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DIGITIZATION OF CULTURAL HERITAGE RESOURCES ON THE EXAMPLE OF A SACRAL OBJECT USING A 3D LASER SCANNING SYSTEM

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Abstract

The article presents the role and process of digitization of cultural heritage resources using the example of a parish church in Borowno, Poland, built in 1845–1846. It is an impressive neo-Baroque building, single-nave, with a semicircularly closed presbytery and a two-tower façade. The Trimble X7 3D laser scanning system was used to inventory the object, which enabled precise mapping of geometry in the form of a point cloud. The obtained data was analyzed in terms of scanning quality, accuracy of mapping architectural details, and the possibility of their further use in conservation documentation and 3D modeling. The results of the analysis showed that 3D laser scanning technology is an effective tool for inventorying historic objects, enabling their detailed analysis and archiving in digital form.

Keywords: *Architectural monuments; 3D laser scanning system; Point cloud; Conservation; Architectural digitalization; Poland; Sacral building; Terrestrial laser scanning*

Introduction

Protection of cultural heritage resources is one of the key challenges of modern times, encompassing not only securing monuments but also their documentation and archiving in digital form. With the development of information technology, digitization technology using a 3D laser scanning system, which enables faithful reproduction of the geometry of objects, is becoming increasingly important in the process of inventory and conservation of historical objects. One of the most advanced tools in this area is terrestrial laser scanning 3D TLS (Terrestrial Laser Scanning), which is widely used in the field of protection and conservation of cultural heritage resources [1, 2].

TLS technology allows for quick and accurate acquisition of spatial information in the form of a point cloud, which is the basis for creating 2D documentation, 3D models, and engineering and conservation analyses [3]. The authors in their works [4-9] have shown that 3D laser scanning significantly increases the efficiency of architectural inventory work while minimizing the risk of omitting important architectural details. In addition, the digital form of data allows for their archiving and reuse in the future, both for scientific, educational, and reconstruction purposes.

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The literature also emphasizes the important role of digitization in the context of threats to cultural heritage, such as natural disasters, armed conflicts, or material degradation [10]. Examples of the use of scanning technology in the documentation and conservation of monuments can be found in numerous studies and projects, such as the documentation of the clock tower in Tirana, the facade of the Church of St. Nicholas in Pisa, or the Palace in Seri Menanti [11-13].

This article presents the process of digitalization of a historic parish church in Borowno, Poland, an example of a religious building of high historical and architectural value, entered into the register of monuments under the number PL.1.9.ZIPOZ.NID_N_24_BK.95148 [14, 15]. The Trimble X7 3D laser scanning system was used for the inventory, and the aim of the work was to assess the accuracy of detail reproduction and the potential use of data in conservation documentation and 3D modeling.

Characteristics of the scanned cultural heritage object

The Church of St. Lawrence is a parish church of the Roman Catholic parish of the same name, which is located in the Kłomnice deanery belonging to the Częstochowa Archdiocese, located in the town of Borowno in Poland. The single-nave church was built in the neo-Baroque style on the site of former churches in the years 1845-1846 and rebuilt in the years 1885-1901. It has one nave and a semicircularly closed presbytery, in which there are valuable polychromes. The facade of the church is decorated with two quadrangular towers rising to a height of 50m. The main entrance to the church is from the side of the towers, and it is entered through iron doors from the beginning of the 20th century. The church's equipment includes the following from the end of the 19th century: a baptismal font, pulpit, two impressive chandeliers, and confessionals. The church has a main altar with a historic tabernacle and two side altars. The paintings in it are valuable, especially the 17th-century painting of Our Lady of the Scapular and Child and the silver dresses decorating it, also from the 17th century, as well as paintings of Our Lady of Loreto, the Scourged Lord Jesus, the patron saint – St. Lawrence—and a painting dedicated to the Sacred Heart of Jesus [16, 17]. Due to the condition of the roof truss and roof covering, in 2025, the renovation of the roof and replacement of the roof covering began. The current view of the church from the outside is shown in Figure 1, and the inside in Figure 2.

Fig. 1. View of the church from the outside. Drone photo taken on April 17, 2025

Fig. 2. View of the church interior. Photo taken on March 27, 2025

Methodology and scope of digitization using a 3D laser scanning system

The Trimble X7 3D laser scanning system, shown in Figure 3, was used for the measurements. It is a tool for analyzing objects and their surroundings in the real world, which provides all data on shapes and dimensions in the form of a point cloud. The collected information is necessary to create correctly mapped 2D documentation and a 3D model in digital form. Due to its operation, this process eliminates the need for physical contact with the measured form, which allows us to avoid any damage or human errors. In addition, the scanner is characterized by high measurement accuracy and the ability to work in difficult lighting conditions. The scanner is equipped with an automated leveling system, with a measurement range of up to 80m with a measurement accuracy of ±2mm at a distance of 20m and a scanning speed of up to 500,000 points per second.

Fig. 3. Trimble X7 3D Laser Scanning System

On March 27, 2025, the entire facility was scanned from the outside and all rooms inside, including the roof truss structure. Spatial scanning was performed from a total of 69 measurement stations arranged in such a way that every detail of the building was fully mapped, which allowed obtaining a full point cloud representing the geometry of the facility. The data from the scan was processed in specialized Trimble RealWorks software, which allows for the registration and merging of point clouds, noise filtering, and analysis of the accuracy of the mapping of architectural details. Figure 4 shows a general view of the obtained point cloud, while Figure 5 shows a top view with marked measurement stations. From the 69 scans performed, a point cloud was obtained with a measurement error of 1.48mm.

Fig. 4. Point Cloud—General View

Fig. 5. Top view with measuring stations marked in orange

Analysis of the obtained data

The obtained point cloud was processed in Trimble RealWorks software, removing unnecessary elements of the surroundings and obtaining a point cloud of the church building itself.

The data obtained showed high quality of the building geometry mapping, allowing for precise geometric measurements. Based on the obtained data, a set of visualizations was generated, including a view of the church building in a perspective projection presented in Figure 6.

Fig. 6. Point cloud of the church building in perspective projection

Analyzing the point cloud view, one can see the complete body of the church. The spatial model faithfully reproduces the main architectural features of the building, including the two-tower front façade and the nave body. The lower part of the façade has been reproduced with high accuracy, which allows for clear distinction of elements such as columns, cornices, window niches, and stucco details. The high point density allows for faithful reproduction of architectural details, which allows for their further use in 3D modeling and preparation of conservation documentation. The quality of the reproduction in most areas is very good, although local interference with the presence of scaffolding is noticeable, which affects the limited visibility of details and reduces the precision of the reproduction. Limitations also appear in the highest parts of the towers, where access of the laser beam was difficult, which results in less data. Despite these imperfections, the obtained 3D model is a sufficient source of information about the geometry of the object. In addition, elevation projections and cross-sections of the building were generated from the obtained point cloud; they are presented in Figure 7.

Analyzing the views of the southern elevation (Fig. 7a) and northern elevation (Fig. 7c), one can notice the high quality of the reproduction of the surface of the walls, windows, and architectural details. However, the visible scaffolding prevented the walls from being fully scanned. The fort elevation (Fig. 7b) perfectly reflects the symmetry of the composition of the façade with two towers and centrally located entrance doors. The architectural details were reproduced with great accuracy, which allows their reconstruction in digital 3D form. The longitudinal section through the nave (Fig. 7d) allows for the assessment of the spatial structure of the interior, the arrangement of the vaults, the arrangement of the windows and architectural proportions, as well as the construction of the wooden roof truss. The view from above (roof plan Fig. 7e) shows the geometry of the roof covering, the arrangement of the towers, and their spatial relations to the body of the main nave and the presbytery. The ground floor plan (Fig. 7f) allows for the development of a precise architectural plan of the church. The obtained point cloud is sufficient to develop 2D architectural documentation and a 3D model, which allows for their further use in conservation projects, structural analyses, and even popularization of heritage in digital space. At each position of the measuring station, the scanner takes a high-resolution panoramic photo with a range of 360°, which allows for faithful spatial reproduction of visual elements of the surface, such as frescoes. The view of the panorama from the interior of the church is shown in Figure 8.

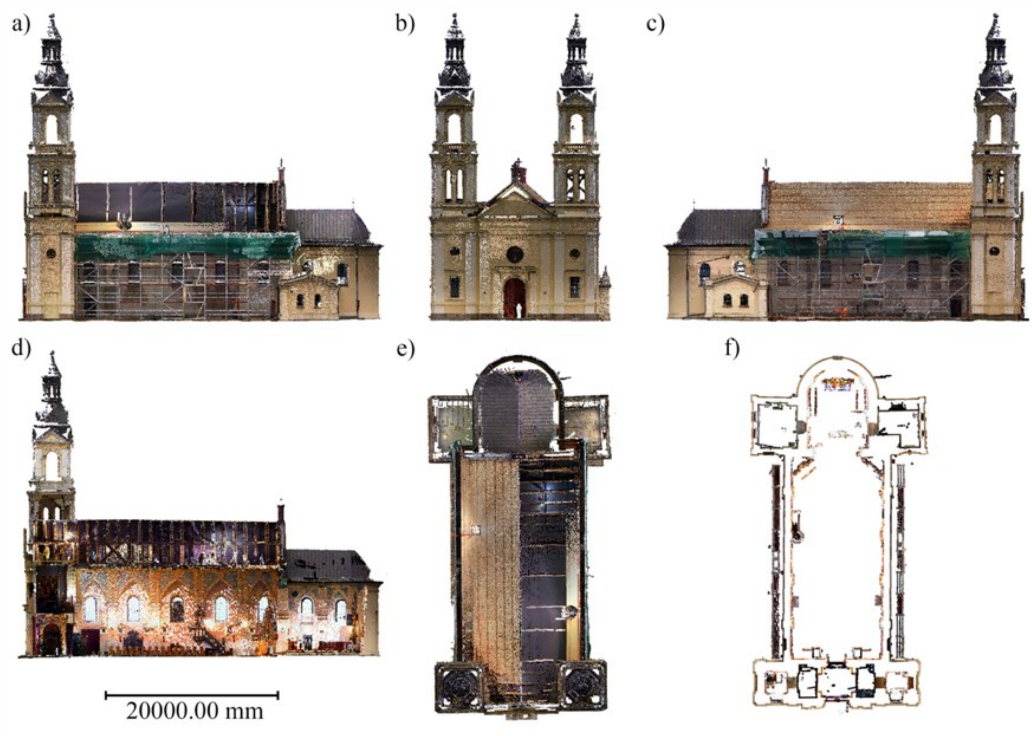

Fig. 7. Projections and point cloud views of the scanned church:
a) south elevation; b) front elevation; c) north elevation; d) vertical section along; e) top view; f) ground floor plan

Fig. 8. 360° panorama from inside the church

Spherical panoramas from each position of the measuring station constitute an important supplement to the digital documentation of the object, enabling virtual representation of the internal space and identification of details. The recorded photographic data enable synchronization with the point cloud, enriching the model with photorealistic texture and visual context for the purposes of archiving or designing conservation works.

Conclusions

The point cloud obtained using 3D laser scanning technology, using the example of a historic church in Borowna in Poland, confirmed its effectiveness in the process of digitizing cultural heritage resources. The digitization carried out will enable the creation of detailed architectural documentation of a sacral object of high historical value. Based on the obtained point cloud, it will be possible to create projections, sections, and visualizations of the elevation, which allow for, among others, a precise analysis of the geometry and spatial layout of the object, identification of architectural details requiring conservation, and archiving the state of the monument in digital form, which is of great importance in the context of protecting cultural heritage. 3D laser scanning allows not only for faithful reproduction of historic objects, but also for their archiving, documentation, and the possibility of making them available in digital form, which is a significant support for conservation activities. Despite certain limitations resulting from terrain and structural conditions, 3D scanning technology has been confirmed as an effective tool for the inventory of architectural monuments.

In summary, the collected data also enable the preparation of three-dimensional models, reconstruction of historical details, and can serve as reference material when planning future conservation works.

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