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Preserving the past: Capturing heritage with 3D laser scanning technology

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Abstract - Heritage buildings are valuable cultural and historical assets that create tangible connection to our past and provide many social and economic benefits. These buildings are often threatened by various environmental and human factors, which impose the need for their timely safeguarding.
Documenting heritage buildings plays significant role in their long-term preservation, ensuring that valuable information is safeguarded for the present and future generations. Innovative techniques, such as 3D laser scanning, can provide accurate digital records, capturing all intricate details of the building that traditional methods often lack. This non-destructive technique generates realistic 3D model of the building that serves as valuable resource for analysis, monitoring changes over time or conservation/restoration planning.
The presented paper explores the application of 3D laser scanning technology on a Byzantine monument in North Macedonia – St. Nikita church near Skopje. It examines the possibilities, benefits and sustainable aspects of 3D laser scanning technology and highlights its role in heritage documentation.

Keywords: historical buildings, Byzantine heritage, 3D laser scanning, heritage documentation, digital archiving, sustainable preservation

I. Introduction

Heritage buildings play significant role in today's societies. As a reflection of our history and culture, these buildings create tangible connection to our past, provide sense of identity and help promote economic and sustainable development, [1].

Heritage buildings are vulnerable to wide range of natural, human and climatic threats, which can lead to damage or even loss of these valuable assets. Additionally, many heritage buildings are located in seismic-prone regions, which make them susceptible to the devastating effects of earthquakes, [2]. Having in mind the delicate "nature" of heritage buildings, it's a challenging task to guarantee their longevity.

North Macedonia is a country with an exceptionally rich tangible heritage, created over the centuries. The country's treasury contains some well-preserve examples of cultural and historical assets: over 1000 churches and monasteries, some archaeological sites, mosques and numerous artifacts, [3].

The selected monument for this study, St. Nikita church, is a notable medieval example for the Byzantine churches (9th-14th century) in North Macedonia, [4]. This church is located in Banjani, 15km north-west from the city of Skopje. It was built in 14th century and designed as domed cross-in-square plan with pentagonal apse on the east side, fig. 1. It's a massive structure built primarily to withstand its own weight - with tick peripheral walls and interior columns which support the central dome and the vaulted roofs. As many of the Byzantine churches, this building have additional system of wooden belts – placed within the wall, and wooden ties – placed in the upper zones of the interior, which improves its overall stability, especially during seismic activities. This is particularly important since some regions in North Macedonia, including Skopje are zones of high seismicity, [5].

Fig. 1 St. Nikita church

Since 1990, Skopje region has been affected by earthquakes of different intensities; the most destructive is the 1963 earthquake with a magnitude of 6.1 on the Richter scale which affected some of the Byzantine churches, including St. Nikita church. In the last 10 years there were several earthquakes in this region, with a magnitude greater than 4, including the 2016 earthquake with intensity of 5.1, [6]. In such regions, accurate documentation of the building plays significant role in ensuring its long-term preservation.

The existing official documentation for St. Nikita church, which can be found in NI National Conservation Center – Skopje, is very limited and mainly consists of historical written texts, legal documents and photos, [4]; which impose the need to provide more accurate and accessible records for further references.

II. Research Methodology

Documenting heritage buildings promotes deeper understanding and appreciation of our history, maintains our

identity and secures it for future generations. Today, there is a variety of documenting techniques applicable in the field of cultural heritage, both traditional (hand measuring, sketching, photography) and modern (photogrammetry, 3D laser scanning, heritage building information modeling (HBIM)), [7]].

3D laser scanning is a non-invasive and non-destructive technology widely implemented in many fields, including cultural heritage. This technology is based on the following concept: the scanner emits laser pulses towards the targeted surface and measures the distance and angle of reflection. In this way, it accurately defines the exact position of each point on object's surface. Millions of data points are recorded in three-dimensional space, creating a "point cloud" that represents building's surface. Furthermore, using suitable software like Autodesk ReCap or Leica Cyclone these data are managed and converted into a precise 3D digital model, [8][9].

In context of heritage buildings, this technology is used for surveying irregular and complex buildings [10], analysis and condition assessment [11][12][13][14][15] and particularly in mapping and documenting [8][16][17][18] since it provides precise records and considerably facilitates the documenting process. This accurate documentation can enhance sustainability in conservation practice, since can prevent unnecessary interventions and reduce waste materials. Furthermore, these records ensure that all important aspects and the significance of the building are preserved for future generations.

In the presented paper, 3D laser scanning technology is implemented for mapping and documenting a Byzantine monument – St. Nikita church near Skopje. The process was performed using the Leica ScanStation P40 which is one of the latest scanner models with exceptional precision and ultra-fast scanning rate of 1 million points per second. The scanner was placed in different positions in exterior and interior of the church (fig. 2), which combined with the drone footage provided complete and precise definition of the building's geometry. The scanner itself also contains a high-resolution digital camera which records the textures and colors of the materials and contributes to the realistic representation of the building. These fieldwork activities were performed in relatively short period of time, within approximately two hours. Furthermore, the Cyclone software was used to process the acquired point-cloud data.

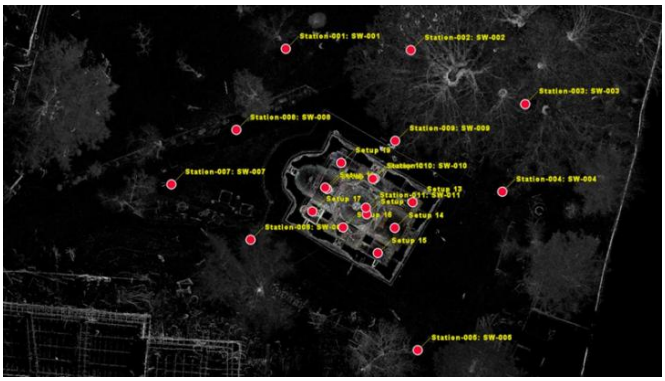

Fig. 2 Measuring positions of the scanner

III. Results

The data from the 3D laser scanner generated highly accurate 3D model, i.e. a digital replica of the monument (fig. 3), which can be analysed and operated from different angles, at any time, regardless the real physical limitations. The accurate representation of the building's geometry enables precise measurements of any required dimension (fig. 4) and detection of even the smallest details.

Fig. 3 Generated 3D model of St. Nikita church

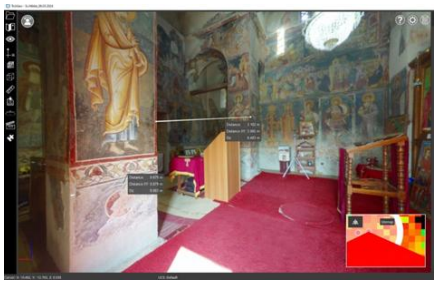

Fig. 4 Interior of St. Nikita church, generated from the scanner

Additionally, the 3D model was imported into CAD software (AutoCAD) which enabled to generate detailed 2D drawings, including floor plans, sections and elevations. These drawings are extracted directly from the 3D model (fig. 5) and can be obtained in any plane of the building, which is useful for presenting intricate details. However, while these two-dimensional drawings represent valuable documentation for the monument, further processing in the program is required to transform them into digital archives of the monument (fig. 6).

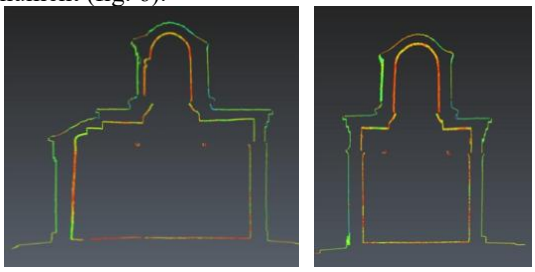

Fig. 5 Sections of St. Nikita church - extracted from the 3D model

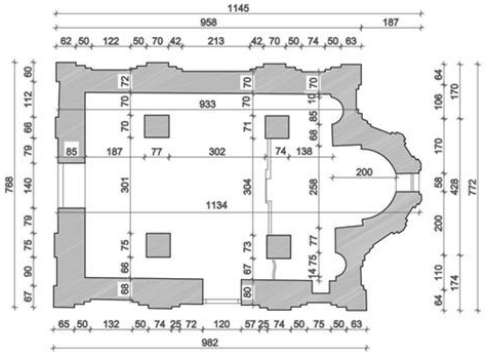

Fig. 6 Floor plan of St. Nikita church - extracted from the 3D model and further processed in AutoCAD

IV. DISCUSSION

The data generated from the 3D laser scanner represents a precise digital record of the monument and helps to create an accurate documentation, preserving all the details, which is particularly significant since the already existing documentation of the monument is relatively limited. These records ensure digital preservation of the building and serve as valuable resource in case of damage or even destruction, caused by the existing threats. Moreover, they represent solid foundation for condition monitoring, track changes over time or as reference for conservation/restoration planning.

The precision of the model gives opportunity to measure any dimension of the elements, including the thickness of the walls, which is otherwise practically impossible to determine. This significantly facilitated the creation of the numerical model used in the further structural analysis of the building.

Implementing new technologies, such as laser scanning, can support sustainable development goals. The creation of highly precise records of heritage building can improve the efficiency of the preservation strategies by preventing unnecessary interventions and minimizing the material waste. Moreover, the accessibility of the digital documentation can create more awareness and appreciation of the heritage values.

V. CONCLUSION

This paper presents the study of the late Byzantine monument – St. Nikita church, utilizing a 3D laser scanner to showcase the potential of this technology in the field of cultural heritage.

The combination of laser scanner (positioned in various points) and drone was used to create a precise 3D model of the church. The accuracy of this model gives opportunity for the architects, conservators and others researchers to explore and analyze the building in different aspects, according to their requirement. In case of St. Nikita church, this technology generated accurate digital records for the building, both in 2D and 3D, which significantly enriched the already existing documentation, which did not include this graphical data. Implementing this non-destructive innovative approach into preservation practices of the country can enhance the already existing protocols. It provides valuable resource for the purpose of the future preservation efforts, education or sustainable goals and safeguards these valuable assets for the future generations and prevents from being forever lost.

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