3Dsurvey RTK Videogrammetry module: Videogrammetry with 3Dsurvey SiteScan app and an external GNSS RTK smartphone antenna

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Abstract

The study aims to demonstrate the accuracy level of videogrammetric approach compared to traditional GNSS surveying. Data was collected on a real construction site using the **3Dsurvey SiteScan app** with an **external RTK GNSS smartphone antenna**. The data was later processed in 3Dsurvey. Without using any GCPs, we achieved an excellent absolute 3D error of **10.2 cm** with a standard deviation of **2.3 cm** and a remarkable relative error of **0.58%**. By using the GCPs, we achieved an absolute error of **1.6 cm** with a standard deviation of **1.9 cm** and a relative error of only **0.03%**, significantly surpassing results from the model without additional GCP georeferencing.

1 Introduction

In the rapidly evolving field of surveying, videogrammetry has opened up new possibilities for achieving high-precision measurements. Videogrammetry, a branch of photogrammetry, operates in a non-contact manner. It is capable of identifying and tracking intricate point clouds with millions of points, providing results that are both highly accurate and reliable. Its simplicity and ability to be fully automated enhances its appeal as a 3D measurement technique. [1]

The study was conducted on a construction site covering approximately 80 square meters, where a new heat pipe was being installed. A total of 10 control points were measured using a GNSS device, followed by the creation of a 3D model using videogrammetry. The videogrammetry process involved the use of a mobile phone for video capture, using the 3Dsurvey SiteScan app combined with a handheld RTK antenna.

The points measured with the GNSS device were then imported into the photogrammetry/videogrammetry software, 3Dsurvey. The subsequent analysis focused on identifying the accuracy of videogrammetric approach, compared to the traditional approach (GNSS measurements).

2 Comparison of 3D model and GNSS data

We initiated the comparison by first employing the traditional method to measure 10 control points on the construction site. This involved marking the points with spray paint and then using a GNSS device for precise measurement. To create a 3D model of the site we used a mobile phone (Google Pixel 7a) combined with a handheld RTK antenna (Redcatch RTK GNSS antenna). We attached the antenna to the phone (Figure 1) and connected to RTK corrections. To create a 3D model, one video was created, filmed directly above the channel, as depicted in Figure 2. The video was captured in Full HD (1920 x 1080).

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(a) (b)

Figure 1: (a) RTK device attached to phone (b) Making a video of the site

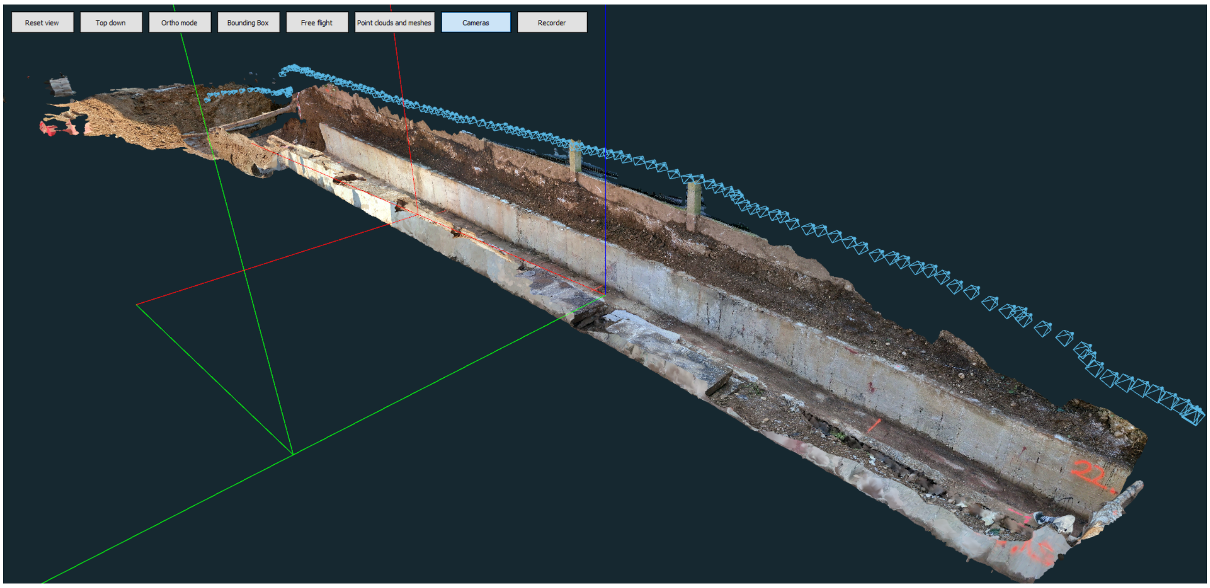
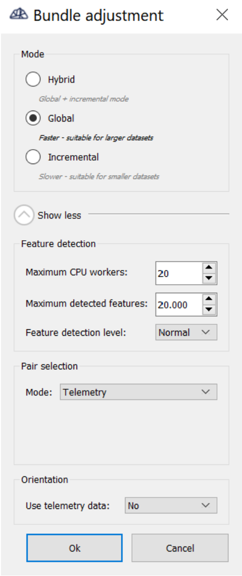
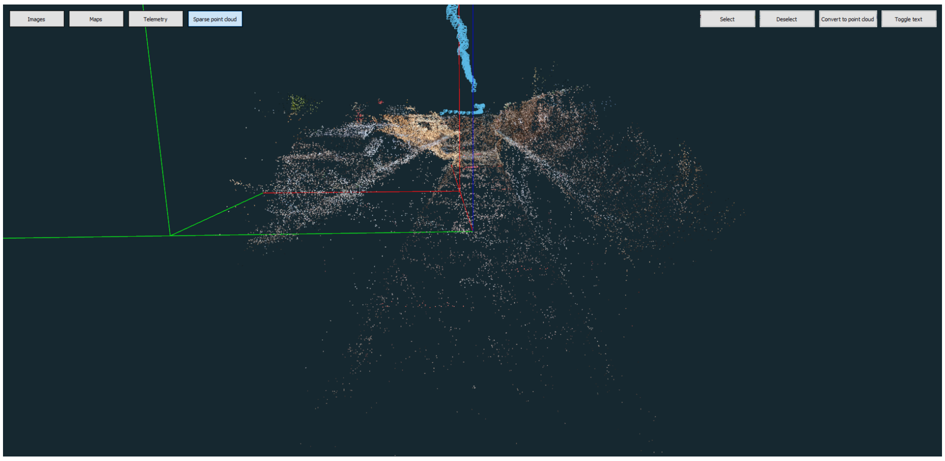


Figure 2: Camera path on the 3D mesh

Upon transferring the videos to the computer, we used 3Dsurvey software for further processing. Using the telemetry mode of extraction, we extracted 136 frames from the video, all of which were registered. We proceeded by performing a "Global" bundle adjustment, with the feature detection level set to "Normal". We used telemetry mode for pair selection, while the model was georeferenced by performing a 7-parameter rigid transformation of photogrammetric camera positions to RTK telemetry data. (Figure 3). The reprojection error was calculated to be 1.20 px.



(a) Bundle adjustment settings



(b) Sparse point cloud (result of bundle adjustment)

Figure 3: Bundle adjustment

After that we proceeded by doing the dense reconstruction on level "High" (Figure 4),

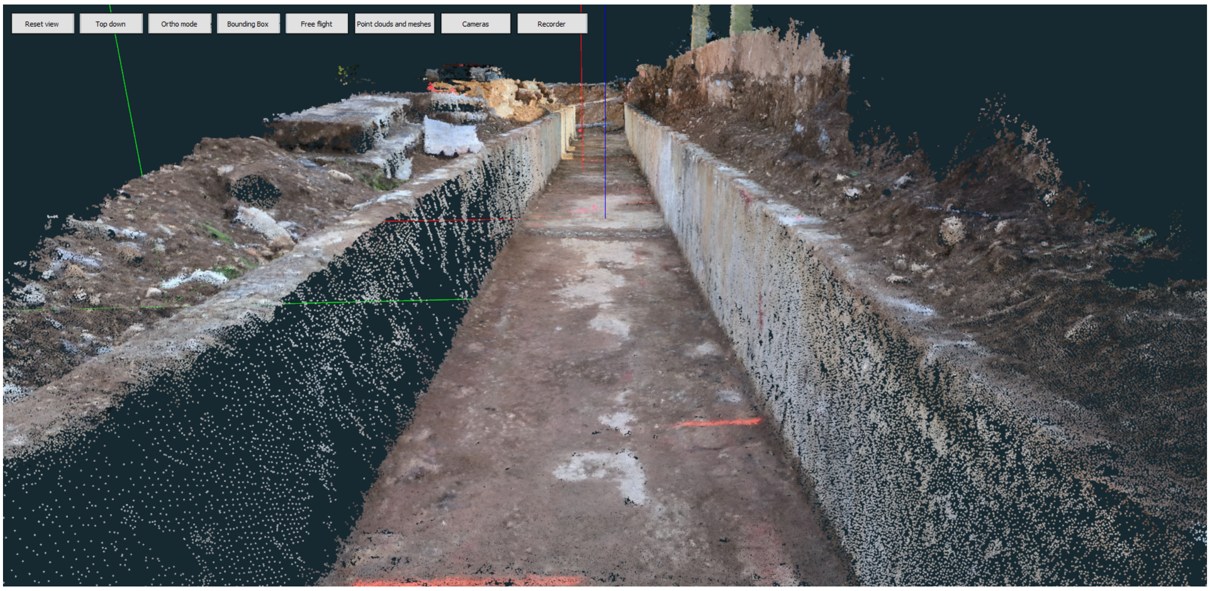


Figure 4: Point cloud

followed by callculation of a "Full 3D" mesh (Figure 5).

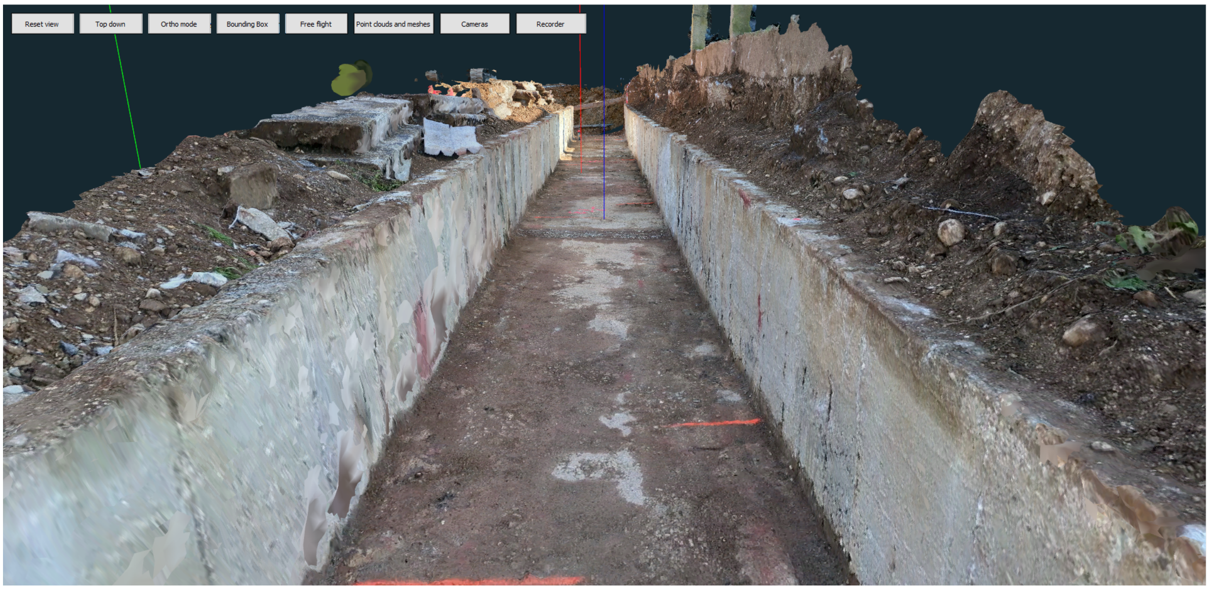


Figure 5: Full 3D mesh

Upon completion of these steps, the GNSS data was imported into the 3D model within the CAD tab, as illustrated in Figure 6.

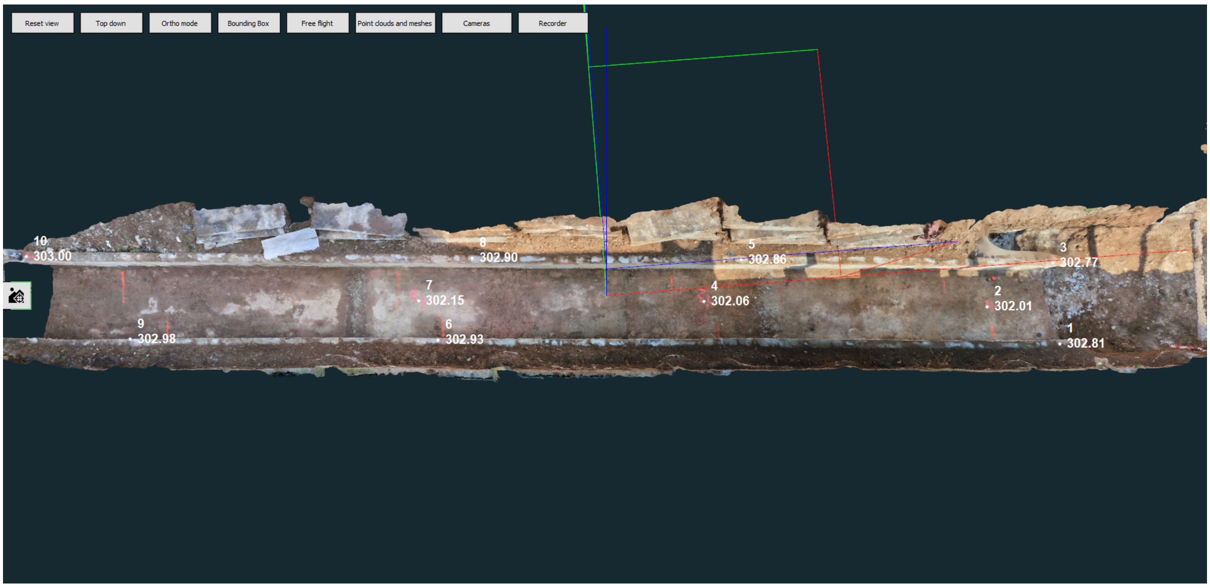


Figure 6: GNSS data imported into 3Dsurvey

3 Examining Measurement Accuracy

In the upcoming chapters, we'll discuss the accuracy of measurements acquired with videogrammetry compared to traditional surveying methods (GNSS measurements). The traditional surveying points, which have an approximate 2 cm error, will serve as our reference for comparison.

3.1 Absolute Error

The absolute error refers to the direct distance between a point measured with videogrammetry and the corresponding point measured traditionally. We measure this in terms of Easting, Northing, Height, and the total 3D distance. This measurement will show us how accurately videogrammetry captures the location of points compared to the standard method.

3.2 Relative Error

Relative error, meanwhile, focuses on the distances between pairs of points. We'll compare the distances measured with videogrammetry to those obtained through traditional surveying. This comparison is key to understanding how well videogrammetry maintains the spatial relationships between points.

These sections aim to clearly present the effectiveness of videogrammetry in replicating site details accurately, providing an essential comparison to conventional surveying techniques.

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4 Accuracy of the 3D Model

This section focuses on the accuracy of the 3D model created with the 3Dsurvey SiteScan app and external GNSS RTK antenna, without performing any additional georeferencing on ground control points (GCP). We directly compare the measured points in the 3D mesh to our reference points from traditional surveying.

4.1 Absolute Error

Because point 10 (marked red) was not captured in enough images, it was not properly reconstructed and represents a gross error; therefore, it was excluded from the calculations of errors. Interestingly, its absolute error is incidentally the smallest recorded in this dataset. Below is a table summarizing the absolute errors for each point measured.

Table 1: Absolute error

Point	**Easting error** $[cm]$	**Northing error** $[cm]$	**Height error** $[cm]$	**3D error** $[cm]$
1	-3.6	-2.4	-8.2	9.3
2	-4.6	0.7	-8.4	9.6
3	-2.5	-1.3	-7.6	8.1
4	-6.0	3.7	-7.5	10.3
5	-3.6	0.0	-5.3	6.4
6	-10.6	2.7	-4.6	11.9
7	-8.1	3.4	-6.1	10.7
8	-8.9	2.0	-6.2	11.0
9	-12.3	7.6	-1.9	14.6
10	-4.0	0.7	-2.0	4.5
Average absolute error	**6.7**	**2.6**	**6.2**	**10.2**
STD	**3.4**	**3.0**	**2.1**	**2.3**

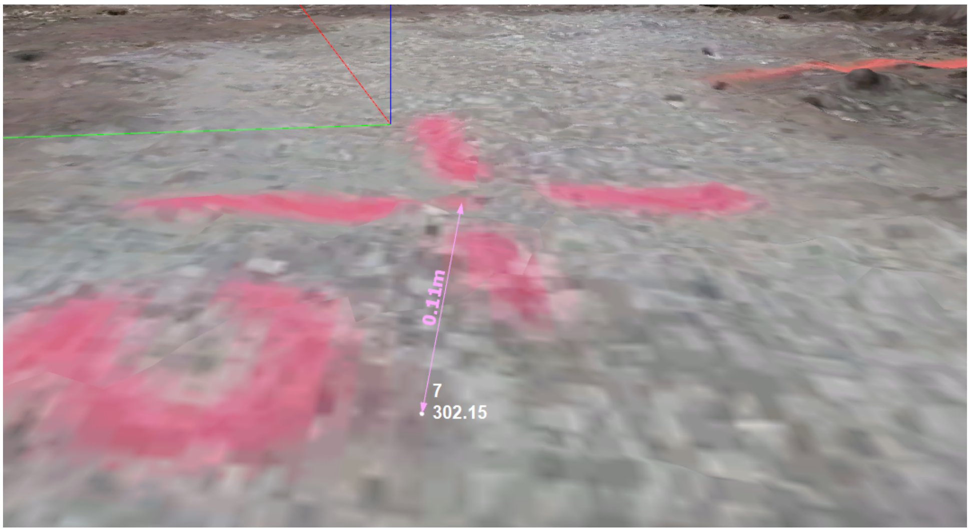

Figure 7: Absolute error of point 7 on the 3D mesh

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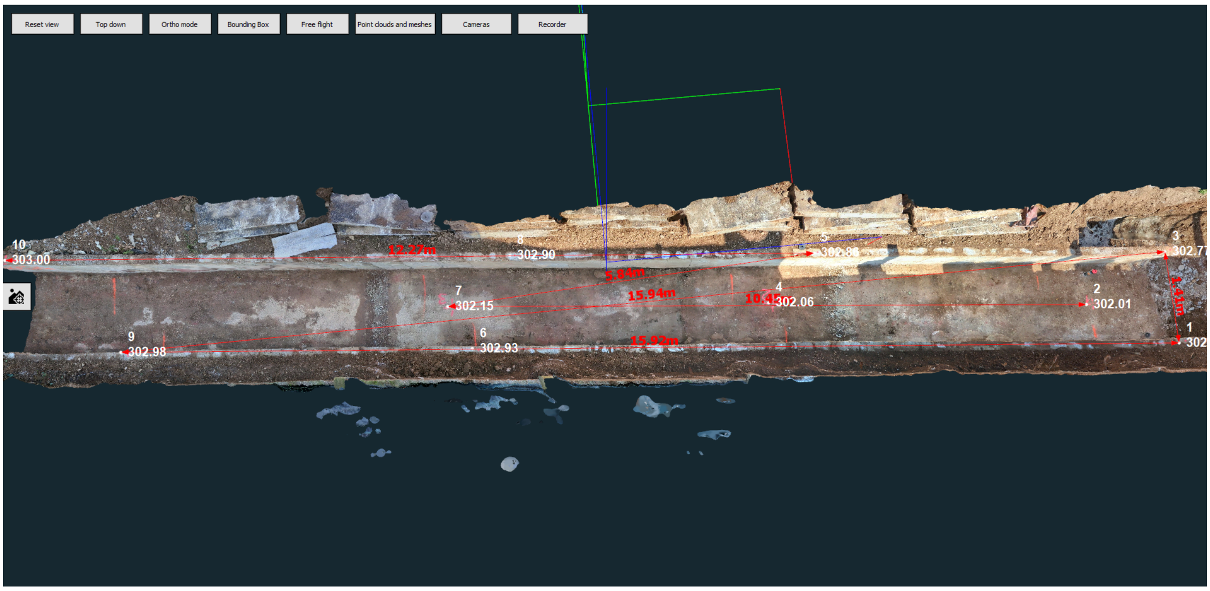
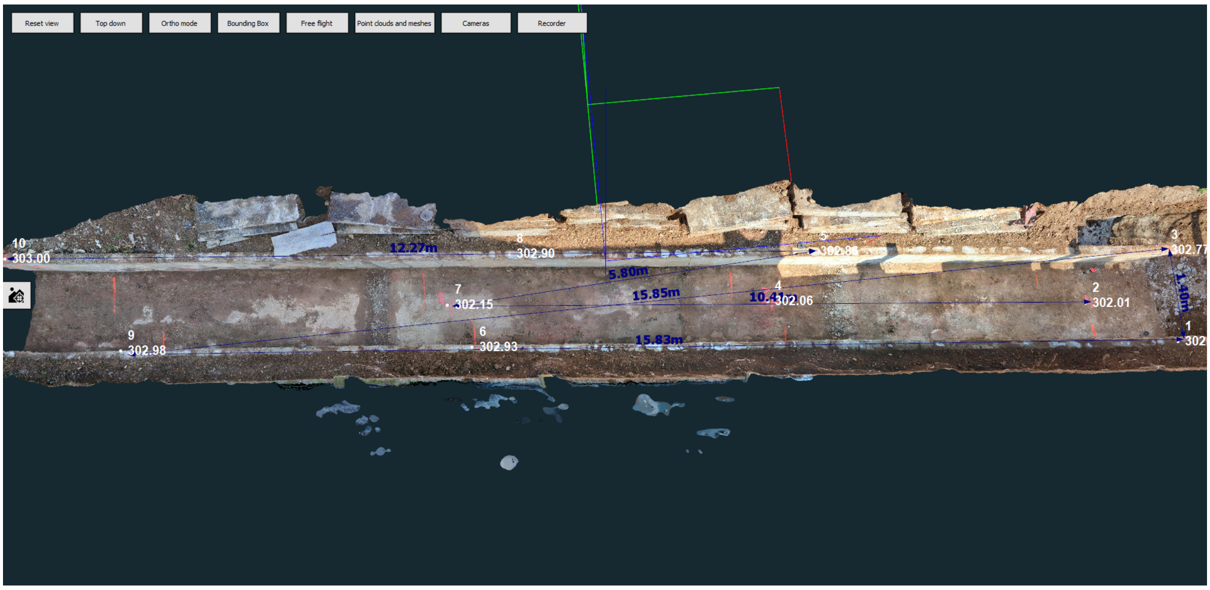
4.2 Relative Error

The relative error analysis compares the distances between points measured in the 3D mesh to those measured traditionally. For comparison, we have chosen specific pairs of points, namely points 1-3, 3-9, 1-9, and 2-7, 5-7, 5-10 as illustrated in Figures 8a and 8b.

The measurement for point pair 5-10 (marked red) was excluded from the calculations because, like in the absolute error analysis, it was not adequately captured in enough images and thus not properly reconstructed.



(a) Traditional Measurements



(b) Videogrammetry Measurements

Figure 8: Comparison of distances between points

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Table 2: Comparison of Distances: **Traditional GNSS** measurements vs. **RTK Videogrammetry** measurements

Pair of Points	**Traditional GNSS Distance** [cm]	**3D Mesh Distance** [cm]	**Error** [cm]	**Error** [%]
1-3	141	140	1	0.71
3-9	1594	1585	9	0.56
1-9	1592	1583	9	0.57
2-7	1045	1041	4	0.38
5-7	584	580	4	0.68
5-10	1227	1227	0	0
Average relative error				**1.6 %**

4.3 Discussion

Our study demonstrates that using a smartphone with the 3Dsurvey SiteScan app and an external RTK GNSS antenna for surveying construction sites is both straightforward and accurate. This method does not require complex equipment or extensive training, making it a quick and user-friendly way to obtain measurements.

We achieved an absolute 3D error of **10.2 cm** with a standard deviation of **2.3 cm** and a remarkable relative error of **0.58%**. This level of accuracy is excellent, and more than sufficient for tasks such as measuring the positions of pipes and installations. The simplicity of this technique, combined with its high accuracy, makes it an outstanding tool for infrastructure documentation, offering a cost-effective alternative to traditional surveying methods.

5 Accuracy of the Model Georeferenced with GCP Data

To refine the accuracy of our 3D model created through videogrammetry, we combined it with traditional surveying data by using Ground Control Points (GCPs). Specifically, we selected points 1, 3, and 9 (marked blue in the Table 3), measured with GNSS, as GCPs for model georeferencing, while the other points were used as validation points. This approach not only aimed to enhance the model's spatial accuracy but also to explore the benefits of merging traditional surveying precision with modern videogrammetry techniques.

Using 3Dsurvey, we processed the videogrammetric data, incorporating the GCPs to align and georeference the 3D model accurately with the site's real-world coordinates.

5.1 Absolute Error in the GCP-georeferenced Model

The table below presents the absolute errors for the GCP-georeferenced model, showing the effectiveness of GCP georeferencing. Point 10 (marked red) has been excluded from the calculations for the reasons previously mentioned in Section 4.1.

Table 3: Absolute error

Point	**Easting error** $[cm]$	**Northing error** $[cm]$	**Height error** $[cm]$	**3D error** $[cm]$
1	0.0	0.0	-0.1	0.1
2	0.7	-0.2	-0.3	0.8
3	-0.1	-0.4	-0.5	0.6
4	0.7	0.4	-2.4	2.5
5	1.1	-1.8	-1.4	2.5
6	-2.0	-1.5	-1.6	3.0
7	0.3	-1.6	-2.8	3.2
8	-0.7	-3.0	-3.3	4.5
9	0.0	0.0	0.1	0.1
10	9.4	-8.4	-1.1	12.7
Average absolute error	**0.9**	**1.1**	**1.3**	**1.6**
STD	**0.6**	**1.0**	**1.4**	**1.9**

5.2 Relative Error in the GCP-georeferenced Model

Just as we did on the 3D model without additional georeferencing, we chose the following pairs of points for comparison: 1-3, 3-9, 1-9, and 2-7, 5-7, 5-10, seen in Figure 9.

Again, exactly as described in Section 4.2, the pair 5-10 (marked red) was excluded from the calculations.

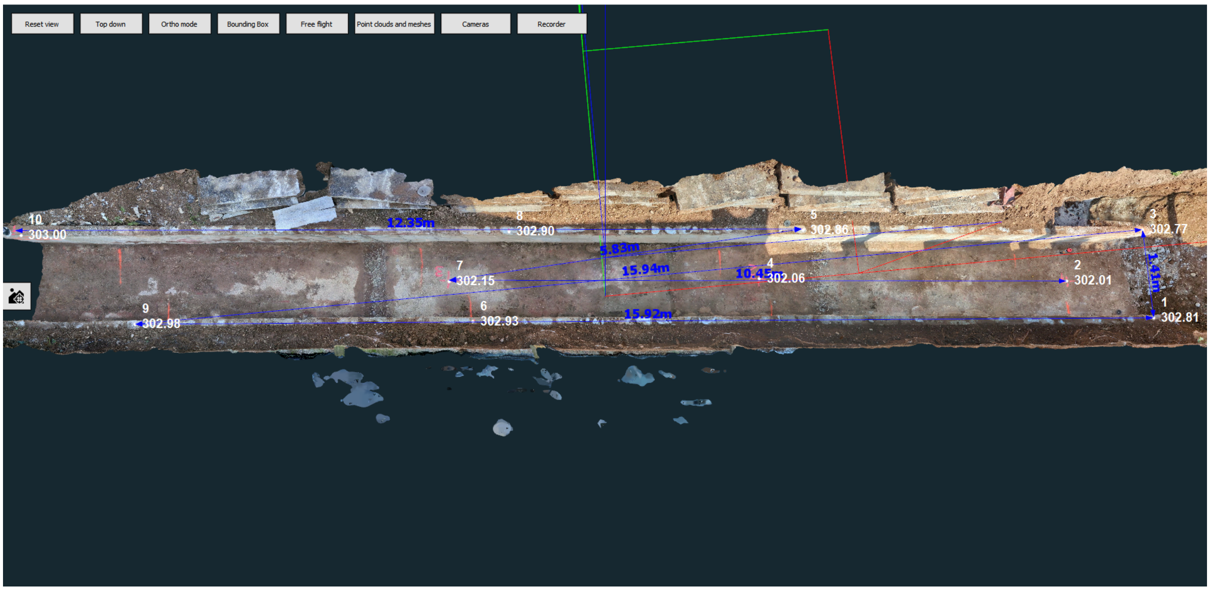

Figure 9: Distances between points of videogrammetry measurements additionally georeferenced with GCP

Table 4: Comparison of Distances: **Traditional GNSS** measurements vs. **RTK Videogrammetry** measurements

Pair of Points	**Traditional GNSS Distance** [cm]	**3D Mesh Distance** [cm]	**Error** [cm]	**Error** [%]
1-3	141	141	0	0
3-9	1594	1594	0	0
1-9	1592	1592	0	0
2-7	1045	1045	0	0
5-7	584	583	1	0.17
5-10	1227	1235	8	0.65
Average relative error				**0.03 %**

5.3 Discussion

Our study achieved an absolute error of **1.6 cm** with a standard deviation of **1.9 cm** and a relative error of only **0.03%.** These results significantly surpass those from the model without additional GCP georeferencing. However, it is important to note that achieving this enhanced accuracy requires using both videogrammetry and traditional methods. This integration ensures the highest precision but does involve additional steps.

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References

[1] Armin Gruen. Fundamentals of videogrammetry - a review. Human Movement Science, 16(2):155–187, 1997.

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