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Methodology for determining coordinate points using automated software and aircraft

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Abstract. Engineers are currently facing questions about the use of geographic information systems or software to implement projects in a short time. The problem with using geographic information systems in construction is the relevance of the available data. An example is open sources with satellite images. This problem appeared even before satellite-positioning systems emerged. In this connection, the purpose of this article is to find the deviation of source points when performing photogrammetry with marker detection in Agisoft PhotoScan software. This method of determining coordinates using a single point and its correlation on the ground is applicable in the case of rapid calculations, where the volumes of earth masses are large enough and do not require increased accuracy at the stage of approximate calculations. As a result of the comparison of traditional and automated methods of definition of coordinates on the ground has been found an essential distinction, both in total values and in time spent for the definition of points of coordinates. The considerable difference revealed by the results of the comparison of coordinates is presented in the table as a color gradation. The average deviation between known coordinates and coordinates obtained in Agisoft PhotoScan by axes was: X=0.87%, Y=0.45%, Z=0.12%.

Keywords: Agisoft PhotoScan, surveying, automation, photogrammetry, geodesy, topographic mapping.

1. Introduction

The use of digital tools in automating construction processes is rapidly advancing, despite the challenges posed by the complexity and diversity of these processes. There is a growing interest in leveraging geographic information systems and software to streamline project implementation, which raises questions for engineers about how best to apply these tools within tight timeframes. However, integrating such tools can lead to errors and deviations caused by human mistakes or insufficient information on their practical application [1].

When it comes to using geographic information systems in construction, the main challenge is the quality and relevance of the available data. For instance, open sources like satellite images may be of limited use due to their quality, coverage, and the current state of urbanization in the area being assessed. This can make it difficult to accurately evaluate the situation for construction projects [2].

Although surveying a plane with a GPS receiver is relatively straightforward, those who use optical and satellite instruments should be aware of the potential challenges associated with these tools. Attempting to integrate traditional and satellite surveying instruments can lead to several points for consideration [3], including:

- The coordinate system used when taking pictures;
- Relativity surface;
- Scale factor of the projection;
- Correction for projection height, etc.

This issue has been a challenge even prior to the advent of satellite positioning systems. For example, when using high-precision total stations of the Leica series, it was found that the deviation was about 0.2 meters, factoring in the coordinate system adopted in the region being surveyed. This deviation occurs despite considering the installation of the device and the position of the reflector. It's important to note that Leica GPS receivers typically determine the coordinates of points in the WGS-84 geodetic coordinate system. However, in practice, the UTM32 coordinate system is used when converting to plane coordinates, which establishes the relationship between the ellipsoid surface part and the plane coordinates in the projection. Different results can be obtained by using a Leica TPS total station (Figure 1), which determines the coordinates over a peg. Measurements taken with a reflector can also have significant errors if the ellipsoid surface is not taken into account [4].

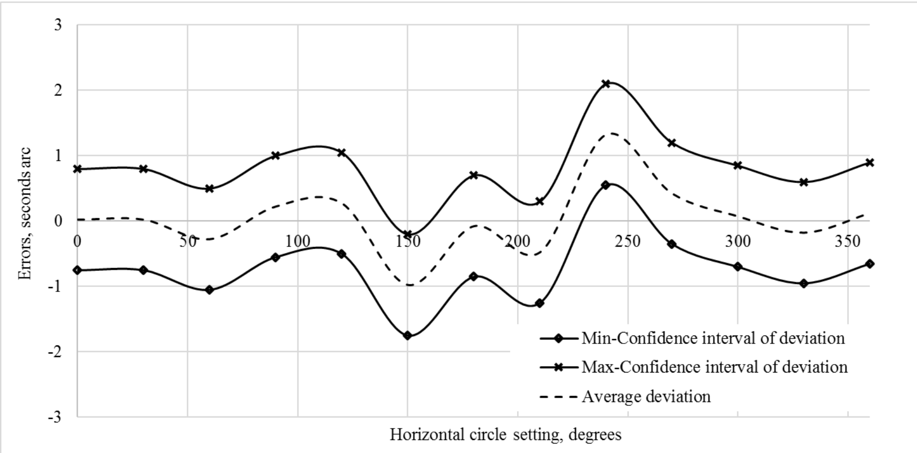

Figure 1 – Tachymeter accuracy Leica TSO06 [4]

Moreover, there are software programs available that can automate surface breakdowns by correlating points based on surface topography. However, deviations in these measurements can lead to unpredictable consequences, as minimum and maximum values can significantly affect the accuracy of the results [5]. The accuracy of the measuring instrument used, as well as other factors such as image quality, weather conditions, and the skill of the operator flying drones or other aircraft, are critical considerations in automating the surveying process [6].

Therefore, the objective of this article is to determine the deviation of baseline points when conducting photogrammetry using marker detection in the Agisoft PhotoScan software. Agisoft PhotoScan is primarily an autonomous software tool that can conduct photogrammetric processing of digital images and generate three-dimensional spatial data for use in Geographic Information Systems (GIS). Therefore, the authors of this article showcase an example of executing topographic surveys using this software. The example pertains to a ground excavation site, which was utilized for embankment or excavation during the construction of residential complexes [7].

2. Methods

The method used in this study to determine coordinates involves using a single point and its correlation on the ground, which is suitable for quick calculations when the volume of earth masses is sufficiently large and high accuracy is not required at the stage of approximate calculations.

For this study, Agisoft PhotoScan software was utilized. In addition to the advantages previously mentioned, an additional benefit of using stand-alone software is its flexibility and adaptability to various systems for calculations.

The drone used in this study for photogrammetry is the Quadcopter DJI Mini 3 Pro. The selection of this model was based on the manufacturer's specifications, with special emphasis on the matrix size and resolution of the captured frames. Additionally, the number of frames captured and the time of day of shooting are critical factors to consider. A higher number of frames captured enables the accurate construction of a 3D model, while the absence of shadow zones facilitates the calculation of surface relief [8].

The survey process is illustrated in Figure 2 below. The drone's trajectory for mapping the terrain can follow a continuous circular motion around the center or the edge of the surveyed area, or move along a path from the beginning to the end of the polygon within the defined boundaries of the area. The captured images are aligned with a certain degree of accuracy, where the orientation of each image is tied to the angle of view of the drone's camera, resulting in the creation of a point cloud.

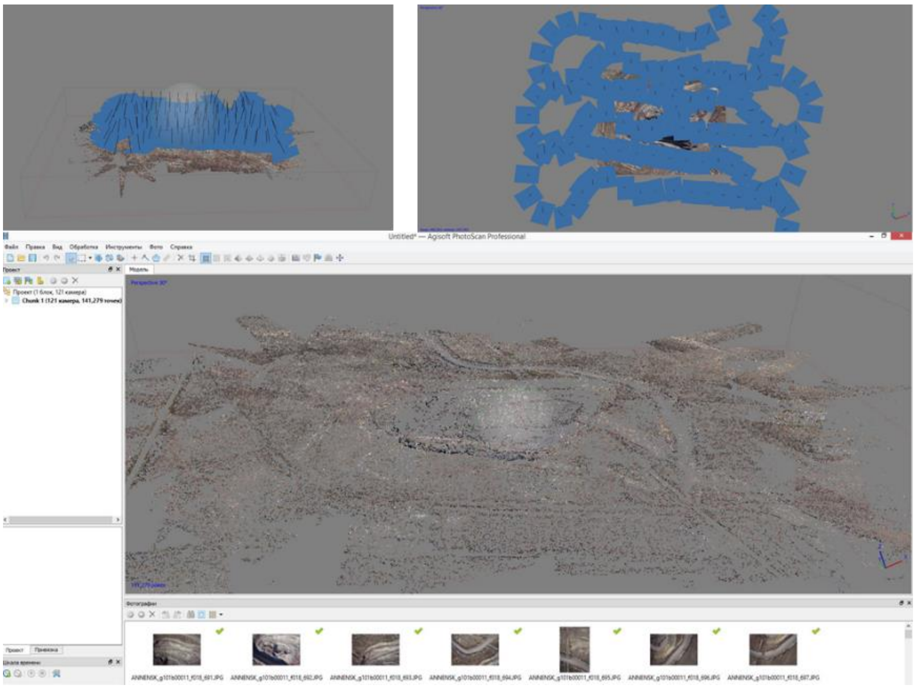

Figure 2 – The process of building a point cloud for polygon photogrammetry in Agisoft PhotoScan

The process of creating a model for marker detection involves processing the point cloud, which is a time-consuming task. However, the output is a model of high quality that can be used to detect markers. These markers, which are placed on the boundary of the area being defined, contain the initial coordinates of reference points. In the field, these reference points are determined at the survey site by marking. The markers can take the form of a "+" mark, such as a plus sign, which is easily visible in an aerial survey, or an object with a clear center, as shown in Figure 3.

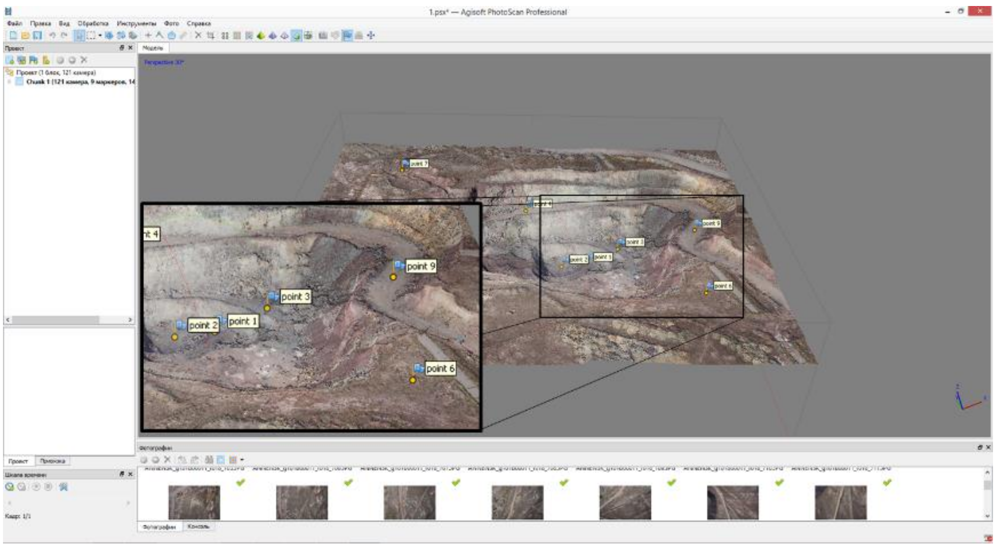

Figure 3 – Identification of markers on the territory of the polygon in the Agisoft PhotoScan environment

3. Results and Discussion

After comparing traditional and automated methods of determining ground coordinates, it was discovered that there were notable discrepancies in both the final values and the time taken to determine coordinate points. Previous research exploring comparative deviation analysis, focused on creating point clouds via laser and digital photogrammetry, is discussed in [9]. The accuracy of point positioning by computer programs is analyzed in [10], where the coordinates of points obtained through tachymetric survey are used as the reference system by the authors.

Figure 4 below shows the model subjected to linear transformations.

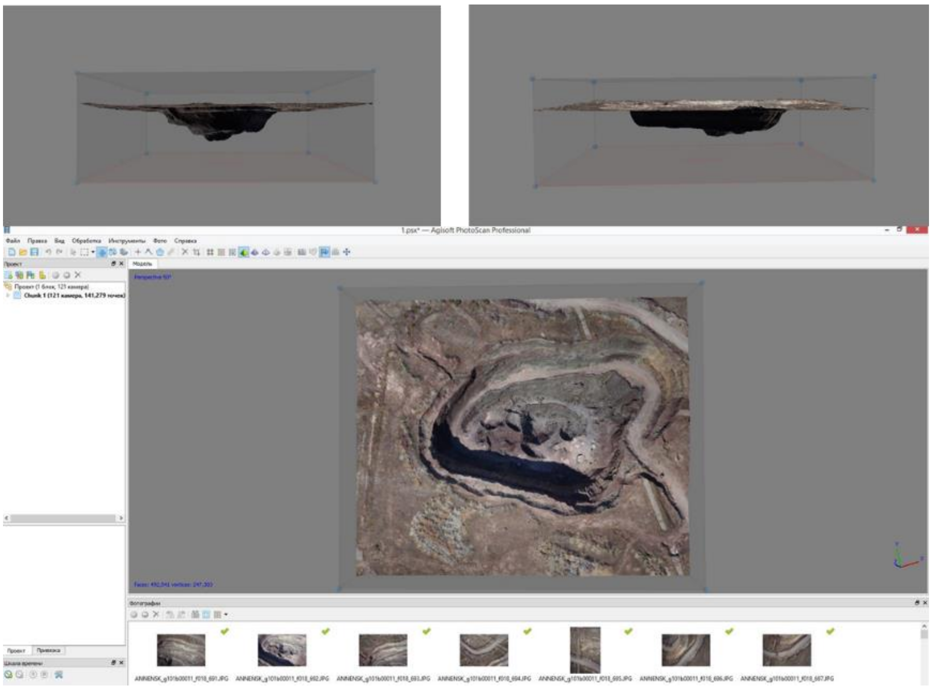

Figure 4 – Building a vertical leveling profile in Agisoft PhotoScan according to markers

The similarity transformation model is derived from 7 parameters: 3 translation parameters, 3 rotation parameters, 1 stretching and compression parameter). This approach solves only linear distortions while nonlinear distortions which are also present in the model can be the reason for further errors in the model georeferencing and calculations. To reduce influence of nonlinear distortions markers or reference points with known coordinates were used.

Table 1 below shows the deviation between traditional point coordinates (X1, Y1, Z1) and automated (X2, Y2, Z2) methods in Agisoft PhotoScan.

Table 1 – Deviation of coordinates

№	X1	X2	Xdiff	Incl%	Y1	Y2	Ydiff	Incl%	Z1	Z2	Zdiff	Incl%
1	47.8771	48.8834	1.0063	2.10%	67.5170	68.5548	1.0378	1.54%	356.9000	357.9265	1.0265	0.29%
2	47.8771	48.9085	1.0314	2.15%	67.5170	67.5309	0.0139	0.02%	357.2000	357.2502	0.0502	0.01%
3	47.8771	48.8904	1.0133	2.12%	67.5170	67.5378	0.0209	0.03%	356.5000	356.5235	0.0235	0.01%
4	47.8771	47.9010	0.0240	0.05%	67.5170	67.5509	0.0339	0.05%	356.7000	356.7276	0.0276	0.01%
5	47.8771	47.9171	0.0400	0.08%	67.5170	67.5235	0.0065	0.01%	356.2000	357,2477	1,0477	0,29%
6	47,8771	47,8840	0,0069	0,01%	67,5170	67,5432	0,0262	0.04%	357.0000	357.0320	0.0320	0.01%
7	47.8771	47.9259	0.0488	0.10%	67.5170	68.5227	1.0057	1.49%	356.3000	356.3364	0.0364	0.01%
8	47.8771	47.9240	0.0470	0.10%	67.5170	67.5344	0.0174	0.03%	356.8000	357.8267	1.0267	0.29%
9	47.8771	48.9218	1.0447	2.18%	67.5170	67.5628	0.0458	0.07%	356.6000	357.6500	1.0500	0.29%
10	47.8771	48.8881	1.0110	2.11%	67.5170	67.5474	0.0303	0.04%	357.2000	357.2447	0.0447	0.01%

11	47.8771	47.8801	0.0031	0.01%	67.5170	67.5482	0.0312	0.05%	356.9000	356.9422	0.0422	0.01%
12	47.8771	48.8946	1.0175	2.13%	67.5170	67.5557	0.0387	0.06%	356.9000	356.9248	0.0248	0.01%
13	47.8771	47.9170	0.0399	0.08%	67.5170	67.5515	0.0345	0.05%	356.9000	356.9343	0.0343	0.01%
14	47.8771	48.9023	1.0252	2.14%	67.5170	67.5509	0.0339	0.05%	357.2000	358.2510	1.0510	0.29%
15	47.8817	48.9001	1.0185	2.13%	67.5212	67.5470	0.0258	0.04%	517.7000	519.7231	2.0231	0.39%
16	47.8818	47.8932	0.0115	0.02%	67.5205	67.5551	0.0346	0.05%	513.8000	513.8261	0.0261	0.01%
17	47.8815	47.9037	0.0222	0.05%	67.5198	68.5253	1.0055	1.49%	514.1000	514.1107	0.0107	0.00%
18	47.8812	47.9295	0.0483	0.10%	67.5192	68.5481	1.0288	1.52%	519.1000	519.1238	0.0238	0.00%
19	47.8810	47.9173	0.0363	0.08%	67.5187	68.5557	1.0370	1.54%	523.0000	524.0058	1.0058	0.19%
20	47.8809	47.8956	0.0147	0.03%	67.5181	67.5601	0.0420	0.06%	519.7000	520.7050	1.0050	0.19%
21	47.8809	47.8950	0.0140	0.03%	67.5175	67.5570	0.0395	0.06%	514.3000	514.3113	0.0113	0.00%
22	47.8810	47.8855	0.0045	0.01%	67.5168	67.5617	0.0448	0.07%	515.5000	515.5459	0.0459	0.01%
23	47.8810	47.8849	0.0039	0.01%	67.5162	68.5228	1.0066	1.49%	516.3000	517.3044	1.0044	0.19%
24	47.8809	48.9207	1.0397	2.17%	67.5156	67.5662	0.0506	0.07%	514.6000	515.6264	1.0264	0.20%
25	47.8809	47.9215	0.0406	0.08%	67.5150	67.5656	0.0507	0.08%	514.9000	514.9234	0.0234	0.00%
26	47.8809	48.8988	1.0179	2.13%	67.5144	67.5491	0.0348	0.05%	516.2000	517.2142	1.0142	0.20%
27	47.8808	48.9199	1.0391	2.17%	67.5138	67.5177	0.0039	0.01%	518.9000	518.9173	0.0173	0.00%
28	47.8805	47.8847	0.0042	0.01%	67.5132	68.5253	1.0121	1.50%	518.1000	520.1299	2.0299	0.39%
29	47.8801	47.9012	0.0211	0.04%	67.5130	67.5457	0.0327	0.05%	514.1000	515.1421	1.0421	0.20%
30	47.8797	48.9117	1.0320	2.16%	67.5130	67.5453	0.0323	0.05%	511.4000	511.4121	0.0121	0.00%
31	47.8793	47.9150	0.0356	0.07%	67.5134	67.5615	0.0481	0.07%	510.1000	511.1148	1.0148	0.20%
32	47.8792	48.8821	1.0028	2.09%	67.5140	67.5262	0.0122	0.02%	509.0000	510.0468	1.0468	0.21%
33	47.8795	47.8830	0.0036	0.01%	67.5145	67.5199	0.0055	0.01%	507.8000	508.8086	1.0086	0.20%
34	47.8798	48.8924	1.0126	2.11%	67.5148	67.5628	0.0480	0.07%	511.4000	511.4267	0.0267	0.01%
35	47.8800	48.9268	1.0468	2.19%	67.5151	68.5507	1.0356	1.53%	517.0000	517.0330	0.0330	0.01%
36	47.8802	47.8893	0.0091	0.02%	67.5157	68.5276	1.0120	1.50%	519.6000	519.6370	0.0370	0.01%
37	47.8801	47.9178	0.0377	0.08%	67.5163	68.5386	1.0223	1.51%	514.1000	516.1508	2.0508	0.40%
38	47.8800	47.8879	0.0079	0.02%	67.5169	67.5306	0.0136	0.02%	517.6000	518.6193	1.0193	0.20%
39	47.8800	47.9297	0.0497	0.10%	67.5175	67.5415	0.0239	0.04%	518.2000	518.2295	0.0295	0.01%
40	47.8800	47.8880	0.0079	0.02%	67.5181	67.5552	0.0371	0.05%	519.5000	520.5162	1.0162	0.20%
41	47.8801	47.9212	0.0412	0.09%	67.5188	67.5326	0.0138	0.02%	523.0000	524.0091	1.0091	0.19%
42	47.8801	47.9189	0.0389	0.08%	67.5194	68.5565	1.0371	1.54%	525.1000	526.1468	1.0468	0.20%
43	47.8801	47.8880	0.0079	0.02%	67.5200	67.5338	0.0138	0.02%	522.3000	522.3347	0.0347	0.01%
44	47.8801	48.9036	1.0235	2.14%	67.5207	67.5462	0.0255	0.04%	519.1000	519.1506	0.0506	0.01%
45	47.8801	47.8925	0.0124	0.03%	67.5214	68.5583	1.0369	1.54%	523.5000	523.5495	0.0495	0.01%
46	47.8801	47.8932	0.0131	0.03%	67.5220	68.5394	1.0174	1.51%	525.1000	526.1498	1.0498	0.20%
47	47.8800	47.8933	0.0134	0.03%	67.5227	67.5401	0.0174	0.03%	526.8000	527.8038	1.0038	0.19%
48	47.8797	48.8975	1.0178	2.13%	67.5231	68.5328	1.0097	1.50%	526.1000	526.1165	0.0165	0.00%
49	47.8792	47.8908	0.0115	0.02%	67.5232	67.5451	0.0219	0.03%	522.4000	522.4164	0.0164	0.00%
50	47.8788	47.9000	0.0212	0.04%	67.5229	67.5335	0.0106	0.02%	518.5000	518.5383	0.0383	0.01%
51	47.8787	48.9074	1.0287	2.15%	67.5223	67.5487	0.0264	0.04%	515.4000	516.4364	1.0364	0.20%
52	47.8789	47.9252	0.0464	0.10%	67.5217	67.5382	0.0165	0.02%	513.9000	514.9192	1.0192	0.20%
53	47.8791	48.9035	1.0244	2.14%	67.5212	67.5285	0.0072	0.01%	518.8000	519.8361	1.0361	0.20%
54	47.8793	48.8923	1.0130	2.12%	67.5208	67.5703	0.0495	0.07%	527.0000	528.0124	1.0124	0.19%
55	47.8794	48.9292	1.0498	2.19%	67.5202	68.5319	1.0117	1.50%	523.8000	523.8103	0.0103	0.00%
56	47.8793	47.9194	0.0401	0.08%	67.5195	67.5540	0.0345	0.05%	521.2000	522.2282	1.0282	0.20%
57	47.8793	47.9292	0.0499	0.10%	67.5188	68.5230	1.0041	1.49%	524.0000	524.0398	0.0398	0.01%
58	47.8793	47.8832	0.0039	0.01%	67.5181	67.5221	0.0040	0.01%	525.2000	528.2248	3.0248	0.58%

59	47.8793	47.9169	0.0376	0.08%	67.5174	67.5514	0.0340	0.05%	522.9000	523.9322	1.0322	0.20%
60	47.8793	47.9067	0.0274	0.06%	67.5168	67.5470	0.0303	0.04%	521.4000	521.4080	0.0080	0.00%
61	47.8793	47.8961	0.0168	0.04%	67.5161	67.5236	0.0076	0.01%	522.6000	523.6199	1.0199	0.20%
62	47.8793	48.8959	1.0166	2.12%	67.5155	68.5212	1.0058	1.49%	523.8000	524.8058	1.0058	0.19%
63	47.8793	47.8951	0.0158	0.03%	67.5148	67.5374	0.0226	0.03%	523.1000	523.1313	0.0313	0.01%
64	47.8793	47.9154	0.0361	0.08%	67.5142	67.5367	0.0225	0.03%	521.9000	521.9084	0.0084	0.00%
65	47.8792	47.8827	0.0035	0.01%	67.5135	67.5402	0.0267	0.04%	521.1000	522.1182	1.0182	0.20%
66	47.8788	47.8903	0.0115	0.02%	67.5130	67.5183	0.0052	0.01%	518.9000	518.9364	0.0364	0.01%
67	47.8784	48.8870	1.0086	2.11%	67.5128	68.5520	1.0392	1.54%	514.7000	515.7388	1.0388	0.20%
68	47.8779	49.9242	2.0463	4.27%	67.5130	67.5605	0.0476	0.07%	509.7000	510.7340	1.0340	0.20%
69	47.8777	48.9171	1.0395	2.17%	67.5134	68.5548	1.0414	1.54%	505.8000	506.8484	1.0484	0.21%
70	47.8776	48.8997	1.0221	2.13%	67.5140	67.5509	0.0369	0.05%	504.3000	504.3095	0.0095	0.00%
71	47.8779	47.8896	0.0117	0.02%	67.5144	67.5550	0.0406	0.06%	505.0000	505.0104	0.0104	0.00%
72	47.8782	47.9158	0.0376	0.08%	67.5147	67.5396	0.0249	0.04%	511.2000	513.2402	2.0402	0.40%
73	47.8785	48.8962	1.0177	2.13%	67.5151	67.5195	0.0044	0.01%	516.5000	517.5420	1.0420	0.20%
74	47.8786	47.8837	0.0051	0.01%	67.5156	68.5368	1.0212	1.51%	515.8000	515.8089	0.0089	0.00%
75	47.8785	48.8996	1.0211	2.13%	67.5163	67.5403	0.0240	0.04%	513.9000	514.9069	1.0069	0.20%
76	47.8784	47.9091	0.0307	0.06%	67.5169	67.5538	0.0369	0.05%	517.1000	517.1283	0.0283	0.01%
77	47.8784	48.8963	1.0179	2.13%	67.5174	68.5362	1.0188	1.51%	518.0000	518.0403	0.0403	0.01%
78	47.8785	47.8952	0.0167	0.03%	67.5180	67.5225	0.0045	0.01%	517.3000	517.3493	0.0493	0.01%
79	47.8785	47.8878	0.0093	0.02%	67.5186	68.5608	1.0422	1.54%	519.9000	519.9151	0.0151	0.00%
80	47.8785	48.9018	1.0234	2.14%	67.5193	68.5669	1.0476	1.55%	515.5000	515.5244	0.0244	0.00%
81	47.8784	48.8978	1.0194	2.13%	67.5200	67.5333	0.0133	0.02%	516.3000	517.3090	1.0090	0.20%
82	47.8785	47.8816	0.0031	0.01%	67.5206	68.5364	1.0158	1.50%	520.0000	522.0214	2.0214	0.39%
83	47.8785	48.9266	1.0482	2.19%	67.5212	68.5350	1.0138	1.50%	521.4000	521.4258	0.0258	0.00%
84	47.8785	47.9192	0.0407	0.09%	67.5218	67.5366	0.0148	0.02%	520.1000	520.1106	0.0106	0.00%
85	47.8784	47.9140	0.0356	0.07%	67.5224	67.5578	0.0354	0.05%	519.9000	519.9459	0.0459	0.01%
86	47.8781	47.8990	0.0209	0.04%	67.5228	67.5277	0.0049	0.01%	516.9000	517.9433	1.0433	0.20%
87	47.8777	47.8979	0.0202	0.04%	67.5228	67.5567	0.0339	0.05%	507.9000	508.9377	1.0377	0.20%
88	47.8773	47.9068	0.0295	0.06%	67.5224	68.5406	1.0182	1.51%	504.7000	505.7085	1.0085	0.20%
89	47.8773	47.9063	0.0290	0.06%	67.5218	67.5608	0.0390	0.06%	509.0000	509.0043	0.0043	0.00%
90	47.8774	47.9283	0.0508	0.11%	67.5212	67.5248	0.0036	0.01%	509.5000	510.5238	1.0238	0.20%
91	47.8776	47.9033	0.0257	0.05%	67.5207	67.5596	0.0389	0.06%	513.8000	513.8052	0.0052	0.00%
92	47.8777	48.9081	1.0304	2.15%	67.5201	67.5565	0.0364	0.05%	519.0000	520.0415	1.0415	0.20%
93	47.8777	47.8878	0.0101	0.02%	67.5195	67.5222	0.0027	0.00%	518.5000	518.5161	0.0161	0.00%
94	47.8777	47.8822	0.0046	0.01%	67.5189	67.5265	0.0076	0.01%	520.3000	521.3109	1.0109	0.19%
95	47.8777	47.8957	0.0180	0.04%	67.5182	67.5389	0.0206	0.03%	521.5000	521.5281	0.0281	0.01%
96	47.8777	47.8909	0.0132	0.03%	67.5176	68.5394	1.0217	1.51%	519.9000	520.9314	1.0314	0.20%
97	47.8777	47.9227	0.0450	0.09%	67.5170	68.5631	1.0461	1.55%	517.7000	517.7328	0.0328	0.01%
98	47.8777	47.9290	0.0512	0.11%	67.5163	67.5333	0.0169	0.03%	517.7000	518.7373	1.0373	0.20%
99	47.8777	48.8983	1.0205	2.13%	67.5157	67.5269	0.0111	0.02%	518.8000	519.8412	1.0412	0.20%
100	47.8777	48.9057	1.0280	2.15%	67.5151	67.5465	0.0314	0.05%	517.6000	517.6168	0.0168	0.00%
101	47.8777	47.9001	0.0224	0.05%	67.5145	67.5375	0.0230	0.03%	517.0000	517.0477	0.0477	0.01%
102	47.8776	48.8898	1.0122	2.11%	67.5139	67.5614	0.0475	0.07%	515.3000	515.3031	0.0031	0.00%
103	47.8773	47.8843	0.0070	0.01%	67.5133	67.5586	0.0452	0.07%	511.2000	511.2159	0.0159	0.00%
104	47.8769	48.8985	1.0216	2.13%	67.5131	67.5240	0.0110	0.02%	506.2000	506.2144	0.0144	0.00%
105	47.8764	49.8932	2.0168	4.21%	67.5132	67.5250	0.0118	0.02%	504.8000	504.8493	0.0493	0.01%
106	47.8761	48.9068	1.0307	2.15%	67.5137	67.5602	0.0465	0.07%	504.7000	504.7240	0.0240	0.00%

107	47.8760	48.9202	1.0442	2.18%	67.5143	67.5414	0.0271	0.04%	504.8000	505.8174	1.0174	0.20%
108	47.8762	48.8832	1.0069	2.10%	67.5148	68.5347	1.0200	1.51%	506.0000	507.0223	1.0223	0.20%
109	47.8765	48.8858	1.0092	2.11%	67.5151	68.5238	1.0087	1.49%	509.3000	510.3066	1.0066	0.20%
110	47.8768	47.8932	0.0164	0.03%	67.5155	67.5433	0.0278	0.04%	514.3000	514.3387	0.0387	0.01%
111	47.8769	47.8948	0.0179	0.04%	67.5160	68.5544	1.0384	1.54%	513.6000	513.6049	0.0049	0.00%
112	47.8768	47.8995	0.0227	0.05%	67.5166	67.5477	0.0310	0.05%	512.2000	513.2256	1.0256	0.20%
113	47.8768	47.9158	0.0391	0.08%	67.5172	68.5326	1.0154	1.50%	514.7000	515.7281	1.0281	0.20%
114	47.8768	47.9087	0.0319	0.07%	67.5179	68.5479	1.0300	1.53%	513.7000	513.7311	0.0311	0.01%
115	47.8769	47.8816	0.0048	0.01%	67.5185	67.5247	0.0061	0.01%	513.8000	513.8040	0.0040	0.00%
116	47.8769	48.9042	1.0273	2.15%	67.5192	68.5669	1.0477	1.55%	516.3000	516.3253	0.0253	0.00%
117	47.8769	49.8816	2.0047	4.19%	67.5198	67.5407	0.0209	0.03%	516.9000	517.9249	1.0249	0.20%
118	47.8769	47.9025	0.0257	0.05%	67.5204	67.5297	0.0093	0.01%	517.9000	518.9306	1.0306	0.20%
119	47.8769	47.8811	0.0042	0.01%	67.5210	67.5444	0.0234	0.03%	516.6000	516.6403	0.0403	0.01%
120	47.8769	48.8822	1.0053	2.10%	67.5216	67.5660	0.0444	0.07%	512.4000	514.4281	2.0281	0.40%
121	47.8768	47.9244	0.0475	0.10%	67.5221	67.5611	0.0389	0.06%	514.2000	514.2438	0.0438	0.01%
122	47.8766	47.9217	0.0450	0.09%	67.5226	67.5420	0.0194	0.03%	513.5000	514.5417	1.0417	0.20%
Average deviation				0.87%				0.45%				0.12%

The Agisoft PhotoScan software capability was evaluated based on a comparison of the data obtained with the Leica TSO06 total station. As noted earlier, the instrument itself has a level of tolerance (Figure 1), so it is worth paying attention to the smallest and largest values. This problem is extensively discussed in [11], where the object of the study is a specific building with right angles and a flat surface. In our case, the ground, which forms the relief of the object on which the survey was carried out, gives a large error, which is visually reflected in the table above. Minimal error in X-axis was 0.0031, in Y-axis 0.0027 and in Z-axis 0.0031 degrees. Maximum values for X axis was 2.0463, Y axis 1.0477 and Z axis 3.0248 degrees. As expected earlier in the construction of points in the plane difficulties were caused by the triangulation angle, because the scheme of building depends on the geometry of the object, which has no clear reference points in nature. At all this sighting error has a higher priority than instrumental origin and ranges between ±0.3-0.4" in first-class work and ±1" in networks of crowding, which is worth considering when surveying [12]. Similar measurements to confirm the allowable errors were carried out in the article [13] , where the relative error was less than 10%, which corresponds to the real field data. The use of non-metric cameras is quite a serious step for photogravimetry, but correctly chosen software allows to minimize the error range.

A color-coded system was used to indicate the level of difference between the known and obtained coordinates, with green, yellow, and red signifying minimally acceptable, not significant, and maximum critical differences, respectively. The average deviation between the known and Agisoft PhotoScan coordinates was 0.87% in the X-axis, 0.45% in the Y-axis, and 0.12% in the Z-axis. The total station survey took approximately two days to complete for all 122 points, while finding the remaining 121 points only took about three hours due to the process being automated. It should be noted that the time spent working with the software can also be reduced by using a more powerful computer to process the data received from the aircraft.

4. Conclusions

The authors of the article conducted a comparative analysis between traditional and automated processes for determining surveying coordinates. Based on the results of the study, the following conclusions were made:

1. The traditional method allowed for a quick visual estimation of the survey area.
2. The traditional method also allowed for the consideration of terrain peculiarities and existing objects.

3. The automated method provided visualization of the current situation on the construction site.

4. The automated method allowed for an automatic process of coordinate determination using one initial point obtained with a total station.

5. The study revealed some level of inaccuracy in coordinate values when comparing data obtained from the total station and the software.

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