



TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. XX, Issue xx, Month, 20xx

EVALUATING THE VIABILITY OF PHOTOGRAMMETRY AS AN ALTERNATIVE TO STRUCTURED LIGHT SCANNING IN WOODWORKING SCULPTURE DIGITIZATION

Radu COMES, Zsolt Levente BUNA, Stefan BODI, Grigore Marian POP

Abstract: The study explores the strengths and limitations of photogrammetry and structured light scanning methods in generating detailed 3D representations of handcrafted and machined wooden components. A high-quality woodworking part with intricate surfaces and fine detailing served as the test object, scanned using a Creaform Go!SCAN 50 with VXelements software, and, separately, digitized through a photogrammetric workflow. Both resulting 3D models were aligned and compared against each other, with the structured light scan serving as the reference due to its higher expected precision. The comparison evaluated dimensional accuracy, surface detail retention, and geometric fidelity. The study examines the advantages and drawbacks of each method with respect to precision, usability, processing time, and their applicability within woodworking design, reproduction, and quality assurance workflows. The research aim is to evaluate whether photogrammetry can serve as a cost-effective substitute for structured light scanning in woodworking contexts, particularly in applications involving custom furniture making, intricate joinery, and the restoration of heritage artifacts.

Key words: Structured light scanning, photogrammetry, 3d scanning, reverse engineering, dimensional accuracy

1. INTRODUCTION

In recent years, woodworking has seen a shift with the rise of digital tools like 3D scanning which allow for the accurate capture of wooden parts and support everything from custom design and fabrication to quality checks and the preservation of heritage pieces. Among the most widely used non-contact scanning methods are photogrammetry and structured light scanning, each offering its own set of strengths and trade-offs when it comes to accuracy, ease of use, and cost[1].

Structured light scanners are prized for their precision and capability to capture detailed surface features, making them popular in industrial settings. However, they tend to be costly and often require specialized skills to operate, which can limit their accessibility. In contrast, photogrammetry relies on everyday photography, including smartphone cameras and user-friendly software, providing a more flexible and affordable option that's particularly

attractive to smaller workshops and restoration specialists.

This study aims to critically evaluate the effectiveness of photogrammetry compared to structured light scanning in the context of woodworking. A high-quality wooden component featuring both handcrafted and machined features was selected as a test object to ensure a diverse range of surface geometries. The object was scanned using both methods, with the structured light model serving as a reference standard due to its higher expected accuracy. Through comparative analysis of dimensional fidelity, surface detail retention, and geometric consistency, the study investigates the practical trade-offs between these two technologies.

The findings contribute to a clearer understanding of how each scanning method performs in real-world scenarios, offering guidance regarding 3D digitization strategies for design, reproduction, and quality assurance.

2. RELATED WORKS

The application of 3D scanning technologies in manufacturing and quality assurance has been extensively studied, particularly concerning their accuracy and suitability for inspecting metal components. A related study demonstrated the use of 3D optical scanning systems for inspecting sheet-metal parts in automotive manufacturing, achieving measurement times as short as 20 minutes and detecting deviations within tolerances as tight as 0.1 mm [2].

Modern structured light scanners, like those produced by Artec and Creaform, are engineered to provide high-resolution 3D scans quickly and with exceptional detail. For instance, the Artec Spider can capture up to 1 million 3D points per second, achieving a resolution of up to 0.1 mm and an accuracy as fine as 0.05 mm.

State of the art scanner Artec Spider II can acquire up to 8 million points per second [3]. These are the technical specifications provided by the manufacturer, but practical factors usually limit the actual data acquisition values.

Both systems acquire data quickly but require substantial postprocessing time, due to tasks like full-resolution mesh generation, alignment, and noise reduction, which vary based on scan complexity and hardware performance.

Thus, while these scanners offer substantial benefits in terms of accuracy and throughput, the high volume of data collected necessitates a trade-off in terms of processing time, which can be a bottleneck in fast-paced production environments.

Similarly, research on the metrological processing of structured light scanners highlighted the importance of accurate calibration and processing algorithms to ensure measurement features and control features are reliably extracted, facilitating precise dimensional analysis [4].

Photogrammetry is typically more affordable and accessible, in some cases even free using open-source solutions. However, it faces difficulties matching the precision of structured light scanning. The overall accuracy of photogrammetry can be affected by a wide variety of variables such as surface texture and lighting conditions. In cases where high precision is critical, such as machined metal

parts, photogrammetry might require extra surface treatment or may fall short of meeting strict tolerance standards.

A wooden decorative sculpted component was chosen because its matte textured surface suits photogrammetry by reducing reflectivity, enabling a clearer comparison of the output mesh with structured light scanning output mesh. Additionally, wood is easier to work with in assembly, making it practical for furniture design and fabrication. In contrast, metal parts often require coating with a spray to reduce reflectivity for effective scanning or photogrammetry.

Comparative studies of these two techniques have emphasized their distinct advantages and drawbacks. In research focused on digitizing physical prototypes, structured light scanning demonstrated higher detail resolution, while photogrammetry proved to be more flexible and cost-effective to operate [5].

In the context of cultural heritage preservation, photogrammetry has been successfully applied to document historical measurement instruments made from various materials, capturing intricate details while maintaining geometric accuracy [6].

In the woodworking industry, a study focusing on the digitization of wood products found that structured light scanning methods yielded highly detailed 3D models, while photogrammetry required more processing time but still produced satisfactory results [7].

Related studies in forestry have used photogrammetric techniques to assess tree health, demonstrating the method's ability to capture complex natural structures [8]. Although structured light scanning is known for its high dimensional accuracy and precision, not all scanners can capture color information in textures.

Photogrammetry naturally captures detailed color data, benefiting applications needing realistic textures like digital archiving and heritage preservation. While some structured light scanners, such as the Artec Space Spider and Creaform Go!SCAN 50, also capture color, this feature is not universal. Although texture accuracy was not important for this case study, photogrammetry still holds an advantage in visual fidelity.

3. 3D MODEL DATA ACQUISITION

The case study part used for this research is a sculpted wooden component measuring approximately $487 \times 158 \times 35$ mm. This is part of an armchair with intricate surfaces and fine detailing as it is illustrated within Figure 1.



Fig. 1. Case study wooden part

To accurately capture the geometry of the wooden part, two complementary 3D scanning techniques were employed: structured light scanning using the Creaform Go!SCAN 50 [9] and photogrammetry using Reality Capture mobile app [10]. The aim was to evaluate not only the capabilities of the professional structured light scanner but also to assess whether photogrammetry performed using a simple smartphone and a free-to-use Reality Capture app can serve as a viable alternative for producing detailed and dimensionally accurate 3D models suitable for CNC machining and mass production. The following subsections describe the scanning procedures and data processing workflows applied for each technique.

3.1 Structured light scanning

The wooden component was positioned on a turntable which has multiple positioning targets applied to ensure accurate tracking by the VXelements software and the Go!SCAN 50 scanner. The part was first scanned in the top position, with the component lying flat on the turntable. After completing the initial scan, the piece was flipped to scan the opposite side. Following data acquisition, the two separate scans were aligned and merged within

VXelements to create a complete and accurate 3D model of the wooden part.



Fig. 2. 3D scanning using Go!SCAN 50 structured light scanning

In this case study, the 3D scan was conducted at a resolution of 0.5 mm. As shown in Figure 3, wooden components scanned with structured light often display noise in the geometric data due to surface texture and natural grain variations; these cause irregularities such as scattered points and minor artifacts that do not accurately reflect the true shape of the object. Consequently, the scan data requires thorough post-processing including noise filtering, surface smoothing, and mesh refinement to eliminate unwanted data while preserving essential surface details. This process is crucial to producing a precise and clean 3D model suitable for applications such as CNC machining and digital fabrication.

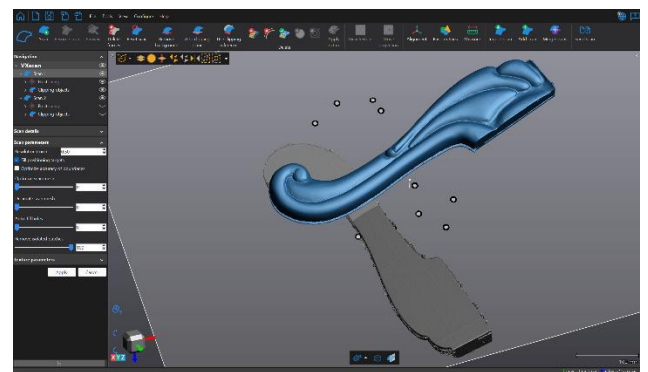


Fig. 3. The two sides as individual scans within VXelements

The 3D model was post-processed to remove noise and refine the geometry for improved accuracy. The result is illustrated in Figure 4, displayed in Blender. Both the solid mesh and the corresponding wireframe model are presented to highlight the surface quality and geometric structure achieved after processing.

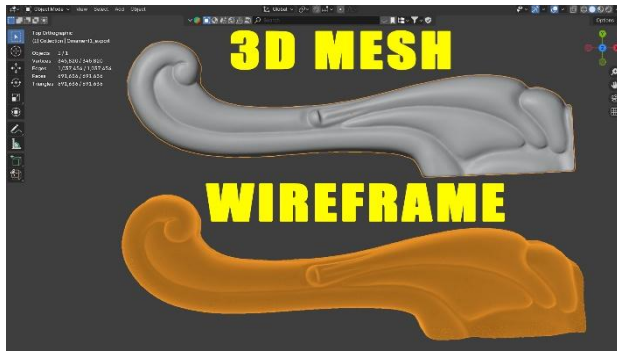


Fig. 4. Case study Mesh – 3D Mesh and Wireframe

3.2 Photogrammetry

To investigate the viability of photogrammetry as a cost-effective alternative to structured light scanning for digitizing woodworking components, a Samsung Galaxy S22 Ultra mobile phone was used in combination with RealityCapture software. The study aimed to evaluate how varying image capture modes influence the quality and completeness of the resulting 3D mesh.

The target wooden component was placed on a neutral, non-reflective background in evenly diffused natural lighting. Two sets of images were captured:

- **Model A:** Captured in Augmented Reality (AR) mode, which provided guided positioning but limited manual control. This method prioritized ease-of-use and speed but introduced constraints on focus and exposure consistency.
- **Model B:** Captured in Camera Control mode, allowing full manual adjustment of focus, exposure, white balance, and ISO. This enabled deliberate optimization of image clarity and consistency across all viewing angles.

Both models were photographed using an orbital capture strategy, rotating around the object horizontally and vertically with approximately 70% overlap between adjacent photos. Model A displayed small gaps and surface inconsistencies, especially in less textured zones, due to limited input data and automatic camera settings. In contrast, Model B resulted in a complete mesh with higher detail and no empty areas, confirming the advantage of controlled image capture and denser coverage in photogrammetry workflows for wooden parts.

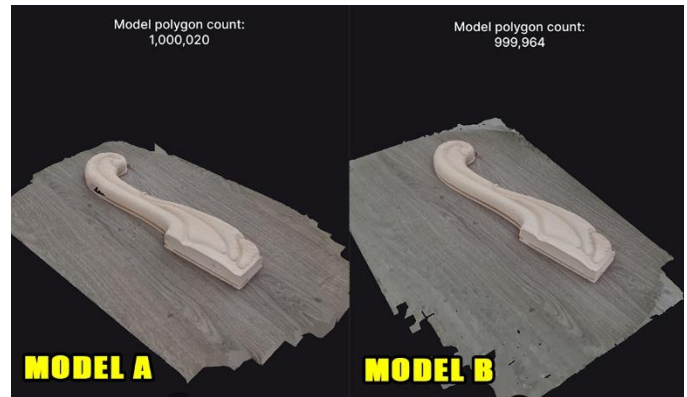


Fig. 5. Reality Capture mobile application 3D models outputs

Although the free version of RealityCapture restricts exported models to a maximum of 1 million triangles, it permits the use of up to 250 input images per project. This capability enables the creation of highly detailed and comprehensive 3D meshes, as the larger number of high-quality images greatly improves the accuracy of the reconstruction. As observed in the second photogrammetric model (Model B) generated using 101 images in Camera Control mode, the resulting mesh exhibited superior geometric fidelity, and the output mesh didn't have any gaps and had surface continuity.

Both resulting models were further processed to remove any background geometry. As is typical with photogrammetry-based models, they were not generated at true scale. To correct this, the models were uniformly scaled in Blender, ensuring that their proportions accurately captured during the photogrammetry process were preserved without distortion. In this case, the 3D scanned model obtained via structured light scanning was used as a reference for scaling.

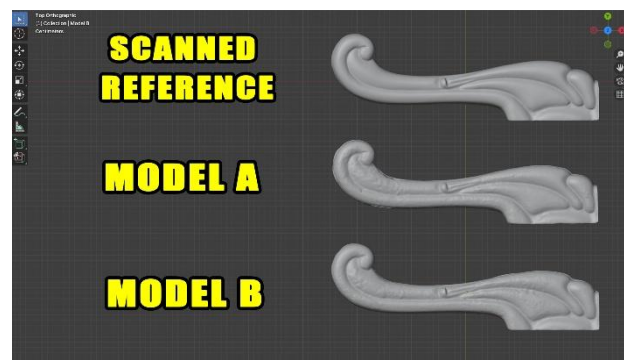


Fig. 6. The 3D models scaled to match the scanned reference

However, this adjustment can also be performed using simple physical measurements by measuring a known dimension of the object with a standard ruler in real life and matching it in Blender using the scale tool.

4. DEVIATION ANALYSIS

Two deviation analysis were performed to assess the geometric accuracy of the photogrammetry-derived models in comparison to the structured light scan reference. This analysis was conducted using Dassault Systèmes' CATIA V5 within the Digitized Shape Editor workbench.

The 3D models were spatially aligned using best-fit registration based on their geometry to ensure proper overlay. Following registration, deviation analyses were performed separately: first between Model A and the structured light scan reference, and second between Model B and the reference model. The analysis provided color maps visualizing areas of deviation and numerical data highlighting the degree of mismatch across the surfaces. This comparative approach allowed for an objective evaluation of the dimensional fidelity of the photogrammetry models, revealing the impact of capture settings and image count on reconstruction accuracy.

Figure 7 illustrates the first deviation analysis, comparing Model A to the 3D scan reference. The maximum negative deviation of -13.533 mm occurs in an area that was originally not well defined in the photogrammetry model, located within the cutout slot in the wood. This region is not critical, as the cutout will be performed in a separate operation after the overall shape of the ornament is machined.

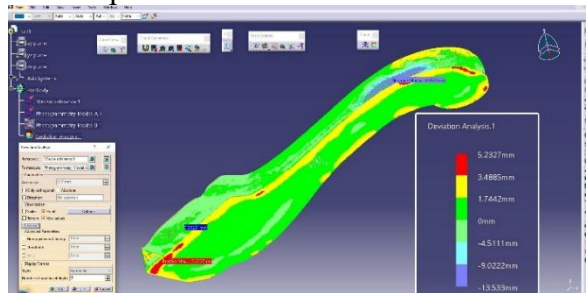


Fig. 7. Deviation analysis between scanned reference and Model A

The second deviation analysis, shown in Figure 8, compares Model B to the 3D structured

light scan reference. The maximum negative deviation is -7.4749 mm, while the maximum positive deviation is 6.1459 mm. Both deviations are located on the same side of the wooden ornament, near the top of the part.

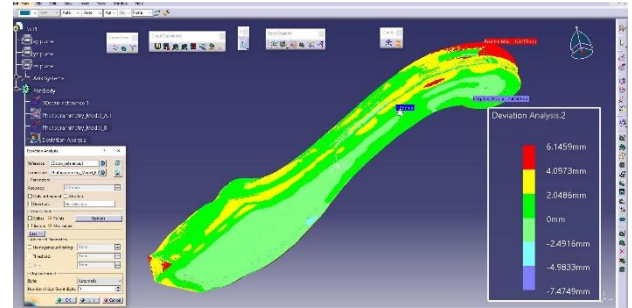


Fig. 8. Deviation analysis between scanned reference and Model B

5. CONCLUSIONS

As demonstrated in this case study, photogrammetry can effectively be used to obtain 3D scanned models of wooden sculpted ornaments. The overall deviations of the photogrammetry models compared to the structured light scan reference mostly fall within the range of -3 mm to +3 mm from the nominal values of the 3D scanned ornament. Notably, even the model generated with only 51 images showed acceptable accuracy, while the model created with 101 images exhibited slightly improved detail and reduced uncertainty, as confirmed by the deviation analysis.

Both photogrammetry-generated models required additional surface smoothing to reduce noise and irregularities, whereas the model obtained via structured light scanning was acquired with a much more smoother surface. Although smoothing can be easily performed in Blender, this process may further alter the deviations of the final surface.

Woodworking allows some tolerance due to the natural variability of the material, the finishing process (sanding, carving, fitting), and the final assembly where small gaps or minor adjustments are manageable. However, the acceptability of ± 3 mm depends on the specific application and function of the part. In this case, the decorative armchair element falls within acceptable limits, as it can be further adjusted during the assembly or finishing process.

However, additional investigation is required to assess the reproducibility and consistency of photogrammetry in capturing similar parts. While photogrammetry provides a flexible and cost-effective method for 3D digitization, structured light scanners remain more robust in terms of precision and repeatability, offering greater confidence in dimensional accuracy across multiple scans.

6. REFERENCES

- [1] P. Triviño-Tarradas, D. F. García-Molina, and J. I. Rojas-Sola, "Impact of 3D Digitising Technologies and Their Implementation," *Technologies* 2024, Vol. 12, Page 260, vol. 12, no. 12, p. 260, Dec. 2024, doi: 10.3390/TECHNOLOGIES12120260.
- [2] A. Kuş, "Implementation of 3D Optical Scanning Technology for Automotive Applications," *Sensors* 2009, Vol. 9, Pages 1967-1979, vol. 9, no. 3, pp. 1967-1979, Mar. 2009, doi: 10.3390/S90301967.
- [3] "Artec Handheld 3D scanners | Portable 3D scanning solutions." Accessed: May 25, 2025. [Online]. Available: <https://www.artec3d.com/portable-3d-scanners>
- [4] J. Sitnicka et al., "Assessing the optical configuration of a structured light scanner in metrological use," *Meas Sci Technol*, vol. 33, no. 8, p. 085018, May 2022, doi: 10.1088/1361-6501/AC6E2F.
- [5] O. Freeman Gebler et al., "A comparison of structured light scanning and photogrammetry for the digitisation of physical prototypes," *Proceedings of the Design Society*, vol. 1, pp. 11-20, 2021, doi: 10.1017/PDS.2021.2.
- [6] M. E. Atik, Z. Duran, M. Yanalak, D. Z. Seker, and A. Ak, "3D modeling of historical measurement instruments using photogrammetric and laser scanning techniques," *Digital Applications in Archaeology and Cultural Heritage*, vol. 30, p. e00286, Sep. 2023, doi: 10.1016/J.DAACH.2023.E00286.
- [7] L. Odrščil, P. Valent, V. Kaputa, and M. Fabrika, "Digitization and Virtualization of Wood Products for Its Commercial Use," *Forests* 2024, Vol. 15, Page 2263, vol. 15, no. 12, p. 2263, Dec. 2024, doi: 10.3390/F15122263.
- [8] J. Iglhaut, C. Cabo, S. Puliti, L. Piermattei, J. O'Connor, and J. Rosette, "Structure from Motion Photogrammetry in Forestry: a Review," *Current Forestry Reports*, vol. 5, no. 3, pp. 155-168, Sep. 2019, doi: 10.1007/S40725-019-00094-3/FIGURES/4.
- [9] "3D Scanners, CMM Scanners & Metrology Measurement Solutions | Creaform." Accessed: May 25, 2025. [Online]. Available: <https://www.creaform3d.com/>
- [10] "RealityCapture - 3D Models from Photos and/or Laser Scans." Accessed: May 25, 2025. [Online]. Available: <https://www.capturingreality.com/>

EVALUAREA VIABILITĂȚII FOTOGRAMETRIEI CA ALTERNATIVĂ LA SCANAREA CU LUMINĂ STRUCTURATĂ ÎN DIGITIZAREA SCULPTURILOR DIN LEMN

Radu COMES, Ph.D., Eng., Associate Professor at the Department of Design Engineering and Robotics, Technical University of Cluj-Napoca, radu.comes@muri.utcluj.ro, 103-105 Muncii Blvd., 400641 Cluj-Napoca, Cluj County, Romania

Zsolt Levente BUNA, Ph.D., Eng., Lecturer at the Department of Design Engineering and Robotics, Technical University of Cluj-Napoca, zsolt.buna@muri.utcluj.ro, 103-105 Muncii Blvd., 400641 Cluj-Napoca, Cluj County, Romania

Ștefan BODI, Ph.D., Eng., Associate Professor at the Department of Design Engineering and Robotics, Technical University of Cluj-Napoca, stefan.bodi@muri.utcluj.ro, 103-105 Muncii Blvd., 400641 Cluj-Napoca, Cluj County, Romania

Grigore Marian POP, Ph.D., Eng., Associate Professor at the Department of Design Engineering and Robotics, Technical University of Cluj-Napoca, grigore.pop@muri.utcluj.ro, 103-105 Muncii Blvd., 400641 Cluj-Napoca, Cluj County, Romania