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POSSIBILITIES OF USING THE MOBILE DEVICE VIDOC RTK ROVER FOR THE REAL ESTATE CADASTRE

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Abstract. Measuring work using mobile devices is already an established technology in geodetic practice today. Mobile handheld device are mostly used for surveying and 3D rendering of interior spaces. However, the subject of this paper will be the area of real estate cadastre. This paper aims to verify the capabilities of the viDoc RTK rover handheld geodetic device for real estate cadastre purposes. The paper will focus on surveying activities related to preparing a survey sketch to mark a building on a cadastral map. The actual accuracy of the survey and the efficiency of the measurement will be analyzed. The aim will be to verify and analyze the situation on specific data obtained in real terrain during practical measurements. Experimental measurements will be performed on an atypical object. The results obtained using the viDoc RTK rover will be compared with the results of a combined GNSS and terrestrial survey using a total station. For surveying work in the real estate cadastre in the Czech Republic, it is necessary to use the mandatory coordinate reference system S-JTSK.

Keywords: viDoc RTK rover, building, cadastral map, survey sketch, GNSS-RTK, real estate cadastre.

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1. Introduction

The development of mobile mapping systems and SLAM-based technologies has significantly influenced modern geodetic practice, enabling rapid and efficient acquisition of spatial data. These systems are increasingly used for documenting complex objects, including buildings with irregular geometries (Sammartano & Spanò, 2018; Chen et al., 2018).

However, their application in cadastral surveying remains limited due to strict requirements for positional accuracy and the need for standardized representation of buildings (Paijitprapaporn et al., 2021). In practice, a wide range of building types is encountered, differing in shape, size, and structural complexity. Despite the existence of general rules for surveying and mapping buildings, inconsistencies in their representation in cadastral maps are still observed.

These inconsistencies are often caused by subjective decisions made by surveyors during field measurements and subsequent data processing, particularly when dealing with complex building geometries. As a result, discrepancies may arise between the actual shape of a building and

its representation in cadastral documentation. This highlights the need for more objective, reliable, and comprehensive data acquisition methods (Chen et al., 2018).

Mobile mapping technologies, such as the viDoc RTK rover, offer the potential to capture detailed spatial information in the form of point clouds, enabling a more faithful reconstruction of building geometry. Furthermore, the possibility of processing data in an office environment reduces the need for complex decision-making directly in the field and may significantly improve the efficiency of surveying workflows (Rehak et al., 2025).

However, there is still a lack of studies specifically addressing the accuracy and practical applicability of handheld mobile mapping systems integrated with RTK GNSS in the context of cadastral surveying.

The aim of this paper is to evaluate the positional accuracy of the viDoc RTK rover and to compare its performance with the conventional terrestrial polar method based on experimental measurements carried out under real conditions (Zollini & Marconi, 2025).

2. Realization of experimental measurement

The test object was the Geological Pavilion of Prof. Pošepný situated in the premises of VŠB-TUO. When selecting a building for the experimental measurements, it was important to choose an object that would represent a certain group of buildings in geodetic practice. The aim was to select an atypical building, with the walls of the building overlapping the terrain. The term “atypical object” refers to a building with complex geometry, including overhanging structures and irregular shapes, which may negatively influence both traditional surveying and photogrammetric data acquisition. Such buildings are encountered more and more often. Thus, the Geology Pavilion building, with its shape, number of points, and complexity of plan, offered itself as a suitable building for testing.

According to the valid regulations in the area of the cadastre, the change to be measured must be linked to the binding coordinate system S-JTSK (Datum of Uniform Trigonometric Cadastral Network) without exception. Therefore, for each measurement for the purposes of the land registry, it is necessary to carry out activities related to connecting the site to the binding S-JTSK reference system (Staňková & Černota, 2012).

The application of measurement work with handheld devices in general is not usually associated with referencing a binding coordinate system. In most cases, we make do with the results in the local coordinate system of the device. However, if we were to consider the possibilities of using this technology for cadastral purposes, the reliable connection of the resulting point cloud would be one of the core tasks of the whole workflow. The test object is shown in Figure 1.



Figure 1. Test object – geological pavilion of Prof. Pošepný

Based on the above, a workflow for the field measurement work was proposed. The workflow was chosen in such a way that its widespread implementation could be considered regardless of the specifics of the site of interest. Other requirements for the workflow include simplicity and clarity for any surveyor with previous experience in land registration (Popov, 2019).

As part of the Geology Pavilion test measurements, the paper was extended to test a pair of ground control point types. Black and white ground control points, designated as Type B, and red and white Type A ground control points were acquired. An example of the ground control points is shown in Figure 2.

The ground control points were evenly spaced in the vicinity of the object according to the general geometric principles in geodesy. The coordinates of the individual points were determined twice independently by GNSS technology using the RTK method. The GNSS equipment chosen for the measurements was a Leica GS18 T receiver and a Leica CS20 controller (Hofmann-Wellenhof et al., 2008).

The test measurement was carried out with the viDoc RTK rover mobile device. The advantages of this system, in particular the linking of the acquired data to a binding reference system in real time using the RTK method. This fact could significantly contribute to and streamline activities related to scanning objects for the purposes of the real estate cadastre. The actual implementation of the surveying work consists of preparing the entire scanning system before the measurement. It is necessary to physically connect the viDoc RTK rover to the iPhone 14 mobile device using the SP connector and connect it wirelessly via Bluetooth technology. Since this is a GNSS device which allows the reception of RTK corrections in real time, similar to a regular GNSS receiver in geodetic practice, it is necessary to ensure mobile data services via a data SIM card. The reception of corrections is ensured using the NTRIP service linked to the network solution of permanent reference stations CZEPOS. The field measurement workflow included the following steps, illustrated in Figure 3.

Terrain data were captured using mobile photogrammetry combined with the viDoc RTK rover. According to the manufacturer, the device provides a practical absolute accuracy of approximately 5 cm in 3D models, while supporting multi-constellation GNSS (GPS, GLONASS, BeiDou, Galileo) and compact dimensions (153 × 72 × 19 mm, 242 g), making it suitable for rapid and reliable



Figure 2. Type of ground control points

field measurements. GNSS antenna provides theoretical position accuracy of up to 1 cm + 1 ppm and height accuracy of 1 cm + 1 ppm (Plesnik et al., 2023).

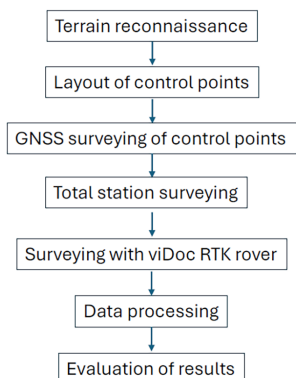


Figure 3. Field measurement workflow

The measuring process in the field consists of launching the application, where it is possible to select image capture intervals as part of the measurement parameter settings. Setting these parameters is very important and it is advisable to pay sufficient attention to it. The set values of these parameters will ultimately determine how often the device will take images, thus directly affecting the number of images taken and, in essence, the time required for subsequent processing. If we set, for example, a distance of 30 cm and an angle of 20°, this will result in an image being taken and fixed when the position changes by 30 cm or the inclination of the device by 20°. The parameter settings must be balanced with respect to the expected or required accuracy, quality, and density of the resulting data. Of course, it is also necessary to take into account that the set parameters ensure a reliable solution and evaluation of the measured data based on photogrammetric principles. Therefore, it is necessary to set a sufficient image overlap. During test measurements, scanning was performed with various configurations of the above parameters.

Based on initial test measurements, it was determined that the optimal configuration in the case of using the results for the purposes of the real estate cadastre could be around 20 to 40 cm in the distance parameter and 20° to 30° angular changes. With these parameters, there was usually no problem with data evaluation, the amount of acquired data was adequate, and the resulting models were of sufficient quality. With lower values, it was necessary to process an unnecessarily large amount of data, which did not significantly affect the quality of the results. On the contrary, if the aforementioned parameters were increased, it may happen that the measured data will be insufficient and will not cover the resulting 3D models or point clouds in sufficient quality (Labant & Weiss, 2012).

This technology has the potential to perform measurements and geolocation of images without the need to use fitting points. Nevertheless, fitting points were used in the test measurements. The scanning time is directly

dependent on the size of the object, the complexity of the object and the walking speed. In the case of this object, the scan time was between 2 and 3 minutes. It should be noted that in processing the results so far, it was found that there was no need to purposely slow down the walking. This time is incomparable to the time of a classical terrestrial measurement, where for this more complex object it was necessary to select five stations and the whole measurement process, including connection to the binding reference system S-JTSK, amounted to two hours.

The 30 × 30 cm checkerboard ground control points are commonly used in aerial photogrammetry in the application of unmanned aerial vehicle technology and as ground control points in measuring with viDoc RTK rover. Ground control points are made of hardened plastic in black and white. As it is necessary to stabilize the points so that the same position of the control target is ensured throughout the measurement period, partial adjustment and addition of the purchased ground control points was started. The lower part of the threading point was supplemented with a cylinder-shaped preparation into which a threaded hole was made. A steel mandrel is screwed into this hole, which will enable a reliable and stable securing of the ground control point in the field during the entire scanning period, including its subsequent targeting by the GNSS-RTK receiver. The fixtures used to anchor the insertion points to the terrain were designed and manufactured on a 3D printer directly at the Department of Geodesy and Mining Surveying in Ostrava. An example of the solution can be seen in Figure 4.



Figure 4. Ground control points – technical solution and GNSS measurements

When working with the device, it is necessary to adapt the measuring trajectory to the object to be measured, taking into account the theoretical range of the handheld device. According to the technical parameters and based on personal experience with the viDoc RTK rover we can state that the real reliable usable range of the handheld scanner is around 50 meters. These facts must be taken into account not only in the scanning process, but especially in the activities related to the placement of the ground control points. During the entire measurement campaign, the GNSS solution remained in “Fixed” mode for 100% of the observation time, ensuring centimetre-level positioning accuracy. It should be noted that the accuracy of the viDoc RTK rover is influenced by environmental conditions,

particularly GNSS signal quality and sky visibility (Mikoláš et al., 2013).

It is therefore highly desirable to carefully consider the positions and placement of the ground control points not only in relation to the object to be measured but also to the planned measuring route (Sužiedelytė-Visockienė, 2012). The measurement must be done in such a way that the resulting point cloud contains the measured object, including all the ground control points (Annok et al., 2021). Working with viDoc RTK rover can be seen in Figure 5.



Figure 5. Measuring process in the field with viDoc RTK rover

Figure 6 shows the number and location of the auxiliary points of the measurement network from which the reference terrestrial orientation was carried out using the polar method, which documents the time-consuming nature of the classical procedure. Furthermore, the approximate trajectory using a handheld scanner and the spatial relationship between the chosen scan trajectory, the ground control points and the object of measurement are indicated.

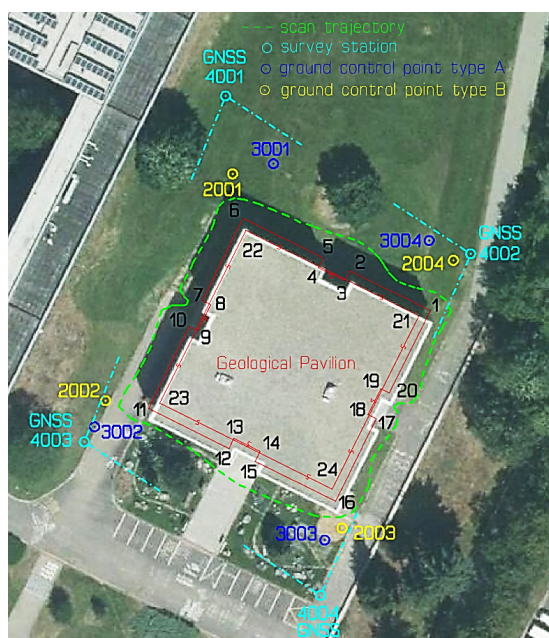


Figure 6. Situational plan

The tested objects were also targeted by commonly established procedures in the field of real estate cadastre. Individual points on the perimeter of the building were focused using the terrestrial polar method, which is well-established in the literature (Ghilani, 2017). The terrestrial survey served as a reference measurement for subsequent evaluation and analysis of the accuracy of the procedures used.

To evaluate the performance of the ViDoc RTK rover in comparison with the terrestrial polar method, several evaluation metrics were defined. The assessment is based on coordinate differences between the reference measurements and the results obtained using the ViDoc RTK rover, expressed as Δx and Δy . The measurement accuracy was evaluated using standard deviations where σ_x and σ_y represent standard deviations in individual coordinate components, σ_{xy} is the combined positional standard deviation, and σ_p expresses the planar positional deviation. The positional accuracy is quantified using mean coordinate errors and Root Mean Square Errors (RMSE) in individual coordinate components. A combined positional error is subsequently derived to express the overall planar accuracy. These metrics are commonly used in geodetic practice and enable an objective comparison between different measurement methods in terms of positional accuracy and reliability.

3. Processing of measured data

A key step towards the successful use of the measured data for cadastral purposes will be the georeferencing of the 3D point cloud into the S-JTSK binding reference system. If this computational step could not be implemented for some reason, it would completely preclude the use of this measurement for making a geometric plan. The transformation of the 3D point cloud is carried out by means of ground control points located e.g., by GNSS technology (Sužiedelytė-Visockienė & Bručas, 2012). The processing of the measured data including the transformation was performed with the Pix4D mapper software (Mudička & Kapica, 2023). After successful transformation of the 3D point cloud, the coordinates from the 3D point cloud were offset in Leica Infinity. An example of measured data processing is shown in the Figure 7.

4. Results

The results are evaluated using the metrics defined in the previous section. The results of the experimental measurements are summarized in Tables 1–2 below. A total of 24 points were tested, with the majority of points consisting of atypical building overhangs above the ground. Terrestrial surveying was carried out from four sites, with the time required for terrestrial surveying being approximately 2 hours of measurement time. Scanning with the viDoc RTK rover took approximately 3 minutes, the processing process took less than 13 minutes and 580 images were pro-



Figure 7. Point cloud in Leica Infinity

cessed. Georeferencing to the binding reference system was successful, the transformation accuracy was favorable the spatial mean transformation error reached 0.024 m.

To compare the coordinates of the selection of detailed points, the coordinate differences are calculated, where y_m and x_m are the resulting coordinates of the detailed point determined by the terrestrial polar method and y_k , x_k are the coordinates of the same point as the results of the above-described procedure of determining these points by viDoc RTK rover. The mean sampling coordinate error $RMSE_{xy}$ is calculated as the quadratic mean of the mean coordinate errors $RMSE_x$, $RMSE_y$, which are determined from the following formulas. The Root Mean Square Errors in the X and Y directions were calculated using standard formulas. In addition to $RMSE$, the standard deviations in the individual coordinate components (σ_x , σ_y) and the combined standard deviation (σ_{xy}) were calculated to further assess the positional accuracy (e.g., Mikhail et al., 2001).

$$RMSE_x = \sqrt{\frac{1}{k \cdot N} \sum_{i=1}^n \Delta x_i^2}; \quad RMSE_y = \sqrt{\frac{1}{k \cdot N} \sum_{i=1}^n \Delta y_i^2}; \quad (1)$$

$$RMSE_{xy} = \sqrt{\frac{RMSE_x^2 + RMSE_y^2}{2}}; \quad (2)$$

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n \Delta x_i; \quad (3)$$

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n \Delta y_i; \quad (4)$$

$$\sigma_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (\Delta x_i - \bar{\Delta x})^2}; \quad (5)$$

$$\sigma_y = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (\Delta y_i - \bar{\Delta y})^2}; \quad (6)$$

$$\sigma_{xy} = \sqrt{\frac{\sigma_x^2 + \sigma_y^2}{2}}. \quad (7)$$

In relation is N equal to the number of points in the selection and k is equal to 2 if the control determination has the same accuracy as the position measurement, or is equal to 1 if the control measurement has a higher accuracy. $Dy = y_m - y_k$ and $Dx = x_m - x_k$ are the deviations, the coordinate differences between the terrestrially determined coordinates and the coordinates that were determined by laser scanning technology. The sampling mean coordinate error reached $m_{xy} = 0.028$ m in the case of viDoc RTK rover measurements.

The correlation coefficient was $r = 0.3$, indicating a weak positive correlation between the coordinate components. However, for cadastral applications, the decisive criterion is the magnitude of positional deviations and their compliance with the required accuracy standards. In this context, the achieved coordinate differences meet the accuracy requirements for cadastral surveying (Jiroušek et al., 2014).

Figure 8 illustrates the graphical representation of the deviation vectors between the viDoc RTK rover and terrestrial measurements. The vectors indicate both the magnitude and direction of positional differences at individual

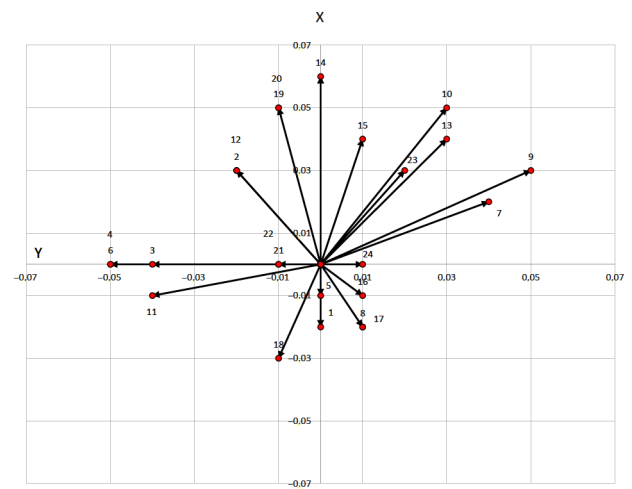
Table 1. Results achieved viDoc RTK rover

Test object – Geological pavilion of Prof. Posepny							
Point number	viDoc RTK rover		Terestricky		Diferences		
	y [m]	x [m]	y [m]	x [m]	Δy [m]	Δx [m]	Δp [m]
1	479137.50	1101213.28	479137.50	1101213.26	0.00	−0.02	0.02
2	479150.72	1101206.68	479150.70	1101206.71	−0.02	0.03	0.03
3	479151.52	1101208.36	479151.48	1101208.36	−0.04	0.00	0.04
4	479155.85	1101206.23	479155.80	1101206.23	−0.05	0.00	0.05
5	479154.99	1101204.62	479154.99	1101204.61	0.00	−0.01	0.01
6	479168.21	1101198.11	479168.16	1101198.11	−0.05	0.00	0.05
7	479174.81	1101211.56	479174.85	1101211.58	0.04	0.02	0.05
8	479173.45	1101212.30	479173.46	1101212.28	0.01	−0.02	0.02
9	479175.50	1101216.48	479175.55	1101216.51	0.05	0.03	0.06
10	479176.97	1101215.79	479177.00	1101215.84	0.03	0.05	0.06
11	479183.68	1101229.32	479183.64	1101229.31	−0.04	−0.01	0.04
12	479170.46	1101235.84	479170.44	1101235.87	−0.02	0.03	0.04
13	479169.66	1101234.21	479169.69	1101234.25	0.03	0.04	0.05
14	479165.37	1101236.30	479165.37	1101236.36	0.00	0.06	0.06
15	479166.19	1101237.96	479166.20	1101238.00	0.01	0.04	0.04
16	479153.00	1101244.52	479153.01	1101244.51	0.01	−0.01	0.02
17	479146.31	1101231.04	479146.32	1101231.02	0.01	−0.02	0.02
18	479147.71	1101230.34	479147.70	1101230.31	−0.01	−0.03	0.03
19	479145.63	1101226.03	479145.62	1101226.08	−0.01	0.05	0.05
20	479144.20	1101226.70	479144.19	1101226.75	−0.01	0.05	0.05
21	479139.38	1101214.11	479139.37	1101214.11	−0.01	0.00	0.01
22	479167.70	1101200.10	479167.69	1101200.10	−0.01	0.00	0.01
23	479181.82	1101228.46	479181.84	1101228.49	0.02	0.03	0.04
24	479153.50	1101242.53	479153.51	1101242.53	0.01	0.00	0.01

points. The graphical representation confirms that most deviations are small and randomly distributed, without significant systematic trends, which is consistent with the computed accuracy indicators.

Table 2. RMSE and standard deviation of measurement differences

Statistic	Value [m]
Std. deviation in Y (σ_y)	0.027
Std. deviation in X (σ_x)	0.027
Combined std. deviation (σ_{xy})	0.027
RMSE _y	0.026
RMSE _x	0.029
RMSE _{xy}	0.028

**Figure 8.** Deviation vectors between viDoc RTK and terrestrial measurements

5. Discussion

The red and white ground control points are also reliably identifiable in point clouds despite their smaller size (20 x 20 cm), but the checkerboard targets in black and white are clearly more impressive in point clouds. Here, the resulting contrast is quite unambiguous and the marking of such an insertion point is more reliable and simpler. Even so, some experience is necessary when working with point clouds.

Another important factor that can to some extent influence the resulting quality of the georeferencing into a binding coordinate system and consequently the whole measurement result is the shadows of the building. When carrying out the measurement work, it is advisable to take into account the current lighting conditions and the orientation of the sunlight or cast shadows of the building. It is advisable to place the aiming points on the illuminated part of the terrain. If they were signalled at locations where shadow falls, these points would be more difficult to identify. Ultimately, this could have a negative impact on the resulting accuracy of the transformation. Especially when using a viDoc RTK rover, where the point cloud does not exhibit the same quality as a static scanner. Also shows a higher level of noise in the trajectory of the moving scanner due to the movement of the meter. Therefore, it is desirable to choose the position for the ground control points appropriately and to adjust the trajectory of the handheld scanner so that the ground control points are not overwhelmed by unwanted noise. An example of the ground control points is in Figure 9, where you can see ground control point type A on the right and type B on the left.

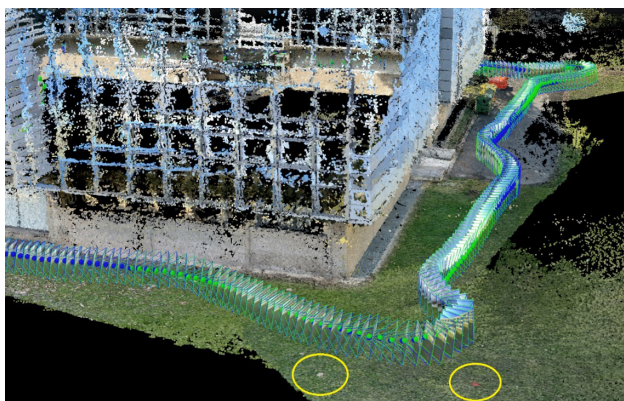


Figure 9. Ground control points in point cloud in Pix4Dmapper

It is also essential to highlight the importance of conducting a preliminary site inspection prior to the actual measurement process. This preparatory phase plays a crucial role in planning the optimal measuring route, selecting appropriate equipment, and identifying areas that may pose a risk of reduced measurement accuracy. In practice, insufficient preparation often results in lower quality output data, particularly in areas that are shaded, obstructed,

or difficult to access. Another significant factor influencing the measurement quality is the current lighting conditions and the orientation of the scanning trajectory in relation to the sun (Naminat & Palamar, 2019). These aspects are especially critical when using mobile devices, where measurement accuracy may vary considerably depending on the direction of the operator's movement and external environmental conditions. Therefore, survey measuring should always be adapted to the specific characteristics and constraints of the measured object to ensure the highest possible data quality and minimize systematic errors. Figure 10 shows the problematic areas.



Figure 10. Problematic points on the building

6. Conclusions

The viDoc RTK rover provides a practical measurement accuracy of approximately 5 cm, making it favorable for cadastral surveying purposes. There were a total of 24 detailed points on the Geology Pavilion test object. The results of the deviations obtained using the manual scanning with the viDoc RTK rover are favourable for land registry purposes. Points 9, 10 and 14 show the lowest accuracy. The most susceptible parts of the tested objects are the inner corners of the building, with shorter dimensions of the masonry plan. In the case of the Geology Pavilion, other factors were also negatively affected. In particular, a technical element in the form of an exit evacuation ladder, installed directly on the building to be surveyed. Already when viewing the point cloud, the situation in the vicinity of detail point 9 was negatively affected by the presence of the exit ladder and the position of the point was not as clear as it was for detail points in other parts of the building.

In the case of measurements with mobile devices such as the viDoc RTK rover, it is important to determine the measuring direction relative to the object being measured and the current illumination of the object. Before the actual measurement, a thorough reconnaissance should be carried out. Based on a well performed reconnaissance of the building, we will get an overview of which parts of the building will need to be measured with increased care, critical areas, where there are potential obstacles,

how complex the building layout is, in which direction the building casts a shadow, etc. If we do not carry out these activities and start scanning immediately, we are unable to take these facts and circumstances into account when scanning. Very often, this thoughtless and incorrect measuring procedure will then have a negative impact on the final accuracy and quality of the overall work. The precision achieved is undoubtedly satisfactory for land registry purposes. In the Czech Republic, the required accuracy is characterised by a primary mean coordinate error of 0.14 m. The limit is the error twice the primary error.

Several factors were identified that negatively affect the resulting measurement accuracy and usability. The most critical areas include inner corners with shorter masonry dimensions, obstacles such as the exit ladder, and measurement conditions including illumination and scanning direction. In our measurements, points 9, 10, and 14 exhibited the largest deviations, illustrating the impact of these factors. Proper reconnaissance, planning of scanning direction, and awareness of obstacles can mitigate these influences, ensuring that the measurements remain suitable for cadastral purposes.

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Author contributions

Tereza Jadviščoková and Petr Jadvišček carried out the field survey work. Petr Jadvišček performed the data analysis.

Disclosure statement

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References

- Annok, G., Tammin, V., & Liba, N. (2021). Mobile laser scanning elevation data accuracy in closed and partially open sky area. *Geodesy and Cartography*, 47(1), 21–26. <https://doi.org/10.3846/gac.2021.12044>
- Chen, Y., Tang, J., Changhui, J., Zhu, L., Lehtomäki, M., Kaartinen, H., Kaijaluo, R., Wang, Y., Hyyppä, J., Hyyppä, H., Zhou, H., Pei, L., & Chen, R. (2018). The accuracy comparison of three simultaneous localization and mapping (SLAM)-based indoor mapping technologies. *Sensors*, 18(10), Article 3228. <https://doi.org/10.3390/s18103228>
- Ghilani, C. D. (2017). *Adjustment computations: Spatial data analysis* (6th ed.). Wiley. <https://doi.org/10.1002/9781119390664>
- Hofmann-Wellenhof, B., Lichtenegger, H., & Wasle, E. (2008). *GNSS – Global Navigation Satellite Systems: GPS, Glonass, Galileo, and more*. Springer.
- Jiroušek, T., Kapica, R., & Vrublová, D. (2014). The testing of photostan 3D object modelling software. *Geodesy and Cartography*, 40(2), 68–74. <https://doi.org/10.3846/20296991.2014.930251>
- Labant, S., & Weiss, G. (2012). Analysis of a simulation of missing satellite observations in the deformation network. *Acta Montanistica Slovaca*, 17(3), 158–166.
- Mikhail, E. M., Bethel, J. S., & McGlone, J. C. (2001). *Introduction to modern photogrammetry*. Wiley.
- Mikoláš, M., Dandoš, R., & Subiková, M. (2013). Measuring shifts base to calibrate test equipment GNSS. *Geodesy and Cartography*, 39(1), 1–6. <https://doi.org/10.3846/20296991.2013.786870>
- Mudička, Š., & Kapica, R. (2023). Digital heritage, the possibilities of information visualisation through extended reality tools. *Heritage*, 6(1), 112–131. <https://doi.org/10.3390/heritage6010006>
- Naminat, O., & Palamar, A. (2019). A field surveying on the geodetic control of engineering linear structures using a terrestrial laser scanner. *Geodesy and Cartography*, 45(2), 49–56. <https://doi.org/10.3846/gac.2019.6255>
- Paijitprapaporn, C., Thongtan, T., & Satirapod, C. (2021). Accuracy assessment of integrated GNSS measurements with LiDAR mobile mapping data in urban environments. *Measurement: Sensors*, 18, Article 100078. <https://doi.org/10.1016/j.measen.2021.100078>
- Plesník, J., Staňková, H., & Černota, P. (2023). Use of TLS technology in highway construction. *Geodesy and Cartography*, 49(1), 1–11. <https://doi.org/10.3846/gac.2023.15796>
- Popov, A. (2019). Land cadastre development in Ukraine: Issues to be addressed. *Geodesy and Cartography*, 45(3), 126–136. <https://doi.org/10.3846/gac.2019.7121>
- Rehak, M., Cucci, D., Magnin, J.-B., & Strecha, C. (2025). Accurate mapping of subterranean structures with mobile phones. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-G-2025, 1269–1275. <https://doi.org/10.5194/isprs-archives-XLVIII-G-2025-1269-2025>
- Sammartano, G., & Spanò, A. (2018). Point clouds by SLAM-based mobile mapping systems: accuracy and geometric content validation. *Applied Geomatics*, 10, 317–339. <https://doi.org/10.1007/s12518-018-0221-7>
- Staňková, H., & Černota, P. (2012). A principle of forming and developing geodetic bases in the Czech Republic. *Geodesy and Cartography*, 36(3), 103–112. <https://doi.org/10.3846/gc.2010.17>
- Sužiedelytė-Visockienė, J. (2012). Photogrammetry requirements for digital camera calibration applying Tcc and MatLab software. *Geodesy and Cartography*, 38(3), 106–110. <https://doi.org/10.3846/20296991.2012.728895>
- Sužiedelytė-Visockienė, J., & Bručas, D. (2012). Digital photogrammetry for building measurements and reverseengineering. *Geodesy and Cartography*, 35(2), 61–65. <https://doi.org/10.3846/1392-1541.2009.35.61-65>
- Zollini, S., & Marconi, L. (2025). Evaluation of positioning accuracy using smartphone RGB and LiDAR sensors with the viDoc RTK rover. *Sensors*, 25(13), Article 3867. <https://doi.org/10.3390/s25133867>