Accuracy of UAV based data collection (case studies)

Balázsik Valéria – Dr. Tóth Zoltán*
* Óbuda University, Alba Regia Technical Faculty of Technology of the Institute of Geoinformatics, Székesfehérvár, Hungary
toth.zoltan@amk.uni-obuda.hu

Abstract — Nowadays many new data acquisition technologies have been appeared. Due to the increasingly advanced digital devices, high resolution cameras and utility of fast processing, Unmanned Aerial Vehicles (UAV) have become a prominent feature of the various remote sensing procedures. In the past, UAVs were only available for military purposes but over the last decade the 'drone' equipment has become easily accessible to everybody. While in the past photogrammetry was only used by qualified professionals, it is now applied successfully in many fields. Even though UAVs are widespread in surveying practice too, the related accuracy issues are not determined regularly. The manufacturing companies may calibrate the instruments of the device one by one, e.g. camera, GNSS receiver, in which way the nominal precision of an UAV, as an integrated system can be derived considering the error propagation law. However, in the practice the actual precision may notably differ from the nominal one, caused by different internal and external effects, such the flying stability of the device (platform), weather conditions, features of the observation object, etc. Because the benefits of the technology may justify the use of data in topographic mapping, cadastral mapping or even engineering geodesy, we have conducted studies to determine the accuracy that can be achieved using UAV as an integrated data acquisition tool. First, we developed a test field in rural area for investigations. The results of the test flights conducted there were determined that what conditions influence the accuracy of the survey. In addition, cadastral measurements were performed in the populated area using UAV and GNSS technologies and the results were compared with digital cadastral map data. Investigating the feasibility of engineering geodetic applications, we have performed an artificial surface survey using UAV technology. The results and conclusions of these studies are presented in this article.

I. INTRUDUCTION

Nowadays, UAV technology has become part of everyday practice for certain applications. In our previous articles we have provided examples in archeology [4] and mining [6]. After analysing the test measurements, we present two additional practical examples in which UAV technology has been applied. The studies are based our students' thesis works [2, 5].

II. CREATING A LARGE SCALE ENGINEERING MAP

In many engineering applications, the high relative reliability of height data is important. These technologies are typically slow and costly measurements such as levelling or conventional surveying, and usually deliver low resolution map. The purpose of our study is to determine the data accuracy and reliability of data acquisition using UAV, and to answer the question that the short range and high number of overlaps UAV technology may replace the traditional surveying for engineering geodetic tasks. In the example shown on Figure 8, measurements were made on a test field in a horizontal parking lot. From 4 positions (red dots), 6 photogrammetry GCP (yellow dots) and 35 test points were determined conventionally by a total station survey in a local network, which after has been adjusted and inserted into the national reference system of Hungary (Fig. 1).

Figure 1. Test field with point marks in a parking lot [2]

Each test point was determined by as many redundant measurements as possible. The results of a purely total station survey were determined by adjustment as an independent network. Network-specific statistics are listed in the Table 1.

	ΔY[mm]	ΔX[mm]	ΔH[mm]
average	2,4	2,5	0,7
maximum	3,8	3,7	1,3

Table 1. Residual errors after the adjustment [2]

The data in Table 1 show that the network is one order of magnitude more accurate than one would expect from a photogrammetric survey, so it may be suitable for examination. The images were taken with a vertical camera axis, 80% overlapping in-line and inter-row directions, with a low, 29 m flight altitude and an estimated 0.9 cm/pixel geometric resolution. In addition, oblique images (with 60-degree camera axis) and lower altitude images were taken with a smaller, approximately 60% overlapping (Fig. 2). Processing was done with Agisoft Photoscan, using the conventional steps (image alignment, point cloud generation, absolute orientation, surface generation, orthophoto generation). 6 GCPs were added to process. The residual errors of GCP on the georeferenced model were less than 1 cm. In order to compare the results of the traditional and the photogrammetric surveys, the point cloud was displayed in a general-purpose commercial CAD program supplemented with orthophoto mosaic of the area (Figure 3). Test points were manually selected for comparison, thus, of course, the results are also influenced by the quantization of the point cloud.

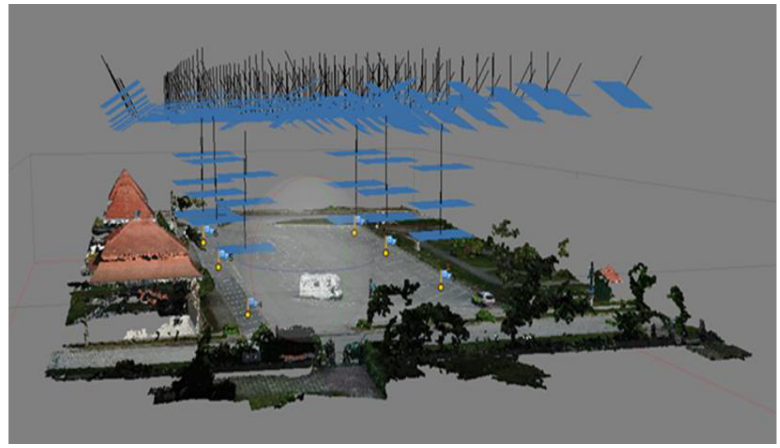

Figure 2. The location and position of images [2]

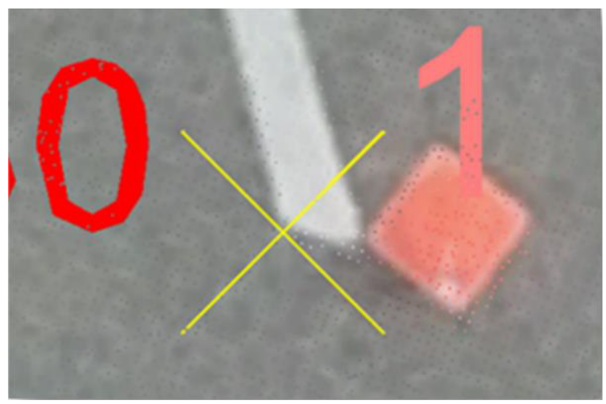

Figure 3. The location and position of images [2]

Table 2. summarizes the typical coordinate deviations of the test points measured by the ground survey and determined by UAV technology.

	ΔY[m]	ΔX[m]	ΔH[m]
average	0,012	0,012	0,007
RMS	0,009	0,008	0,004
maximum	0,044	0,031	0,018

Table 2. Deviations on the test points by processing all images [2]

The processing of the photogrammetric survey was repeated using only images with vertical axis (nadir images) and significantly less favourable results were obtained (Table 3).

	ΔY[m]	ΔX[m]	ΔH[m]
average	0,049	0,061	0,063
maximum	0,098	0,199	0,103

Table 3. Deviations on the test points by processing only nadir images [2]

The results obtained with photogrammetric processing are clearly improved by the favourable arrangement of the images. Table 2 shows the reliability achieved with UAV technology, which practically determines its reliable applications. Based on the values obtained, general-purpose surveys can definitely be replaced by this technology. The further advantages of the UAV technology are that the resolution of survey is better, and the time required for the survey is significantly less than conventional (see polar survey) methods. For high-accuracy surveys, additional oblique images can improve the accuracy to achieve the expected quality.

III. UAV TECHNOLOGY IN CADASTRAL MAPPING

In many countries of the world, including Hungary, no digital cadastral maps for the entire country, made by a new survey is available [7, 8]. At those regions of the country where a new survey for digital mapping has not been conducted, older analog maps have been digitized. However, older maps were made in different projection systems, so besides the digital transformation, they had to be transformed into the currently used national projection system. Thus, in addition to errors of drawing and digitizing of the analog maps, the transformation procedure also resulted errors in the data of the digital map. While the reliability of the parcels of the new survey digital cadastral maps is appr. ±9 cm, the reliability of the corner points of the buildings is appr. ±15 cm; nevertheless, in the case of digitized, projected old analog maps these values can be up to meters. UAV photogrammetry can produce not only high-resolution orthophotos but also 3-dimensional surface models. This can be used to measure the walls of buildings, which were not usually seen on orthophotos produced using traditional aerial photogrammetry, due to the overhang the roof.

Figure 4. Dense cloud of the area [5]

Our investigations were carried out on a rural block containing 20-30 land parcels. At low flight altitudes of 35 m were taken images, with overlapping 75% in-line and 65% inter-row directions. As in the previous example, in addition to vertical axis images, oblique images also were made with ~65°. With a GNSS receiver, we measured 9 GCP for photogrammetric processing and also determined the boundaries of the parcels. The dense spot cloud of the area (Figure 4) was produced by the usual processing method and its orthophoto mosaic (Figure 5) for further examination.

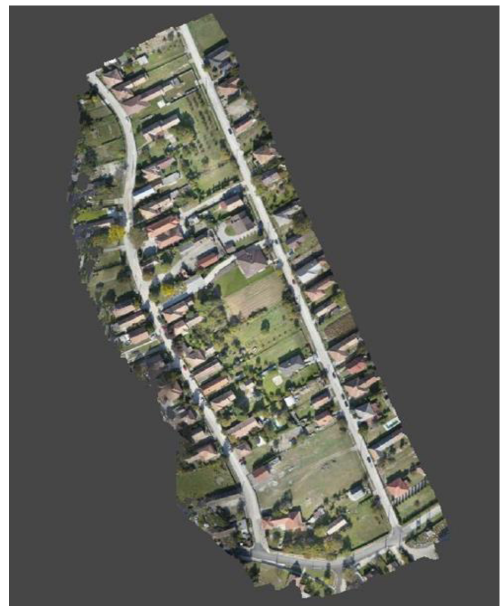

Figure 5. Orthophoto mosaic of the block [5]

Our aim was to investigate that the resulting orthophoto is suitable to replace the cadastral survey. We studied how reliably the elements to be mapped (eg. fence corners) can be identified and how accurate and efficient the technology is. To do this, parcel by parcel we compared the map elements measured by the conventional method and identified from the orthophoto (Fig. 6). The Table 4, 5 and 6 show some typical values.

Figure 6. Cadastral map displayed on orthophoto [5]

	GNSS		UAV			
id 112	**Y**	**X**	**Y**	**X**	**ΔY**	**ΔX**
239	638738,80	196847,22	638738,70	196847,22	0,10	0
231	638748,77	196822,08	638748,67	196822,07	0,10	0,01
237	638711,63	196798,56	638711,55	196798,49	0,08	0,07
238	638697,28	196821,32	638697,20	196821,35	0,08	-0,03

Table 4. [5]

	GNSS		UAV			
id 129/ 1	**Y**	**X**	**Y**	**X**	**ΔY**	**ΔX**
131	638603,50	196973,68	638603,58	196973,61	-0,08	0,07
132	638604,52	196959,52	638603,58	196959,53	-0,07	-0,01
138	638646,62	196981,67	638646,70	196981,62	-0,08	0,05
140	638639,59	196993,46	638639,62	196993,54	-0,03	-0,08

Table 5. [5]

	GNSS		UAV			
id 131	**Y**	**X**	**Y**	**X**	**ΔY**	**ΔX**
102	638603,29	197032,63	638603,23	197032,61	0,06	0,02
119	638655,92	197060,91	638655,84	197060,96	0,08	-0,05
125	638606,77	196992,04	638606,69	196992,06	0,08	-0,02
120	638668,68	197026,59	638668,75	197026,60	-0,07	-0,01

Table 6. [5]

According to the Tables, it can be concluded that the magnitude of the deviations is within the tolerance expected from cadastral surveys. Note that these values are significantly influenced by the reliability of the detail point identification. Due to the nature of some elements, this technology is not, or only partially applicable.

CONCLUSIONS

In this article we have presented accuracy estimates of UAV survey based on image matching photogrammetry. Accuracy estimate has also been presented for two relatively less investigated applications (surveying for cadastral, and large scale engineering map). Beyond the known accuracy results, the technology can provide a good basis for cost requirements of the survey. Based on the results of the test measurements and it's low cost, the technology is expected to spread in many areas.

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