USE OF UAV IN CADASTRAL MAPPING OF THE CZECH REPUBLIC

V.Šafář[1], M.Potůčková[2], J.Karas[3], J.Tlustý[4], E.Štefanová[2], M.Jančovič[2], D. Cígler Žofková[5]

[1]VSB - Technical University of Ostrava, Faculty of Mining and Geology, Department of Geodesy and Mine Surveying, Ostrava-Poruba, 708 00, 17. listopadu 2172/15, Czech Republic

[2] Charles University, Faculty of Science, Department of Applied Geoinformatics and Cartography, 128 43, Albertov 6, Prague 2, Czech Republic

[3]Upvision Ltd., 158 00, Klikatá 18, Praha 5 – Jinonice, Czech Republic

[4] Cadastral Office for the region Plzeň, Radobyčická 2465/12, 30100, Jižní Předměstí Plzeň, Czech Republic

[5] Czech technical university in Prague, Faculty of Civil Engineering, Department of Building Structures, 166 29, Thákurova 7, Praha 6, Czech Republic

Correspondence to: V.Šafář[1] (vaclav.safar@vsb.cz)

Abstract

The main challenge in the new mapping and updating the cadastre of the Czech Republic is to achieve maximum efficiency but to retain the required accuracy of 0.14m in position of all points in the register. The article discusses possibility of using UAV photogrammetry and laser scanning for cadastral mapping of the Czech Republic. Point clouds from images and laser scans together with orthoimages were acquired over seven test areas. Control and check points were measured by geodetic methods (GNSS-RTK, total stations). The accuracy of detailed survey based on UAV technologies was checked on a thousand of points, namely building corners and points on fences. The results show that the required accuracy of 0.14m was achieved on more that 80% of points in the case of the image point clouds and orthoimages and on 98% in the case of LiDAR point cloud, respectively. The paper also describes changes in the organization and technological processes of the applied mapping methods and provides a comparison of their costs.

Keywords: UAV, cadastral mapping, photogrammetric mapping, laser scanning, data quality, geometric accuracy, impact assessment

INTRODUCTION

Cadastre mapping is a complex process in most countries. Instructions for measuring the land register of the Czech Republic and related documents have several thousand pages (SALC, 2019 – Only in Czech). When testing new mapping methods for cadastre, it is important to guarantee both the required mapping accuracy and all procedural steps in determining boundaries between landowners. There are publications describing the use of UAV photogrammetry for the creation of large-scale maps in various contexts. However, they only focus on some sub-steps of procedures connected to cadastre mapping. For example, Stöcker et al. (2019) test different software and the necessary number of ground control points to achieve the required accuracy of the orthophotomap. Manyoky et al. (2011) deal with a direct evaluation of the usability of UAV methods in cadastral mapping but their work lack an evaluation of the financial aspects of cadastral mapping. High-quality and comprehensive mapping quality analysis, including mapping cost assessments, are reported in a few papers only (Ramadhani et al.2018, Barnes et al. 2014). The main question in the cadastral mapping by photogrammetric and laser methods is their accuracy, traceability in combination with other traditional geodetic methods and time demands. Buildings are the most complicated mapping objects. The main limiting factor for using traditional stereo photogrammetry in cadastral mapping is the requirement of determining the intersection of the building with the terrain. Many authors have been dealing with this problem since the 1970s. An important recent work was published by Rhee and Kim (2017). Most approaches try to circumvent stereophotogrammetry by creating dense cloud of points from aerial photographs, or by direct measurement by a LiDAR. From the 3D point cloud, the intersection of a building with the ground can be determined with guaranteed accuracy, repeatability, provability and conclusiveness. The motivation for our work was to find out the conditions under which contactless mapping methods can be used in order to fulfil accuracy requirements of the cadastre of the Czech Republic.

TEST AREAS, EQUIPMENT AND DATA COLLECTION

Between 2017 and 2019, UAV mapping tests were carried out in the cadastral territories of Bohy, Rakolusky, Tymákov, Soběšice u Sušice, Železná Ruda, Plzeň – Doubravka. Tests were performed over the built-up parts of these areas using only UAV photogrammetry. The images were acquired with 85% forward overlap and 70% side overlap. Ground sample distance was from 2.5 to 5cm.

The next test area was the cadastre Dlouhá Ves u Sušice where both UAV photogrammetry and LiDAR acquisitions were performed. The photo flight mission was carried out by MV Sirius UAV with camera Panasonic Lumis GX1, f=14mm, CMOS 4952x3448, forward overlap 80%, side overlap 70%, 4698 photos in block (whole cadastral area), GSD 2 cm, 33 GCP, term: 6th March 2019, 6 flights from 10:39 to 15:20 CET. The laser flight mission was carried out 5th June 2019 by Hexacopter DJI Matrice 600 Pro with laser LiDAR RIEGL mimiVUX-1UAV with GNSS/IMU Apllanix15. UAV - speed of Hexacopter 2.3 m/s, number points per square meter - from 120 to 300. Laser scanning mission was split up to three parts, see Figure 1.

Fig. 1. The test cadastre territory Dlouhá Ves u Sušice central part of Figure 1 – the whole area of the Sirius MV flight and three laser scanning test areas where in detail from each: up – new builds, right – high density of buildings in the old part of the village, and left – buildings in compact blocks

50 points were signalised for the UAV MV Sirius flight mission. Of these points, 33 GCP were signalised with 6cm diameter round targets. 17 points were check points and were signalised with 6x6cm squares. The different signal shape was chosen to distinguish the point on the orthophotomap. All points were placed in the terrain level (see the left photography on Figure 2). The points were stabilized permanently with a survey mark or temporarily with a pin hammered to ground level. All targets were painted with a green signal reflective paint. Control and check points were measured by GNSS RTK technology with extended observations. Each point was measured twice with an interval of at least one hour, resulting in $RMSE_{xyz}$ = 0.015mm.

Two types of signals were used for the laser scanning mission. The first type was a square located at ground level, which was fitted with an aluminium foil to increase the reflectivity of the target Figure 2. The target hit at least 12 laser beams in each pass while scanning. Despite this, it was not possible to accurately identify the targets in the point cloud. For this reason, naturally signalised GCP were measured. These points were measured from two points by forward intersection. Measurements were supplemented by length measurement by reflectorless total stations. The error of these points on buildings was approximately $RMSE_{xyz}$ = 0.026mm.

Fig. 2. two types GCP for laser scanning from UAV

METHODS OF IMAGE PROCESSING

Aerial images taken by Lumis GX1 were processed in Agisoft Photoscan Pro. Orthophoimages with GSD 2cm and a digital surface model (point cloud) were created. Mapping points were measured by two methods. The corners of the buildings were interpreted from point clouds in the extension of the Microstation software (GeoStore V6 version 6.8.12, produced by the company Geovap Pardubice). The points of ownership boundaries on fences with retaining walls were determined directly by measuring from the orthophotomap. All these points were also measured by geodetic methods.

METHODS OF LIDAR DATA PROCESSING

Raw GNSS and IMU measurements were processed in the PosPac software. The CZEPOS service (Czech GNSS permanent station system) was used for GNSS corrections. The coordinates of the points in the XYZ / ETRS89 geocentric coordinates were calculated in RiProcess. Point clouds were cut according to trajectories into individual strips. These were aligned in the RiProcess software using automatically derived planar surfaces. The displacement and rotation of the individual strips were unknown parameters in the alignment. The standard deviation of the distance between the planes was 0.04 m (for area 1), 0.02 m (for area 2) and 0.04 m (for area 3) after alignment, with a maximum deviation not exceeding 0,10m at of 90% of planes. The point clouds were transformed from the XYZ / ETRS89 to the national S-JSTSK system and the Bpv elevation system in ETJTZU software (Czech Surveying Office). By combining roofing modelling and visual inspection, the coordinates of GCP were subtracted from the point clouds. Point clouds were shifted in each of the three coordinates by the median difference values in the Lastools software. Point clouds obtained by laser scanning were used to evaluate cadastre points of buildings, which were compared with points determined by GNSS as in the case of aerial photography by UAV.

RESULTS

The first result was orthophotomap quality control at 17 check points, see Figure 3

Bod	Y Test	X Test	KvT	Y Ref	X Ref	KvR	dY	dX	dPol
4034	822440.83	1131238.38	3	822440.81	1131238.39		-0.02	0.01	0.02
4035	821995.75	1131475.11	3	821995.74	1131475.10		-0.01	-0.01	0.02
4036	821833.69	1131865.06	3	821833.70	1131865.04		0.01	-0.02	0.02
4037	821649.84	1131925.85	3	821649.82	1131925.85		-0.02	-0.00	0.02
4038	821878.04	1131656.62	3	821878.03	1131656.61		-0.01	-0.01	0.01
4039	822304.38	1131806.32	3	822304.37	1131806.31		-0.01	-0.02	0.02
4040	822844.45	1132371.27	3	822844.45	1132371.28		0.00	0.01	0.01
4041	822638.46	1131738.08	3	822638.46	1131738.09		-0.00	0.01	0.01
4042	823196.08	1131542.50	3	823196.06	1131542.54		-0.02	0.04	0.04
4043	822611.61	1131311.66	3	822611.61	1131311.68		-0.00	0.02	0.02
4044	823189.31	1131878.15	3	823189.31	1131878.14		-0.00	-0.02	0.02
4045	822215.02	1131201.01	3	822215.02	1131201.01		0.00	-0.00	0.00
4046	822167.97	1131605.65	3	822167.97	1131605.64		-0.00	-0.01	0.01
4047	822021.71	1131810.95	3	822021.72	1131810.94		0.01	-0.02	0.02
4048	822939.28	1131736.75	3	822939.29	1131736.75		0.01	0.00	0.01
4049	823286.28	1131774.39	3	823286.23	1131774.39		-0.05	0.00	0.05
4050	822245.83	1131784.53	3	822245.84	1131784.52		0.01	-0.01	0.02

Fig. 3. differences on the check points

In the second step, geodetically measured points were compared with points interpreted from point cloud and orthoimages. Accuracy and completeness of point corners from point clouds resulting from correlation of aerial photographs and orthoimage interpretation were compared. In the last step, the accuracy and completeness of the evaluation of the points obtained from laser scanning was verified. See Table 1 and Table 2 for details.

Table 1. compared points from geodetic, photogrammetry and laser scanning from UAV

Statistic	**Photogrammetry ver. Classical Measuring - corners**	**Photogrammetry ver. GNSS "fence" points**	**Scanning ver. Classical plus GNSS**
Number of compared points	464,0	378,0	291,0
Requested (m_{xy})	0.140m	0.140m	0.140m
Limited error (u_{xy}=2.0*m_{xy})	0.280m	0.280m	0.280m
Confidence coefficient	2,0	2,0	2,0
Number of points in the interval <0, m_{xy})	384 (82.8%)	303 (80.2%)	287 (98.6%)
Number of points in the interval (m_{xy}, 2.0*m_{xy})	80 (17.2%)	75 (19.8%)	4 (1.4%)
Number of points in the interval <2.0*m_{xy}, infinity)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Table 2. compared number of points from geodetic measuring and photogrammetry and laser scanning

Test areas / number of measuring point	**Photogrammetry (points from clouds plus from ortophoto)**	**% from all points (geod.meas.)**	**LIDAR**	**% from all points (geod.meas.)**	**Geodesy measuring**
1	176	55,3	119	37,4	318
2	205	55,0	105	28,2	373
3	156	46,0	69	20,4	339
SUMA	537		293		1030

CONCLUSIONS

Both tested non-contact measurement methods met the requirement for accuracy of point measurements in the cadastre of the Czech Republic. The precision of the point determined from the point cloud obtained by laser scanning is about 30% better than the cloud obtained by correlating aerial images with GSD=2cm. If the success rate of identification remained at the level shown in the Table 2, in combination with traditional methods, approximately 17% of the funds would be saved and cadastral mapping would be accelerated by approximately 15-20%.

REFERENCES

Barnes, G., et al., 2014. Drones for peace : Part 1 of 2 design and testing of a UAV-based cadastral surveying and mapping methodology in Albania. In: World bank conference on land and poverty, Washington DC, USA, 24–27 March 2014

Manyoky, M., Theiler, P., Steudler, D., and Eisenbeiss, H.(2011) Unmanned aerial vehicle in cadastral applications, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XXXVIII-1/C22, 57-62, https://doi.org/10.5194/isprsarchives-XXXVIII-1-C22-57-2011

Ramadhani, S.A., Bennett, R.M. & Nex, F.C. (2018) Exploring UAV in Indonesian cadastral boundary data acquisition. Earth Sci Inform 11, 129–146 https://doi.org/10.1007/s12145-017-0314-6

Rhee, S. and Kim, T.: (2017) Investigation of 1 : 1,000 scale map generation by stereo plotting using uav images, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W6, 319-324, https://doi.org/10.5194/isprs-archives-XLII-2-W6-319-2017

State Administration of Land Surveying and Cadastre (SALSC) https://www.cuzk.cz/Predpisy/Resortni-predpisy-a-opatreni/Navody-CUZK.aspx (2019) 20.12.2019, Czech Republic

Stöcker, C., Nex, F., Koeva, M., and Gerke, M. (2019) UAV based cadastral mapping: an assessment of the impact of flight parameters and ground truth measurements on the absolute accuracy of derived orthoimages, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W13, 613-617, https://doi.org/10.5194/isprs-archives-XLII-2-W13-613-2019