Research Journal of Agricultural Science, 57 (4), 2025; ISSN: 2668-926X

http://doi.org/10.59463/RJAS.2025.4.02

PRESERVATION OF HERITAGE MONUMENT ST. NICHOLAS CHURCH FROM BRASOV USING GEOMATICS TECHNOLOGY

M. AVĂDANEI[1], Anda VUȘCAN[1], I. VETO[1], Florina ȚÂRLE BURESCU[1], F. SALA[2,3], M.V. HERBEI[1,2]

[1]University of Petrosani , 332006, University Street, nr. 20, Petroșani, Romania

[2]University of Life Sciences "King Mihai I" from Timisoara, 300645, 119, Calea Aradului, Timisoara, Romania

[3]Agricultural Research and Development Station Lovrin, 307250, Lovrin, Romania

Corresponding author: florin_sala@usvt.ro

Abstract. *This paper presents a comprehensive workflow for data acquisition using the Leica BLK360 3D laser scanning technology, with a particular focus on the advantages of performing real-time registration directly in the field through the Cyclone Field 360 application. The primary objective of this study is the documentation and long-term preservation of the St. Nicholas Church in Brașov, Romania, an important heritage monument with significant cultural and historical value. The methodology involved capturing high-resolution 3D scans of the building, which were subsequently processed in the Leica Cyclone Register 360 Plus software. Georeferencing was carried out by integrating three black-and-white targets, whose precise coordinates were determined with the Leica GS07 GNSS RTK solution. This integration of laser scanning and GNSS technologies ensured both high spatial accuracy and global positioning reliability. The main outcome of the project is a georeferenced point cloud that provides a robust basis for generating accurate 2D architectural drawings as well as for constructing a detailed 3D digital model of the monument. Such deliverables are essential for heritage conservation efforts, enabling accurate documentation, condition assessment, restoration planning, and future monitoring of structural changes. By combining advanced 3D laser scanning with GNSS georeferencing, this workflow demonstrates a highly efficient and precise approach to cultural heritage documentation. Beyond its application to the St. Nicholas Church, the methodology can serve as a reference model for similar projects aiming to safeguard and digitally preserve architectural monuments.*

Keywords*: Terestrial laser scanning, 3D, GNSS, Georeferencing, Cyclone Register 360*

INTRODUCTION

To preserve our cultural and natural heritage for future generations, three-dimensional (3D) laser scanning opens the door to document, study, understand and monitor any element or site of our cultural world heritage (INGENSAND, 2006; ALBA AND SCAIONI, 2007; LOGOTHETIS ET AL., 2015; TKÁČ AND MESÁROŠ, 2016; POMPEJANO, 2020; LLABANI AND ABAZAJ, 2024).

With 3D laser scanning solutions, surveyors around the world can measure with precision and high resolution any historical monument or building. Point clouds can be converted into 3D mesh models (RASHEED ET AL., 2020; BOTIN-SANABRIA ET AL., 2022), which can be archived in case structures are damaged and need to be restored to their former glory. Datasets can also be used to understand all possible risks a monument or structure might face.

The convergence of heritage preservation and technological innovation has given rise to a new era in archaeological and architectural documentation, where the 3D representation (LOGOTHETIS ET AL., 2015) of cultural heritage plays a pivotal role. Terrestrial laser scanning (TLS) (ABBAS ET AL., 2014; UGGLA AND HOREMUZ, 2020; SIMON ET AL., 2023) a non-contact and non-destructive surveying technique, has proven to be an invaluable asset in capturing highly accurate and detailed spatial information of heritage sites.

This technique utilizes laser beams emitted from a scanner to measure the distance to objects, creating a dense point cloud that accurately represents the surfaces and geometry of the scanned environment.

The deliverables produced with 3D laser scanning can be used beyond heritage. The information can also be used to help expand the scope of heritage projects, engage sponsors and even increase both physical and virtual tourism (ALBA AND SCAIONI, 2007; RASHEED ET AL., 2020).

The present study focuses on the integration of Leica BLK360 3D Laser Scanning technology and the Leica GS07 GNSS solution to achieve a high-accuracy georeferenced 3D (HERBEI ET AL., 2013; ABBAS ET AL., 2014; UGGLA, G., HOREMUZ, 2020; DREIER ET AL., 2021; ȘMULEAC ET AL., 2022) documentation of the St. Nicholas Church in Brașov, Romania - one of the most significant historical and architectural landmarks in Transylvania. St. Nicholas Church a Romanian Orthodox church in Brașov (Figure 1), dominating the historic district of Șcheii Brașovului. One of the oldest Orthodox churches in the country and an important cultural center for the Romanians in Țara Bârsei, it is documented as being built on the site of a wooden cross dating to 1292.

Figure 1. The St. Nicholas Church in Brașov

The Leica BLK360 scanner, known for its compact design and high precision (LEICA BLK 360 G2, 2025), enables rapid acquisition of dense point cloud data, capturing intricate architectural details with millimeter-level accuracy.

Complementarily, the Leica GS07 GNSS receiver ensures reliable spatial referencing, allowing the alignment of the laser scanning dataset within a global coordinate system and facilitating further integration with geographic information system (GIS) platforms.

By combining these two technologies, the research aims to establish an efficient workflow for digital heritage preservation, emphasizing the advantages of multi-sensor data integration in terms of accuracy, speed, and reproducibility. The study not only demonstrates the technical feasibility of the proposed approach but also highlights its potential for broader applications in the digital documentation and management of cultural heritage (LOGOTHETIS ET AL., 2015). The results obtained from the St. Nicholas Church case study can serve as a methodological reference for future projects, contributing to the ongoing efforts of safeguarding Romania's architectural heritage through innovative geospatial technologies.

MATERIAL AND METHODS

For 3D data acquisition, we used the Leica BLK360 scanner together with the Leica Cyclone Field 360 application (Figure 2). The Leica BLK360 is an advanced precision imaging laser scanner.

Blaze through job sites with best-in-class rapid scanning that doesn't compromise on quality, while the Visual Inertial System (VIS) Technology automatically combines your scans on-site to speed up the workflow and help you make sure your datasets are complete.

Figure 2. Leica BLK360 laser scanner

http://doi.org/10.59463/RJAS.2025.4.02

Leica BLK360 comes with a rate of 680,000 points per second and can complete a full 360° scan with photos in as little as 20 seconds. Supports high-speed USB-C and Wi-Fi connectivity for quick and seamless data management (LEICA BLK 360 G2, 2025) .

Cyclone FIELD 360 facilitates direct 3D data acquisition on the field, seamlessly connecting to Leica BLK360 imaging laser scanner. Cyclone FIELD 360 enables users to automatically capture, register, and examine both scan and image data, directly in the field. With its intuitive user interface, remote scanner control and on-site point cloud display, navigation, with full imagery and point cloud data delivered directly to a tablet using edge computing technology.

For improved interpretation in Leica Cyclone REGISTER 360 PLUS post-processing, and to add extra value and information to 3D data, Cyclone FIELD 360 enables on-site tagging of measurements, videos, images, text or voice files to the point cloud geometry simply by using a tablet or smartphone (LEICA CYCLONE REGISTER 360 PLUS, 2025). With Cyclone FIELD 360, automatically pre-registered point cloud data enables users to quickly conduct on-site quality control checks, improves productivity and makes for better-informed decisions in the field.

In Cyclone Field 360, a Setup represents a stand-alone unit of reality capture data, which may be either structured (from static or terrestrial laser scans) or unstructured (from mobile or kinematic scans). Each Setup can serve as a foundational element in the registration process, functioning independently or combined with other Setups to form a Bundle (LEICA CYCLONE REGISTER 360 PLUS, 2025).

In our work, we used the in-field pre-registration method in the Cyclone Field 360 application to have greater control over the integrity and quality of the point cloud. In-field pre-registration avoids costly rework and significantly streamlines the work in the office.

After each scan, acquired data in the field is automatically registered with the previous scan data. The resulting combined point cloud is instantly accessible on a tablet. This allows the operator to immediately see what data has been captured and what data is missing, optimally plan the next scanner setup and, above all, perform a completeness check while still onsite. This capability is possible with VIS technology, which is achieved through an inertial measurement unit (IMU) and four VIS cameras built into the BLK360 laser scanner.

A total of 222 setups were captured using both medium and high resolution settings. For each setup, 360° panoramic images were also acquired, serving for point cloud colorization as well as for detailed inspection during office-based data analysis (Figure 3).

For data georeferencing, we used the strict method georeferencing that simply transforms a point cloud from its local coordinate system to the Earth centered, Earth-fixed (ECEF) coordinates (X; Y; Z). This does not require any information regarding the position of the scanner, but it does require at least three non-collinear ground control points (GCPs) (UGGLA AND HOREMUZ, 2020; ȘMULEAC ET AL., 2022).

For the georeferencing process, a set of 3 GCPs was established in the field to ensure the spatial accuracy and consistency of the laser scanning data. The coordinates of these control points were determined using the Leica GS07 GNSS RTK system, which operated with real-time corrections provided by ROMPOS, the Romanian National Permanent GNSS Reference Station Network.

All measurements were referenced in the Stereo 70 coordinate system (HERBEI ET AL., 2013), the official projection used for geodetic and cartographic works in Romania. To materialize the control points on site, black-and-white targets were strategically placed and clearly visible from multiple scanning positions. These targets served as reference markers during the registration and alignment of the individual point clouds, allowing the integration of all datasets into a common georeferenced coordinate system.

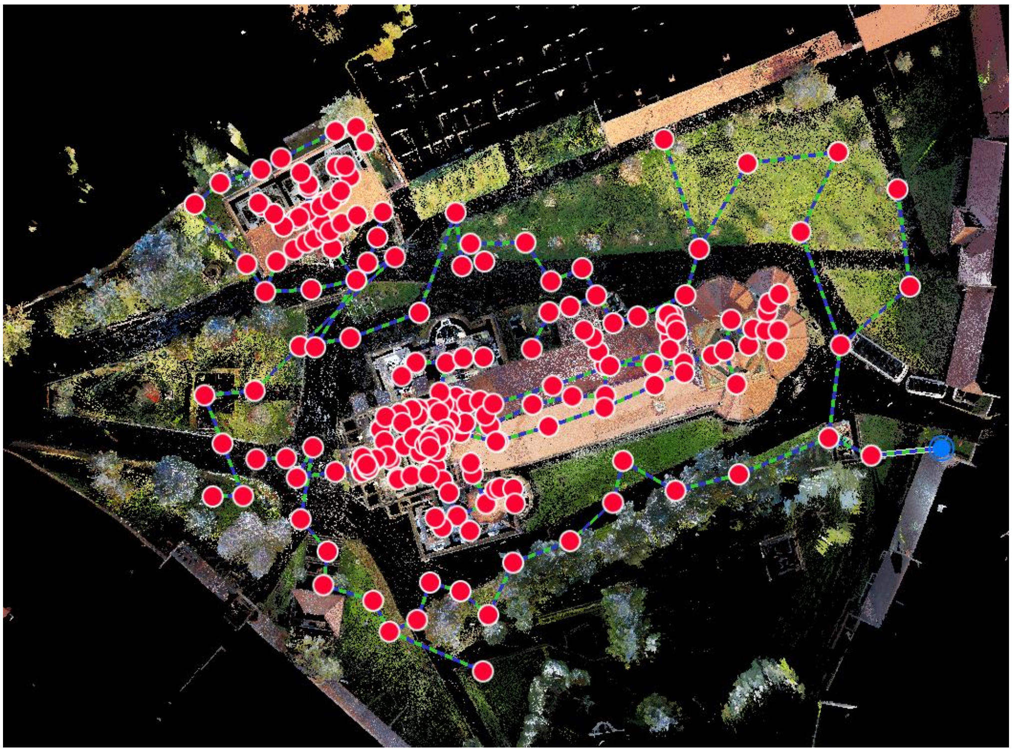

Figure 3. The Bundle Cloud from Cyclone Register 360 Plus

The import and processing of the data were carried out using the Leica Cyclone REGISTER 360 Plus software. Cyclone Register 360 Plus is a comprehensive point cloud registration an date preparation solution designed to import Leica Geosystems and third-party sensor data and prepare it for analysis and deliverable creation.

Powerful yet intuitive quality assurance (QA) tools make it easy to set project tolerances and identify scans or regions outside limits (LEICA CYCLONE REGISTER 360 PLUS, 2025).

After importing the data, the quality of the field registration was verified using the TruSlicer tool, which enables users to inspect horizontal slices in order to spot-check the registration accuracy. During the import stage, the list of ground control point coordinates was also imported into the project.

For the identification and creation of the targets, the “Show in Setup Cloud Viewer” option was used. After creating the three targets corresponding to the ground control points, the georeferencing process was carried out by assigning each target its corresponding set of coordinates (Figure 4).

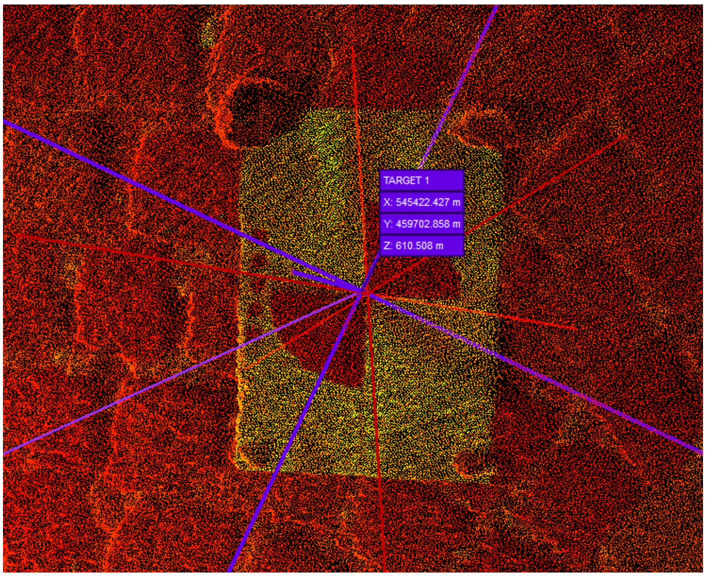

Figure 4. Control point aplied to the target

RESULTS AND DISCUSSIONS

The integration of the Leica BLK360 3D laser scanning system with the Leica GS07 GNSS RTK solution proved to be highly effective for the precise documentation and georeferencing of the St. Nicholas Church in Brașov. The resulting georeferenced point cloud provided a detailed and accurate representation of the monument, capturing both exterior (Figure 5) and interior (Figure 6) architectural elements with millimeter precision.


Figure 5. Exterior point cloud


Figure 6. Interior point cloud

The dataset consisted of 2.81 billion points, generated from multiple scan positions strategically distributed around and inside the monument to minimize occlusions and ensure full coverage (Figure 7).

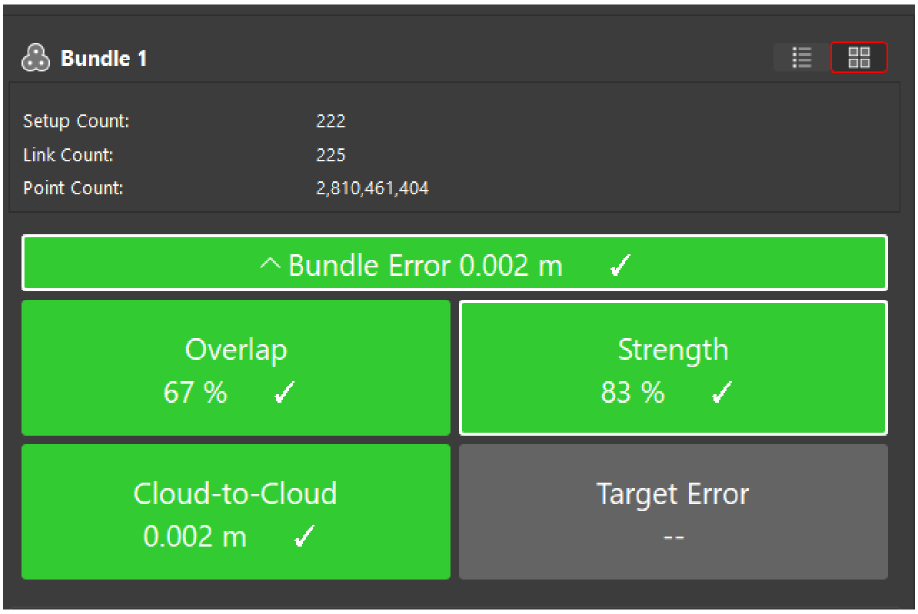

Figure 7. Bundle error information in Cyclone Register 360 Plus

Research Journal of Agricultural Science, 57 (4), 2025; ISSN: 2668-926X
http://doi.org/10.59463/RJAS.2025.4.02

The use of 225 scan links enabled consistent overlap between adjacent scans, improving the robustness of the registration process. The final bundle adjustment error of 0.002 m indicates a high level of precision, validating the efficiency of the field pre-registration (cloud-to-cloud) method used during data acquisition.

Additionally, the registration strength value of 83% confirms the overall quality and reliability of the registration process. The Strength calculation represents the relative stiffness of the Cloud-to-Cloud (C2C) registration with respect to the six degrees of freedom (X, Y, Z). As always, Strength, C2C, and target error values are used together with visual inspection to determine the quality of any registration (LEICA CYCLONE REGISTER 360 PLUS, 2025).

The Stereo 70 coordinate system, combined with GNSS measurements corrected through the ROMPOS network, ensured the integration of the dataset into Romania’s national geodetic framework.

This approach facilitates potential interoperability with other spatial datasets, such as cadastral or topographic information, enhancing the usability of the 3D model for conservation planning and urban documentation purposes.

Error vectors are displayed for target-to-target registrations (Figure 8), showing the slope distance and error vector between targets, offering detailed metrics on the slope and the combined average of C2C constraints (LEICA CYCLONE REGISTER 360 PLUS, 2025).

Control Constraints

	Label	Setup	Error	Error Vector NEZ	Weight
✓	TARGET 3	Sf. Nicolae- Setup 004	0.008 m	-0.007 0.002 0.000 m	1
✓	TARGET 2	Sf. Nicolae- Setup 003	0.006 m	0.003 -0.005 -0.000 m	1
✓	TARGET 1	Sf. Nicolae- Setup 002	0.005 m	0.004 0.003 0.000 m	1

Figure 8. Error vectors for targets constrains

From a qualitative perspective, the resulting point cloud exhibits exceptional completeness and geometric accuracy, allowing for precise extraction of architectural details, dimensional analysis, and the creation of accurate 3D models or orthophotos. The use of Leica Cyclone REGISTER 360 Plus and its QA tools contributed significantly to verifying data consistency and eliminating residual alignment errors, ensuring that the final dataset meets professional standards for heritage documentation.

Beyond the technical outcomes, this study demonstrates the broader potential of integrating TLS and GNSS technologies for cultural heritage preservation. The workflow developed here supports long-term monitoring, restoration planning, and virtual reconstruction of historical sites. Moreover, the generated 3D data can serve as a reliable digital archive, preserving valuable spatial information for future generations and supporting research in architecture, archaeology, and conservation science.

CONCLUSIONS

This study demonstrated the effectiveness of integrating Leica BLK360 3D laser scanning technology with the Leica GS07 GNSS RTK system for the accurate documentation

http://doi.org/10.59463/RJAS.2025.4.02

and georeferencing of cultural heritage sites. The workflow developed for the St. Nicholas Church in Brașov proved to be efficient, precise, and adaptable to complex architectural environments, enabling the generation of a detailed georeferenced 3D point cloud suitable for conservation and restoration purposes.

The results highlighted the advantages of combining terrestrial laser scanning (TLS) and GNSS positioning technologies, which together ensured high spatial accuracy, rapid data collection, and reliable registration strength. The use of ROMPOS real-time corrections within the Stereo 70 national coordinate system provided a robust geodetic framework, allowing seamless integration with other spatial datasets and national mapping systems. The achieved bundle adjustment error of 0.002 m and a registration strength of 83% confirm the overall quality and consistency of the dataset.

Beyond its technical achievements, this research contributes to the broader goal of digital heritage preservation, offering a methodological reference that can be replicated or adapted for other historical sites in Romania and beyond. The produced 3D model serves as a permanent digital archive, supporting architectural analysis, restoration planning, and public dissemination of cultural heritage through virtual platforms.

Future research will focus on expanding the workflow to include automated point cloud segmentation, BIM (Building Information Modeling) integration, and temporal monitoring of structural changes. These developments will further enhance the precision, efficiency, and long-term sustainability of digital documentation techniques applied to historical monuments.

ACKNOWLEDGEMENT: The authors thank the company Top Geocart SRL for providing access to the equipment and software necessary for the preparation of this paper.

BIBLIOGRAPHY

ABBAS, M.A., LUH, L.C., SETAN, H., MAJID, Z., CHONG, A.K., ASPURI, A., IDRIS, K.M., .ARIFF, M.F.M., 2014 - Terrestrial laser scanners pre-processing: Registration and georeferencing. Jurnal Teknologi (Sciences & Engineering), 71(4): 115-122.

ALBA, M., SCAIONI, M., 2007 - Comparison of techniques for terrestrial laser scanning data georeferencing applied to 3D modelling of cultural heritage. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXVI, 9pp.

BOTIN-SANABRIA, D.M., MIHAITA, A.-S., PEIMBERT-GARCIA, R.E., RAMÍREZ-MORENO, M.A., RAMÍREZ-MENDOZA, R.A., LOZOYA-SANTOS, J.J., 2022 - Digital twin technology challenges and applications: A comprehensive review. Remote Sensing, 14(6): 1335-1335.

DREIER, A., JANßEN, J., KUHLMANN, H., KLINGBEIL, L., 2021 - Quality analysis of direct georeferencing in aspects of absolute accuracy and precision for a UAV-based laser scanning system. Remote Sensing, 13(18):, 3564.

HERBEI M., HERBEI, R., DRAGOMR, L., SMULEAC, A., 2013 - The analysis of cartographic projections used in Romania. Research Journal of Agricultural Science, 45(2): 127-136.

INGENSAND, H., 2006 - Metrological Aspects in Laser-Scanning Technology. In: Proc. of 3rd IAG/12th FIG Symp., Baden", Austria, May 22-24, pp. 10, unpaginated CDROM.

LEICA BLK 360 G2, 2025 - User manual, online.

LEICA CYCLONE REGISTER 360 PLUS, 2025 - User manul, online at: https://rcdocs.leica-geosystems.com/cyclone-register-360/latest/help-cyclone-register-360

LLABANI, A., ABAZAJ, F., 2024 - 3D documentation of cultural heritage using terrestrial laser scanning. Journal of Applied Engineering Science, 22(2): 267-271.

LOGOTHETIS, S., DELINASIOU, A., STYLIANIDIS, E., 2015 - Building information modelling for cultural

http://doi.org/10.59463/RJAS.2025.4.02

heritage: a review. ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, II-5/W3: 177-183.

POMPEJANO, F., 2020 - From national to cultural monuments: An overview of architectural heritage protection in Albania (1912-1992). Journal of Architectural Conservation, 26(1): 55-70.

RASHEED, A., SAN O., KVAMSDAL, T., 2020 - Digital twin: Values, challenges and enablers from a modeling perspective. IEEE Access, 8: 21980-22012.

SIMON, M., NEO, O., ȘMULEAC, L., ȘMULEAC, A., 2023 - The use of LIDAR technology-mobile mapping in urban road infrastructure. Research Journal of Agricultural Science, 55(4): 229-239.

ȘMULEAC, A., ȘMULEAC, L., PAȘCALĂU, R., POPESCU, G., HORABLAGA, A., 2022 - Using ground control points (GCP) and UAV poind cloud processinf in Water Management. International Multidisciplinary Scientific GeoConference: SGEM 22, (3.2): 231-238.

TKÁČ, M., MESÁROŠ, P., 2016 - 3D laser scannig of the historic Greek Catholic Church - Case Study. Czech Journal of Civil Engineering, 2(1): 123-128.

UGGLA, G., HOREMUZ, M., 2020- Conceptualizing georeferencing for terrestrial laser scanning and improving point cloud metadata. Journal of Surveying Engineering, 147, diva2:1475516.