fund awarded a subsidy for the restoration and conservation of the facility. After the completion of this work, carried out in 2004–2006, the Fayaztepa Buddhist temple complex turned into an open-air museum and reopened its doors to visitors. The complex is a Buddhist artistic heritage in Uzbekistan and is known all over the world.

One of the outstanding finds in the Fayaztepa complex was a statue of a Buddha sitting in a pose of peace and spiritual harmony under the sacred Bodhi tree, and two monks standing on either side of him. The sculpture, carved in limestone and covered with gilding, dates from the 1st-2nd century AD. Today, this sculptural composition is one of the most valuable exhibits of the State Museum of the History of Uzbekistan in Tashkent. A copy of it can be seen in the Archaeological Museum of Termez.

3. 3D scanning a Buddha statue from Fayaztepa complex

In the year 2019, during the 3rd Scientific Expedition of the Lublin University of Technology to Central Asia [15], a 3D digitalisation attempt of the Buddha statue has been conducted. It consisted of several stages, with first one conducted directly at the exhibition site, and the following stages conducted at a later time at the LUT.

The stages were:

1. 3D Scanning with structural light scanner
2. Raw scans processing
3. Generation of 3D model
4. Model processing and hole filling
5. Texture inpainting and model exporting

The 1st stage has been conducted at the exhibition site – in the field. During the preparation for this stage a survey of the exhibition place was conducted to assess the possibility and problems of the scanning process of this particular exhibit.

In general scanning with structural light scanner requires good lighting and free access to all sides of the object. Unfortunately the statue could not be removed from its stand and the glass showcase had only one side opening (Fig. 1). On the other hand the statue is presented in the middle of the exhibition room with a free access to all its sides. The lighting conditions were also acceptable. Easy access to electric power was also important.

Figure 1. The Buddha statue in its exhibition place, photo: M. Miłosz

The survey outcomes were positive and the scanning process could be performed. The glass showcase problem was solved by scanning the front of the statue from the inside of the showcase (Fig. 2). The rear, less important part of the statue was scanned by taking advantage of the scanner ability to bypass transparent surfaces. Scanning through glass is generally avoided as it can cause additional inaccuracy. In this case the possible error was within acceptable limit. Finally 18 partial scans were gathered, resulting in approximately 4.5 GB of raw data.

Figure 2. Scanning the Buddha statue from the inside of the showcase, photo: M. Miłosz

The 2nd stage involved processing of the raw, partial scans. They were cleaned up of unwanted data and an aligning algorithm was applied (Fig. 3) to create one common point cloud of the whole statue (Fig. 4). It consisted of over 100 million 3D points.

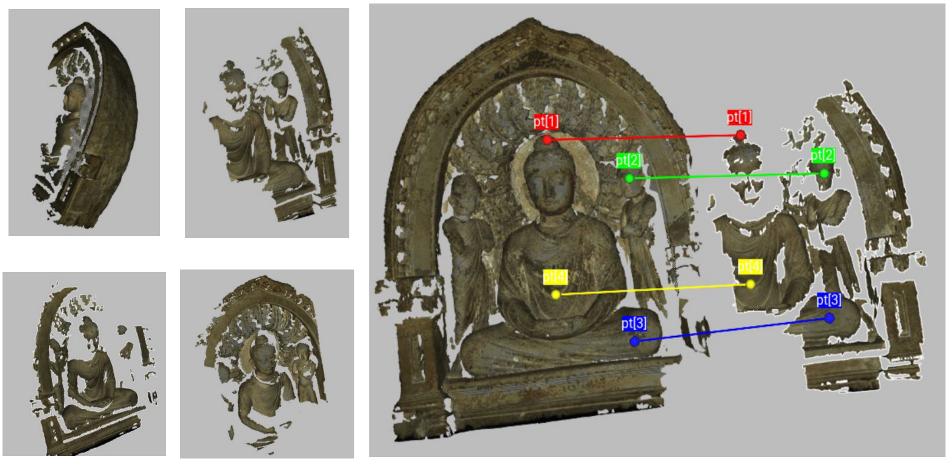

Figure 3. Partial scans of the Buddha statue (on the left) and their aligning process (on the right)

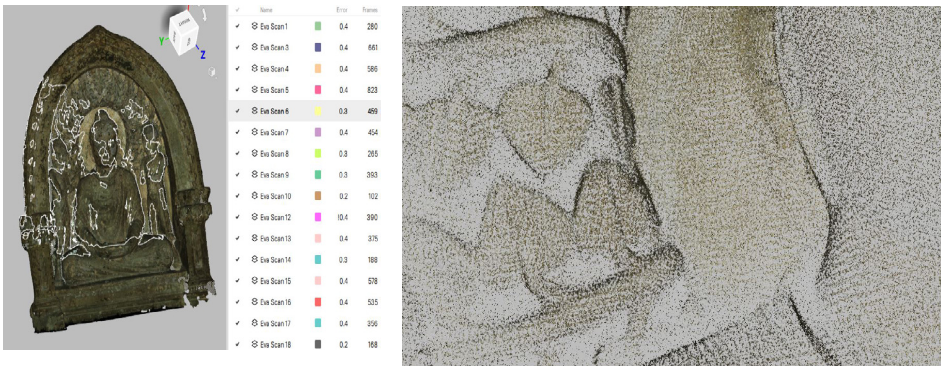

Figure 4. The combined point cloud of the Buddha statue (on the left) and close-up of the point cloud fragment (on the right)

Point clouds are used as source data in design applications. Direct displaying of object models in the point cloud state is rarely used as the data amount is highly excessive for just showing a 3D view. On the other hand, lowering the number of points leads to visible gaps in the object surface. The solution is creation of a mesh model forming a continuous surface limited to a small number of points compared to the point cloud. A standard in 3D graphics is a triangle mesh forming the surface of object model. In the 3rd stage an algorithm that creates such a mesh, and follows the shape described by the point cloud, was implemented to the acquired data. The obtained model has 3.2 million points (vertexes) and 491 MB data. The resulting triangle mesh model is shown in Figure 5.

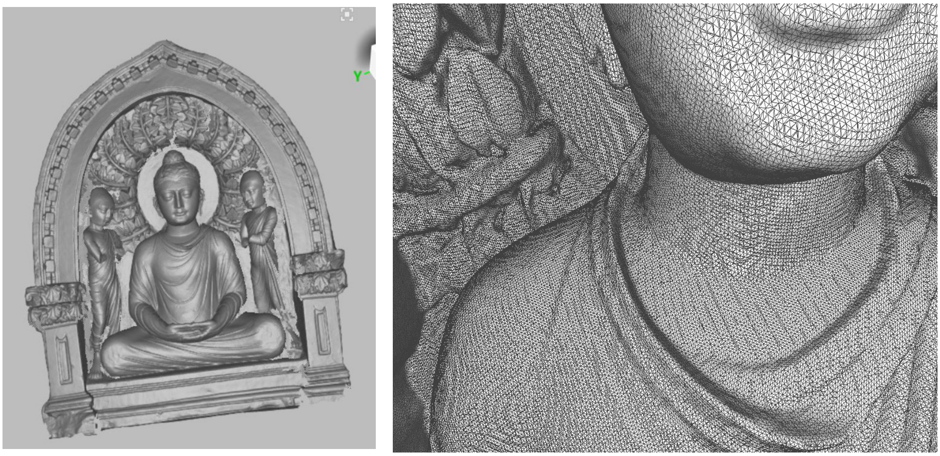

Figure 5. The resulting triangle mesh of the Buddha statue (on the left) and a close-up showing the individual triangles (on the right)

The 4th stage considers the triangle 3D model. It contains still too great a number of points (vertexes) in order to be suitable for dissemination. A mesh simplification algorithm reduces the number of triangles (and thus the number of vertexes) while keeping continuous surface (Fig. 6).

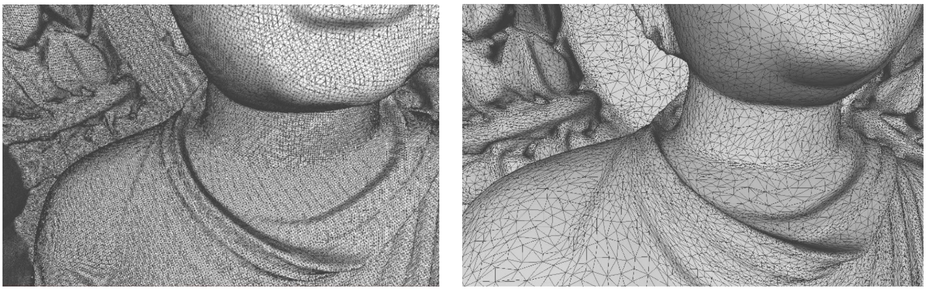

Figure 6. Visualisation of 3D mesh simplification. Original mesh (on the left) and simplified one (on the right)

Mesh simplification leads to degradation of the object model surface fidelity, which can be significant when applying a high simplification factor. Thus it is advisable to keep the original mesh as the base model.

For the presentation or reproduction purpose it is required for the model to be a complete closed surface without any gaps. However the 3D scanning is subject to limitations so that deep and narrow cavities cannot be scanned properly. That leads to occurrence of gaps in the acquired 3D mesh. A properly applied hole curing algorithm can restore continuous surface without leading to visible inconsistency with the real object (Fig. 7).

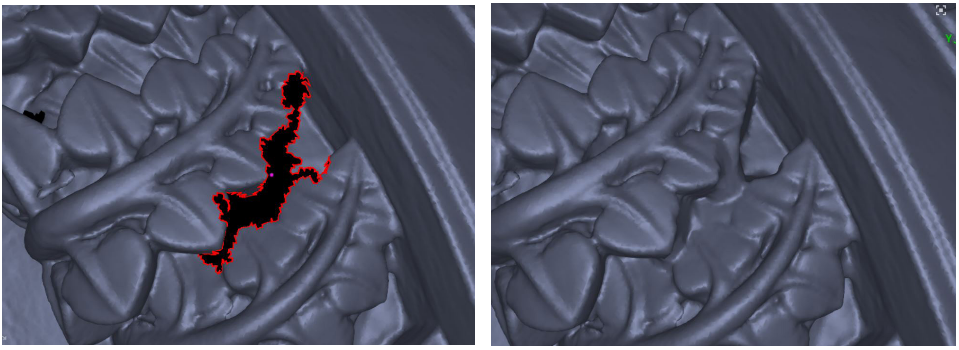

Figure 7. Visualisation of curing 3D mesh discontinuities. Mesh before hole curing (on the left) and after curing (on the right)

The last stage is inpainting the colours to the model surface based on the colour image data acquired during the scanning process. The fidelity of surface colours depends greatly on the lighting quality, thus a proper lighting during scanning is in order. The scanner uses own light to illuminate the currently scanned part. As it can be scanned from various distances and in higher or lower brightness, a correction algorithm needs to be applied in order to acquire an evenly illuminated surface on the whole model.

Finally a texturised 3D model was acquired and exported into a universal format, suitable for dissemination (Fig. 8).

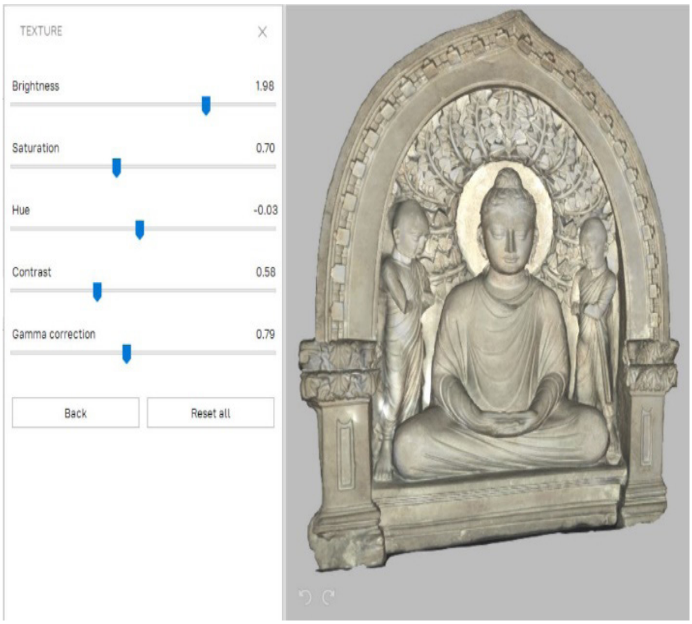

Figure 8. Visualisation of final 3D model with texturised surface

4. Obtained results

Having the 3D model one can utilise it to get various results depending on the needs. The most obvious groups are visualisation and printing.

In the visualisation case the colorised model is required, but its complexity depends on the end point usage. The photo-like renders require higher level of details than live visualisation through the Internet, where the data bandwidth is a main concern. In Figure 9 a case of placing the model in the view of the Fayaztepa site is presented, thus making it look as if the sculpture were restored to the place of its finding. The 3D modelling software was used to obtain the model illumination consistent with the rest of the image.

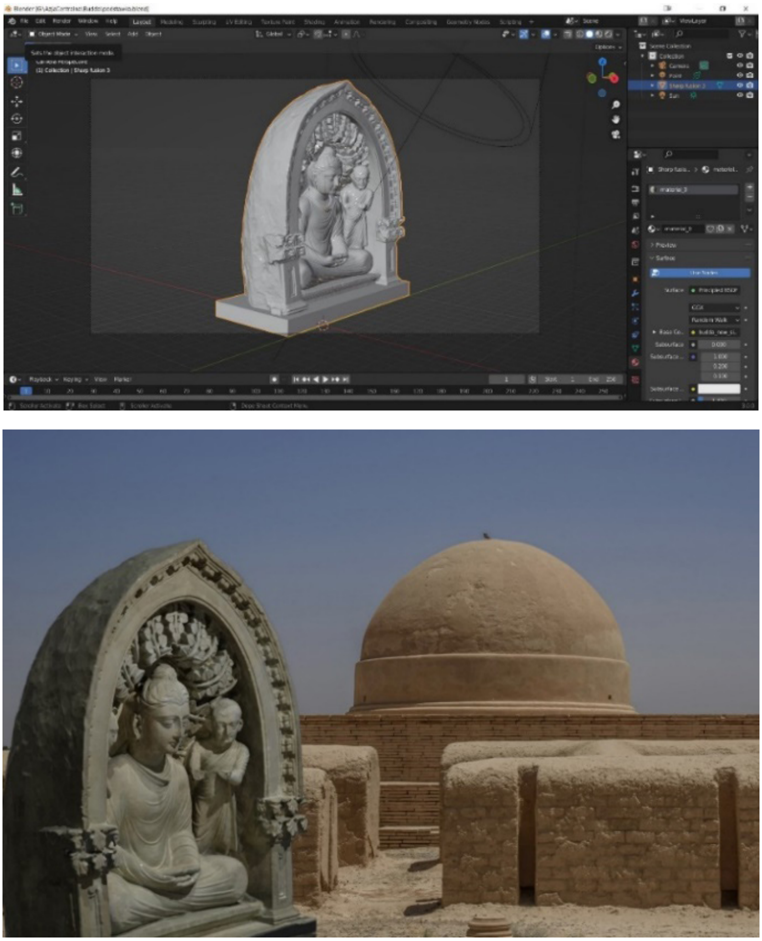

Figure 9. The visualisation setup for placing the model in real view image (on the left) and the photo-like render (on the right)

While visualisations can be attractive for dissemination, the possibility to touch the real-life object is attractive as well. Nowadays 3D print technology allows for quick production of the copies of famous artefacts that can be used for many purposes: recreation of sites to which the object belonged, enabling contact with the artefact for the visually impaired or simply making souvenirs. In Figure 10 a print preparation application and a printed copy are presented. The size of the copy can be easily adjusted from small figurines to original size model.

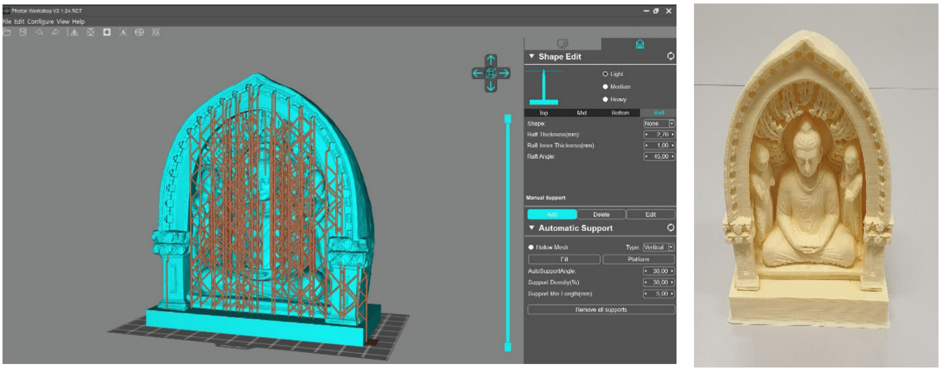

Figure 10. The preparation for 3D printing (on the left) and the printed copy (on the right)

The developed model of the Buddha statue from Termez can be repeatedly duplicated and printed in 3D technology. It can also be disseminated in digital form (Fig. 11).

Figure 11. Handing over a physical 3D print of the Buddha statue from Termez and its digital model during an expedition to Tashkent, photo: E. Miłosz

5. Summary

3D digitisation of sculptures, especially famous artefacts of cultural-heritage, is a well proven method of preserving their shape for next generations. The obtained data can be used to create natural looking visualisations or real-life copies using 3D print technology.

The Buddha statue from Termez is only one of the great number of valuable artefacts found and preserved in Uzbekistan. This article confirms that the goal of the digitisation of Uzbekistan's monuments set by its authorities can be achieved with cooperation of cultural heritage and IT specialists. The example presented in this article shows clearly that such digitisation can be successfully performed despite non-perfect conditions and the results obtained are sound enough for archiving, visualisation and creation of copies.

References

[1] Marek Miłosz, Jacek Kęsik, Jerzy Montusiewicz. 3D Scanning and Visualisation of Large Monuments of Timurid Architecture in Central Asia: A Methodical Approach. *Journal on Computing and Cultural Heritage*. 2021, vol. 14, № 1, pp. 1–31.

[2] Jerzy Montusiewicz, Marek Miłosz. Architectural Jewels of Lublin: A Modern Computerised Board Game in Cultural Heritage Education. *Journal on Computing and Cultural Heritage*. 2021, vol. 14, № 3, pp. 1–21.

[3] Jacek Kęsik, Marek Miłosz, Jerzy Montusiewicz, Khonkul Samarov. Documenting the geometry of large architectural monuments using 3D scanning: the case of the dome of the Golden Mosque of the Tillya-Kori Madrasah in Samarkand. *Digital Applications in Archaeology and Cultural Heritage*. 2021, vol. 22, pp. 1–11.

[4] Maria Skublewska-Paszkowska, Paweł Powroźnik, Jakub Smołka, Marek Miłosz, Edyta Łukasik, Dilbar Mukhamedova and Elżbieta Miłosz. Methodology of 3D Scanning of Intangible Cultural Heritage: The Example of Lazgi Dance. *Applied Sciences*. 2021, vol. 11, № 23, pp. 1–17.

[5] Piotr Wójcicki, Sylwester Korga, Marek Miłosz. Preliminary Application of the Algorithm Highlighting Petroglyph Patterns. *Applied Sciences*. 2022, vol. 12, № 3, pp. 1–14.

[6] Jerzy Montusiewicz, Marek Miłosz, Jacek Kęsik and Kamil Żyła. Structured-light 3D scanning of exhibited historical clothing: a first-ever methodical trial and its results. *Heritage Science*. 2021, vol. 9, № 1, pp. 1–20.

[7] Marek Miłosz, Stanisław Skulimowski, Jacek Kęsik, Jerzy Montusiewicz. Virtual and interactive museum of archaeological artefacts from Afrasiyab: An ancient city on the silk road. *Digital Applications in Archaeology and Cultural Heritage*. 2020, vol. 18, pp. 1–12.

[8] Marcin Barszcz, Jerzy Montusiewicz, Magdalena Paśnikowska-Łukaszuk and Anna Sałamacha. Comparative Analysis of Digital Models of Objects of Cultural Heritage Obtained by the "3D SLS" and "SfM" Methods. *Applied Sciences*. 2021, vol. 11, № 12, pp. 1–20.

[9] Jerzy Montusiewicz, Marcin Barszcz, Krzysztof Dziedzic, Tomasz Nowicki. The Method of Decomposition of Architectural Objects for the preparation of 3D Virtual Models and Replication. *Advances in Science and Technology Research Journal*. 2021, vol. 15, № 2, pp. 247–257.

[10] Jerzy Montusiewicz, Stanisław Skulimowski. A Search Method for Reassembling the Elements of a Broken 2D Object. *Advances in Science and Technology Research Journal*. 2020, vol. 14, № 3, pp. 49–56.

[11] http://www.orientalstudies.ru/rus/index.php?option=com_personalities&Itemid=74&person=593
[12] Альбаум Л. И. Раскопки буддийского комплекса Фаяз-Тепе (по материалам 1968–1972 гг.). Древняя Бактрия. Л., 1974; Альбаум Л. И. Исследование Фаяз-Тепе в *1973 г.* Бактрийские древности. Л., 1976.
[13] Асанов А. А. Фаяз-тепа. Архитектура и строительство, 1976 г. № 9.
[14] Ульмасов А. Архитектура буддийского храмового комплекса Фаязтепа. Санъат. 01/04/2006.
[15] https://cs.pollub.pl/3-naukowa-ekspedycja-politechniki-lubelskiej-do-centralnej-azji-czesc-2 – taszkient-uzbekistan-17–20-maja-2019/?lang=en

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RECONSTRUCTION OF THE KALADZHIK-KALA MONUMENT USING INFORMATION TECHNOLOGY

Abstract

The article reveals new tools for historical reconstruction, working with a database, special software tools for linguistic analysis of historical text, the use of aerial visual observation and aerial photography using quadrocopters, the promising value of GPS (Global Positioning System), GIS (Geographic Information System) and 3D technologies modelling in the process of reconstruction of the Kalajik-kala monument located in the Khorezm oasis. The paper presents an analysis of foreign experience in the application of innovations and achievements of modern technologies in the field of archeology and historical reconstruction. Such scientific areas as "digital history", "virtual archeology", "settlement archeology" are especially noted.

Keywords: Kalajik-kala, palace, towers, loopholes, archaeological research, information technology, GPS (Global Positioning System), GIS (Geographic Information System), 3D modelling, reconstruction.

1. Introduction

Before presenting information from sources, we will briefly talk about Kaladzhik-Kala. This monument is located 25 km from Khazarasp, in the Bagat region, and 21 km to the west from the region's the centre. The fortress has the shape of an irregular quadrangle, the length of the northern wall is 184 m, the southern one is 211 m, the western one is 72 m, and the eastern one is 114 m. The total area is 6 hectares, it was built in the 4th century BC. Information about Kalajik-Kala is found in Arabic-Persian sources of the 9th–12th centuries. At this time, a high development of culture and economy is manifested in the East.

2. Literary Review

Kalajik-Kala is mentioned under different names in mediaeval sources. In the work *Hudud al-Alam* ['Limits of the World'] by an unknown author in Persian, this is Kardnaskhaz, while in al-Istakhriy and al-Maqdisi, Kardanhosh and Kardanhos; Munis and Ogakhi, Khorezm historians, have Kardankhast or Gardankhast. In these works, there are different opinions regarding the name Kardanhos. For example, *Hudud al-Alam* refers to this city as a small city with rich agriculture and surrounded by settlements, al-Istakhri wrote that it was a large fortress, like Khazarasp, with reliable protection. Maqdisi noted the following: “It was a trading centre, it had large wooden gates with a moat and strong fortifications” [1].

In the 10th century, the economy developed rapidly in Khorezm, as evidenced by archaeological excavations. This progressive process gave impetus to the rapid development of cities. The Arab historian Tabari wrote that only 3 cities: Kat (Far), Khazarasp and Urgench could be captured by the Arabs [2]. Another Arab historian (in about 930–933) mentioned 13 cities such as: Khorezm (Kas), Dargan, Khazarasp, Khiva, Khushmisan, Ardakhushmisan, Safardiz, Nuzbar, Kardarankhas, Kardar, Barategin, Mazminia and Zhurzhoniya (Gurganj). In 985, the Arab geographer al-Maqdisi, who arrived in Khorezm, counted 32 cities. The author of *Hudud al-Alam* did not list all the cities, but wrote a summary of some of them [1].

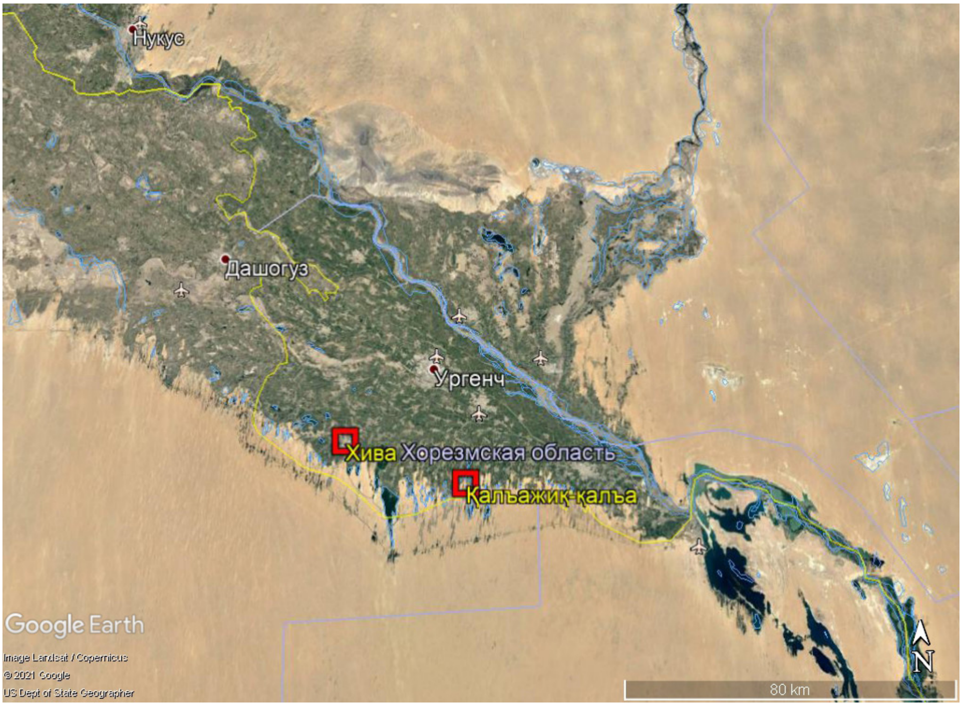

Figure. 1. Kaladzhik-kala on Google Earth map

Kardanhas, described in medieval sources, is the current Kalajik, the first to prove this was the Dutch historian De Gui in the 19th century. He deeply studied the Arabic-Persian sources, along with them the ancient Uzbek manuscripts, and emphasised that in the work of Abulgazi Gardankhast is the same as the city of Kardankhas in the Arab historians [3]. The Arab traveller of the tenth century, al-Istakhri, in his journey to Central Asia, especially to Khorezm, provided information about Khorezm and nearby settlements and cities. He describes them by their location on the trade routes of those times. Of these, he divided the described caravan routes from Khazarasp to Kata, the capital of Khorezm, into three parts: Khazarasp-Kardarankhas – distance 3 farsakh (1 farsakh – 6–8 km), Kardankhas-Khiva – 5 farsakh, Khiva-Safardiz – 5 farsakh, Safardiz-Kat – 3 farsakh [1]. If we measure the current distance from the fortress of Kardaranhas to Katta Kalajik, the village of Madir near Safardiz Khang, given that Kat is the modern Beruni, then al-Istakhri's calculations are close to the truth. Why, in order to reach Kata from Khazarasp, it was necessary to make a circle through Zardukh, Kaladzhik, Khiva and Safardiz? Maybe because during this period the channel of the Amu Darya ran next to the Karakum and merchants and travellers went around.

In turn, another Arab traveller al-Maqdisi visited Khorezm, leaving information about the internal trade routes of Khorezm, he described the distance from Khazarasp to Gurganj as follows: Khazarasp-Zardukh (on the right bank) – 2 barid (1 barid – 2 farsakh – 14–16 km, stopping place): Kardaranhas – 1 barid (stopping place); Khiva – 2 stopping place; Rahushmitan or Ardahushmitan – 1 stopping place; Daskananhos – 1 stopping place (fortress – a city located near the river, was considered a place of passage); Uzarmand or Vazarmand – 2 stopping place; Ruzund – 1 stopping place; Nuzvar – 2 stopping place; Zamakhshar – 1 crossing point; Gurganzh – 1 crossing point [1].

The locations of the individual cities described above have been clarified by archaeologists. For example, there are different opinions about the location of the city of Zurda. V. V. Bartold and Ya. G. Gulyamov believe that this city is incorrectly given by Maqdisi [4, 5]. They confirm this opinion by the fact that in the Middle Ages this city was located not on the left bank, but on the opposite side on the right bank of the river. The right bank was included in the list of cities of Khorezm. Archaeologist M. Mambetullaev compares Kaladzhik with the ancient settlement of Gayibat in the Bagat region (now the ruins of Gayibat are used as a cemetery and therefore there is no way to study it). In addition, the inconsistency of some sources complicates our study [6].

Figure 2. View of the Kaladzhik-kala arch, photo: K. Masharipov

3. Analysis

The emergence of cities in Khorezm, the development of agriculture and handicrafts, but especially the improvement of artificial irrigation, gave impetus to the progress of the economy. In the Middle Ages, not only the Kardanhasan fortress was mentioned, but also the canal that flowed next to it. "Starting from Khazarasp to the banks of Zhaihun, a canal was dug," writes al-Istakhri, "between them there is a Khazarasp canal, the length of which is equal to half of the Gavkhara canal. Then from Khazarasp they stretched a canal, 2 fars long, to Kardarankhas, more than the Khazarasp canal. Then the Khiva canal is larger than the Kardankhas canal, boats sailed along it to Khiva" [1]. According to Istakhri, on the left bank of the Amu Darya, the Khazorasp (Khass canal), Kardarankhas (Kalazhik canal, Dovud kala), Khiva (Polvonep), Madra (Gazavat), Buva (Yormish) and Vadak (next Shahabad) canals stretched, which contributed to the development of agriculture trade and culture of the city. If we compare and study historical knowledge on trade routes and centres that connected Khorezm and Maverannakhr, then we will find a waterway along the Amu Darya and a land trade route that connected Khazarasp with Kardaranhos in the Middle Ages. Along with this, most of the trade routes passed through Kardaranhos. The history of Kalajik is summarised in the work of Abulgazi "Shazhariy Turk" and in the manuscript of Munis and Agakhi "Firdavs ul-ikbal". They describe a lake in the Kalajik-Kala district, which was called Kardanhast, as well as Lake Nukus (17^{th}–19^{th} centuries). Abulgazi in "Shazharai Turk" described the campaign of the Khan of Bukhara Ubaidullakhan to Khorezm, it describes the second campaign, in which the commander Dinmukhammed with Khorezem soldiers defeated them near Kardanhast (Kalajik) [5]. These events found their place in the works of Muniz and Agakhi. They also cited the history of the Mangit uprising during the reign of Muhammad Amin inak. From the result of the suppression of popular unrest, it becomes clear that the Khan of Khiva, after the defeat of the Mangits, and the destruction of their Nukus fortress, resettled its inhabitants in Besharyk. They could have been resettled precisely from the region of Kaladzhik. Not far from the ruins of Kaladzhik there are lakes, Nukuskul [7].

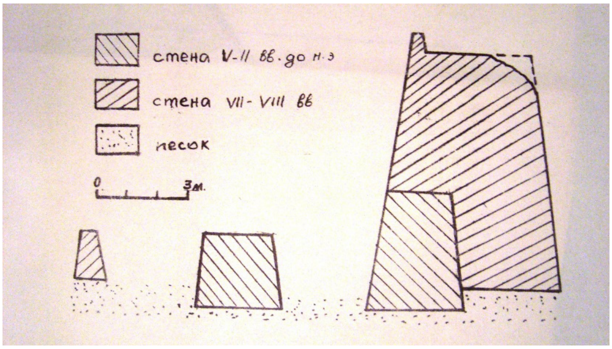

Figure 3. Schematic plan by M. Mambetullaev, reflecting the fortress wall construction stages

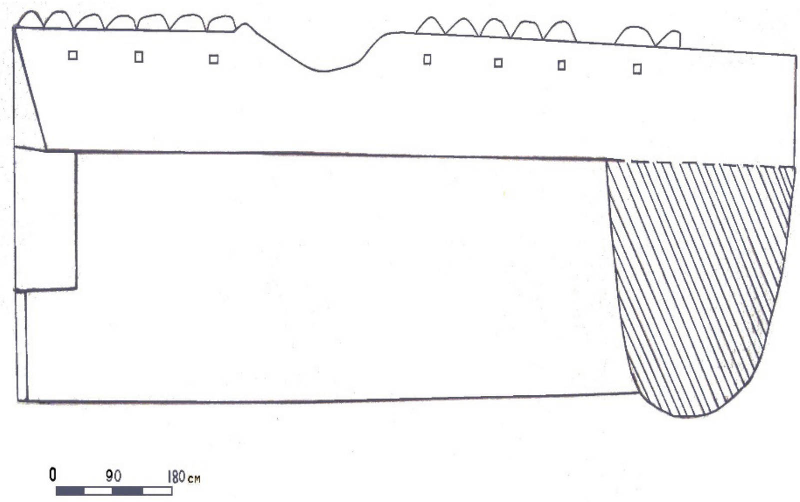

Figure 4. Drawing by M. Mambetullayev of 1973–1974, reflecting the development stages of the fortress walls

Regarding the name Kaladzhik, there are a number of assumptions, but most reveal its meaning as a "small fortress". In the name of a number of medieval cities of Khorezm, there is an appendix "khas". Between Khiva and Kat are Kardanhas and Daskanonhas. Professor V. A. Livshits assumed that the word "khas" means "place of residence", "locality", in Sogdian – kand-kat-kav, i.e. may have a connection with the city in an etymological sense [8]. G. P. Snesarev, who deeply studied the ethnography of the Khorezm Uzbeks, argued that the application "khas" is found in the South Khorezm toponyms: Zhuvorkhas, Navkhas, Pirnakhas, Zenakhas, Nezakhas, Charkhas, which in the Middle Ages were considered settlements with a large population. From this it follows that the word Kardaranhas means "village, center of the village, gathering place" or "central city" [9].

In the future, when studying other cities of Khorezm, it is necessary to use toponymy. In general, the opportunity to replenish the historical documents of Khorezm in the 10^{th}-15^{th} centuries. archaeological knowledge expanded. At present, historians are comparing the travel notes of al-Istakhri, al-Maqdisi and other authors with archaeological data.

Much information was obtained from the diaries of travellers and merchants, but this is not enough for historians to fully describe the state of the economy and culture of medieval Khorezm. To this end, archaeological work is essential.

Scientific research of Kaladzhik-Kala began in the second half of the 20^{th} century. It was first studied by the famous Uzbek archaeologist Ya. G. Gulyamov. When studying the irrigation system in 1938–1940 and 1946–1950, he drew attention to this fortress. Ya. G. Gulyamov believed that the fortress was built in the 4^{th}–3^{rd} centuries BC. In his opinion, life flourished in Kaladzhik in the 4^{th}-1^{st} century BC. In the 4^{th} century AD the fortress was completely abandoned. Starting from the 4th century, the second stage of life in the fortress began, which lasted until the 7th century. After the Arab invasion, it was empty again. Only in the 9th–13th centuries the fortress comes back to life. Ya. G. Gulyamov, relying on the heritage of the historians Abulgazi, Munis and Agakhi, believed that life in Kalazhik partially continued in the 16th-18th centuries [5].

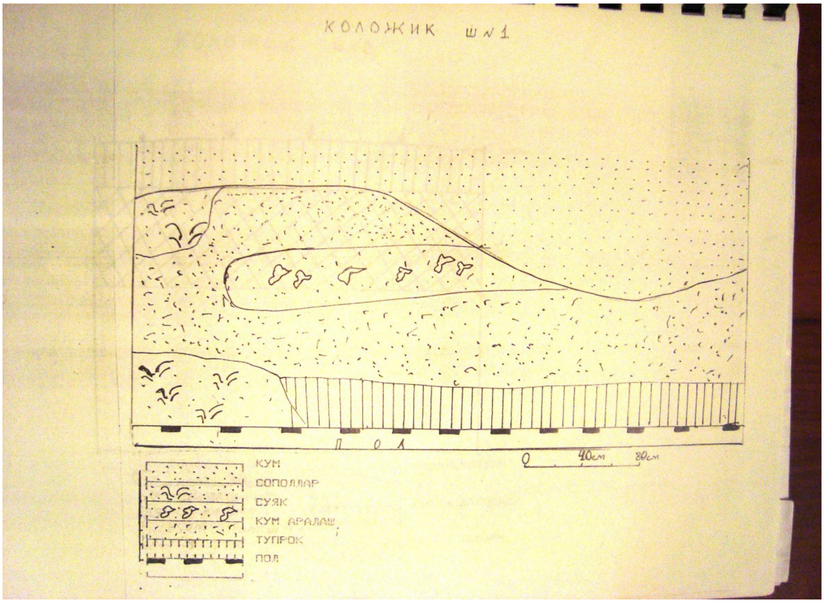

Figure. 5. Drawing by M. Mambetullayev of 1973–1974, reflecting the stages of development of the fortress walls

Figure 6. Plan of Kalajik-kala, scale 1:1500

Along with archaeological research, ethnographic work was also carried out. In 1958–1960 an archaeological ethnographic expedition in Khorezm led by G. P. Snesarev carried out work in the district of Kaladzhik-Kala. The members of the expedition laid a pit. Fragments of dishes from the 4th–3rd centuries BC and the 7th–12th centuries AD were found in it. This is how the age of the fortress was determined [10].

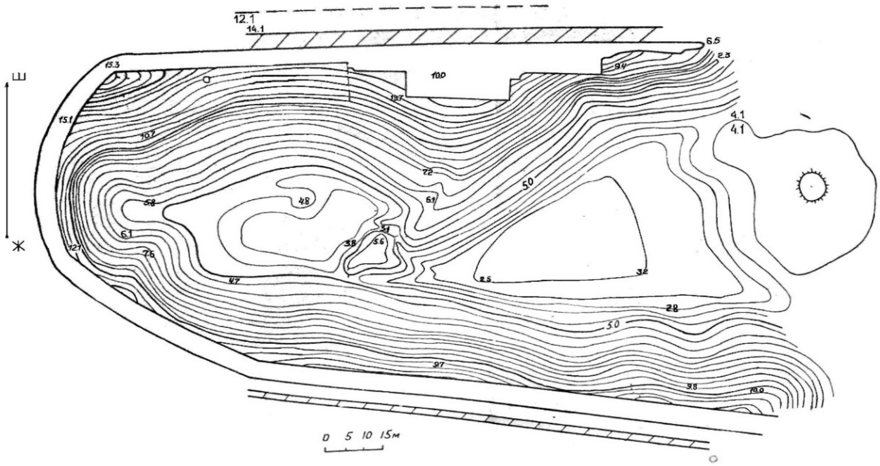

Figure 7. Plan of Kalajik-kala

Figure 8. Kalajik-kala. View from space, photo: K. Masharipov

Hazarasp was used for military protection. In the first historical period, an adobe wall was erected, in two parts, 2.75 m wide and with a path on top. The thickness of the outer wall was 1.5 m, and the inner one was 0.75 m. At the foot of the eastern wall there is a hill, maybe this is the entrance. In the second period of construction, another wall was erected from square bricks (40x40x10, 44x44x13) on the adobe wall. At a distance of 5 m from the outer wall, an adobe wall was erected, 0.8–1.2 m high. And the distance between the outer wall was 1.34–1.35 m, the width was 0.2 m, the height was 60 cm. 1.5 m long [11].

A group of archaeologists led by M. Mambetullaev carried out a clean-up of cultural deposits and laid two pits here (on the central and eastern parts) in order to determine the stratigraphy and chronology. As a result, it turned out that the city is not rich in cultural deposits. Kaladzhik in its original form had the shape of a regular quadrangle and two rows of protective walls. There is a corridor between the walls, 2.8–3 m wide. In this corridor there were shelters up to the chest of a person, and the distance between them was 1.20 m. Kaladzhik does not have towers, but only ditches. "G". The entrance was built taking into account the fact that the warriors wore a shield on the left side, and when the enemy attacks the castle, he, with the unprotected, right side, stands up to the defenders of the fortress. This led to heavy losses, and made it more difficult to capture the city. Maybe the walls of Kaladzhik were of two layers, like all the fortresses of Khorezm. But in the course of history they could change.

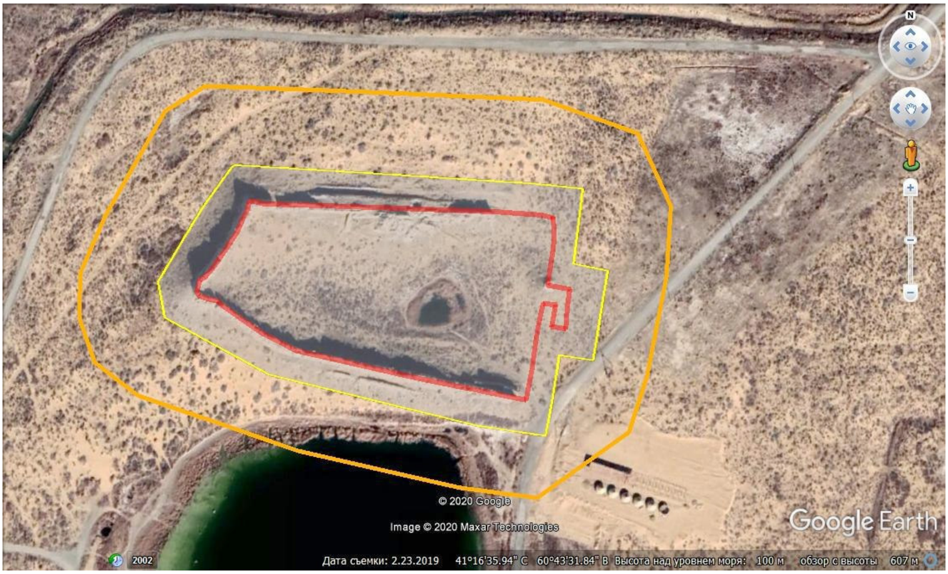

Figure 9. General view of the castle-fortress. Castles of the defensive wall of the castle (yellow line) and the defence zone (orange line), on Google Earth map

Figure 10. Suggested approximate distance view limit of the general view of the castle, on Google Earth map

From the results of the research of M. Mambetullaev, Kalazhik was a fortification for protection both in ancient times and in the Middle Ages. Taking into account the main finds of vital activity in the vicinity of the fortress and the presence of several archaeological sites, the fortress was used to hide from enemies [11].

In 1991, an expedition of the Russian Academy of Sciences, the St. Petersburg Department of the Institute of Archeology, headed by V. Zavyalov, carried out excavations at Katta Kaladzhik. They mainly worked in the northern part of the wall and around the fortress. As a result, the remains of the ruler's residence were found near the mentioned wall. It was erected in the Middle Ages, a ramp rose to it from the western side. The length of the ramp was 11.7 m, the width was 3–3.6 m, starting from the north side it extended to the east. The results of the research by V. Zavyalovo coincided with the results of the excavations by M. Mambetullaev, but he believed that Kalazhik was not built earlier than the 3rd century BC, which he was wrong about. He, apparently, did not compare the fragments of dishes that are inherent in the 4th century BC [12].

In Khorezm, there were cities, along with them, Kaladzhik, of a rectangular layout, least of all rounded. The city was surrounded by strong defensive walls and a moat. The defensive walls were reinforced with moats and semicircular towers. In the ancient urban planning of Central Asia, there are two parts of the city, built up with houses, these parts are separated by a road that leads to the temple. But this is not observed in Kaladzhik-Kala, it, like the Ayazkala-1 fortress in Karakalpakstan, was used by the population only during the enemy's attack.

In the last periods of antiquity, the raids of nomads from the north became more frequent, which led to the decline of the fortress, which also manifests itself in the quality of the manufacture of pottery.

4. Conclusion

The revival of life in Kaladzhiki and on the entire left bank of the Amu Darya, according to historical sources, falls on the 9th–12th centuries. During this period, the Anushteginid dynasty ruled in Khorezm. It was during this period that Kaladzhik-Kala was inhabited and was one of the centres of trade. Kalajik-Kala must have been surrounded by mosques, bazaars and caravanserais. The conquest of Khorezm by the Mongols led by Genghis Khan (1219–1221) caused the devastation of cities. Kalajik until the 17th century was abandoned [13].

The fact that the castle's defense system is well preserved further increases the importance of studying the site in the future. The very well-preserved fortifications make it possible to realise promising tourist plans by rebuilding it and turning it into an open-air museum. The presence of a healing lake near the castle and the enjoyment of the surrounding natural landscape, along with historical tourism, also play an important role in the development of ecotourism.

One of the important aspects of the tourist route is that the monument is located near the Khazarasp-Khiva highway. The fact that this route matches the ancient Silk Road network adds to its importance. In this direction, it is possible to organise the route Khiva-Kalajik-Khazarasp-Khumbuztepa.

Considering the uniqueness of the monument, its museum value is relevant today. It is also necessary to take into account local features in the field of construction, using the achievements of world experience in the conservation and restoration of the monument. Currently, in developed countries, the method of using special glazed canopies to preserve monuments is widely used, but this method loses its ideality when viewing a monument from a real distance.

The very good preservation of the fortifications, the great prospects for its reconstruction and transformation into an open-air museum make it necessary to cover a much larger area of the protected area of the monument. Because it is natural for a tourist visiting a monument to observe it close up or from the side and take pictures from a distance.

It is the same with artists. Today, the monument has an observation deck for almost everyone. It is these aspects that preserve the tourist potential of the monument and serve to enhance the prestige of its regular visitors. At the same time, the preservation of the observation zone over a large area around Kaladzhik-kala reduces the influence of the human factor on the monument and further increases its service life.

In turn, it is necessary to conduct regular archaeological research in the vicinity of the monument during the tourist season, and after the completion of each research season, it is desirable to carry out gradual conservation work. At the same time, within the framework of the current legislation, it is possible to increase the interest of visitors to the monument by attracting tourists to research and ensuring their participation. If a museum is created next to the preserved monument, then the finds collected as a result of archaeological research can become a unique museum exposition fund.

Of course, the development of the infrastructure of this place by attracting local and foreign investments, the creation of new jobs for local residents will become an important factor in the development of tourism in the Khorezm region.

References

[1] Materialy po istorii turkmenov i turkmenov (daleye MITT). T. I. – M.-L.: Nauka, 1939. – S. 178–179, 181, 187–189, 206, 216. (in Russian)

[2] Tolstov S.P. Po sledam drevnekhorezmiyskoy tsivilizatsii. — M.-L.: AN SSSR, 1948. — 328 s. (in Russian)

[3] De Goyye M.Dzh. Das alte Bett des Oxus Amu darja. – Leyden: Kessinger Publishing, 1875, 120 r. (in Russian)

[4] Bartol'd V.V. Turkestan v zadnem mongol'skom rezerve // Sochineniya, t. 1, s. 2. — M.: «Nauka», 1964. — 657 s. (in Russian)

[5] Ġulomov YA.Ġ. Khorazmning suġorilish tarikhi. K̦adimgi zamonlardan x̦ozirgacha. — T.: Fan, 1959. — 326 b. (in Russian)

[6] Mambetullayev M. Otchet ob arkheologo-topograficheskikh izyskaniyakh na territorii Khorezmskoy oblasti v 1974 godu. Nukus, 1974. Madaniy meros departamenta arkhivi. A 9355/M-22. (in Russian)

[7] Munis va Ogax̦iy. Firdavs ul – Ik̦bol. (Mas"ul mux̦arrir v turkum muallifi SH. Vox̦idov). – Toshkent: Yangi asr avlodi, 2010. – 518 s. (in Russian)

[8] Nerazik Ye.Ye. K probleme razvitiya gorodov Khorezma // V kn .: Kul'tura i iskusstvo drevnego Khorezma. — M.: «Nauka», 1981. — S. 219–227. (in Russian)

[9] Snesarev G.P. Ob"yasnitel'naya zapiska k "Karte rasseleniya uzbekov na territorii Khorezmskoy oblasti (konets XIX — nachalo XX v.). // V sb.: Khozyaystvenno-kul'turnyye traditsii narodov Sredney Azii i Kazakhstana. — M.: Nauka, Gl. red. vost. lit. ., 1975. – S. 75–94. (in Russian)

[10] Tolstov S.P., Zhdanko T.A., Itina M.A. Raboty Khorezmskoy arkheologo-etnograficheskoy ekspeditsii AN SSSR v 1958–1960 gg. – MKHE, vyp. 6. M.: Nauka, 1963. – S.3–91. (in Russian)

[11] Mambetullayev M. Gorodishche Kaladzhik. Vestnik KK «Fan» UzSSR, Nukus, №1, 1983. – S.69–73. (in Russian)

[12] Zav'yalov V.A. Otchet o rabote Bagatskoy ekspeditsii IIMK v kreposti Kaladzhik v maye-iyune 1991 g. Sankt-Peterburg, 1992. Madaniy meros departamenta arkhivi. A 9351/Z-13. (in Russian)

[13] Masharipov K̦., Rakhimova X̦. K̦al"azhik̦-k̦al"a. – Urgench, UrDU nashiriyoti, 2016. – 28 b. (in Russian)

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THE USE OF INFORMATION TECHNOLOGIES IN THE PRESERVATION OF MONUMENTS OF ARCHITECTURE OF THE REGISTAN ENSEMBLE

Abstract

The article describes the work done in recent years on the use of traditional and information technologies in the restoration and preservation of the Registan Ensemble. Presented are works related to the renovation of arcchitectural details made in the Ulugbek Madrasah, the main wooden gates of the Sherdor Madrasah and conservation of the outer dome of the Golden Mosque in the Tillya-Kari Madrasah. Also discussed is collaboration with a team of IT specialists from the Lublin University of Technology from Poland.

Keywords: architecture, information technology, restoration, conservation, Registan.

The city of Samarkand is one of the ancient cities of the world, the history of which is about 3 thousand years old. Many monuments of cultural heritage, both archaeological and architectural, are concentrated here.

One of the brightest pages in the calendar of significant dates in Samarkand is the City Day. The tradition to widely celebrate this date was founded in October 1996 as part of the celebration of the 660th anniversary of the birth of Amir Temur. On the same day, one of the oldest cities in the world was awarded the Order of Amir Temur. It is no coincidence that the date is associated with the name of Sahibkiran. During the reign of Amir Temur and his descendants, Samarkand became the capital of a vast empire, a centre of science, trade and handicrafts. The unfading glory of the "Pearl of the East" was brought by the unique architectural structures erected here in the era of the Temurids, recognised as masterpieces of world architecture. Much of this heritage has survived to this day and is guarded with trepidation by the modern generation of Samarkand residents.

The Registan architectural ensemble is called the heart and face of the ancient city. The architectural structures created in the 15th-17th centuries in this complex is an attraction for millions of guests and tourists from all over the world. For many centuries, major events in the life of the city have been taking place here. Today the Registan ensemble is one of the cultural centres of the Central Asian region and the Republic of Uzbekistan.

To preserve and use this heritage of the people, a lot of work is being done, and modern information technologies are being actively used. Restoration of architectural monuments is a laborious process. It depends on many factors. Before the work of restoration and conservation of an architectural monument begins, a number of scientific studies are carried out, including scientific methods for studying its architectural features, a cycle of engineering and technical surveys, design work on the restoration of this object is being implemented.

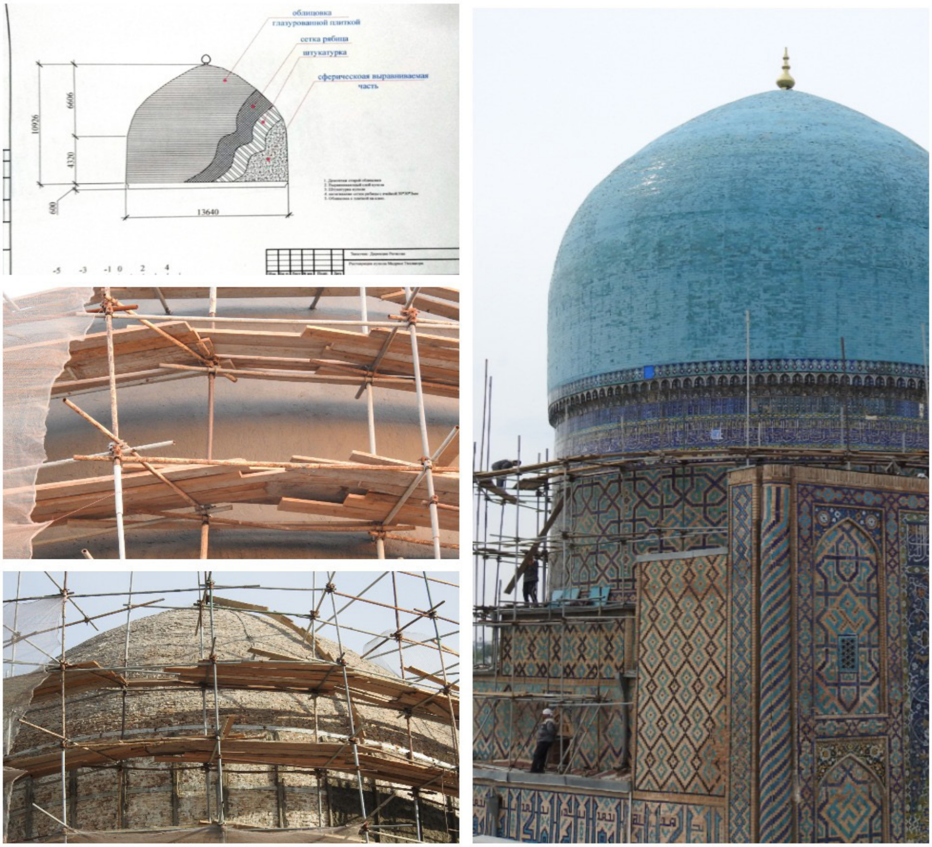

Figure 1. Conservation of the outer dome of the Golden Mosque in the Tillya-Kari Madrasah, source: The Registan archives

It was after such a comprehensive work in 2018–2019 that work began on the restoration of the main dome of the mosque of the Tillya-Kari madrasah. As may be known, this dome of the mosque was restored in the 1970s, and by that time many facing materials made of ceramic products had fallen into disrepair and required a complete restoration with the replacement of the dome lining. During the restoration of the dome in the 1970s, the restorers tried to use too many building materials, which subsequently affected the load on the foundation of this structure. The excess load of the dome led to the fact that cracks appeared in the walls of the mosque, after which a series of fortification works were carried out to preserve the monument. After cleaning it from damaged ceramics and a massive substrate, the dome was strengthened. The cleaned surface is plastered with a special solution with the addition of elements that prevent the penetration of moisture. Thanks to the use of modern technologies in the process of laying new, waterproof tiles on the surface of the dome, the restorers managed to maintain all the proportions and symmetry on the spherical element of the mosque. The subtlety of the work carried out is evidenced by the fact that on individual architectural fragments in each square meter up to two thousand elements of typesetting mosaics are laid. After a major restoration, the Tillya-Kari dome became lighter by more than a hundred tons, and accordingly, the load on the entire building also decreased. According to experts, updating and lightening the dome will significantly extend the life of the architectural and iconic masterpiece.

Preserving the original appearance of a historic building using traditional methods is often difficult. To protect the walls for a long time and at the same time preserve the beauty of monumental structures, transparent materials for the protection of façades can be used. For example, the dry film resulting from the application of translucent coatings is dirt-repellent and highly weather-resistant for 50 years. This conservation method was used as an experiment on the main gate of the Sherdor Madrasah, on the marble slabs of the Ulugbek Madrasah and the Tillya-Kari Madrasah.

Figure 2. Marble slabs of Tillya-Kari Madrasah, source: The Registan archives

Figure 3. Marble slabs of Ulugbek Madrasah, source: The Registan archives

Figure 4. One of the main gates of the Sherdor Madrasah, source: The Registan archives

Figure 5. Evidence of collaboration with the Lublin University of Technology from Poland: conference poster, preparation of boards of the mosaic of the front of the Sherdor Madrasah, 3D scanning of objects of the Registan Ensemble, source: The Registan archives

In recent years, new achievements of information technology have been widely used in the Registan ensemble for the preservation and use of architectural monuments. One of these was widely used in the practice of the restorers of the Registan ensemble, who actively introduced the technology of laser scanning of architectural monuments, which is widely used throughout the world. This is due to the cooperation agreement between the directorate of the Registan Ensemble and the Lublin University of Technology, which was concluded in 2018. In most cases, only using a 3D laser scanner, it is possible to most fully, accurately and efficiently perform façade surveys, architectural measurements, three-dimensional fixation of the state of the structure with the identification of defects and deformations, and monitoring the state of the object at different stages of its operation. Such techniques reduce the human factor to zero, contributing to the preservation of the original appearance of masterpieces. It was this method, in collaboration with the Lublin University of Technology (Poland), that scanned the composition of the main entrance portal of the Sherdor madrasah, the inner and outer dome of the mosque of the Tillya-kori madrasah, the stalactites of all 3 madrasahs of the Registan ensemble and other objects of the site. This made it possible, on the basis of special laboratory studies, to determine as accurately as possible the colour schemes used by the masters of the past, the sizes and arrangement of all the details of the decor with an accuracy of a millimeter.

In addition, these works make it possible to save scanned materials for further study, preservation and promotion of this object. And also scanned materials can serve as a good material for designers, engineers, constructors, restorers, technical supervision inspectors and other specialists.

In 2021, according to the cooperation agreement between the Registan Ensemble and the Polish university, within the framework of the 3D Silk Road Digital project, specialists from the Lublin University of Technology, with the support of Poland's National Academy for Academic Cooperation (NAWA), digitised the inner and outer domes of the Tillya-Kori madrasah mosque, after restoration of this dome in the summer of 2019. This made it possible to analyse the state of this object before and after restoration, the change in the design of the type of the dome itself. Joint work on scanning the architectural objects of the Registan ensemble with Polish partners continues and in the future we plan to scan all our cultural heritage sites.

Preserving for future generations our priceless architectural monuments with a long history is possible only by using new innovative technologies and materials in the process of preserving and restoring these objects, harmoniously complementing the unique experience of the creators of the Eastern Renaissance.

References

[1] E. M. Balzannikova. Bulletin of Eurasian Science. Internet journal *Science*, Volume 7, No. 2 (2015).

[2] E. S. Kovaleva Information technology in the preservation and presentation of intangible cultural heritage in the museum. *Modern scientific research and innovation*. 2015. No. 5. Part 5.

[3] M. Miłosz, E. Milosz , J. Montusiewicz. Determination of the surface area of ceramic tiles on the medieval Sher-Dor mosaic in Samarkand – Problems and solutions, Digital Applications in Archaeology and Cultural Heritage. – 2020, vol. 16, pp. 1–6.

[4] M. Miłosz, R. Kayumov, H. Samarov. Cooperation in the digitisation of cultural heritage. *Moziydan sado* magazine, No. 1, 2021, pp. 20–25.

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TECHNICAL ASPECTS OF PREPARING 3D MODELS FROM THE COLLECTION OF THE AFRASIAB MUSEUM

Abstract

The collection of museum objects of the Afrasiab museum was created as a result of archaeological works carried out over several decades in the ancient city of the same name. For over 1,000 years the ancient city of Afrasiab was an important trading centre on the Silk Road linking China with the Middle East and Europe. Selected small ceramic artefacts were successfully digitised using 3D scanning and post-processing on silkroad3d.com. Problems related to the process of 3D scanning and processing of data obtained from scanners working in the technology of structured light of museum objects with dimensions of 1–2 meters are discussed in this article.

Keywords: Silk Road, Afrasiab museum, 3D scanning, 3D model post-processing

1. Introduction

The Silk Road was a network of roads connecting China with the countries of the Middle East and Europe, passing through many cities acting as local centers for the exchange of goods and services [1]. The ancient city of Afriasiab performed this function until 1220, when it was completely destroyed by Chingis Khan troops [2]. Currently, the area of ancient Afrasiab lies within the borders of Samarkand (Uzbekistan), and the area of almost 200 ha is the area of archaeological excavations. Afrasiab Museum (Fig. 1) contains more than 22,000 unique artefacts, of which only selected objects are presented (glazed plates and dishes, pitchers, ossuaries and skulls of the inhabitants) and the frescoes known as the Ambassadors' Paintings or the Hall of Ambassadors Murals from the seventh and eighth centuries unearthed in the ruins of the city [3, 4].

Figure 1. View of the pediment of the Afrasiab Museum building, photo: J. Montusiewicz

The richness of museum exhibits means that not all of them can be presented in permanent exhibitions, and placed in closed showcases are not always clearly visible, or their viewing is possible only from one direction of observation. Placing too many exhibits in the available exhibitions often causes distraction of visitors, and it would take too much time to see all the objects. It seems that the currently available and at the same time modern solution is the creation of alternative exhibitions in the digital space, in which digital three-dimensional copies of real objects will be shown [5], also in the Virtual Reality (VR) technology version [6]. Such exhibitions may be available on the websites of individual museums and usually offer different viewing opportunities for museum artefacts. Thus, digital 3D objects can be freely rotated (which allows to see them from the inaccessible side when they lie in showcases), moreover, by enlarging them, it is possible to carefully examine them. The undoubted advantage of such exhibitions is the fact that they can be viewed at the most convenient hours (there is no need to adapt to the opening times of museums), and most importantly, it can be done without leaving home, i.e. in the on-line system. The presented objects can be reconstructed in a digital version, which may further stimulate the viewer's imagination [7–9]. Of course, a personal presence in a museum brings other unique experiences, so the exhibition created in a virtual museum is only an interesting addition.

The process of pilot work on 3D digitisation of museum collections began in 2017, when employees from the Lublin University of Technolgy (LUT), in cooperation with Rahim Kayumow from Samarkand State University (SamSU), could appear in the museum with professional equipment for digitisation of small museum objects [10], Fig. 2. Object digitisation work continued in 2019 using a terrestrial laser scanner (TLS). Selected results of these activities can be viewed on an accessible website [11] and in work [12].

Figure 2. Part of the 1st expedition team, from the left: Marek Miłosz (LUT), Rahim Kayumov (SamSU), Samariddin Mustafokulov (director of the Afrasiab museum), Jerzy Montusiewicz (LUT), photo: J. Kęsik

The aim of the article is to present the technical aspects of the 3D digitisation process by 3D scanners working in the scanning light structure (SLS) technology of objects whose dimensions are in the order of 1–2 meters in in situ conditions. The authors of the paper asked themselves the following research question: Does the creation of digital 3D artefacts of large objects with complex surfaces by using SLS technology require equipment with high operational parameters

2. Method and materials

The process of 3D digitisation of so-called small museum artefacts (with the exception of architectural objects) can be realised in many ways: with the use of handheld laser scanners [13], scanning in structured light technology (SLS) [14, 15], or photogramatrical technology also known as Structure from Motion (SfM) [15] (this technology can also be used for architectural objects). It should be added that the SfM technology is not able to transfer the dimensions of digitised objects (for this purpose, markers placed on the surface of the exhibit should be used and additional measurements of the distance between them should be made). Handheld laser scanners require markers to be placed on the surface of the artefact so that the points taken from the surface can be properly positioned in relation to each other. SLS technology enables both the collection of points from the surface of the artefact, its texture and dimensions.

3. Methodology of 3D scanning

The adopted methodology of 3D scanning of museum objects using SLS technology included the following activities:
1. Planning the digitisation process.
2. Equipment selection, program installation.
3. Creating work stand in situ conditions.
4. Fixing parameters of the scanning process.
5. 3D scanning with control of working parameters.
6. Saving partial results and final scan.

4. Comments

1. When organising scientific expeditions, we are not able to predict all the circumstances that we will encounter in specific museums. In such a situation, the planning process is very difficult, especially when it is the first field trip to a very distant country with a completely different native culture and tradition, and organisational standards that are not known more closely.
2. The choice of hardware, software and complementary equipment is critical to the success of the entire project. The following hardware and software was chosen, Table 1.

Table 1. Devices and programs for scanning and generating 3D models

No.	Devices / programs	Information and parameters
1.	Artec Eva scanner (in situ)	• hand-held structured-light technology scanner • 50–100 microns accuracy • saving textures • battery with charger
2.	Laptop for scanning (in situ)	• processor – i7 • memory RAM – 16 GB • graphics card – GTX 980 8 GB • HDD disc – 0.5 TB (SSD) + 1 TB
3.	Computer set for data processing (in laboratory)	• processor – Intel Core i7–6700CPU 3.40 GHz • memory RAM – 64 GB • graphics card – NVIDIA GeForce GTX1080 8 GB GDDR5x • HDD disc – 1 TB
4.	Program for data processing (in situ and laboratory)	• software on site – Artec Studio 12 Professional • post-processing software – Blender v2.8 and MeshLab v2020.04.
5.	Camera: Nikon D5300 (in situ)	• matrix size: 24x18 mm (6000x4000 px) • set of lenses: Nikkor 18–140 mm, 1: 3.5–5.6; Nikkor 70–300 mm, • 1: 4–6.3
6.	Additional equipment (in situ)	• extension cords and splitters • rotating table for placing small museum artefacts

3. The implementation of this point cannot be planned. First of all, you should ensure access to the power socket. Due to the high temperatures in Samarkand, you should

try to access an air conditioner or stay in an air-conditioned room. The creation of appropriate scanning conditions allows the cooling of devices which, when used for a long time, have a tendency to heat up and exceed the permissible operating temperatures.

4. Fixing parameters of the scanning process must be adapted to the size of the digitised object, its colour, surface details, its gloss, as well as the temperature conditions in the room (you can control e.g. the frequency of flashes projecting a defined structure on the scanned surface).
5. In the scanning process, the set parameters should be verified by observing the scanning process and viewing the already saved point clouds. When scanning large museum exhibits, an important issue is to observe information about the used and free space of RAM memory.
6. When the area of the available RAM decreases below 1 GB, the acquired data should be saved, which results in both data processing with the elimination of data on the same surface points, and a complete release of the occupied memory. The size of the data saved so far takes up many times less disk space than the data collected and stored in the operating memory.

5. Scanned objects

From large museum objects in the Afrasiab museum, 3 objects were digitised: two reliefs – Fig. 3, Fig. 4. and a model of the clay pot kiln, Fig. 5. The general characteristics of these objects were as follows: large dimensions, large number of details and no manipulation possibility. In the case of the reliefs it was also uniform colour, and in the case of the burning oven – no access to some surfaces of the objects.

Figure 3. Relief 1, size: 205x105 cm, photo: J. Montusiewicz

Figure 4. Relief 2, size: 203x98 cm, photo: J. Montusiewicz

Figure 5. Burning oven, size: 280x220 cm, photo: J. Montusiewicz

6. 3D scanning process

Previous experience in the process of 3D scanning of museum and archaeological objects with the use of Artec scanners (Eva and Spider types) has shown that 3 different situations are possible:

- interruption of continuity of digitisation proces,
- slowing of digitisation process (RAM full),
- inability to start the scanning proces.

Depending on the situation, the following activities were carried out:

- in the case of phenomenon (i), the following was introduced: distribution of additional markers and switching off texture identification,
- in the case of phenomenon (ii) – saving individual scans,
- in the case of phenomenon (iii) – additional cooling of the scanner and laptop.

Thus, in the realised 3D scanning process of the reliefs, 2 different approaches were implemented (Fig. 6):

- due to the single colour of the object, the positioning of the scanner based on the texture of the object was turned off, leaving only the recognition of surface shapes.
- the placement of additional markers (they were not glued), which were placed in places where the original details were not preserved (smooth fillings).

When scanning the burning oven, positioning was enabled based on information about the textures of the objects.

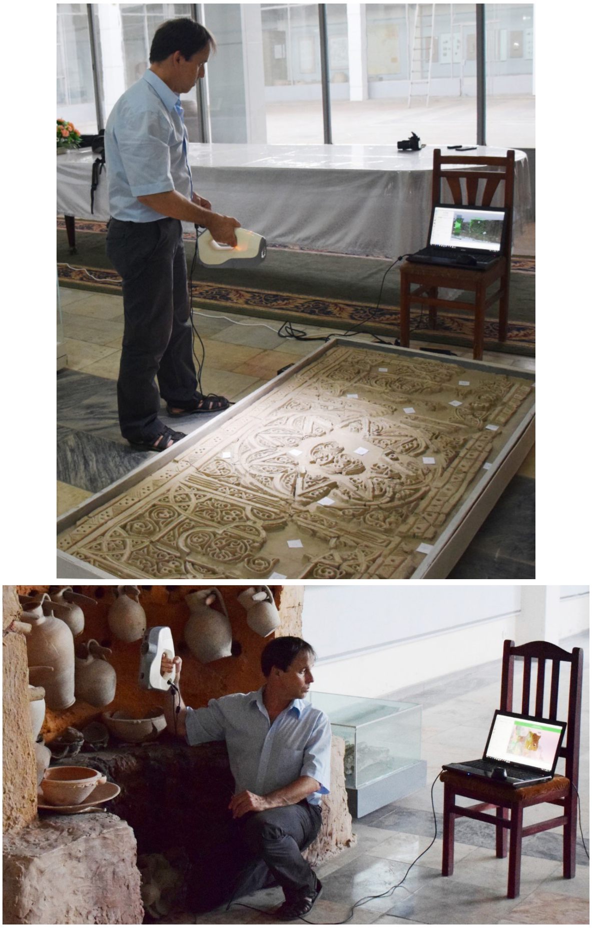

Figure 6. Scanning of the Relief 2 and burning oven, photo: S. Mustafokulov

7. Results

The process of 3D scanning of large and small museum objects was carried out in 2017, and the processing of large museum objects (Table 2, item 1–3) was performed only in 2021 after the purchase of a computer set with the correct calculation parameters (Table 1, item 3). To compare the results obtained for large and small museum objects, Table 2 (items 4–8) also includes information on scans and post-processing of small museum objects, which were performed in 2017 due to much lower hardware requirements. These objects can be viewed on the 3D Digital Silk Road portal [11].

Table 2. Information about scanned objects

No.	Name of objects	Size of raw scan, point cloud	Size of processed scan, point cloud
1.	Relief 1	5,33 GB	5,50 GB
2.	Relief 2	4,58 GB	7,14 GB
3.	Burning oven	19,2 GB	11,5GB
Comparative objects (small museum artefacts)			
4.	Cornice 1	1,84 GB	2,29 GB
5.	Cornice 2	579 MB	3,50 GB
6.	Cornice 4	902 MB	3.11 GB
7.	Cornice 5	454 MB	0.68 GB
8.	Cornice 6	397 MB	1,65 GB

The process of preprocessing scans involves transferring all partial scans to one coordinate system, eliminating repetitive points while remembering raw scans. There is a redundancy phenomenon, so the size of these files is usually larger than the original files, so this situation requires large capacity RAM.

During the 3D scanning process of large museum objects (with dimensions of 1–2 m), the phenomena described in chapter 2 in the "3D scanning process" section occurred many times. Most often, the RAM was quickly filled up due to the large area scanned. When this memory was full, the process of downloading data from the scanner basically stopped, because the communication of the scanner with the standard disks of the computer was much too slow. Interrupting the scan and saving the current data healed the situation.

The obtained digital 3D mesh models of the scanned objects are shown in Figs. 7–10. Long-term scanning led to multiple overheating of the scanner, which required stopping work and cooling the device. This situation was quite troublesome and significantly extended the data acquisition process.

The size of the scanned objects made certain scan areas impossible to reach. In the case of the reliefs, their width (about 1 m) was so large that the free reach of the hand ended and in order to reach beyond half of their width, the entire torso had to be bent (definitely a non-ergonomic position), which after some time caused back pain.

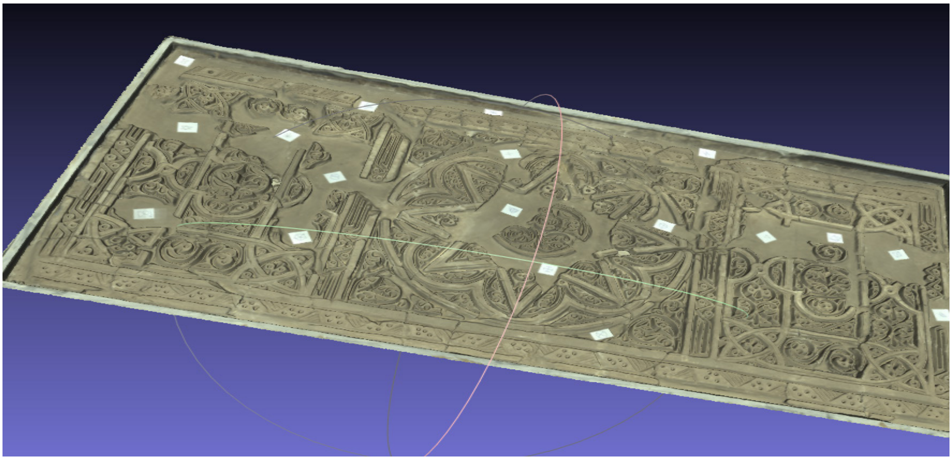

Figure 7. Relief 2, mesh model, size: 132 MB, number of vertices: 888,200, number of faces: 1,775,000

a) b)

c)

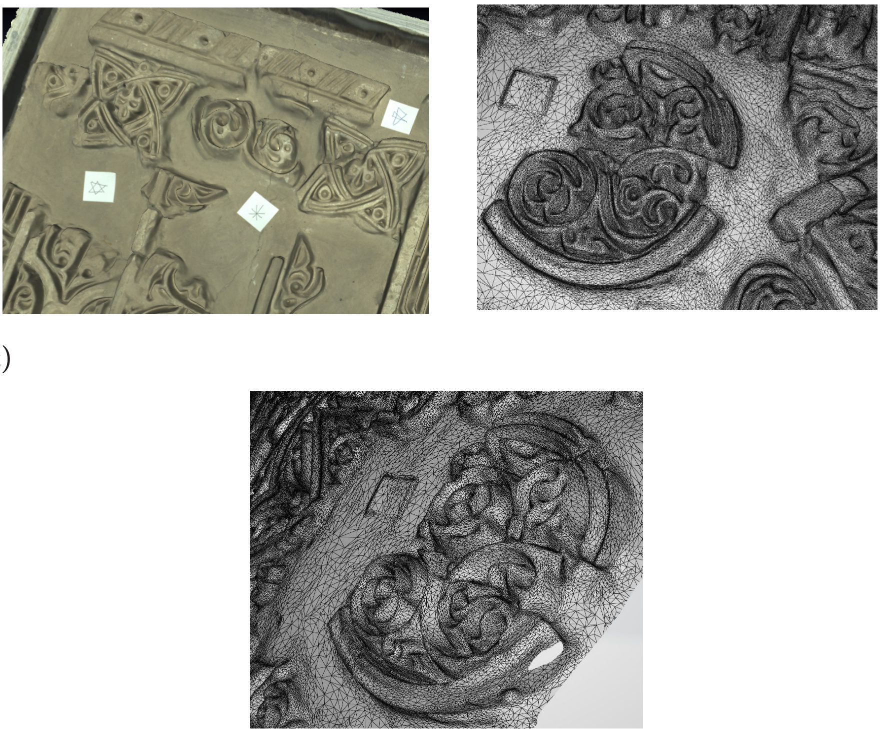

Figure 8. Relief 2, mesh model of details: a) solid view, b) and c) mesh view

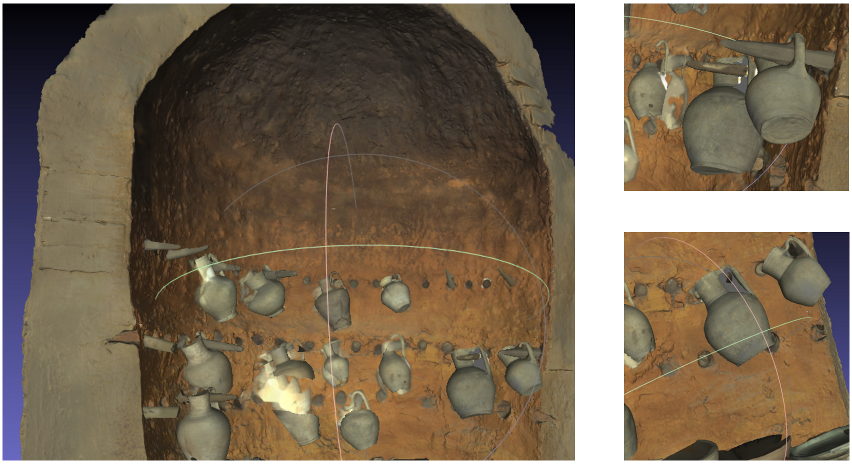

Figure 9. Burning oven, mesh model, size: 326 MB, number of vertices: 2,110,145, number of faces: 4,199,200

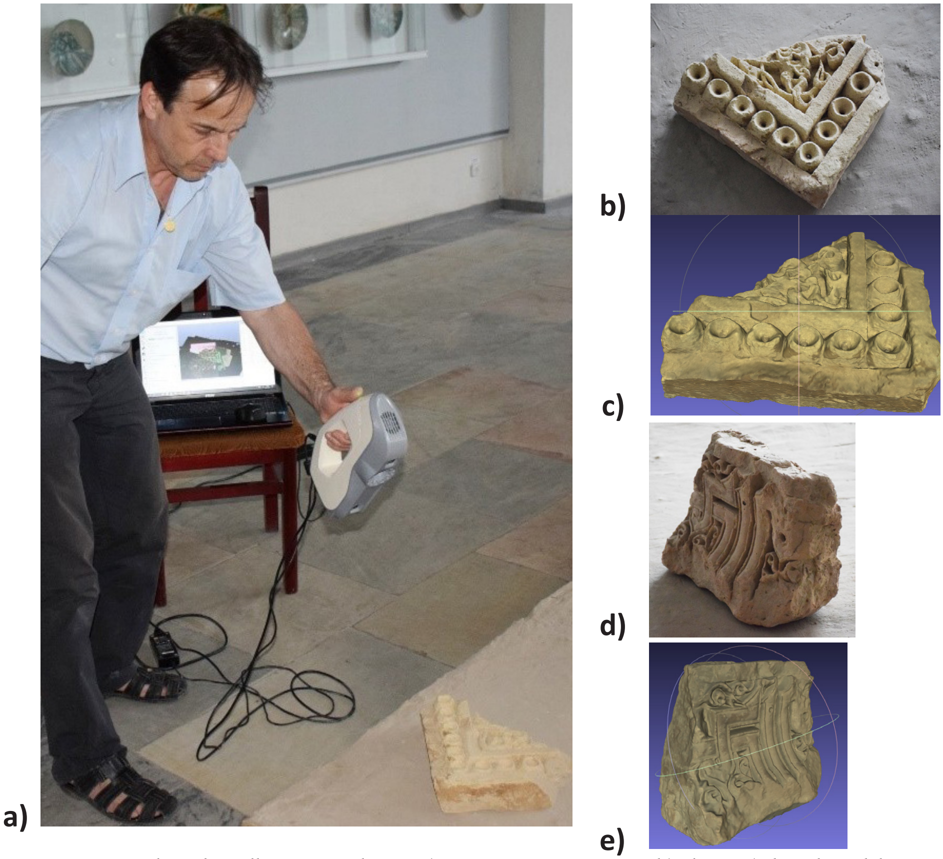

Figure 10. Selected small museum objects: a) 3D scanning, cornice 1: b) object, c) digital model, cornice 2: d) object, e) digital model

8. Conclusions

The authors of the paper asked the following research question: Does the creation of digital 3D artefacts of large objects with complex surfaces using SLS technology require equipment with high operational parameters? The conducted in situ 3D scans at the Afrasiab museum in Uzbekistan made it possible to clearly state that this scanning technology requires equipment with very good operational parameters and devices with efficient cooling systems.

In the light of the activities carried out, it can also be stated that:

- Large-size 3D scanning of objects with insufficient RAM requires frequent saving of data.
- Failure to control RAM consumption during the scanning process leads to its exhaustion and blocking the scanning process.
- Poorly configured computer hardware to which SLS scanners are connected increases the scannning or prevents it.

It is also worth remembering that the 3D scanning process allows to download data about an object in the form of a point cloud, which leads to the so-called perpetual archiving of the facility. Such data have information about the surface, texture and its dimensions. Practice shows that the data processing procedure can be postponed until equipment with the correct computing parameters is obtained and better software is purchased.

Acknowledgements

This article has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00004 titled "3D DIGITAL SILK ROAD".

References

[1] Aigul, T., Zibagul, I., Saira, S., 2016. The great silk road as a cultural phenomena, International Journal of Economic Perspectives, vol. 10, no. 4, pp. 41–46.

[2] Hansen, V., 2012. The Silk Road: A New History, Oxford University Press, 320 p.

[3] Azarpay, G., 2014. The Afrasiab Murals: a Pictorial Narrative Reconsidered, The Silk Road, vol. 12, pp. 49–56. Retrieved 27 January 2020, http://silkroadfoundation.org/newsletter/vol12/

[4] Marshak, B.I., Grenet, F., Sadowska-Daguin, M., 1994. Le programme iconographique des peintures de la « Salledes ambassadeurs » à Afrasiab (Samarkand), Arts asiatiques, vol. 49, pp. 5–20, doi: 10.3406/arasi.1994.1349.

[5] Barbieri L., Bruno F., Muzzupappa M., 2017. Virtual museum system evaluation through user studies, Journal of Cultural Heritage, no. 26, pp. 101–108.

[6] Żyła K., Montusiewicz J., Skulimowski S., Kayumov R., 2020. VR technologies as an extension to the museum exhibition: A case study of the Silk Road museums in Samarkand, Muzeologia a Kulturne Dedicstvo = Museology and Cultural Heritage, no. 4, pp. 73–93

[7] Kęsik J., Montusiewicz J., Kayumov R. 2017, An approach to computer-aided reconstruction of museum exhibits, Advances in Science and Technology Research Journal, vol. 11, no. 2, pp. 87–94

[8] Pierdicca R., 2018. Mapping Chimu's settlements for conservation purposes using UAV and close range photogrammetry. The virtual reconstruction of Palacio Tschudi, Chan Chan, Peru, Digital Appli¬cations in Archaeology and Cultural Heritage, no. 8, pp. 27–34.
[9] Montusiewicz J., Barszcz M., Dziedzic K., 2019. Photorealistic 3D digital reconstruction of a clay pitcher, Advances in Science and Technology Research Journal, vol. 13, no. 4, pp. 255–263.
[10] Miłosz M., Montusiewicz J., Kęsik J., 2020. 3D Information Technologies in Cultural Heritage Preservation and Popularization – a Series of Seminars for Museologists Made by Computer Scientists. [in]: EDULEARN 20: 12th Annual International Conference on Education and New Learning Technologies, Walencja, Spain 6–7.07 2020: conference proceedings, pp. 544–549
[11] Portal "3D Didital Silk Road", silkroad3d.com
[12] Miłosz M., Skulimowski S., Kęsik J., Montusiewicz J. 2020, Virtual and interactive museum of archaeological artefacts from Afrasiyab – An ancient city on the silk road", *Digital Applications in Archaeology and Cultural Heritage*, vol. 18, pp. 1–12
[13] Montusiewicz J., Czyż Z., Kayumov R., 2015, Selected methods of making three – dimensional virtual models of museum ceramic objectsm, Applied Computer Science, vol. 11, no. 1, pp. 1–16
[14] Graciano A., Ortega L., Segura R.J., Feito F.R., 2017. Digitization of religious artifacts with a structured light scanner, Virtual Archaeology Review, no. 8(17), pp. 49–55.
[15] Barszcz M., Montusiewicz J., Paśnikowska-Łukaszuk M., Sałamacha A., 2021. Comparative Analysis of Digital Models of Objects of Cultural Heritage Obtained by the "3D SLS" and "SfM" Methods, Applied Sciences, vol. 11, pp. 1–20

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APPLICATION OF ARTIFICIAL INTELLIGENCE METHODS IN ARCHEOLOGICAL ARTIFACTS

Abstract

This paper considers the method of processing and analysing archaeological data in the form of hidden rules and patterns for extracting knowledge from databases. The discovery of new knowledge should help to improve the efficiency of decision-making in the fields of archeology. It is proposed to use the method of calculating generalised estimations of archeological objects to define their belonging to certain classes. The calculations concern aggregated indicators that do not have explicit units of measurement.

Keywords: artificial intelligence, archaeological objects, calculating generalised estimations

1. Introduction

On the basis of data provided by archaeologists in their research on Central Asian archeology, it can be said that the pottery schools of all the states that ruled in this region had their own direction. Uzbekistan is one of the places that has preserved the richest heritage of ceramics, not least because representatives of modern traditional and non-traditional ceramics (historically formed in the XIX century) are interested in the historical layers of local culture. From time immemorial, handicraft centres of each oasis have been formed in Uzbekistan. According to the method of production, pottery is divided into two main types – glazed and unglazed. Unglazed pottery has an ancient history. Late 8^{th}–early 9^{th} centuries glazed pottery was widespread in the cities of Movarounnahr (or the area between the two main rivers in Central Asia, the Amudarya and the Syrdarya). In the 9^{th}–18^{th} centuries, this style reached artistic perfection and high technological quality.

In the 20^{th} century, basic schools and centres were established in the territory of modern Uzbekistan: a) Samarkand-Bukhara school, Tashkent, Samarkand, Urgut, Bukhara, Gijduvan, Shahrisabz, Kitab, Kattakurgan, Denau centres; b) Fergana school with Rishtan and Gurumsaroy centres; c) Khorezm school with the centres of Honka, Modir village, Kattabag and Chimbay. Each centre has its own local characteristics. At present, they produce flat (bowls) and upward (jugs, jars) types of pottery and household items.

2. Main part

On most Fergana and Khorezm pottery the traditional blue alkaline glaze is found, but they are distinguished by a variety of unique patterns and products (representatives M. Turopov (Gurumsaroy), I. Komilov (Rishtan), R. Khormaz) and others.

Lead glaze and yellow-green or brown paint (used by Alisher and Abdulla Narzullaev) play an important role in the development of Bukhara-Samarkand ceramics. Kashkadarya (Kasbi) pottery currently produces only unglazed items.

In contrast to the past, the art of ceramics is being supported and promoted by the government in all directions, and a favourable attitude is being created for its further development. A clear example of this is the decision of the President of the Republic of Uzbekistan No. pq-5033 of 03.03.2021 on the development and support of pottery.

In particular, in ancient Khorezm from the earliest times the main building material was clay. Clay household items were very common, especially in the period up to the 20th century. This, of course, can be explained by the fact that household items made with other materials of these periods, such as wood, iron, copper, silver or gold, are relatively cumbersome and expensive. There are many types of pottery made of clay, among which the most common household items are especially jugs, bowls and ossuaries. Therefore, in almost all archeological expeditions in these areas, similar archeological artefacts made of clay of various shapes or their fragments were found (Fig.1):

a) an assuary b) a jug c) a bowl

Figure 1. Examples of archeological artefacts. (a) an ossuary 1st–2nd centuries AD. Pos. Chuck-Cham, Tashkent region. b) 1st–2nd centuries, Kavardan, Tashkent region. c) 1st–2nd centuries BC, Kavardan, Tashkent region

Today, museums located in the territory of Uzbekistan have a very large collection of various specimens of archeological artefacts made of clay. This in turn allows for various studies to be conducted on them. Archaeological artefacts (e.g. jugs, palms, trays) can be subjected to a number of research enquiries:

- assessment of similarities and differences between the objects of different pottery schools (regions) in Central Asia [1];
- identification of the main features that distinguish them from each other;
- determination of the region to which unknown archeological artefact belongs on the basis of objects collected by pottery schools;
- issues such as finding and interpreting latent regularities by visualising specimens belonging to different schools of pottery in 2- or 3-dimensional space (e.g. by the t-sne method [2], hierarchical agglomerative grouping [3]).

Many scientific articles have been published on the application of artificial intelligence methods in archeology. They are aimed at solving various problems of archeology. For example, [4] presents an alternative approach to archaeological typology, using deep learning to classify digital images of decorated pottery shards into an existing typological framework. Their results show that when properly trained, a deep learning model can assign types to digital images of decorated shards with an accuracy comparable to, and sometimes higher than, four expert-level contemporary archaeologists. The technique also offers novel tools for visualising both the importance of diagnostic design elements and overall design relationships between groups of pottery shards.

Deep learning is a powerful tool for exploring large datasets and discovering new patterns. In [5] an account is presented of a metric learning-based deep convolutional neural network (CNN) applied to an archaeological dataset. In [6] the use of computer vision techniques in archaeology is illustrated with two examples: (1) a content-based image retrieval system for historical glass and (2) an automatic system for mediaeval coin classification.

In [7] two complementary machine-learning tools are developed to propose identifications based on images captured on site. One method relies on the shape of the fracture outline of a shard; the other is based on decorative features.

It should be noted that the characteristics of objects are formed according to what issue is considered as research:

- if images of archaeological artefacts are given as initial data, it is required to form n quantitative attributes as features. Usually in such cases it is reflected in the object's feature table using the methods of artificial intelligence (primary processing methods). That is, a vector $X = (x_1, .., x_n)$ is generated for each image representing the archaeological artefact. In this way, the object's feature matrix of dimension $m \times n$ is formed.
- if archaeological artefacts are represented by their physical and chemical properties, i.e. their size, period, discovery area, mechanical composition of the material and

other such properties measured by experts, objects are described by n different categories of features $X(n) = (x_1,\dots, x_n)$. In such cases, ξ of the features are measured on interval scales and n-ξ are measured on nominal scales. Sets of numerical and nominal features are determined by I and J, respectively.

Problem statement. After the preparation of archeological artefacts in the form of object-features, as mentioned above, various studies can be carried out using artificial intelligence methods. As an example, let us consider a standard form of the pattern recognition problem for inclusion of an archeological artefact (for example, a jug) in certain area:

For the given m objects (jugs) as data, consider the problem of calculating the generalised value of each object, whether it belongs to a pre-selected region (K_1) or does not belong to it (K_2) [1]. In [1], the problem of calculating aggregated generalised indicators (estimates) that do not have explicit units of measurement is considered. These include, for example, the severity of the disease, the level of security of computer networks and other aggregated indicators like this, generated on the base of initial features.

A specific step in solving the problem is to determine the values of the objective function (consequence) by the values of dependent indicators (causes). The difference between this problem and regression lies in the absence of known values of the generalised indicator, according to which the dependence could be restored. For the solution, the values obtained from experts are used. Due to the subjective nature of expert assessments, it is almost impossible to trace the change in their values on various sets of dependent indicators. There is no methodological justification for the choice of informative sets of dependent indicators, taking into account various measurement scales.

It is considered that a set of $E_0 = \{S_1,\dots,S_m\}$ objects of two disjoint classes K_1, K_2 is given. The description of objects is made using n quantitative features. The need to consider the solution of the two-class recognition problem is related to the fact that:

- any generalised assessment (indicator) is relative. Objects of each of the classes are opposed to objects of the opposite class;
- there are no classes of analytical functions for restoring dependencies in the space of different types of features.

It is required to define a procedure for calculating generalised estimates of objects of class K_1 with the aim of their linear ordering.

Let us denote by I the set of numbers, respectively, of quantitative attributes $X = (x_1,\dots, x_n)$ in the description of admissible objects. Let us determine the weights of quantitative features, taking into account the division of objects into classes K_1 and K_2.

The ordered set of values of the feature $x_j, j \in I$ is divided into two intervals $[c_0, c_1]$,$[c_1, c_2]$, each of which is considered as a gradation of the nominal characteristic. The criterion for determining the boundary c_1 is based on testing the hypothesis (statement) that each of the two intervals contains the values of the quantitative attribute of objects of only one class.

Let $u_1^1, u_1^2\left(u_2^1, u_2^2\right)$ be the number of values of the feature $x_j, j \in I$ of the class K_i, $i = 1,2$ respectively, in the intervals $[c_0, c_1]$ and $[c_1, c_2]$, p is the ordinal number of the element of the sequence of values x_j from E_0 ordered in ascending order $r_{j_1},\dots,r_{j_p},\dots,r$, defining the boundaries of the intervals as $c_0 = r_{j_1}$ $, c_1 = r_{j_p}$, $c_2 = r_{j_m}$. The criterion below

$$\left(\frac{\sum_{p=1}^{2}\sum_{i=1}^{2} u_i^p\left(u_i^p - 1\right)}{m_1(m_1-1)+m_2(m_2-1)}\right)\left(\frac{\sum_{p=1}^{2} u_1^p\left(m_2 - u_2^p\right)+u_2^p\left(m_1-u_1^p\right)}{2m_1m_2}\right) \to max \tag{1}$$

allows to calculate the optimal value of the border between the intervals $[c_0, c_1]$, $[c_1, c_2]$ and use it to determine the gradations of the quantitative feature in the nominal measurement scale. The expression in the left brackets (1) represents the intra-class similarity, in the right ones the inter-class difference.

Let w_i be the optimal value of criterion (1) by the i-th feature $i \in I$, and c_0^i, c_1^i, c_2^i – the ends of the partition intervals corresponding to this value and by K_1 and K_2. Generalised assessments of objects described by quantitative features are determined as follows. To calculate the estimate of an arbitrary feasible object $S = \left(x_1,\dots,x_n\right)$, the functional

$$R(S) = \sum_{i=1}^{n} w_i t_i \left(x_i - c_1^i\right)/\left(c_2^i - c_0^i\right) \tag{2}$$

where $t_i \in \{-1,1\}$, a vector $T = \left(t_1,\dots,t_n\right)$ is defined from the conditio

$$\min_{S_p \in K_1} R\left(S_p\right) - \max_{S_p \in K_2} R\left(S_p\right) \to max \tag{3}$$

Stochastic and deterministic algorithms for finding generalised estimates using this (2) function are presented in [1]. Unlike expert assessments used to make a decision, there is a possibility of a qualitative understanding of the reasons for inaccuracies (assessments) and its quantitative measurement. For example, the value of criterion (1) according to generalised estimates of objects from E_0 shows the degree of blurring of the boundaries of classes K_1 and K_2. The higher the value, the less blurring. A correct (error-free) division of classes is achieved when the value (1) is equal to 1. In this case, (1) can be recommended as a decision function in discriminant data analysis.

It is appropriate to give a comparison of the algorithms for calculating estimates and generalised estimates that are widely used in recognition theory (see Table 1).

Table 1. Comparison of algorithms for calculating estimates and generalised estimates

Algorithms for calculating estimates	Generalised estimates
Estimates are calculated by object, by class or by reference sets of features.	Estimates are the optimal mapping of objects from a heterogeneous feature space or part of it onto the numerical axis according to defined criteria.
The computation of grade grades is defined as the action of the recognising operator.	Relationships between objects are transformed into relationships between objects on a number line or plane.
The operations of addition, multiplication and multiplication by a number are performed on the set of recognising operators. These operations are used to construct the linear and algebraic closure of recognising operators.	Estimates are used as a tool for clustering heterogeneous features. The values of the estimates are invariant with respect to the measurement scales.

A technique for searching for hidden patterns from databases is described, with the help of which an explanation of the process of calculating generalised estimates is constructed. Within the framework of this technique, experts have the opportunity to test their hypotheses regarding the problem under consideration. Based on the results of the verification, they can formulate the obtained (extracted) knowledge in the form of linguistic rules, and in some cases in the form of clear formulas.

References

[1] N. A. Ignatiev, *Generalised estimates and local metrics of objects in data mining*. Monograph. Tashkent: University Publishing House. (in Russian)

[2] Laurens van der Maaten, Geoffrey Hinton. Visualizing Data using t-SNE, *Journal of Machine Learning Research* 9(86): 2008, pp. 2579–2605.

[3] D. Y. Saidov. Data Visualization and its Proof by Compactness Criterion of Objects of Classes. *International Journal of Intelligent Systems & Applications*, vol. 9, Issue 8, 2017, pp. 51–58.

[4] Leszek M. Pawłowicz, Christian E. Downum. Applications of deep learning to decorated ceramic typology and classification: A case study using Tusayan White Ware from Northeast Arizona. *Journal of Archaeological Science*, vol. 130, June 2021, 105375.

[5] Resler, A., Yeshurun, R., Natalio, F. et al. A deep-learning model for predictive archaeology and archaeological community detection. *Humanit Soc Sci Commun* 8, 295 (2021).

[6] Laurens van der Maaten, Paul Boon, Guus Lange, Hans Paijmans and Eric Postma. Computer vision and machine learning for archaeology. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34^{th} Conference, Fargo, United States, April 2006.

[7] F. Anichini, N. Dershowitz, N. Dubbini, G. Gattiglia, B. Itkin, L. Wolf. The automatic recognition of ceramics from only one photo: The ArchAIDE app, April 2021, *Journal of Archaeological Science*: Reports 36(2): 102788.

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ANALYSIS OF SELECTED LAZGI DANCE SEQUENCES USING THREE-DIMENSIONAL MOTION CAPTURE DATA

Abstract

Modern technologies are widely used to collect, record and publish Intangible Culture Heritage (ICH) for the next generations. Traditional dance is one of the key elements of ICH. The aim of this paper is the analysis of dance sequences. The Lazgi dance, included in the UNESCO ICH list, was scanned using three-dimensional Vicon motion capture system. The dancer's movements were registered, with particular emphasis on the movements of the hands and fingers. The results are presented for selected sequences of this dance, taking into account individual parts of the body.

Keywords: dance sequence analysis, motion capture, Lazgi dance

1. Introduction

Intangible cultural heritage (ICH) is an important factor in maintaining and cultivating cultural diversity in the face of growing globalisation in a world dominated by material values. ICH ranges from vocal and instrumental music, dance and theatre to pantomime, sung verse and beyond [9]. They are very specific for different nationalities and include cultural expressions. ICH is appreciated for its individuality and exceptional value. It is passed on to the rest of the community from generation to generation. In recent years, however, these cultural traditions have been disappearing very quickly due to the lack of interest in young people.

Folk dances are one of the elements of ICH. They were created over the centuries based on national tradition. Their shape is influenced, among others, by the national culture, because very often they reflect awareness of national distinctiveness [22]. In the modern world the art of folk dancing is disappearing, that is why the preservation of this type of culture plays such an important role.

Currently, more and more modern technologies, including three-dimensional (3D) ones, are applied to register, preserve and publish ICH. They are used for 3D dance scanning in order to capture real-world data. The obtained 3D model reflects the dancer's shape and moves. For 3D dance scanning there are many highly specialised devices, one of them are optical motion capture systems based on retro-reflecting markers attached directly to the human body or to a special suit. The collected data can be then processed, analysed and displayed. This may lead to further understanding ICH, which is a challenging task.

Lazgi is an ancient dance created by the inhabitants of the downstream areas of the Amu-Daria River. The ancient meaning of the word "lazgi" is trembling, characterised by vigorous body movement and facial expression. It very vividly reflects the characteristics of this dance. Legend says that this dance was created of the soul-body connection thanks to the rhythms of Lazgi. After the act of creating the human body, it could not be brought to life. The soul entered the body when it heard the melody of the Lazgi dance [13]. Lazgi starts with a leisurely introduction, then the dancer takes a position with a hand raised to the sun. The movements of the hands, wrists and fingers play a very important role in this dance. It is a combination of turns and swings. The rhythm of the dance gradually speeds up [24]. In 2019 it was inscribed on the Representative List of the Intangible Cultural Heritage of Humanity UNESCO [12].

The aim of this paper is to analyse selected Lazgi dance sequences. Scanning the dance using the motion capture system was performed. The biomechanical Plug-in model was applied for the dancer. The model of the dancer's hand was also created which is essential for the analysis of hand and finger movements is essential. It should be emphasised that the Plug-in Gait model does not include them. The trajectories for the selected parts of the upper and lower body and fingers, as well as changes in angles have been analysed in this dance.

2. Related works

Dance sequences may be defined as a joint action that depends on the interaction of sensory, motor and cognitive processes [3]. Therefore, they are the key elements for proper learning movement. The novice dancers may improve their skills by synchronous imitation of an expert or by asynchronous one while observing the expert's movements and trying to follow them.

Dances have been widely analysed in many scientific papers. Many studies concerned three-dimensional analysis. This type of data were obtained in various ways, including: active methods (laser scanners, range finders, structured light projectors) and passive ones (stereo vision and visual hulls) [6]. 3D visualisation and 3D poses estimation from a video were described in [21]. Many studies applied accurate movement analysis, where dance was registered by various motion capture systems, like: Vicon [2], [4], [23], [27], [28], [29], [33], [35], [36], [37], OptiTrack [7], [14], [15], [20] or Phasespace4 Impulse X2 [1], [30]. Less accurate systems, like Microsoft Kinect, was also widely used in capturing dance [5], [17], [25], [28]. Tools like gyroscopes and accelerometers [19], smartphones [18] as well as Inertial Measurement Unit (IMU) sensors [32] were often applied. There were also studies concerning video camera dance acquisition [8], [10], [11].

In recent years, studies about dance sequence analysis gained more and more interest. Some of them were focused on analysis of trajectories obtained from motion capture systems, which showed the dance rhythm and body kinematics and kinetics parameters. It allowed for a better understanding of various dance performance [20], [27]. In [36] trajectories of hip and foot joints showing the rhythm and periodicity of Greek dance were characterised. The average Silhouette value over all frames were also indicated for particular dancers. In [4] the analysis of hip, knee and ankle joint angles was performed. Male dancers had narrower angles in all the mentioned joints of all the six steps than female dancers during the implementation of the Greek Syrtos dance. Additionally, in [35], average precision and recall values for different frequency of the dance sequences were analysed. The selected sequences of Lazgi dance were studied in [29]. The trajectories for lower and upper body parts, as well as finger movements were analysed.

In [32] the identification of the key distinguishing components of movement in traditional "Ayala" dance using IMU sensors was presented. Rhythm features for three independent sequences were obtained. Indicating the optical key points from 3D trajectories of Greek dance for determining the best choreography was described in [27]. The specified method significantly reduced the amount of information required for processing and storage dance data. The identification of dance choreographies based on heterogeneous motion data gathered by two motion capture systems (Vicon and Kinect) were presented in [28]. Whole body and finger movements were captured using the Perception Neuron sensor for the "Didim" dance for storing purposes was presented in [19]. An example of traditional Hungarian dance analysis considering lower body kinematics, kinetics, biomechanical parameters (Centre of Pressure) and balancing ability through dance movements was described in [20]. The kinematic parameters, such as: Range of Motion (ROM) of knee flexion angle, hip flexion angle, and pelvis tilt angle as well as kinetics ones like hip and knee flexion-extension for the successive dance steps were taken into consideration.

Extracting the key frames for following sequences by using automatic methods, like: density based, Kennard Stone, conventional Sparse Modelling for Representative Selection (SMRS) and its hierarchical scheme called H-SMRS were presented in [23]. They were compared against the ground truth data indicated by dance experts.

Traditional Greek dances were analysed with the use of characteristic elements of these dances. Two participants performed the dances simultaneously. The analysis concerned human joint points from 3D data. In [16], the Tsamiko dance motion patterns from skeletal animation data captured by multiple Kinect sensors were presented. The skeletal data were split into five different body parts (torso, left hand, right hand, left leg and right leg), which were then transformed to allow invariant posture recognition.

The Generative Adversarial Network (GAN) based cross-modal association model, namely DeepDance was presented in [31]. Its aims were to create the desired dance sequence based on the input music. The proposed methodology consisted of two steps: musical feature extraction and dance motion generation. At the beginning given music clip was divided into 5 parts. Next, low-level features vector using libROSA package were applied. The final music features were extracted by CNN-LSTM network. An encoder-decoder architecture was used for final dance motion generation.

A Bayesian optimised, bi-directional Long Short-Term Memory (LSTM) network for pose characterisation of a choreography for Greek dance was proposed in [26].

3. Three-dimensional movement acquisition

3.1. Vicon system

Motion data were recorded using a passive motion capture system (Vicon, Oxford, UK). The system consisted of eight T40 near-infrared cameras and 720p Bonita video reference cameras. The motion was recorded at 100 frames per second. To account for unavoidable camera movements the system was calibrated before each session began. Standard Vicon calibration procedure was used [34]. Retroreflective markers were placed on the subject using standard Plug-in-Gait layout.

3.2. Participant

A professional Lazgi dancer took part in the study. The dancer wore a special suit that consisted of a sweatshirt, trousers and a cap. It was made of Velcro material, so that 14 mm retro-reflexive markers could be attached to it according to the Plug-in Gait layout (Fig. 1). In order to properly use this model, the participant had to be measured. The following dancer data had to be input to Vicon Nexus: height, weight, left and right leg length, right and left shoulder offset, left and right knee width, left and right ankle width, left and right elbow width, left and right wrist width and finally left and right hand width.

As a part of the calibration process a short recording was made. The participant assumed static "motorbike pose". This allowed for the human body model in Plug-in Gait to be adjust to the participant. As a result, the model could be used to compute multiple values such as angles used in this study.

The whole dance was recorded in one go. The analysed sequences were extracted later. During recording the Lazgi dance music was playing. An important factor influencing the quality of the recording was the presence of an extraneous reflective object. Special care was taken to eliminate such elements from the cameras' field of view.

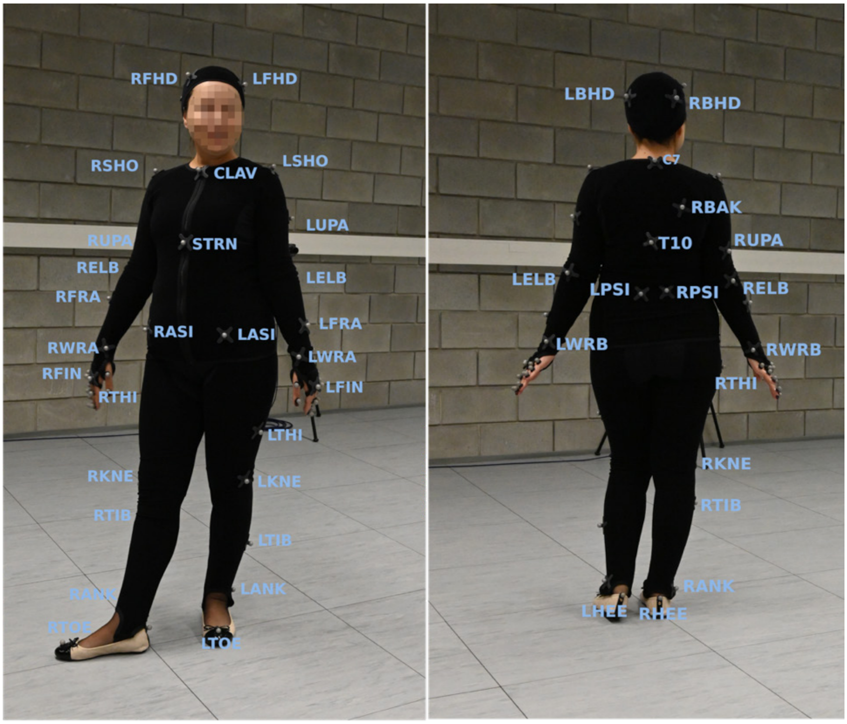

Figure 1. Participant preparation

3.3. Data post-processing

3D motion data in each trial were manually post-processed. The procedure consisted in: (1) reviewing the recording and labelling the standard and non-standard markers, (2) reviewing the recording and filling the gaps in marker trajectories; gap filling methods using nearby markers were preferred, (3) removal of spurious/non-labelled markers, and (4) execution of the Plug-in-Gait model in order to compute angle values used for anomaly detection. Video recordings used by experts for visual assessment did not require post-processing. An expert determined start and end times for each sequence.

4. Parameter extraction

Parameter extraction for each sequence was partially automated. A custom piece of software was created for this purpose. It uses the Biomechanical Toolkit and Eigen libraries. The procedure of extracting values provided by Plug-in Gait was as follows: (1) time ranges of the sequences were manually selected and the sequences were saved to separate c3d files, (2) consecutive sequences were read from c3d files, and the c3d files were verified – the existence of required markers / model outputs was checked (the residuals were negative if markers / model outputs were not present), (3) the required values were exported to spreadsheet files for further processing. The following recorded trajectories and Plug-in Gait outputs were extracted using this method: shoulder marker trajectory, elbow marker trajectory, inner wrist marker trajectory, hip frontal marker trajectory, knee marker trajectory, ankle marker trajectory, knee angles, angle angles, pelvis angles, shoulder angles, elbow angles, wrist angles for both left and right side of the body.

The procedure of extracting finger angles was different because Plug-in Gait does not take precise finger movements into account. The procedure consisted in: (1) reading the c3d files containing dance sequences prepared previously; the c3d files were verified – the existence of required markers was checked for negative residuals, (2) for each finger three markers were specified (start, middle and end marker; middle marker was located on a finger joint); (3) using pairs of markers (start-middle and middle-end) two vectors were constructed for each finger; the angles were computed for each frame of the sequence using the following equations:

$$cross = \left\|\overrightarrow{\mathrm{STARTMIDDLE}} \times \overrightarrow{\mathrm{MIDDLEEND}}\right\|$$
$$\mathrm{dot} = \overrightarrow{\mathrm{STARTMIDDLE}} \cdot \overrightarrow{\mathrm{MIDDLEEND}}$$
$$\alpha = |\mathrm{atan2}(\mathrm{cross} \cdot \mathrm{dot})|$$

The resulting angle was in the [0, π] range. The atan2 function is a 2-argument implementation of arctangent available in multiple programming languages. This method was used for computing the angles for: ring finger, middle finger, index finger, little finger for both left and right hand.

5. Results

Two dance sequences were selected for detailed analysis. They included body and hand movements. One was quite slow while the other had a faster pace. In the first sequence, the dancer extended the hand towards the sky and then bows. In the second sequence the dancer stamped while moving the arms up and to the sides. The latter included very dynamic hand movements.

Graphs presenting the trajectories of movements and angles of selected parts of the body are shown. The trajectories for lower body parts concerning hips (right and left) in two planes during the first sequence are presented in Figure 2. The angles for upper body parts concerning shoulders (right and left) are presented in Figure 3. The trajectories for lower body parts concerning hips (right and left) in two planes during the second sequence are presented in Figure 4 and the angles for pelvis (right and left) – in Figure 5.

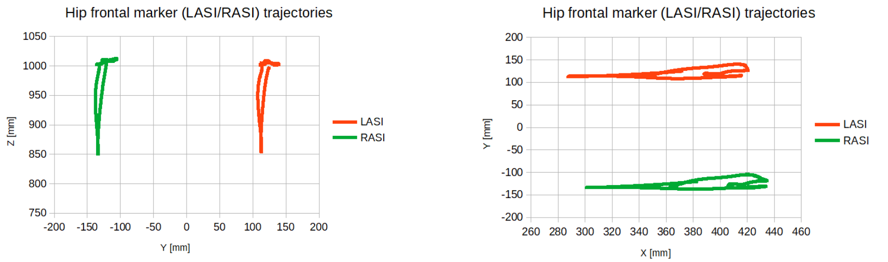

Figure 2. Hip marker trajectories for the first sequence

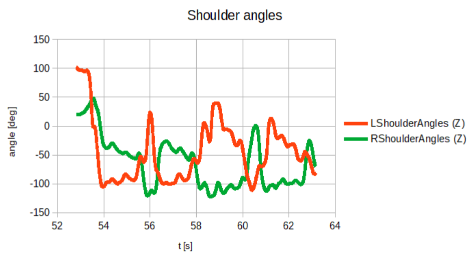

Figure 3. Shoulder angles for the first sequence

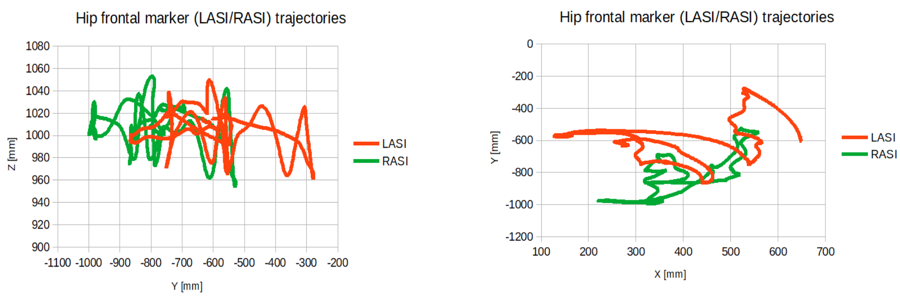

Figure 4. Hip marker trajectories for the second sequence

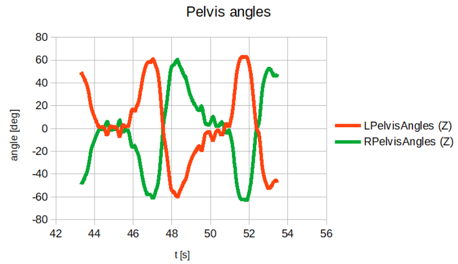

Figure 5. Pelvis angles for the second sequence

The index finger movement trajectories (markers: LFR8, RFR8) for the right and left hand in two planes are shown in Figures 6 and 7 for the first and the second sequences, respectively.

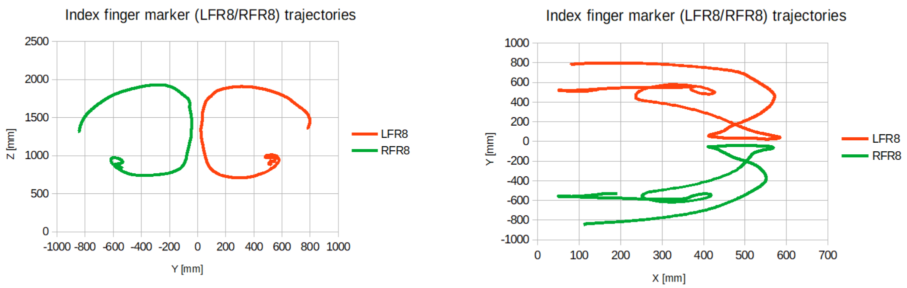

Figure 6. Index finger trajectories for the first sequence

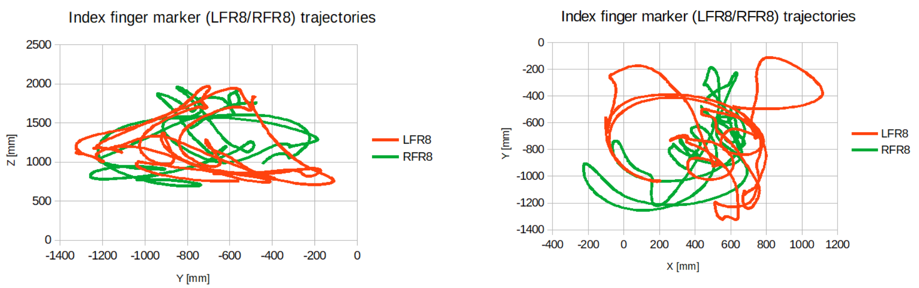

Figure 7. Index finger trajectories for the second sequence

The bend angles of the four fingers: ring, middle, index and little were also calculated for both hands. The angles were calculated between the middle and the proximal phalanges. The results for the first sequence is presented in Figure 8 and for the latter in Figure 9.

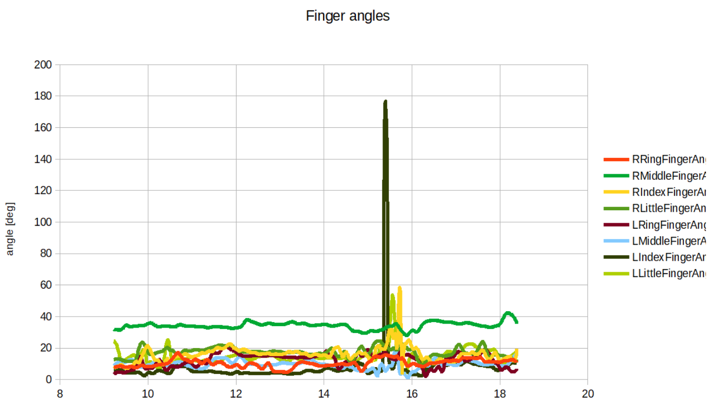

Figure 8. Finger angles for the first sequence

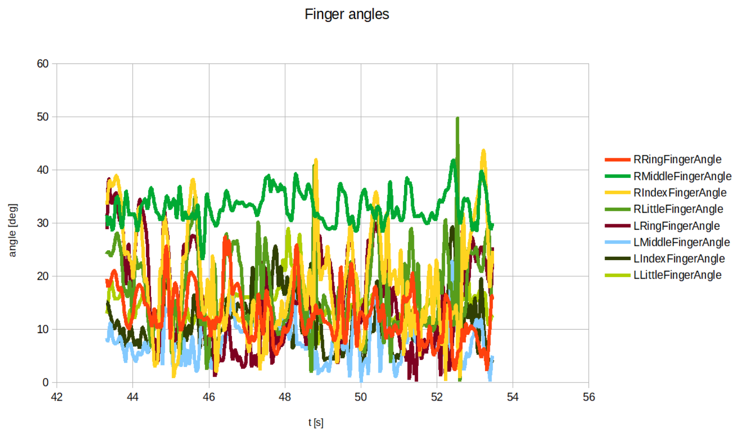

Figure 9. Finger angles for the second sequence

The first sequence is not very dynamic, which can be seen in Figures 2 and 3. The movements performed are symmetrical in relation to the axis of symmetry of the body, which proves a more static posture of the dancer. This is confirmed by the angles indicated for shoulders.

The second sequence is very dynamic, which is shown in Figures 4 and 5. The lack of trajectory symmetry indicates the movement of the whole body. The dancer, however, kept the hip movement symmetry.

A similar situation occurs with the movement of the fingers. For the first sequence, the finger trajectories are symmetrical (Fig. 6). The data presented in Figure 7 show the dynamics of the movement of selected fingers. The calculated angles for the first and second sequence (Fig. 8 and 9) confirm the above conclusions.

6. Conclusions

The article presents the possibilities of using 3D technology to scan dances. The Plug-in-Gait model used, extended with the hand model created, gives a wide range of possibilities for studying dance elements. They were shown on the example of the Lazgi dance, which is very dynamic. Hand and finger movements play a very important role in this dance.

The analysis of selected movement sequences allows to compare the repeatability of the movements of the same dancer, as well as for different ones. Having recorded patterns of individual sequences of movements, it is also possible to recognise from which dance the studied sequence originates.

The data obtained in motion capture systems enable kinematic and kinetic analysis of each dance sequence. These works make it possible to create and visualise 3D models for folklore dances to preserve this disappearing art. Thanks to this, dances as elements of ICH will be passed on for the next generations.

References

[1] Aristidou, P., Stavrakis, E., Charalambous, P., Chrysanthou, Y., Himona, S.L. Folk dance evaluation using laban movement analysis. *J. Comput. Cult. Herit*. 2015, 8, 20.

[2] Chan, J. C. P, Leung, H., Tang, J. K. T., Komura, T. A Virtual Reality Dance Training System Using Motion Capture Technology. *IEEE Trans. Learn. Technol.,* 2011, vol. 4, no. 2, 187–195.

[3] Crone, C. L., Rigoli, L. M., Patil, G., Pini, S., Sutton, J., Kallen, R. W., & Richardson, M. J. (2021). Synchronous vs. non-synchronous imitation: Using dance to explore interpersonal coordination during observational learning. *Human Movement Science*, *76*, 102776.

[4] Douka, S., Ziagkas, E., Zilidou, V., Loukovitis, A., Tsiatsos, T. The 3D Motion Capturing Process of Greek Traditional Dance "Syrtos in Three" and a Proposed Method for the Sex Identification of Performing Dancers. *Adv. Intell. Syst. Comput.,* 2021, 366–374.

[5] Doulamis, A., Voulodimos, A., Doulamis, N., Soile, S., Lampropoulos, A. Transforming intangible Folkloric performing arts into tangible choreographic digital objects: The Terpsichore approach. *In Proceedings of the 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications*, Porto, Portugal, 27 February–1 March 2017; volume 5, pp. 451–460.

[6] Doulamis, A.; Voulodimos, A.; Doulamis, N.; Soile, S.; Lampropoulos, A. Transforming intangible folkloric performing arts into tangible choreographic digital objects: The Terpsichore approach. In Proceedings of the 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications, Porto, Portugal, 27 February–1 March 2017; volume 5, pp. 451–460.

[7] Hajdin, M., Kico, I., Dolezal, M., Chmelik, J., Doulamis, A., Liarokapis, F. Digitization and Visualization of Movements of Slovak Folk Dances. *Adv. Intell. Syst. Comput*. 2019, 917, 245–256.

[8] Han, T., Yao, H., Xu, C., Sun, X., Zhang, Y., Corso, J.J. Dancelets Mining for Video Recommendation Based on Dance Styles. *IEEE Trans. Multimed*. 2017, 19, 712–724.

[9] Intangible Heritage Domains in the 2003 Convention. Available online: https://ich.unesco.org/en/intangible-heritage-domains-00052 (accessed on 12 October 2021).

[10] Jain, N., Bansal, V., Virmani, D., Gupta, V., Salas-Morera, L., Garcia-Hernandez, L. An Enhanced Deep Convolutional Neural Network for Classifying Indian Classical Dance Forms. *Appl. Sci.* 2021, 11, 6253.

[11] Jain, N., Bansal, V.; Virmani, D., Gupta, V., Salas-Morera, L., Garcia-Hernandez, L. An Enhanced Deep Convolutional Neural Network for Classifying Indian Classical Dance Forms. *Appl. Sci.* 2021, 11, 6253.

[12] Khorazm Dance, Lazgi. Available online: https://ich.unesco.org/en/RL/khorazm-dance-lazgi-01364 (accessed on 12 October2021).

[13] Khorezm Lazgi: The Sunniest Dance on Earth. Available online: https://voicesoncentralasia.org/khorezm-lazgi-the-sunniestdance-on-earth/ (accessed on 12 October 2021).

[14] Kico, I., Liarokapis, F. Enhancing the learning process of folk dances using augmented reality and non-invasive brain stimulation. *Entertain. Comput*., 2022, vol. 40 100455.

[15] Kico, I., Liarokapis, F. Investigating the Learning Process of Folk Dances Using Mobile Augmented Reality. *Appl. Sci,* 2020, vol. 10, 599.

[16] Kitsikidis, A., Dimitropoulos, K., Douka, S., Grammalidis, N. Dance analysis using multiple Kinect sensors. In *Proceedings of the 2014 International Conference on Computer Vision Theory and Applications, VISAPP 2014*, Lisbon, Portugal, 5–8 January 2014; pp. 789–795.

[17] Laraba, S., Tilmanne, J. Dance performance evaluation using hidden Markov models. *Comp. Anim. Virtual Worlds* 2016, 27, 321–329.

[18] Lee, H. M., Garg, S., Lim, K. M., Lee, H. P. The sound of drumming for traditional Taiko drumming and lion dance. *Appl. Acoust*. 2022, 185, 108434.

[19] Lim, Y. K., Park, J. W. The way to preserve Korean intangible cultural assets. In *Proceedings of the HCI International 2018 – Extended Poster Abstracts*, Las Vegas, NV, USA, 15–20 July 2018; pp. 192–195.

[20] Molnár, C., Pálya, Z., Kiss, R.M. Static Balancing Ability and Lower Body Kinematics Examination of Hungarian Folk Dancers: A Pilot Study Investigating the "Kalocsai Mars" Dance Sequence. *Appl. Sci. 2021*, 11, 8789.

[21] Pistola T., Diplaris S., Stentoumis C., Stathopoulos E. A., Loupas G., Mandilaras T., Kalantzis G., Kalisperakis I., Tellios A., Zavraka D. and others. Creating immersive experiences based on intangible cultural heritage. *In 2021 IEEE International Conference on Intelligent Reality, Proceedings of the 2021 IEEE International Conference on Intelligent Reality (ICIR)*, 2021, 17–24.

[22] Pistola T., Diplaris S., Stentoumis C., Stathopoulos E.A., Loupas G., Mandilaras T., Kalantzis G., Kalisperakis I., Tellios A., Zavraka D., et al. Creating immersive experiences based on intangible cultural heritage. In Proceedings of the 2021 IEEE International Conference on Intelligent Reality (ICIR), Virtual Event, 12–13 May 2021; pp. 17–24.

[23] Protopapadakis E., Rallis I., Doulamis A., Doulamis N., & Voulodimos A. (2020). Unsupervised 3D Motion Summarization Using Stacked Auto-Encoders. *Applied Sciences*, *10*(22), 8226.

[24] Rakhimov, B. The Eternity of Lazgi. Eurasian Music Sci. J. **2020**, 2, 22, doi:10.52847/EAMSJ/vol_2020_issue_2/A3.

[25] Rallis, I., Bakalos, N., Doulamis, N., Doulamis, A., Voulodimos, A. Bidirectional long short-term memory networks and sparse hierarchical modeling for scalable educational learning of dance choreographies. *Vis. Comput.,* 2021, vol. 37, issue 1, 47–62.

[26] Rallis, I., Bakalos, N., Doulamis, N., Voulodimos, A., Doulamis, A., Protopapadakis, E. Learning Choreographic Primitives Through A Bayesian Optimized Bi-Directional LSTM Model. *In Proceedings of the International Conference on Image Processing*, ICIP, Taipei, Taiwan, 22–29 September 2019; pp. 1940–1944.

[27] Rallis, I., Georgoulas, I., Doulamis, N., Voulodimos, A., Terzopoulos, P. Extraction of key postures from 3D human motion data for choreography summarization. *In Proceedings of the 9th International Conference on Virtual Worlds and Games for Serious Applications, VS-Games 2017*, Athens, Greece, 6–8 September 2017; pp. 94–101.

[28] Rallis, I., Protopapadakis, E., Voulodimos, A., Doulamis, N., Doulamis, A., Bardis, G. Choreographic Pattern Analysis from Heterogeneous Motion Capture Systems Using Dynamic Time Warping. *Technol.,* 2019, vol. 7, issue 3, article no. 56.

[29] Skublewska-Paszkowska, M.; Powroźnik, P.; Smołka, J.; Miłosz, M.; Łukasik, E.; Mukhamedova, D.; Miłosz, E. Methodology of 3D Scanning of Intangible Cultural Heritage – The Example of Lazgi Dance. Appl. Sci. 2021, 11, 11568.
[30] Stavrakis, E., Aristidou, A., Savva, M., Himona, S.L., Chrysanthou Y. Digitization of Cypriot Folk Dances. *In Ioannides, M.; Fritsch, D.; Leissner, J.; Davies, R.; Remondino, F.; Caffo, R. (eds) Progress in Cultural Heritage Preservation*, 2012, 7616 LNCS, 404–413.
[31] Sun, G., Wong, Y., Cheng, Z., Kankanhalli, M. S., Geng W., Li, X., DeepDance: Music-to-Dance Motion Choreography with Adversarial Learning, in *IEEE Transactions on Multimedia*, vol. 23, pp. 497–509, 2021.
[32] Udawatta, L., Daniels, B., Hissem, S., Wivou, J., Pathirana, P.N., Nguyen, D.K., Nguyen, N.D. Motion Capturing of Biomechanical Systems in Traditional Dance using IMU Sensors. *In Proceedings of the 2017 International Conference on Electrical and Computing Technologies and Applications*, Icecta, Aurak, United Arab Emirates, 21–23 November 2017; pp. 1–5.
[33] Utsugi, A., Masaya, T., Takaoka, H. Analysis of Movements of Body Trunk in Japanese Traditional Dance. *In Proceedings of the 2017 International Conference on Culture and Computing*, Kyoto, Japan, 10–12 September 2017.
[34] Vicon Nexus Product Guide, https://documentation.vicon.com/nexus/v2.2/Nexus1_8Guide.pdf.
[35] Voulodimos, A., Doulamis, N., Doulamis, A.; Rallis, I. Kinematics-based Extraction of Salient 3D Human Motion Data for Summarization of Choreographic Sequences. *In proceedings International Conference on Pattern Recognition*, vol. 2018-August, article no. 8545078, 2018, 3013–3018.
[36] Voulodimos, A.; Rallis, I., Doulamis, N. Physics-based keyframe selection for human motion summarization.*Multimed. Tools Appl.*, 2020, vol. 79, issue 5–6, 3243–3259.
[37] Ziagkas, E., Zilidou, V., Loukovitis, A., Douka, S., Tsiatsos, T. Greek Traditional Dances Capturing and a Kinematic Analysis Approach of the Greek Traditional Dance "Syrtos" (Terpsichore Project). *Adv. Intell. Syst. Comput.*, 2021, 514–523.

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THE TRANSLATOR FROM SAMARKAND: PROOFREADING AN AUTOMATIC UZBEK VERSION OF A SHORT STORY BY KSAWERY PRUSZYŃSKI

Abstract

In preparation of a literary translation of a Polish short story whose plot includes a key episode in Uzbekistan, an automatic Uzbek version of the text is obtained. Proofreading it by a native speaker becomes a task in itself, leading to a statistically supported study of the efficiency of one translation engine. A guarded, but positive conclusion is drawn, with room for the machine's further improvement along the lines alluded to in the article.

Keywords: automatic vs literary translation, Ksawery Pruszyński, *Trumpeter from Samarkand*

1. Introduction

In the second decade of the third millennium CE, the Department of Computer Science of the Lublin University of Technology began a programme of cooperation with Samarkand University in Uzbekistan, later extended to other scientific centres in Central Asia. Samarkand is one of the oldest continuously inhabited cities of the region, nearing 3000 years of history. During this span of time the Polish connections featured also in other ways than the recent academic contacts. Two of them stand out: the legendary mediaeval connection with the city of Cracow and the more recent hospitality it lent to the Polish Army on its long way back home during World War 2. Both events received a literary record in the form of a short story, which binds them together in unexpected twists of the plot. The current Polish-Uzbek contacts are a good opportunity to refresh our memory of this piece of prose or to make it familiar to those yet unaware of it. On top of regular e-mail communication, the mutual visits of working teams in Poland and Uzbekistan have helped the development of a translation microproject, which should contribute to the promotion of the two nations' common heritage.

2. Aim of the article

The main aim of this study is to examine the quality of a computer translation of a literary text, a mid 20th century Polish short story, ultimately to be published in four languages: English, Russian, Uzbek and Tajik. The reason for attempting such automatic conversion into a different medium is to obtain an aid in the prospective creation of a literary form of the text, thus offering the readers in Samarkand the story in their own vernacular. For now, only the Uzbek version is considered.

A parallel accompanying challenge was the verification of the authenticity of the story, i.e. comparing the literary licence with historical factography. This has already repeatedly been addressed before, and for our purposes reviewed by one of the present authors in an earlier article, i.e. 'Cracow and Samarkand: two cities, one legend', which appears in another LUT monograph in this series [1].

3. Motivation behind the story

The rationale for selecting the text for the Uzbek reader can be plainly seen in its title. In his 1946 collection of wartime short stories, Ksawery Pruszyński, a Polish lawyer, reporter, writer and diplomat (Fig. 1) included one called *The Trumpeter of Samarkand*. In it, the author as narrator reminisces on his colleague and their time together, first as researchers of the history of law in pre-WW2 Cracow, and then as fellow soldiers in general Anders' army making its way out of the then Soviet Union into the Middle East.

Both of these stages of their lives find an unexpected connection in the city of Samarkand. Just as they are aptly synthesised in an artist's idea of a cover for one particular edition of Pruszyński's *Stories* (Fig. 2).

Figure 1. Ksawery Pruszyński [3]

Figure 2. One edition of Pruszyński's *Stories* [4]

The two men, with their academic background in Poland's oldest – and one of Europe's first – universities, the Jagiellonian University of Cracow, were well-placed to appreciate this connection. Particularly the author's friend, who – in contrast to mainstream historians – put much faith in the testimonial value of oral tradition and legend. Not least of one such story about the *Lajkonik* – a yearly Cracow pageant with a Tatar hobby-horse apparently commemorating a mediaeval siege of the city, during which a trumpeter is to this day widely believed to have been killed by a Tatar arrow while sounding an alarm call to wake up the sleeping citizens.

4. Historical context

So much about pre-war Cracow and its legends. And now for the Samarkand connection. In very sparing, understated terms Pruszyński sets the scene for what already then and for decades since had to be glossed-over: the less widely known half of Poland's WW2 tragedy.

More recently, books have been published about it, also in English, such as this one by Norman Davies, a British historian with Polish interests. The book's blurb summarises the situation:

> *Following the conquest of Poland by Nazi Germany and the Soviet Union in 1939, hundreds of thousands of Polish families were torn from their homes and sent eastwards to the arctic wastes of Siberia. Prisoners of war, refugees, those regarded as 'social criminals' by Stalin's regime, and those rounded up by sheer chance were all sent 'to see the Great White Bear'.*
>
> *However, with Hitler's invasion of the Soviet Union in Operation Barbarossa just two years later, Russia and the Allied powers found themselves on the same side once more. Turning to those that it had previously deemed 'undesirable', Russia sought to raise a Polish army from the men, women and children that it had imprisoned within its labour camps. In this remarkable work, renowned historian Professor Norman Davies draws from years of meticulous research to recount the compelling story of this unit, the Polish II Corps or 'Anders Army', and their exceptional journey from the Gulag of Siberia through Iran, the Middle East and North Africa to the battlefields of Italy to fight shoulder-to-shoulder with Allied forces.*

Norman Davies, *Trail of Hope* (from the blurb) [**5**]

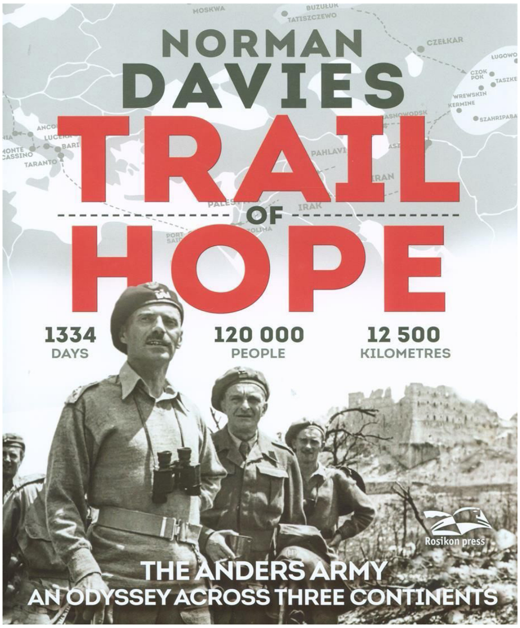

Figure 3. Cover of Norman Davies' *Trail of Hope* [6]

And here is an outline of the II Corps' route:

Figure 4. Map of the Trail of Hope [7]

The map has its shortcomings, such as lack of a few major cities for reference (Tatiszczewo is next to Saratov, and what should be Tockoje is confused with what should be the nearby Troickoje). More importantly, the trail on the map has no roots. While it has to be admitted that the Anders river that flowed out of Russia to Uzbekistan in early 1942 had many tributaries, a minority were soldier prisoners of war, most of whom had been all too forcibly withheld from joining the trail of hope. Even Pruszyński drops in his story the ominous names of (in Polish spelling) Kozielsk, Starobielsk and Griazowiec, a practice all the more telling for his lack of comment or deflecting the effect in an unexpected direction ('Kozielsk, what a monastery there is! Orthodox baroque!'). The author's friend was lucky: from Griazowiec, together with a mere 400 of other fortunates, they made it into Tashkent.

For the sake of the content of the story, Samarkand is south-west of Tahshkent, and Teheran – just under the Caspian Sea, the latter city being where the author's friend tells him about what happened in Samarkand. (That is one text-internal clue that the two at least were not there together.)

In keeping with the story's cut convention, the presentation of the plot will now stop short of the crux, referring the reader to a summary in [1], or to the story itself, hopefully soon to be available in English, Russian, Uzbek and Tajik. In the meantime, let us look at some of the problems inherent in automatic translation on the example of the text of the story.

5. Material and methodology

5.1. Target text

A digital version of the text of the story was obtained from the Internet [8] and adopted as a working copy after some minor corrections and completion according to one print edition [9]. It is a text of 2359 words in the Polish original.

5.2. Project procedure

An outline plan of action was designed for the Polish-Uzbek collaboration in the project. The present study is the result of the following steps.

1. Choice of the language of communication – Russian.
2. Translation of the text of the story into Russian (Polish side).
3. Automatic translation of the story into Uzbek (Polish side).
4. Acquaintance with the story in both versions (Uzbek side).
5. Proofreading of automatic translation into Uzbek (Uzbek side).
6. Analysis of differences between automatic and proofread versions (Polish side).

Russian was chosen as a means of communication due to its status of a post-imperial language, still familiar to middle-aged Poles and even younger Uzbeks. It is thus a common medium in personal contacts, as well as being a default version for a text to be worked on.Automatic translation has been adopted both as a practical aid in preparing a literary version of the story, and also due to the theoretical interest within the sphere of the Department of Computer Science of the LUT in the workings of the tools providing such service.

5.3. Inauguration of automatic

Historically, the beginnings of computation-based translation can be traced back to al-Kindi (801–873), a fellow scholar of modern-day Uzbekistan-born al-Khwarizmi (780–850), with whom he introduced Indian numerals (renamed as Arabic) to the West. Al-Kindi made the first steps into statistical inference and frequency analysis in language [10].

In the 1970s, the early or classical years of concerted machine translation, the process was based on linguistic rules, or the models of the multilevel structure of both the source and target language. Machine knowledge of such structure was permanently incomplete and a challenge to enlarge.

The 1980s saw a departure from reliance on deep linguistic structure and a turn towards surface alternation of words and phrases. The example-based method was espoused. It availed itself of large linguistic corpora or text collections, which began to be compiled at that time. More recently, the focus shifted towards predictability. For ten years (April 2006 to November 2016) the Google Translate machine translation service used statistical models built on the basis of algorithms aimed at pattern recognition.

Since then Google has moved on to neural machine translation, an approach based on artificial neural networks, modelled on biological ones found in animal brains. It enables automatic feature learning and detection. In particular, deep or multi-layer networks are used, the process known as deep learning. Google Translate uses a long short-term memory artificial neural network, capable of processing not only single data points, but whole sequences of data. Thus, at a given moment, it translates whole sentences. As of May 2022, Google Translate supports 133 languages, including – from December 2014 – Tajik and Uzbek, with another 103 languages in development.

5.4. Detection of differences

There are a number of programs, many of them freely available in the Internet, for comparing texts. There are even shortlists of them for better comparison of the programs. For our purposes, we have looked at two, DiffChecker and DiffNow, but will resist a temptation here of a metacomparison of text in both of them (no doubt an illustrative move when deciding between the programs). Our choice of DiffNow was motivated by arguably better graphics and more detailed statistics.

The following types of changes are shown in colour by DiffNow [11] between any two samples of text: added, deleted, changed, changed in changed and ignored.

5.5. Sample selection

Essentially, four types of literary style have been identified by us in the text of the story: narrative, descriptive, argumentative and communicative, and a sample of each, of a similar size of 150 words, is presented below with the idea of comparing how well, if differently, Google Translate copes with each style. This can be done by counting the number of changes between the automatic and corrected versions of each sample. Thus, over a quarter of the text of the whole story (600 words out of 2178 in the Google Translate version of it) was subjected to such analysis in this study. We have not calculated the proportion of each style relative to the whole of the story.

6. Computational comparison

The DiffNow program visualises the results of the comparison of both texts by colouring the background under the words and changing the font colour depending on the type of the identified difference.

6.1. Narrative

The narrative style is primarily an account of events, although it includes states of affairs. Typical parts of speech here will be past-tense verbs. Indeed, in the original there 23 verbs, 20 of which are in the past tense.

Table 1. Comparison of the narrative sample

Uzbek by Google Tranlate	Uzbek by Rahim Kayumov
Biz esa dissertatsiyani suddan keyin, ishdan keyin yozdik. U Culmene qonuni ustida ishlayotganda, men qirollik mulklarini tartibga solishni Charlemagne Capitulare de villisdan boshladim. U Qirol Prussiya munitsipal qonunchiligiga nazar tashlar ekan, men Monteskyoning uchinchi may konstitutsiyasiga ta'siri haqidagi tadqiqotni tugatayotgan edim.	Bizlar esa dissertatsiyalarni birin ketin yozardik, ishdan keyin yana ishlar edik. U Kulmene qonuni ustida ishlayotganda, men o'zimning qirollik mulklarini tartibga solishni asarimni Buyuk Karlning Capitulare de villis"dan boshladim. U Prussiya Qirolligining shahar qonunchiligida o'rganishni boshlaganda, men Monteskening Uchinchi May konstitutsiyasiga ta'siri haqidagi tadqiqotni tugatgan edim.
Faqat Krakov va G'arbda men uchun bu sirli dunyoning kalitlari yo'q edi. Lekin u hammasini o'z ixtiyoriga oldi.	Faqat Krakov va g'arbdagi sirli dunyoning men uchun kalitlari yo'q edi.
Biz bir xil ilmiy ehtiroslarga ega bo'lganimiz uchun katta kelishuvga erishdik.	Biz bir xil ilmiy ehtiroslarga ega bo'lganimiz uchun, bir birimizni yaxshi tushunar edik.
Biz allaqachon Tehronda o'tirgan edik, afsonalar shahri, Sharq shahri va Rossiyani tark etganidan keyin odamlarni quvontirgan Evropa axlati orqali Sharq bizga egilib, derazalarimizga qaradi.	Biz allaqachon Sharqning Shahrizoda afsonalar shahri bo'lgan Tehronda o'tirgan edik. Bu Evropa axlati orqali Rossiyani tark etganidan keyin odamlarni quvontirgan, Sharq bizga egilib, derazalarimizga qaraganday tuyuldi.

c.d. Table 1. Comparison of the narrative sample

Uzbek by Google Tranlate	Uzbek by Rahim Kayumov
Do'stim shaharning oxirida, armanlarda yashadi. Uyning hovlisida, daraxtlar tagida, yolg'iz bo'lib o'tirdik. Bir paytlar Gołębia kadagi seminarda qilgan kashfiyotlari yoki kuzatuvlari haqida aytganidek, u menga biror narsa aytishini bilar edim. U Samarqand haqida gapira boshladi. ularning afsonasiga o'xshash, afsonaning yarmi kabi edi Bizning iqlimimizda bo'lgani kabi, biz ularning dashti modellarini topamiz, shuning uchun bu afsonaning chizilgan rasmini biz izlaymiz.	Mening do'stim shaharning oxirida, armanlarnikida yashardi. Bizlar uyning hovlisida, daraxtlar tagida, yolg'iz bo'lib o'tirardik. U bir paytlar Gołuboyda seminar paytida qilgan kashfiyotlari yoki kuzatuvlari haqida aytganidek, menga biror narsa aytishini bilar edim. U Samarqand haqida gapira boshladi. ularning afsonalari, bizning afsonaning yarmiga o'xshab ketadi Bizning iqlimimizda bo'lgani kabi, biz ularning dashti naqshlarini topamiz, shuning uchun bu afsonalarda o'zimizning izlarimizni izlaymiz.

6.2. Descriptive

The descriptive style depicts people, objects or places. Typical words are adjectives and adverbs. The original passage contains 17 of them.

Table 2. Comparison of the descriptive sample

Uzbek by Google Tranlate	Uzbek by Rahim Kayumov
Quyidagi qish Vavel monastirlarining qayta tiklanishiga oq qorli erminlarni yubordi; Keyingi bahorlarda Sikornik Green Parkning maysazoridan ham yoshroq yashil rangga ega bo'ldi. Ammo Gołębia ko'chasi 20-uyning qorong'i xonalari, u erda eski Sigismund davridan beri universitet binolari joylashgan, har doim bir xil qorong'i edi, balki bahorda namroq bo'lishi mumkin edi. Komi yashilligida tarix izlari yo'q, Ural uchun emas, kam va yosh Volgada. Biroq, Kaspiy dengizi orqasida va Fors chegarasiga to'g'ri kelib, tarix mingyillikning qatlamlarida o'rnatildi. Butun mamlakat vayronaga aylanib qolgan vulqonga o'xshaydi, bular asrlar davomida lava bayramiga to'kilgan. Mahalliy xalqlar faqat lava kabi. U keng va uzoq joylarga to'kilgan, urush, olov va kuya olib keldi. U o'zini yo'qotmaguncha va sovib qoldi. U halokatli uylarning ostonasida hali ham o'tiribdi va nimani bilishni kutmoqda. Hatto inqilob hali bu ruhiy tushkunlikka tushmadi. Sharqiy. allaqachon qorong'ulashib ketgan va arman uyining devorida ko'k oydan soyalar bor edi Ko'k rangli oqshomda oq, siyanchilik devori ostida	Keyingi qish vavel galereyasini qayta tiklanishiga oq qorli erminlarni yubordi; keyingi bahorlarda Green Parkning Sikorniki maysazoridan ham yoshroq yashil rangga ega bo'ldi. Ammo Gołuby ko'chasi 20-uyning qorong'i xonalari, u erda Eski Zigmunt davridan beri universitet binolari joylashgan, har doim bir xil qorong'i edi, balki bahorda namroq bo'lishi ham mumkin edi. Komi yashilliklarida tarix izlari yo'q, Ural ortida ham yo'q, Volgada kam va yosh tarix mavjud.. Biroq, Kaspiy dengizi ortida va Fors chegarasiga to'g'ri kelib, tarix mingyillikning qatlamlarida o'ralgan. Butun mamlakat vayronaga aylanib, qotib qolgan vulqonga o'xshaydi, xuddiy bular asrlar davomida dunyoda lava to'kilgan. Mahalliy xalqlar – faqat lava kabi. U keng va uzoq joylarga to'kilgan, urush, olov va vabo olib keldi. Hozircha u yuqotilmagan va sovib qolmagan. U endi harakatsiz xarob uylar ostonasida o'zini yo'qotmaguncha va sovib o'tirib qolgan.. Hatto inqilob hali bu ruhiy tushkunlikdan olib chiqmadi. Sharq. allaqachon qorong'ulashib ketgan va arman uyining devorida ko'k oydan soyalar boshlaganligini Ko'k rangli oqshomda oq, siyanchilik devori ostida

6.3. Argumentative

The argumentative style may not differ much formally from narration, other than the verbs being in the present tense. Sentences will normally be statements of opinion. As it happens, in the passages selected here for argumentation there are 23 relevant verbs, i.e. as many as in the narrative fragments.

Table 3. Comparison of the argumentative sample

Uzbek by Google Tranlate	Uzbek by Rahim Kayumov
Yosh tarixchilar, odatda, biz afsona, marosim, xalq ertaklari deb ta'riflagan va aniq hujjatlar dalillari bilan isbotlab bo'lmaydigan hamma narsaga nafrat bilan qaraydilar.	Yosh tarixchilar, odatda, biz afsona, marosim, xalq ertaklari deb ta'riflagan va aniq hujjatlar dalillari bilan isbotlab bo'lmaydigan hamma narsaga nafrat bilan qaraydilar.
Ma'lumki, professorlarga afsonalar yoqmaydi, lekin ular aniqlikni yaxshi ko'radilar.	Ma'lumki, professorlar afsonalarni yoqtirmaydilar, lekin ular aniqlikni yoqdiradilar.
Ko'rib turganingizdek, ba'zan afsonalar to'g'ri.	Ko'rib turganingizdek, ba'zan afsonalar to'g'ri.
"Sening ishlaring, senga osmon azobini yuborsin". Har bir bahorda boshqa odamlarning yerlarini ag'darib tashlamaysiz, chet el shaharlarini qamrab olmaysiz, qirolligingiz yiqilib qoladi, masjidlar xarobalarida begona o'tlar o'sib chiqadi va cho'l shuhrati unutiladi. Biroq, farovonlik quyoshi ham siz uchun porlaydi. Biroq, Lechistandan trubkasi Samarqand bozoridagi qo'shiqni yutib yubormasdan oldin sodir bo'lmaydi, u endi tugamadi". Samarqand afsonasi shunday deydi. Shunday qilib, barcha mo'g'ul qabilalari Tian Shan tomonidan Kaspiy dengizining qirg'oqlariga ishonadilar. Chingizxonning ruhi Osiyo dashtlari bo'ylab yuribdi.	"Sizlarning ishlaring, – aytishdi ular, – senlarga osmon azobini yuborsin. Har bir bahorda boshqa odamlarning yerlarini ag'darib tashlamaysiz, chet el shaharlarini bosib olmaysiz, qirolligingiz emirilib qoladi, masjidlar xarobalarida aylanib, begona o'tlar o'sib chiqadi va cho'l shuhrati unutiladi. Biroq, farovonlik quyoshi ham siz uchun porlashi uchun Lexistanlik karnaychini Samarqand bozoridagi karnay sadosida boshlagan qo'shg'i oxiriga etishi kerak, chunki o'sha paytda uni oxirigach etkazila olmagan edi. Samarqand afsonasi shunday hikoya qiladi. Shunday qilib, barcha mo'g'ul qabilalari Tiyan-Shandan tortib Kaspiy dengizining qirg'oqlarigacha yashaydiganlar bu afsonaga ishonadilar. Chingizxonning ruhi Osiyo dashtlari bo'ylab izg'ib yuribdi.
Haqiqiy yoki soxta hujjatlar mavjud; haqiqiy yoki soxta afsonalar yo'q. Afsonalarda rekord yo'q. Yangi mamlakatlarda afsonalar yo'q; Qadimgi davlatlar bunga ega. Bir necha avloddagi mo'ylovlarda vino kabi sharobga o'xshash fermentlar kuchli kuchga ega.	Haqiqiy yoki soxta hujjatlar mavjud; haqiqiy yoki soxta afsonalar yo'q. Afsonalarda hudud yo'q. Yangi mamlakatlarda afsonalar yo'q; Bunga faqat qadimgi davlatlar ega. Afsonalar bir necha avlodlar miyyasida vino kabi chanlarda achib turgandek katta kuch to'plamoqda.

6.4. Communicative

Finally, the communicative style differs the most visually from the other three: it has the form of dialogue, though it may be either separate or incorporated into the text. It is often characterised by colloquial language, including questions (here 4), exclamations (here 8) and a degree of idiomaticity. Verbs often occur in the first two persons (here 17), rather than just the third, or can take the imperative form (here 3).

Table 4. Comparison of the communicative sample

Uzbek by Google Tranlate	Uzbek by Rahim Kayumov
– Siz hammasidan omon qolmaganingiz uchun aqldan afsusdasiz. Kozielsk, bu qanday monastir! Bu qanday buyuklik!	– Afsus Siz bularni hammasini o'z boshingizdan o'tkazmadingiz. Kozyolsk, bu erda qanday cherkovlar! Bu qanday buyuklik!
– Sen kelganda, men senga bir narsani aytaman ... senga go'zal narsani aytaman.	– Sen kelganda, men senga bir narsani aytaman ... senga go'zal narsani aytaman.
Bilasizmi, u: "men nafas olaman", dedi.	Bilasanmi, dedi u: "men nafas ola boshladim", dedi.
"To'g'ri, siz o'g'illari Lechistan bo'ladi?" "Biz". "Va siz o'ng, askarlar bor?" "Biz". "Allohga iymon keltiringlarmi? Sening eski xudoingda, ha?" "Biz ishonamizki, onalar, oh, ko'raylik, biz xochlarni olib yuramiz" – dedik. "A karnaylarni siz bor?" "Biz!" "Biz sizga Lechistan va askarlar bilan bo'lsa... sizga katta ne'mat topish kerak va Chunki iymon... va karnaylarni uning Xudoga sen bor... Agar bizning eski bozorga bilan pufladi sizning ertaga kechqurun karnaychilaringizga aytib olmadi? masjid oldida, unda Temur Buyuk? Alright. "Siz o'ynash ishonchingiz komilmi?" "Biz o'yin olaman."	"Siz Lecxiston o'g'lunlari, shunday emasmi?" "Ha". "Sizlar askarlar, to'g'rimi?" "Ha". "Yana xudoga ham ishonasizlar? O'zlaringning eski xudoyinggzga, ha?" "Biz ishonamiz, bizlar ruhoniylarmiz biz xochlarni olib yuramiz" – dedik. "Sizlarda karnaychi bormi?" "Bor!" "Biz sizlarni Lexistondan va askarlar ekanligingizni, xudoga ishonishlaringizni, sizlarda karnaychi borligini ham bilamiz. Shuning uchun agar bizning eski bozorga kechqurun sizlarni karnaychingiz karnayini chalib tursa yaxshi bo'lar edi. Bozor yaqinida eski masjit yonidagi Amir Temur qo'nim topgan maskanda karnay chalishga rozilik berdik.
– Krakov? – Bilmadim. – Agar boy bo'lsa, Krakow emas. – Kechirasiz, Samarqand ham aql-idrokida boy shahar. – Xo'sh, agar Samarqand...	– Krakovmi? – Bilmadim. – Agar boy bo'lsa, unda bu Krakow emas. – Kechirasiz, ular Samarqandni ham boy shahar deb hisoblashadilar. – Agar Samarqand bo'lsa ...
– Bu lajkonik! – Ehtiyot bo'l!	– Bu laykonik-ku! – Ehtiyot bo'l!
– Demak, bu bizning afsonamizmi? – Kuting. Lekin nima uchun ular karnaychilarimizni o'ynashni xohlashlarini bilasizmi?	– Demak, bu haqiqatdan ham bizning afsonamizmi? – To'xta. Lekin sen bilasanmi, nega ular karnaychilarimizni o'ynashni xohlashlarini?
– Demak, bu haqiqiy afsonadir? – Bu nimani anglatadi: haqiqiy afson?	– Demak, bu haqiqiy afsonami? – Bu haqiqiy afsona nimani anglatadi?

7. Results and conclusions

The quantitative differences calculated by the program and visualised in colour in Tables 1–4 are presented in Table 5.

Table 5. Quantitative identification of the differences detected

Narrative: 1 difference: 11 lines, 41 inline differences in 11 changed lines

Added(0,8)	Deleted(0,3)	Changed(11)	Changed in changed(30)	Ignored

Descriptive: 1 difference: 6 lines, 32 inline differences in 6 changed lines

Added(0,9)	Deleted(0,3)	Changed(6)	Changed in changed(20)	Ignored

Argumentative: 2 differences: 7 lines, 31 inline differences in 7 changed lines

Added(0,6)	Deleted(0,2)	Changed(7)	Changed in changed(23)	Ignored

Communicative:5 differences: 15 lines, 56 inline differences in 15 changed lines

Added(0,14)	Deleted(0,8)	Changed(15)	Changed in changed(34)	Ignored

In the light of the results obtained on the research samples, it can be concluded that there are noticeable differences between the selected types of text. The smallest variations are between the Descriptive and Argumentative styles in all change categories, and the largest between Communicative on the one hand and Argumentative and Descriptive on the other. Similar differences obtain between Communicative and Narrative styles.

The Uzbek-speaking expert who corrected the automatic text stated that the text was generally understandable, and estimated the scope of the corrections at around 15–20%. An example of a terminological problem was the name of the instrument referred to in the title, because such a device generally does not occur in the musical culture of Uzbekistan, and it was necessary to borrow from the European music culture to find the correct counterpart.

The authors plan to further work on comparing automatic and proofread versions of the story, carrying out a statistical analysis of the entire text and extending the size or number of samples as well as doing this to the story's translation into Tajik.

References

[1] Jerzy Montusiewicz, Bakhodir Eshchanov (eds), *Cultural Heritage of Uzbekistan: From Petroglyphs to the Present Days*, Wydawnictwo Politechniki Lubelskiej [Lublin University of Technology Publishers], Lublin 2022, pp. 107–118.

[2] Shoulder sleeve insignia of the Polish Armed Forces in the West – https://en.wikipedia.org/wiki/Polish_Armed_Forces_in_the_West (retrieved on 17 May 2022).

[3] Photograph from the 1940 Narvik campaign – https://www.warrelics.eu/forum/polish-armed-forces-west-polskie-si-y-zbrojne-na-zachodzie-1939–1947/narvik-1940-a-659863–3/ (retrieved on 17 May 2022).

[4] Ksawery Pruszyński, *Opowieści*, https://staradobraksiazka.pl/8784-opowiesci-ksawery-pruszynski (retrieved on 28 March 2020).

[5] Norman Davies, *Trail of Hope* (blurb), https://www.waterstones.com/book/trail-of-hope/norman-davies/9781472816030 (retrieved on 17 May 2022).
[6] Norman Davies, *Trail of Hope* (cover), Publisher: Bloomsbury Publishing PLC, ISBN: 9781472816030
[7] Norman Davies, *Trail of Hope* (map), https://dzieje.pl/infografiki/armia-andersa (retrieved on 17 May 2022).
[8] https://docer.pl/doc/nvsns08
[9] Ksawery Pruszyński, "Trębacz z Samarkandy", in: *Opowieści* (A selection), Państwowy Instytut Wydawniczy, Warszawa 1968: 7–13.
[10] https://en.wikipedia.org/wiki/Al-Kindi
[11] https://www.diffnow.com.

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DIGITISATION OF PHOTOS FROM CENTRAL ASIA FROM THE BEGINNING OF THE 20TH CENTURY – TWO EXAMPLES

Abstract

At the turn of the 19th and 20th centuries, Europeans began exploring the territory of Turkestan in Central Asia. Many scientific and research expeditions were sent to these areas. Most of them, however, were military. They obtained information about unknown areas lying on the Great Silk Roads. Much of this information was related to cartography, geology, natural and human resources, and political systems. However, the explorers also made photographic documentation of these areas. The most famous collections of colour photographs from Central Asia at the turn of the 19th and 20th centuries are those of S. M. Prokudin-Gorski and L. S. Barszczewski. The paper presents the history of the creation of these collections and their further history, with particular emphasis on the processes of their digitisation in recent years.

Keywords: digitisation, Silk Road, 2D photographs

1. Introduction

The first contacts between the representatives of tsarist Russia (the Russian Empire) and the khanates educated in Central Asia date back to the 16th century. The tsar sent messages to the khanates with proposals to establish trade contacts. It was then that Russia began colonising Siberia (up to the western shores of the United States) and the Great Steppe – an area located from the southern Volga and the Caspian Sea to today's Mongolia, from Siberia in the north to the great deserts and Pamir mountains of Central Asia. The conquest of Central Asia ended in 1885 [1]. In this field, Russia competed with Victorian England to gain access to the Indian Ocean. England, on the other hand, defended its sovereignty over India. This geopolitical competition has been called the Big Game [2]. In 1815, Central Asia was already partially conquered and incorporated into the Russian Empire – the territory of today's Kazakhstan (Fig. 1). The rest of Central Asia was occupied by three countries: the Emirate of Bukhara, the Khiva Khanate and the Khanate of Kokand (Fig. 1). These countries were gradually incorporated into the Russian Empire, creating the Russian governorate of Turkestan.

Figure 1. Central Asia in 1805 [1]

The colonisation of Central Asia was carried out by the Russian Empire on four levels:

- Military – taking territories by force, suppressing resistance, but also setting roads to India and China.
- Trade – exchange of goods, cotton and silk procurement, and silkworm farming.
- Economic – taking over geological resources, including arable lands, and transferring them to the incoming Slavic population.
- Political – changes in the governance system, the influx of settlers, breaking tribal and family ties.

After the lands of Central Asia were incorporated into the Russian Empire, intensive research began into new lands in search of resources, mapping, etc. At the end of the 19th century, two very different people were exploring Central Asia: Leon Barszczewski and Siergiey Prokudin-Gorski. They both left behind, inter alia, photos taken during trips around Central Asia.

2. Barszczewski – Polish photographer of Central Asia

Leon Barszczewski was born in 1849 in Warsaw (Poland) as a subject of the Russian Empire [3] to a Polish noble family. After the premature death of his parents and the loss of his brothers (sentenced for participation in the January Uprising of 1863), being of noble birth, he was taken under the care of tsarist regime and brought up to be a military man. In the tsarist army he achieved the rank of colonel. In 1876 he went as a volunteer to Turkestan as a member of the topographic division of the tsarist army. He was stationed mainly in Samarkand. He organised and carried out research trips, mainly towards Afghanistan and China. He was the first to excavate ancient Afrasiab. He accumulated a large number of artefacts. This collection became the beginning of the Samarkand History Museum.

Leon Barszczewski was also a geologist-explorer, botanist and glaciologist. As a geologist, he discovered deposits of coal, copper and other minerals. As a botanist, he amassed a large collection of dried plants. He was the first Pole to explore the Pamir glaciers. His knowledge of a glaciologist has been appreciated in the scientific world. One of the glaciers in the Hisar Mountains was named after him [4].

Leon Barszczewski was sent in 1897 from Samarkand to Siedlce (Poland). It was probably punishing the colonel for refusing to change his religion from Catholic to Orthodox [3].

The most spectacular legacy of Leonid Barszczewski is a collection of several hundred black and white photographs on glass plates. He photographed everything: mountains, rivers, glaciers, buildings and people [3] (Fig. 2–7).


Figure 2. Leon Barszczewski in his home with collected artefacts [3]


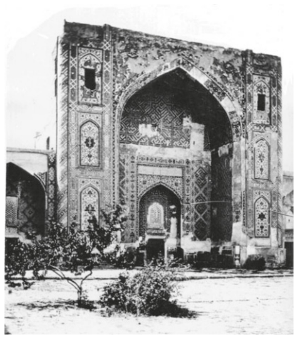

Figure 3. Leon Barszczewski's pictures of the Tilla-Kari madrasah in Samarkand [3]

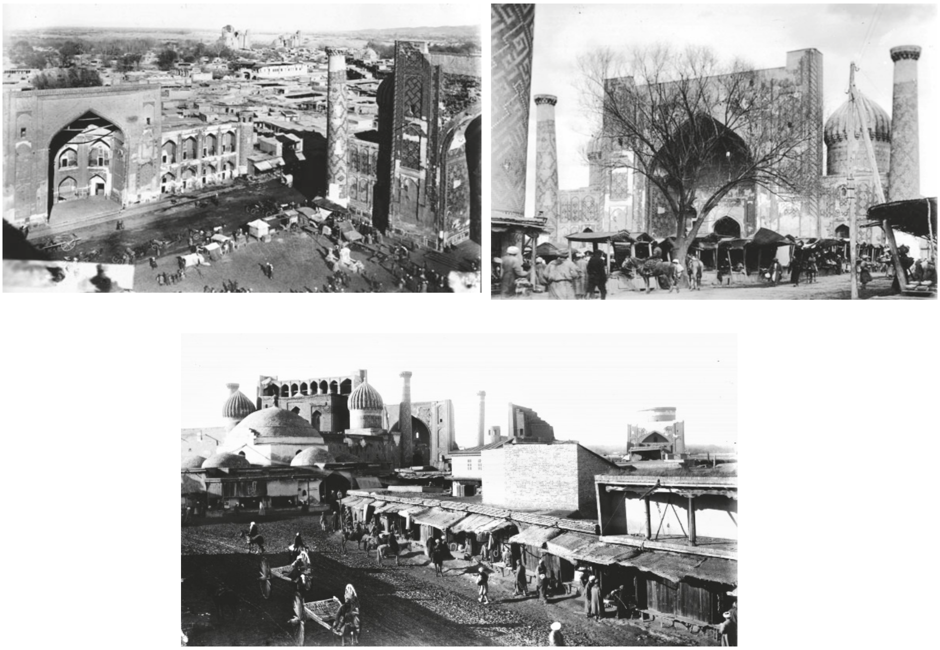

Figure 4. Photos of the Registan Square taken by Leon Barszczewski [3]

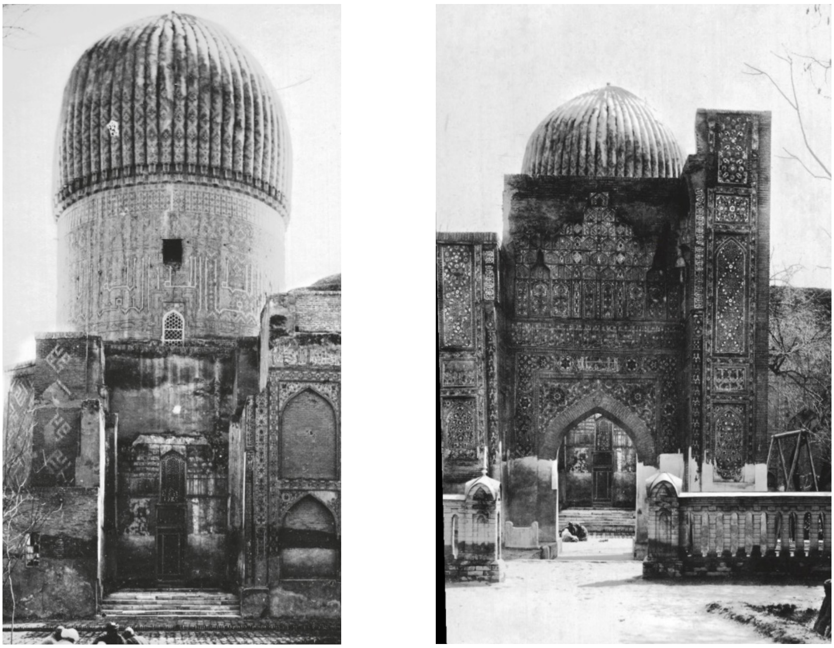

Figure 5. Leon Barszczewski's pictures of the Gur-i Emir mosque in Samarkand [3]

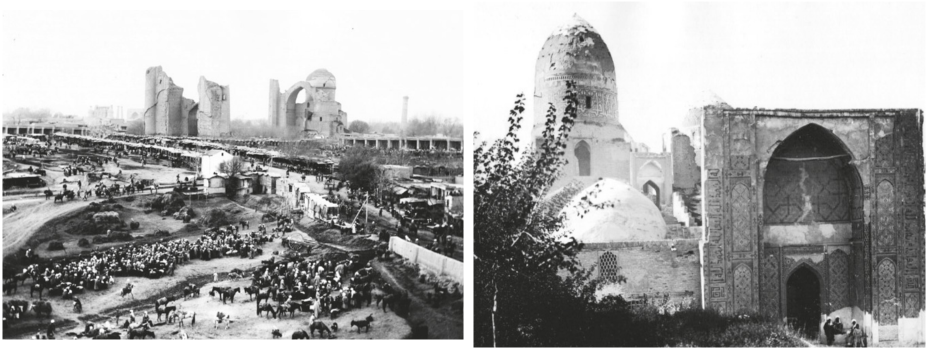

Figure 6. Leon Barszczewski's pictures of the Market square in front of the Bibi-Khanum mosque (on the left) and the main entrance to the Shah-i Zinda mausoleum complex (on the right) in Samarkand [3]

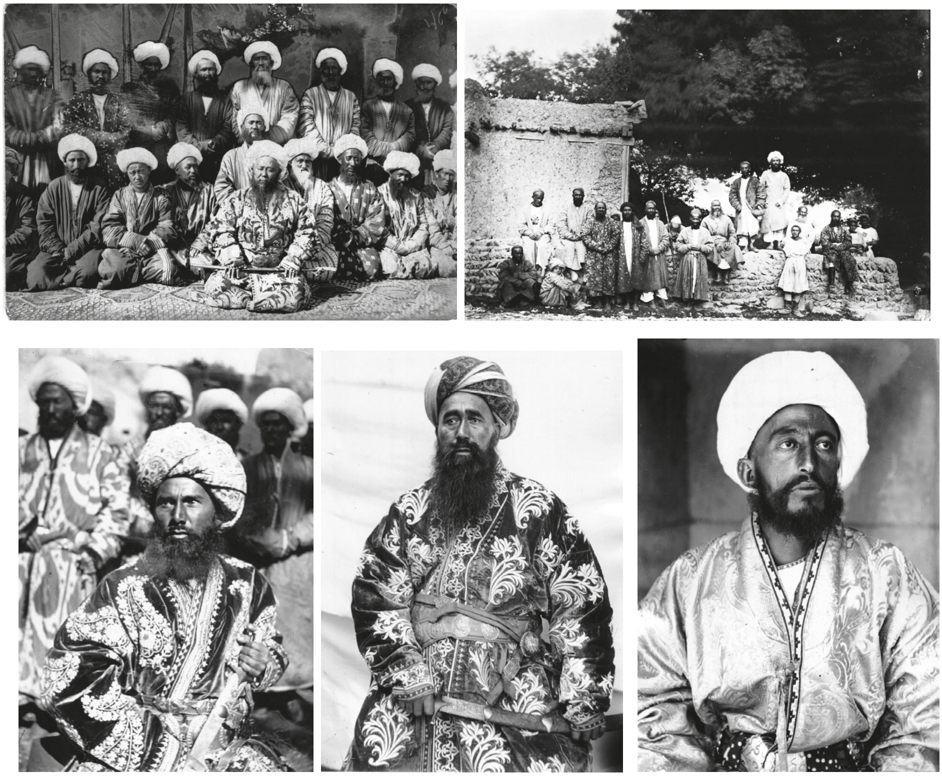

Figure 7. Photos of the inhabitants of Central Asia taken by Leon Barszczewski [3]

3. Sergey Prokudin-Gorski – photographer of the Russian Empire

Sergey Prokudin-Gorski was a Russian nobleman, born in 1863, 14 years after Leon Barszczewski. He was a well-educated chemist – he studied under Dmitri Mendeleev [5]. He tied his fate with photography. He is known for pioneering work in Russia on the technology of colour photography, using three black and white photos taken with filters in red, green and blue (currently: RGB colour channels and additive colour creation technology). These works brought him so much recognition in the world and in Russia that the Russian Tsar Nicholas II gave him the means for a project of photographing in colour the Russian Empire. These measures included a special railway carriage in which Sergey Prokudin-Gorski travelled throughout Russia, and a photographic darkroom was arranged. He also obtained finance and, which was not without significance in the then Russian Empire, letters from the tsar obliging his administration to provide comprehensive assistance and permission to enter the closed areas [5].

Sergey Prokudin-Gorski carried out the project of photographing Russia at the expense of the Tsar of Russia in 1909–1915. As a result, he created a collection of over 10,000 photos [5]. They were all made in colour photography technology. After completing the project, Sergey Prokudin-Gorski continued his life's work until the revolution of 1918 and the civil war in Russia. Then he emigrated from Soviet Russia and settled in Paris, where he died. During his emigration, Sergey Prokudin-Gorski had about 3,500 negatives. Some of them were confiscated by the Soviet authorities as representing strategic objects (e.g. bridges, sluices, etc.) [5]. After Sergey Prokudin-Gorski's death, his heirs sold 1,902 negatives to the Library of Congress in 1948.

In Central Asia, Sergey Prokudin-Gorski mainly photographed people, nature and buildings (Fig. 8–9).

Figure 8. Photographs of Sergey Prokudin-Gorski of Central Asian dignitaries [6]

Figure 9. Sergey Prokudin-Gorski's photographs of the monuments of Samarkand [6]

4. Digitisation of photos and their availability

Both of the discussed collections of photographs had different histories.

Sergey Prokudin-Gorski's photographs are stored in the Library of Congress of the United States of America. In the years 2001–2004 the collection was digitised and made public on the library website [6]. The virtual exhibition organised at that time presents photos with descriptions and catalogue, as well as a whole range of additional information about the author himself, the history of his life and the history of the Russian Empire, technology, albums released at the beginning of the 20th century, etc.

Using the database of digital copies of Sergey Prokudin-Gorski's photos (three for each colour) placed in the Library of Congress, the Digital Technologies in Restoration Lab of the Scientific Council for Cybernetics (Russian Academy of Sciences) and the "Restavrator-M" Restoration Centre created a collection of colour photos and placed it on the Internet [7]. Files from the Library of Congress have been processed to maximise the accuracy of the overlapping of the three images of the permanent elements of the photograph. In addition, works were carried out (manually) to eliminate random defects in the photos.

In 2008, the International Research Project "Legacy of S. M. Prokudin-Gorsky" [8] began. The initiator and manager of the project is V. Dryuchin, Honoured Teacher of the Russian Federation, the founder of the Museum of S. M. Prokudin-Gorsky in Moscow [8]. During the project implementation, the Internet community was asked to help in participating in the project by [8]:

- taking part in discussions at the project's forum;
- making for the project digital restoration of Prokudin-Gorsky's images;
- making photos of the same views and objects as Prokudin-Gorsky did (for comparison);
- providing us with any suggestions and remarks on the content of project;
- assisting us in locating and copying the archival and library sources related to the Prokudin-Gorsky and his collection;
- telling about the project to all those who may be interested in the photographic legacy of Prokudin-Gorsky.

As part of the project [8], colour digital photos created and digitally enhanced as well as additional functionalities created by digital technologies were made public. One very interesting functionality of portal [8] is the possibility to dynamically compare the appearance of objects nowadays (sometimes at different times – to choose from) and with the photo of Sergey Prokudin-Gorski (Fig. 10). Another interesting functionality of portal [8] is the possibility of comparing the appearance of objects from other sources (e.g. postcards, usually in black and white technology) from the beginning of the 20th century with a photo: Sergey Prokudin-Gorski (Fig. 11).

Photos taken by Sergey Prokudin-Gorski are available today and can be used in open access.

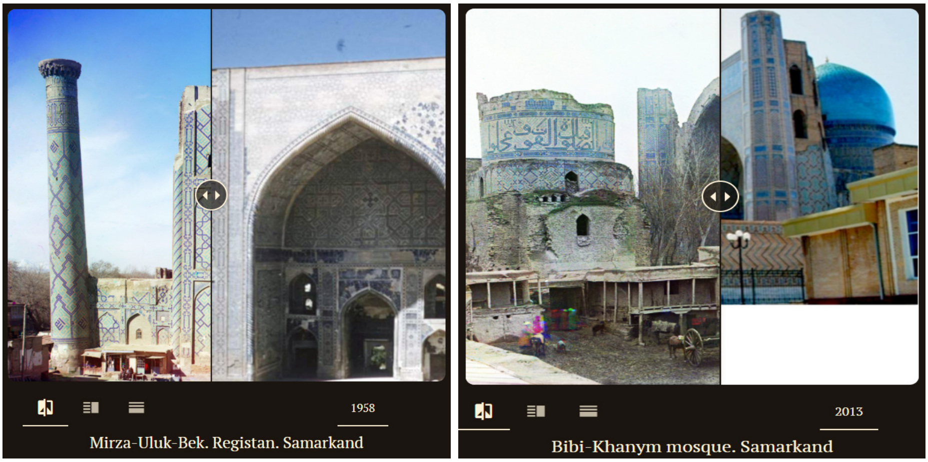

Figure 10. Photographs by Sergey Prokudin-Gorski and a photo from later times (1958 – left, 2013 – right) – comparison on portal [8]

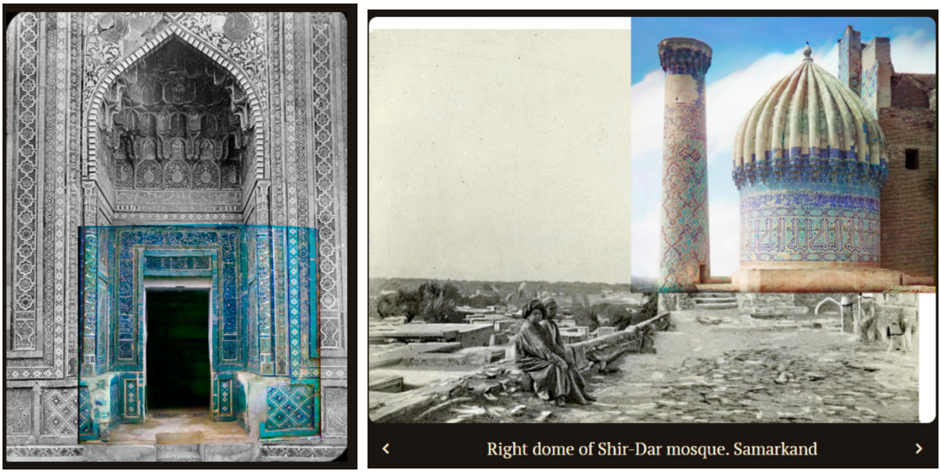

Figure 11. Photos of Sergey Prokudin-Gorski (colour) and photos of other authors extending them [8]

Leon Barszczewski's collection of negatives remained in private hands. The photos were and are used by his heirs in various activities, such as the preparation, publication and sale of books [3]. There is only one known project of digitising Leon Barszczewski's photos, implemented as part of the Digital Archive project. Józef Bursza [9]. In the generally accessible database of the Archives, made available in 2014, there were only 35 photos [9].

At the moment, it is not possible to use other photos of Leon Barszczewski, which significantly limits their availability.

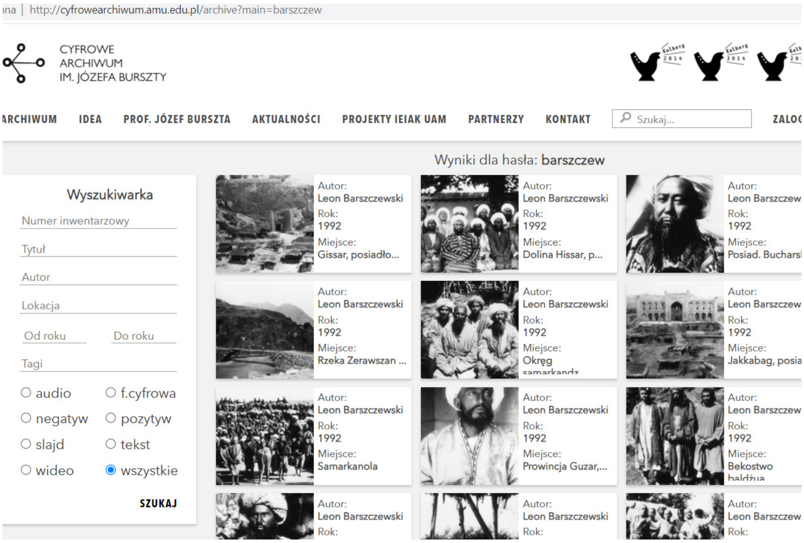

Figure 12. Photographs of Leon Barszczewski in the digital database
of the University of Adam Mickiewicz in Poznań

5. Conclusions

During the recognition of the new colonies by the Russian Empire, as well as documenting and disseminating information about the Empire, the technology of black-and-white and colour photography, innovative at the turn of the 19th and 20th centuries, was used. Unfortunately, the photos that have survived from those times have a different history and availability. Nevertheless, they are used to promote various cultural events (Fig. 13).

Figure 13. Photo exhibition of Sergey Prokudin-Gorsky's photos at the 5th International Congress "Cultural Heritage of Uzbekistan – The Foundation of the New Renaissance", Tashkent, Uzbekistan, September 13–20, 2021, photo: E. Miłosz

We should strive for digitisation and universal sharing of photographic resources, various authors, presenting the state of our history. These resources should become widely available for all mankind. The photo story of Sergey Prokudin-Gorsky is a very good example of such a process.

References

[1] Perkowska, A. Przedradziecka tożsamość narodowa w Azji Centralnej w kontekście polityki narodowościowej ZSRR. Przegląd badań. Studia z Dziejów Rosji i Europy Środkowo-Wschodniej, vol. 50/1, 2015, pp. 119–168.

[2] Hopkirk P. The Great Game: The Struggle for Empire in Central Asia. Kodansha International, New York; Tokyo & London, 1992, 564 p.

[3] Strojecki, I. Podróże Leona Barszczewskiego po XIX-wiecznej Azjii Środkowej. Utracony świat. Helion, Gliwice, 2017, 345 p.

[4] Leon Barszewski, https://pl.wikipedia.org/wiki/Leon_Barszczewski (dostęp 18.02.2022).

[5] Siergiej Prokudin-Gorski, https://en.wikipedia.org/wiki/Sergey_Prokudin-Gorsky (dostęp 18.02.2022).

[6] The Prokudin-Gorskii Photographic Record Recreated: The Empire That Was Russia, Library of Congress, https://www.loc.gov/exhibits/empire/index.html (dostęp 18.02.2022).

[7] The World of 1900–1917 in Color, http://www.prokudin-gorsky.ru/ (dostęp 18.02.2022).

[8] International Research Project "The Legacy of S. M. Prokudin-Gorsky", https://prokudin-gorsky.org/, (dostęp 18.02.2022).

[9] Cyfrowe Archiwum im. Józefa Burszty, http://cyfrowearchiwum.amu.edu.pl/archive?tags=leon%20barszczewski, (dostęp 18.02.2022)

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MODELLING THE VIBRATIONAL PROCESSES OF HISTORICAL HIGH-RISE STRUCTURES OF ASIAN CULTURAL HERITAGE

Abstract

In Uzbekistan, earthquakes sometimes occur, which is visible in the appearance of many architectural monuments. Developing mathematical models of the behaviour of buildings to different types of variable loads and solving them contributes to understanding these issues. In the paper presented the analytical description of vibration loads of a complex building structure is considered as systems of masses connected by viscoelastic springs. To take into account the rheological properties of the spring material, the Boltzmann-Volterra principle was used. Mathematical models of the problem under consideration are obtained, which are reduced to solving systems of nonlinear integro-differential equations. A solution method based on the use of quadrature formulas has been developed and a computer program has been compiled on its basis, the results of which are reflected in the form of graphs. The influence of nonlinear and rheological properties of a spring on the amplitude and phase of mass oscillations is investigated.

Keywords: deformation, relaxation, rheological properties, viscoelasticity, physical nonlinearity, integral operator, kernel of heredity.

1. Introduction

In the course of operation, high-rise structures of tower and mast type are exposed to variable loads: these are loads caused by the operation of equipment, wind load, seismic disturbances.

The idea of vibration isolation was implemented in the Middle Ages. Thus, during the construction of Central Asian minarets, special “reed belts” or cushions made of bulk material were placed in the foundations. However, the theory of vibration isolation has been developed only in the last 25–30 years. The first works in this area were aimed at reducing inertial seismic loads by reducing the period of the fundamental vibration of the structure [1].

The calculation of buildings and structures designed for seismic regions is carried out according to the building regulations method based on a linear spectral approach. This calculation method does not allow us to assess the probabilities of deviation of the calculated reaction values from the actual values, as well as to reveal the strength reserves of structures associated with the physically nonlinear properties of structural materials, which appear under dynamic loading [2].

Currently, there are a large number of design varieties of vibration protection devices designed both to protect equipment installed on vibrating bases, and to protect foundations from dynamic effects.

Since the damping forces for a real structure of an industrial building cannot be estimated with the same accuracy as elastic and inertial forces, rigorous mathematical modelling of damping phenomena is impossible. However, to explain the dissipative forces present in any design, an assumption should be made about the type of damping, which allows the damping forces to be estimated in practice. In addition, the type of damping should facilitate simple mathematical operations specifically applied to linear equations of motion – this means that when harmonically excited, the damping forces also change harmonically. Two such suitable forms of damping are viscous and hysteresis damping. In any vibration protection system, both forms of damping are present, but in different proportions [3].

2. Statement of goals

For an analytical description of vibration loads, a complex building structure can be considered as a system of masses connected by viscoelastic elements. Consider the vertical vibrations of four weights (Fig. 1) with masses and , connected by nonlinear viscoelastic elements. Let us denote the displacements of weights with masses and from the static equilibrium position through and , and the force of action by the elements on the mass – through.

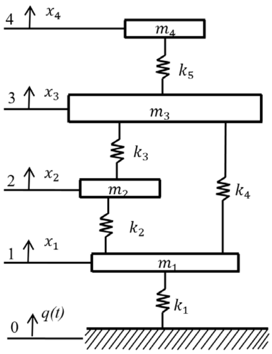

Figure 1. Diagram of the vibration protection system of a building structure

Using the d'Alembert principle and considering the fictitious equilibrium of masses, to which the inertial and restoring forces are applied, we obtain:

[4,5]:
$$\begin{cases} m_1\ddot{x}_1 + F(x_1) - F(x_2 - x_1) - F(x_3 - x_1) = q \\ m_2\ddot{x}_2 + F(x_2 - x_1) - F(x_3 - x_2) = 0 \\ m_3\ddot{x}_3 + F(x_3 - x_1) + F_3(x_3 - x_2) - F(x_4 - x_3) = 0 \\ m_4\ddot{x}_4 + F(x_4 - x_3) = 0\,, \end{cases} \quad (1)$$

For the function *F(z)*, we take the expression [6–8]:

$$F(z) = k(1 - R^*)z(1 + \gamma z^2) \quad (2)$$

where k is the stiffness coefficient of viscoelastic bonds (element); $\cdot\,\gamma.$ – coefficient of nonlinearity, depending on the physical properties of the element material; and R^* – integral operator with relaxation kernel.

$$R(t,\tau) = \varepsilon e^{-\beta(t-\tau)} \cdot (t-\tau)^{\alpha-1}:$$
$$R^*z = \int_0^t R(t,\tau)z(\tau)d\tau.$$

Then, taking into account (2), system (1) will have the form:

$$\begin{cases} m_1\ddot{x}_1 + k_1(1 - R_1^*)x_1(1 + \gamma_1 x_1^2) - k_2(1 - R_2^*)(x_2 - x_1)[1 + \gamma_2(x_2 - x_1)^2] - \\ -k_4(1 - R_4^*)(x_3 - x_1)[1 + \gamma_4(x_3 - x_1)^2] = q_1; \\ m_2\ddot{x}_2 + k_2(1 - R_2^*)(x_2 - x_1)[1 + \gamma_2(x_2 - x_1)^2] - k_3(1 - R_3^*)(x_3 - x_2)[1 + \gamma_3(x_3 - x_2)^2] = 0; \\ m_3\ddot{x}_3 + k_4(1 - R_4^*)(x_3 - x_1)[1 + \gamma_4(x_3 - x_1)^2] - k_3(1 - R_3^*)(x_3 - x_2)[1 + \gamma_3(x_3 - x_2)^2] - \\ -k_5(1 - R_5^*)(x_4 - x_3)[1 + \gamma_5(x_4 - x_3)^2] = 0; \\ m_4\ddot{x}_4 + k_5(1 - R_5^*)(x_4 - x_3)[1 + \gamma_5(x_4 - x_3)^2] = 0\,. \end{cases}$$

We accept that $x_1(0) = \dot{x}_1(0) = x_2(0) = \dot{x}_2(0) = x_3(0) = \dot{x}_3(0) = x_4(0) = \dot{x}_4(0) = 0.$

Solution methods. Introducing dimensionless parameters

$$\frac{t}{\tau};\ \frac{R_i}{\tau};\ \frac{x_1}{l};\ \frac{x_2}{l};\ \frac{x_3}{l};\ \frac{x_4}{l};\ \frac{q_1}{q_0};\ \frac{\gamma_i}{l^2}$$

and keeping the same notation, we have:

$$
\begin{cases}
\ddot{x}_1 + c_1(1-R_1^*)x_1(1+\gamma_1 x_1^2) - c_2(1-R_2^*)(x_2-x_1)[1+\gamma_2(x_2-x_1)^2] - \\
-c_3(1-R_4^*)(x_3-x_1)[1+\gamma_4(x_3-x_1)^2] = q_1; \\
\ddot{x}_2 + c_4(1-R_2^*)(x_2-x_1)[1+\gamma_2(x_2-x_1)^2] - c_5(1-R_3^*)(x_3-x_2)[1+\gamma_3(x_3-x_2)^2] = 0; \\
\ddot{x}_3 + c_6(1-R_4^*)(x_3-x_1)[1+\gamma_4(x_3-x_1)^2] - c_7(1-R_3^*)(x_3-x_2)[1+\gamma_3(x_3-x_2)^2] - \\
-c_8(1-R_5^*)(x_4-x_3)[1+\gamma_5(x_4-x_3)^2] = 0; \\
\ddot{x}_4 + c_9(1-R_5^*)(x_4-x_3)[1+\gamma_5(x_4-x_3)^2] = 0\,.
\end{cases} \tag{3}
$$

where

$$
c_1 = \frac{k_1\tau^2}{m_1}; \quad c_2 = \frac{k_2\tau^2}{m_1}; \quad c_3 = \frac{k_4\tau^2}{m_1}; \quad c_4 = \frac{k_2\tau^2}{m_2}; \quad c_5 = \frac{k_3\tau^2}{m_2}; \quad c_6 = \frac{k_4\tau^2}{m_3};
$$

$$
c_7 = \frac{k_3\tau^2}{m_3}; \quad c_8 = \frac{k_5\tau^2}{m_3}; \quad c_9 = \frac{k_5\tau^2}{m_4}; \quad q = \frac{\tau^2}{m_1 l}\cdot q_1\,.
$$

System (3) is solved by methods based on the use of a quadrature formula [7–9]. Integrating systems (3) over t twice, on the interval we have:

$$
x_1(t) = -c_1\int_0^t G_1(t-s)x_1(s)[1+\gamma_1 x_1^2(s)]ds +
$$

$$
+c_2\int_0^t G_2(t-s)[x_2(s)-x_1(s)]\{1+\gamma_2[x_2(s)-x_1(s)]^2\}ds +
$$

$$
+c_3\int_0^t G_4(t-s)[x_3(s)-x_1(s)]\{1+\gamma_4[x_3(s)-x_1(s)]^2\}ds + \int_0^t (t-s)q_1(s)ds\,;
$$

$$
x_2(t) = -c_4\int_0^t G_2(t-s)[x_2(s)-x_1(s)]\{1+\gamma_2[x_2(s)-x_1(s)]^2\}ds +
$$

$$
+c_5\int_0^t G_3(t-s)[x_3(s)-x_2(s)]\{1+\gamma_3[x_3(s)-x_2(s)]^2\}ds\,;
$$

$$
x_3(t) = -c_6\int_0^t G_4(t-s)[x_3(s)-x_1(s)]\{1+\gamma_4[x_3(s)-x_1(s)]^2\}ds +
$$

$$
+c_7\int_0^t G_3(t-s)[x_3(s)-x_2(s)]\{1+\gamma_3[x_3(s)-x_2(s)]^2\}ds +
$$

$$
+c_8\int_0^t G_5(t-s)[x_4(s)-x_3(s)]\{1+\gamma_5[x_4(s)-x_3(s)]^2\}ds\,;
$$

$$
x_4(t) = -c_9\int_0^t G_5(t-s)[x_4(s)-x_3(s)]\{1+\gamma_5[x_4(s)-x_3(s)]^2\}ds\,;
$$

where

$$G_i(t-s) = t-s-\int_0^{t-s}(t-s-\tau)R_i(\tau)d\tau, \qquad R_i(t) = \varepsilon_i e^{-\beta_i t}\cdot t^{\alpha_i-1}, \qquad \left(i=\overline{1,5}\right).$$

In the latter systems, replacing the integrals with the quadrature formulas of the trapezoid, to determine the displacement of the load from the static equilibrium position $x_{1i} = x_1(t_i)$, $x_{2i} = x_2(t_i)$, $x_{3i} = x_3(t_i)$ and $x_{4i} = x_4(t_i)$ $(i = 1,2,3, \ldots)$, we have the following recursive relations:

$$x_{1n} = -c_1\sum_{i=0}^{n-1} A_i G_1(t_n-t_i)x_{1i}(s)[1+\gamma_1 x_{1i}^2(s)] +$$
$$+c_2\sum_{i=0}^{n-1} A_i G_2(t_n-t_i)[x_{2i}(s)-x_{1i}(s)]\{1+\gamma_2[x_{2i}(s)-x_{1i}(s)]^2\} +$$
$$+c_3\sum_{i=0}^{n-1} A_i G_4(t_n-t_i)[x_{3i}(s)-x_{1i}(s)]\{1+\gamma_4[x_{3i}(s)-x_{1i}(s)]^2\} + \sum_{i=0}^{n-1} A_i(t_n-t_i)q_1(t_i);$$
$$x_{2n} = -c_4\sum_{i=0}^{n-1} A_i G_2(t_n-t_i)[x_{2i}(s)-x_{1i}(s)]\{1+\gamma_2[x_{2i}(s)-x_{1i}(s)]^2\} +$$
$$+c_5\sum_{i=0}^{n-1} A_i G_3(t_n-t_i)[x_{3i}(s)-x_{2i}(s)]\{1+\gamma_3[x_{3i}(s)-x_{2i}(s)]^2\};$$
$$x_{3n} = -c_6\sum^{n-1} A_i G_4(t_n-t_i)[x_{3i}(s)-x_{1i}(s)]\{1+\gamma_4[x_{3i}(s)-x_{1i}(s)]^2\} +$$
$$+c_7\sum_{i=0}^{n-1} A_i G_3(t_n-t_i)[x_{3i}(s)-x_{2i}(s)]\{1+\gamma_3[x_{3i}(s)-x_{2i}(s)]^2\} +$$
$$+c_8\sum_{i=0}^{n-1} A_i G_5(t_n-t_i)[x_{4i}(s)-x_{3i}(s)]\{1+\gamma_5[x_{4i}(s)-x_{3i}(s)]^2\};$$
$$x_{4n} = -c_9\sum_{i=0}^{n-1} A_i G_5(t_n-t_i)[x_{4i}(s)-x_{3i}(s)]\{1+\gamma_5[x_{4i}(s)-x_{3i}(s)]^2\};$$

where $t_i = i\cdot\Delta t$; $i=\overline{0,n}$; $A_0 = A_n = \frac{\Delta t}{2}$; $A_j = \Delta t$, and $j = \overline{1,n-1}$.

3. Results and conclusions

For carrying out a computational experiment, a computer program has been developed, whose results are reflected in the form of graphs. The calculation used the following initial data: c_1 = 2,84; c_2 = 2,84; c_3 = 2,71; c_4 = 2,75; c_5 = 1,32; c_6 = 2,30; c_7 = 1,15; c_8 = 2,76; c_9 = 4,41; γ_1 = 15; γ_2 = 20; γ_3 = 16; γ_4 = 17; γ_5 = 19; α_i = 0,25; β_i = 0,05; ε_i = 0,01 $\left(i=\overline{1,5}\right)$; $q(t) = 1{,}2e^{-0{,}7t}\sin 2{,}1\pi t$.

Figures 2, 3, 4 and 5 show nonlinear elastic (solid line) and viscoelastic (dashed line) oscillation of loads with masses m_1, m_2, m_3 and m_4 from the position of static equilibrium. The graph shows that taking into account the rheological property of the element leads to a decrease in the load amplitude from the position of static equilibrium. A decrease in the frequency of oscillation of the weight leads to a phase shift. Over time, the viscoelastic properties of an element significantly affect the amplitudes and frequencies of vibrations of the weights.

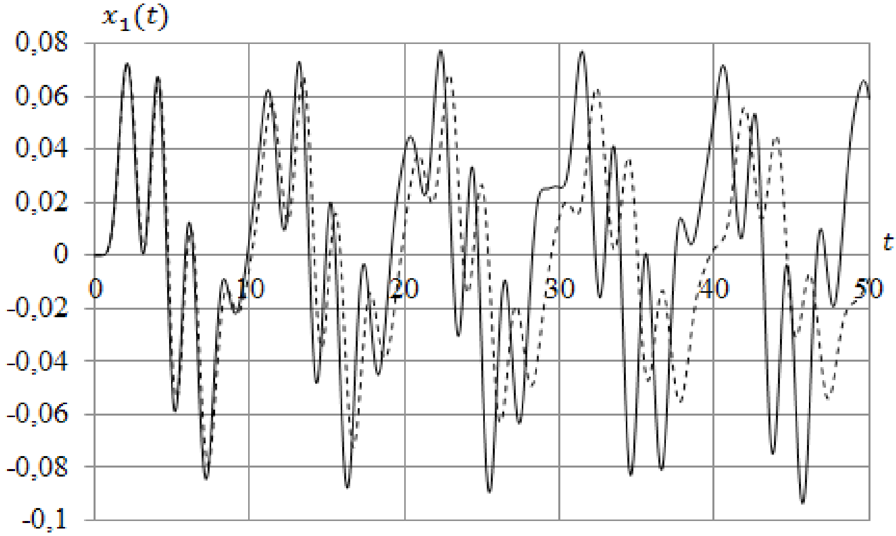

Figure 2. The form of vibration of the load with the mass

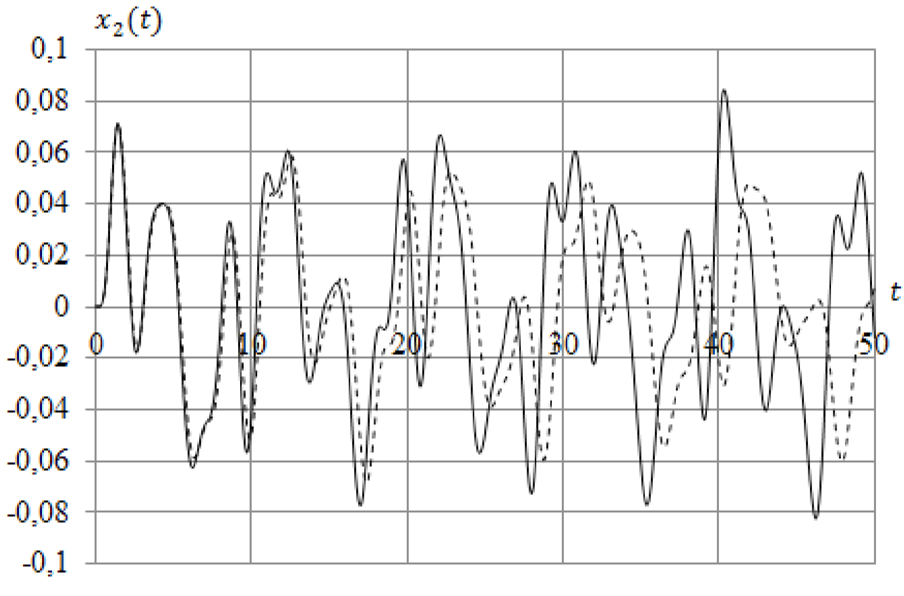

Figure 3. The form of vibration of the load with the mass

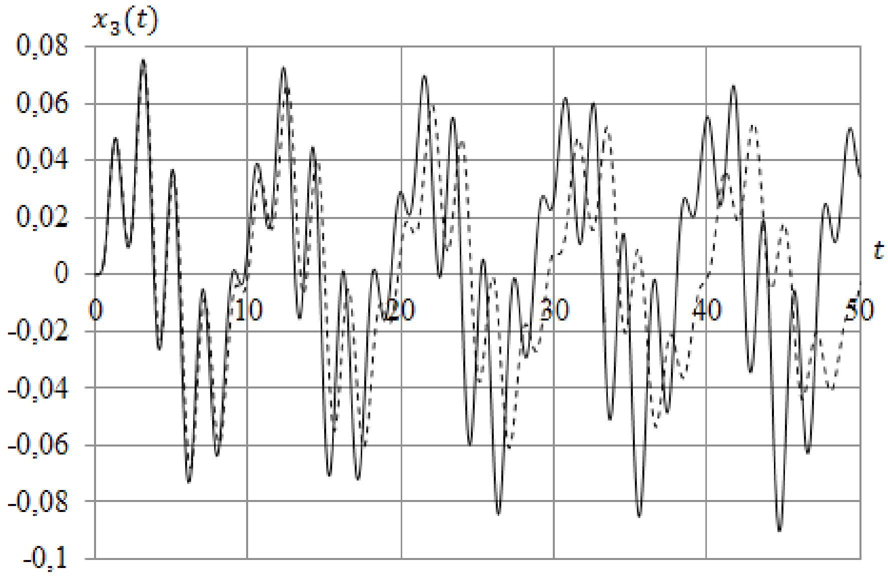

Figure 4. The form of vibration of the load with the mass

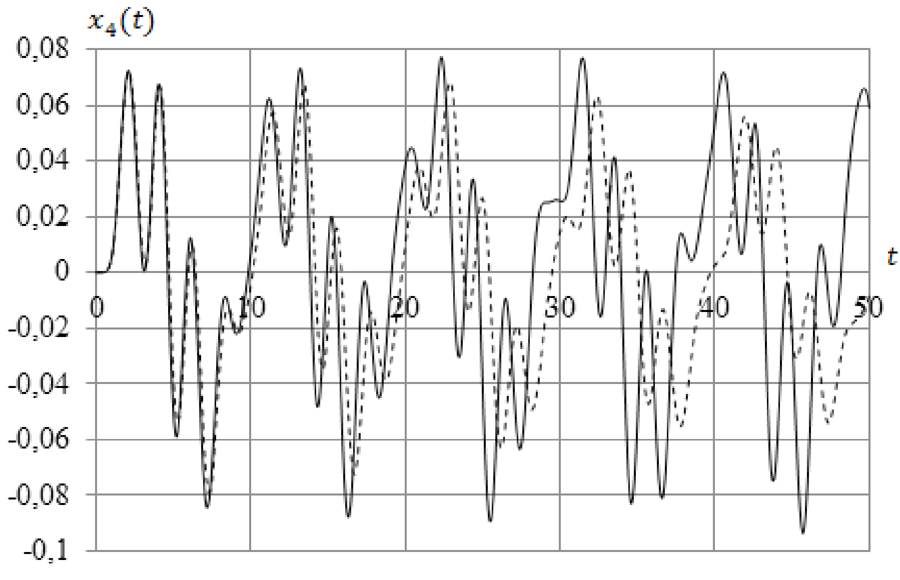

Figure 5. The form of vibration of the load with the mass

The solution of vibration damping problems is associated with the need to carry out multiple calculations in the process of optimising the parameters of the dampers. Therefore, in a number of cases, it is advisable to carry out preliminary calculations using simplified design schemes to determine the approximate efficiency and parameters of the vibration protection system. The use of schemes that allow obtaining a solution in a closed form or using algorithms like (4) is of great interest. It is these capabilities that are provided by a significant part of this work, not to mention, of course, those cases when the design scheme of the structure is directly reflected by the hereditary deformable models considered here. The results obtained allow us to conclude that it is advisable to use a dynamic damper to reduce the amplitude of oscillations in both ideal elastic and hereditarily deformable systems during transient processes.

References

[1] Uzdin A.M. Fundamentals of the theory of seismic resistance and earthquake-resistant construction of buildings and structures. St. Petersburg: VNII, 1993, p. 178.

[2] Birbraer A.N. Calculation of structures for seismic resistance. SPb.: Nauka, 1998. p. 255.

[3] Gordeev B.A., Filatov L.V., Ainbinder R.M. Mathematical models of vibration protection systems. Nizhny Novgorod, NNGASU, 2018. p. 168.

[4] Bondar N.G. Non-linear stand-alone systems of structural mechanics. M.: Stroyizdat, 1972, p. 128.

[5] Bondar N.G. Oscillations of nonlinear conservative systems with several degrees of freedom. M.: PM, 1967, vol. 3, issue 5, pp. 1–8.

[6] Ilyushin A.A., Ogibalov P.M. Quasilinear theory of viscoelasticity and the small parameter method. Mechanics of polymers, 1962, No. 2, pp. 170–189.

[7] Kauderer G. Nonlinear mechanics. M.: Mir, 1961, p. 778.

[8] Aldoshin G. T. Theory of linear and nonlinear oscillations. St. Petersburg, Publishing house LAN, 2013, p. 320.

[9] Badalov FB, Eshmatov Kh., Yusupov M. On some methods of solving systems of integro-differential equations encountered in viscoelastic problems. M.: PMM, 1986.

[10] Abdullaev Z., Yusupov M., Mirzaev S., Noraliev N.,Kusharov Z. Dynamic dampers of vibrations of inherited-deformable systems with finite number of degrees of freedom. International Conference on Materials Physics, Building Structures and Technologies in Construction, Industrial and Production Engineering (MPCPE 2020) 27–28 April 2020, Alexander and Nikolay Stoletov Vladimir State University, Vladimir, Russian Federation.

[11] Yusupov M., Rahkmankulova B., Ziyaeva Sh., Kushaev A. Vehicle oscillation taking into account the rheological properties of the suspension. International Conference on Materials Physics, Building Structures and Technologies in Construction, Industrial and Production Engineering (MPCPE 2020) 27–28 April 2020, Alexander and Nikolay Stoletov Vladimir State University, Vladimir, Russian Federation.

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USING IT IN PRESERVING THE CULTURAL HERITAGE OF THE SILK ROAD (EXPERIENCE OF UZBEK-POLISH COOPERATION IN THIS DIRECTION)

Abstract

This article is devoted to the Uzbek-Polish cooperation on the use of information technology in the preservation of cultural heritage sites of the Great Silk Road. Since 2015, specialists from the Lublin University of Technology and the Samarkand State University have been working together to use information technology to preserve the cultural heritage of Samarkand. Over the past 6 years of joint work, the project participants scanned 60 items. storage of museum items stored in the scientific and practical museum-laboratory of SamSU, the museum of the history of the city's foundation on Afrasiyab and the State Museum of the history of culture of Uzbekistan, 5 architectural monuments of Samarkand, the volume of which is more than 200 GB. 3 scientific seminars, 2 International scientific conferences, 2 photo exhibitions were held, 20 scientific articles and 18 popular science articles were written and published, developed and exhibited on the Internet online portal silkroad3D.com. Within the framework of this project, the Lublin University of Technology developed a new project and applied to the Polish National Agency for Academic Exchange (NAWA) to provide funds for the 3D Digital Silk Road project. In addition to the Lublin University of Technology (LUT), 4 more university partners from Uzbekistan are participating in the project.

Keywords: Silk Road, information technology, cultural heritage, 3D scanning, museum items, architectural monuments, International conference.

1. Introduction

Samarkand, located in the centre of the Great Silk Road, is a city with rich history where many objects of cultural heritage can be found. These are archaeological, architectural, monumental heritage sites, as well as many museum items stored in the funds of Samarkand museums. Today, according to official data, there are 1607 cultural heritage sites in the Samarkand region, of which 992 are archaeological, 537 are architectural and 78 are monumental. In addition, the collections of more than 40 museums contain about 500,000 archaeological, ethnographic, photo-documentary, art history and other types of museum items. The study, preservation and promotion of these cultural heritage sites is one of the most important tasks of cultural policy. For these purposes, a lot of work is being done in the country by local, republican and international organisations. Much attention in this direction is paid by the state of the Republic of Uzbekistan. In recent years, a number of documents have been adopted on the preservation and promotion of cultural heritage in Uzbekistan.

Since the emergence and development of Information Technologies in the 21st century, many cultural institutions began to use these new technologies in their work on the preservation and use of cultural heritage sites.

The first work in this direction in the museums of Samarkand began in 2005 by digitising museum items stored in the collections of museums and photographing archaeological and architectural monuments. And in 2008–2012, about 16,000 storage units of glass photographs of negatives were digitised, which had been filmed in the 1920–40s during the scientific expedition of the museum staff to the regions of the republic, to replenish their stocks.

In addition, in 2012, the first 3D virtual tour of the museum of Mirzo Ulugbek was created in the republic, and in 2014 a 3D multimedia film was created for the wall painting of the Afrosiyab museum. Work has begun on the creation of a 3D tour of the State Museum of the History of Culture of Uzbekistan, the Samarkand Regional Museum of Local Lore and the Museum of the History of the City on Afrasiyab and others. The relevance of the use of IT in the preservation and use of cultural heritage is growing from year to year. Thus today there is no sphere where IT is not used, including in the sphere of culture and architecture. In the development of the use of IT in the preservation and accessibility of cultural heritage sites of Samarkand and Uzbekistan, a special role is played by the Uzbek-Polish cooperation, which in a short period has produced remarkable results.

The cooperation began with the arrival in Samarkand in August 2014 of representatives of the staff of the Lublin University of Technology, Marek Miłosz and Elżbieta Miłosz, and their meeting with Rahim Kayumov, employee of the scientific-practical museum-laboratory of SamSU. During the meeting, Marek Miłosz spoke about the work of Polish specialists in the use of IT in the preservation and promotion of cultural heritage sites in Poland. After that, Rahim Kayumov informed the guests about the cultural heritage objects in the Samarkand region and offered to cooperate in this direction.

Marek Miłosz, upon his arrival in Poland, informed his colleagues about the meeting in Samarkand and gathered a team of professors, M. Miłosz, J. Montusiewicz and associate professor J. Kęsik, to develop a project on joint work of the Lublin University of Technology and Samarkand State University in the field of applications of information technology in the preservation of cultural heritage.

2. State of the use of IT in cultural heritage sites in Samarkand

As indicated in the Samarkand region, there are numerous museums and objects of cultural heritage in Uzbekistan, which are of world and republican importance.

In Samarkand, among the numerous monuments of cultural heritage, architectural monuments of the Temurid period, when Samarkand was the capital of Temur's empire, are of particular importance. Many architectural structures have survived here until today, such as the Amir Temur Cathedral Mosque (Bibi-Khanim Mosque), the Guri-Amir Mausoleum, the ensemble Shakhi-zinda, Mirzo Ulugbek madrasah on Registan, Ulugbek observatory, Rukhobod, Ishrat-khon, Ak-Saray, Khoja Abdi Darun and Khoja Abdi Berun mausoleums and many others. Over the past century, these architectural objects have been restored and improved and now proudly feature as tourist destinations. Even though in museums some work is carried out on the use of IT, in architectural monuments not enough of such efforts are done. Work on the monuments is carried out mainly by travel companies and has only informational purposes for the development of tourism.

However, the institutions involved in the conservation and use of cultural heritage sites themselves do not use IT in their work. Therefore, in the course of fulfilling the task facing our joint project and the scientific expedition, more attention was paid to the architectural monuments of the Temurid period. Out of 3 scientific expeditions on 3D scanning of cultural heritage objects of Samarkand, 2 expeditions were devoted to scanning these architectural monuments. Scanned architectural monuments on a laser scanner make it possible to deeply study the state of these monuments, save the data obtained as a result of 3D scanning for monitoring their state, as well as for studying, analysing and preparing a proposal for the restoration of these objects. In addition, such work is carried out for the scientific study of architectural monuments, the impact of natural phenomena on their safety, for the popularisation of these objects through the Internet or for the possible virtual restoration of some monuments which have as yet not been restored to their original form.

Therefore, the participants of the joint project on 3D digitisation of cultural heritage sites of the Silk Road in Uzbekistan and Samarkand paid more attention to the more relevant and popular objects, which are architectural monuments of the 14^{th}–15^{th} centuries. Over the past period, the project participants have carried out certain work in this regard and have achieved tangible results, which we will talk about some more in this article.

3. Uzbek-Polish cooperation in the use of IT in the preservation and presentation of cultural heritage

According to the agreement "On cooperation" between the Samarkand State University and the Lublin University of Technology in 2015, the employees were asked to study and use information technology in preserving the cultural heritage of the Silk Road in this region, in particular Samarkand and Uzbekistan.

For preliminary work, at the request of Polish partners, at the end of 2014 Rahim Kayumov filmed and sent to Poland several photographs of museum items from the museums of SamSU and the Afrosiyab Museum for processing in 3D. The results of this joint work were published in 2015–2016 in 7 scientific articles.

After the signing of the agreement "On cooperation" in May 2015, work on the development of a joint project intensified and a specific action plan was developed in preparation for the implementation of this project. According to this plan, the parties in the first stages were to get more closely acquainted with the conditions and capabilities of each other. For this purpose it was necessary to organise scientific trips to visit each other. Thanks to the Erasmus+ programme such an opportunity arose in 2017, which, according to the application of the Lublin University of Technology, allocated a travel grant to 2 employees.

The first trip of representatives of Samarkand State University to Lublin took place in May 2017, where they got acquainted with the work of their partners and were familiarised with further work, as well as the work plan of the project. In addition, they visited the historic sights of Lublin and participated in a scientific seminar at the Lublin University of Technology.

The return trip and the first scientific expedition of the staff of the Lublin University of Technology to Uzbekistan took place in May-June 2017. During the first scientific expedition, Polish specialists scanned objects of cultural heritage in the scientific and practical museum-laboratory of SamSU and the museum of the history of the city of Afrasiyab. As a result, about 60 storage items were scanned, hujra interior and others. The total volume of scanned materials was 75 GB.

Figure 1. 3D scanning with the use of the FARO scanner, 2018, Samarkand, Uzbekistan, photo: J. Montusiewicz

In addition, they got acquainted with the architectural monuments and sights of Samarkand and the city of Shakhrisabz, Kashkadarya region. While familiarising themselves with the architectural monuments of Samarkand, the guests also studied the possibilities of further work on these architectural structures with laser scanners, i.e. scanning these monuments.

Specialists of the Lublin University of Technology also held a seminar for students and teachers of SamSU on the topic "Preparation and submission of scientific grants", "Using IT in the preservation of cultural heritage", "From the experience of LTU in 3D scanning of cultural heritage objects" and others.

After the first expedition, all scanned museum items were processed in the laboratory of the Lublin University of Technology and displayed on the website of this university.

The second expedition of specialists from the Lublin Technological University to Uzbekistan and Samarkand took place in May-June 2018, where they worked mainly in the architectural monuments of Samarkand, such as the Registan ensemble, the Gur-Emir mausoleum, the Shakhi-zinda ensemble, the Ulugbek observatory and the wall paintings of the Afrosiyab museum.

At the request of the leadership of the Registan ensemble, the expedition members scanned the entrance portal of the Sher-Dor madrasah in the form of an arch where a lion and a lamb made of multi-coloured building glazed materials are depicted on an area of 105 m^2. This work was carried out to prepare and develop a proposal for the restoration of this entrance portal of the madrasah, which was restored in the 1970s and began to dilapidate at the beginning of the 21st century. Therefore, the entrance portal is stretched with a metal mesh for the safety of visitors to this object. The total volume of captured and scanned objects during the 2nd scientific expedition was 100 GB.

During this expedition, they also organised a scientific and practical training seminar at SamSU with the receipt of a certificate, where the results of the first scientific expedition and joint work of LTU and SamSU were demonstrated. In addition to specialists from SamSU, the training seminar was also attended by specialists from SamGASI, State Museum-Reserve, the Registan ensemble, MITSAI, artistic expertise, the regional A. S. Pushkin library and others.

The guests from Poland also presented to the management of SamSU and the State Museum-Reserve compact disks with the results of the work of the first scientific expedition, when museum items of the SamSU and Afrasiyab museums were scanned.

The term of the agreement "On cooperation" between LUT and SamSU was extended for an unlimited period.

This time the guests visited and got acquainted with the sights of ancient Bukhara and Gijduvan.

Since 2018, the Samarkand State Museum-Reserve and the Registan Ensemble have joined this project, after which the scope of the project has expanded.

In May 2019, the 3rd scientific expedition of the Lublin University of Technology to Central Asia took place, which was divided into 3 parts.

The first stage of the third expedition was in Kyrgyzstan on May 13–17, 2019, where employees of the Lublin University of Technology – members of the expedition Professor Jerzy Montusiewicz, Dr Marek Miłosz and Dr Jacek Kęsik – scanned the Burana minaret tower and the ruins of the mediaeval (10th-12th century) city of Balasagun near Bishkek, the capital of Kyrgyzstan. In addition, they scanned rock paintings – petroglyphs in the city of Cholpon-ata. This work was carried out as an experiment, since this was the first time such work with the ancient settlement and the rock art was carried out.

The second stage of the 3rd scientific expedition of the Lublin University of Technology to Central Asia was the city of Tashkent, the capital of Uzbekistan. Here on May 17–19, 2019, the members of the expedition Professor Jerzy Montusiewicz, Dr Marek Miłosz and Dr Jacek Kęsik scanned artefacts at the National Museum of the History of Uzbekistan. Perhaps the most interesting artefact in this museum is a stone sculpture – an altar depicting Buddha surrounded by praying monks. The stone Buddha dates back to the 1st–3rd centuries and was found in the Fayaztepa region near the city of Termez. During the expedition, a 3D scan of 32 museum items was carried out and more than 30 GB of data were obtained.

The expedition members also took part in a seminar at the Academy of Sciences of Uzbekistan. The topic of the seminar was "3D technologies in cultural heritage". During it, the technologies used during the expeditions of the Lublin University of Technology, as well as the results and contribution to the popularisation of the Central Asian regions through a multimedia exhibition were presented. The portal "3D Digital Silk Road" (silkroad3d.com) was also introduced.

The third stage of the 3rd scientific expedition of the Lublin University of Technology to Central Asia took place on May 20–25, 2019 in the city of Samarkand. The main task of the expedition members was to hold an International Conference and scan stalactites – decoration of Registan mosques and historical costumes of the 19th century – from the stock of the State Museum of the History of Culture of Uzbekistan.

4. The results of the Uzbek-Polish cooperation in the use of IT in the preservation and presentation of cultural heritage

In October 2018, on the premises of the Lublin University of Technology, an International Scientific and Practical Conference on the topic "The Use of IT in the Management of Cultural Heritage" was held, and 8 representatives from Samarkand took part. The conference was organised by the Lublin University of Technology, the Zamoyski Museum in Kozłówka and the Lublin branch of the Polish Information Society. The conference was held under the honorary patronage of Prof. dr hab. inż.

Piotr Kacejko – the rector of the Lublin University of Technology, Marshal of the Lublin Voivodeship, the Lublin Scientific Society and the Year of European Cultural Heritage. Media patronage was provided by the regional Polish television TVP3 Lublin, the monthly *Forum Akademickie* and the Polish Radio Lublin.

Figure 2. Participants of the conference in Lublin, Poland, 2018, photo: J. Montusiewicz

The conference participants were employees of many museums of the Lublin and Subcarpathian regions, directors of the main museums of Samarkand (Uzbekistan): the Registan ensemble, the Afrasiab Museum, the Mirzo Ulugbek Museum, the Gur-Emir mausoleum, the Khoja Doniyor mausoleum, as well as researchers of the Samarkand State University, the National University of Uzbekistan and Institute of History of the Academy of Sciences of Uzbekistan, employees of the archeological company "Archee" and cultural institutions from Lublin, as well as the Brama Grodzka Centre.

The conference was aimed at familiarisation with the experience of using information technologies in the management of cultural heritage, deepening contacts of Polish museum workers with representatives of museums in Samarkand and Uzbekistan as well as discussion with colleagues of the experience of the Lublin museums in the field of archeology.

The programme included 15 papers presented by authors from Poland and Uzbekistan. The first group of questions related to the discussion of existing IT systems, standards and software that allow managing certain areas of cultural heritage and museology. In the second group of questions, the guests from Samarkand presented the specifics of their museums and architectural monuments, and also discussed the state of the collections stored in them, taking into account the computer technologies used. The third group included presentations of the staff of the Institute of Computer Science, where they presented the results of the 1st and 2nd expeditions of the Lublin University of Technology to Central Asia in order to conduct three-dimensional archiving of artefacts from the collection of museum collections in Uzbekistan, using the technology of "reverse engineering", 3D scanning of large architectural objects, their digital representations in the Internet and the reality of the virtual world (VR), as well as an exhibition of 3D technologies dedicated to museology and archeology at the Laboratory 3D of the Institute of Computer Science.

The last group included presentations of the excavations in Świętoduska Street in Lublin, carried out in the 2017 season by Archee, taking into account the computer 3D technologies used to archive the state of the excavations.

The guests from Uzbekistan also presented issues related to the historical heritage of the Silk Road on the example of Samarkand, with the possibility of preparing a future digital exhibition available on the Internet using three-dimensional models developed by the staff of the Institute of Computer Science. The last work of this group concerned the intangible cultural heritage, that is a study of the fate of the Poles deported to Uzbekistan during the Second World War.

In addition to the conference, a mini-seminar was organised for guests from Uzbekistan in the following days at the Lab 3D laboratory, where computer 3D technologies were presented that can be successfully used for archiving and visualisation of museum and archaeological sites.

Structural light scanners were presented (Artec Eva and Spider; laser scanner Faro Focus X330, 3D printers using FFF technology – MarketBot Z18 and SLS-DWS 020X, specialised 3D monitor zSpace, VR helmets: Oculus Rift DK2, Samsung VR Gear and a system for human-computer communication in Leap Motion. A practical addition to all this was a visit prepared by Anna Fitz-Lazor, director of the Zamoyski Museum in Kozłówka.

The conference is clear evidence that interdisciplinary research is being carried out at the Lublin University of Technology, combining culture, archaeology, museology and technical sciences. It is also a significant contribution of the university to the so-called 3rd mission of universities or their contribution to the development of society in Poland and around the world.

Within the framework of the conference, an agreement was implemented and concluded for the preparation of recommendations for calculating the volume of dilapidation and restoration of the façade building materials of the entrance portal of the Sher-dor madrasah at the Registan ensemble.

In November 2018, the International Institute for Central Asian Studies (IICAS), operating under the auspices of UNESCO, organised in Samarkand the International

Scientific Conference "Afghanistan, Central Asia and Iran – Common Heritage Along the Great Silk Road and Corridors from Europe to Europe". Among those invited were the participants of our project, guests from Poland, the Dean of the Faculty of Electrical Engineering and Computer Science – Professor Henryka D. Stryczewska and employees of the Institute of Computer Science – professors Jerzy Montusiewicz and Marek Miłosz.

The conference was devoted to the issues of protection and access to the cultural heritage of the Silk Road and ancient cities, caravanserais, irrigation systems and others. The Silk Road is a caravan road about 12,800 km long from China to Europe. During the conference, participants presented the results of their research at the intersection of the Silk Road, coexisting cultures in the fields of architecture, ornament and music. In the course of numerous discussions, it was proposed to organise a travelling exhibition of objects stored in museums in different countries.

At the conference, the project participants presented a report "3D scanning of artefacts of the Samarkand Museum. Polish-Uzbek international cooperation." As the speakers noted, the Polish-Uzbek project in the field of scanning small museum objects, as well as architectural monuments, has been operating in Central Asia (Uzbekistan and Kazakhstan) since 2017. At the moment, during two expeditions, the project participants have collected about 200 GB of data, from which several dozen digital 3D models have been built. During the presentation, the speakers presented reverse engineering technologies (equipment, programs, post-processing) that allow to create digital 3D models, as well as typical museum objects that can be enlarged and reduced, as well as rotated in space when viewed on a monitor.

In addition, the generated panoramas of omnidirectional interiors of objects, when installed on smartphones, placed in special glasses, allow to immerse a person in virtual reality. The demonstration came as a big surprise to the conference participants and it became clear that the digital 3D world was not yet familiar in the field of museology. The speakers suggested considering the possibility of creating an interactive 3D digital exhibition presenting the cultural heritage of the Silk Road route called Digital Silk Road. Such a solution would be much more mobile and accessible for people interested in the subject (including people with disabilities), and would become a kind of patronage, encouraging personal visits to selected sites and a travelling exhibition created under the auspices of UNESCO.

During the 3rd scientific expedition in Samarkand on May 22, 2019, the International Conference "Information Technologies in the Management of Cultural Heritage" was held at the Ulugbek madrasah on the Registan. The conference was organised by the Lublin University of Technology, Samarkand State University, the Registan ensemble and the International Institute for Central Asian Research "IICAI").

Scientists from the USA, Great Britain, Germany, France, Russia, Kazakhstan, Kyrgyzstan, Uzbekistan and Poland took part in the conference. The guests of the conference were the Ambassador of the Republic of Poland to Uzbekistan Piotr

Iwaszkiewicz, the deputy khokim of the Samarkand region (Rustam Kobilov), the rector of the Samarkand State University (Rustam Khalmuradov) and the director of IICAI Dimitri Voyakin.

During the conference, the Ambassador of the Republic of Poland to Uzbekistan Piotr Iwaszkiewicz presented on behalf of the Council of the Institute of Computer Science of the Lublin University of Technology the nomination of the Programme Council members of the Digital 3D Silk Road portal (silkroard3d.com).

On August 26, 2019, Samarkand hosted an international conference on the topic "Preservation of tangible and intangible heritage: current problems and strategies for their solution", where the participants of the joint project made reports: Marek Miłosz – "ICT in the preservation and popularisation of cultural heritage – the experience of the Polish-Uzbek cooperation" and Rahim Kayumov –" The use of information technologies in the museums of the city of Samarkand".

In 2019, the Lublin University of Technology applied to the Polish National Agency for Academic Exchange (NAWA) to provide funds for the 3D Digital Silk Road project. In addition to the Lublin University of Technology (LUT), 4 other university partners from Uzbekistan are participating in the project.

The project manager, Elżbieta Miłosz, is an employee of the Faculty of Computer Science, her assistants are 4 coordinators from each university.

The goal of the project is to conduct research work in the field of digitisation of cultural heritage monuments of the Great Silk Road in Uzbekistan, as well as organise scientific expeditions by specialists of the Lublin University of Technology in cooperation with partners from Uzbekistan and disseminate research results through international scientific conferences, workshops, monographs and an online portal silkroad3D.com.

The main objectives of the project include: organisation of 4 scientific expeditions to 4 cities of Uzbekistan for 3D scanning of cultural monuments; processing the received data, preparing digital panoramas and 3D models and posting them on the silkroad3D.com website; organisation of 2 international conferences (one in Poland, the other in Uzbekistan); organisation of 2 photo exhibitions in Poland; training of scientific personnel from universities of Uzbekistan in the field of using 3D technologies in museology (2 training sessions in Poland); preparation and publication of a joint scientific monograph in Poland; as well as support and development of the silkroad3D.com website in three languages: English, Uzbek and Russian.

Figure 3. Participants of the conference in Samarkand, Uzbekistan, 2019, photo: J. Montusiewicz

On July 16–17, 2020, the International Scientific Conference on the topic "Samarkand State University – the successor of the Ulugbek madrasah", organised by Samarkand State University, took place remotely. The conference was held within the framework of the celebration of the 600th anniversary of Samarkand State University.

More than 200 participants from all over the world took part in the conference. In addition to the official speeches of Uzbek ministers and rectors of universities cooperating with Samarkand State University, more than 40 scientific reports were read.

During the conference, the participants of the joint project, teachers of the Department of Computer Science of the Lublin University of Technology made the following presentations:

1. Marek Miłosz, Rahim Kayumov. Building digital bridges between mediaeval history and the present with the help of ICT as a result of Polish-Uzbek cooperation.
2. Jerzy Montusiewicz, Marcin Barszcz, Krzysztof Dziedzic, Samariddin Mustafokulov: Photorealistic 3D digital reconstruction of a clay jug from Afrasiab.
3. Elżbieta Miłosz, Dilbar Mukhamedova, Honkul Samarov: The 3D Digital Silk Road Project – Digitisation of Silk Road Cultural Monuments in Uzbekistan.

Today, despite the quarantine to do with the Covid pandemic, 19 project partners are doing a lot of work to fulfil the tasks ahead of the project. In view of the situation, the sponsors agreed to extend the project for another 1 year. Despite this, the project manager developed a working plan for the implementation of the tasks within the project, with some adjustments made due to the unforeseen sanitary circumstances.

5. Conclusions

Based on the above, the following conclusions can be drawn from the work of the Uzbek-Polish cooperation in the field of using IT in the study, preservation and promotion of cultural heritage.

1. As a result of joint Uzbek-Polish cooperation, many museum items and architectural memorials of Samarkand have been digitised. This work has already produced its results and continues to do so.
2. To develop the efficiency of work and enhance the results of scientific research, the circle of participants in the project was expanded directly with the organisations of cultural heritage, such as the Samarkand State Museum-Reserve, which manages all the museums and architectural monuments of the Samarkand region and the Registan ensemble.
3. The significance of this project has gone beyond the framework of 2 universities (LUT and SamSU) and involves museums as well as architectural and archaeological monuments from other regions of Uzbekistan and Central Asian states (Kazakhstan and Kyrgyzstan).
4. Thanks to this project, the scanned objects of cultural heritage are displayed on the websites and access to these objects is possible via the Internet.
5. Within the framework of the project, the participants published more than 20 scientific and 18 popular articles in various publications, organised 3 photo exhibitions, held 2 International conferences and 4 seminars.
6. Based on the results of the work of Polish specialists who prepared measurements and calculations of the dilapidation of the façade building matrials of the entrance portal of the Sher-dor madrasah as well as a draft proposal for the restoration of this object, which, without the participation of Polish specialists, would have cost the Registan ensemble about 450–500 million soums or 50 thousand dollars.
7. Studying the experience of Polish specialists within the framework of the project at the scientific-practical museum-laboratory of SamSU, the site sammuseum.uz was developed, which contains information about the museums of the Samarkand region and 3D virtual excursions of 4 museums.
8. Within the framework of the project, today the silkroad3D.com portal is successfully operating in 4 languages, where information about the progress of the project as well as the Uzbek-Polish cooperation is displayed.
9. Some foreign museums and objects of cultural heritage are interested in this project, the issue is being studied and negotiations carried with specialists from these countries.
10. The nature of the project can be not only scientific, but also practical, for which it is necessary to train specialists in this area.
11. This project also gave the opportunity and confidence to widely use IT in all aspects of the work of museums and cultural heritage sites.

12. Taking into account the interest of the country's leadership in the digitisation of various spheres of life, especially objects of cultural heritage that give opportunities for the development of tourism, it is necessary to prepare various methods.
13. Within the framework of the project, it is possible to arrange work on the production of copies of museum items as souvenirs for guests and tourists of cultural sites.

Acknowledgments

As employees of SamSU we would like to thank the Polish National Agency for Academic Exchange (NAWA) for the support of our project and the allocated funds, which will allow the continuation of our joint cooperation in the use of IT such as 3D scanning in the preservation of the cultural heritage of the Great Silk Road. This article was also supported by the Polish National Agency for Academic Exchange (NAWA) under Grant No. PPI/APM/2019/1/00004 entitled "3D DIGITAL SILK ROAD".

References

[1] M. Miłosz, J. Montusiewicz, R. Kayumov 3D computer technologies as a tool of modern archeology. *Vestink Kaznu im. Al-Farabi*, Series: Mathematics, Mechanics and Informatics. 2015, vol. 86, no. 3, pp. 181–190.

[2] J. Kęsik, J. Montusiewicz, R. Kayumov Proposal of a methodology for remote access to source materials for 3D scanning of museum items using SFM. EDULEARN 15: 7th International Conference on Education and New Learning Technologies, Barcelona (Spain), July 6–8, 2015: *Conference proceedings* [WOS]. 2015, pp. 1831–1840.

[3] J. Montusiewicz, Z. Czyż, R. Kayumov Selected methods of creating three-dimensional virtual models of museum ceramics. *Applied Informatics*. 2015, vol. 11, no. 1, pp. 1–16.

[4] J. Montusiewicz, M. Miłosz, R. Kayumov Digital 3D technologies in practical exercises for archaeologists. INTED 2016: 10th International Conference on Technology, Education and Development INTED, March 6–9, 2016, Valencia, Spain: conference proceedings [WOS]. 2016, pp. 7451–7458.

[5] J. Kęsik, J. Montusiewicz, R. Kayumov Approach to computer reconstruction of museum exhibits. *Achievements of Science and Technology* Journal. 2017, vol. 11, no. 2, pp. 87–94.

[6] J. Montusiewicz, M. Barszcz, S. Skulimowski, R. Kayumov, M. Buzrukov The concept of an inexpensive interactive and playful virtual exhibition. INTED 2018: 12th International Conference on Technology, Education and Development [WOS]. 2018, pp. 353–363.

[7] J. Montusiewicz, M. Miłosz, J. Kęsik, R. Kayumov Interdisciplinary Technologies for Virtual Museum Creation – the Case of Archaeological Museum Development. INTED 2018: 12th International Conference on Technology, Education and Development [WOS]. 2018, pp. 326–336.

[8] J. Montusiewicz, M. Miłosz 3D-scanning of artifacts of the Samarkand Museum – Polish-Uzbek international cooperation". International scientific conference "Afghanistan, Central Asia and Iran – common heritage along the Great Silk Road and corridors from Europe to Europe." Samarkand 2018.

[9] M. Miłosz ICT in the preservation and popularisation of cultural heritage – the experience of Polish-Uzbek cooperation. International conference "Preservation of tangible and intangible heritage: actual problems and strategies for their solution". Samarkand 2019.

[10] R. Kayumov "The use of information technologies in the museums of the city of Samarkand". International conference "Preservation of tangible and intangible heritage: current problems and strategies for their solution". Samarkand 2019.
[11] M. Miłosz, E. Miłosz, J. Montusiewicz Determination of the color surface area of ceramic tiles on the mediaeval mosaic of Sher-Dor madrasah in Samarkand – problems and solutions. Digital applications in archeology and cultural heritage. 2020, vol. 16, pp. 1–6.
[12] M. Miłosz, S. Skulimowski, J. Kęsik, J. Montusiewicz Virtual and interactive museum of archaeological artifacts from Afrasiab – an ancient city on the Great Silk Road Digital applications in archeology and cultural heritage. 2020, v. 18, pp. 1–12.
[13] M. Miłosz, R. Kayumov Building digital bridges between medieval history and the present with the help of ICT – the result of Polish-Uzbek cooperation. International scientific conference on the topic "Samarkand State University – the receiver of Ulugbek madrasah". Samarkand 15–16 July 2020.
[14] J. Montusiewicz, M. Barszcz, K. Dziedzic, S. Mustafokulov Photorealistic 3D digital reconstruction of a clay jug from Afrasiab. International scientific conference "Samarkand State University – the receiver of Ulugbek madrasah". Samarkand 15–16 July 2020.
[15] E. Miłosz, D. Mukhamedova, H. Samarov: 3D Digital Silk Road Project – Digitisation of Silk Road Cultural Monuments in Uzbekistan. International scientific conference "Samarkand State University – the receiver of Ulugbek madrasah". Samarkand 15–16 July 2020.

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A NEW VIEW ON THE USE OF MODERN EDUCATIONAL TECHNOLOGIES IN EDUCATION (3D AS A FACTOR IN THE EFFECTIVENESS OF EDUCATION TECHNOLOGY)

Abstract

Management of 3D educational technology programmes allows students of any level to actively participate in the learning and cognitive process and demonstrate their ideas at a high level. Ultimately, lessons can be conducted at a high level of complexity that includes questions that are interesting and understandable to all. This article directly provides practical assistance in the development of students' learning skills and increase their creative activity through the introduction of modern educational technologies in the educational process.

Keywords: 3D-images, 3D-learning technologies, competence, Crocodile biologics program, Crocodile Technology program.

1. Introduction

Today, the education sector in Uzbekistan can be described as the most important area of innovative change. There is no doubt that the quality of education in the republic will rise to a higher level if the basis for such changes is the development of non-standard approaches in the educational process. One of the urgent issues is the introduction of 3-D educational technologies in the educational process, both at its fundamental level and as continuity at all levels of public education.

As the famous mathematician G. Birkgoff said in 1969: "... we can predict the growing competition between man and machine, in which each participant performs a task." E. Mamford said about this in 1972: "There is a growing intellectual recognition of the human-machine appearance in all systems ...". In education, this means that in a computerised society, the purpose of teaching is determined in relation to the student, his or her computer software, as well as his or her ability to use it in teaching and learning. Thus, a new object of learning, i.e. a student-computer tandem has entered. The cognitive dissonance caused by computer interaction with the student can serve to activate the student's cognitive process [1], (Mukhamedov, & Makhmudova, 2020).

The preparation of special assignments in order to create a basis for inductive mental inference, designed to use the computer and all its capabilities, is a complex methodological problem. Its clear solution by the speaker or the author of the textbook provides fundamentally new opportunities in activating in students the process of independent learning and leads to the formation of a creative personality. Like any other technology, the 3-D learning technology is based on organising the student's cognitive activity. This, in turn, requires the widespread introduction of 3-D learning technologies into education. Modern educational policy is aimed at forming a new pedagogical paradigm of teaching and education, revealing the knowledge and creative potential of the individual, in which e-learning resources and e-libraries play an important role.

2. Materials and methods

The formation of basic and science-specific competencies of students on the basis of an integrative approach serves to express a general description of all social processes. In some sources, production technology is understood as a whole process defined by a period that includes the processes from the selection of raw materials to the delivery of a particular product to the consumer. But there are integrative and differential features of technologies in the educational process with technological processes in social life.

We will consider several ways to use 3D models in school education practice [2] (Fomin, 2005):

- use in conducting complex topics and lessons;
- special technologies for development (for example, the development of creative abilities);
- health technologies (combining teaching with health improvement);
- Improving students' focus on the lesson, their absorption of the material.

In the process of sharing their experiences, the educators noted the following: "Initially, it was difficult for us to create 3D images and videos for laboratory classes. However, in the process, the difficulty was overcome by independent learning, and then by teaching students", and the following conclusions were drawn [3] (Ergasheva, 2018):

- The most important criterion for the use of innovation is students' demonstration of their abilities in the educational process, the proposed system allows them to develop and use 3D-images, videos and applications.
- 3D-technology essentially improves the learning process and expands the understanding of many areas: technology, chemistry, geography, biology, fine arts, drawing, etc., improves the process of teaching and deepening new knowledge acquired by students in the process of teaching [4], (Eshchanov, Matyakubov 2020).

With the help of virtual practical and laboratory assignments, training, film in 3D format, students will have the opportunity not only to master the theoretical material, but also to apply it in practice.

This is confirmed by the fact that these educational technologies are now being introduced into the natural sciences. These valuable devices help students to develop an interest in the subject of the lesson while revealing the essence of the structure and function of the digestive system. Working with three-dimensional images is very simple. It is necessary to wear eyeglasses to see the full depth and size of any model. To view digestion in 3D, students' attention should be focused on the joint functioning of all organs of the digestive system. The bite passes through the throat, oesophagus and digestive tract and enters the stomach. Once food enters the digestive tract, it undergoes a process of hydration and mechanical breakdown by digestive juices. In 3D, the teacher needs to show not only the size of the model, but also the anatomical structure of the organs at different angles, working with concepts, finding these terms in the textbook and recording them in a notebook, class control, drawing students' attention to them. To consider a cut stomach model, separate several layers: the inner layer is the mucous membrane layer, the moistening layer, as well as the submucosa. They serve to absorb certain substances, producing enzymes and gastric juice. The middle layer is the muscle layer. Its importance is to shrink the walls, grind and mix the food. The outer layer of the stomach is called the adventitious or serous membrane.

The mucous membrane consists of 3 layers: the epithelium, a special layer of connective tissue, and the muscular layers of the mucous membrane. During the description of the inner layer of the stomach, the teacher asks a problematic question about the importance of each layer, the interaction of the cells of each layer. Such questions are easy for students, each cell of the stomach model has a size, and using the 3D model of the stomach, it is clearly observed that one cell interacts with another cell. The stomach model is used by the teacher to check homework assignments and reinforce the material covered. Thus, the base serves as a synopsis in response to the 3D model of the stomach. In the 3D-learning process, the learner is a participant in the messages and receives a lot of learning information. The material described in this way is remembered faster than a traditional lesson, and as a result leads to a higher level of mastery of the science. It is possible to recommend several types of 3D technologies aimed at developing high quality teaching tools for a similar education system [3], (Ergasheva, 2018).

The education system based on the new pedagogical paradigm should, in particular, ensure the development of innovative and developmental teaching and learning methods aimed at revealing the knowledge and creative potential of the individual, developing human abilities for creativity. This will ensure that the younger generation prepares for the future in a timely and adequate manner [4], (Makhmudova, 2019).

It should be noted that the choice of software is an important factor in the successful formation of students' professional competence in the use of elements of 3D modelling technology [5], (Karakhonova, 2019). Therefore, it is expedient to characterise and introduce several types of it:

3. 3D Blender software

Another versatile freeware application for 3D modelling is the use of a 3D Blender-editor. The editor provides the ability to create models, animations, texting, lighting, recommends a variety of materials. The program interface is quite complex, but students learn 3D modelling in a modular way without unnecessary effort, which contributes to the consistent development of editing management skills. Many of the commands in the blender are done using keyboard alignment, so that students always have a "dictionary" of keyboard commands in their hands.

Blender for modelling supports many standard geometric shapes, Bizier curves, sculptural modelling, division surfaces, colouring of interactive edges, quick skeleton creation and much more.

In addition, Blender allows us to create animations. To do this, the program supports: skeleton animation, non-linear animation (and an editor for this), morphing, reverse kinematics, linking different frames, and more. This feature has not been used yet, but there is an opportunity to implement it in the future.

4. Crocodile biology program

The Crocodile biologics program is a powerful simulator that allows to model and monitor biological processes.

4.1. Crocodile Technology software.

This program allows students to take advantage of modern information technology in a deeper study of biology.

4.2. Crocodile Chemistry software.

Through the Crocodile Chemistry program, it is possible to study the properties of all vital processes that take place in living organisms. It is usually impossible to observe the vital processes that take place in the body (at the molecular level). Through this program it is possible to model processes, conduct various reactions and, most importantly, do it safely.

5. Conclusions

These modelling technologies cover not only the quality of education, but also the effective acquisition of knowledge by students at different stages of the education system.

A group of students who were actively involved in various competitions and research projects related to 3D modelling in the organisation of project activities were identified. Students should be able to use the knowledge they have acquired in the study of relevant subjects. Group and individual counselling is organised outside of class.

The results of working with the project will allow to determine the basic skills of 3D modelling and the basic level of their use in the relevant disciplines. Independent activity of students in the performance of design or research work is considered as a type of educational work that allows them to purposefully form and develop their independence in the process of solving tasks focused on practical work.

References

[1] Mukhamedov, G. I., & Makhmudova, D. M. (2020). On the Application of Information – Communication Technologies in the Development of Independent Creative Thinking of Youth. *International Journal of Psychosocial Rehabilitation*, 24(09), 468–478. https://www.psychosocial.com/article/PR290055/21298/

[2] Fomin G. (2005). 3D modeling [Text] / Per. from English. M.: Publishing house "Slovo".

[3] Ergasheva G. (2018). Improving the effective use of interactive software in biology education: Doctor of Pedagogical Sciences (DSc) diss. Abstract. Tashkent. NUU.

[4] Eshchanov B. Kh., Matyakubov K. K. (2020) Using of information and communication technologies in the teaching of the school Course in general physics. International Journal of Scientific & Technology Research, Vol. 9, Issue 02, , p. 4119–4124

[5] Makhmudova, D. M. (2019). Electronic educational resources as a new component of a traditional educational process. *Academia Open*, 1(1), June Education. https://press.umsida.ac.id/index.php/acopen/article/view/12/15

[6] Karakhonova, L. M. (2018). Electronic educational resources and biology educational process efficiency in general educational schools. *Eastern European Scientific Journal*, 5, p. 273–275.

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TRANSFORMATION OF HISTORICAL KNOWLEDGE OR REFLECTIONS ON "DIGITAL HISTORY"

Abstract

The past is analogue, the future is digital. Historians are creators of the future. This couple of the paper's conclusions aptly sums up the challenges and chances facing today's humanities, including historical investigation and dissemination. The study reviews the impact of the information revolution on the discipline of history, considering the novel methodology of recording, preserving and retrieving historic content.

Keywords: historical knowledge, digital history, information technology, QR code, smart tourism

The process of digitisation has influenced all aspects of life in the 21st century, with digital transformation in the last few years finding itself on one of the front burners. Digitisation creates a multitude of opportunities, while at the same time requiring a new mindset and preparedness for change. The new media context transforms historical science and art as well, the "digital history" apparently becoming a new professional reality where new ways of information storing, processing and research enter the everyday inventory of modern historical research [1].

Digital history is an absolutely new form of historical knowledge and is already quite widely represented both in the West and in Russia. Digital history is a modern name of a field that deals with theoretical and practical aspects of transferring records of historical and cultural heritage into the digital format with subsequent publishing of such digitisation results in the Internet [1]. It is not a linear narrative but a website, map or database allowing not only to present historical sources in a complete and accurate manner, but to find a non-hierarchical visual form of representation of different viewpoints, private and public matters, documents and memoirs.

The growth of digital technologies alters the ways historians practise their art. In the last twenty years historical practice has underwent a dramatic change. In the digital era historians gather, disseminate and preserve information differently, transferring historical sources and records to digital format. According to J. Frau, digital history focuses on the creation of new methods of digital document and artefact recording, preserving and retrieving; establishment of authenticity of the digital content; development of technologies allowing to transfer archive materials digitised in obsolete digital formats into newer formats and standards; facilitation of access to digitised data for physically or economically challenged users [2].

New digital tools in history have also changed historians' mindset, their viewpoint as to how such professionals can disseminate and apply their knowledge. A large amount of analogue historical records has, during the last decade, become digital. For instance, the Library of Congress American Memory Project presents over 8 million historical documents. The ProQuest historical newspapers offer full text versions of five major newspapers, including all issues of the New York Times and Los Angeles Times. Thomson Corporation's website dedicated to the 18th century's 33 million pages in the Internet features all significant names in English and foreign languages printed in Great Britain during this period [3].

This treasure of digital history represents an immense wealth for historians and offers extensive opportunities for online research and learning that would be unimaginable just several years ago. A beginner digital historian also finds another advantage here getting a set of model tests and approaches created by the first generation of digitisers that helps them transform historical documents to their own website more efficiently and with better reproductions.

Media, in particular visual ones have become as important historical source as chronicles and other archive documents. Digital era provides an opportunity to represent history not in its traditional form but as a website, mobile application, multimedia map, database, QR-code etc. Nowadays not only professional photographers and web-developers, but literally everyone with a digital gadget can document historical events and put them in the network with their own comments, making every user implicated in history. Thus, digital media do not simply reflect and construct, but co-create history.

The digital world is broader than the traditional one and encompasses larger groups of people, which means the events occurring right in front of our eyes are already being documented in a completely different manner. At the same time, we are getting a huge amount of accounts of new events, which creates a new methodological problem for a traditional historian, who becomes unable to process this kind of knowledge volume. The role of historians as narrators is supplemented by their becoming designers as well. A digital historian carries out virtual reconstruction of cultural heritage objects, development of large-scale Internet resources (online encyclopedias, atlases, dictionaries). "Another important field is building 3D representations of historical information on maps employing geographical systems" [4]. The current stage of development of digital technologies makes historical research an interdisciplinary matter combining geographical and quantitative analysis of data with historical sources.

Thus, a digital transit or digital transformation has taken place, and one has to be a hermit to stay unaffected by the digital civilisation. Not very long ago, historians themselves appeared to be such hermits avoiding new technologies and feeling themselves comfortable in the silence of reading rooms in libraries and archives. Extending the subject, it would be in order to reflect on the effect of new technological shifts not only on the course of history itself, but also on the historical knowledge transformation and the emergence of unavoidable novelties in historiography.

More often than not, professional historians are skeptical of any media representations of history. As a matter of fact, any historical material presented to the Internet audience requires scholarly interpretation and critical analysis, but on the other hand this allows the historical community to find common ground by discussing certain controversial historical subjects.

Historical knowledge is fundamentally based on reconstruction (that is to say, informational modelling). This is the reason professional aspects of a historical research in the "digital era" are defined by the examination of new opportunities of working with information sources. Digital history as an interdisciplinary field is increasingly gaining attention of historians worldwide, the main cause of that being the high-paced development of electronic resources and services that are becoming an unalienable part of the profession. On an everyday basis, historians turn to full-text online libraries, bibliographical catalogues and electronic archives of scholarly journals. In the last few years, these have actively been followed by online archive resources offering access to digitised documents, both written and audiovisual. Today we can notice that electronic resources often acquire significance and functions of their own, ceasing to be just digital copies of analogue documents.

It is already evident that "digital history" is becoming a professional reality where new ways of information storing, processing and researching are a part of a routine inventory of modern historical research.

At a certain moment, peculiar squares with unintelligible code started catching the eye on websites, ads, billboards and even on business cards. These squares are the so-called QR (or quick response) code, a two-dimensional bar code developed by Denso Wave, a Japanese firm. This tiny data carrier stores about 3000 bytes of text that encodes various information (website address, phone number, electronic business card, whereabouts etc.) consisting of symbols (including alphanumeric character and special symbols). One QR code can contain up to 7089 numbers or 4296 letters and is easily read with specialised applications (bar-code scanners) that are either pre-installed on smartphones or tablet PCs or can be easily installed. These applications are available free of charge for most existing devices and work under Android, Windows and iOS.

In our view, this new digital reality where younger generation lives and studies makes the creation of a history textbook in a QR-code format quite topical. Such a textbook would meet innovative learning demands and trigger students' interest to the educational process.

There are numerous options for using QR codes in historical education. One is attaching QR codes containing links to websites with interactive maps, videos and educational animation to a textbook's page. A QR code placed on a book cover or some other historical source may contain additional information about the author, serve as a link to the electronic version of the source or multimedia content accompanying the work (e.g. historical movie on the subject). QR code may help to quickly and easily convey to students, for instance, a recommended reading list along with links to electronic texts, thus creating a study resource with links to useful informational resources. QR codes come in handy when there is a lack of room and space, they can be used on informationally busy pictures such as genealogical trees of time scales. A student needs only to scan the needed QR code with his smartphone or tablet PC, click a link to the relevant multimedia content and instantly get the digital resource to work with on screen. QR codes are particularly convenient to use for independent work assignments (especially if assignments are cumbersome and contain a lot of text, illustrations, video and audio materials). Codes can be printed out and pasted in students' workbooks and notebooks. They also facilitate carrying our online polls among students during classes.

The above considerations bring us to the conclusion that the use of QR codes in historical education is both justified and affordable, as it does not incur additional expenses.

QR codes are very efficient in tourism development where they are used as part of signs placed on various historical and cultural sights, enabling tourists to instantly obtain information on every object bearing a QR code with their smartphones. QR code is aimed at the promotion of the country on the international tourism market as a SMART-tourism country.

Thus, transformation of historical knowledge via digitisation is a new format of representation of history as an educational and scholarly field.

The past is analogue, the future is digital. Historians are creators of the future. Consequently, they must be capable of interpreting, critically assessing and analysing each and every digitised source in order to create quality digital history.

References

[1] A. Volodin "Digital History: A Historian's Art in the Digital Era". https://www.academia.edu/20191534/ (in Russian).

[2] L. Borodkin Digital history: application of digital methods in preserving historical and cultural heritage. Digital media in preserving historical and cultural heritage. https://www.academia.edu/8493435/ (in Russian).

[3] Daniel J. Cohen, Roy Rosenzweig. Digital history. A guide to gathering, preserving and presenting the past on the web. http://chnm.gmu.edu/digitalhistory/digitizing/.

[4] E. Gmyzina. Representation of History in the Digital Media Era. https://cyberleninka.ru/article/n/reprezentatsiya-istorii-v-epohu-tsifrovyh-media (in Russian).

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CREATION OF A MODERN INTELLIGENT PLATFORM FOR THE PRESERVATION OF HISTORICAL MONUMENTS

Abstract

Historical monuments play an important role in the study of the past. Every state is proud of its ancient monuments. Many millennial monuments are eroded as a result of various influences: ecological, technogenic, anthropogenic and so on. Reducing external influences on the monument, preventing various natural and unnatural damage plays an important role in its preservation. Therefore, it is necessary to prevent any negative impact rather than repair the monument after it has been damaged. In today's age of digital technology, of course, this is possible. A permanent database will be formed by installing various cameras and sensors in the facility and connecting it to a central computer system. In the case of deviation from the norm, artificial intelligence sends a signal to the Cultural Heritage Specialist about the relevant problem that arises in the monument. In turn, constant monitoring will be carried out and a list of facilities that need to be repaired in the first place will be developed.

Keywords: historical monuments, smart platform, environmental impact, technogenic, anthropogenic, monitoring

1. Introduction

On the example of the Republic of Uzbekistan, a comprehensive approach to the preservation of cultural heritage is needed. At present, more than 8,000 cultural heritage monuments are registered in the country. Ancient cities such as Khiva, Bukhara, Samarkand or Shakhrisabz are included in the UNESCO list of cultural heritage. A special approach is needed to the types of archeological, architectural and artistic monuments (mainly sculptures) of historical and cultural heritage. At the present time, in the process of development of information technology and artificial intelligence, it is necessary to develop a special platform for the protection of historical heritage from various ecological, technogenic and anthropogenic influences. An interdisciplinary approach plays an important role in this. Archaeologists, historians, architects, restorers, ICT specialists, biologists, zoologists and other necessary specialists should be involved in the creation of the platform.

2. Literature review

There are a lot of scientific publications on the study of historical monuments, especially archeological, architectural and sculptural works. In the field of archeology, in particular the writings of S. P. Tolstov, Y. G. Gulamov, Sh. Matrasulov, M. Mambetullaev, N. Yusupov, V. Yagodin, G. Khojaniyozov, S. Baratov, K. Sobirov, B. Sadullaev, who carried out archeological excavations. In the field of architecture, investigations have been conducted by I. Notkin, V. Bulatova, L. Mankovskaya, P. Zohidov, G. Durdieva and others. Especially in recent years, under the leadership of Doctor of Architecture G. Durdieva, scientists of the Khorezm Mamun Academy have conducted research on the protection of historical monuments from various external influences and developed new technical methods. As an example, the research of M. Abdullaev on sculpture can be taken into consideration. However, no scientific research has been conducted on the use of modern ICT technologies in the protection of cultural heritage monuments.

3. Research methods

Reducing external influences on the monument, preventing various natural and unnatural damage, plays an important role in its preservation. Therefore, it is necessary to prevent any negative impact rather than repair the monument after it has been damaged. In today's age of digital technology, of course, this is possible. A permanent database will be formed by installing various cameras and sensors in the facility and connecting it to a central computer system. This is where security surveillance cameras (against anthropogenic factors), fire, moisture content, cracking, drowning (against the anthropogenic factors) are installed to prevent motion sensors. All surveillance cameras and counters are connected to the Central System. In the case of deviation from the norm, artificial intelligence sends a signal to the Cultural Heritage Specialist about the relevant problem that arises in the monument. In turn, constant monitoring will be carried out and a list of facilities that need to be repaired in the first place will be developed. This will help the staff closely involved in preserving the cultural heritage.

4. Research and obtained results

We consider the historical monuments of ancient Khorezm on the example of archeological monuments. In this case, we choose as an example an object in two different conditions: 1. the monument of Ayaz-kala, which is relatively unaffected by direct human influence at the present time, and 2. the Khazorasp archeological site, which is still inhabited by people and is in danger of being exposed to certain influences on a daily basis.

Figure 1. Ayaz-kala monument, photo by H. Yusupov

Ayaz-kala is a rectangular structure with a height of 182x152 m, built at a height of 60 m on the ridge of Sultan Uvays Mountain in the Ellikkala district. The three sides of the monument are protected by a deep cliff. In ancient times, it was surrounded by a two-row wall, the surviving height of which is 5–10 meters. The outer wall thickness is 2–4 m and the inner wall is 2.1 m. There was a 2.5 m corridor between the outer and inner wall. The closed corridor in the wattle-and-daub wall is 1.87 m high and covered with bricks in the form of an arch at a height. The gate is located on the south wall and is reinforced with a right-angled labyrinth structure, 5–8 m high, 37 m to the side from the outer wall, 27 m to the east. The entrance to the complex maze is on the east wall and is 4 m wide. Semicircular towers were built along the outer wall. There are 35 of them. The labyrinth guarding the monument gate also has semicircular constellations, a total of three. The size of the area between the towers on the wall varies. The distance between the towers on the east and west walls is 13.8 m, 11.5 m on the north and 9–15 m on the south. In the corners of the wall, there are semicircular towers in the form of "a swallow's tail"; the distance between the side exit from the wall is 1.50 cm, the exit at the end is 3.5 m, the total exit length from the wall is 6–8 m, the exit from the wall to the side is 8–10 m, width is 6–8 m. Square bricks were used in the wattle-and-daub and tower walls. On the brick walls there are chess – and spear-shaped holes, the width of which is 13–20 cm, the height of the entrance is 0.48 cm, the exit is 2.9–3.5 m, the distance between them is 1.5 m. The towers had 7 holes, four of which had a curved direction [1].

Currently, Ayaz-kala is used for tourism purposes. But there is no permanent supervisor to protect the object. Therefore, visitors of different ages who come to this monument can draw on the walls, copy the stones and pottery that protrude from the ground and take them away as a souvenir. As the walls of the monument are in an open position, they are eroding as a result of snow, rain and wind. If constant control were established with the help of artificial intelligence, it would be possible to carry out the necessary repairs quickly and purposefully. There may be some technical problems with connecting such monuments to a smart platform: the area is far away, there is no electricity, there is a safety issue of the installed equipment. Electricity can be solved using small solar and wind power plants that operate autonomously. Given that the site is a tourist destination, the second problem can be solved through the development of tourism business around this object. The business owner can receive benefits from the state, set up accommodation facilities, catering and other service outlets near the monument.

Figure 2. Khazorasp fortress, photo by H. Yusupov

Khazorasp is located in the southern part of the Khorezm oasis, at a distance of 70 km from the city of Urgench. The monument is built in the form of a square (340x320m, i.e. 10.8 ha), the average height of which in the preserved part of the defensive wall is 4–5m. On the south-eastern side of the monument there is a fortified structure, which is known among the locals as Devsolgan, its area is a 40x40 m square. There are semicircular constellations at a certain distance in the Khazorasp defensive wall, 7 of which are preserved on the northern wall, 6 on the western wall, 4 on the eastern wall and 1 on the southern wall. The distance between the constellations varies, the distance between the corner constellation and the adjacent constellations is 10 m and the distance between the constellations in the main wall is 55 m. The entrance to the castle is located in the centre of the south wall and is 8 m wide. A straight street passed through the gate and a mosque was on its left side. The monument is surrounded by a wide ditch on the east side. Based on the archeological finds obtained as a result of the construction of the monument and the study of the cultural layers in it, the conclusion was made that it belongs to the 4thcentury BC [2].

Unfortunately, archeological excavations have not been carried out until the most ancient cultural strata of Khazorasp. For this reason, the question of the origin of the city, the history of its development has been controversial for decades. Excavations were carried out near the mosque in the interior of Khazorasp and in the centre of the north wall and in the north-west corner, as a result of which the ancient wattle-and-daub wall was studied. On the wall, there is a rectangular tower or pilaster, in the centre of which is a spear-axis pointed spire, 18 cm wide and 40 cm high. The inside of the hole wall was plastered with mud mixed with straw. As a result of excavations in the interior of the Devsolgan, it is 15 m long and 30 cm high. The wattle-and-daub wall was studied, the height of the North wall was 2 m, the two-row wall was studied and the width of the corridor between them was 2 m. The inner wall is 1.5 m thick, the height is 2 m rebuilt from wattle-and-daub, the outer wall is 1.5 m thick from the outside, and the outer wall thickness is 3.5 m as a result of the additional wattle-and-daub wall built. Inside the mosque, a trench was dug to a depth of four to six meters, and the artefacts were used to illuminate some pages of the city's construction history. The artefacts from Shurf allow us to describe the history of the construction of the monument as follows [3].

During the 1stconstruction period, the Khazorasp city was surrounded by a two-row wattle-and-daub wall, the width of the corridor between them was 2.1 m. The total thickness of the defensive wall is 5 m.

Construction period 2. A square-shaped raw brick wall 1.5 m high (45x45x10, 44x44x8cm) was built on the wattle-and-daub wall. The bricks are built in a checkerboard pattern, 0.2–0.5 cm thick with clay poured on their sides and joints. At the bottom of the brick there are different markings (circle, straight line, dot, semicircle). Raw bricks of the same size were also used in the construction of the inner wall. The height of the city wall is 3.5 m, the width of the corridor is 2.1 m. On the north-east side of the city there was an arc, in the areas of the east-south, west of the city there was economic and cultural life. Of course, cultural life did not appear all at once in all parts of the city. Unfortunately, due to the dense population in the inner part of the city, it is not possible to conduct large-scale archeological research and study the cultural layer there. During construction, the corridor is arched over the defensive wall. On the outside, a 1 m thick wattle-and-daub wall was built, resulting in a wall thickness of 5 m and a height of 6 m. The towers also have an additional wall of the same thickness. Baked bricks (28x28x6, 27x27x5cm) were used on the wall built in the outer corner of Devsolgan. Archaeological excavations have revealed the construction of the monument in BC times and allowed to be identified as the 5th century. The corridor between the inner and outer wall was filled with cotton, resulting in a wall thickness of 7–8 m and a height of 6–14 m. Unfortunately, archeological excavations have not been carried out until the most ancient cultural layer of the monument [4].

People still live in Khazorasp. In this monument, the antropogenic impact was stronger than the ecological, technogenic impacts. Especially as a result of the abandonment of the area by the former Soviet Union, the walls of the monument were demolished, mud bricks were removed and people rebuilt their homes instead of walls. Such problems apply not only to Khazorasp, but also to many settlements located on the site of ancient cities. As a solution to the problem, the development of the master plan of cities and regions should be considered as a promising strategy for the gradual relocation of the population of the region to nearby areas over the years. It is not too difficult to install equipment and connect to a smart platform at the monuments in the settlements, as there is infrastructure in these areas. Public oversight can also help in preserving the monument.

Most of the archeological monuments are partially or completely preserved underground. In the process of studying them, archaeologists re-bury them as a primary conservation. Now, it is necessary to take immediate measures to museumise the excavated objects in cooperation with the Agency for Cultural Heritage. An example is the closure of an object using a lightweight construction using transparent windows. This will help to increase the number of tourist facilities and protect it by helping to connect to a smart platform later.

There are also two different situations in the protection of architectural objects using artificial intelligence. In the Khorezm region, architectural buildings are mainly used for tourism and pilgrimage.

1. The objects used for pilgrimage are mainly located in or around cemeteries. These include mausoleums, khanakahs (prayer places in mosques) and mosques.

An example is the mausoleum of Shakhpirbobo in the village of Mukhomon of the Khazorasp district. One of the ancient fortresses of Khorezm is the mausoleum of Shahpir Bobo and the mosque "Shahpir". This sacred place is associated with the name of the Khorezmian shakh Abu Muharram Muhammad Muzrabshakh, who lived in the 8th century. He was born in 705 and died in 775. During this period, Islam was widespread in Khorezm. When Muzrabshakh came to power, the Islamic world was ruled by a common caliphate and the local peoples were severely oppressed. As a result, the people of Khorasan and Khorezm revolted in support of the Abbasid rule under Abu Muslim. This struggle ends with the victory of the Abbasids. Abu Muslim was executed in 755. His grave is in Darganota. Muhammad Muzrabshakh died in 755 in Khazorasp and was buried in the main cemetery of the city [5].

Figure 3. Tomb of Shakhpirbobo, photo by B. Sadullaev

In honour of the king, this place will be famous by the names of Shahbobo and Shahpir. Shahbobo mausoleum was built in the middle of the 17thcentury by the order of Abulghazikhan. At that time, a large khanakah was built near the Shahpir cemetery and it became popularly known as the "Bird of Pir". This khanakah, which operated until 1935, was converted into a store-room of a commercial enterprise during the former Soviet regime. The Shahpir Mosque is currently operating. During the independence period, a new building was built for the mosque – a prayer room and service rooms.

Such buildings are at high environmental, technogenic and anthropogenic risk, because these types of monuments are owned by religious institutions or beautification organisations, which do not have specialists to protect them. In many cases, the population encounters irregular repairs with their own strength and knowledge. If surveillance cameras and other equipment are installed and connected to the central system, the level of risk to these types of monuments will be drastically reduced. Public scrutiny at these facilities also greatly helps.

2. Architectural constructions with direct tourist objects. In the Khorezm region, they are mainly located in Khiva, Ichan-kala and Dishan-kala. The mausoleum of Sayyid Alovuddin is one of the oldest monuments of Ichan-kala. The mausoleum consists of a shrine and a tomb. Over the centuries, the tomb has remained below ground level due to the proliferation of the tombs around it. Archaeological excavations have revealed a great deal of information about the previous appearance and history of the monuments. Akhmad Razi, a historian who lived in the past, added Sayyid Alovuddin to the list of famous Khorezmian sheikhs, saying that he was the greatest sheikh after Sheikh Najmiddin Kubro. This information is given in the works of Jomiy and Navoi. He was a master of Pahlavon Mahmud.

Figure 4. Tomb in the mausoleum of Sayyid Alovuddin, photo: H. Yusupov

In the tomb of the mausoleum, there is a magnificent tiled tomb, which is considered sacred, the tomb is covered with very beautiful green-blue and white tiles. All the pattern flowers on the tiles are embossed. The tomb is unique in Khiva, its peers and counterparts are found in the tombs of Sheikh Najmiddin Kubro in Old Urgench and Qusam ibn Abbas in Shahi Zinda (Samarkand). The mausoleum was built by Amir Kulol – an apprentice of Sheikh Sayyid Alovuddin. The mausoleum structure has a large bowl cover, a dome-shaped, eight-pointed roof that looks extremely simple. There are two little graves on the tomb. The small plant-like flowers are very realistically depicted, and their shape resembles the ornaments on household utensils of that period. The flowers used in the tomb tiles, the small stripes inside the large shape all together make it look cozy and attractive. Against the backdrop of muted colourful ornaments, the white inscriptions on the small faces of the graves stand out.

Bizning buyuk Shayhimiz Alovuddin,	Our great Sheikh Alovuddin,
Vafoti bilan Allohning marhamatiga yetdi	With his death, he reached the mercy of Allah
Ketgan kun baxtli shabon oyidan	Gone are the days of happy shaban month
O‘n kun o‘n kun o‘tgach sodir bo‘ldi.	It happened ten days later.

It is clear from this poem that the sheikh died on March 18, 1303. The mausoleums over the tombs of famous sheikhs have become shrines over time. Khiva khan Allakulikhan (1825–1842) believed in him, built a mausoleum over his tomb in his time and separated the waqf lands (a name of shared lands for agriculture for the sake of mosques). In 1825, the mausoleum was completely renovated. The inside shelves are covered, the room stage is tiled and the walls are plastered. There are 14 poems written on the wall, and it is known from the inscriptions that the renovation of the building was carried out by the order of Allakulikhan under the leadership of Hamidkhoja, the son of Khubbiqulikhoja.

Surveillance cameras and security equipment are installed in the vast majority of buildings in tourist facilities. They are constantly monitored. Great care is taken to preserve the original. In the past, there were some problems with the use of these monuments, but now, with the help of UNESCO and local organisations, much attention is paid to the use of historical architectural monuments in a way that does not affect the building at all.

Another type of cultural heritage that needs to be constantly protected by artificial intelligence is sculptural works of art. There are 87 sculptural monuments in the Khorezm region. Most of them are plaster and bronze busts. Most of the statues are dedicated not only to local but also to the Republic and world-renowned scholars such as Muhammad al-Khorazzmi, Beruni, Abu Ali ibn Sina, Alisher Navoi and Agahi.

Figure 5. Statue of Muhammad al-Khorazmi, [6]

The statue of Muhammad al-Khorazmi is located in the Al-Khorazmi Square on the central Al-Khorazmi Avenue in the city of Urgench. In front of the building of the House of Councils of the regional administration, there is a bronze statue of our great ancestor Al-Khorazmi with a semicircular four-column arch. The statue was created by P. Salaev.

Abu Jafar (Abu Abdullah) Muhammad ibn Musa al-Khorazmi (783–850) was a great Central Asian mathematician, astronomer, geographer, one of the first encyclopaedic scientists in the history of science. He was a leading scholar and scientific adviser in Bayt ul-Hikmat (House of Wisdom). Khorezmi founded the science of algebra. Among the hundreds of books written in the Middle Ages in the field of mathematics, astronomy and other sciences, the works of Khorezmi are the most widespread in both East and West and have made the greatest contribution to human development. This was due to the original-narrative style widely used by Khorezmi. Underlying this method lies the idea of an algorithm. This idea of Khorezmi has become more and more important over time and has become one of the most important factors in the development of society today – the processing of digital information is based on it.

It is also important to protect these monuments through the installation of surveillance cameras, equipment against various impacts and a smart platform.

5. Conclusions

The use of new information technologies is important in protecting historical monuments from environmental, technogenic and anthropogenic negative impacts. Rather than repairing a monument after it has been damaged, it will be necessary to prevent any adverse effects. In today's age of digital technology, of course, this is possible. This system is important in protecting monuments from external influences and repairing them if necessary.

Suggestions

1. It is necessary to create a permanent database by installing various cameras and sensors on archeological, architectural and sculptural monuments in the Khorezm region and connecting it to the central computer system.
2. It is necessary to constantly monitor objects with the help of artificial intelligence and develop a list of those that need to be repaired in the first place.

Acknowledgments

The authors would like to thank Elżbieta Miłosz, General Coordinator of the "3D DIGITAL SILK ROAD" Programme within NAWA (Poland's National Academic Cooperation), and photographer Hurmat Yusupov for their assistance in using the photographs.

References

[1] Khodjaniyozov G. Qadimgi Khorazm mudofaa inshootlari: mil. avv. VI asrdan mil. IV asrgacha. Tashkent, 2007. 216 b.

[2] Vorobyova M. G., Lapirov-Skoblo M. S., Nerazik Y. Y. Arkheologicheskiye raboty v Khazaraspe v 1958–1960. MKhE, 6th edition. Moscow: Nauka, 1963. pp. 157–180.

[3] Baratov S., Matrasulov Sh. Arkheologicheskiye raboty v yuzhnom Khorezme. Archeological studies in Uzbekistan in 2002. Samarkand, 2003. 3rd edition. pp. 4–15.

[4] Sobirov K., Ruzimov S. Arkheologicheskiye raboty v Khazaraspe. *Vestnik of KKOAn Ruz*. Nukus, № 3–4, 2003. pp. 108–109.

[5] Passports of the objects of Cultural Heritage. № 5. Khazorasp, № 114, Shahpi Bobo Mausoleum, № 40, Sayyid Alowiddin Mausoleum.

[6] https;//www.windoworld.ru/uzbekistan/

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USING MODERN INFORMATION AND COMMUNICATION TECHNOLOGIES IN MUSEUMISING CULTURAL HERITAGE OBJECTS

Abstract

The article is dedicated to the museumisation of historical sites and buildings. It covers the issues of museumisation with the widespread use of modern technologies, without compromising history. In the Republic of Uzbekistan, there are many monuments of cultural heritage in such ancient cities as Samarkand, Shakhrisabz, Bukhara, Khiva, Tashkent, Termez. Cultural heritage sites in the country include archeological monuments, architectural structures, sights and monumental works of art. At present, new museum expositions are being organised mainly in architectural structures. There are 8,210 registered objects in the country, of which 4,788 are archeological and 2,267 are architectural structures. There are 37 archeological and 134 architectural monuments in the Khorezm region. Museum expositions are organised in 20 historical buildings in Khiva. The article provides information on museum issues on the example of expositions opened in recent years.

Keywords: "Ichan-kala", museum, museumisation, architectural structures, museum expositions

1. Literature review

Many materials on the activities of the State Architectural Museum-Reserve "Ichan-kala" were published in the periodicals. Some information is also available at www.khivamuseum.uz. Authors such as Y. Gulamov, O. Abdullaev, A. Abdurasulov, K. Khudayberganov conducted research on museum monuments and expositions. In recent years, Dilmurod Babojonov, a senior researcher at the Khorezm Mamun Academy, has been conducting serious research on the subject.

2. Research and results

Ichan-kala State Museum-Reserve. The first museum in Khorezm was established in 1920. In 1967, Ichan-kala State Museum-Reserve received the official status of the Open-Air Museum. Known for its unique historical and architectural monuments, Khiva is the 100th city on the globe to be included in the list of world cultural monuments. At the 28th session of UNESCO in Paris, the role and importance of Khiva in the development of world culture was emphasised. On October 20, 1997, the 2,500th anniversary of the city of Khiva was celebrated internationally.

The museum-reserve is located in the "Ichan-kala" part of Khiva, surrounded by a high wattle-and-daub wall, with four gates – Ota Gate, Polvon Gate, Tosh Gate and Boghcha Gate. The circumference of the wall is about 2200 meters, the height is 7–8 meters and the thickness of the foundation is 5–6 meters. Ichan-kala is built in the form of a rectangle, 650 meters long and 400 meters wide, covering an area of 26 hectares [1].

Khiva "Ichan-kala" State Museum-Reserve has 19 permanent expositions located in various madrasahs and other historical buildings. They are:

1. Department of Ancient Khorezm History (Old Ark Palace)
2. Department of History of Khorezmshahs (Old Ark Palace)
3. Department of History of Khorezm khans (Madrasah of Muhammad Rahimkhan II)
4. Museum of Fine Arts (Kutlugh Murad inaq madrasah)
5. History of music (Kozikalon madrasah)
6. Department of Khorezm Applied Arts (Islam Khoja madrasah)
7. Department of Khorezm public education (Russian school)
8. Calligraphy department (Matpanoboy madrasah)
9. Department of Khorezm Nature (Abdullakhan madrasah)
10. Department of Monumental Architecture (Toshkhavli Palace)
11. Pottery exhibition (Toshkhavli Palace)
12. History of German Mennonites (Polvon Qori trade house)
13. Permanent exhibition of life and activity of Khudoibergan Devonov (Russian school)
14. Dorul Hikmat val Maorif (Muhammad Amin Inaq Madrasa) [2].

Figure 1. The mausoleum of Pahlavon Makhmud and Islam Khoja Minaret, which became the symbol of the city of Khiva, photo: H. Yusupov

There are also Al-Khorazmi (Al-Khorazmi Street in Urgench) and Al-Beruni Museums (Al-Khorazmi Street in Urgench) and Khiva Ichan-kala State Museum-Reserve Fund (Arab Muhammadkhan Madrasah). The fund of the Khiva State Museum-Reserve "Ichan-kala" contains 52,000 unique exhibits [2].

Figure 2. Exposition of the history of ancient Khorezm, photo: M. Abdullaev 2021

Figure 3. Exhibition "Dorul hikmat val maorif", photo: M. Abdullaev 2021

“**Dorul hikmat val maorif”.** The museum exposition was organised in the building of Muhammad Amin Inaq madrasah of Ichan-kala complex in Khiva. A distinctive feature of the interior solution by the designers is related to the area of the main hall, which in the plan is 173 square meters octagon. The hall is equipped with an artistic digital panel where hologram images of 7 key scientists, members of the Mamun Academy, appear and basic information is provided. These are such scholars as Abu Rayhan Beruni, Abu Ali ibn Sina, Abu Nasr ibn Iraq, Abu Sahl al-Masihi, Abu Mansur al-Saalibi, Abul-Khair al-Hammar and Ibn Miskawayh, who worked in various fields of science. These scientists are recognised worldwide for their unparalleled works in mathematics, astronomy, history, medicine, poetry, philosophy and other fields.

New technologies have been used in the museum: the figures of great scientists appear on a thin mesh surface of a panel made of a special coating in 3D format. Their images were accompanied by visual images in mapping and their drama and content were also prepared by the authors [1].

In the main hall, there is a display of various equipment invented by scientists of “Dorul Hikmat val Maorif” and used in their work. In particular, copies of instruments such as globe, quadrant, sextant, astrolabe, medical equipments were made on the basis of drawings in manuscripts, photos in foreign museums. The exhibition includes facsimiles of 10 manuscripts of scholars working at the Mamun Academy.

At the entrance to the main hall, on the right, there is a mosque, and on the left, the interior of the library “Dorul Hikmat val Maorif”. The mosque is represented by the altar, which shows the qibla (the side Muslims face while praying), a traditional sheet for the Koran, a prayer mat, a turban, and so on. In the centre of the interior of the library there are wax statues of young scientists Beruni and Ibn Sina, who worked in “Dorul Hikmat val Maorif”. The plot of their conversation is based on the composition of a painting by the famous artist Ch. Akhmarov. In the composition, Ibn Sina explains to Beruni a drawing of his new instrument. On the walls of the library there are video materials about the activities of these scientists and virtual exhibits reflecting the environment of that period.

Along the perimeter of the main hall are small rooms, each of which reflects the activities of great scientists-members of the Mamun Academy. Each small room is decorated with compositions that reflect the specific features of the activities of a particular scientist, as well as household items, interesting information about the activities of member-scientists of the Mamun Academy.

The Department of Khorezm Applied Arts is located in the Islam Khoja Madrasah. The exhibition was organised in 1983 on the occasion of the 1200th anniversary of Al Khorezmi. The exposition occupies 420 sq. m [2].

The museum has the richest and most unique exhibits (387 pieces). The exhibition covers all the developed areas of Khorezm applied art – wood carving, pottery, jewelry, marble carving, pottery, carpet weaving, weaving and floral printing, tanning.

Figure 4. Exposition of German Mennonites, photo: H. Yusupov 2020

Figure 5. Tashhavli. Harem, photo: H. Yusupov 2020

Khorezm products are completely different from other regions in terms of their originality and decoration. In the museum rooms you can see original items of wood carving, such as doors, columns, fence, ceramics such as bodiya (a wide earthen dish used for having meat together with the family), bowls, big earthen pitcher, chintavakh (also a wide iron glittered dish), jewelry such as takyaduzi, jiga, osmaduzi. The museum also covers the life and work of masters. In particular, master Allakora, master potter Yusup, R. Matchonov, O. Palvonov, S. Boghibekov, A. Boltaev and others.

The majestic architectural department is the Tashhavli Palace (1832–1838). The highest examples of Khorezmian architecture are used here. The palace is richly decorated with paintings, plaster, marble and wood carvings, tiles. In particular, the lobby and the mosque are delicately decorated. The palace consists of three large courtyards with a view, a hotel and a harem and has 163 rooms. The five large porches of the harem are decorated with incredibly beautiful tile coverings. The palace tiles were made by master Abdullah. Doors and columns are among the highest examples of Khiva wood carving. The most perfect art of Khiva masters is reflected in the silent carvings on the marble columns and iron bars. The Tashhavli palace was built by Nurmuhammad Taji and master Qalandar Khivaqiy. The Tashhavli Palace was completely renovated in 1996–1997 on the occasion of the 2500th anniversary of Khiva. About 100 samples of wood and marble carvings are on display in Tashhavl [3].

The Museum of Music History is located in the Kozikalon Madrasah. The madrasah was built in 1905 by Salim Akhun, the chief judge of the Khiva khanate. The area of the museum is 32.5x23.4 meters. The museum displays the Khorezm note line, Khorezm musical instruments, personal belongings of famous musicians.

The Museum of Fine Arts is located in Kutlugh Murad Inaq Madrasah. The madrasah was built in 1804–1812. The museum has been collecting works of fine art since the 1920s. Different exhibitions have been organised in different years. The exhibition was launched in 2008. The museum has 52 historical paintings, including the Battle of Massagets, diplomatic relations with Russia, the Mamun Academy and the years of repression. There are also portraits of famous Khorezmian historical figures in the exhibition. The exposition occupies 140 sq. m [2].

A permanent exhibition of the life and work of Khudoibergan Devonov was organised in 2002 at the Russian school in front of the Islam Khoja Madrasah. The exposition was created by the chief keeper of the museum O. Karimov. The exhibition includes about 200 exhibits depicting the life and work of the first Uzbek photographer and cinematographer Kh. Devonov, as well as his own photographs. The museum was re-exhibited in 2009. The exposition is located in the area of 36 sq. m.

Permanent exposition of Khorezm history and culture at the Khorezm Mamun Academy. The Museum of the History of Science was established in 2006 at the Khorezm Mamun Academy on the occasion of the 1000th anniversary of the academy. The museum consists of 3 sections – science in ancient times, science in the Middle Ages and the successors of the Mamun Academy [4]. The museum shows the emergence of the first observatory, writing, fine arts in Central Asia, the activities of "Bayt ul-Hikma", "Dorul hikmat val maorif", the development of science in Uzbekistan today. The museum is located in the building of the Khorezm Mamun Academy and contains unique archeological finds, rare manuscripts and other historical exhibits. The total number of exhibits is 421, including 111 unique archeological and ethnographic exhibits, 20 manuscripts and lithographs. The exhibits and manuscripts exhibited in the museum are used as a source for the study of Khorezm statehood, history, literature, art and culture, to promote our cultural heritage to the younger generation and to raise children loyal to the motherland. The museum's activities are widely promoted through the organisation of excursions.

Archaeological and ethnographic expeditions are being carried out to enrich the museum of the Khorezm Mamun Academy with exhibits. There is a booklet and an electronic version of the museum exhibits.

Museum of Repression Victims in the structure of Urgench State University. The house-monument of Kasimjon Salimjanov consists of two parts: the house of K. Salimjanov and the trade office. The monument is located on the northwest side of the city of Urgench, on the west side of the city hall. Construction work was carried out in 1910–1912. Russian brick was used in the process. The windows and doors are designed in a new style [5].

K. Salimjanov's trading house was reconstructed in 1992 and a museum of local lore was established. In 2013, the facade and roof of the building were renovated on the basis of a new construction.

This museum was inaugurated on August 31, 2018 – the Day of Remembrance of the Victims of Repression. The museum was highly praised by the general public. The museum contains the sections as "Occupation of Khiva Khanate by Tsarist Russia, the struggle of the local people for freedom and liberty (1868–1900)", "The national awakening movement in Khiva Khanate, its practical directions and representatives (1901–1917)", "The end of the Khorezm People's Republic and the region", "the establishment of Bolshevik government (1917–1929)", "The beginning of the repressive policy of the Soviet state (1929–1936)", "The Great Massacre of 1937–1938", "Political Repressions of 1940–1950", "Repression of the 1980s", "Cotton Campaign", "Restoration of historical justice during the years of independence, perpetuation of the memory of the victims of repressions, historical work on the preservation and development of national values (post-1991 period)".

3. Conclusions

The use of modern information and communication technologies in the museumisation of cultural heritage sites helps to preserve the originality and prolong the life of the building. Also, modern technology will further increase the interest of the audience.

Suggestions

1. In the museum of historical buildings, it is expedient to organise expositions in accordance with its primary purpose.
2. Wider use of modern technologies in the transformation of Cultural heritage sites into museums.

Acknowledgments

The authors would like to thank Elżbieta Miłosz, General Coordinator of the "3D DIGITAL SILK ROAD" Programme within NAWA (Poland's National Academic Cooperation) and Dilmurod Babojonov for their support in the museum's exhibits, and photographer Hurmat Yusupov for his assistance in using the photographs.

References

[1] Abdurasulov A., Khiva. Tashkent, O'zbekiston, 1997. 27 p.
[2] www.khiva.museum.uz
[3] Babojonov D., Abdurasulov M., Heavenly city. Khiva, 2008. 65 p.
[4] www.mamun.uz
[5] Passport of the object of cultural heritage. № 100.

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EFFECTIVE USE OF MODERN TECHNOLOGIES IN THE PRACTICE OF UNIVERSITY STUDENTS

Abstract

The article discusses the advantages of 3D technologies in the practice of students of higher educational institutions and the requirements for their use. Addressed are issues concerning 3D modelling and 3D printing of architectural objects on the example of the mediaeval fortress of Khiva in the context of teaching within the STEM conception.

Keywords: 3D printing, technology features, internal technology, design method, STEM.

1. Introduction

The development of modern technologies does not bypass educational institutions. Ceiling projectors in the 1930s, pocket calculators in the 1970s, personal computers in the 2000s, technology has always been used to engage students and prepare them for postgraduate realities. Already, the requirements for technical professions related to industrial production are changing, the tasks of specialists who will have to work in smart factories or conduct scientific research are being rethought. Therefore, schools and universities are faced with a responsible task – to give future engineers, technologists, constructors and designers deep enough knowledge and practical skills in the field of the latest technologies so that they enter the digital world fully armed.

The era has come when 3D printing will completely change the idea of classrooms and laboratories. Advances in 3D printing have made the technology more convenient and accessible, helping to increase its popularity in educational circles. Employees of almost any scientific disciplines have the opportunity to use 3D printing as part of the educational process, both in classic face-to-face seminars and in online classes.

The thoughtful integration of this technology into educational platforms will allow teachers to increase academic performance by developing students' analytical abilities and critical thinking skills [1]. 3D technologies can be applied at all levels of education, from elementary schools to universities, not to mention that virtually any subject is much easier to teach with 3D printing.

For example, a physics teacher learning how to operate a jet engine might ask students to create a working 3D model of a rocket, or a geography teacher might ask students to print a 3D model of anywhere in the world to help children better understand the region they are studying. This makes the learning process more interesting and the knowledge gained through such experiences much more sustainable. In addition, 3D printing is accessible to students with different perceptions of the material, which means that kinesthetic and visual learners will equally experience all the benefits of this approach to learning.

Figure 1. Working with a 3D pen, own source

2. Materials

In the field of teaching, there are many opportunities to use 3D printing of 3D versions of their creative works, historians – to recreate historical artefacts, architects – to print 3D models of building designs. 3D printing can be introduced into the educational process not only in engineering areas: biology students can print anatomical models of organs, future chemists can study the structure of molecules from their 3D models, graphic designers can create.

The following main reasons for the introduction of 3D printing technology into the educational process can be indicated: creation of an interactive learning environment; development of creativity and innovation; improved perception of the real world; preparation for postgraduate practice; involvement in digital processes; developing problem-solving skills; development of design thinking [2].

Students with great pleasure immerse themselves in the process being studied if the learning environment makes them participants in this process. Material presented through slides can at best only arouse interest and hold attention for a short time. 3D printing technology makes learning dynamic by encouraging students to develop critical thinking skills while designing models. Interactive sessions allow to explore advanced topics in more depth while developing practical skills such as decision making and problem solving.

Despite the spread of the remote learning format, the opportunity to gain practical skills has been preserved thanks to technology. A case in point was the case of Michael Silver, an architecture professor at the University of Kentucky College of Design and Architecture, who printed and mailed models of buildings his students were working on. Having physical models of objects helps students analyse their own concepts and ideas. As a result, despite the remote format of classes, 3D printing allowed to maintain the important principle of "immersion in the process".

The following main advantages of using 3D printing in education can be named:

- Science and technology education (STEM). 3D printing technology educates students to be creators. Instead of buying or consuming ready-made products, they become inventors, identifying their needs and finding solutions, creatively combining the knowledge and skills they gain with technology. 3D printing is a technology that scientists and engineers are using to change the world. Transferring this technology to students can acquaint them with the problems facing the whole society and instill skills that will be useful in further education and acquiring a profession [3].
- Development of imagination and creativity. With 3D printing, art is gradually returning to technology, and students become designers and artists, using advanced technology to visualise the fruits of their own imagination. The process of learning develops spatial thinking and the ability to design and implement new things.
- Attract "lazy" students. 3D printing is still a very new technology that is not always available to the average consumer. Therefore, it has a "wow factor" that attracts students who are cool about their learning. Access to 3D technology is a great way to motivate students who are lagging behind in other subjects as well.
- Education of social skills. Using 3D printing in the classroom will allow students to become part of the growing online 3D printing community, rate and comment on their peers' creations, be tolerant of their mistakes, and learn from the best examples. The links between classroom levels in the school, bringing younger and older students together to work together on a 3D project, allows older students to prove themselves as good teachers and learn to appreciate the respect that they are awarded by younger colleagues.
- Cultivation of purposefulness. With 3D printing, almost anything can be realised. To immerse yourself in the atmosphere of ancient societies – design and print a model of a mummy or pyramid. The student dreams of travelling – the seal of a treasure island or a mountain peak. The child wants to protect the city from natural disasters – designing and printing a flood dam that can be immediately tested. This list has no end, it is only important not to stop at the idea stage, but to implement it. Students learn that it is perfectly acceptable to fail the first time and then try again to improve. When children begin to understand that failure is part of the process, they become less afraid to try new and different ideas. This builds student confidence and teachers enjoy the fact that students are motivated and self-confident.

Figure 2. 3D design course in Tashkent [6]

Regardless of the level of education, when purchasing a 3D printer in an educational institution, several key points should be considered:

- Safety. It must be remembered that very inexperienced users who experience an irresistible desire to touch everything will work with the devices. 3D printers using FDM/FFF technology have a print head with a temperature of 100 to 500°C, and the photopolymer resin is very difficult to wash off. Therefore, a 3D printer with a closed print chamber would be a reasonable choice. Please note that when printing, printers emit far from always harmless vapours from the print material, so educational institutions need to be equipped with trapping filters.
- The cost of the device. Whatever precautions the teacher takes, there is a high chance that the device will break down during training, and the cost of repairing it can be high. In the case of an inexpensive device, it can be replaced entirely or by large nodes.
- Simplicity of a design. The simpler, more rigid and more reliable the design, the less likely it is that an expensive device will be disabled by some kind of incorrect manipulation.
- Availability of consumables. As much as there is no point using very expensive branded materials to get perfect products, it should be remembered that the main purpose of purchasing a 3D printer is education. Therefore, there will always be a lot of defects, the consumption of materials will always be large, and the printer must be able to print the cheapest and most common of them.
- Service. Ease of repair and replacement of broken parts. Training is a continuous process, and the manufacturer's official representative office and service centre located nearby will save a lot of time and money during repairs.

- Use of free software. Initial training does not aim to turn the user into a professional. The teacher should give the student an initial knowledge of 3D technologies and a desire to develop them further. The use of complex professional software packages, in addition to their high cost, can often make an inexperienced user feel insecure about their abilities.
- Corporate training courses. Many manufacturers of 3D devices interested in advertising their products release special training courses on how to work with their devices, both for students and teachers. The presence of such a course will avoid many mistakes and increase the effectiveness of training.
- Branded motivation programs. Some companies have their own grant programmes to motivate the most talented teachers and students.

Effective teaching of 3D modelling is impossible without a prepared methodology and didactic materials. For this, lecture notes, presentations, methodological instructions for practical exercises with open access for students on the personal website of the teacher have been developed. At the initial stage, 1–2 years of study on the basis of basic education, as part of the training sessions for computer science and information technology, we consider the KOMPAS-3D, AutoCAD programs for automating engineering and graphic work, create three-dimensional models of simple parts, learn to work with drawing and editing tools, set the dimensions on the drawing. We consider the basic concepts of three-dimensional modelling and the methodology of computer modelling.

Knowledge of computer modelling will be used in course and diploma design and contribute to the development of students' competencies such as:

- ability to understand the possibilities of using IT in industry, construction and architecture; education of professionally significant qualities, the ability to apply the acquired knowledge in professional activities, responsibility for the work performed, ingenuity and attentiveness in the performance of practical work;
- the ability to solve applied problems and the correct use of computers in their professional activities; own information culture, analyse and evaluate information using information and communication technologies;
- work in a community and in a team, communicate effectively with colleagues, management, consumers;
- organise their own activities, choose standard methods and methods for performing professional tasks, evaluate their effectiveness and quality; ability to apply knowledge from related disciplines;
- to form the skills and abilities of independent mental work.

The transition of open source software to new generation standards, which rely on a competency-based approach, involves widespread use of advanced educational technologies [4]. Such methods may include the use of design technologies. For clarity, a brief overview of several completed projects in various 3D modelling software products could be given.

Project No. 1. Construction of an architectural object by the method of computer modelling and creating a layout (on the example of the mediaeval fortress of Khiva)

Discipline: Informatics, 1st year.

Relevance The fortresses of the Middle Ages were of great importance for a long period of time in all countries of the world. The fortresses of that period are an example of the highest architectural art and are of professional interest to both builders and architects. The development of a holistic view of the Middle Ages is impossible without a comprehensive study of the buildings and structures of that time.

The **goal** set by the Authors of this project: to form an idea of the fortress of the Middle Ages by the method of computer modelling and layout.

Achieving this goal is possible by solving the following tasks: to study the features of structures of a given time; identify the main thing in the geographical location of the fortresses of the Middle Ages; reveal the features of the architectural construction of that time; choose software for computer modelling of the fortress; create a three-dimensional model of the fortress; create a layout of the fortress using 3D modelling data; compare the resulting 3D model and the layout of the fortress.

Object of research and design: architecture of fortresses in the Middle Ages

Methods and tools for research: information, computer modelling in Compass-3D, prototyping

Form of organisation: group.

In order to better understand all this, imagine and have a visual image, they created the Khiva fortress. We started by building a 3D model, and then a real (reduced) model on a scale of 1:100, depicting not only the buildings, but also the relief of its terrain, people, those who inhabit it, and the warriors defending the fortress walls.

3. Conclusions

It is no secret that educational institutions need a large number of visual aids, samples and layouts, and their purchase is quite expensive. 3D printing reduces costs: The low cost of 3D printed materials for FDM printers will allow one to print the required number of teaching aids.

Student-made: The mock-up model can and is used in history lessons. A 3D model created in the Compass program can become a visual practical work in a computer science lesson. Layouts and models allow to study the interaction of volumes or get an idea of how they look from different angles. Thus, a miniature copy of the object is needed to check certain architectural solutions, identify shortcomings, search for rationality, expediency and perfection of the planned structure.

3D printing possibilities:

1. dummies of human organs and body fragments;
2. visual layout of complex items or even formulas;

3. geographical objects, as well as objects of archaeological or historical significance;
4. tools and simple details and products/objects.

The list of possible products is not exhaustive, and it is not necessary to design a print model yourself, it can be easily found in the Internet.

The project method is focused on the independent activity of students – individual, pair, group, which students perform for a certain period of time [5]. A distinctive feature of project activities in the classroom is that the teacher controls the process of developing the project, is more actively involved in its creation. But the time in such classes is strictly limited, and the educational material must be mastered by each student, so such projects can be several lessons long. With the skillful organisation of the process of creating a project and its correctly chosen product, this method is quite effective, as it allows creating conditions for students to develop the skills to identify a problem, search for ways to solve it, extract information (this can be a textbook, additional materials; access to an electronic library, book, Internet resources since the lesson takes place in a computer class), its generalisations, presentation of conclusions in the form of some final product – an information computer model.

References

[1] Smotrite; Stupnitskaya M.A. Novyye pedagogicheskiye tekhnologii. uchimsya rabotat' nad proyektami. Rekomendatsii dlya uchiteley, uchiteley i roditeley. – Yaroslavl': Akademiya razvitiya, 2008.

[2] Stupnitskaya M.A.Chto takoye uchebnyy proyekt? /– M.: pervoye sentyabrya, 2010. – 44 s.

[3] http://ru.wikipedia.org/wiki/BIM Informatsionnoye modelirovaniye zdaniy (BIM)

[4] https://edu.ascon.ru Resheniya ASKON dlya studentov, shkol'nikov, prepodavateley.

[5] https://gsketchup.ru/ Uroki Sketchap dlya nachinayushchikh. https://www.autodesk.ru / education/ PO i resursy uchashchikhsya i prepodavateley

[6] https://etz.uz/upload/images/kartinki_dlya_kursov/raboti_uchennikov/photo_20171212_ 145 833–564.jpg

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INTRODUCTION OF 3D TECHNOLOGIES IN THE EDUCATIONA PROCESS

Abstract

3D technology significantly improves the learning process and expands the understanding of many fields: technology, chemistry, geography, biology, fine arts, drawing, etc., improves the process of teaching and deepening new knowledge acquired by students during the teaching process. This article focuses on the use and effectiveness of 3D programs, which are now considered modern educational technologies.

Keywords: continuing education system, modern educational technologies, 3D technology, 3D modelling software, 3D software.

1. Introduction

At the current stage of technology, designers, architects, physicists, biologists and others make extensive use of 3D technology in their research activities. Of course, this innovation did not bypass the field of education and the educational process.

3D modelling is one of the most common uses of information communication technologies, which is practised not only by professionals but also by new users. Any modern multimedia programme cannot be done without computer graphics. The tasks facing students are interesting and often difficult to solve, which requires increasing learning motivation, developing logical thinking, using their skills in computer science and identifying connections with mathematics, using creative opportunities. This technology not only helps students to acquire the necessary knowledge and skills, but also to achieve a high level of intellectual development, the formation of the ability to learn independently through their creative activities, develop interest in educational work, provide continuous learning outcomes [1], (Makhmudova, 2019).

2. Materials and methods

Management of 3D technology programs allows students of any level to participate actively in the learning and cognitive process and demonstrate their ideas at a high level: lessons are held at a high level of complexity, including questions that are interesting and understandable to all [2], (Khutorskoy, 2012). The use of elements of 3D modelling technology in the classroom improves the practical training of schoolchildren, which leads to the successful acquisition of technical specialties. Computer modelling activities not only deepen students' spatial imagination, but also help them develop their intellectual and creative skills in modelling.

Today, the world's leading universities are working on virtualisation, software optimisation, mass online demonstrative courses, mega-portals and innovative learning. The rapid popularity of e-learning (platforms such as Moodle) requires from students of higher education creative activity and development of skills by constantly seeking out and implementing new ideas [3], (Makhmudova, 2018).

Many subjects in education are characterised by the breadth of computer 3D modelling capabilities, including the high level of interdisciplinary interaction with mathematics, physics and other disciplines. In order to have a complete scientific outlook, to develop creative abilities, to become a professional in the future, students need to master the basics of 3D modelling on a computer and apply their knowledge in their educational activities.

The study of 3D modelling as part of the development of students' professional competencies is a creative task of the teacher and involves the use of many pedagogical technologies in the learning process [4], (Ergasheva, 2018):

- The use of problem-based learning technology helps students acquire knowledge, skills and competencies that develop their mental abilities;
- Differentiated educational technology, smart students prove their creative abilities, weak students have the opportunity to achieve academic success and increase the level of professional aspiration;
- Design technology allows students to develop individual creative abilities, a conscious approach to professional and social self-determination;

The research method allows students to supplement their knowledge independently, to study the problem in depth and to suggest ways to solve it, which is important in shaping the worldview. This is important to determine the individual development path of each student [5], (Khayrullaeva, 2019).

Information technology is used to organise the learning process, which significantly affects the nature and organisation of the learning process, as the nature of the interaction between student and teacher changes, and some of the pedagogical functions are transferred to the computer. L. S. Vygotsky stressed the importance of developing a learning strategy for the intellectual development of students and said: "Teaching is good only if it goes ahead of development. Only in this way can it revive and bring to life a number of tasks that are in a state of maturity, close to the development" [3], (Makhmudova, 2018).

Without methodological training and didactic materials it is not possible to conduct effective teaching using 3D modelling, because the coverage of those who want to practise modelling makes up a majority, and their level of preparation varies. Detailed instructions for each student on how to complete the assignments will allow them to effectively "load" the material depending on their ability and speed of mastering the material. The preparation of special tasks in order to create a basis for inductive reasoning, using the computer and all its capabilities, is a complex methodological problem. Its clear solution by the speaker or the author of the textbook gives fundamentally new opportunities in activating the process of independent learning in students and leads to the formation of a creative personality [6], (Mukhamedov, & Makhmudova, 2020).

Each student can present their identity. Individual, group and frontal forms of work are used in this experiment: lectures, practical work, creative project, educational game, competition and thematic exercises.

Assignments using elements of 3D technology will be taught independently in extracurricular activities. Assignments are designed to be completed by students of all levels of preparation.

Practical tasks in 3D software are creative with reference to spatial modelling elements. Such training includes the use of the following methods: synchronous work of students on computers, homework to strengthen their knowledge, testing their skills, preparing students for the design of lesson plans on the computer; necessary for planning independent work assignments, organising and coordinating students' learning activities on the computer.

In the "Educational Information and Communication Technologies" class, when studying the topic of "3D modelling", students make more complex changes in the body. The work is organised in groups, which allows almost every student to prove their success in discussions, collaborative decision-making, adjusting the level of knowledge on the topic, developing the ability to work independently and demonstrating leadership skills.

During the practical work, team members have the opportunity to present their ideas on how to model events and processes, how to solve problems and evaluate their strengths. In addition, group activities provide an opportunity to gain experience in communication, to have the ability to prove their point of view, which is important in the formation of professional competencies of students.

The priority form of work that helps to form professional competencies is the project method, the purpose is to give students the opportunity to learn independently, to solve problems and tasks that require the integration of knowledge from different disciplines. This technology allows students to make the learning process more interesting due to their ability to solve problems using previously acquired knowledge and skills, to express themselves in practical independent activities. It is best to leave students with the choice of tools and methods to solve the problem. This leads to the creation of a state of success and the intensification of educational and professional activities. A group of students who are actively involved in various competitions and research projects related to 3D modelling in the organisation of project activities were identified. Students should be able to use the knowledge they have acquired in the study of relevant subjects. Group and individual counseling is organised outside of class. The results of the project will allow to determine the basic skills of 3D modelling and the basic level of their use in the relevant disciplines. In design or research work, students' independent activity is seen as a type of learning activity that allows them to purposefully form and develop their independence in the process of solving practical tasks. An important factor in the successful formation of students' professional competence in the use of elements of 3D modelling technology is the choice of software [7], (Karakhonova, 2019). Universal 3D editors, as a rule, include all the necessary tools for modelling, animation and visualisation.

The following factors were taken into account when selecting the application: the functionality of the applications; ease of use (intuitive interface, etc.); availability, price. 3D modelling is the process of creating a three-dimensional model of an object. The task of 3D modelling is to develop a visual three-dimensional image of the desired object. Thus, the optimal conditions for the use of elements of 3D modelling technology in the process of working on this experiment will allow students to develop professional skills. It is well-known that our educators often face the problem of inattention or indifference of students in the educational process. This process takes on a deeper meaning in the delivery of complex theoretical material. This is where 3D technology comes in handy and makes it easier for students to master and understand the material in the textbook. Thus, there is a mismatch between the demands of the time and the needs of the modern person. The use of 3D models in the education system is highly effective in improving the quality of teaching and effectively solving the problem of increasing students' motivation for science.

3. Conclusions

The use of 3D technology in education allows to perform the following effective tasks [8], (Kornilova, Trapeznikova, Raevskaya, & Inyutina, 2015):

- Increases the ability to direct students to scientific and research activities, helps to make the teaching process interesting and understandable;
- Stimulates the creative activity of each student, improves the quality of education;
- Increases the level of preparation of students;
- effective organisation of extracurricular activities;
- interesting competitions and events;
- Provides access to computerised models.

At the same time, the use of 3D technology in the educational process allows to observe processes that are difficult or complex to demonstrate in real situations and enhances students' spatial imagination, increases their interest in reading, their cognitive, creative and heuristic thinking, develops skills. This will increase the effectiveness of the quality of learning materials.

References

[1] Makhmudova D.M. (2019). Advantages of problem-based learning methods in teaching students. Continuing education, 4, 3–7.

[2] Khutorskoy A. V. (2012). Key design Technology and subject competence. eidos.ru journal // 0829–05.html

[3] Makhmudova D.M. (2018). The use of problematic issues in the development of independent creative activity in students. Doctor of Pedagogical Sciences (PhD) abstract. Tashkent UzNU, p. 48.

[4] Ergasheva G. (2018). Improving the effective use of interactive software in biology education. Doctor of Pedagogical Sciences (DSc) abstract. Tashkent UzNUU, p. 56.

[5] Khayrullaeva N.D. (2019). Use of 3D technology elements in the formation of students' professional competence. Teacher and Continuing Education, №4.

[6] Mukhamedov G.I., Makhmudova D.M. (2020). On the Application of Information – Communication Technologies in the Development of Independent Creative Thinking of Youth, International Journal of Psychosocial Rehabilitation, 24(09), 468–478.

[7] Karakhonova L.M. (2019). Using the electronic educational resources in biology lessons XIII International correspondence scientific specialized conference «International scientific review of the problems of philisophy, Psychology and pedagogy». Boston. USA. September №. 10–11, 35–40.

[8] Kornilova E.A., Trapeznikova I.V., Raevskaya M.V., Inyutina T.S. (2015). Methodical recommendations for the study of technology 3D-modeling in general educational institutions of the Belgorod region. Belgorod 2015.

Additional sources

[9] Eshchanov B.Kh., Gaipov D.N., Egamberganov I.Sh. (2020). Using distance learning in colloboration With social networks in teaching photonics and Optoinformatics// International Journal of Scientific & Technology Research, 9(2), 3809–3815.

[10] Fomin G. (2005). 3D modeling [Text] / Trans. from English. M. Izdatelstvo «Slovo», 290 pp.

[11] Eshchanov B.Kh., Arzikulov Z.K. (2020). Using information technology in the teaching of Atomic physics in higher educational institutions //International Journal of Scientific & Technology Research, 9(2), 6218–6222.

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EFFECTIVE USE OF 3D TECHNOLOGIES IN THE PROCESS OF TEACHING ASTRONOMY STUDENTS OF PEDAGOGICAL UNIVERSITIES

Abstract

This article reveals the possibilities of using 3D technologies in teaching students the discipline of astronomy in pedagogical universities. Instructions are also given on the use of working with a 3D printer in teaching astronomy students in pedagogical institutions.

Keywords: teaching astronomy, 3D modelling, 3D printing, STEM

1. Introduction

The subject of astronomy forms a scientific outlook, develops thinking and students' general idea of the universe. But the study of astronomy in universities is impossible without observations of celestial bodies. Not all universities of the Republic of Uzbekistan, where students study the subject of astronomy, have telescopes with modern equipment. In this article, we will explain the possibilities of using 3D technologies in teaching astronomy to university students.

The requirements for improving the quality of education in pedagogical universities, training future teachers – their compliance with modern requirements encourage applicants and doctoral students in the field of pedagogical science to search for new effective forms, methods, technologies for intensifying students' cognitive activity. In a variety of pedagogical innovations, the search for optimal means, methods and technologies, the training of teachers, one of the most promising is the technology of computer modelling using 3D technologies and 3D equipment: scanner, printer, pen, interactive whiteboard, etc. This technology synthesises a visual and practical method for teaching astronomy students.

A necessary condition for mastering modelling using 3D technologies is practical work with computer models, during this work students get acquainted with modelling methods, the possibility of using these technologies in solving problems in astronomy, getting an idea of the model parameters, the relationship between an astronomical model and a real celestial object when observing it with a telescope. With such types of work, students of pedagogical universities develop the skills of research activities, competent comprehension and analysis of the results.

The importance of using the means of packages of three-dimensional graphics and 3D technologies in modern education is determined by the fact that graphics and animation form a virtual information environment in which the student finds new opportunities not only for the perception and assimilation of new knowledge in astronomy, but also for developing abilities to operate with this knowledge in their future professional activities. Three-dimensional graphics allows to create three-dimensional astronomical models of celestial bodies, and models of telescopes, for example, repeating their geometric shape and emitting the material from which they are made. You can get a complete picture of a particular object (astronomy, astronautics, astrophysics), consider it from all sides, from different points in the best light. (Fig. 1)

Figure 1. 3D model of the Moon [8]

High technologies every year penetrate deeper into the daily life of society. Multimedia, interactive, mobile and 3D technologies have created a modern information environment with new types of communications. 90% of students in Uzbekistan have modern information devices: computers, tablets, cell phones with Internet access via 3G, 4G and wi-fi. In the educational process, from primary to university education, multimedia equipment and telecommunication technologies are widely used: 3D scanner, 3D printer, projector, laptop, computer, etc. 3D technologies have a huge educational potential that meets all the requirements in educational technologies.

3D technologies used in teaching students in the subject of astronomy make it possible to diversify the usual lectures and practical classes, make the educational process effective and visually capacious. The use of 3D content in classrooms at universities makes it possible to visually explain new material to students, and contributes to "immersion" in the topic in astronomy classes. It allows to dynamically move from the whole structure (for example, studying the topic Galaxy), to its individual elements (the solar system, individual stars), from simple to complex and vice versa.

In our article, we want to show the advantages of using 3D technology over other innovative technologies when teaching astronomy students in pedagogical universities:

1. The astronomy teacher has high-quality teaching material, which saves time to explain complex concepts in astronomy.
2. Visualisation of «difficult topics» in the Astronomy course programme can help students better understand astronomical phenomena.
3. The inclusion of 3D models of astronomical processes and celestial objects in traditional teaching methods introduces innovation into the learning process and increases the motivation of students to study the science of astronomy.
4. It allows to systematise students' knowledge of astronomy.
5. It promotes the assimilation of a large amount of information, which can positively affect the result of the final and intermediate control of students' knowledge of astronomy.

2. 3D printing in teaching astronomy

When using 3D technologies in astronomy classes, students have the opportunity to study in detail both the external and internal characteristics of stereoscopic models. For example, travelling from planet to planet is virtual. Interactivity is an important teaching method, as astronomical objects are difficult to visualise and sometimes observe for reasons such as air pollution, city lighting, very distant celestial objects, etc.

Since 2013, 3D printers have been actively introduced into schools and universities in America, Great Britain and Japan. In Russia, 3D printing in education appeared in 2014. In many CIS countries, including Uzbekistan, 3D technologies are used in education at universities.

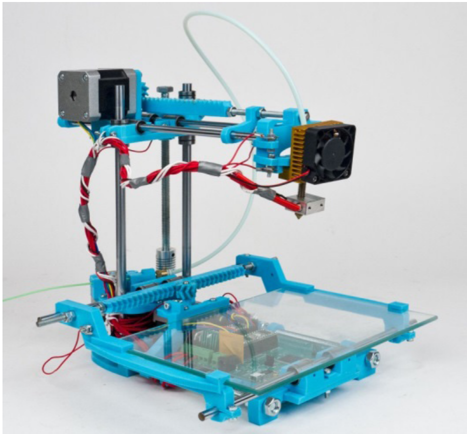

Figure 2. 3D printer – constructor [9]

A 3D printer makes it possible to design, for example, astronomical instruments. The use of 3D printing paves the way for interactive modelling. Students can design 3D telescope parts, print and evaluate them. The involvement of 3D technologies leads to an increase in innovations in the preparation of term papers and final qualification works of students of pedagogical universities [5]. Having drawn an idea on a piece of paper and modelled it in CAD and printed it with a 3D printer, students will use this method again [6].

If a 3D printer is equipped in the classroom of the university, then it can perform the tasks of teachers and students – who are given tasks by subject teachers. Students, having completed the drawing, a model of an astronomical object, will learn discipline and perseverance. This is because before you complete the tasks, you need to understand how to do it, while developing thinking and logic. Students also need to study a program in which a project or model of a celestial body or an astronomical phenomenon will be developed. A student, having learned to work with 3D technologies, can independently complete tasks, and not use ready-made solutions and conclusions, coming to lectures and other types of classes at a university. A 3D printer enables university teachers to bring students to a higher level – creativity, self-organisation, focus on work, the emergence of new ideas [5].

The novelty of 3D printing technology allows to create unique objects, including in the field of astronomy. 3D printing is closely related to working with a computer, many tasks are optimised. 3D printing is being actively researched and improved to produce more astronomy models in less time. Having learned how to work with 3D printing, you can find a job in another area of interest in production and science, in addition to the field of education.

Students who learn how to use 3D printers while studying astronomy can learn the fundamentals of the technology used on this device. In Russia, there is an Association of 3D Education, there are international competitions and olympiads: the International Junior Skills Championship, or the All-Russian Olympiad in 3D Technologies [7].

After the conducted pedagogical experiments, it can be concluded that students of pedagogical universities improve their academic performance due to the development of analytical abilities and critical thinking skills in the course of their teaching astronomy and using 3D technologies.

Positive reasons for the introduction of 3D printing in the educational process when teaching astronomy students in pedagogical universities:

1. Creation of an interactive learning environment;
2. Development of creativity and innovation;
3. Improving the perception of the real universe;
4. Preparation for the final qualifying work;
5. Involvement in digital processes;
6. Development of problem solving skills in astronomy;
7. Development of design thinking.

Students with great pleasure immerse themselves in the process of studying astronomy if the learning environment at the university makes them participants in this process. The experience of using 3D printing technology makes teaching astronomy dynamic [3]. Astronomy material presented through computer slides can arouse interest and hold students' attention only for a short time.

3D printing is available to students with different perceptions of the material, which means that kinesthetics and visuals will equally appreciate this approach to teaching astronomy in pedagogical universities. Creativity is an important skill of students who excel in knowledge [4]. It influences the ability to generate new ideas and develop innovative solutions. 3D printing technology is entirely based on creative skills, encouraging students to solve problems in astronomy, design astronomical models by using it, use automatic design programs, and work on printing optimisation. After all, ready-made 3D models printed using stereolithography (SLA) technology are distinguished by a smooth surface, every detail is drawn and they are characterised by a significant ease of painting.

A 3D printer is the main tool for a STEM lab that can be used in astronomy labs at pedagogical universities. With its help, students will be able to have practical experience in creating astronomical models, because 3D printing of objects develops creativity, spatial representation and practical skills in building objects. 3D modelling allows to quickly create a fully-fledged astronomical model according to the required parameters. The use of a 3D printer allows to produce copies of celestial bodies, graphics, models of space telescopes, etc.

The use of 3D printing opens up a fast path to iterative modelling. Students and teachers can design 3D astronomy models, print and evaluate them. If the result is not the model or part of the model that was planned, you can try again to redo it. When studying the theoretical and practical aspects of modelling in astronomy, there is an integration of education. Inter-subject connections between astronomy and information technology are being implemented, students of pedagogical institutions are becoming more enthusiastic and motivated to teach astronomy. To master the content of the subject of astronomy, you can use the possibilities of information technology, expressed through the teaching functions of computer modelling, students acquire these necessary knowledge and skills in computer science classes.

Students who have knowledge of 3D printing are more prepared for their future work as teachers. By mastering 3D printing while studying at the university, students develop creativity and creative abilities, which will allow them to easily cope with professional duties at school in the future. The inclusion of the study of 3D technologies in teaching astronomy to students of pedagogical universities will allow them to better navigate digital educational processes. During the training, students comprehensively analyse all digital processes: from designing a model in a CAD program to post-processing of a finished model in astronomy. For example, the study of galaxy models, as a basis for the study, several photographs of galaxy models taken from different positions (top view, side view) are used – the images are transferred to a 3D model (Fig. 3). Students, using a critical approach, get the opportunity to go from an abstract idea to a real three-dimensional object (for example, a galaxy) by analysing how these concepts relate to each other. 3D printing allows solving problems using a logical systems approach, further developing creative thinking.

Figure 3. 3D model of our galaxy – the Milky Way [10]

It can be concluded that 3D printing is a multidisciplinary technology that allows developing any skills when teaching astronomy students in pedagogical universities. Any program in the course of astronomy, or when teaching students of astrophysics, supplemented by the study and use of 3D printing in teaching, can become more exciting and applied, and contribute to a higher result in mastering educational material both in lectures and in practical and laboratory classes in pedagogical universities. 3D printing technology is a fully-fledged and important element of modern astronomy education in universities.

2. 3D modeling in teaching astronomy

In many general education schools, academic lyceums and universities, a multimedia projector, a computer or laptop, as well as an integrative board are used in lessons and classes. In order to improve the efficiency of assimilation of the curriculum in astronomy, in schools, academic lyceums, universities, it is necessary to use programs with 3D technology to create a three-dimensional image of objects. As experience shows, three-dimensional educational materials are perceived with interest by pupils and students. Animations produced by 3D technology evoke associations in students when memorising new educational material [1].

For example, in lessons and classes in astronomy, when studying the topic: "Structure and composition of the solar system", you can use a video in 3D format, where, when showing three-dimensional graphics, students can see the structure of the solar system, the movement of planets, their rotation around Sun. In order to observe the depth and volume of an astronomical model, you need to wear 3D glasses. When considering the rotation of the bodies of the solar system in 3D, one can visually estimate the comparative sizes of the planets – giants and terrestrial planets. Since the celestial bodies in space are very far from the earthly observer, therefore, using 3D models of the planets of the solar system in astronomy lessons will allow students to see these celestial bodies for the first time. The study of the solar system can help students not only visit the planets, but also feel the beauty of the giant planetary system, understand the position of the Earth relative to the Sun [2].

3D demonstrations focus the attention of students and students on the chosen topic of the lesson, which allows them to gain more knowledge than traditional teaching methods. When presenting new material on the topic: "The internal structure of the Sun", students can see with the help of a 3D model each part of the internal structure of the Sun: the core, the radiative transfer zone, the convective zone, the photosphere, the chromosphere and the solar corona. It is also possible for students in universities to clearly explain the topic: "The Evolution of Stars", using 3D technologies.

Students and pupils, thanks to the use of 3D technologies in the educational process in astronomy, form a cognitive interest.

3. Conclutions

But the 3D product is not recommended to be used for more than 10–15 minutes, as it may cause dizziness and nausea for students when taking off the 3D glasses. We can conclude that 3D technology in astronomy classes is a short-term, planned source of information aimed at enhancing cognitive activity in teaching pupils and students.

References

[1] Innovations in the field of education based on 3D prototyping technologies [Electronic resource]. Access mode: smileexpo.ru> public/upload…v…obrazovaniya…file.pdf (in Russian)

[2] Subject concepts as a methodological basis for the modernisation of the content and technologies of education: materials of the Interregional scientific and practical conference "Actual problems of natural and mathematical education." October 2017: at 2 pm Part 2. Lipetsk: GAUDPO LO "IRO", 2017. 106 p. (in Russian)

[3] 3d today.ru, encyclopedia of 3D printing (in Russian)

[4] Ilyin E. P. Psychology of creativity, creativity, giftedness. St. Petersburg: Piter, 2012, p. 40. (in Russian)

[5] Sergeev I. S. How to organise the project activities of students: A practical guide for employees of 15 educational institutions. 2nd ed., rev. and additional M.: ARKTI, 2005. 80 p. (in Russian)

[6] 3D printers in education: the coming future (in Russian) http://newtonew.com:81/tech/3d-printer-in-school

[7] All-Russian Olympiad in 3D technologies http://center-intellect.ru › olimpiady › 3D_technology

[8] https://cutewallpaper.org/24/eclipce-png/view-page-24.html

[9] https://www.ixbt.com/printer/3d/3d_masterkit_mc2.shtml

[10] https://zimo.dnevnik.hr/clanak/znanstvenici-otkrili-zanimljve-obline-u-nasoj-galaksiji---570331.html

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PROBLEMS AND PROSPECTS OF DIGITISING ARABOGRAPHIC MANUSCRIPT SOURCES RETAINED IN SAMGU

Abstract

Digital technologies are gradually becoming an integral part in all spheres of human life. Including in the field of research and development. Digitisation is widely used in the preservation and study of historical monuments. This article deals with the problems and prospects of digitising historical handwritten sources, which are stored at Samarkand State University. They are written by masters of their craft on Samarkand paper. The digitisation of such folios expands the geography of openness and accessibility of handwritten sources to a wide user circulation.

Keywords: digitisation, new Uzbekistan, manuscript funds, archive, museum, library, Samarkand State University, Lublin University of Technology

1. Introduction

In the modern globalised world, digital technologies are gradually becoming an integral part in all spheres of human life. Digitisation has a significant impact on the development of traditional sectors of the economy and the transformation of the social life of people. It is also widely used in the preservation and study of historical memory, and the scientific and cultural heritage of the peoples of the world.

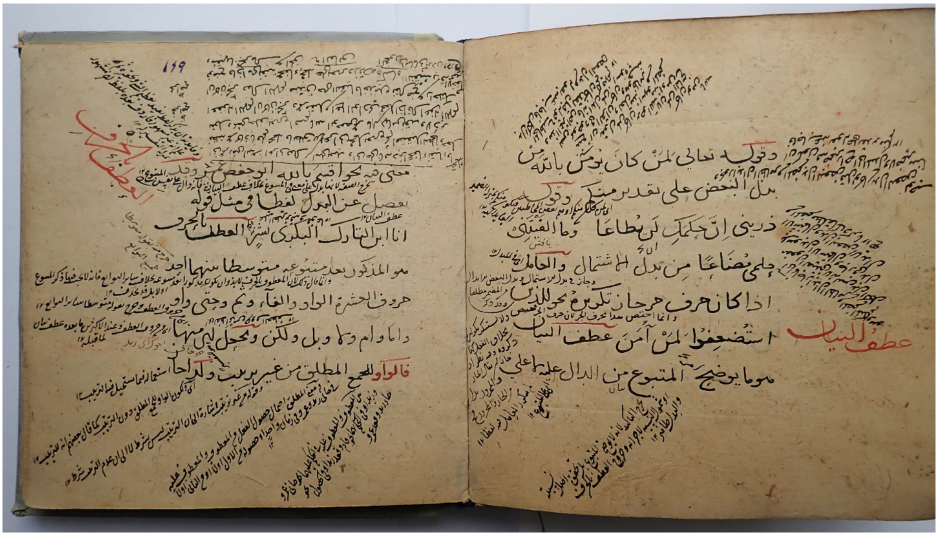

Figure 1. A book from the SamSU collection

The new Uzbekistan, led by Shavkat Mirziyoyev, is carrying out large-scale reforms to ensure that civil society meets the requirements of the digital age. Social media, online information, big data and information governance issues such as freedom and transparency of information, property, open government and information security reflect new large-scale trends that today require new perspectives on the preservation and study of the handwritten heritage of great mediaeval thinkers of Maverannahr.

The state archives, museums, libraries, manuscript funds and private collections of Uzbekistan have at their disposal a large number of truly unique manuscripts. But, if certain steps are not soon taken to digitise them, they can simply be lost. And these handwritten sources are of extremely important value, both for individual people and the state and society as a whole.

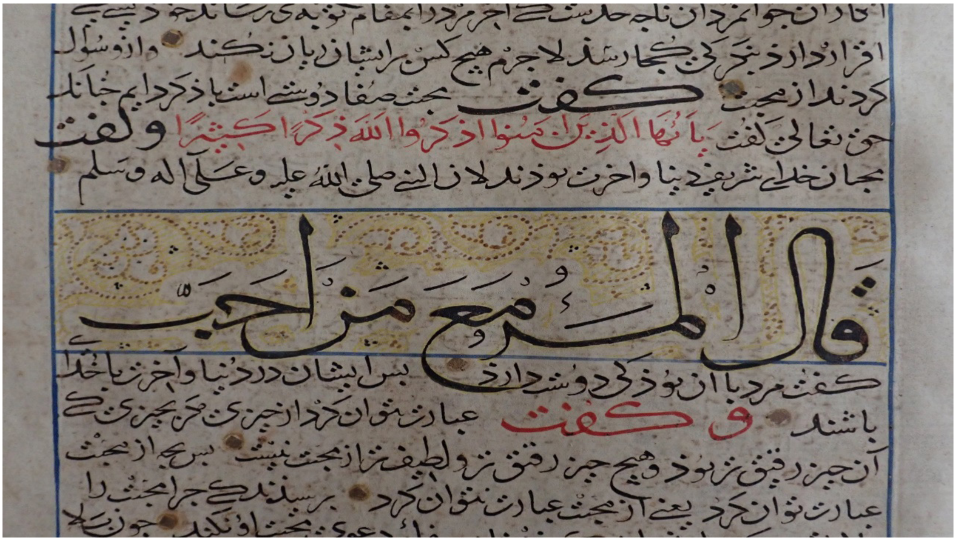

Figure 2. An example of decorative calligraphy from the SamSU collection

In this article, we will dwell on the problems of digitisation of arabographic handwritten sources stored at Samarkand State University (SamSU) and the prospects for mutual cooperation on this issue.

Uzbekistan legislation and local experience

Modern digital realities require the need to introduce modern information and communication technologies into the field of preservation and study of the manuscript heritage of the peoples of Uzbekistan, the use of digital acquisition tools, and state accounting.

This is in line with the tasks for the modernisation of specialised institutions, previously outlined in the President's decree "On measures for the innovative development of the sphere of culture and art in the Republic of Uzbekistan" dated August 26, 2018.

The document launched an experimental Renovation Programme, which envisages, among other things, a more active use of IT and the introduction of "smart" technologies: electronic guides in different languages, information kiosks, 3D visualisations, holograms and QR codes, digitisation of exhibits and mass access to them through the Internet. On this basis, Uzbekistan began to create electronic catalogues for the National Museum Fund. The initial task is to form an internal database for employees based on the software of the Swiss company Zetcom. It is successfully used by the Louvre, leading museums in the United States and other countries. And then it is planned to open public Internet galleries of these museums.

Figure 3. Miniatures in an Arabic book from the SamSU museum collection

The President of Uzbekistan put forward the idea of creating a Virtual Museum of Cultural Heritage of the CIS member states (Commonwealth of Independent States). It was approved. The project was discussed with interest at a meeting of the working group of the CIS Executive Committee in Minsk. Uzbekistan is ready to present and manage the web platform. Invaluable wealth will be collected that cannot be imagined physically gathered in one place – the most significant artefacts of the tangible and intangible heritage of the peoples of Eurasia. They will be presented using 3D tours, digital panoramas and stands, multimedia and animation tools.

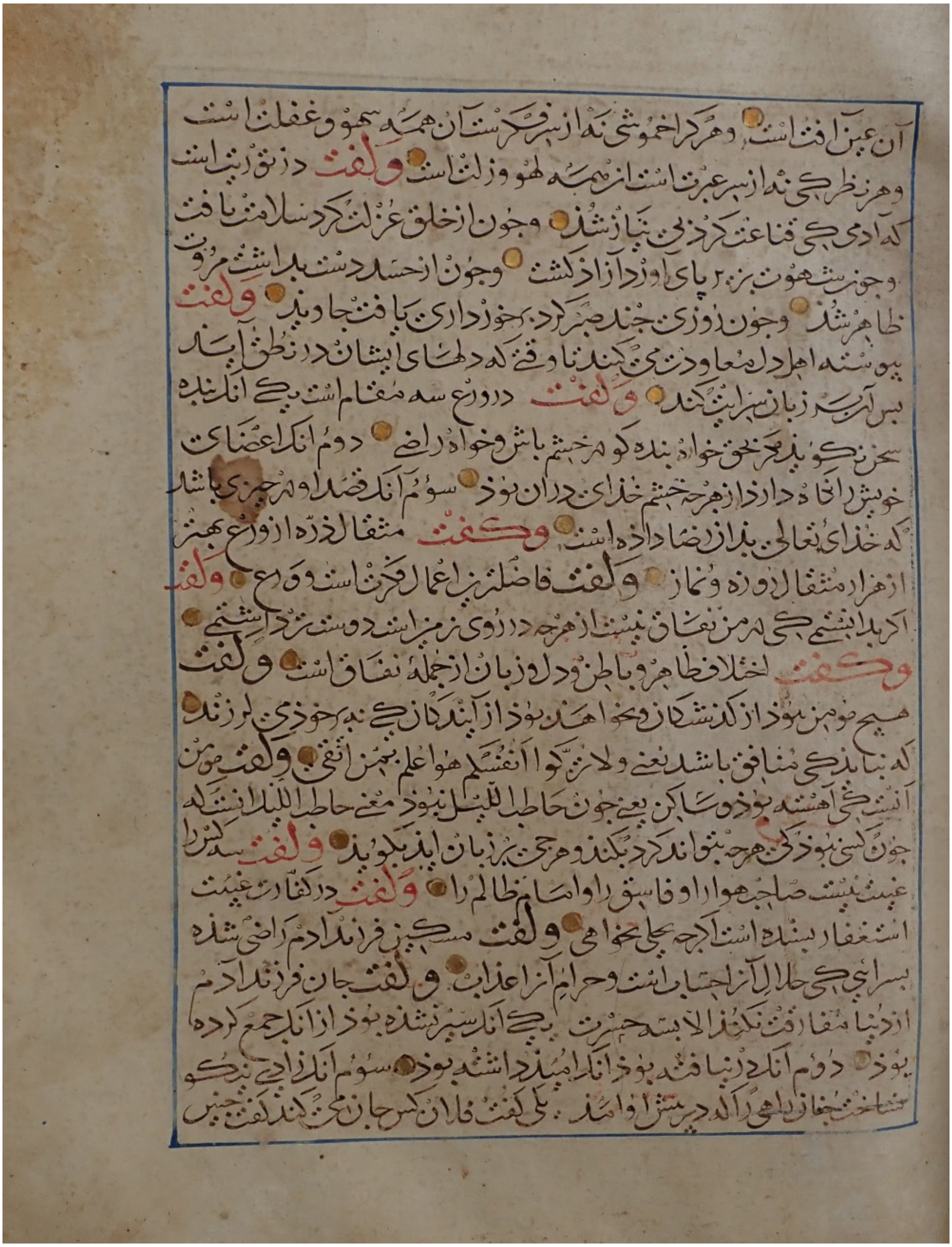

Figure 4. An example of Arabic calligraphy from the SamSU collection

In order to improve public administration and control in the field of archiving and office work, further accelerate the digitisation of documents in paper form, film, photographic and audio documents, on September 20, 2019, the President of the Republic of Uzbekistan issued a decree "On measures to improve archiving and office work in the Republic Uzbekistan". In it digitisation (making electronic copies) of archival documents, books and manuscripts was designated as the main task. The main directions for improving the sphere of archiving and office work are: the accelerated introduction of modern information and communication technologies in the activities of archiving and office work as well as phased digitisation and the creation of insurance copies of archival documents of the National Archive Fund of the Republic of Uzbekistan.

In particular, in the National State Archives of the Republic of Uzbekistan, active work is underway to digitise especially valuable documents. These are the documents that are most in demand, as well as those that are in poor physical condition. That is, the priority is given to valuable historical documents and those that require conservation with a fading text.

Based on the above legislation, each organisation that keeps handwritten sources with them is working on digitisation. For example, the Alisher Navai National Library of Uzbekistan website (nodir.natlib.uz) includes historical sources. This can also be traced on the websites of the Abu Raikhan Biruni Institute of Oriental Studies (beruni.uz) [15], the Mamun Khorezm Academy (mamun.uz), the Imam al Bukhari International Research Centre (bukhari.uz) and others.

In our opinion, in order to further modernise and improve this area, it is advisable to refer to the experience of foreign countries which have a more developed infrastructure for using digital technologies for digitising historical handwritten sources and implementing projects for the long-term storage of electronic documents.

The President of the Republic of Uzbekistan Shavkat Mirziyoyev, at a meeting with leading representatives of domestic science, noted: "The time itself requires further development of scientific cooperation with leading world institutions, universities, research centres and academies of sciences" [1].

2. Overseas experience

The countries whose experience will be useful for the digitisation of manuscripts include, first of all, the USA, Japan, Korea and the countries of the European Union, which are successfully moving forward in the development of this area.

The leading libraries, archives and museums of the world are engaged in the digitisation of historical sources and their placement in the Internet. For example, the British Library of England has electronic databases of documents [16]. The National Archives of France (Archives nationales de France) has created a lot of user-friendliness on its website [17]. Photocopies of authentic historical sources can be found on special

Internet sites and telegram channels of the National Library and Archives of the Islamic Republic of Iran. Some of them are also available through Russian sites [18].

But especially noteworthy here is the experience of our connections with the Republic of Poland, which closely cooperates with Uzbekistan. Samarkand State University in the field of digitisation of historical and cultural heritage is conducting fruitful collaboration with the Lublin University of Technology. In this regard, it would be profitable to address the topic of digitisation of arabographic historical sources, which are preserved in the manuscript collection of SamSU.

3. About the handwritten fund of SamSU

Samarkand State University (SamSU) is not only the successor of mediaeval madrasas, but also the custodian of invaluable Arabic script sources reflecting the tradition of Islamic (or Muslim) education. The "Manuscript Fund" of SamSU is considered to be the richest "repository" of the most valuable handwritten folios. There are collections of written monuments dating from the 13th to early 20th centuries. The fund has more than 12 thousand items in store, consisting of oriental manuscripts and lithographic publications in Tajik-Persian, Turkic-Uzbek, Arabic and other languages. The Foundation has attracted and continues to attract close attention of not only domestic, but also foreign researchers.

The "Manuscript Fund" of SamSU is considered to be the richest "repository" of the most valuable manuscript folios. There are unique manuscripts written over centuries. The oldest manuscript comes from the 13th century, and the most recent from the beginning of the 20th century.

From the first steps, the activities of the foundation were associated with research work. The first attempt to inform the scientific and general public was a bibliographic work published in Arabic script in 1977 [19]. It lists the names of the manuscripts and their inventory numbers in three sections: Turkic-Uzbek, Tajik-Persian and Arabic. For the first time, this edition revealed to specialists the content of the manuscript collection of SamSU.

Some results of long-term work in this regard was the publication of the catalogue in the Tajik language in Arabic script in 1989 [12], an index compiled in Uzbek, Russian and English, published in Cyrillic, Latin and Arabic script in 1990 [4] or a bibliographic index of physical and mathematical works, published in 1991 [14]. SamSU "Manuscript Fund" has its own experience in studying and using manuscripts for educational purposes [13, 2, 3].

The collection of oriental manuscripts of SamSU is mainly devoted to the history, science, language and literature of the peoples living in Central Asia. The Foundation is of great scientific importance, it is the pride of not only the university, but also the national treasure of the Republic. This is probably why many foreign researchers were interested in the foundation and are interested in them, who left their sincere responses in the "visitors' book". Until now, the fund has collaborated with scientific institutions and academies of sciences of China, Poland, Germany, Romania, Bulgaria, Czechoslovakia, Afghanistan, Burma, Egypt, Iran, India, Pakistan, France, Holland, USA, England, Japan [5].

The “visitor’s book” of the department of oriental manuscripts contains reviews of Alma Hamilton from Sydney, Dr Hilge from the University of Maryland, USA, the rector of Ankara University – Mahmud Kemal Erkin, a member of the Turkish Academy of Faik-Rashid [6], Dr Zarrinzoda from Azerbaijan [7], Professor Raziullah Ansari from the Indian University Aligarh, Dr. Beatrice Harvard University (USA), Professor Bert Frager from the German University of Bamberg, Dr Philip Bern from the University of California (USA), Professor David King from the University of New York, Professor Devin Davis from Indiana University (USA) and many others. Reviews are written in English, Farsi, Hindi, Urdu and other languages.

In recent years, the foundation has been collaborating with Japanese scientists. The “Agreement on cooperation between SamSU and the Aichi Art University” was drawn up for the study, preservation and restoration of ancient oriental manuscript books [8]. Joint work is underway within the framework of the project [9, 10, 11].

Among the manuscripts there are not only rare, valuable, but also unique, irreplaceable autographs. Among them, the manuscript of the work “Tazkirat al-auliya” by Farid ad-din ‘Attar is of particular value. The author of this manuscript died at a very advanced age during the Mongol conquest in 1221 or 1229.

The manuscript “Tazkirat al-auliya”, is stored in the SamSU fund under No. 1008579. For centuries, the cover and first page of the manuscript have been damaged, so they are completely replaced. Also damaged were writings on pages 2, 3 and 4, now successfully restored. During the process, the “colophon” was saved and glued to new paper.

The manuscript was rewritten in the month of “Rabe ul Avval”, 685th year of the Hijra, which corresponds to AD 1286. The scribe was Abdurrakhim bin Makhmud. The text is written in “suls” (a type of calligraphy) with black ink. It is placed in a rectangular frame outlined in blue. The beginning words of passages and the verses are written in red ink. The points at the end of logical sentences are used as an element of ornament, because the Arabic manuscript books did not use punctuation marks. This manuscript used gold points for division of a particular text from others.

Handmade subtlety and colour combination can be seen when writing Quranic quotes, especially in headlines. Perhaps in their time all the headlines were gilded, although today not all are noticeable.

4. Conclusions

To sum up, one has to note that the manuscript department of SamSU is an invaluable repository of oriental folios. It is an unique trove, a source of knowledge and wisdom for successive generations of people, and an excellent material for new research. Therefore, it requires special attention in matters of the collection’s storage and use.

The digitisation of such folios expands the geography of the openness and accessibility of handwritten sources to a wide user circulation. It is to be hoped that this achievement will be just one of many results in our fruitful and effective cooperation with the Polish colleagues.

References

[1] Achievements of science are an important factor in development, Gazeta Narodnoye slovo, 31 December 2016. (In Russian)

[2] A guide to using ancient manuscripts in the learning process. Compiled by Abduhakim Abduhamidov. Part 1, Samarkand, 2009. p. 56. (In Uzbek)

[3] A guide to using ancient manuscripts in the learning process. Compiled by Abduhakim Abduhamidov. Part 2. Samarkand, 2009. p. 44. (In Uzbek)

[4] Bibliographic index of manuscripts and lithographs of Alisher Navoi's. Developers: Sh. M. Aminov, A. B. Pulatov, X. K. Akhrorov. Edited by professor B. N. Valikhodjaev, Samarkand: SamGU, 1990. p.149. (In Uzbek)

[5] Fayzullayev X., Krupneyshaya bibloteka Sredney Azii. Gazeta Leninskiy put, 26 December 1957, No. 255 (5102). (In Russian)

[6] Grekallo N., From the depths of centuries, Gazeta Leninskiy put, 31 December 1963, No. 260 (6756). (In Russian)

[7] Guests of our university, Gazeta Samarqand Universiteti, 5 July 1966, No.. 16 (257). (In Uzbek)

[8] Kayumov R., Japanese scientists will share the secrets of restoration, Gazeta Samarkandskiy vestnik, 23 May 2018, No 40 (188144). (In Russian)

[9] Kayumov R., Japansi interested in manuscripts, Gazeta Pravda vostoka 23 May 2018, No 98 (28809). (In Russian)

[10] Kayumov R., International scientific and practical seminar in Samarkand) Sayt Samcity.uz, 02.03.2019. (In Russian)

[11] Kayumov R., An international scientific and practical seminar in Samarkand was devoted to the study of the processes of history and the manufacture of old paper, Sayt Kultura.uz. 03.03.2019. (In Russian)

[12] Catalogue of handwritten works of Abdurrahman Jami. Part I, Sostaviteli: A. Pulatov, Sh. M. Aminov. Obshchaya redaksiya i predisloviye d.f.n., prof. B. Valixodjayeva, Samarkand, 1989. p.100. (In Russian)

[13] Guidelines for the use of handwritten works in courses on the methodology of teaching mathematics and the history of mathematics, Samarkand, 1992. (In Russian)

[14] Descriptions of physical and mathematical manuscripts and lithographs of the Eastern Department of the Samgu Scientific Library. Part I, Sostavateli: D. X. Kayumov, G. X. Dalili. Otvet. redaktor: X. K. Axrorov, Sh .M. Aminov. Pod obshchey redaksiey prof. B.N. Valixodjayeva, Samarkand, 1991. p. 144. (In Russian)

[15] See: http://beruni.uz/en-ca/ilmiy-hayot-2/item/302-elektron-katalog-bazasi.html.

[16] See: https://www.bl.uk/.

[17] See: http://www.archives-nationales.culture.gouv.fr

[18] See: https:// www.wdl.org/ru.

[19] List of Oriental Manuscripts of the Alisher Navoi Fundamental Library of Samarkand State University, Sostaviteli: A. Pulatov, X. K. Axrorov. Otvet. redactor, kandidat istoricheskix nauk A. A. Abbosov, Samarkand,1977. p. 74. (In Russian)

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THE USE OF MODERN IT TECHNOLOGIES IN THE STUDY AND PRESERVATION OF OBJECTS "ZIYORAT TURIZMA" OF THE CITY OF SAMARKAND

Abstract

Located at the crossroads of the Great Silk Road, Samarkand is one of the largest tourist centres in the world. Registan, the heart of the city, has become its distinctive brand. This complex is valued not only as a place of "pilgrimage tourism" for local but also for all Muslim tourists. In recent years, Polish scientists have been actively involved in the preservation and study of historical monuments located here. In particular, they make a worthy contribution to the use of IT technologies in this area.

Keywords: Great Silk Road, tourism, Samarkand, "pilgrimage tourism", tourist, potential, Registan, Sher-dor, Tillya-kori, digitisation, NAWA, Lublin University of Technology

1. Introduction

Located at the crossroads of the Great Silk Road, Samarkand has been and remains an international tourist centre throughout its history. This lovely city will charm any person. Anyone who has seen it once will never forget it.

The city of Samarkand integrates the most ancient times and modern life. With its magnificent architectural monuments, blue domes, unique oriental look and spirit, it attracts the attention of travellers, tourists and visitors.

Registan, which has become a unique brand of the city, is valued not only as a place of "pilgrimage tourism" for local but also for all Muslim tourists. Polish scientists are making a worthy contribution to the use of IT technology in the study and preservation of historical monuments located in Registan Square. We will discuss these in more detail below.

2. The Great Silk Road and international tourism

Tourism has served to strengthen the ties of friendship between the peoples of the planet since ancient times. People set out to explore new lands, see and know the world, develop trade, and establish cultural and diplomatic ties.

The expansion of trade relations led to the migration of the population. They also brought with them their own traditions and worldviews, which are reflected in the products of architecture, cultural monuments, numismatics and handicrafts.

As we analyse the history of the emergence and formation of international tourism, in addition to establishing trade relations, recreation and travel, to study and know the history, culture, customs and traditions of the peoples of the world and strengthen the qualities of solidarity and tolerance between peoples, we are once again convinced that it is also an important component of tourism.

It was through Samarkand that the Great Silk Road ran – one of the most significant cultural and socio-economic phenomena of world history. Already in the 3rd-2nd millennium BC, communication systems were formed that linked the most distant cultures and countries in the vast region of the Middle East, stretching from the plains of Mesopotamia to the Indus valleys and from the oases of Central Asia to the Arabian Sea. It was they who later became one of the main routes of the Great Silk Road.

The historic Great Silk Road still serves for new prospects for the development of international tourism. Samarkand played an important role in this process, as trade caravans crossed paths and were located at the crossroads of cultures and civilisations.

3. Tourist potential of Samarkand

In recent years, Uzbekistan has been paying great attention to the development of tourism. Because this sector also makes a significant contribution to the growth of the country's economic power. Speaking about the huge tourist potential of Uzbekistan, "first of all, we mean the most ancient civilisations and cultures formed and developed in the country, rock inscriptions and hieroglyphs, unique historical monuments, glorious and unique examples of material culture and architecture. They are currently being studied by many scientists and experts from Japan, France, Germany and other countries. At the same time, the richness and diversity of our beautiful nature, which with its charm and beauty is not inferior to the best places of rest and travel in the world, is our greatest opportunity in this regard [20]. All this serves to turn Uzbekistan into one of the world's tourism centres.

Samarkand, with a rich history of almost three thousand years, is a crossroads of different cultures and a masterpiece of world civilisation. The Huffington Post, an internationally recognised American publication, has ranked Samarkand as one of the 50 cities in the world that a person must visit at least once in his or her lifetime [20].

The murals in Samarkand reflect the visits of ambassadors, traders and travellers from around the world to Central Asia. This unique historical work depicts the ceremonies of receiving ambassadors of China, Korea, South and North Asia and other countries in the palace of the ruler of Afrasiab more than 2,500 years ago.

Therefore, it is no coincidence that 20 years ago, the Samarkand Declaration of the member countries of the international project on tourism development along the Great Silk Road was adopted in Samarkand. This document describes the revival and development of international tourism in this ancient transcontinental direction, which 2–2.5 thousand years ago passed through the vast regions of the Middle East, Central

Asia and the Middle East, connecting Asia and Europe with trade and cultural ties. It was in Samarkand in 2004 that the World Tourism Organisation decided to establish a regional centre on the Silk Road [20].

4. Patterns and ornaments on Registan monuments

The medieval patterns and ornaments of the Samarkand architectural monuments included in the UNESCO World Heritage List are unique. They are of interest to experts in various fields. An example of this are the decorations of the Sher-dor madrasah in Registan.

Registan is a rectangular square and three historical and architectural monuments border it with their large façades: the Ulugbek, Tillya-kori and Sher-dor madrassahs. Such establishments were higher educational institutions – the universities of their time.

The creation of a powerful centralised state on the territory of Maverannahr at the end of the 14th century by Amir Timur (1370–1405) served to further develop the region. Amir Temur went down in world history not only as an outstanding commander and statesman who created a powerful and prosperous state. He turned his capital – Samarkand into one of the cultural and scientific centres of the world [7].

The creative work begun during the time of Amir Timur was continued during the reign of his grandson Ulugbek (1409–1449). He paid much attention to the improvement of his capital – Samarkand [15]. It was under him that the improvement of Registan Square began. Two large buildings were built here. One of them is a higher educational institution "madrasah", named after the builder. The second is a khanaka, a hostel for God-seekers and a hospice. The grandiose construction works of the Ulugbek era are well reflected in the sources [1 p. 377; 22 p. 45] and studies [2, 6, 14].

The first half of the 17th century, the reign of the Ashtarkhanid dynasty for the regions of the Zerafshan valley, was a period of cultural upsurge. At that time, in Samarkand, just as two centuries ago, vigorous construction activity broke out again. In a few decades, the city and its environs were adorned with a number of large architectural monuments that imitated the buildings of the Timurids. Many of the newly erected structures were almost as good as their models in terms of the amount of materials, labour and time spent.

It was at that time that two more majestic madrasahs on Registan Square – Sher-dor and Tillya-kori emerged. Both owe their appearance to the hokim (mayor) of Samarkand – Yalangtush-biy bakhadur. Taking advantage of the weakness of the central government, he began to pursue an independent policy. He exerted great efforts to improve the city.

The Sher-Dor madrasah was the first to be built in the reign of Imam-Kuli Khan (1611–1642). Information about this is given in the source "Tarixi Sayyid Roqim" under the title «خیرات بانی مدرسهٔ اول یلنگتوش بی بهادر», that is, "the history of the construction of the first madrasah Yalangtush-biy Bahadur" [21]. By his order, on the site where Ulugbek's khanaka used to be, which was a huge ruin in the 17th century, construction began. The building was built over 17 years (1619–1636). It contains absolutely original paired mosaic images placed on the tympanums of the portal, the main figures of which are sher, which gave the name to the madrasah itself, Sher-dor, which means 'decorated with lions' in translation [19 p. 12]. The name of the architect is written in white letters in a small black medallion: "Abduljabbar – the architect" [4]. This name undoubtedly deserves the memory of posterity.

In Central Asia, the term "sher" denoted both a lion and a tiger at the same time. It would be correct to translate this term as tiger. In the sources on the history of Central Asia, there is information about representatives of a large cat breed – lions (shirs). They were, in fact, local tigers. The Central Asian or Turanian tiger belongs to a special subspecies with soft, relatively long and light-coloured hair (Tigris virgata Matschie). It was large, reaching a length of more than two meters without a tail, a bloodthirsty predator, which also had terrible strength. It was called in Turkic – "yulbars" or "dzhulbars", in Persian-Tajik – "sher" or "shir". It was considered the king of all local animals. The participation of the image of the tiger in the cultural life of the population of Central Asia [16] is considered a topic for a separate study. It should be noted that the Sher-dor Madrasah with the image of a tiger is not the only phenomenon. This can be traced in other architectural monuments of Maverannahr.

According to the Spanish ambassador Clavijo, who visited the city of Shakhrisyabz in 1404, images of a lion and the sun were placed there above the entrance to the main building of Amir Timur's palace "Aksaray" [11]. Perhaps they served as a model for the figures of the Sher-dor madrasah.

There were tiled images of birds and white lions on the main portal of the Divan-begi madrasah in Bukhara [14 p. 17]. By the way, the Samarkand madrasah Divan-begi is known under the name "Outer Sher-dor" (Sher-dor-i berun) [3 p. 28]. Since, on its portal in tiled tympanums there were images of a pair of large tigers and under them a pair of small ones.

10 years have passed since the completion of the construction of the Sher-dor Madrasah. In 1056/1646–1647, Yalangtush-biy Bahadur, at an advanced age, began the construction of a new madrasah. The building, which was supposed to close the Registan Square with its front façade from the third northern side. The Tilla-kari madrasah was erected on the site of a caravansaray built by Ulugbek. Construction was completed in 1660 [12].

5. The contribution of Polish scientists to the study and preservation of the monuments of Registan

From the moment of the first construction on Registan Square to the present day, a lot of time has passed – 6 centuries. The appearance in which we can see the Registan today is the painstaking work of hundreds of craftsmen, restorers.

Figure 1. Fragment of a printed matrix in 1:1 scale for renovation of the mosaic in the Sher-dor Madrasa, prepared by staff of the Lublin University of Technology, photo: J. Montusiewicz

Throughout its existence, the Sher-dor Madrasah has experienced several earthquakes, the most devastating of which occurred at the beginning and at the end of the 19th century. The building survived, but it was still damaged: the vault of its main portal was severely deformed, the cladding collapsed in many places, and the minarets squinted. In the early 1920s, by a decree of the Soviet authorities, teaching in the madrasah was discontinued. The building was nationalised and restoration work began in 1924. The hujras were repaired, the collapsed part of the brick vault of the portal arch was restored, the carved mosaic of the tympanum of the main portal was strengthened, its deformed vault was dismantled and re-laid, the domes and vaults of the hujras were rebuilt, and the cladding of the facades of the madrasah was restored. At the end of the 1950s, archaeological surveys were carried out on the territory of the madrasah, after which a new stage of restoration began. In 1960–1962, the minarets of the madrasah were repaired, and in 1962, according to the project of the artist V. N. Gorokhov and architect A. I. Freitag, the tympanum mosaic above the arch of the main portal was restored. Restoration and strengthening works of the madrasah were completed in 1965–1967.

Registan Square has been especially beautiful since the country's independence. Great creative work is carried out regularly. In 1994, on the occasion of the 600th anniversary of Mirzo Ulugbek, his madrasah was renewed. The second floor was recovered and the madrasa was coated. Repairs were also made at the Sher-dor and the Creatland Madrases [13 p. 32]. In recent years, IT technologies are widely used to study and maintain Registan monuments in recent years. Polish experts and NAWA in this regard make a significant contribution.

In May-June 2018, a number of scientists of the Lublin Technological University (Politechnika Lubelska) visited Samarkand to discuss the use of information technologies in cultural heritage sites. During the trip, a composition of lions and deer on the Sher-dor Madrasa, and the colour balance, size and location of the parts were measured in millimeters were scanned. The results of the study are published in solid publications [9, 10, 17, 18].

Figure 2. Scanning stalactites in the Sher-dor Madrasa by staff member of the Lublin University of Technology, photo: J. Montusiewicz

The signed Memorandum of Cooperation between the Polytechnic University and the Ensemble Registan, serves to further strengthen the joint mutual cooperation. Within the framework of the Memorandum, May 21–23, 2019, a scientific-practical conference on the project "Using Information Technologies in Cultural Heritage Management" was organised in the Ulugbek Madrasa. The event was attended by the Extraordinary and Plenipotentiary Ambassador of Poland in Uzbekistan Piotr Iwaszkiewicz, Rector of the Samarkand State University Rustam Halmuradov and Deputy Governor of the Samarkand Region Rustam Kobilov [19 p. 15]. The conference discussed the problems of digitising cultural heritage objects, their study and preservation.

6. Conclusions

In recent years, Uzbekistan has been paying great attention to the development of tourism. Polish scientists are making a significant contribution to further strengthening its tourism prestige and potential, increasing its attractiveness via the Internet. They are actively involved in creating a virtual form of tourist facilities in Samarkand, located at the crossroads of the Great Silk Road.

It is gratifying that the 3D Digital Silk Road site, created by scientists from the University of Lublin, has a virtual location of the Sher-dor Madrasa in Registan Square. We think it is also interesting and up-to-date to place on this site the digital form of other historical monuments with the image of the lion, located on the Great Silk Road. This will, first, expand the site's audience. Second, the gathering of monuments with the image of a lion on the Great Silk Road will be of great convenience to researchers. As mentioned above, the participation of the image of the lion in the life of the people of Central Asia is a little-studied topic, of interest to theologians and culturologists.

References

[1] Abdurazzoq S., Matlai sadayn va majmai bahrain,. Persian translation preface and commentary by A. Urinbayev. Volume 2, Part 1 (events of 1405–1429). Tashkent: Uzbekistan, 2008. p. 377.

[2] Abramov M. M., Ulugbek and improvement of the cities of Uzbekistan: Samarkand, Bukhara, Gijduvan, Shakhrisabz), Samarkand, 1994. (in Russian).

[3] Abu T., Samaria. F. A., Sattori translation, [in] eds B. B. Ahmedov, A. Juvonmardiev (eds), Indicators compiled by M. Khodjaeva. Tashkent: Kamalak, 1991. p. 28. (in Uzbek)

[4] Aleskerov Yu. N., Umnyakov I. I., Samarkand, Tashkent: Uzbekistan State Publishing House, 1963. p. 85.

[6] Bartold V.V., Ulugbek and his time, Nauka, 1964. vol. 2. Part 2. pp. 25–177. (in Uzbek)

[7] Beaupertuis-Bressand F., L'art Timuride: Un art original, né sous l'impulsion de Timur. Mawerannakhr in the Epoch of Amir Temur: archeology, history, culture. – Tashkent: Adabiyot uchqunlari, 2018. pp. 291–295.

[9] Kayumov R., A silver coin with the image of the great Polish astronomer Nicolaus Copernicus was handed over to the museum complex of Mirzo Ulugbek in Samarkand, Narodnoye slovo 10 sentyabrya 2021, No. 189. (in Russian)

[10] Kęsik J., Miłosz M., Montusiewicz J., Samarov K., Documenting the geometry of large architectural monuments using 3D scanning – the case of the dome of the Golden Mosque of the Tillya-Kori Madrasah in Samarkand. In: Digital Applications in Archaeology and Cultural Heritage, 2021, vol. 22, pp. 1–11
[11] La route de Samarkand au temps de Tamerlan. Ruy Gonzàles de Clavijo. Trad. et comm. Par Lucien Kehren, Paris, 1990. p. 257.
[12] Mahmudov N., Registan Square – the heart of Samarkand: historical records, Zarafshan newspaper, June 17, 2010. (in Uzbek)
[13] Marufiy B., Pearls of Samarkand, Tashkent: Publishing House, 2019. p. 32. (in Uzbek)
[14] Masson M.Ye. Registan i yego medrese (Registan and its madrasah), Samarkand: Uzkomstaris, 1929. p. 32.
[15] Masson M. Ye., Samarkand of Ulugbek's time. Zvezda Vostoka. 1948, No.5. p. 90. (in Uzbek)
[16] Masson M. Ye., From the past of tigers in Central Asia: Historical reference, Scientific works of Tashkent State University. Issue 200. Historical sciences, book 41. Tashkent, 1963. pp. 151–160. (in Uzbek)
[17] Miłosz M., Miłosz E., Montusiewicz J., Determination of ceramic tile colour surface areas on the medieval Sher-dor Madrasah mosaic in Samarkand – problems and solutions. In: Digital Applications in Archaeology and Cultural Heritage, 2020, vol. 16, pp. 1–6.
[18] Miłosz M., Kayumov R., Samarov K., Cooperation in the digitisation of cultural heritage. Echo of History. 2021, No.1. pp. 24–25.
[19] Samarov K., The Registan Ensemble – an Architectural Jewel of the Silk Road. [in] Tangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan (E. Miłosz, D. Mukhamedova, eds., Lublin, 2021, pp. 9–16.
[20] Speech by the first President of the Republic of Uzbekistan Islam Karimov on October 2, 2014 at the opening of the 99th session of the Executive Council of the UN World Tourism Organisation.
[21] "Tarix-I Sayyid Roqim" (History of Sayyid Roqim). In Persian. Manuscript of SamSU, No. 1187724. p. 214.
[22] Zahiriddin Muhammad Bobur. Boburnoma. Prepared by P. Shamsiev, Tashkent, 1989. p. 45.

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A METHODOLOGICAL PROPOSAL FOR DISTANCE TEACHING OF CREATING 3D MODELS OF ARTEFACTS FROM THE SILK ROAD AREA

Abstract

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 preparation of didactic materials, 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 is 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.

Keywords: Silk Road, artefacts, 3D model post-processing, distance learning.

1. Introduction

The pandemic resulting from the worldwide spread of the SARS-CoV-2 virus 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 practised at the LUT (Lublin University of Technology), the 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 directives.

Unfortunately, the use of IT in educational processes is associated with many problems. Particularly difficult to implement is the content of materials which require the provision of pragmatic information. In such cases, appropriate cooperation at learner-teacher level is particularly important. The current situation related to the pandemic has significantly reduced interpersonal contacts in the teaching processes. The use of IT has made it possible to replace real contact with virtual contact. The IT used in such conditions in the teaching processes has made it possible to maintain their continuity. This type of approach is called remote learning, which strongly correlates with the e-learning process, allowing, by available technical means, the relationship between the learner and the teacher [1, 2, 3, 4]. Teaching by means of computers and educational platforms is called different things, 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 or Zoom make it possible to carry out complex learning processes in such teaching areas 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 scope of use in remote learning.

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 the 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].

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 elearning 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 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.

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. It 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 programs for processing data in the form of a point cloud.

Due to the existence of the course "Basics of Computer Graphics" at the LUT in BSc level 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 effectively only 1/6 of the total number of hours left to introduce new topics.

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 object creation – parametric and non-parametric modelling, use of primitives and extrusion functions.
LAB7	Complex object creation using constructive solid geometry methods. Editing the model mesh and making a 3D object from pattern. 3D scene construction. Basics of automation scripts for fast 3D scene construction and transformations.
LAB8	UV decomposition exercises and application of textures on 3D objects

The aims of the course are as follows:

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

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. The Silk tury BCE until the mid-15th century. Spanning over 6,400 kilometres, it played a central role in facilitating economic, cultural, political and religious interactions between the East and West.

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, 24] Examples of research results are presented in Figure 1.

Through remote learning using Microsoft Teams software, students will learn about the individual stages of post-processing 3D models. By sharing a desktop view, the 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.

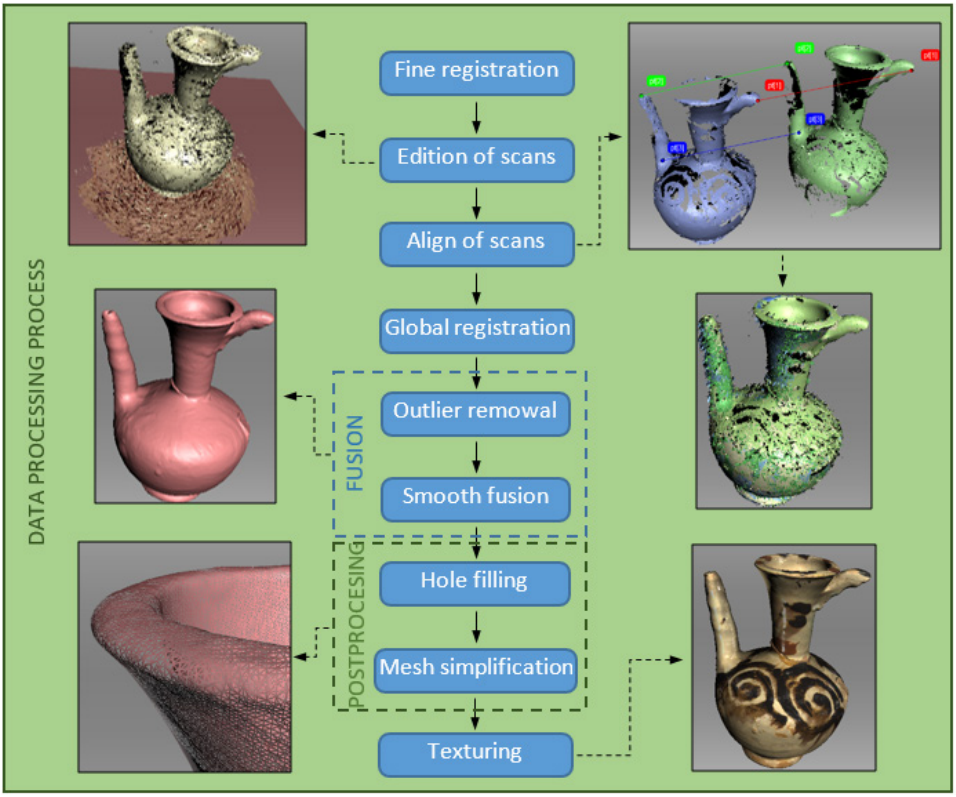


Figure 1. Stages of post-processing [24]

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. Figure 2 presents exemplary stages of post-processing of a glazed jug from the 11th–12th century (Afrasiyab, Uzbekistan).

Figure 2a shows a 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 Figure 2b. This figure also shows the possibility of measuring the geometric size of the object. Figure 2c shows a 3D digital model with texture overlay. The final result is a realistic appearance of the digitally reproduced artefact model.

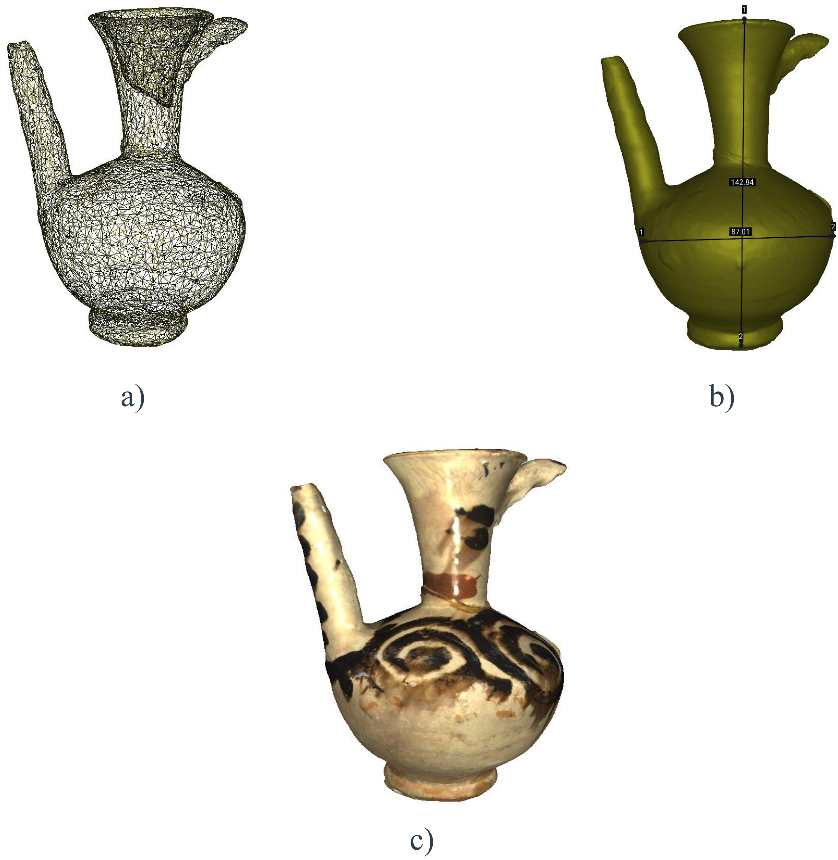
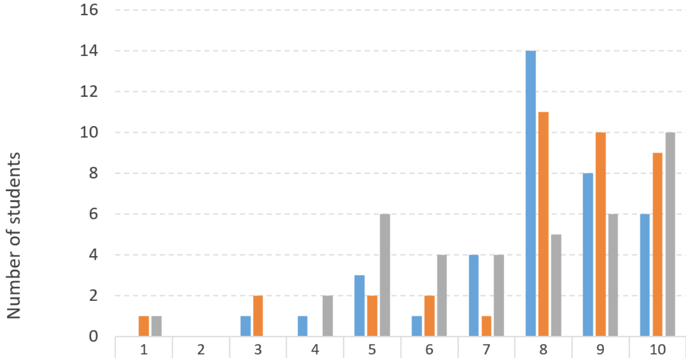


Figure 2. Example results of the post-processing of a 11th–12th century glazed jug: a) mesh model, b) measurement of geometric dimensions, c) model after texturing

Figure 2a shows a 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 Figure 2b. This figure also shows the possibility of measuring the geometric size of the object. Figure 2c 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.



	1	2	3	4	5	6	7	8	9	10
Was it easy for you to understand the content provided by the teacher during the remote classes	0	0	1	1	3	1	4	14	8	6
Assess whether distance learning was effective in the realisation of educational results	1	0	2	0	2	2	1	11	10	9
Evaluate the selection of teaching content in 3D graphics	1	0	0	2	6	4	4	5	6	10

Figure 3. Answers to the question "Was it easy for you to understand the content provided by the teacher during the remote classes?", "Assess whether distance learning was effective in the realisation of educational results", "Evaluate the selection of teaching content in 3D graphics".

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 3 also 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.

The latter question was formulated in the following way: "Evaluate the selection of teaching content in the field of 3D graphics". Figure 3 also 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. 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. 3).

Acknowledgements

This article has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00004 titled “3D DIGITAL SILK ROAD”.

References

[1] A. Wysocki, “Wybór platformy e-learningowej dla organizacji kształcącej,” Master’s thesis supervised by Waldemar Wolski, Uniwersytet Szczeciński 2009.
[2] A. Duda, S. Korga, S. Gnapowski, “The role of e-learning in educational processes,” *Advances in Science and Technology Research Journal*, vol. 8, pp. 61–65, 2014.
[3] K. Chrabąszcz, “Using e-learning in the process of students education” in *Research Papers Collection*, vol. 1, no. 17, pp. 55–66, 2011.
[4] M. Hołowiecki, “Wykorzystanie e-learningu jako formy kształcenia zdalnego na publicznych uczelniach wyższych w Polsce,” *Lingua ac communitas,* vol. 24, pp. 185–206, 2014.
[5] F. Adelabu, M. Makgato, M. Ramaligela, “The Importance of Dynamic Geometry Computer,” Software in *Learners’ Performance in Geometry*, volume 17, issue 1, pp.1–65, 2019.
[6] J. Aiello, A. Mongibello, “Supporting EFL learners with a virtual environment: a focus on L2 pronunciation,” *Journal of e-Learning and Knowledge Society*. *The Italian e-Learning Association Journal*, vol. 15, no. 1, 2019.

[7] S. Korga, E. Jakubczak "Badanie wpływu technologii informatycznych na efekty w nauce uczniów Szkoły Podstawowej w Tarnogórze," *Aplikacyjne metody obliczeniowe oraz zarządzanie danymi*, pp. 320–330, 2017.
[8] F. Nascimbeni, U.-D. Ehlers. Open Teaching: research and practice on open, innovative and engaging pedagogies, *Journal of e-Learning and Knowledge Society*, vol. 16, no. 4, pp. I-IV, 2020.
[9] K. Dziedzic, M. Włodarczyk, M. Paśnikowska-Łukaszuk," The usage of computer visualization in teaching technical subjects," *Advances in Science and Technology Research Journal*, vol. 8, pp. 72–75, 2014.
[10] P. Bradford, M. Porciello, N. Balkon, D. Backus, "The Blackboard Learning System," *The Journal of Educational Technology Systems,* vol. 35, pp. 301–314, 2007.
[11] W. Barber, "Building Creative Critical Online Learning Communities through Digital Moments," *The Electronic Journal of e-Learning*, vol. 18, no. 5, pp. 373–459, 2020.
[12] P. Kopciał, "Analiza metod e-learningowych stosowanych w kształceniu osób dorosłych," *Zeszyty Naukowe Warszawskiej Wyższej Szkoły Informatyki*, Nr 9, pp. 79–99, 2013.
[13] R. E. Mayer, *Multimedia Learning*, Second Edition, Cambridge University Press, Cambridge, 2009.
[14] T. Thien, M. Stramp, J. Pearce, R. Chun, *Document builder,* Department of Computer Science, San Jose, 2012.
[15] T. Szymczyk, S. Skulimowski, "The use of virtual and augmented reality in the teaching process," 11th International Conference on Technology, Education and Development (INTED), *INTED Proceedings*, pp. 6570–6577, 2017.
[16] J. Montusiewicz, M. Miłosz, J. Kęsik, M. Barszcz, K. Dziedzic, M. Tokovarov, P. Kopniak," Developing an educational board game using information technology," *EDULEARN 17 : 9th International Conference on Education and New Learning Technologies*, IATED Academy, pp. 7396–7405, 2017.
[17] K. Dziedzic, M. Barszcz, M. Paśnikowska-Łukaszuk, A. Jankowska," The role of computer animation in teaching technical subjects," *Advances in Science and Technology Research Journal*, vol. 9, pp. 134–138, 2015.
[18] M. M. Organero, C. D. Kloss, P. M. Merino, "Personalized Service-Oriented E-learning Environments," *IEEE Internet Computing*, vol. 14, no. 2, pp. 62–27, 2010.
[19] A. Makarewicz, S. Korga, W. Rosa, "The types of computer graphics and their application at different levels of knowledge," *Advances in Science and Technology Research Journal*, vol. 9, pp. 149–152, 2015.
[20] C. Laici, M. Pentucci. "DEPIT application: open and shared digital artefacts for visible design," *Journal of e – Learning and Knowledge Society, vol.* 16, no. 4, pp. 11–19, 2020.
[21] P. Ruszniak, J. Jóźwik, K. Dziedzic, D. Ostrowski, "Shearing strength test of orthopaedic titanium alloy screw produced in the process of 3D printing technology," *Advances in Science and Technology Research Journal*, vol. 11, pp. 128–137, 2017.
[22] J. Montusiewicz, M. Barszcz, K. Dziedzic, "Photorealistic 3D digital reconstruction of a clay pitcher," *Advances in Science and Technology Research Journal*, vol. 13, no. 4, pp. 255–263, 2019.
[23] M. Miłosz, S. Skulimowski, J. Kęsik, J. Montusiewicz, "Virtual and interactive museum of archaeological artefacts from Afrasiyab – An ancient city on the silk road", *Digital Applications in Archaeology and Cultural Heritage*, vol. 18, pp. 1–12, 2020.
[24] M. Barszcz, J. Montusiewicz, M. Paśnikowska-Łukaszuk, A. Sałamacha, "Comparative Analysis of Digital Models of Objects of Cultural Heritage Obtained by the "3D SLS" and "SfM" Methods", *Applied Sciences*, vol. 11, pp. 1–20, 2021.

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THE USE OF IT TECHNOLOGIES IN THE STUDY AND PRESERVATION OF HISTORICAL MONUMENTS OF SAMARKAND OF THE ASHTARKHANID ERA

Abstract

Registan, the heart of Samarkand, has an ancient history. It came to its present appearance during the Ashtarkhanid period. Yalangtush-biy Bahodir's contribution to this is great. From the moment of the first construction on Registan Square to the present day, a lot of time has passed – 6 centuries. The appearance in which we can see the Registan today is the painstaking work of hundreds of restorer craftsmen. In recent years, IT technology has been widely used in the study and preservation of historical monuments in Registan. Polish scientists are also making a worthy contribution to this.

Keywords: Great Silk Road, Samarkand, Ashtarkhanid period, Registan, Sher-dor, Tillya-kori, digitisation, NAWA, Lublin University of Technology

1. Introduction

Located at the crossroads of the Great Silk Road, the city of Samarkand attracts many tourists and scientists with its historical and cultural monuments.

The current appearance of Registan Square, the heart of Samarkand, was formed during the Ashtarkhanid period. The governor of Samarkand, Yalangtush-biy, made a significant contribution to this. The complex attracts research scientists with its grandeur and service. This article is a biography of Yalangtush-biy Bahodir, the builder of the Registan complex, and uses IT technologies in the preservation and study of historical monuments he built.

2. Formation of the Registan area

Registan is a rectangular square and three historical and architectural monuments bordering it with large façades: the Ulugbek, Sher-dor and Tillya-kori madrasahs. Such "madrasahs" were higher educational institutions – the universities of their time.

The creation of a powerful centralised state on the territory of Maverannahr at the end of the 14th century by Amir Timur (1370–1405) served to further develop the region. Amir Temur went down in world history not only as an outstanding commander and statesman who created a powerful and prosperous state. He turned his capital – Samarkand into one of the cultural and scientific centers of the world [10].

The creative work begun during the time of Amir Timur was continued during the reign of his grandson Ulugbek (1409–1449). He paid much attention to the improvement of his capital – Samarkand [20]. It was under him that the improvement of Registan Square began. Two large buildings were built here. One of them was a madrasah bearing the builder's name. The second was a *khanaka*, a hostel for God-seekers and a hospice. The grandiose construction works of the Ulugbek era are well reflected in the sources [2 p. 377; 27 p. 45] and studies [3, 9, 19].

The first half of the 17th century, the reign of the Ashtarkhanid dynasty for the regions of the Zerafshan valley, was a period of cultural upsurge. At that time, in Samarkand, like two centuries ago, vigorous construction activity broke out again. In a few decades, the city and its environs were adorned with a number of large architectural monuments that imitated the buildings of the Timurids. Many of the newly erected structures were almost as good as their models in terms of the amount of materials, labor and time spent.

It was to this time that two more majestic madrasahs on Registan Square – Sher-dor and Tillya-kori emerged. Both owe their appearance to the hokim (mayor) of Samarkand – Yalangtush-biy Bakhadur. Taking advantage of the weakness of the central government, he began to pursue an independent policy and went to great lengths regarding the improvement of the city.

3. Buildings built by the Barefooted Hero

The Sher-dor madrasah was the first to be built in the reign of Imam-Kuli Khan (1611–1642). Information about this is given in the source "Tarixi Sayyid Roqim" under the Persian title «ردامب ی ب شوتگنلی لوا ۀسردم یانب خیرات», that is, 'the history of the construction of the first Yalangtush-biy Bahadur madrasah' [26]. By his order, on the site where Ulugbek›s khanaka used to be, which was a huge ruin in the 17th century, construction began. The building was built over 17 years (1619–1636). It contains absolutely original paired mosaic images placed on the tympanums of the portal, the main figures of which are *sher*, which gave the name to the madrasah itself. Sher-dor in translation means 'decorated with lions' [24 p. 12]. The name of the architect is written in white letters in a small black medallion: "Abduljabbar – the architect" [6]. This name undoubtedly deserves the memory of posterity.

10 years passed since the completion of the construction of the Sher-dor Madrasah. In 1056/1646–1647, Yalangtush-biy Bahadur, at an advanced age, began the construction of a new madrasah. The building, which was supposed to close the Registan Square with its front façade from the third northern side. During this period of time, two dynasts changed on the khan's throne. After Imamkulikhan, his brother Nadir Muhammadkhan (1642–1645) sat on the throne. Then the son of the latter Abd-al-Azizkhan (1645–1680) occupied it. And the ruler of Samarkand was still Yalangtush-biy Bahadur.

Ten years after the laying of the Tillya-kori Madrasah, its builder Yalangtush-biy Bahadur, who died in 1066/1656, died. Ten years is not enough time to rebuild such a building as the Tillya-kori madrasah, which remained unfinished. Probably, it is precisely the premature death of Yalangtush-biy Bahadur that should explain the appearance of tiled decorations that were too heterogeneous in quality, shape and shades. Among them, the pale yellow lemon-coloured paint on the square majolica tiles of some tympanums in the niches of courtyard hujras is especially striking. Perhaps this cheaper decoration was laid down under the heirs of Yalangtush-biy Bahadur, who, while somehow completing the building, were not interested in a particularly thorough completion of a broadly conceived structure. The Tilla-kori madrasah was erected on the site of a carvansaray built by Ulugbek. Construction was completed in 1660 [17].

During the reign of Yalangtush-biy Bahadur, culture developed and dozens of monuments were built. Following his example, courtiers, scholars and officials also built the necessary facilities for the needs of the people, such as madrassas, mosques, baths, bridges, wells. During his time, so many madrassas were built in Samarkand that in the Middle Ages this was rare [11].

4. Yalangtush-biy Bahadur is the ruler of Samarkand

According to "'Tarixi Sayyid Roqim", Yalangtush-biy Bahodir was from the "Olchin jamoa" [26]. According to G. Tanieva, "Olchin" is one of the ancient Turkic tribes, which includes Kazakhs, Bashkirs, Kazan Tatars, Crimean and North Caucasus nomads, Karakalpaks and Uzbeks. It is found in Kazakhs, Bashkirs, Kazan Tatars, Crimean and North Caucasus Nogai, Karakalpaks and Uzbeks [25 p. 21].

There is no information in the sources about the year and place of birth of Yalangtush-biy. Many studies state that he was born in 1576 in the family of the governor of Nurata.

M. A. Abduraimov, based on the work "Historical World of Abbasids", writes that at the age of 19 Yalangtush-biy Bahadur entered the military service at the hands of the governor of Bukhara Dinmuhammadkhan [1 p. 40]. Komilkhon Kattaev also cited the incident, but did not specify the source. According to him, Yalangtush-biy Bahodir joined the army of Dinmuhammadkhan from Ashtarkhan at the age of 12 [12 p. 101].

Mahmud ibn Wali [16] writes about the naked warrior: Olchin came from the building nation; real name is Hatoy Bahodir. During the time of Dinmukhamedkhan, he entered the service of Sagnoq from Azak district; He became one of the top men behind his efforts [8 p. 228]. Later, his control of bravery and loyalty won the trust of the Ashtarkhanid dynasty.

At the beginning of the 17th century, the Bukhara Khanate was embroiled in a power struggle between the Ashtarkhanids. According to Mahmud ibn Wali, in the course of the mutual struggle in 1611 from the emirs Nodirbek, Shukurbi palace, Muhammad Boqi Kalmak, Khoja Hashim Dahbedi, Yalangtush-biy Bahadur and others passed from Wali Muhammadkhan (1606–1611) to Imamqulikhan (1611–1642) [5 p. 143; 7 p. 105].

According to Komilhon Kattav, the ascension of Yalangtush-biy to the throne of Samarkand by the will of Khoja Hashim Dahbedi had a positive effect on the beautification and creation of the city [12 p. 95].

During the reign of Nadir Muhammad Khan (1642–1645), Yalangtush-biy's rank increased and he was appointed his father. Darayi Suf, Mulgon, Kohmard provinces; The lands of the Tulkichi, Saikanchi, Zerangi, Kilagi, Hazarai Nekudari tribes, and the lands of the tribes up to Ghazna, Kandahar, Zamindovar, Gur and Khorasan were given to him as *iqta*. The governors of Kandahar, Seiston, and other provinces trembled before him.

Anisim Gribov (1641), the Russian ambassador to Uzbekistan at the time, said that Garchistan, which stretched from Ghazni to Kandahar, was the property of the Yalangtush-biy warrior in the form of *iqta*. The road from Balkh to the Indian villages in the Hindu Kush valley is a 7-day journey for the horseman and a 14-day journey for the camel. The villages and towns between the Balkh and Indian borders are the property of Amir Yalangtush, a close relative of the Bukhara and Balkh khans [8 p. 228].

Having acquired such large estates, Yalangtush-biy became one of the richest men of his time. In the sources, his wealth was equal to the state treasury, his prestige not inferior to that of kings, and the amount of his property comparable with the state treasury.

Yalangtush-biy Bahodur, who was able to carry out large-scale construction work during his reign, died in 1656. According to his will, he was buried at the foot of the tomb of Hoja Hashim Dahbedi.

Yalangtushbiy Bahodur was the governor of Samarkand during the reigns of three Ashtarkhan kings Imamqulikhan, Nodir Muhammadkhan and Abdulazizkhan (1645–1680). His word was decisive for the Ashtarkhan rulers. Nevertheless, the activities of this governor, who built such buildings in Samarkand as Amir Temur and Ulugbek and added to his fame, have not yet found their place in the history of Uzbekistan.

5. Application of IT technologies in the study of the monuments of Registan

From the moment of the first construction on Registan Square to the present day, a lot of time has passed – 6 centuries. The appearance in which we can see the Registan today is the painstaking work of hundreds of craftsmen and restorers.

One of the first, Kuchkunchikhan (1510–1531), who was the grandson of Ulugbek from his daughter, repaired and decorated those madrasas, khanakas, mosques and buildings of charitable institutions that had fallen into disrepair.

In 1580, Abdullakhan (1583–1598) visited Ulugbek's madrasah. He ordered to repair those buildings that remained in Samarkand and began to collapse. Probably, during both repairs, Ulugbek's madrasah was not forgotten either [19 p. 12].

It is very likely that under the first Ashtarkhanids in the first half of the 17th century, when the mayor of Samarkand, Yalangtush-biy Bahadur, paid so much attention to the Registan, a solid repair of the Ulugbek madrasah was also carried out. According to M. E. Masson in 1920, when examining the courtyard of the latter, under the floor of the entrance niche of one of the hujras, more than two hundred blue, light blue and white tiled bricks were found, which were not in use, undoubtedly of later origin and made at one time, apparently, for restoration purposes during one of major repairs [19 p. 23].

In 1752, when Rakhim-biy atalyk, the future founder of the new Mangyt dynasty and already at that time the actual ruler of the Bukhara Khanate, was preparing provisions for a campaign against the restless inhabitants of the Urgut and Penjeket mountains, the Registan madrasahs stood empty. They poured all the grain collected on this occasion in the amount of 7000 Harvars.

Representatives of the Mangyt dynasty took an active part in the preservation and restoration of the monuments of Registan. For example, being the heir to the throne and the ruler of Samarkand Shahmurad-biy, his son and successor Emir Khaidar (1800–1826) and others.

In pre-revolutionary times, small "household" repairs of the buildings of the Registan madrasah were carried out quite often either for *waqf* sums, or from special state appropriations, and even with funds given by private charity. In 1924, beautiful mosaic tympanums depicting lions, which had fallen in a state of severe destruction, were fixed at the Sher-dor madrasah. Particularly risky was the successful completion in 1925 of the complete re-laying of almost all of the heavily deformed masonry with internal breaks, which began to collapse in parts of the huge vault of the main portal of the same madrasah [19 p. 23]. A major work of the 20th century in the Registan was the straightening, shifting the minarets of the Ulugbek madrasah into their place. In 1918, the north-eastern tower of Ulugbek Madrasah was demolished. In 1932 the tower was restored to its original state. In the 1960s, the south-eastern tower of this madrasa fell into the same situation. It was renovated in 1965 [17].

Just like in the Ulugbek madrasah, the Sher-dor madrasah underwent extensive restoration work: hujras were mounted, the upper part of the portal arch was fixed, and both minarets were re-clad. Throughout its existence, the Sher-dor madrasah has experienced several earthquakes, the most devastating of which occurred at the beginning and at the end of the 19th century. The building survived, but it was still damaged: the vault of its main portal was severely deformed, the cladding collapsed in many places, and the minarets squinted. In the early 1920s, by a decree of the Soviet authorities, teaching in the madrasah was discontinued. The building was nationalised and restoration work began in 1924. The hujras were repaired, the collapsed part of the brick vault of the portal arch was restored, the carved mosaic of the tympanum of the main portal was strengthened, its deformed vault was dismantled and re-laid, the domes and vaults of the hujras were rebuilt, and the cladding of the facades of the madrasah was restored. At the end of the 1950s, archaeological surveys were carried out on the territory of the madrasah, after which a new stage of restoration began. In 1960–1962, the minarets of the madrasah were repaired, and in 1962, according to the project of the artist V. N. Gorokhov and architect A. I. Freitag, the tympanum mosaic above the arch of the main portal was restored. Restoration and strengthening works of the madrasah were completed in 1965–1967.

Registan Square is especially beautiful during the independence. Great creative work is carried out regularly. In 1994, on the occasion of the 600th anniversary of Mirzo Ulugbek, his madrasah was renewed. The second floor was recovering and the madrasa was coated. Repairs were also done at the Sher-dor [18 p. 32]. In recent years, IT technologies are widely used to study and maintain Registan monuments. Polish experts and their national NAWA organisation make a significant contribution in this regard.

In May-June 2018, a number of scientists of the Lublin Technological University (Politechnika Lubelska) visited Samarkand to discuss the use of information technologies in cultural heritage sites. During the trip, a composition from lions and deer at the Sher-dor madrasa, and the colour balance, size and location of the parts were measured in millimeters and scanned. The results of the study are published in [13, 14, 22, 23].

The signed Memorandum of Cooperation between the Lublin Technological University and the Registan Ensemble, serves to further strengthen the joint mutual cooperation. Within the framework of the Memorandum, on May 21–23, 2019, a scientific-practical conference on the project "Using Information Technologies in Cultural Heritage Management" was organised in the Ulugbek madrasa. The event was attended by the Extraordinary and Plenipotentiary Ambassador of Poland in Uzbekistan Peter Ivanashkevich, Rector of the Samarkand State University Rustam Halmuradov and Deputy Governor of the Samarkand Region Rustam Kobilov [24 p. 15]. The conference discussed the problems of digitising cultural heritage objects, their study and preservation.

6. Conclusions

The three-famous rulers – Amir Temur, Ulugbek and Bilachtoz-Bahodir made a significant contribution to the restoration of Samarkand's architectural monuments. Amir Temur made Samarkand into the capital of its state and began to build unique buildings. Ulugbek, who continued his work, created a madrassa in the present Registan Square, consisting of three buildings, such as the Kingah and Caravanserai. In place of it, Bilancheosh-Biya Bahrir will also build a royal and goldish madrasah, not violating the structure of the complex built by Ulugbek. Since then, Registan Square has become the heart of Samarkand.

Historical monuments of Samarkand became the city's high-ranking historical constructions after the Temurids in the first half of the 17th century. It was during this period that Registan first had the current look.

References

[1] Abduraimov M. A., Essays on agrarian relations in the Bukhara Khanate between the 16th and the first half of the 19th century. Vol. 2, Tashkent, 1966. pp. 39–40. (in Russian)

[2] Abdurazzoq S., Matlai sadayn va majmai bahrain. Persian translation preface and commentary by A. Urinbayev. Vol. 2, Part 1 (events of 1405–1429). Tashkent: Uzbekistan, 2008. p. 377.

[3] Abramov M. M., Ulugbek and improvement of the cities of Uzbekistan: Samarkand, Bukhara, Gijduvan, Shakhrisabz), Samarkand, 1994. (in Russian)

[4] Abu Tohirxoja. Samaria. Forschadan A. Sattoriy tarjimasi. By editors B. B. Ahmedov, A. Juvonmardiev. Indicators compiled by M. Khodjaeva. – Tashkent: Kamalak, 1991. p. 28.

[5] Alekseev A. K., Central Asia under the Ashtarkhanids in the 17th-18th centuries: According to the Persian-language historical work "Bahr al asror", Sankt-Petersburg, 2004. p. 143. (in Russian)

[6] Aleskerov Yu. N., Umnyakov I. I., Samarkand, Tashkent: Uzbekistan State Publishing House, 1963. p. 85.

[7] Axmedov B. A., History of Balkh (16th – first half of the 18th century), Tashkent: Fan, 1982. p. 105. (in Russian)

[8] Axmedov B. Lessons from history, Tashkent, 1994. p. 228. (in Uzbek)

[9] Bartold V.V., Ulugbek and his time, Nauka, 1964. vol. 2. Part 2. pp. 25–177. (in Uzbek)

[10] Beaupertuis-Bressand F., L'art Timuride: Un art original, né sous l'impulsion de Timur. Mawerannakhr in the Epoch of Amir Temur: archeology, history, culture. – Tashkent: Adabiyot uchqunlari, 2018. p. 291–295.

[11] Kattaev K., Samarkand madrasas and development of science, Samarkand: Zarafshon, 2007. (in Uzbek)

[12] Kattaev K., The history of Makhdumi A'zam and the order of the perfect Dahbedis, Samarkand: Makhdumi Azam Dahbedi Research Foundation, 2011. p. 101–144. (in Uzbek)

[13] Kayumov R., A silver coin with the image of the great Polish astronomer Nicolaus Copernicus was handed over to the museum complex of Mirzo Ulugbek in Samarkand, Narodnoye slovo 10 sentyabrya 2021, No. 189. (in Russian)

[14] Kęsik J., Miłosz M., Montusiewicz J., Samarov K., Documenting the geometry of large architectural monuments using 3D scanning – the case of the dome of the Golden Mosque of the Tillya-Kori Madrasah in Samarkand. In: Digital Applications in Archaeology and Cultural Heritage, 2021, vol. 22, p. 1–11.

[15] La route de Samarkand au temps de Tamerlan. Ruy Gonzàles de Clavijo. Trad. et comm. Par Lucien Kehren, Paris, 1990. p. 257.

[16] Mahmud ibn Vali., A Sea of Mysteries Concerning Noble Virtues: Geography. Vvedeniye, perevod, primechaniya, ukazateli B. A. Axmedova, Tashkent: Fan, 1977. (in Uzbek)

[17] Mahmudov N., Registan Square – the heart of Samarkand: historical records, Zarafshan newspaper, June 17, 2010. (in Uzbek)

[18] Marufiy B., Pearls of Samarkand, Tashkent: Publishing House, 2019. p. 32. (in Uzbek)

[19] Masson M.Ye., Registan and its madrasah, Samarkand: Uzkomstaris, 1929. 32 p. (in Uzbek)

[20] Masson M. Ye., Samarkand of Ulugbek's time. Zvezda Vostoka. 1948, No.5. p. 90. (in Uzbek)

[21] Masson M. Ye., From the past of tigers in Central Asia: Historical reference, Scientific works of Tashkent State University. Issue 200. Historical sciences, book 41. Tashkent, 1963. p. 151–160. (in Uzbek)

[22] Miłosz M., Miłosz E., Montusiewicz J., Determination of ceramic tile colour surface areas on the medieval Sher-dor Madrasah mosaic in Samarkand – problems and solutions. In: Digital Applications in Archaeology and Cultural Heritage, 2020, vol. 16, p. 1–6.
[23] Miłosz M., Kayumov R., Samarov K., Cooperation in the digitisation of cultural heritage. Echo of History. 2021, No.1. p. 24–25.
[24] Samarov K., The Registan Ensemble – an Architectural Jewel of the Silk Road. [in] Tangible Cultural Heritage of the Silk Road from the Area of Modern Uzbekistan (E. Miłosz, D. Mukhamedova, eds., Lublin, 2021, p. 9–16.
[25] Tanieva G., The role of Yalangtush Bahodir in ensuring the political stability of the Bukhara Khanate, History of Uzbekistan, 2019, No. 3. p. 21. (in Uzbek)
[26] History of Sayyid Roqim, In Persian. Manuscript of SamSU, No. 1187724. p. 214a. (in Uzbek)
[27] Zahiriddin M. B. B., Shamsiev P., Tashkent, 1989. p. 45.

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THE USE OF INFORMATION TECHNOLOGY IN THE WORK OF THE MUSEUMS OF SAMARKAND

Abstract

A brief review is offered of the history of museology in Uzbekistan, and in particular in Samarkand. From humble beginnings a century and a half ago, within a decade and a half local museums have been undergoing an IT-aided transition into the 21st century. Instrumental in this process has been collaboration with European centres in restoration and reformation of the home heritage sector. Plans and prospects for the future are addressed.

Keywords: Samarkand, museum artefacts, protection of cultural heritage, Silk Road

1. Introduction

The first museum in Samarkand opened in 1874. It was one of the first in the Central Asian region. After that, a museum of history and nature was opened in Tashkent in 1876, on the basis of which the State Museum of the History of Uzbekistan and the State Museum of Nature of Uzbekistan are successfully operating today. Also at the end of the 19th century, a museum was opened in Fergana. Many museums in Uzbekistan were organised in the twentieth century.

Today in our country, according to the latest data from the Ministry of Culture of the Republic of Uzbekistan, there are 350 museums, of which about 100 are state-owned, and the rest are in possession of other subjects. There are more than 3 million museum artefacts and 7476 objects of cultural heritage, which are divided into archaeological, architectural, memorial and others.

There are about 40 museums in Samarkand, of which 8 are state and 30 are non-state, where more than half a million museum items are kept. More than 1 million visitors visit these museums annually. The profiles of these outfits are different, i.e. historical, natural, artistic, literary, memorial and others.

2. Method and materials

The museums of Samarkand are doing a lot of work on the study, preservation, display and promotion of their exhibits, using modern information technology.

With the advent and acquisition of the first information technology equipment in museums, they began to widely use it in their work. First of all, museums began to compile electronic lists of museum items that are stored in their collections, as well as scan and digitise all exhibits. After the completion of these tasks, they published an album-catalogue of these museum items in 3 languages. Thanks to the development of information technology and new programs, museums have the opportunity to widely publicise their exhibits. For example, in 2008–2012, a lot of work was done to digitise 16,000 units of storage of glass negatives, which are kept in the collections of the Samarkand State Museum-Reserve. These negatives were filmed during a scientific expedition across the republic by the museum's researchers in the 1920s and 1930s, and are of great scientific value. Thanks to this project, a photo exhibition was organised in Tashkent and Samarkand. This project was financially supported by the UNESCO Representative Office and the German Embassy in Uzbekistan.

Since 2011, all the museums of the Republic have begun to create electronic scientific cards of all museum items that are stored in their collections. After the completion of these tasks, a unified electronic database of the country's museum objects of the national museum stock and its catalogue will be created. This will allow all interested parties to familiarise themselves with this fund via the Internet and use it at their own discretion for scientific and educational purposes. Further, this will allow to strengthen control over the safety of museum items. For this, a special national programme "SKM-Museum" was developed, which differs from other similar museum programmes.

Work is underway to use modern information technology in the activity of Samarkand museums in the field of promoting the museum exposition around the world via the Internet. For example, in 2012, for the first time in the Republic, a virtual tour of the Mirzo Ulugbek Museum in 3 languages in 3D format was developed and posted on the museum's website at www.ulugbekobservatory.parusinfo.com. After the creation of this virtual museum and its placement on the museum website, the number of visitors to the museum increased several times. In addition, the museum distributes this virtual tour among schools as a visual aid in the form of DVD disks. This project was developed with the support of the Desht-i-Art Laboratory Centre of the Republic of Kazakhstan.

The same version of the virtual tour was developed on the basis of the wall painting of the ancient Afrasiyab in 2014, together with Korean partners. Today this multimedia product is firmly included in the excursion programmes of the Afrasiyab Museum and shows them to visitors in 8 languages.

Since 2015, the scientific and practical museum-laboratory of Samarkand State University has been working together with specialists from the Lublin University of Technology (Poland) on three-dimensional scanning of museum items and architectural monuments of Samarkand. In 2017, we scanned more than 100 storage units of archaeological museum collections from the stock of our SamSU Museum and the Afrasiyab Museum. After processing them in the laboratory of the Lublin University of Technology, it became clear that we were on the right track. We showed the first results of this project at the reporting workshop in Samarkand in May 2018, and they were also presented at the International Scientific Conference in November 2018. This project will provide an opportunity to restore many museum items, even if only a part of an item is extant. In addition, the results of our work are displayed on the website of the Lublin University of Technology. Interest in this project has increased, and today, in addition to the museums of Samarkand, the State Museum of the History of Uzbekistan, the Turkestan Regional Museum of Local Lore (Kazakhstan) and others have joined us.

Figure 1. 3D scanning with the FARO scanner, Samarkand, Uzbekistan, 2019, photo: J. Montusiewicz

In 2018, our team scanned the architectural monuments of Samarkand, such as the Registan ensemble, the Shahi-zinda ensemble, the Guri-emir mausoleum, the Ulugbek Observatory and the Afrasiyab murals. In the course of work at the Registan ensemble, at the suggestion of the Registan administration, colleagues scanned the entrance portal in the Sher-Dor madrasah with an image of lions on an area of 105 m^2 for further restoration and reinstallment of these images. After scanning and processing them, the Polish specialists managed to prepare their clear version (templates) for further work of the restorers. Thus, the administration of the Registan ensemble significantly reduced the time for the restoration of this building and saved a sum of their finances.

Figure 2. Participants of the expedition in Shahi-zinda ensemble, Samarkand, Uzbekistan, 2021, photo: J. Montusiewicz

Studying the experience of museums in different countries, we have created a group at the scientific and practical museum-laboratory of SamSU to develop virtual tours in 3D format to museums and architectural monuments of Samarkand. The first results can be viewed on the website www.sammuseum.uz, where the most famous museums of Samarkand and architectural monuments of Samarkand are covered. In the future, we plan to create such information about each museum in Samarkand, and put it on this website. Unfortunately, all this work is carried out on a voluntary basis and thus free of charge. Therefore, our work in this direction is proceeding very slowly. We tried several times to find a sponsor to support this project, but so far the concerned department and government agency are in no hurry to provide assistance and aid. Nevertheless we do not lose hope and keep looking for sponsors to support our project.

3. Conclusions

1. The community representing Samarkand museums plans to create universal information about each museum in the city and post it on a specialised website intended for tourists and historians.
2. Museologists will look for funds from the governmental programmes of Uzbekistan, local government programmes, as well as from international UNESCO funds.
3. It seems necessary for suitable activities to be implemented in cooperation with foreign partners, such as the Lublin University of Technology from Poland.

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