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Comprehensive Comparative Analysis of Photogrammetric Point Cloud Generation Using Diverse Data Collection Methods

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***Abstract*— This study presents a detailed comparison of three data collection tools — the Ricoh Theta Z1 360° camera, Leica ScanStation C10 laser scanner, and Matterport PRO 3 mobile scanner—for generating photogrammetric point clouds. Conducted in the challenging environment of the Geoinformatics Institute's ground-floor corridor and three additional rooms at Óbuda University, the research evaluates accuracy, compactness, ease of use, survey speed, and processing efficiency. Data processing utilized Agisoft Metashape [1], Autodesk Recap Pro [7], and CloudCompare [5], with measurements validated against a Leica Disto rangefinder. Results show the Leica C10 offers superior accuracy but is hindered by slow survey times and bulkiness, the Matterport PRO 3 balances speed and precision with VR capabilities, and the Ricoh Theta Z1 excels in rapid surveys but lacks precision. These findings guide tool selection for geospatial applications, highlighting trade-offs in accuracy, portability, and efficiency.**

Keywords — Photogrammetry, Point Cloud, Ricoh Theta Z1, Leica ScanStation C10, Matterport PRO 3, Geospatial Analysis

I. Introduction

The generation of high-fidelity 3D point clouds is critical for geospatial analysis, enabling precise visualization, measurement, and modeling in applications such as building information modeling (BIM), heritage documentation, and virtual reality (VR). This study evaluates three distinct data collection tools: the Ricoh Theta Z1 360° camera [2], Leica ScanStation C10 laser scanner [3], and Matterport PRO 3 mobile scanner [4]. The test area, located at the Geoinformatics Institute, Óbuda University, includes a uniform ground-floor corridor and three additional rooms (office, classroom, and community room), selected to assess performance in both feature-scarce and complex environments. The research compares the tools based on accuracy, compactness, ease of use, survey speed, and processing efficiency, using Agisoft Metashape [1], Autodesk Recap Pro [7], and CloudCompare [5] for data processing. Measurements were validated against a Leica Disto rangefinder [6]. Motivated by a practical inquiry into 3D modeling for industrial applications, this study provides actionable insights for selecting appropriate tools for geospatial workflows.

II. Survey Area Description

The test area comprised the ground-floor corridor of the Geoinformatics Institute, characterized by uniform checkered flooring and plain ceilings, which posed challenges for automatic point cloud alignment due to limited distinct features. Three additional rooms, an office, a classroom, and a community room—were included in the Leica C10 and Matterport PRO 3 surveys to introduce complex geometries, such as doorways and varied furniture. The Ricoh Theta Z1 survey was limited to the corridor, focusing on its panoramic imaging capabilities. The corridor's homogeneity and the rooms' transitional elements provided a robust testbed for evaluating tool performance.

1. Figure - Test area

III. Tools and Equipment

A. *Ricoh Theta Z1 360° Camera*

- **Specifications**:
  - Weight: ~200 g
  - Image Resolution: 6720 x 3360 pixels
  - Video Resolution: 2K and 4K
  - Features: Compact design with dual fisheye lenses for 360° panoramic imaging, shutter speed from 1/25000 to 1/30 seconds, supported by a dedicated tripod.

- **Survey Process**: Captured 23 panoramic images along the corridor, ensuring adequate overlap without calibration markers. The camera's portability and simple interface enabled rapid data collection in minutes, ideal for quick surveys in accessible areas. [2]
- The Ricoh Theta Z1 is illustrated in the 2nd figure.

2. Figure - RICOH THETA Z1 360° camera [2]

B. Leica ScanStation C10 Laser Scanner

- **Specifications**:
  - Weight: ~16 kg
  - Range: 0.1–300 m
  - Measurement Speed: 50,000 points/s
  - Accuracy: Position (6 mm), Distance (4 mm), Angular (60 µrad)
  - Features: High-precision terrestrial laser scanner with integrated color camera, operating in 0°C to 40°C.
- **Survey Process**: Conducted over two days with 12 stations, using 3- and 6-inch HDS targets for alignment. Captured 260 photographs to record surface material properties (e.g., color, texture), increasing data richness but requiring significant survey time. [3]
- The Leica ScanStation C10 is shown in the 3rd figure.

3. Figure - Leica ScanStation C10 laser scanner

C. Matterport PRO 3 Mobile Scanner

- **Specifications**:
  - Weight: 2.2 kg
  - Depth Technology: LiDAR (Class 1, 904 nm)
  - Field of View: 360° horizontal, 295° vertical
  - Accuracy: ±20 mm at 10 m
  - Depth Resolution: 100,000 points/s, up to 1.5 million points per scan
- **Survey Process**: Utilized 38 stations, controlled via the Matterport Capture app on a Samsung tablet. Required significant overlap for automatic registration, completing the survey in minutes due to fast scan times (<20 seconds per station). [4]
- Matterport PRO 3 is depicted in the 4th figure.

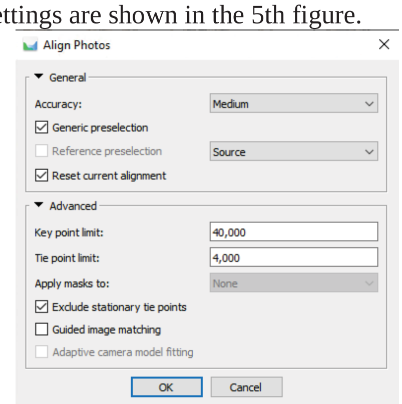
4. Figure - Matterport PRO 3 mobile scanners [4]

IV. DATA PROCESSING

A. Ricoh Theta Z1 Processing

The 23 panoramic images were exported as JPEG files and processed in Agisoft Metashape: [1]

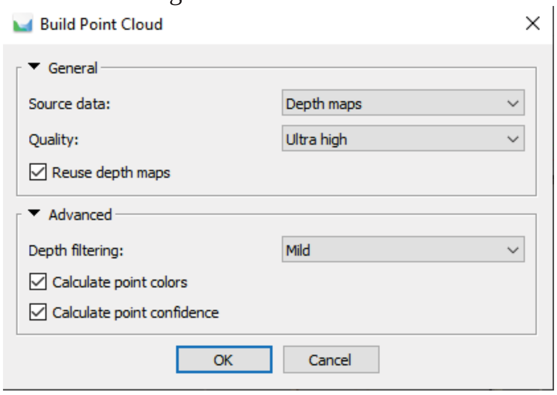
1. **Image Import and Alignment**: Imported via “Add Photos” and aligned using “Align Photos” with medium accuracy, 40,000 key points, and 4,000 tie points. No external coordinates were used, leading to potential scale inaccuracies. The alignment settings are shown in the 5th figure.



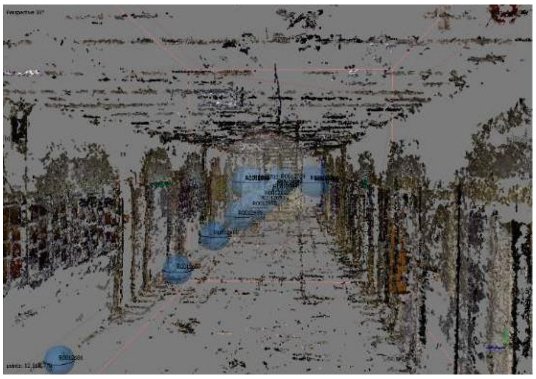
5. Figure - Align Photos settings

2. **Point Cloud Generation**: Built from depth maps with ultrahigh quality and mild depth filtering. Point colors and confidence values were calculated to enhance visualization. The resulting point cloud is

illustrated in the 7th figure, and the parameters you can see at 6th figure.

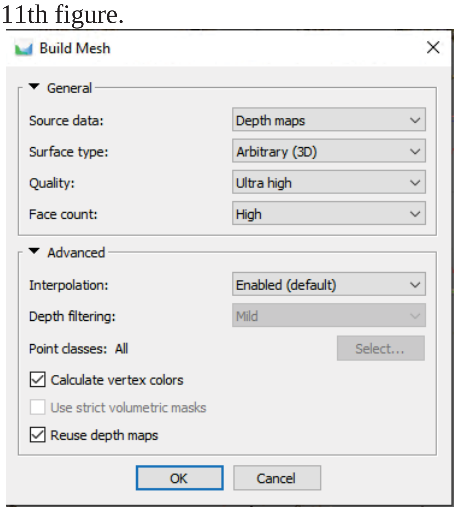


6. Figure - Point Cloud settings



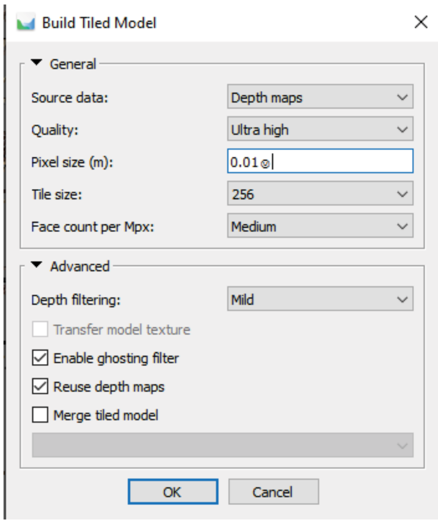
7. Figure - Point Cloud of 360° camera

3. **Mesh and Tiled Model Creation**: Generated a mesh model, followed by a tiled model for smoother visualization, suitable for large-scale 3D modeling. The mesh model settings are shown in the 8th figure, and the resulting mesh model is depicted in the 9th figure. The tiled model settings are illustrated in the 10th figure, with the final tiled model shown in the 11th figure.



8. Figure - Mesh model settings

9. Figure - Mesh model



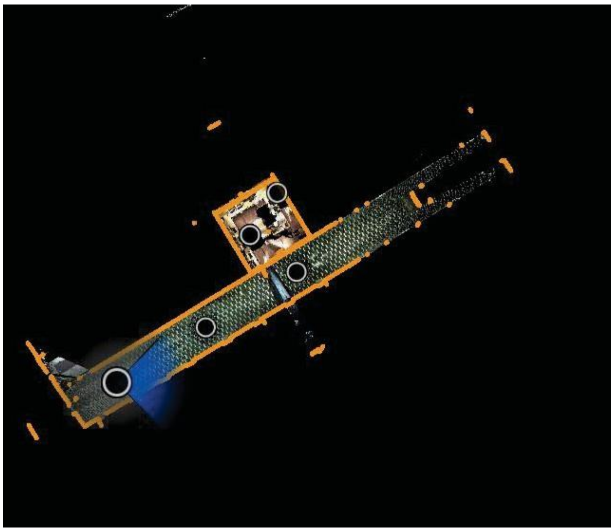
10. Figure - Tiled Model settings

11. Figure - Tiled model

B. *Leica ScanStation C10 Processing*

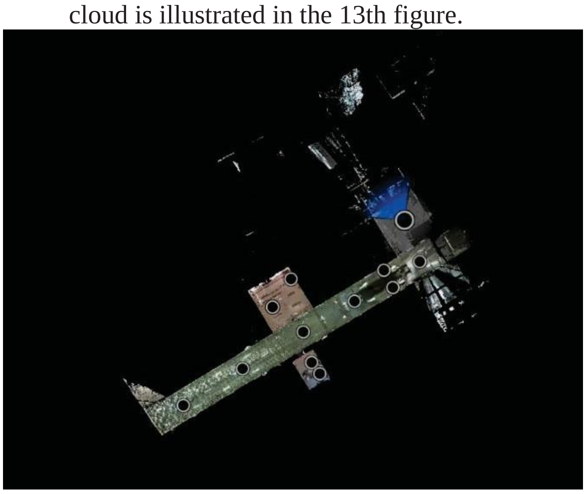
Data was processed using Autodesk Recap Pro (educational version): [7]

1. **Data Import**: Imported E57 files from 12 stations with minimal filtering to preserve data integrity.
2. **Registration**: Automatic registration failed due to corridor homogeneity, causing deformations (e.g., compressed corridor length). Manual registration used three common points per station pair, leveraging HDS targets and identifiable features (e.g., corners). The manual alignment process is shown in the 12th figure.



12. Figure - Manual alignment process on C10 scan

3. **Cleanup**: Removed noise from glass reflections, improving point cloud quality. The resulting point cloud is illustrated in the 13th figure.

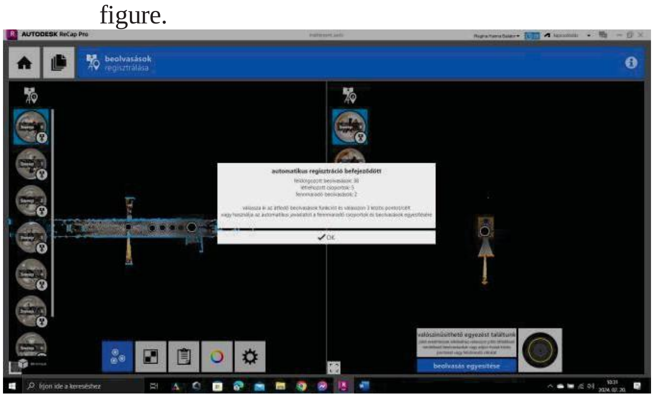


13. Figure - The result point cloud

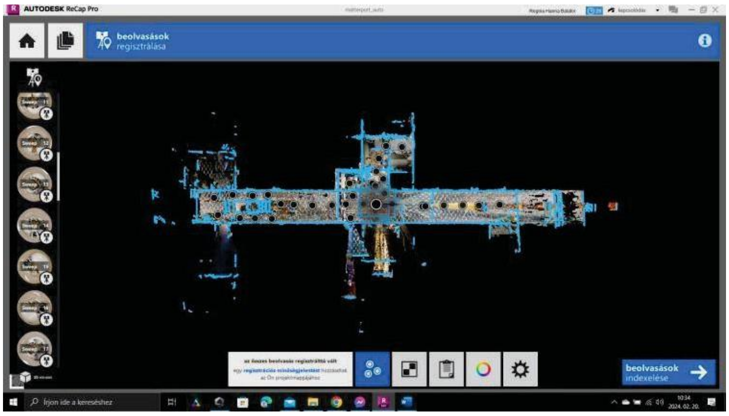
C. *Matterport PRO 3 Processing*

Processed in Recap Pro [7], with measurements on the Matterport VR platform:[4]

1. **Automatic Registration**: Aligned 38 stations in 10–11 minutes, with distortions in room alignments due to overlapping data. The result of automatic registration is shown in the 14th figure, with the result of automatic alignments illustrated in the 15th figure.

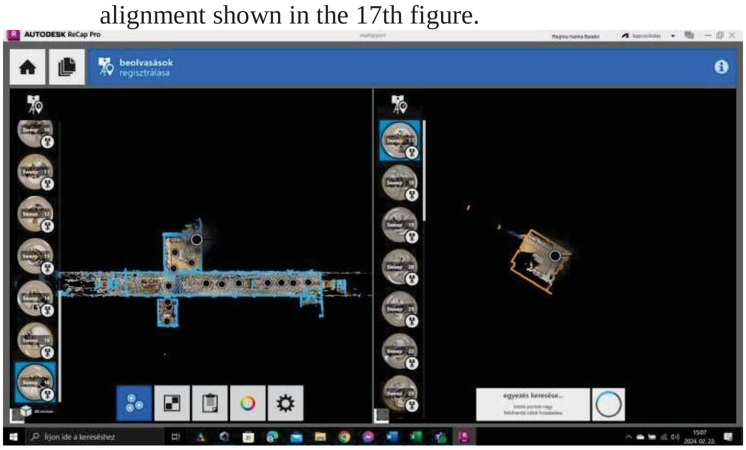


14. Figure - Result of automatic registration

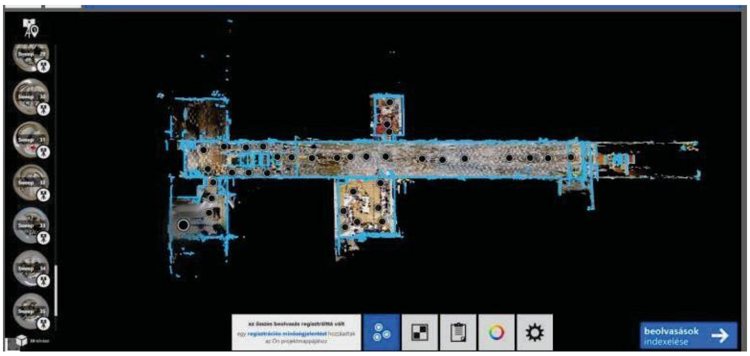


15. Figure - Result of automatic alignments

2. **Manual Registration**: Improved accuracy by manually aligning stations, addressing challenges in homogeneous areas and room transitions. The manual matching process is depicted in the 16th figure, with the position of stations after correct alignment shown in the 17th figure.

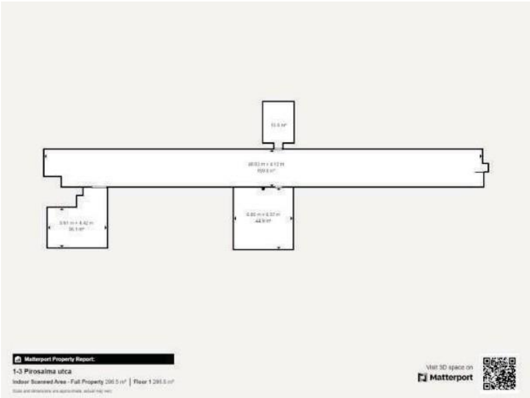


16. Figure - Manual matching process in Recap

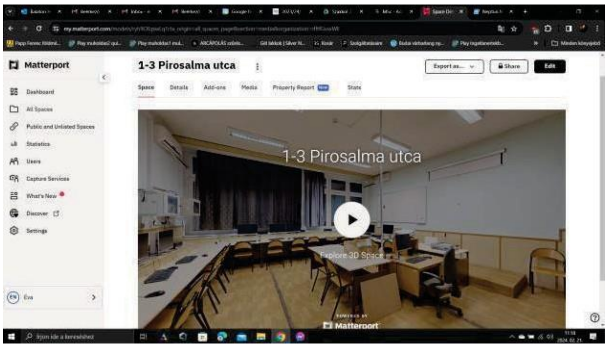


17. Figure - Position of positions after correct alignment

3. **Output**: Exported as an E57 file, with the VR platform providing walkable models and floor plans. The test area floor plan is illustrated in the 18th figure, and the Matterport website is shown in the 19th figure.



18. Figure - Test area floor plan



19. Figure - Matterport website

V. Comparison and Analysis

A. General Comparison

The tools were evaluated based on physical and operational characteristics:

Criteria	Ricoh Theta Z1	Leica C10	Matterport PRO 3
Weight	~200 g	~16 kg	2.2 kg
Compactness	Highly compact	Large, bulky	Compact
Ease of Use	Simple interface	Simple, technical	Simple, app-based
Survey Speed	Fast (~minutes)	Slow (~days)	Fast (~minutes)

1. table - General comparison

The Ricoh Theta Z1 and Matterport PRO 3 excelled in portability and speed, while the Leica C10 prioritized precision at the cost of time and maneuverability.

B. Measurement Accuracy

Measurements were compared with Leica Disto data: [6] The measurements on the Leica C10 point cloud in Recap are shown in the 20th figure, while the measurements on the Matterport point cloud are illustrated in the 21st figure.

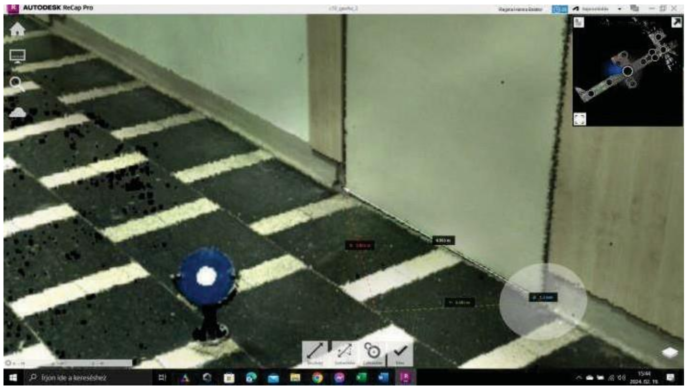
Location	Leica Disto	Ricoh Theta Z1	Deviation	Leica C10	Deviation
Corridor	4.13 m	4.18 m	-0.05 m	4.15 m	-0.02 m
Office	3.32 m	—	—	3.38 m	-0.06 m
Corridor	2.47 m	2.65 m	-0.18 m	2.47 m	0.00 m
Office	4.70 m	—	—	4.61 m	0.09 m
Classroom	1.27 m	—	—	1.23 m	0.04 m

2. table – Measuring results I.

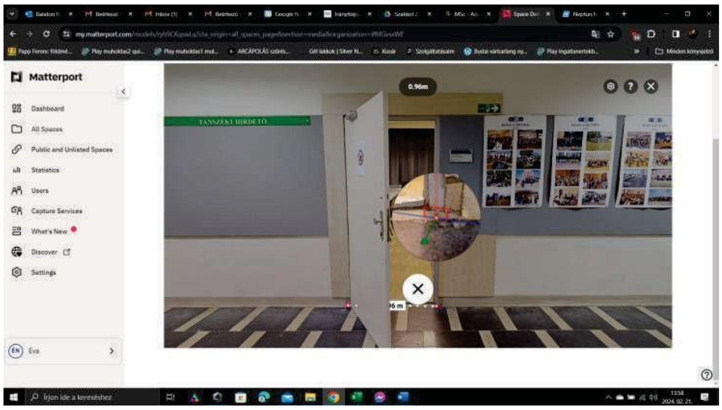
Location	Matterport (Recap)	Deviation	Matterport (VR)	Deviation
Corridor	4.13 m	0.00 m	4.12 m	0.01 m
Office	3.36 m	-0.04 m	3.36 m	-0.04 m
Corridor	2.47 m	0.00 m	2.48 m	-0.01 m
Office	4.62 m	0.08 m	—	—
Classroom	1.18 m	0.09 m	—	—

3. table – Measuring results II.

- **Ricoh Theta Z1**: Largest deviations (e.g., -0.18 m in corridor), due to sparse point clouds and lack of calibration.
- **Leica C10**: Highest accuracy (0.00–0.09 m deviations), reflecting precise laser measurements.
- **Matterport PRO 3**: Reliable accuracy (0.00–0.09 m), comparable to Leica C10, with consistent VR platform measurements.



20. Figure - Measurement in Recap on the C10 point cloud

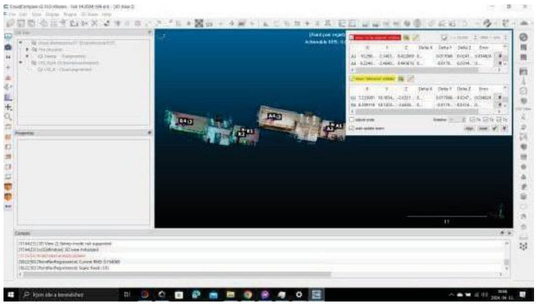


21. Figure - Measurement on Matterport

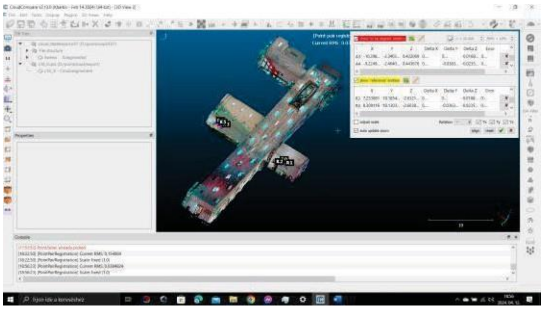
C. Point Cloud Alignment

Aligned in CloudCompare [5] using Leica C10 as the reference:

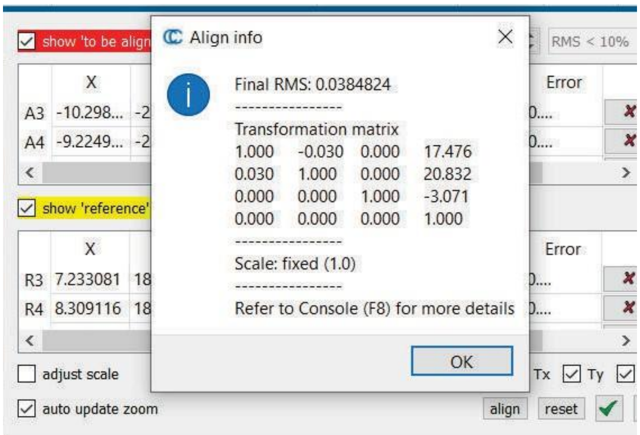
- **Matterport vs. Leica C10**: Aligned with six common points, RMS error of 4 cm, with errors near glass surfaces and staircases. The matching process of Matterport and laser scanner point clouds is shown in the 22nd figure, with the transformation result illustrated in the 23rd figure and the transformation parameters in the 24th figure.



22. Figure - Matching Matterport and laser scanner point clouds

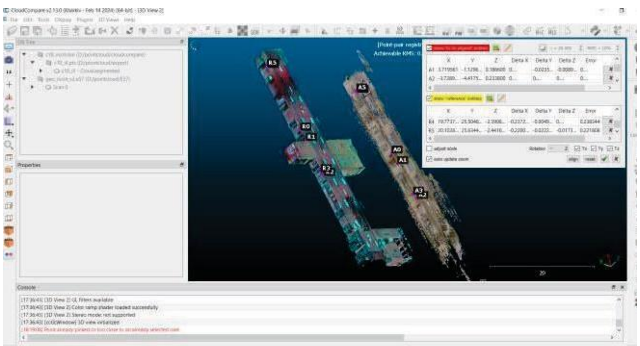


23. Figure - The result of the transformation

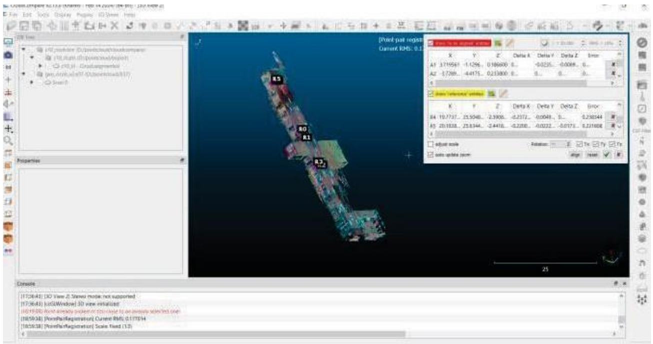


24. Figure - Transformation parameters

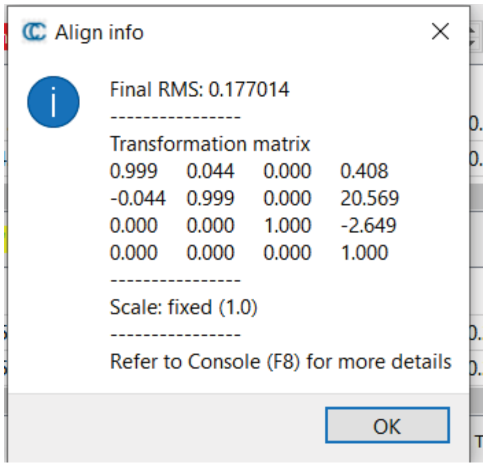
- **Ricoh Theta Z1 vs. Leica C10**: Aligned with five common points, RMS error of 18 cm, due to sparse point clouds. The transformation process of the 360° camera and C10 point cloud in CloudCompare is depicted in the 25th figure, with the result shown in the 26th figure and the transformation matrix in the 27th figure.



25. Figure - Transforming a 360° camera and a C10 point cloud in *CloudCompare*



26. Figure - The result of the transformation

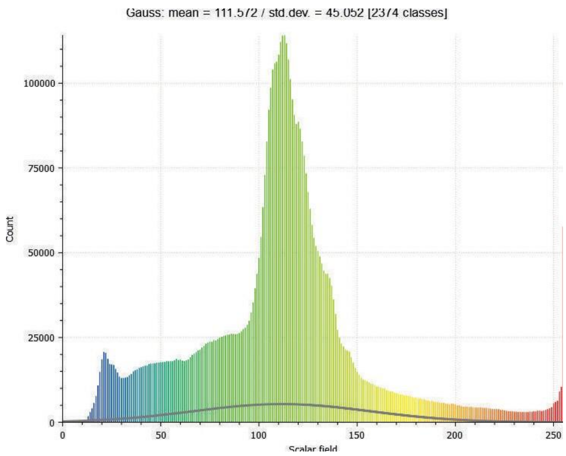


27. Figure - Transformation matrix

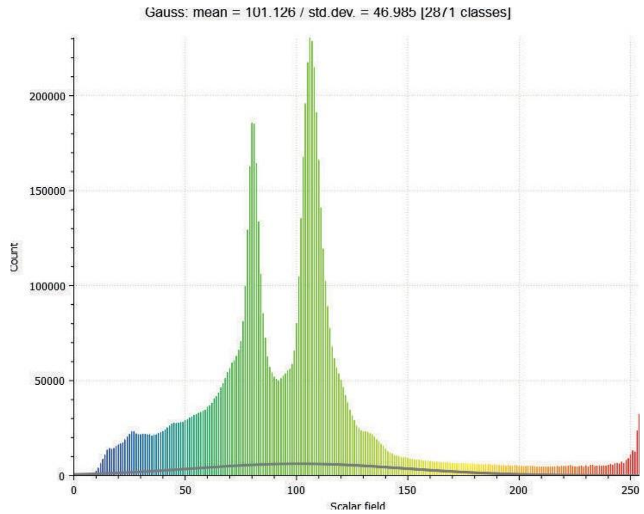
D. *Error Distribution*

Gaussian error distributions were analyzed:

- **Office and Classroom**: Minimal discrepancies (0.04–0.08 m) for Matterport and Leica C10. The error distribution for the office is shown in the 28th figure, and for the classroom in the 29th figure.

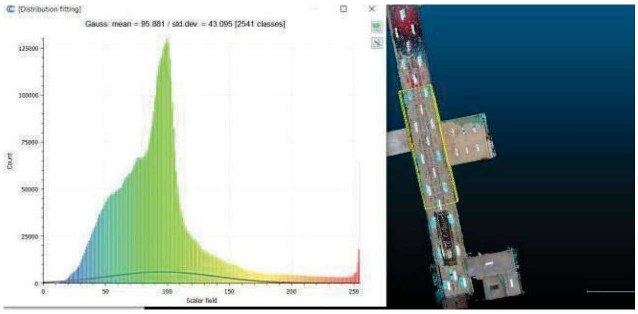


28. Figure - C10 and Matterport clouds office distribution

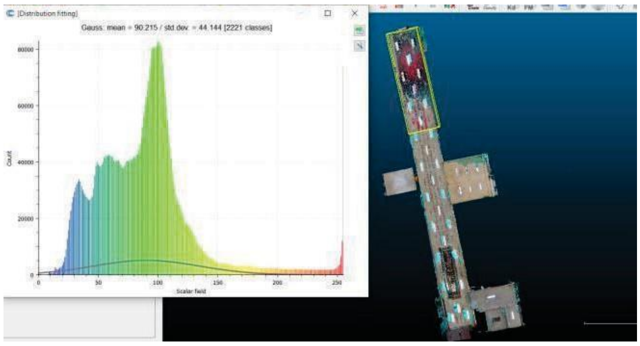


29. Figure - C10 and Matterport Cloud Classroom Distribution

- **Corridor (Middle and End)**: Small errors (0.00–0.01 m), effective in uniform areas. The middle piece of the corridor and its associated Gaussian error distribution are shown in the 30th figure, with the end of the corridor depicted in the 31st figure.

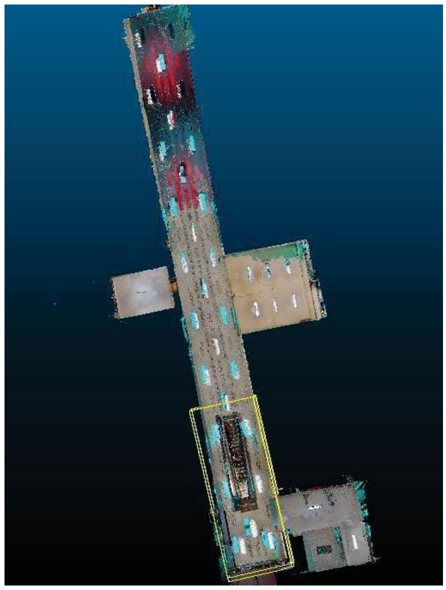


30. Figure - The middle piece of the corridor and its associated Gaussian error distribution

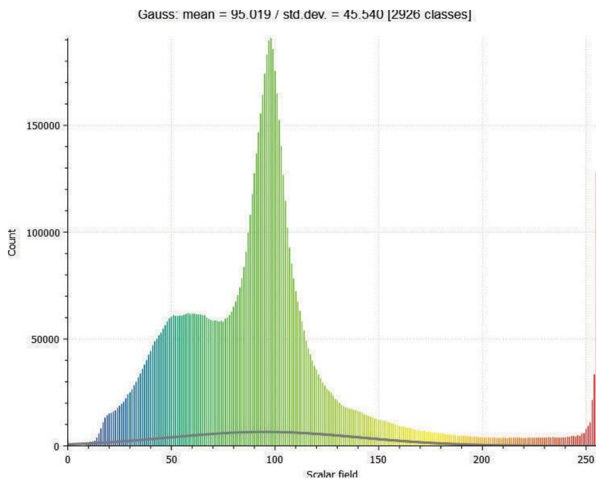


31. Figure - The end of the corridor and the associated Gaussian error distribution

- **Staircase Area**: Larger errors (up to 60 cm, reduced to 15 cm with filtering) for Matterport PRO 3 due to reflective surfaces. The staircase section is depicted in the 32nd figure, with the associated error distribution shown in the 33rd figure.



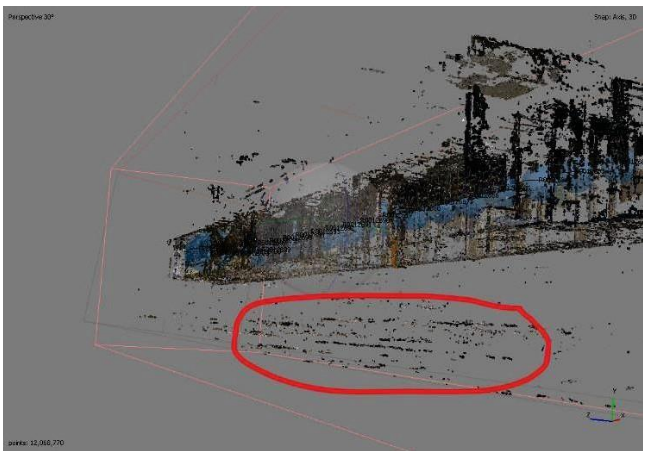
32. Figure - Staircase section corridor section



33. Figure - Error distribution of the stepped part

E. *Noise and Artifacts*

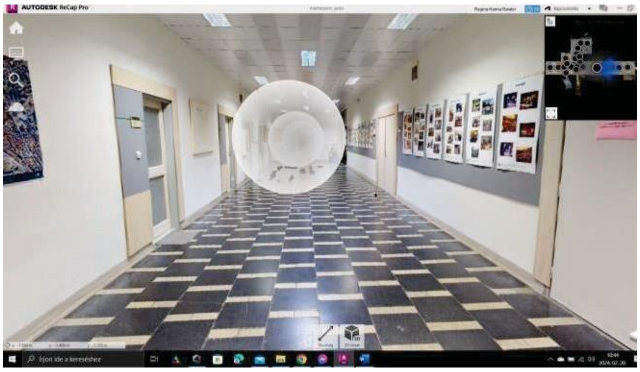
- **Ricoh Theta Z1**: Noise below floor level due to fisheye lens distortions, , as shown in the 34th figure.



34. Figure - Noise below floor level

- **Leica C10**: Minimal noise, with artifacts from glass reflections.

- **Matterport PRO 3**: Significant noise near reflective surfaces, resulting in black spots, as illustrated in the 35th figure.



35. Figure - Black noise spots were also created when moving through the aisle positions

VI. Results

- **Ricoh Theta Z1**: Completed surveys in minutes but produced sparse point clouds with deviations of 0.05–0.18 m, suitable for visualization tasks like virtual tours. [2] [6] [12]
- **Leica C10**: Achieved the highest accuracy (0.00–0.09 m deviations), ideal for precise applications, but required two days for 12 stations due to its bulkiness.
- **Matterport PRO 3**: Balanced speed and accuracy (0.00–0.09 m deviations), with VR platform enhancing visualization. Noise from reflective surfaces required manual cleanup. [12]

Challenges included:

- **Homogeneous Areas**: Uniform corridor surfaces caused alignment issues, particularly for Ricoh Theta Z1.
- **Reflective Surfaces**: Glass introduced noise, especially in Matterport PRO 3 point clouds.
- **Calibration Limitations**: Ricoh Theta Z1's lack of calibration in Agisoft Metashape reduced accuracy at image edges. [13]

VII. Conclusion

The choice of tool depends on project requirements:

- **Ricoh Theta Z1**: Best for rapid, low-cost surveys with moderate accuracy, [8] [10] [11] suitable for preliminary visualizations.
- **Leica C10**: Ideal for high-precision applications like structural analysis, despite slow speed and bulkiness.
- **Matterport PRO 3**: Balances speed, portability, and accuracy, suitable for BIM and VR applications.

Future research could explore hybrid approaches, combining rapid imaging with precise laser scanning, or advanced calibration techniques to enhance accuracy. Economic analyses could assess cost-effectiveness, considering equipment costs, survey time, and processing requirements.

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