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USE OF MODERN TECHNOLOGIES IN DIGITIZING MILEŠEVA MONASTERY: A REPORT ON THE WORKFLOW

ABSTRACT

Modern methods for the presentation and protection of cultural heritage are inseparable from the use of digital technologies. The digitization process has made it possible to examine movable and immovable heritage objects in detail and document their condition and, as such, has found a purposeful use in research, education and presentation processes. This paper focuses on the application of modern technologies in digitising a cultural property and presents its workflow. Through 3D laser scanning, drone recording, standard and spherical (360°) photography, scanning of old and rare books and, finally, the creation of a web presentation and application for mobile devices, we explore the methods of the digital documentation of cultural heritage using the example of the medieval Mileševa Monastery, one of the most important spiritual and cultural centres of the Serbian people. The advantages of the project are presented, together with ideas for further development. Digitization of heritage is not only a technical but also a cultural undertaking and, therefore, is of utmost importance for humanity. Thus, the goal of this project was to enable better access and preservation of the multi-layered cultural heritage of the Mileševa Monastery for future generations.

KEYWORDS: DIGITIZATION OF CULTURAL HERITAGE, MODERN TECHNOLOGIES, MILEŠEVA MONASTERY, CULTURAL HERITAGE PRESERVATION, 3D LASER SCANNING, WEB-BASED VISUALISATION, DIGITAL DOCUMENTATION.

INTRODUCTION

Digitization of cultural heritage has long been imperative in modern society, and has been greatly advanced by the development of cutting-edge technologies that enable detailed documentation and presentation, thereby facilitating the digital preservation of movable and immovable heritage objects, whose physical changes are inevitable over time (Stylianidis and Remondino 2016). The most commonly used techniques for these purposes are: 3D laser scanning, aerial recording with unmanned vehicles, professional photography, 360° photography, and the digitization of documents, websites and mobile applications.

3D laser scanning is an imaging technique that uses lasers to measure and map the surface of objects precisely. Due to the possibility of collecting detailed data, it has long been useful in industry, geodesy, medical diagnostics, and digitizing cultural monuments (Yastikli 2007).

Unmanned aerial vehicles (UAV) - drones have become an indispensable tool in the process of digitizing immovable cultural heritage, thanks to the possibility of filming from different angles and

heights. They have proven to be very useful for collecting data on large objects and geographical areas from different perspectives, allowing access to locations that are difficult to access or carry a certain security risk for researchers (Westoby *et al.* 2012).

Photographing with professional cameras is an inseparable part of the digitization process that serves for detailed documentation and preservation of visual data (Cultural Heritage Digitisation 2023; Rieger, T. *et al*. 2023). In this way, quality visual archives of various purposes are created, primarily for education, research and presentation. Photographs of buildings, architectural elements, paintings, works of art, and treasure objects have long been additionally used for generating 3D models (Remondino and El-Hakim 2006) allowing the detailed study and preservation of monuments.

360° photography is used to obtain spherical images that offer a comprehensive view of space, which is particularly useful for digitizing the interior of buildings such as religious monuments or archaeological sites, and more specifically those that are in very remote areas, hard to visit or forbidden for extensive visits to ensure their long-term preservation. The importance of this technology became especially evident during the COVID-19 pandemic when travel to monuments and sites was limited and visitors from all around the world relied on websites offering virtual tours using 360° photography. Subsequently, this method of presentation and interpretation of heritage has become a permanent part of the tourism offers (Ren and Chen 2021: 1192–1194).

Original documents, old books and manuscripts are often fragile and prone to damage during handling, so generating digital versions reduces the need for physical contact with the originals, thus extending their lifespan. Redundant and backup copies further ensure the longevity of these digital resources (Aly and Chernevych 2024: 3). Thus, their digitization is crucial for their preservation and ease of access (Anderson 2018).

Creating a website is essential for the presentation of digitized cultural heritage materials to a wider audience. The development of a mobile application enables simple, quick and more flexible access to digitized materials and their interactive content on smart devices. Users can, thus, easily explore cultural heritage through their phones and tablets, regardless of where they are (Silva *et al.* 2020; Attractions.io 2023; ARCHES 2023). Websites and applications, in addition to textual information, mostly include rich multimedia content, such as photo galleries, videos, audio guides and interactive graphs, while multilingual support is more than welcome to bring the wealth of cultural heritage closer to the widest possible circle of interested parties from different speaking areas.

In 2022–2023, on the initiative of the Mathematical Institute SASA (MISASA), and with the financial support of the Ministry of Culture of the Republic of Serbia, the medieval Mileševa Monastery was chosen to be digitized. Due to its multi-layered heritage, it was an ideal candidate for the application of modern techniques and technologies for digitization, with the intention of presenting it to experts, researchers and the wider public in an innovative way.

MATERIALS AND METHODS: TECHNIQUES AND TOOLS USED

This paper provides a report on the digitization of different elements of the Mileševa Monastery using the techniques mentioned above. Using 3D laser scanning, a precise mapping of buildings was completed, and aerial photography with unmanned aerial vehicles (drones) was used to create photogrammetric models, while photographs of buildings, paintings and treasure objects were taken to obtain high-quality visual records. The 360° photography enabled immersive views of space, while the digitization of documents contained recordings of books and other archival materials to preserve their content and ensure easier accessibility. Finally, for the presentation of the monastery and its digitized content, a website and a mobile application were created, using the obtained inputs, as dissemination platforms and the final outputs and results of the whole process.

Review of the spatial context

The Mileševa Monastery is a famous endowment and the burial church of King Stefan Vladislav, the second son of King Stefan the First-Crowned, the first Serbian king of the

Nemanjić dynasty. It is situated near today's town of Prijepolje in south-western Serbia. In 1947, it was protected as an immovable cultural property (Решење 1947), while in 1979 it was declared a property of exceptional importance for the then Socialist Republic of Serbia (Одлука 1979), which is the status it maintains to this day.

Although the monastery was founded around 1219, the precise year of the construction of its Church of the Ascension of Christ remains unknown. Since the foundation charter has not been preserved, the precious portraits of the Nemanjić rulers and later written records remain the primary sources of information about the temple. The monastery was founded near an important medieval trade route between the Adriatic Sea and the inland. Starting from 1237–1238, when King Vladislav transferred the remains of his uncle, Saint Sava, from Trnovo (Bulgaria) to Mileševa, this prestigious place of worship became the centre of Saint Sava's cult, which would reflect its status in the church hierarchy. Thus, Mileševa's hegumen was accorded second place, right after the hegumen of Studenica. The monastery was probably ruined at the end of the 13th century by the Cumans, while during the fall of the Serbian medieval state in 1459, large-scale destruction occurred at the hands of the Ottomans. After the renewal, it reached its peak in the 16th century, developing important economic ties with Dubrovnik, and cultural and craft activities associated with copying, binding and printing books. During the 17th and 18th centuries, the cycle of destruction repeated, due to floods and Ottoman attacks, leaving the monastery abandoned in 1782. Mileševa was fully restored in 1863 and it played a prominent role in the awakening of national consciousness and identity. In this period, it also became the centre of interest of an increasing number of foreign scholars, travellers and diplomats who, amazed by the beauty of the preserved frescoes, widely affirmed its importance. Saint Sava relics were kept in the monastery until 1594–1595, when the Ottomans took them and burned them in Belgrade. Today, only his left hand and his archbishop's sceptre remain. His cult has been nurtured in the monastery for centuries (Кандић и Поповић 1995: 5–12).

The monastery complex today consists of the church, bell tower, and chapel, as well as other buildings, such as the treasury, guest residences, library and episcopal building. The whole complex was the subject of digitalization, but the focus was on the church, its frescoes and its material treasures.

3D laser scanning

For the digitization of the heritage of the Mileševa Monastery, we used a Faro Focus S150 laser scanner. This device enables the collection of extremely precise data with an error margin of only ±1 mm (at 10 m). The data obtained by scanning was processed in Scene software, which is specialised for working with Faro scanners. For further processing and visualisation, the Blender programme was used, which enables detailed processing and the creation of 3D models.

Aerial recording with unmanned vehicles

During the digitization of the Mileševa Monastery, we used several models of drones: *DJI Mavic Mini 3 Pro*[1] for recording the interior of the monastery church, and, among others, *DJI Inspire 2*[2], *DJI Mavic 2 Pro*[3] and *DJI Mavic 2 Zoom*[4] for external recording. These drones enable high-quality video recordings and photos, which were used to create photogrammetric models or a short presentation film. Sufficiently precise data can be extracted from the obtained material for analysis, presentations and the generation of textures for the 3D model. Using software such as *Polycam*[5] and *Blender,* photos taken by the drones were processed and combined into three-dimensional models.

Photographing of a representative set of movable and immovable heritage objects

Canon EOS 5D mk4, *Canon Eos 6D mk2* and *Nikon Z6 II* digital cameras were used to document the multi-layered heritage of the Mileševa Monastery. The processing of the obtained visual

[1] See more on: https://www.dji.com/global/mini-3-pro.
[2] See more on: https://www.dji.com/global/inspire-2
[3] See more on: https://www.dji.com/mavic-2/info.
[4] See more on: https://www.dji.com/mavic-2/info.
[5] See more on: https://poly.cam.

material using *Adobe Photoshop*[6] and *Affinity photo*[7].

360° photography

For obtaining material to enable interactive space exploration 360° cameras are used, such as *GoPro Max*[8] or *Insta 360 X3*[9]. In the case of the Mileševa Monastery, a *GoPro Max* camera was used, which has dual lenses and allows the recording of high-resolution spherical photos with different configurations. When used as a regular camera (*Single-Lens Hero Mode*), photos have a resolution of up to 16.6 megapixels. In recording mode with both lenses (*360° Mode*), photos can have a total resolution of up to 18 megapixels. Processing of 360° photos was done using specialized software and other work tools, such as *Affinity Photo*[10] or *Adobe Photoshop*[11]. After processing, the interactive panoramas were created using the specialised *Kolor Panotour Pro*[12] software.

Digitization of old and rare books

Given that the process of digitizing cultural heritage is mostly field-based, the *Travelers Conservation Copy Stand (TCCS 4232)*, which has a camera mount, book/document holder, and shadow avoidance lights, proved to be the optimal solution. The photographic equipment installed in our case was a *Canon Eos 5D mk4*[13]**.** The *TCCS 4232* stand, also known as the "Traveller", was developed by Manfred Mayer at the University of Graz Library (Austria) and is designed for the digitization of books and manuscript heritage in a way that minimizes damage. Another advantage is its mobility: the stand fits into a convenient and easily portable protective case that also includes additional digitizing equipment, such as lamps, mirrors and acrylic plates (Kapeller and Schön 2017: 5–6).

RESULTS AND DISCUSSION

During the working process for obtaining digitized data on the monastery, a general methodology was followed, developed similarly to those used by other authors in the process of object recording and modelling of cultural heritage, which comprises *data acquisition*, *data processing, data administration*, *data analysis* and *data representation* (Gruen 2013: 114–115). It consisted of *process preparation*, *data recording* and *data processing*, while the final step was *delivering the results*, no matter what technique was used. These results further served as inputs for delivering the final results of the whole digitization process – the presentation and dissemination tools – the website and the mobile application.

3D laser scanning

Except in the field of protection and preservation of cultural heritage, data collected by laser scanning can find applications in other disciplines as well, including archaeology, history, history of art, architecture and engineering. Through the interdisciplinary use of 3D models, the corpus of knowledge about cultural heritage is further affirmed and enriched, and contributes to its more comprehensive preservation. As a valuable cognitive-educational resource, 3D models can be used in professional work, educational programmes, virtual museums and digital platforms, allowing students and researchers to better understand and explore cultural heritage (Ferdani *et al.* 2020). This technology requires specialised equipment and training, as well as detailed post-production of the data to create the final model.

The 3D laser scanning process of the Mileševa Monastery included the following activities:

Process preparation. The first step involved defining the physical building and scan area,

[6] See more on: https://www.adobe.com/products/photoshop.html

[7] See more on: https://affinity.serif.com/en-gb/photo/

[8] See more on: https://gopro.com/en/rs/shop/cameras/max/CHDHZ-202-master.html

[9] See more on: https://www.insta360.com/product/insta360-x3

[10] See more on: https://affinity.serif.com/en-gb/photo/

[11] See more on: https://www.adobe.com/products/photoshop.html

[12] See more on: https://krpano.com/panotourproupdate/

[13] See more on: https://www.usa.canon.com/shop/p/eos-5d-mark-iv?color=Black&type=New&srsltid=AfmBOooy2ZrGh6JvzRKeS28q73-G0BZpsMsrBVTJJWAXZg9leQGmWhH2

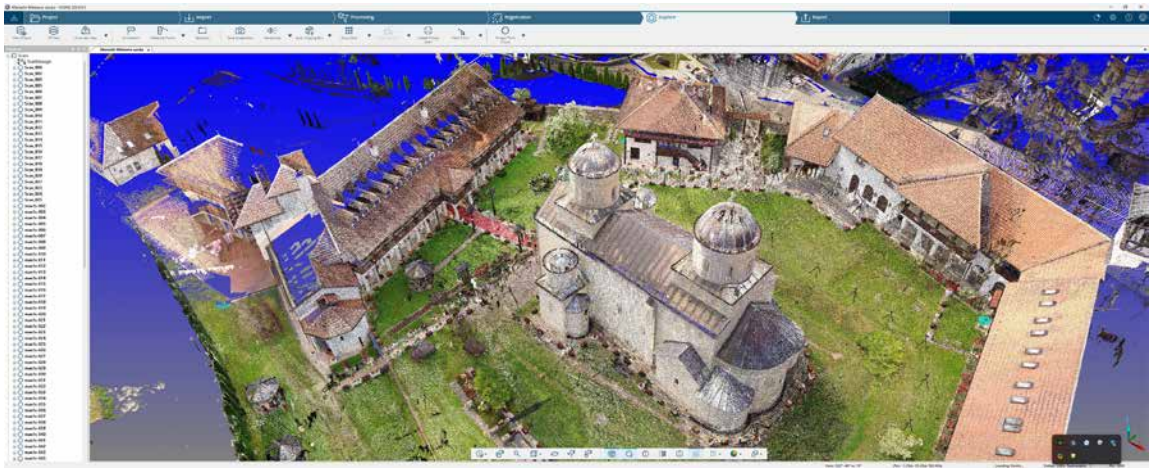

Figure 1. Point cloud obtained with the *Faro Focus S150* laser scanner (author Dragan Aćimović).

identifying key points and planning the scan to capture all relevant details.

Data recording. Scanning was performed using stationary laser scanners that emit laser beams towards the surface of the building. The reflected rays were then collected by sensors that measure the time it takes for the rays to return. Based on these measurements, the so-called *cloud of points (Point Cloud)* (**Figure 1**) was then translated into a representation of the building in the form of a *mesh*.

Data processing. Textures were added to the obtained representation of the building in the processing stage using photographs of the objects themselves. The data collected by laser scanning was processed to obtain a complete 3D model of the building.

Delivering the results: A total of 127 scans were performed for the exterior of Mileševa (Mean Point Error: 2.4 mm), while 92 scans were conducted for the interior (Mean Point Error: 0.8 mm). Point spacing**:** 3.1 mm at 10 m, number of points**:** 20,480 over 360 degrees, total points in a single scan**:** 174.8 million. This number of scans ensures adequate coverage of the complex architectural structure and details, with each part of the structure captured from multiple perspectives to minimize "blind spots" in the point cloud. The Faro Focus S 150, used for this purpose achieves this level of precision thanks to its high resolution and system stability. With this point cloud density, a precise documentation of cultural heritage can be achieved.

Aerial recording with unmanned vehicles

The advantage of the photogrammetry method is that it enables fast and relatively affordable digitization of large surfaces and objects, with a high level of detail due to high-quality textures (Wang *et al.* 2020: 576). In addition, using drones for photogrammetry is often more cost-effective compared to traditional surveying and documentation methods. Drones reduce the need for scaffolding, cranes and other, often bulky and expensive equipment, and also reduce time spent in the field. All of these make photogrammetry an affordable and accessible option for many heritage institutions (Shad *et al*. 2024; Themistocleous 2020: 241, 247). Drones are valuable for the documentation of tall buildings, the interior of difficult-to-access parts of monasteries and other cultural monuments, especially those located on steep and inaccessible terrain.

To obtain accurate models, it is necessary to carefully plan the flight path and process large amounts of data. Unmanned aerial vehicles have software technology that enables the creation of panoramic and spherical images that provide a comprehensive view of the entire space. These recordings can later be used for virtual tours, presentations and other promotional and educational purposes, allowing users to explore the space from different angles and perspectives. This advanced technology justifies its didactic role. Data collected by drones can be integrated with geographic information systems (GIS), allowing detailed analysis of spaces and structures.

GIS technologies are used for mapping, analysing and visualising data intuitively, thereby increasing the efficiency of cultural resource management (Liu *et al.* 2024).

Regular drone imaging helps experts identify and monitor the effects of climate conditions and other factors that may affect the condition of cultural monuments.

The drone recording process of the Mileševa Monastery included the following activities:

Process preparation. The preparatory phase involved planning the flight of an unmanned aerial vehicle, choosing the appropriate equipment depending on the type of recording (whether the exterior or interior of the building is being filmed, whether the priority is video material, photography or creating photogrammetric material) and defining the recording area.

Data recording. The recording process itself was carried out by flying an unmanned aircraft around or inside the building while collecting photographic/video material from different angles. To obtain a 3D model based on photographs, the method of photogrammetry was used, which involved photographing the building with a certain degree of photo overlap and additional settings. In this way, a series of photographs from different angles was generated (Kraus 2007; Mikhail *et al.* 2001; Watts *et al.* 2012) During the determination of the camera angle on the drone, a camera placed at an angle of 45° was found to give the best results because it allows a better insight into the details of facades and other vertical structures. This angle helped in reducing shadows and provides better coverage.

Data processing. Using the software, photos were processed and combined into precise three-dimensional models (**Figure 2**) that faithfully depicted the details of architectural elements or frescoes, which is of great importance for scientific research and the implementation of protection measures on the monument.

Delivering the results: The drone recording results were used in several ways. The first was the generation of photographic and video material. A total of 392 images with a resolution of 6016x3376 (approximately 20.3 MP) were produced (**Figure 3**), along with 378 MP4 files with a resolution of 3840x2160 (commonly referred to as 4K). The second involved the photogrammetric generation of a 3D model from the photographs (50,000 polygons; 12,712 triangles; 6,544 vertices; 19,068 edges; 12.526 faces) for display on a website. The third was the creation of a short film based on the recorded video material.

Figure 2. Photogrammetric 3D model of the Mileševa Monastery, 2022 (author Snežana Mijić).

Photographing of a representative set of movable and immovable heritage objects

As a valuable educational resource, photo archives are gaining an increasingly prominent place in school and academic curricula, often replacing direct contact with cultural heritage. From the middle of the 19th century when it was "an empirical, objective means of recording the world" (Hood 2023: 253) until today's digital era, photography has not lost its relevance, making it easier for researchers to further analyse artistic styles, techniques and materials used in different periods (Holm 2020: 384). This medium has also proven its reliability when "deciphering" layers of information that are not visible to researchers with the naked eye, which further enriches the understanding of the historical context and other specifics of the inspected cultural heritage. Finally, the Internet and information technologies have made photography more accessible than ever; influencing cause-and--effect relationships, and the greater visibility and accessibility of cultural monuments.

Figure 3. Shots of the monastery complex by a Mavic 2 pro drone (photo by the authors, 2022).

The photography process in the Mileševa Monastery included the following activities:

Process preparation. Visual identification and selection of immovable and movable heritage objects for photography (the monastery church, wall paintings , archaeological finds, icons, church vestments and utensils, and old liturgical books).

Data recording. Using professional cameras, high-quality images with a high level of detail were collected. Special attention was paid to lighting, framing, shooting angles, focus and exposure to ensure the greatest possible accuracy of the display, that is, to minimize the possibility of distortion or loss of information.

Data processing. Finally, the processing of the obtained visual material was completed, and the sorting of photos needed for the creation of a digital archive, website and web application was started.

Delivering the results: Photographs (**Figure 4; Figure 5; Figure 6**) were generated for the creation of a digital archive, website, and web application. A total of 562 images with a resolution of 6048x4024 (approximately 24.3 MP) and 369 images with a resolution of 6720x4480 (approximately 30.1 MP) were produced.

Figure 4. a. View of the church from the north by day; **b.** View of the church from the south by night (photos by the authors, 2022).

Figure 5.*White Angel (Archangel Gabriel)*, detail of the fresco composition of the *Myrrhbearers at Christ's Tomb*, third decade of the 13th century, south wall of the nave (photo by the authors, 2022).

a

b

Figure 6. a. Relic box of the proto-hegumen Longinus Mileševac from 1684; **b.** The archbishop's sceptre of Saint Sava handed to him by Patriarch Manojlo I on the occasion of the proclamation of the autocephalous Serbian Orthodox Church in 1219, detail, treasury of the Mileševa monastery (photos by the authors, 2022).

360° photography

Like 2D photos, 360° photos are an important tool for documenting and preserving cultural assets. The main advantage of the 360° virtual tour is reflected in the experience of heritage in a way that was unimaginable until recently, which provides a sense of physical presence and a detailed understanding of the space, the so-called immersive experience (Škola *et al.* 2020: 1). It is possible to explore the digitized space with this technology from any device, including smartphones, tablets and computers. Virtual tours can be easily shared through social networks and websites, further increasing the visibility of the monument and participating in education through user engagement and experience (Argyriou, Economous and Bouki 2020: 846). It is desirable to enrich the user experience with concise text descriptions, annotations, audio guides, links within 360° tours and other multimedia content**.**

The process of photographing with 360° technology in the Mileševa Monastery implied the following activities:

Process preparation. First, the locations where the equipment for 360° photography would be installed were visually identified, in our case at key points in and around the Mileševa Monastery.

Data recording. By using 360° cameras, spherical photos were taken that enable interactive space exploration.

Figure 7. Mileševa Monastery, 360° photo in Flat view mode (photo by the authors, 2022).

Data processing. The photos were then processed and stitched together. Processing of 360° photos was done using specialized software, with which it is possible to easily remove the "print" from the tripod. After processing the 360° photos, interactive panoramas were created using specialised software (**Figure 7**).

Delivering the results. The result of the recording is the generation of 102 images with a resolution of 5760x2880 (approximately 16.6 MP) in a 360° format. Based on these images, a virtual tour was created, optimized for web display and mobile application use.

Digitization of old and rare books

The benefit of scanning books and archives is that it enables the permanent preservation and easier access to information, with the possibility of searching digital documents, especially if the generation of quality metadata is carried out (RDM 2023). At the same time, readability and consistency must be ensured through well-adjusted photographic parameters, as well as adequate storage and organization of digital files. The digitization of books and archival materials brings numerous advantages that significantly contribute to the preservation and accessibility of these important historical sources. Taking into account the fact that digital copies are resistant to physical wear and damage caused both by the human factor and by the effect of natural disasters, the use of modern technologies for digitization achieves the permanent preservation of content that would otherwise be subject to decay and loss (Rieger *et al.* 2023).

The process of recording books and other archival material involved the following activities:

Process preparation. The preparatory phase involved the selection of books and the planning of the recording procedure to ensure the maximum protection of the original documents. The installation of the equipment was done in an adequate location with the setting of photographic parameters adapted to the environment.

Data recording. The process involved careful handling and protection of original documents during scanning/photographing (**Figure 8a**).

Data processing. Digital images (**Figure 8b**) were processed to ensure readability and consistency. This included colour correction, page alignment and removal of other irregularities.

Delivering the results. The Mileševa treasury and library preserve a significant number of valuable books, of which the most valuable copies were included in the digitization, such as the Đurđe Crnojević *Octoechos of the First Voice (Oktoih Prvoglasnik)* from 1494, the *Psalter* (1519) and *Prayer Book* (1540) printed by Božidar Vuković, *the Four Gospels* (1538) and the *Belgrade Four Gospels* (1552).

Figure 8. Book digitization: **a.** Travellers Conservation Copy Stand (TCCS 4232) in operation; **b.** Layout of a recorded book page (photos by the authors, 2022).

Website creation

The main advantage of the website is that it enables global access to digitized material, and increases the transparency of data and the visibility of cultural monuments. What should be paid special attention to is the constant updating and maintenance of the site, as well as optimization for different devices and browsers (UNESCO UK 2023; Europeana 2023; Center for Digital Heritage and Geospatial Information 2023).

It is recommended that the design of the site is interactive and has a user-friendly interface, which facilitates navigation and access to content. A responsive design allows the website to automatically adapt to different screen sizes, whether users are accessing the site from desktop computers, tablets or mobile phones. This is important to ensure a consistent and quality user experience regardless of the device being used. Mobile optimization is useful, considering the growing number of users who access the internet through mobile devices. Implementation of accessibility standards such as WCAG (Web Content Accessibility Guidelines) (WCAG 2023) is also recommended as it ensures that content is accessible to people with different types of disabilities. This includes the use of alt text for images (describing the content of the image), the ability to navigate via keyboard, support for screen readers and adaptive font sizes.

When it comes to increasing a site's visibility on the internet, search engine optimization (SEO) is an indispensable component. Relevant keywords, meta tag optimization, site loading speed and quality backlinks all contribute to a better site ranking on search engines like Google. This intensifies site traffic and allows more users to find and explore digitized materials, and quality content is essential for user retention. All information should be accurate, relevant and well-structured. In addition to textual content, it is important to include multimedia elements such as high-resolution images, video and audio, and interactive graphs.

The creation of website content[14] (**Figure 9**) for the Mileševa Monastery involved following procedural actions:

Process planning. It was necessary to redefine the objectives and structure of the site, as well as to identify the target group.

Design and development. Web design tools such as HTML, CSS, JavaScript and CMS

[14] The website content is available via: http://www.serbia-forum.org/sf/GlavnaSpomenici11.

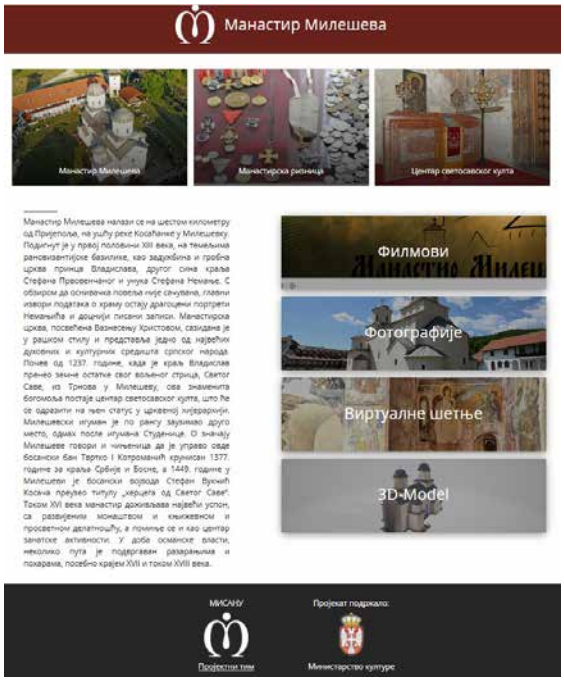

Figure 9. Digital presentation of the Mileševa Monastery on the Serbia-Forum platform (website), Mathematical Institute SASA.

platforms are mostly used to create an interactive and user-friendly site. If flexibility and support for various plugins and modules are preferred, it is recommended to use CMS platforms such as WordPress or Joomla, but in this case, special attention was paid to website security. When security is preferred over simplicity, flexibility and support for various plugins, one can use JSPWiki[15] as the backend and eXist-db as the database (used for Mileševa`s website creation). JSPWiki provides high security and data integrity, while eXist-db provides efficient management of XML-based data, which is ideal for projects that require strict security protocols and complex data structures.

Implementation. This involves placing digitized materials on a site optimized for search using SEO techniques. The site should also feature a responsive design to be accessible on different devices. Depending on the activities carried out, the site can include 3D models, photographs, a short film, virtual tours, descriptions of objects of cultural and historical heritage and other relevant information, which are the elements all included in the website of the Mileševa monastery.

Safety and maintenance. Implementing security measures, regularly updating software and making backup copies of data is the condition sine qua non of any serious web presence. Mileševa`s website maintenance includes regular functionality testing, correcting possible errors and performance optimisation, which contributes to the long-term quality and reliability of the site.

Delivering the results: The website was created in both Serbian and English, offering photos, 3d models, videos and virtual tours, as well as educational texts for its visitors. The website includes the following topics: *Mileševa Monastery* (with subtopics on *History***,** *Architecture* and *Wall Painting*); *The Monastery Treasury* (with subtopics *About the Treasury***,** *Collection of Icons, Church Vestments and Utensils***,** *Archaeological Heritage* and *Liturgical Books*); *The Centre of the Saint Sava Cult*; *Movies* (a 10-minute film created from aerial and terrestrial videos of the Monastery and its surroundings with music); *Photographs; Virtual Tours* (**Figure 10**); and *3D-Model*. All data can be downloaded by website visitors.

Mobile application creation

The user experience of the mobile application can be enriched by the integration of augmented reality (AR) and virtual reality (VR) technologies, further impacting the "cognition, experience, interaction, learning, and overall satisfaction of tourists" (Roodposhti and Esmaeelbeigi 2024: 2). It is also desirable to provide personalisation of the experience through options such as creating a list of favourites, adding notes or searching by keywords and dates, thus facilitating navigation through the digital collection. Enabling offline access to digitized content, even without an internet connection, especially for visitors who are in locations where there is no stable internet connection. The application should be updated regularly so that users have access to the latest information and functionality. Finally, the application must respect the highest standards of security and privacy. The protection of user data is ensured by the application of security protocols, such as data encryption and secure authentication, and compliance with regulations such as the GDPR (Brunswick 2019).

[15] See more on: https://jspwiki.apache.org/.

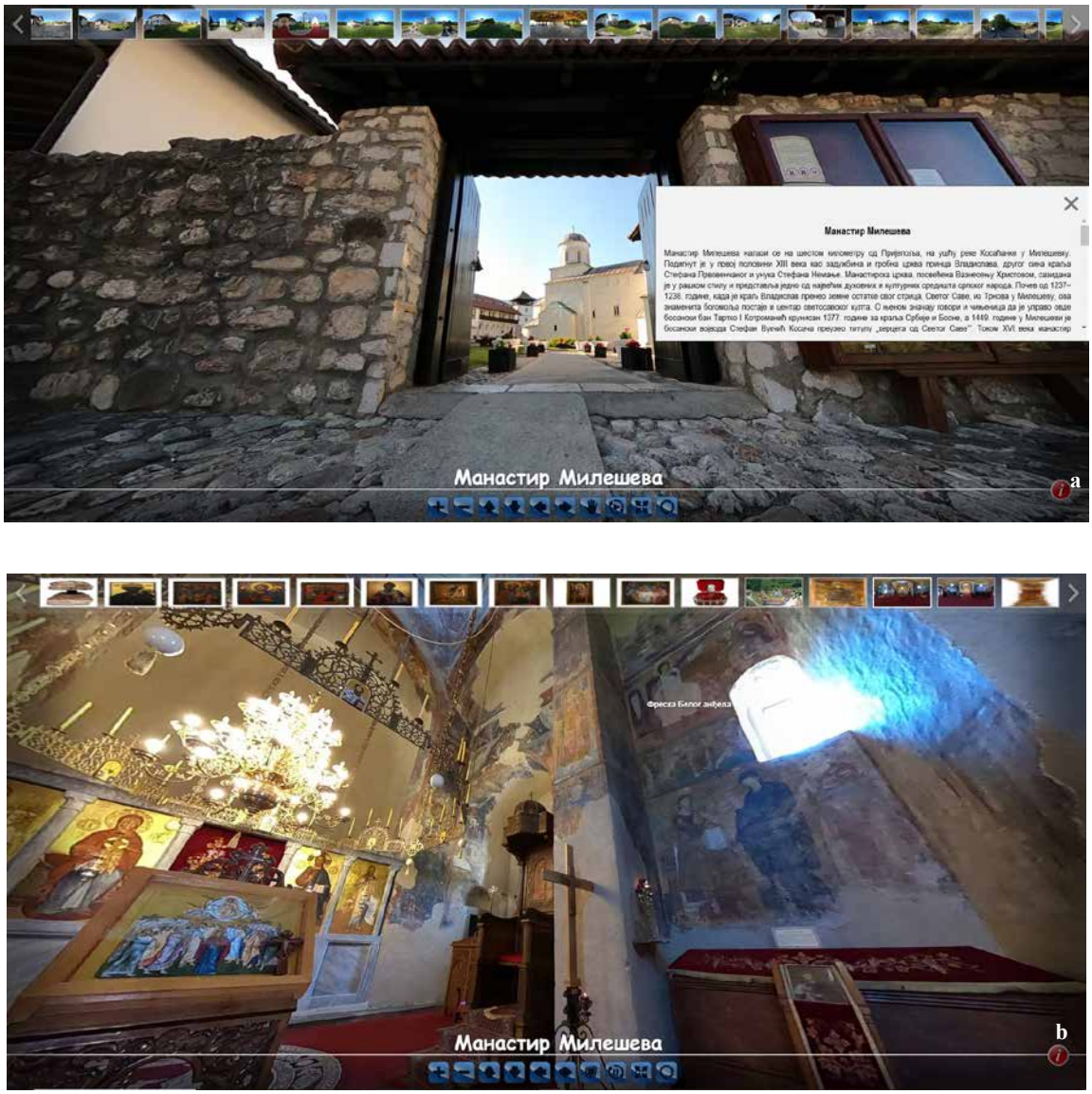

Figure 10. Screenshots of the visual tour available through the platform: **a.** Entrance to the Monastery; **b.** Church interior.

The process steps for creating the mobile application for the Mileševa Monastery (**Figure 11**)[16] were as follows:

Process planning and design. The first step referred to defining the functionality of the application and designing the user interface. The application was made to support iOS and Android platforms. The interface design was created to be simple and intuitive for users, with optimal use of the screen for various device sizes and with an emphasis on ease of navigation and quick access to information.

Development. The development of the application for Mileševa was carried out using Unity, enabling the simultaneous creation of applications for Android and iOS platforms. This cross-platform technology significantly accelerated the development process, while the use of the C# programming language facilitated a modular approach to implementing key functionalities. The application is divided into several modules, including a module for intuitive navigation, a multimedia module for displaying

[16] The application was developed by a team from the Mathematical Institute and the Archimedia Group from Niš.

images, 360° content (virtual tours), text-based content, maps, and virtual tours, as well as an offline module for operating without an internet connection for certain displays.

Testing and implementation. Apps should be tested on different devices to ensure compatibility and optimal performance. Testing of the mobile application for Mileševa was conducted on a wide range of devices to ensure compatibility and stability, while performance was further optimized for fast loading times and efficient use of device resources. Distribution was carried out through the Google Play Store and Apple App Store, adhering to the guidelines of each platform. Unity and C# have proven to be a reliable combination for developing a scalable and functional application tailored to user needs.[17]

Optimization and updating. When the application was developed, it was optimized

[17] Android store: https://play.google.com/store/apps/details?id=org.arhimedia.emg.mileseva&hl=sr&gl=US&pli=1; Apple store: https://apps.apple.com/rs/app/manastir-mileseva/id1661560829.

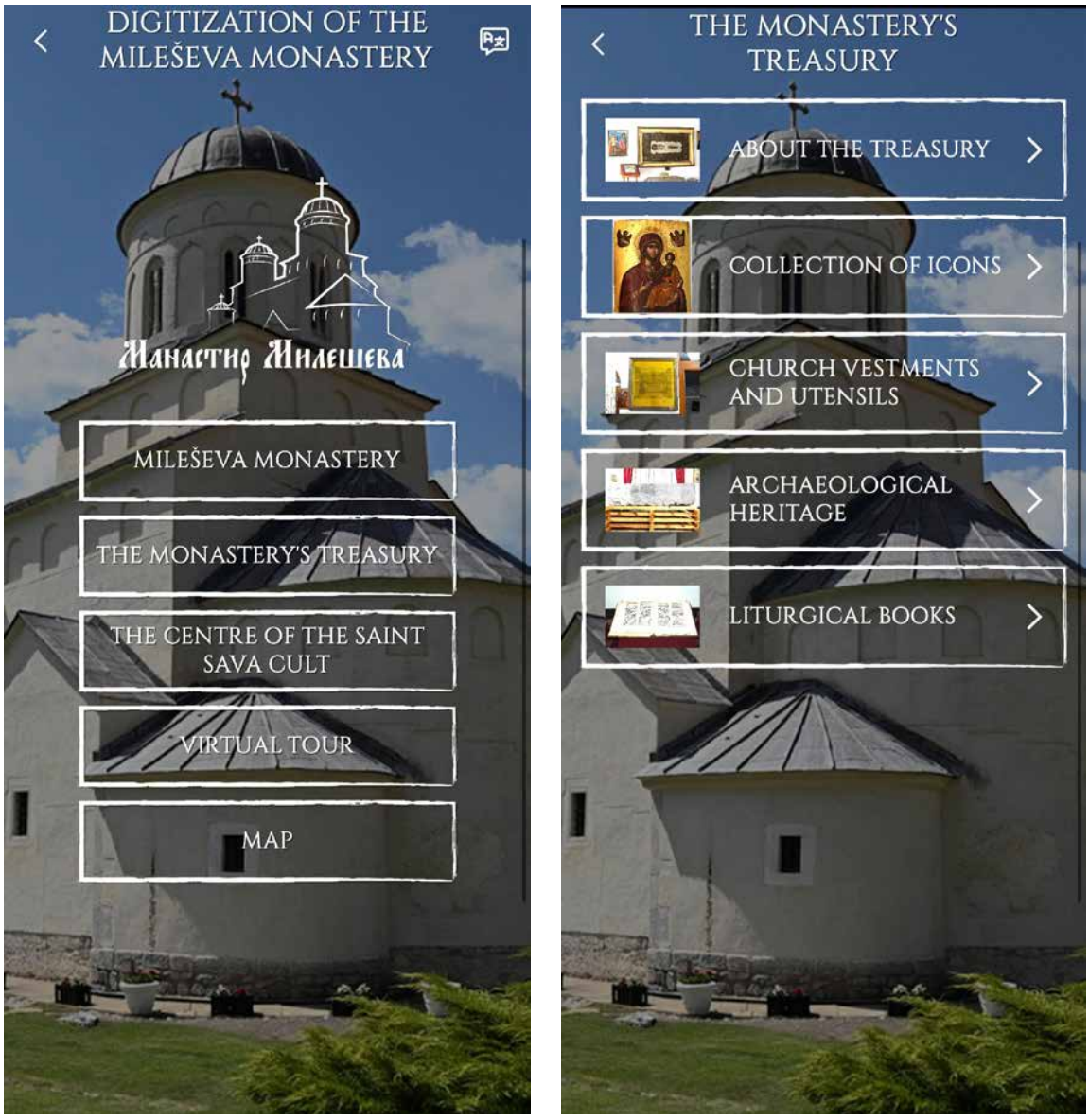

Figure 11. Digital presentation of the Mileševa Monastery on the application for mobile devices, Mathematical Institute SASA and Archimedia Group, 2022.

for performance on mobile devices and is to be regularly updated to add new functionalities and correct errors and possible security omissions.

Delivering the results: The mobile application was created in both Serbian and English (**Figure 11**), offering many photos and educational texts for its visitors. They include the following topics: *Mileševa Monastery* (with subtopics on *History, Architecture* and *Wall Painting*) with the 3d model and the Film; *The Monastery Treasury* (with subtopics *About the Treasury, Collection of Icons, Church Vestments and Utensils, Archaeological Heritage* and *Liturgical Books*); *The Centre of the Saint Sava Cult*; and *Virtual 360 Tour.*

* * *

One of the most important advantages of laser scanning is the possibility of obtaining extremely precise data on the shape and dimensions of an object, which is crucial for documenting and analysing the state of cultural monuments. Laser beams record all irregularities and textures on the surface of objects, providing a comprehensive representation of their physical characteristics. In the case of the Mileševa Monastery, this technique proved to be very useful in documenting complex architectural elements (such as parts of stone sculptural decoration), as well as wall paintings and items from the monastery's treasury. Digital documentation using a 3D laser scanner has brought extremely precise data on architectural features and paintings that represent some of the highest achievements of Serbian and European art of the 13th century. As such, this data will find applications in future scientific research and conservation-restoration interventions. An additional advantage was reflected in the speed and efficiency of collecting large amounts of data (one scanner can record thousands of points per second), which reduces the time required for fieldwork.

The processing and visualisation process enables the creation of a reliable 3D model that provides a precise representation of objects from all angles, and with regular scanning, it is possible to identify and monitor changes and damage caused by the passage of time and/or due to atmospheric influences. Thanks to this, the obtained 3D model of the Mileševa Monastery can serve as a basis for the protection of this monument, allowing experts to react promptly and plan potential conservation and restoration interventions. In addition, restorers can use a digital monument replica to simulate different restoration methods and evaluate their impact before applying them to real objects.

The collection of data, especially from hard-to-access parts of the monument, was enabled by using drones for photogrammetry, while professional and 360° photography further enriched the fund of high-quality visual archives. The interactivity features of 360° photos that allow users to "immerse" themselves in the space, move around at will and choose what they want to explore, in our specific case, generated a virtual tour as an insight, not only into the architectural features and decoration of the Church of the Holy Ascension of Christ, but also into the museological setting of the monastery's treasury. The accessibility reduced barriers and made this heritage more accessible, especially to socially sensitive groups and people with disabilities.

The digitization of old and rare books contributed to the permanent preservation and more efficient access to valuable manuscript heritage of the Mileševa Monastery. Wider access to all digitized materials was achieved through the creation of a website and a mobile application, which will certainly contribute to greater visibility and accessibility of this cultural monument.

The effectiveness and user-orientation of the website were achieved using functionalities that allow interaction with the content, such as zoom options for a detailed view of the frescoes and objects from the treasury, 3D models that can be rotated and viewed from different angles, a short film about the monastery complex itself shot by an unmanned aerial vehicle (**Figure 12**), as well as interactive maps that enable virtual tours with a better experience of the space.

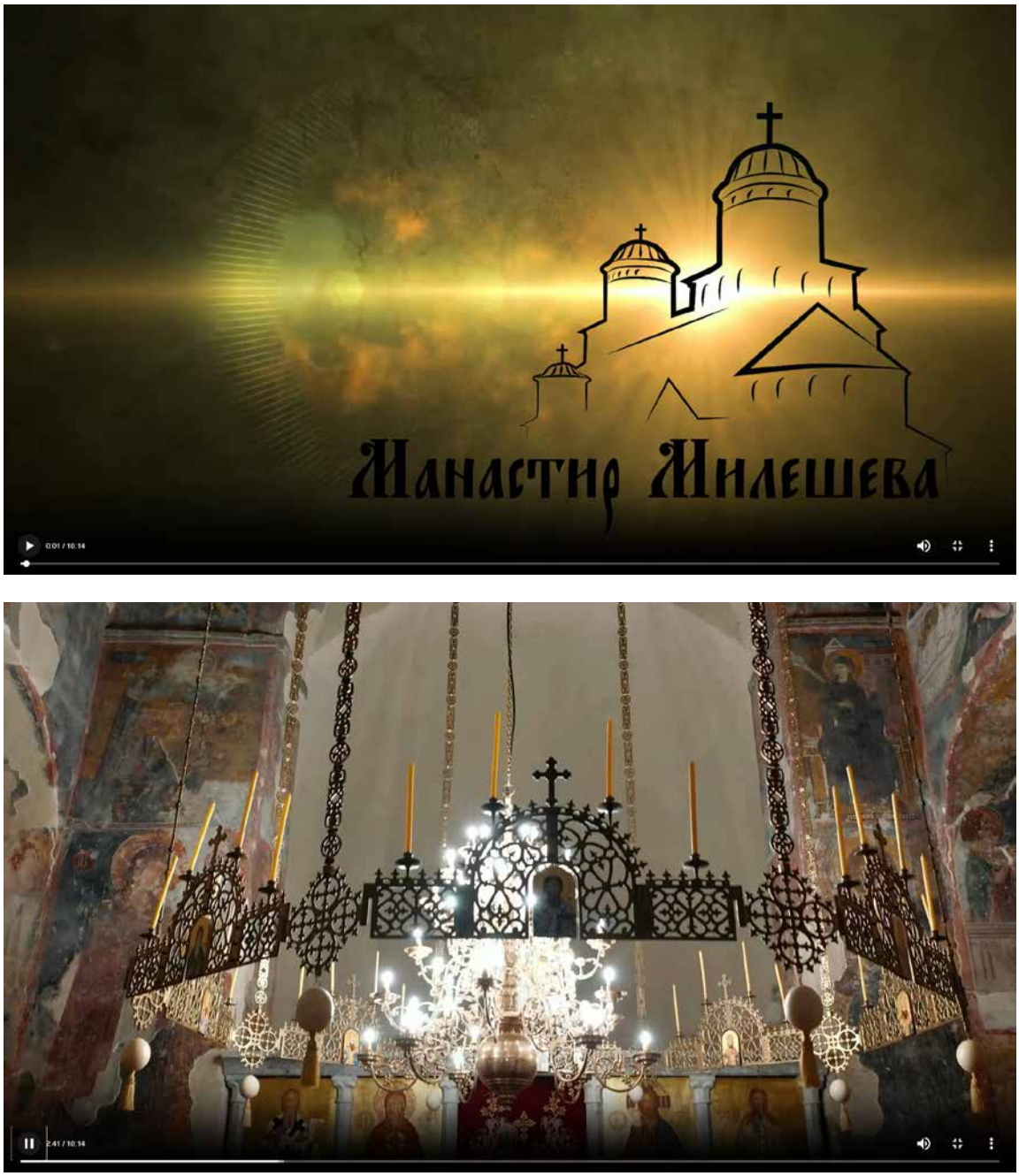

Figure 12. Film about the Mileševa monastery available on the website and mobile application (intro with a still of the film).

CONCLUSION

Digitization through the application of modern technologies represents a significant step towards the preservation and improvement of access to cultural heritage, especially monuments of exceptional importance such as the Mileševa Monastery in Serbia. These technologies are increasingly being used in education as well, which can be confirmed by the fact that the created application for mobile devices was declared by the Ministry of Education of the Republic of Serbia as an additional teaching tool for elementary and secondary schools in September 2023. In addition, this application can stimulate the interest of students and researchers in all scientific fields,

and a no less significant contribution is reflected in the improvement of tourism based on cultural heritage.

Future digitization projects connected to the Mileševa Monastery could include other advanced technologies, such as artificial intelligence, which is increasingly becoming a part of our everyday life and, in the context of cultural heritage, has the potential to be purposefully used for automatic content analysis and classification. Investing in the education and training of qualified staff to work with sophisticated digitization methods was and remains imperative because only in this way can the high quality of collected and processed data be ensured.

Following the great importance of the Mileševa Monastery as a historical, archaeological, architectural and artistic monument, its digital presentation can involve storytelling forms as well as virtual reality and augmented reality in the process of virtual reconstruction (Wang *et al.* 2020: 582). Digital storytelling has already been proven as an effective method for education about the cultural monuments for visitors and the creation of specific user experiences is constantly being advanced (Rizvić, Bošković and Mijatović 2024; Škola *et al.* 2024). Historic stories of the Monastery can be brought to life in this way, involving visitors in the life of the Monastery, with the potential to attract the young generation whose members have been born into a completely digital world.

Digitization of heritage is not only a technical but also a cultural undertaking and, therefore, the digital dissemination of cultural monuments and artefacts will gain more and more importance over time. In this process, an important role will be played by the involvement of the wider community through interactive platforms that allow users to add comments, tags and other indicative information, potentially improving it and increasing their own interest in cultural heritage.

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REZIME

UPOTREBA SAVREMENIH TEHNOLOGIJA U DIGITALIZACIJI MANASTIRA MILEŠEVE: IZVEŠTAJ O RADNOM TOKU

KLJUČNE REČI: DIGITALIZACIJA KULTURNE BAŠTINE, SAVREMENE TEHNOLOGIJE, MANASTIR MILEŠEVA, OČUVANJE KULTURNE BAŠTINE, 3D LASERSKO SKENIRANJE, VIZUALIZACIJA, DIGITALNA DOKUMENTACIJA ZASNOVANA NA VEBU

Primena digitalnih tehnologija u očuvanju i prezentaciji kulturne baštine predstavlja ključni aspekt savremenih praksi u oblasti zaštite i promocije kulturnih dobara. Digitalizacija omogućava detaljno ispitivanje, dokumentovanje i očuvanje kulturnih spomenika, čineći ih dostupnim široj publici i budućim generacijama. Ovaj rad istražuje inovativne tehnike i pristupe u digitalizaciji kulturnih dobara, sa posebnim fokusom na manastir Mileševu, značajan spomenik srpske kulturne i verske baštine.

U ovom projektu korišćene su raznovrsne digitalne tehnologije kako bi se obezbedila visoka preciznost i kvalitet dokumentacije: 1. 3D lasersko skeniranje: Pomoću uređaja kao što je *Faro Focus 150* omogućeno je stvaranje preciznih trodimenzionalnih modela. Ovi modeli nude detaljan uvid u arhitektonske karakteristike manastira, uključujući složene geometrijske strukture i ukrase, čime se omogućava analiza i rekonstrukcija objekata; 2. Snimanje dronovima: Različiti dronovi, uključujući *DJI Inspire 2*, *DJI Mavic Mini 3 Pro* i *DJI Mavic 2 Pro/Zoom*, korišćeni su za kreiranje fotogrametrijskih modela, visokokvalitetnih fotografija i video-snimaka. Ove tehnologije omogućavaju snimanje teško dostupnih područja i pružaju celovit pregled objekata iz različitih perspektiva; 3. Profesionalna fotografija: *Canon* i *Nikon* oprema korišćena je za stvaranje detaljnih i visokorezolutnih fotografija unutrašnjosti i eksterijera manastira. Ove slike služe kao trajni zapis umetničkih i arhitektonskih detalja; 4. 360° fotografija: *GoPro Max* kamera omogućila je stvaranje interaktivnih panoramskih prikaza, pružajući korisnicima mogućnost da istražuju manastir kroz virtuelnu realnost; 5. Digitalizacija knjiga: *Travellers Conservation Copy Stand 4232* u kombinaciji sa opremom *Canon* korišćen je za digitalizaciju starih knjiga i rukopisa. Ova tehnologija osigurava očuvanje fragilnih materijala i njihovu dostupnost u digitalnom formatu; 6. Razvoj veb-sajta i mobilne aplikacije: Omogućava se globalna dostupnost digitalizovanih materijala koji služe kao interaktivni kanali za edukaciju i istraživanje. Veb-sajt je optimizovan za intuitivnu navigaciju i pristup multimedijalnim sadržajima, dok su mobilne aplikacije prilagođene iOS i android uređajima, čineći ih dostupnim širokom spektru korisnika. Digitalne platforme dodatno podstiču angažovanje publike, omogućavajući korisnicima da istražuju sadržaj preko virtuelnih tura, interaktivnih modela i multimedijalnih prikaza.

Digitalizacija manastira Mileševe pruža neprocenjiv doprinos očuvanju ovog kulturnog spomenika. Precizna dokumentacija omogućava istraživačima i studentima detaljan uvid u

arhitekturu, umetnost i istoriju manastira, dok digitalni formati olakšavaju pristup informacijama i njihovu dalju analizu. Javnost, takođe, ima priliku da kroz digitalne kanale istraži manastir, čak i ako nije u mogućnosti da ga fizički poseti.

Ove tehnologije igraju ključnu ulogu u zaštiti podataka o kulturnoj baštini u slučaju potencijalnih rizika, uključujući propadanje usled vremenskih nepogoda, ljudskog faktora ili drugih prirodnih i antropogenih uticaja. Digitalizacija ne samo da osigurava trajnu arhivu već omogućava i kreiranje replika za potrebe edukacije i promocije. Digitalni pristup kulturnoj baštini pruža vredne resurse za obrazovne institucije, istraživačke centre i pojedince zainteresovane za istoriju i umetnost. Virtuelne ture, interaktivni modeli i digitalizovane knjige omogućavaju studentima i istraživačima pristup bogatim sadržajima na način koji je ranije bio nezamisliv. Korišćenje ovih resursa podstiče interdisciplinarna istraživanja i inovativne pristupe u očuvanju i interpretaciji kulturne baštine.

* * *

Use of tools based on large language models and generative AI: None.