

# POTENTIALS OF 3D LASER SCANNING OF CHURCH OBJECTS OF STUDENICA MONASTERY COMPLEX IN PRESERVATION OF CULTURAL HERITAGE



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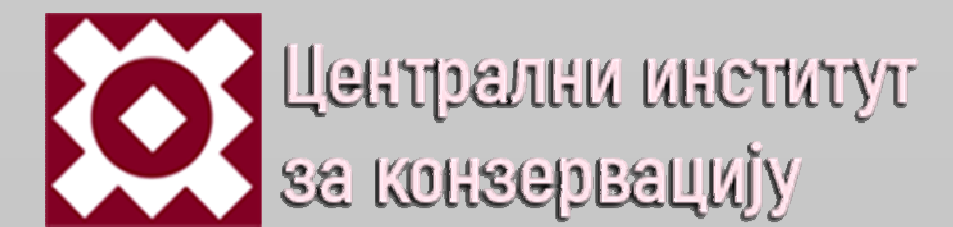


Figure 1 Studenica Monastery complex interior — with Kings' church (on the left), dormitory (in the middle), and Teothokos' church (on the right side) in winter 2017, during laser scanning operation



Figure 2 Studenica complex - Photorealistic presentation: part of the scanned area (registered point cloud data)

Table 1 Performances of Faro Focus 3D S 120 scanner

PERFORMANCE	PARAMETERS	REMARKS
Distance accuracy	up to $\pm 2$ mm	at 10m and 25m
Range	0.6 to 120 m *indoor or outdoor	low ambient light and normal incidence to 90% reflective surface
Field of view	vertical 305°, horizontal 360°	step size 0.009°
Laser	905 nm (3R) 20mW divergence 0.19 mrad	
Small and compact device with large scanning range; dual-axis compensated scanning unit		

Table 2 Performances of Leica Geosystems scan station P20 scanner

PERFORMANCE	PARAMETERS	REMARKS
Distance accuracy	up to $\pm 3$ mm	at 50m distance
Range	up to 300 m	
Field of view	vertical 270°, horizontal 360°	using the range 0.4 m to 120 m
Laser	658 nm, 0.23 mW divergence 0.2 mrad	* visible laser performances
Ultra high-speed laser scanner; dual-axis compensated scanning unit		



Figure 3 3D (on the left) and 2D (on the right) representations of the church St. Joachim and Ana - point cloud deliverables

## INTRODUCTION

**Studenica monastery complex**, established in 12th century, is one of the largest and richest monasteries of the Serbian Orthodox Church, famous for its extraordinary beauty. It is the Monument of Culture of Exceptional Importance of the Republic of Yugoslavia (Serbia) since 1979, and UNESCO World Heritage site since 1986. In overall historical context Studenica has significant role, as the monument being built as the tomb church for Serbian joupan Stefan Nemanja—the first member of ruling dynasty Nemanjić who strongly influenced spread of sacral architecture on the territory of former Raška state and straightened position of Serbian Orthodox church [1].

The complex includes the Theotokos' Church, the church of the Saints Joachim and Ana (known as the King's Church) – both built using white marble, the Church of St. Nicholas and surrounding auxiliary objects (Fig 1). The Theotokos' Church is the representative of architectural style known as Raška school, that joined the Romanesque and Byzantine traditions regarding exterior decoration and structural composition, respectively. A world wide scholar auditorium, including architects, conservators, art and architectural historians, etc., focused on Serbian medieval church architecture and fresco-paintings, are showing constant interest in scientific investigations of diverse topics. Current advances in measurement technology (devices, hardware and software) opened new challenges for obtaining more accurate results during researching of the knowledge and design principles of medieval architects or master builders at the time [2,3]. Terrestrial laser scanning data, i.e. high accurate point clouds became standards for several scientific and practical disciplines engaged in the area of cultural heritage protection (art, architecture, geodesy, civil engineering, various material analytics, etc.) [4,5,6]. In terms of actual cultural heritage needs (missing or demolished objects' parts restoration) such data are of high importance.

During winter 2017 3D terrestrial laser scanning of sacral objects inside Studenica monastery complex is performed for the purposes of scientific project with multidisciplinary approach. Beside principal scientific research aims of previously mentioned disciplines, educational goals were included as well. A group of Civil engineering students (Department of Geodesy) was present during all the phases of the project. Namely, they were taught the field work in measurement design practice and laser scanning performance, i.e. data collecting by two types of scanning devices. Following the streamline in education, final data processing (creation of the 3D mesh models) in adequate software is the final students' contribution to their own study projects.

Central Institute for Conservation in Belgrade and Faculty of Civil Engineering in Belgrade joined technical equipment and other resources in 3D terrestrial laser scanning of several objects inside the Studenica complex. The instruments Faro Focus 3D and Leica scan station P20 were activated in parallel scan processes in efficient terrain data collecting. Performances of each of the two scanning devices are presented in Tables 1-2 [7,8].

## RESULTS AND DISCUSSION

The first part of investigation is related to exterior of architectural objects. Optimal weather conditions for laser scanning procedure were present at the site during scanning performance [8]. In order to obtain sufficient and accurate data, scanning was performed at more than 20 scan stations inside monastery complex.

Visual presentation of deliverables (registered point cloud) in adequate viewer enabled a quick access to the scanned objects dimensions as well as their photorealistic imaging (Fig. 2). In particular, the small church of St. Joachim and Ana was scanned in order to provide new reliable data for documentation purposes and diverse analysis along with visualisation (animation) material (Fig. 3 and Fig.4). 3D parametric studies as novelty in reverse engineering of built heritage opened new exploration possibilities concerning Serbian medieval heritage [3,9]. The first results of parametric analysis were reported in [3] during April 2018. Majority of Serbian medieval churches do not have detail technical documentation (2D drawings), sufficient for 3D reconstruction purposes. Enlarging the digital repository of medieval monuments leads to an unique base for historical, architectural, art and other related research. Besides, excellent material for visual representation of monuments for a wider public auditorium (via virtual museums / collections) is obtained [10].

In accordance to actual preservation and reconstruction needs concerning missing or demolished objects' parts, reliable data are of high importance [2,4]. 3D mesh model, as a result of raw terrain data processing, serves as a base - "mold-prototype" for the accurate reconstruction/repairment of decorative elements on the objects facades.

## CONCLUSIONS

Contemporary measurement technologies and adequate software solutions for data processing have opened numerous new possibilities in cultural heritage area. Terrestrial laser scanning results and data processing deliverables regarding objects inside medieval Monastery Complex Studenica in Serbia are set of valuable materials aimed for scientific research (historical, architectural, geometric, etc.) practical application for object's restoration, digital archives and education. Beside documentation survey and digital archiving its value lies in monuments' cultural revival through new technologies and media. By signifying cultural heritage one does not set limitations, but invokes creativity route for further generations.

## ACKNOWLEDGEMENTS

The authors express their gratitude for the project's support to the Ministry of Culture and Information of the Republic of Serbia Ministry of Education, Science and Technological Development of the Republic of Serbia (TR 3600); Serbian Orthodox Church— Eparchy of Žiča for the blessings research approval as well as The Brotherhood of Studenica Monastery for hospitality and all the necessary help during research.

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## 3D LASERSKO SKENIRANJE CRKVENIH OBJEKATA MANASTIRSKOG KOMPLEKSA STUDENICA U OČUVANJU KULTURNE BAŠTINE

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U okviru projekta namenjenog potrebama zaštite i očuvanja kulturne baštine, izvršeno je 3D lasersko skeniranje crkvenih objekata u okviru manastirskog kompleksa Studenica. Prikupljeni podaci i rezultati obrade će se koristiti kao baza za buduće rekonstrukcije i naučne analize, kao i u svrhe vizuelizacije ovog kulturnog blaga. Uključivanje i studenata Građevinskog fakulteta iz Beograda u ovaj projekat podiže svest o važnosti zaštite Srpske srednjovekovne kulturne baštine.

