THE UNEXPECTED MORPHOMETRY IN DIGITAL TERRAIN MODEL DERIVED FROM UNMANNED AERIAL VEHICLE IMAGES

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ABSTRACT

The wide availability of unmanned aerial vehicles (UAVs) equipped with GPS, inertial system and a digital camera makes them very affordable for many geospatial applications. Just about a decade, such applications were reserved exclusively for aerial photogrammetry. With the development and popularization of UAVs, the software was developed, that allows a very high degree of automation in the preparation of standard photogrammetric products, such as digital orthophoto (DOF) and digital terrain model (DTM). However, during imaging especially in large scales, for which the UAVs mostly are used, errors occur in the modeling of DTMs using the software, based only on use of the Structure from Motion (SFM) algorithm. This paper will explore and show unexpected (incorrect) morphometry, which appears by use of the SfM-algorithm to produce the DTM, and consequently to produce orthophotos. The images obtained by digital photogrammetric camera Vexcel UltracamD will be measured subjectively at a digital photogrammetric workstation using stereoscopy, to get the reference set of data. The second dataset will be obtained by eBee RTK UAV using the procedure and software, as proposed by producer. These two datasets will be compared, and the overall discrepancies will be calculated and presented.

Keywords: photogrammetry, DTM, morphometry, SfM-algorithm

INTRODUCTION

Unmanned Aerial Vehicles (UAVs) find their use in many fields of human activities. During the last decade, the market of UAVs is growing very fast [1], with a tendency to continue its growth at even higher speed. First applications of UAV technology were supporting of military tasks, but soon the advantages of using the UAVs in mapping application has been recognized and such system enter into the focus of broad spectrum of non-military applications. In geodetic applications, the imaging geometry, as well as the processing of images taken by UAVs, were following the standard photogrammetric approaches, extended by new algorithms to achieve a high grade of automation. The first results were really promising [2] especially after the implementation of Structure from Motion algorithm [3]. After the SfM algorithm reaches its maturity, the processing of images and other data gathered by UAVs with the goal to produce orthophoto or even 3D-model of imaged terrain became very simple, provocating even bigger popularity of use the UAVs for mapping needs. The archaeologists [4] and the geologists [5] use this technology for their mapping needs with success. This paper presents the imperfections

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in 3D model, and consequently in orthophoto, using fully automatic approaches. To explore the quality of orthophoto and digital terrain model (DTM) obtained by the UAVs at the present technology, we made a small project of mapping a portion of the settlement with buildings, trees, streets, and other objects, by the eBee RTK UAV.

DATA COLLECTION

The photogrammetric platform eBee RTK is an unmanned aerial vehicle, dedicated to produce orthophotos and digital terrain model as well as a digital surface model with spatial resolution as high as 4cm. Built-in RTK GPS measures the position of projection centers of the camera at the time of shooting with an accuracy of a few centimeters. The camera is spatially calibrated and fully integrated with flight controller. Maximal duration of flight without landing is about 40 minutes, and during this time it can cover by images the area of about 8km2. [6]. The flight was prepared by mission planner eMotion. Ground sampling distance (GSD) was planned to be 4.5 cm/pix. The side overlap between each of 34 strips had to be equal 85% with an along-flight overlap of 70%. The flight route is 18km long with mean height above ground of 136m (Image 2). During flight 242 photos were taken, with 12Mpix spatial resolution and geolocation of projection centers at the shooting moment, saved in EXIF format [7]

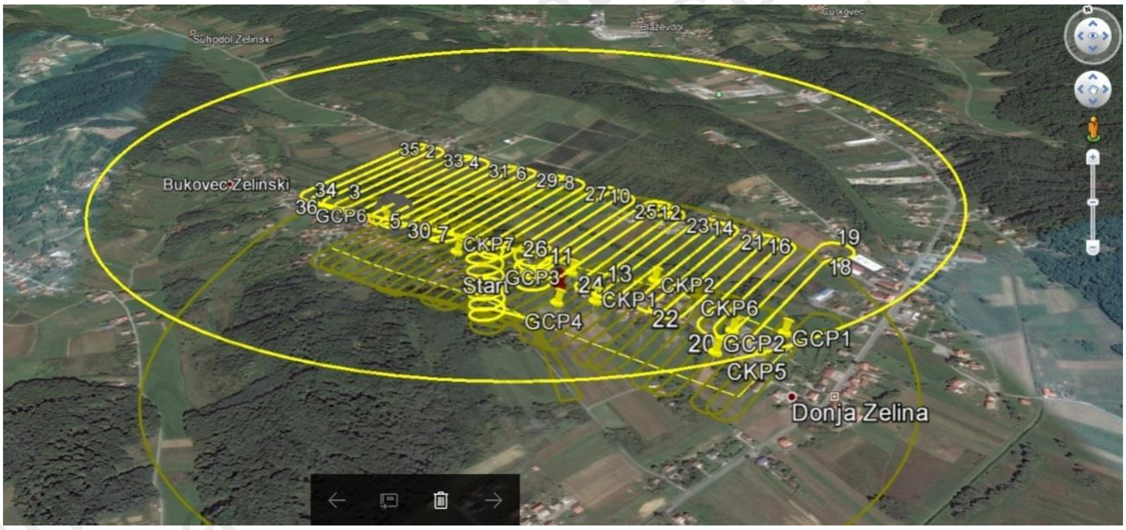

Image 1: The mission plan overlapped on Google map [7]

DATA PROCESSING

The processing of images taken during the flight was done by software PIX4D, and finally, the digital orthophoto and digital surface model (DSM) were obtained. However, first of all, was needed to determine the elements of interior and exterior orientation for every photogrammetric bundle (every image). Thus, the photogrammetric triangulation with self-calibration was calculated. The seven ground control points (GCPs) were marked in the field and measured by GNSS-RTK receivers, to reach the reliable determination of all parameters of inner orientation and exterior orientation. The result of accuracy achieved at control points is shown in Table 1.

Table 1. The report of accuracy achieved at the control points (software PIX4D) [7]

GCP Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
0 out of 6 check points have been labeled as inaccurate.						
Check Point Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
1	0.020/0.020	-0.043	-0.014	-0.026	0.439	10 / 10
2	0.020/0.020	-0.004	-0.010	-0.010	0.423	14 / 14
3	0.020/0.020	-0.016	0.000	-0.031	0.597	11 / 11
4	0.020/0.020	-0.001	-0.012	-0.005	0.344	11 / 11
6	0.020/0.020	0.019	-0.029	-0.016	0.457	11 / 11
7	0.020/0.020	0.001	-0.020	0.009	0.382	9 / 9
Mean [m]		-0.007446	-0.014107	-0.013173		
Sigma [m]		0.018966	0.009099	0.013287		
RMS Error [m]		0.020375	0.016786	0.018710		

After the very promising results of phototriangulation, where maximal RMS error equals just 2cm, one could expect the similar accuracy along the whole test area. Point cloud and DOF were created fully automatic. Point cloud (Image 3) consists of 17billions of points. The average density is 27.47 pts/m3. From the point cloud, the digital surface model is derived with GSD of 4.9cm/pix. The same GSD is kept at DOF (image 4), too.

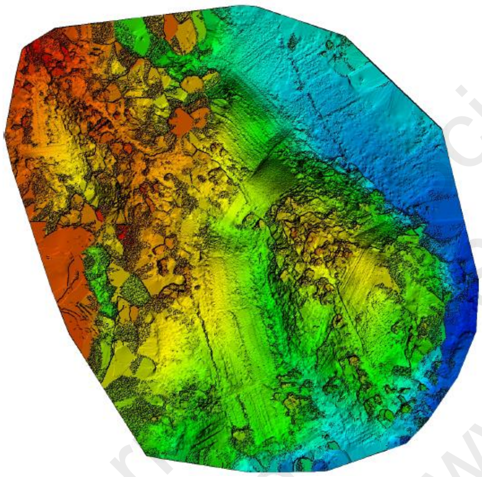

Image 3: Pointcloud of test area [7]

Image 4: DOF of test area [7]

THE ANALYSIS OF ACCURACY AND UNEXPECTED MORPHOMETRY IN DATASET OBTAINED BY UAV AND FULLY AUTOMATIC PROCESSING

The positional accuracy of the 3D-model of the test area and consequently of the orthophoto, both obtained by UAV, was estimated by comparison with reference data set. The reference dataset consists of photogrammetric images, taken by digital photogrammetric camera Vexcel Ultracam XP. These images were phototriangulated and measured using a digital photogrammetric workstation. The photo interpretation and measuring are supported by the stereoscopic vision&metrology system. For the analysis, two types of objects from the whole dataset were chosen: buildings and streets, because they have details, well enough defined to ensure a good precision of measuring process. The typical positional discrepancies at buildings (image 5) and streets (image

6) are presented visually in next images. Where the data obtained by UAV are presented in raster form (DOF) and reference data are presented in vector form (lines).

Image 5: Discrepancies at buildings [7]

Image 6: Discrepancies at streets [7]

Numerically these discrepancies lie between 20-30cm, and they are about 10-15 times bigger comparing to RMSE at control points (Table 1). Beside the positional errors present in data obtained by UAV, the presence of unexpected and erroneous morphometry of chosen types of object are visible. The poor geometry of walls of the building and of the edges of the street degrade significantly the overall quality of final product. After analysis of 3D-model obtained by a fully automatic approach from UAV dataset becomes obvious that the unexpected forms in DOF are caused by imperfections of 3D-model. Visual presentation of 3D-model in parallel projection makes it clear (image 7)

Image 7: The part of distorted 3D-model fully automatic obtained from UAV dataset [7]

CONCLUSION

The fully automatic algorithms of photogrammetric processing, to obtain the standard photogrammetric product (i.e. DTM, DOF, photorealistic 3D-model) are used widely in many photogrammetric applications, especially those where images were taken by UAVs. Outside geodesy the fully automatic processing approaches are appreciated even more because the user does not need to learn specific photogrammetric knowledge and can keep his attention and effort focused at the problematic inside the area of his profession. The very promising results of accuracy analysis at control points, taken as-is and without necessary criticism can make a wrong impression about the overall accuracy of the whole dataset. This paper draws attention to mapping situation where the up-to-date algorithms often fail, heavily degrading the overall quality of the photogrammetric product. This investigation clearly shows the biggest discrepancies at man-made objects, especially buildings. It is worth noting that the degradation of positional accuracy is mostly influenced by imperfections in 3D models produced by fully automatic processing algorithms. In such case, the strategy of choice could be to turn back to standard photogrammetric procedures and perform some critical measurements subjectively using digital photogrammetric workstation supported by stereovision system.

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