Cadastral Mapping Based on UAV Imagery

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1. Introduction

The recent evolution of non-metric high resolution digital cameras and miniaturization of UAVs has promoted development of low-altitude aerial photogrammetry. Considering cost-effectiveness of the flight time of UAVs vs. conventional airplanes, the use of the former is advantageous in many photogrammetric and remote sensing applications including the up-dating of cadastral maps.

As the primary mapping resource for many legal and business uses, including land management, development planning and project location, cadastral maps should be kept up to date.

An increasing number of government agencies worldwide use photogrammetric data from both aerial and satellite imagery for developing and updating cadastral maps. A good example is Bolivia, where cadastral map is produced based on aerial photos [1]. Also Japan used archival aerial imagery for reproducing the limits of cadastral plots as they existed before natural disasters (the earthquake and tsunami of 2011) [2]. In Poland, in order to cadastral maps updating, orthoimage on scale 1: 26 000 developed within the framework of the PHARE (Poland and Hungary: Assistance for Restructuring their Economies) system and LPIS (Land Parcel Identyfication System) are used [3].

The study by Corlazzoli and Fernandez [4] can exemplify the use of satellite imagery for the development of cadastral maps. In this case, orthoimages produced based on high-resolution images from the SPOT 5 satellite were the main source of data for plot limit identi-fication. In certain cases, cadastral maps are plotted based on both airborne and satellite im-agery [5].

However, because of the large scale, low-altitude UAV images serve this purpose much better than the conventional aerial or satellite imagery. UAV images are used for updat-ing cadastral maps [6], [7]. Further, UAV data can help to evaluate up-to-dateness and accu-racy of cadastral maps [8]. The study described in this paper evaluated the suitability of UAV orthoimagery for updating cadastral maps.

2. Data capture

To capture low-altitude aerial photos, the researchers used a Trimble UX5 UAV equipped with a compact SONY NEX5R camera with a wide-angle fixed-focus lens. The platform has a single-frequency GPS receiver and IMU, which enables registration of ap-proximate components of the external reference for each image. The UAV can fly at the alti-tude of 75-750 m and the design overlap of pictures it can take ranges from 60 to 90 percent.

The tests were carried out for the surroundings of the Chrzęsne village (Poland). The land is flat, agricultural, partially forested. The flights were flown in good weather, with no cloud cover. The pictures were taken with the 1/2,500 seconds exposure time, from an altitude of 200 m.

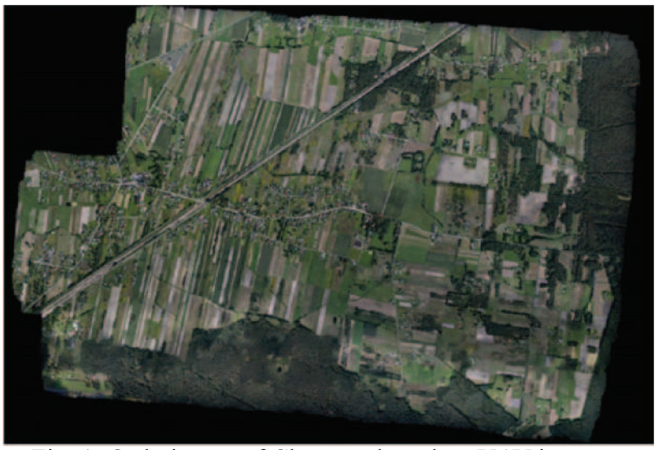

Fig. 1: Orthoimage of Chrzęsne based on UAV imagery

The test package consisted of 3,625 digital photos taken by 3 independent flights within a single mission. The study measured coordinates of the 21 signalized points (16 con-trol and 5 check points). The coordinates of the points were measured with an RTK GPS in-strument. The mean error of the coordinates was approx. 3 cm. The package was processed using the INPHO UASMaster software suite.

Table 1: Test package features

Parameter	Test package
Number of rows	37
Camera / focal length [mm]	NEX 5/ 15.51
overlap (along / across-track direction) [%]	80/ 70
Flight altitude [m]	200
Camera matrix pixel size [µm]	4,75

3. Data processing

After adjustment of the test package, the mean error of a typical observation was 6.9 µm (1.4 px). This large value could be a result of significant rotation angles (ω and φ < 3°). See Table 2 for the package adjustment specifications.

Table 2: Results of the test block adjustment

σ0 [µm]/[pix]	6.9/1.4
Number of control points	16
Number of check points	5
RMS error for control points (X, Y, Z) [m]	0.03; 0.03; 0.09
RMS error for check points (X, Y, Z) [m]	0.11; 0.04; 0.13
mX0 [m] / mY0 [m] / mZ0 [m]	0.10 / 0.08 / 0.09
mω [°] / mφ [°] / mκ [°]	0.020 / 0.026 / 0.007

The values of root mean square errors (calculated from the adjustment) in the X,Y positioning of the signalized control points ranged from 0.03 to 0.09 m. For the independent control points, the RMS errors (calculated as differences between the coordinates set by the ad-justment and the on-ground survey coordinates) ranged from 0.04 to 0.13 m.

The adjustment provided very good results for the determination of coordinates of the centers of perspectives (X0, Y0 and Z0). The values of standard deviations ranged from 0.08 to 0.10 m. The accuracy of determination of the rotation angles (ω, φ and κ) ranged from 0.007° to 0.026°.

The processes of creation of DTM and orthorectification used the Surface and Ortho Generation module of the UASMaster software suite. The creation of a DTM starts from the genera-tion of a point cloud based on stereo. The minimizing of the function of costs is the measure of similarity of features in the adjustment algorithm used to generate the point cloud. The al-gorithm is called "Cost Based Matching" (CBM) [9]. The resulting point cloud was filtered by removing points located underground. The quality of the DTM used to generate the ortho-imagery is critical to the accuracy of the final product. The modification of DTM was fol-lowed by orthorectification and automatic tessellation. A very important aspect of teaseling orthoimagery taken from a low altitude is the merging and adjusting of image radiometry. The automatic tessellation produced a uniform digital orthoimage with 6 cm spatial resolution.

To verify the quality of the geometric orthoimage, its accuracy was evaluated in abso-lute terms by reference to an independent control measurement. This accuracy can be ex-pressed as the root mean square error [10]:

$$m_{orto} = \sqrt{\frac{d}{n}}$$

where:

d – deviation meaning the length of the control point offset vector found on the orthoimages in reference to the position determined with the independent control measurement.

n – number of points

The evaluation used the check points not involved in the adjustment. The accuracy of the resulting orthoimage generated for the test area based on the UAV imagery with a 6.4 cm GSD was about 2 pixels, which means an accuracy of approx. 10-12 cm.

4. Orthoimage vs. cadastral map

Depending on urban development density, Polish cadastral maps are produced at the 1:500, 1:1,000, 1:2,000 and 1:5,000 scales. The accuracy of cadastral maps corresponds to the accuracy of the underlying master maps. The scale used for rural area mapping is 1:2,000 or smaller. It was agreed for rural areas that the acceptable error of point positioning on a cadas-tral map is equal to the accuracy of the 1:2,000 master map (2 m).

To check whether the geometric accuracy and interpretative advantages of the result-ing orthoimages are sufficient to justify investing in desk studies for the update of land and building registers of rural municipalities, the orthoimages were compared to existing cadastral maps. Vector cadastral maps were used as the reference. The review evaluated buildings, plots, roads and single-purpose land stretches.

Fig. 2. Orthoimage based on UAV imagery with vector layers of cadastral maps: buildings and plots

These items were checked for accuracy and in terms of identification on the orthoimages. The check determined the mean error of positioning of the outlines of buildings, plots, roads and single-use land stretches. See Table 3 for the results.

Table 3: Comparison results

	number of objects	**Identification of objects [%]**	**m0 [m]**
Buildings	75	91	0.80
Plots	40	80	0.51
Roads	15	95	1.02
Land stretches	20	80	0.40

Looking at the table, all of the checked master map items meet the accuracy require-ment. It means that the orthoimages developed from UAV are suitable for the updating cadas-tral maps.

5. Summary and conclusions

The recent rapid development of low-altitude photogrammetry made it possible to add a high level of automation to the capturing and processing of high-resolution images.

In the paper, the accuracy of orthoimage generated based on UAV imagery, acquired from non-metric SONY NEX 5R camera and the accuracy of the fragment of cadastral map were compared. The analysis included buildings, plots, roads and single-purpose land stretches. The conclusion from the foregoing study is that the geometric accuracy and interpretative advantages of the resulting orthoimages allow to updating the cadastral map in rural areas. The ability of identifying objects was over 90% (buildings, roads), more than 80% (plots and land stretches). The interpretive possibilities of orthoimages is influenced by the flight altitude pixel size, spectral and radiometric resolution of a sensor. It is estimated that such an update of cadastral maps based on UAV imagery can be approx. 50% less costly than on-ground measurements.

The purpose of the further study will give an answer if it is possible to update cadastral maps concern based on orthoimages developed from UAV data in urban areas.

This paper was developed based on research conducted as part of the Statutory Research Work of the Institute of Geodesy by the personnel of the Department of Remote Sensing and Photogrammetry.

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