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Comprehensive 3D Documentation and Modeling of a Ruined Wooden Church in the Village of Vyazivka for Cultural Heritage Preservation

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SUMMARY

This article presents the results of a comprehensive 3D documentation and modeling of the ruined Church of the Nativity of the Blessed Virgin Mary in the village of Vyazivka, Zhytomyr Oblast—an architectural monument of national significance that was damaged as a result of Russian aggression in 2022. To spatially document the site, data from terrestrial laser scanning, terrestrial digital photogrammetry, and aerial surveying were integrated. The field data included 30 laser scanning stations and 776 photogrammetric images, of which 407 were obtained through terrestrial imaging and 369 via aerial surveying. Data processing was performed in Trimble RealWorks, RealityCapture, and Autodesk Revit. As a result, an integrated point cloud, a high-resolution textured mesh model, a digital elevation model, orthophoto plans of the facades, and a set of graphical documentation of the structure's current condition were generated. The accuracy of data registration using ground control points (GCPs) was within 5 mm. The results confirm the effectiveness of the combined use of laser scanning and photogrammetry for the metrically accurate digital documentation of ruined wooden architecture. The generated digital data can be used for technical analysis, restoration planning, physical rebuilding, and virtual reconstruction of the monument.

Keywords: Cultural heritage; Terrestrial laser scanning; Digital photogrammetry; Aerial surveying; Digital documentation.

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Introduction

The Church of the Nativity of the Blessed Virgin Mary in the village of Vyazivka, Zhytomyr Oblast, built in 1862, is an architectural monument of national significance. As a result of a direct hit during the Russian invasion in the spring of 2022, the church sustained critical damage. The surviving fragments of the wooden structures provide important information about the monument's original configuration and require prompt spatial documentation for further research, restoration, and possible reconstruction. The need for such documentation is also driven by the rapid degradation of the wood due to environmental factors, which could lead to the loss of authentic structural elements (Yilmaz et al., 2026). The preservation of damaged cultural heritage sites amid full-scale war is a critical task for modern engineering geodesy and heritage conservation efforts (Danyliv et al., 2026).

Traditional geodetic measurements, terrestrial laser scanning, and photogrammetric methods are used to survey and spatially document damaged historic structures. Terrestrial laser scanning provides highly accurate three-dimensional geometric information, while photogrammetry enables detailed documentation of the object's surface and texture. The integrated use of these technologies enables the creation of metrically accurate 3D models of damaged structures and structural elements (Danyliv et al., 2026). The application of 3D modeling for documenting and virtually reconstructing historical sites has been demonstrated in a study of fortification heritage (Savchyn & Repechovych, 2024), while geodetic methods have also been effectively used to record geometric changes and deformations in structures (Savchyn et al., 2025).

The aim of this study is to provide comprehensive 3D documentation and modeling of the ruined Church of the Nativity of the Blessed Virgin Mary in the village of Vyazivka, based on the integration of terrestrial laser scanning and photogrammetric survey data, in order to document the surviving structures and create a digital foundation for the monument's future preservation, restoration, and virtual reconstruction.

Method

To achieve this goal, a comprehensive approach combining terrestrial laser scanning, terrestrial digital photogrammetry, and aerial surveying was employed (Oprea et al., 2026; Danesh & Rajabi, 2022). The combination of these methods provides complementary spatial information about the object: terrestrial laser scanning generates highly detailed three-dimensional geometric data (Borkowski & Kubrat, 2024), while digital photogrammetry and aerial surveying provide visual and textural information and enable the documentation of areas inaccessible to laser scanning (Petry & Becker, 2022; Luhmann et al., 2023; Heidarimozaffar & Hosseini, 2026).

Terrestrial laser scanning was performed using a Trimble TX6. The scans covered the preserved facades, wooden structures, and accessible areas of the interior of the ruined church. Aerial surveying was performed using a DJI Air 2S UAV, with the primary goal of capturing the upper parts of the structure, the roof, and the surrounding area for the subsequent creation of orthophoto plans. Terrestrial photogrammetric surveying was conducted using a Canon 60D camera to capture detailed images of the surfaces and structural elements of the building.

To ensure a unified geodetic coordinate system and the spatial alignment of results obtained from different survey methods, ground control points (GCPs) were established at the site. The coordinates of the control points were determined using a Stonex S700A GNSS receiver operating in RTK mode. The obtained coordinates were used for geodetic referencing and for integrating the laser scanning, terrestrial photogrammetry, and aerial survey data into a single spatial model.

Data

During the documentation of the ruined church, a set of spatial data was collected using terrestrial laser scanning, terrestrial digital photogrammetry, and aerial surveying. Terrestrial laser scanning was performed from 30 stations using a Trimble TX6. Data were obtained on the geometry of the preserved facades, wooden structures, interior space, and debris. Terrestrial digital photogrammetry yielded 407 images taken from various angles. The spatial resolution of the images was 1–2 mm/pixel. The forward overlap of the images was at least 80%, and the side overlap was 70%. Aerial surveying using a DJI Air 2S UAV yielded 369 images with a spatial resolution of 3–5 cm/pixel. The imagery covered the roof, the upper parts of the structure, and the surrounding area. The collected dataset was subsequently used to construct the 3D models.

Results

The field data were processed using Trimble RealWorks, RealityCapture, and Autodesk Revit. Each software program was used for a specific stage in the creation of the digital model: laser scan data processing, photogrammetric reconstruction, and subsequent 3D modeling of structural elements.

In Trimble RealWorks, terrestrial laser scan data were processed, individual scans were registered, and a unified point cloud of the object was generated. The resulting point cloud represents the geometry of the preserved parts of the church, the interior space, and fragments of destroyed structures.

Terrestrial and aerial photographs were processed in RealityCapture. Based on these data, a photogrammetric model and point cloud were generated, followed by alignment with the laser scanning data using GCPs. The accuracy of the mutual alignment of the obtained datasets was within 5 mm. Additionally, a high-resolution mesh model Figure 1 was generated from the photogrammetric data and textured Figure 2. The resulting photorealistic model provides a detailed visual representation of the preserved wooden structures, collapsed beams, and remnants of the dome. Orthophoto plans were also created for individual facades, providing metrically accurate representations of their surfaces.

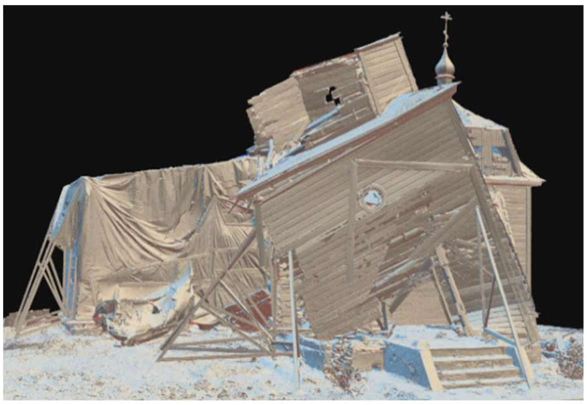

Figure 1. *Mesh model*

Figure 2. *Textured 3D model*

Based on the integrated point cloud and photogrammetric data, a 3D model of the ruined church was created in Autodesk Revit, and a set of graphical materials was prepared to document its current condition. A site plan was generated at a scale of 1:200, showing the recorded locations of fallen and displaced structural fragments Figure 3. A building plan was created at a scale of 1:50, indicating the fallen debris, the four facades (north, east, south, and west), and two cross-sections—a longitudinal section and a transverse section through the transept. In addition, orthophoto plans of the four facades were created based on the integrated laser scanning and photogrammetric data Figure 4.

To assess the completeness of the spatial coverage, a data coverage map was generated, highlighting areas of full and partial coverage, sections covered by tarpaulins or not captured, as well as interior areas inaccessible for surveying. This set of materials provides metrically accurate documentation of the monument's current condition and can serve as a geometric baseline for future restoration and reconstruction.

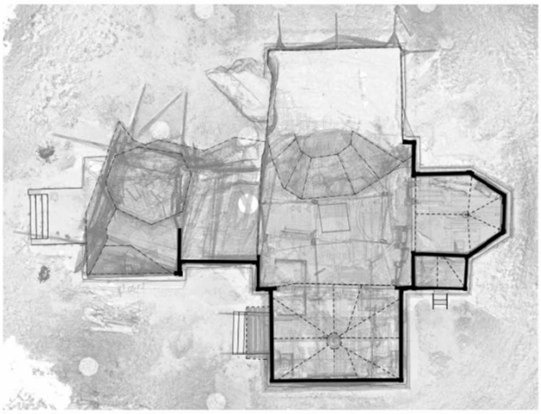

Figure 3. *General site plan at a 1:200 scale*

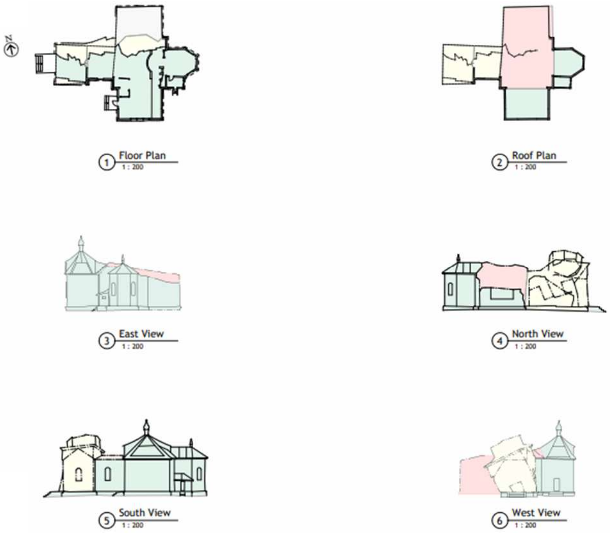

Figure 4. *Facade plans*

Discussion

The results confirm the effectiveness of the integrated use of terrestrial laser scanning and digital photogrammetry for documenting a ruined wooden structure. Compared with traditional surveying methods, particularly total station surveying, this integrated approach provides a significantly denser spatial representation of the object while simultaneously capturing its geometric and visual characteristics. This is particularly important for ruined structures, where a significant portion of the remains has complex and irregular geometry.

The main difficulties encountered during the creation of the 3D model were related to the specific characteristics of the site, including the chaotic arrangement of wooden debris, overlapping elements, shadows, and the presence of vegetation. Such conditions can cause local noise and artifacts during mesh generation (Iakovaki et al., 2026). The use of images with high overlap and the integration of photogrammetric data with laser scanning made it possible to minimize these limitations and ensure more complete reconstruction of the structure's complex geometry.

Unlike the surveying of conventional buildings and infrastructure, documenting ruined wooden architecture requires a higher level of spatial detail. High-resolution data are essential for capturing individual elements of the timber log structure, joints, and signs of damage that may be relevant to future restoration (Olukoya et al., 2025). The resulting digital model and set of orthophoto plans can be considered a metrically accurate basis for further analysis, restoration planning, and virtual reconstruction of the monument.

Conclusions

As a result of this study, comprehensive 3D documentation and modeling of the ruined wooden Church of the Nativity of the Blessed Virgin Mary in the village of Vyazivka were carried out based on the integration of data from terrestrial laser scanning, terrestrial photogrammetry, and aerial surveying. A 3D model, a photorealistic mesh model, a digital elevation model, orthophoto plans of the facades, and a set of as-built drawings depicting the structure's current condition were created. The resulting materials provide metrically accurate digital documentation of the monument and can be used for further technical analysis, restoration planning, rehabilitation, and virtual reconstruction. The proposed approach has demonstrated its practical effectiveness and can be applied to the documentation of other damaged wooden cultural heritage sites.

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