

Accuracy of Orthomosaic Generated by Different Methods in Example of UAV Platform MUST Q

N Liba^{1,2} and J Berg-Jürgens¹

¹Estonian University of Life Sciences, Institute of Forestry and Rural Engineering, Tartu, Estonia

E-mail: natalja.liba@emu.ee

Abstract. Development of photogrammetry has reached a new level due to the use of unmanned aerial vehicles (UAV). In Estonia, the main areas of use of UAVs are monitoring overhead power lines for energy companies and fields in agriculture, and estimating the use of stockpile in mining. The project was carried out by the order of the City of Tartu for future road construction. In this research, automation of UAV platform MUST Q aerial image processing and reduction of time spent on the use of ground control points (GCP) is studied. For that two projects were created with software Pix4D. First one was processed automatically without GCP. Second one did use GCP, but all the processing was done automatically.

As the result of the project, two orthomosaics with the pixel size of 5 cm were composed. Projects allowed ensuring accuracy limit of three times of the pixel size. The project that turned out to be the most accurate was the one using ground control points to do the levelling, which remained within the error limit allowed and the accuracy of the orthomosaic was 0.132 m. The project that didn't use ground control points had the accuracy of 1.417 m.

1. Introduction

Development of photogrammetry has reached a new level due to wide use of unmanned aerial vehicles (UAV). Wide use and availability of UAVs contribute to many fields, like environmental surveillance, agriculture [1], science [2], military and entertainment. On these territories, it is possible to act faster and reduce risks to human well-being.

Furthermore, software designed to process photographic materials made by UAVs has taken great strides toward making it easier to use and to reduce the need for human involvement [3; 4]. At the same time, operational simplicity makes it harder to estimate the quality and precision of the measurements taken. Different fields of study need different levels of precision and on many instances less is sufficient. In this paper we compare the accuracy of orthophotos created automatically with the

² To whom any correspondence should be addressed.



ones created using manual assistance. Differences between the two separate projects will be determined by RMSE.

Former research with similar study has not given any acceptable results for automation orthomosaic generation [5; 6; 7]. But different technology packages provide different accuracy and UAV with different sensors piloting the aerial vehicle could lead to the higher accuracy [8; 9].

2. Materials and method

The object of the study that took place on 17 November, 2014, was the phase one aerial survey of Tartu using UAV flying 1.8 kilometres over boroughs of Ihaste and Annelinn. The project was carried out in collaboration with the City of Tartu, Estonian Mapping Centre, ELI OÜ and Estonian University of Life Sciences. Its goal was to collect up-to-date data for the city planning department of Tartu. Territory that was measured is seen in figure 1.

Flight plan was plotted using Mission Planner (freeware) in which flying altitude, area and flight direction was inserted and the program loaded ground based control station. Flight took place 180 meters from the ground and total of 625 photos were collected (GSD 4.7 cm).



Figure 1. Schematic of partial areal-survey with ground control points of Tartu, concentrating on boroughs of Ihaste and Annelinn.

Measurements were taken using RTK method with receivers Trimble R6 and 5800 GNSS. Ground control points were located using minimal number of satellites and taking into consideration ground obstructions in the surrounding area. The base station of Estonian University of Life Sciences was used as the base station.

In the survey taken on 17 November, 30cm x 30cm plastic marking sheets were used. Survey on 20 November used easily recognisable ground points from nature and areal-photos.

For the areal-photography UAV type of plane named MUST Q was used (figure 2). MUST Q is an unmanned plane developed by ELU OÜ, which is able to take areal-photos and carry out laser scanning.



Figure 2. Unmanned plane MUST Q.

MUST Q is able to fly autonomously on autopilot due to the on-board control system. That system allows, when specific flight plans are necessary or obstacles occur, to repeat the pre-programmed flight plans. However, it is also possible to give commands to the plane manually and track the flight using live video feed.

MUST Q's empty weight is 2.5 kg, it has length of 65 cm and wingspan of 200 cm. The fuselage is made of expanded polypropylene aka EPP, because it is durable and inexpensive to replace when damaged. The airplane is driven by on-board brushless DC electric motor that is powered by a battery, which lasts about 90 minutes and has an operation range up to 10 km. Aircraft speed is from 10 to 25 m/s.



Figure 3. Ground control station used to guide and monitor MUST Q.

Ground Control Station consists of a control module based on Panasonic notebook and antenna, which receives and sends signals from and to the plane (figure 3).

On board an airplane there is a compact camera Panasonic DMC - GX1 (figure 4), used to send out a video feed. Plus there is a 3D Robotics GPS and IMU. All measurements of the sensors are synchronized with GPS that allows all the areal-data to be localized.



Figure 4. Compact camera Panasonic DMC - GX1.

Parameters of the camera Panasonic DMC-GX1 are given in table 1.

Table 1. Panasonic DMC-GX1 parameters.

Resolution	4612 x 3468
Sensor size	3.75 μm x 3.75 μm
Focal length	19.159 mm
Weight	0.318 kg

The data was processed using photogrammetry-software Pix4D, which is capable to create a geo-referenced 2D orthomosaic and 3D point-cloud based on the taken photos. The software has three processing levels (figure 5):

- Initial processing, where it is possible to select an area of orthomosaic with cloud points and add a ground control points, thereby performing areal-triangulation.
- Point Cloud Densification – this will create a 3D point cloud.
- DSM and orthomosaic generation – creates the model of the ground and orthomosaic.

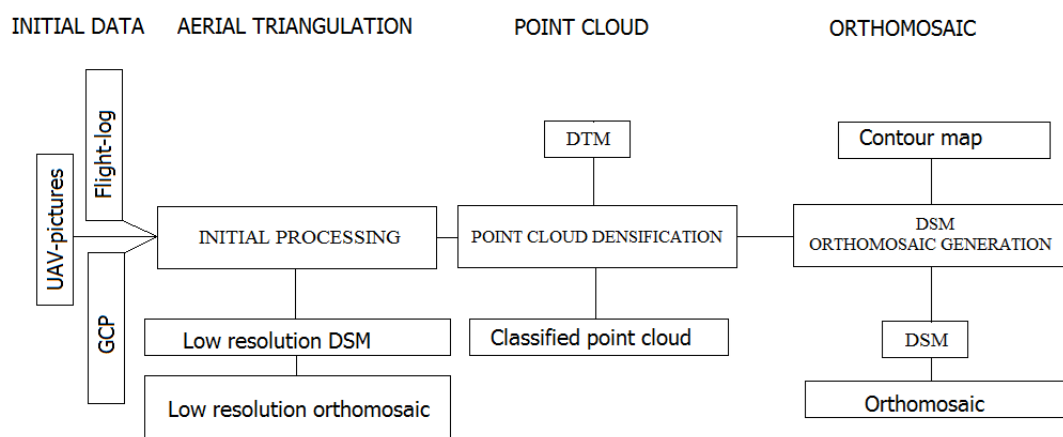


Figure 5. Example of the workflow of Pix4D of UAV.

Flight logs of aerial photos taken by the platform MUST Q are shown in figure 6. The logs reflect all data that are associated with the plane in the air – the condition of the battery, engine, different sensors and the readings, plus the times when photos are taken and GPS measurements.

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GPS, 3, 121966200, 1819, 10, 1.30, 58.3462781, 26.7669005, 0.05, 38.01, 0.03, 311.60, -0.01, 513232
ATT, 513257, 1.21, 6.07, 316.61, 0.01, 0.00
IMU, 513257, 0.0006890818, -0.0003485335, -0.002389171, 1.073766, -0.1952583, -10.00044
ATT, 513355, 1.20, 6.06, 316.60, 0.01, 0.00
IMU, 513355, 0.00334963, -0.001412753, -0.001324952, 1.06419, -0.2197989, -9.993255
  
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Figure 6. Extract from the flight logs of platform MUST Q.

The log files contain all the needed parameters measured by the sensors during the flight, which will allow automatically after the completion of aerial triangulation to set up locations and positions of the photos taken.

The accuracy control and the analysis of orthophotos were performed on the basis of two projects – automatic and semi-manual. Geometric accuracy assessment was measured by calculating the RMSE by comparing it with checkpoints measured from nature and on interactive orthomosaic. Table 2 shows the descriptions of the two projects.

Table 2. Creating orthophotomosaic in different projects (+ manual, - automatic).

Stage	Changeable stage	Project	
		Automatic	Semi-automatic Manual intervention
Initial processing	Flight log	+	+
	GCP	-	+
	Tie points	-	-
Elevation model - DSM	Point cloud	-	-
Orthomosaic		-	-

The automatic method was conducted as automatically as possible. In case of Pix4D software and current project, images and the log file were downloaded and orthomosaic was created without interfering. To pass the areal triangulation, flight log was imported, which was then used to geo-reference areal images. This was used to automatically obtain tie points and level the block adjustment.

In this project, a point cloud was created by triangulating areal block (figure 7a), in which case it was determined in what parts of the areal-photo points were created. The given work considered a half of the image area. In addition, density of the points was set – one point for each of the four pixels. After that, minimum number of images where points can be seen was set – on four images.

Different filters were used to create elevation model DSM. Noise filter was used, which finds corrupted points and reduces their height to medium altitude of surrounding points. In addition, a smoothing filter was used, in this project it is a sharp filter, which tries to portray all objects as close to reality as possible. The pixel size of the orthomosaic (figure 7c) was determined – how precisely it is displayed and correlated.

In case of semi-manual method, leveling was done by some manual intervention. In this method, images and log files were loaded and then ground control points imported and measured. To pass the areal triangulation, nine GCP were used. Points were measured by L-EST 97 coordinate system. To create point-cloud, the parameters analogous to the automatic project were used. After generating the point-cloud (figure 7b) orthomosaic was created (figure 7d), the parameters of which were similar to the automatic project.

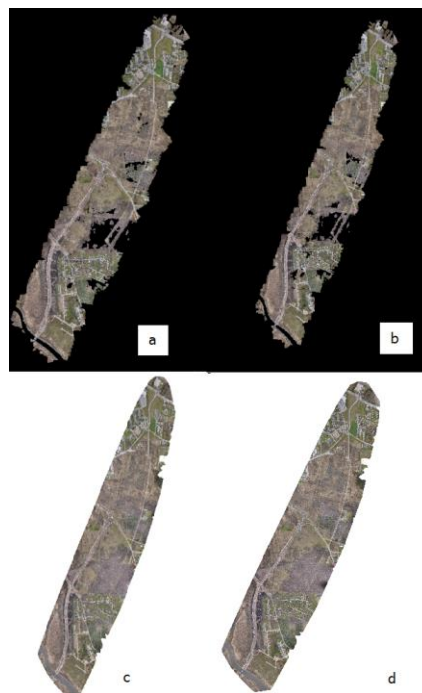


Figure 7. a) point cloud generated by the automatic project; b) point cloud generated by semi-manual project; c) orthomosaic created by the automated method; d) orthomosaic created by semi-manual method.

3. Results

Geometric accuracy assessment of automatic and manual intervention was done on the basis of 10 check points. RMSE were measured and compared to checkpoints measured in nature and interactively on orthophotos.

The results are given in figures 8 and 9.

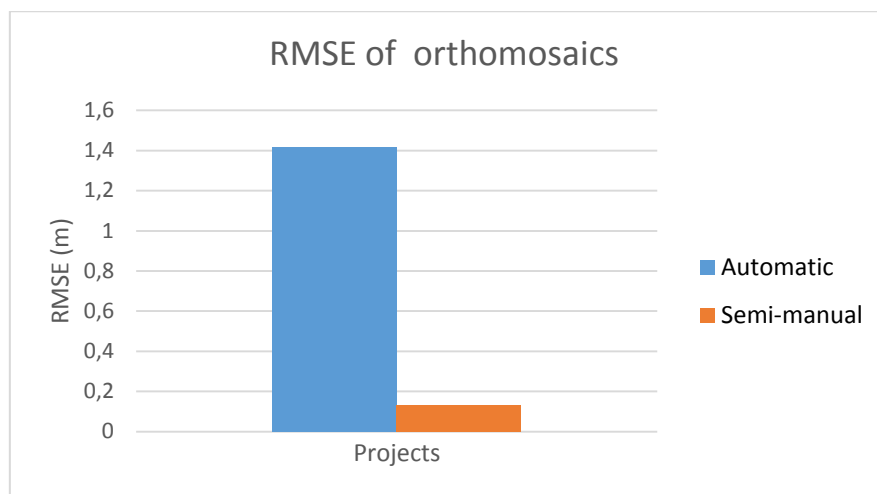


Figure 8. RMSE of orthomosaic.

The projects allowed accuracy limit that was three times of the size of the pixel, in this case it was 15 cm. RMSE of the semi-manual project was 0.132 m, which is within the limit. Accuracy of the automatic project was 1.417 m, which exceeds the allowable limit.

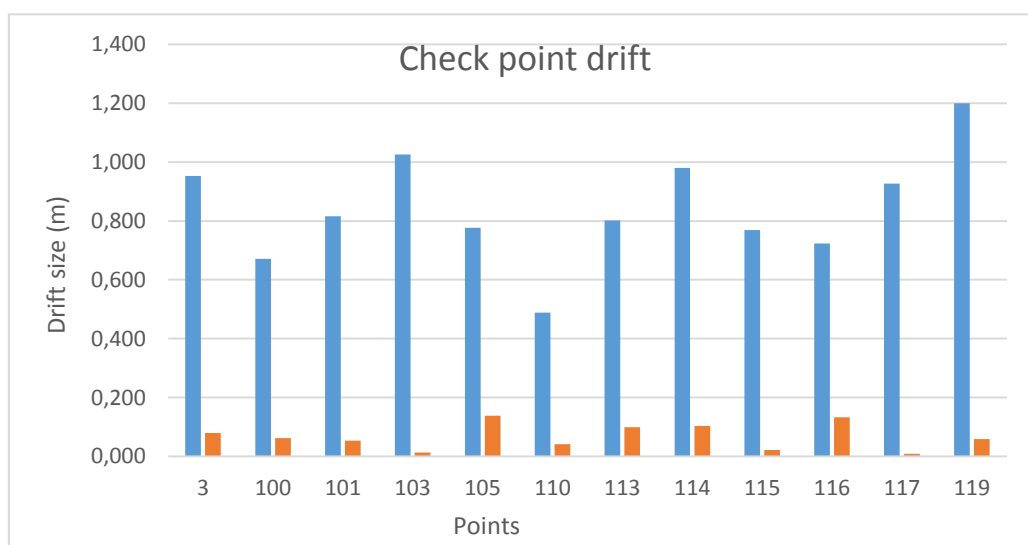


Figure 9. Drift values of the check points.

Figure 9 shows that the smallest differential between the X - axis direction of the automatic draft was 0.358 m, and 0.283 m in the direction of the Y-axis. Semi-manual project had the smallest differential X-axis of 0.000 m and 0.007 m in the direction of Y-axis.

Semi-manual project had the largest displacement of 0.138 m and the lowest of 0.013 m. Automatic project had the largest and smallest shifts of 1.200 and 0.488 m respectively. In the manual project all of the points of the project were within normal limits, but automatic project exceeded all of them.

4. Conclusions

As the result of the work, two orthomosaic by pixel size of 5 cm were obtained. As previously mentioned projects permissible accuracy limit was three times of the pixel size, or 0.15 m. When geometric accuracy of the orthomosaics was measured, we found that RMSE of the semi-manual project was 0.132 and that of automatic project 1.417.

The semi-manual project was within permitted limits and the automatic was not, which means that the use of ground control points is important and without doing it, it is not yet possible to create sufficiently accurate orthophotomosaics using UAVs.

Based on this paper it is recommended that further study of fully manual project is done, where tie points and elevation-model modification are used in addition to the ground control points.

5. References

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