AERIAL DATA APPLICATION FOR CONSTRUCTION OF LARGE-SCALE PLANS

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1. Introduction

In most of cases, topographic site plans (1:500, 1:1000 and larger) are measured in classical ways by geodetic measuring devices. This approach is classic and has been used for many years , but in the case of large cities or territories, the process can be exhausting and it takes a lot of time. Logically surveyors are looking for a way to make this process easier.

This work is going to investigate the possible usability of photographically-captured data for carrying out the topographic site plans.

The analysis of the quality and usability of the products, generated from:

1. Orientated aerial images, taken from the image flight projects from the Office for Geoinformation, Surveying and Land Cadaster in Mecklenburg-Vorpommern.
2. Orientated aerial images, taken by drone imaging system DJI Phantom 4

Comparison of Digital Terrain Models (DTM):

1. Generated from dense point cloud in Agisoft PhotoScan program from images taken by a drone imaging system.
2. Reference DTM measured by classical geodesy methods.

Conclusions about coordinate's accuracy gained from image data processing, in accordance to accuracy required for topographic site plans will be presented.

The further possibility of using the 3D data, obtained from the processing of the above-mentioned images will be analyzed.

The main objective is to find out if the accuracy of photogrammetrically-captured data is enough for mapping purposes and those types of topographic plans (1:500. 1:1000) in order to save time, money and human resources for making terrestrial surveying of a region in classical ways.

2. Methodology

Orientated Aerial Images: The Office for Geoinformation, Surveying and Land Cadaster Mecklebburg Vorpommern coordinates the image flight projects of the country and the public bodies of the country. Each year, aircraft-supported airplanes are estimated to cover about 1/3 of the country's surface area. Since 2004, digital aerial photography has been growing year by year thanks to the digital aerial photographs. These images take place simultaneously on the color channels "red", "green", "blue" (RGB) and the "near infrared" (NIR) with a bottom pixel size of 0.1 m. The aerial photo data recorded since 2004 are georeferenced and oriented.

For further work, original images (RGBI/PAN) with camera orientation parameters in coordinate system UTM Zone 33N are taken. Original data consist of 16 images from 09.03.2014, flying height 1500m and Ground Simple Distance (GSD) 9cm. Images are taken by BSF Swissphoto GmbH Company by panchromatic camera UC-Sxp-1-31217112. The data is processed in UltraMap 3.1.4 by Vexcel Imaging GmbH (Process Lvl02, Automated Tie point Collection, Bundle Adjustment and Analysis).

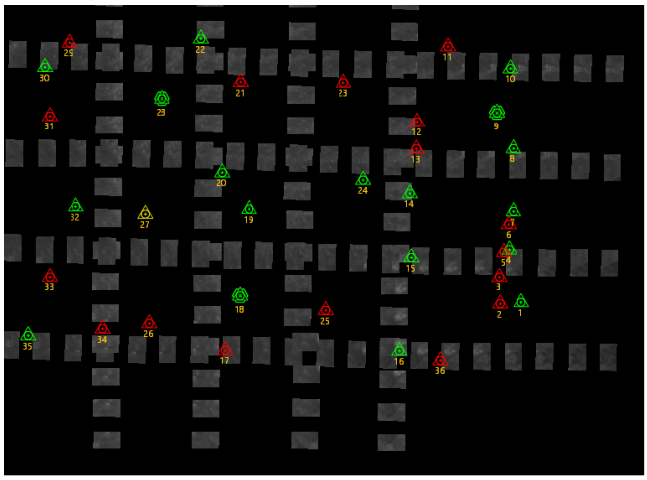

Figure 1: Flight at 1500m (GSD 9sm) [www.swiss.photo]

An unmanned aerial vehicle (UAV) image set: UAV – commonly known as a drone and referred to as a Remotely Piloted Aircraft (RPA) by the International Civil Aviation Organization (ICAO), is an aircraft without a human pilot aboard. UAV's have opened up a completely new world of surveying, orthophoto production, 3D modelling and feature extraction possibilities. A drone, in a technological context, is an unmanned aircraft. There are many different applications for this vehicle, but the greatest interest to us is the possibility to produce high quality dense point cloud and further 3D model of the investigation region.

For this work, multifunctional drone DJI Phantom 4 Pro, from the worldwide company Dà-Jiāng Innovations Science and Technology (DJI) was used. Multicopter DJI Phantom 4 has a built-in camera with a resolution of 20 Megapixels, with support of multi-capture, continuous capture and timed capture, HD Recording (1080/p30 or 1080/60i) and both RAW and JPEG picture formats. It is also equipped with imaging sensor with 8.8 mm focal length, pixel size 0.0024mm and output image size 5464*3640pix.

In order to avoid shades and poorly illuminated places on pictures, surveying with DJI Phantom 4 Pro is done by optimal and not sunny weather. All surveying processes are implemented using the flight-planning program Ground Station Pro, with established side and forward overlapping (80% and 65%) and flight height 77 meters on the area of the interest 128 bright and 92 meters long. In order to better understand what kind of results can be obtained at the end from images, the flight is planned additionally in self-created program.

Table 1

Camera / lens parameters		*Area of Interest*	
Width in pixels	5335	Width in meters	253
Height in pixels	3844	Length in meters	184
Pixel size in mm	0.0024	Line distance in meters	45
Focal length in mm	8,8	Number of flight lines	7
Camera shutter speed (sec)	0,07	Distance between image's centres in meters	18
Imagery Collection Parameters		Number of pictures per line	16
Platform ground speed (m / sec)	3	Total number of pictures	112
Flight height in meters	85		
Images GSD in meters	0,02		

The most important parameter for final results is Ground Simple Distance (GSD) – the distance between two consecutive pixel centers measured on the ground. From a planned height of 77 meters and an appropriate image resolution, GSD is 2 cm, which meets our goals.

Terrestrial surveying of the region: Geodetic surveying of region is done in classical ways by geodetic instruments from Leica TPS 1200, previously calibrated and prepared. The technology of performing the surveying is standard: the instrument is installed above the standpoint and set up by using GPS receiver in Real Time Kinematic mode. Required for terrestrial measurements accuracy:

- Plane coordinates accuracy +/-3cm
- Height accuracy +/- 5cm

Data is collected in two weeks and all measurements are carried out on 33 parcels on the territory 0.080km$^{2.}$

To construct a site plan, ground measurements are taken as basic and as referees for comparison with the results obtained from the image's processing. Nevertheless, one must understand that these measurements are also not free from some kinds of random errors, since measurements are made under different conditions, using different methods of setting up instrument's, etc.

The absolute accuracy of the final plan - is the accuracy within real world point coordinates are measured relative to the fixed projected coordinate system. For calculating this error, the next things need to be taken into account:

1) GPS measurements for setting up the total station, are done with the use of Real Time Kinematic mode and German permanent stations network (SAPOS), which in itself has an accuracy of 2 cm in plane and 3 cm in height.

2) Setting-up of the instrument is done in different ways (free station, known orientation, etc.) with use of the different geometry of the location of the known points of standing. This error includes as well the transformation error (calculation error due to the resection theory) of the station coordinates.

3) The absolute accuracy of the reference data depends on the instrument characteristics. The accuracy of line and angle measurements (1mm+1.5ppm and 0.3mgon on distances to 1800meters for current instrument).

4) An operator random errors are always present

The total error includes other types of the instrumental and external environment errors which are not mentioned here.

3. Results

According to the work objectives, two different products are generated: dense point cloud from orientated aerial images and dense point cloud from orientated UAV images. It is clear, that the quality of dense point cloud data directly depends on images quality, concretely on Ground Simple Distance value.

Theoretically, the accuracy of dense stereo matching products (pixel based matching) are limited on subpixel accuracy, in this case 10.3 cm and 1.9cm respectively for each image set. Both point clouds are generated in high quality due to the software possibilities. Nevertheless, we are interested in what kind of data can be obtained from the calculated dense point clouds and how far away this data is from the data measured by instruments on the area of interest.

For next coordinates comparison, building's "First heights" are taken, since very often during terrestrial measurements it's quite complicated to see roof points and to visualize them on later on plans. That is why, in some cases the real shape of the roof is not depicted on site plans. To get the coordinates of every single point, both data sets are opened in AUTODESK ReCap 360, as this software provides the opportunity to see the coordinates of every point in real time (Table 2).

Even taking into account that the all coordinates are selected manually, and contain operator error, data obtained from dense point cloud generated from orientated aerial images doesn't meet the required for construction development plan accuracy, and could be used just like additional information.

In the same moment, the difference between the original measured coordinates and those taken from dense point cloud generated from drone images, seems to be closer to reality, and the difference in height is maximum 4 cm. It is clear that the actual quality of this data is even better, because this error contains a visual point interpretation error, which means that the point interpreted by operator as the highest on the building, and the point later selected from the 3D dense point cloud data set, could be different.

3D point clouds created from drone images, could be very useful during the construction of development plans and provide a lot of additional information. The problem is manual operator extraction of the points, and the time required for this manual work.

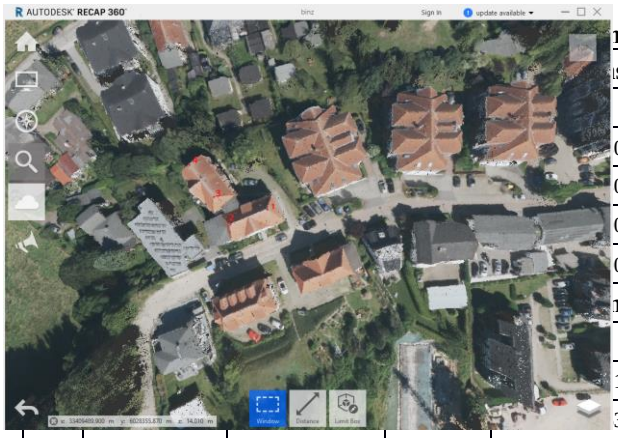

Figure 3: Dense point cloud computed from aerial images

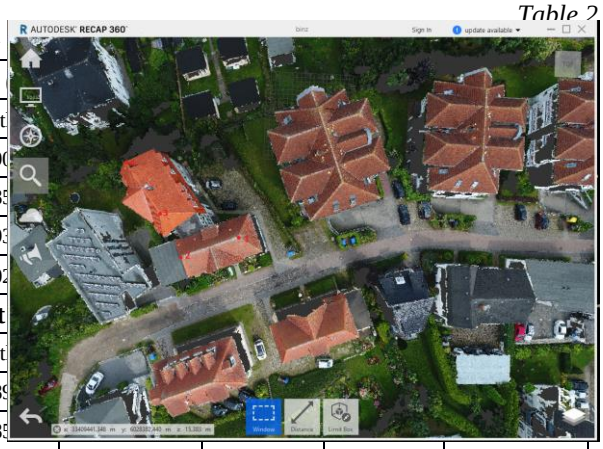

Figure 4: Dense point cloud computed from UAV images.

Table 2

3	33409422,082	6028393,504	25,710	33409422,041	6028393,465	25,660	0,041	-0,161	0,040
4	33409415,206	6028402,350	25,700	33409415,284	6028402,277	25,668	-0,078	0,073	0,032

Due to the work objectives, DTM generated from uav-photos is compared with the original DTM, measured on local area. For this purpose, mesh created only from points classified as "groud points" are used. Original DTM is created in the GeografCAD program.

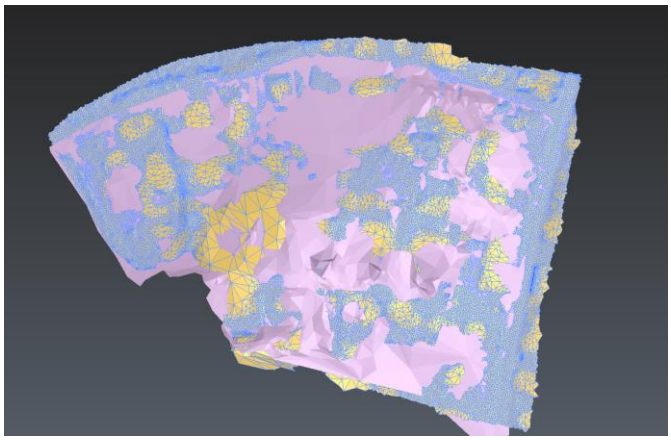

Figure 2: DTM volume comparison.(yellow-generated from mesh, pink- original)

The difference between these two surfaces is 67 m^3, This is approximately 80tons which could be placed in 2 trucks, due to the soil density 1200kg/m^3. This difference may be caused by not a simple relief of the territory (entry into underground garages, sudden height differences, etc.). One more reason is some errors during a full automatic dense point clouds classification process.

Combining terrestrial (ground based) photos with aerial (uav) images: To have the possibility to extract building contours (outlines) for a future plan from 3D model, it is necessary to have a good modeled all building's walls. The problem is that from a flight height of 77 meters wall information is lost in final model. It is not an easy task to interpret a building corner from this kind of data

The found solution to fill in the gaps in the model is the use of terrestrial captured data. The data is collected with the high-resolution camera Canon 600d. In the end, 113 high resolution images were collected. These photos are aligned with the reference data set– uav images taken in nadir direction. As a result, the walls of the buildings are modeled with higher quality and provide more information

Using oblique drone images: To provide more information from the final 3D model, and it is decided to capture additional data with drone and to use oblique images. All surveying processes are implemented in the previously-described way – with use of the flight-planning program and established side and forward overlaying (80% and 45%). To provide better ground simple distance, the flight height is reduced up to 65 meters. Camera's gimbal is tilted at 45°. T

At the end 83 images were collected. These photos are aligned with reference data – images taken in nadir direction and data captured with with camera Canon

600D.

Figure 5: Problems with walls modeling

Figure 6: Final 3D model of part of Binz town, Germany

As a result, the walls, buildings, windows and doors, as well as trees and other things that were distorted in previous model, are modeled more accurate, and fill almost the all gaps in the final model.

4. Conclusions

After the investigation of possibilities for using photogrammetrically-captured data for carrying out topographic site plans, we can make next conclusions:

1. Images ordered from the Office for Geoinformation, Surveying and Land Cadaster in Mecklenburg-Vorpommern, as well as products generated from it, do not meet the requirements needed for the construction of topographic site plans and could be used as additional information, for obtaining the information from images and their products with an accuracy up to 1 m.

2. As was predicted, image model generated from UAV images is much more accurate than model calculated from aerial images. To get stable, accurate model, processing of UAV images requires additional independent measurements of ground control points implemented by classical precise measurements techniques. However, for our objectives and creating development plan construction plans, the accuracy of this model is more than enough. In the same moment, the difference between the measured coordinates and those manually taken from dense point cloud generated from drone images are in range from -3 to +4cm in plane. The difference in buildings heights is a maximum 4 cm. It is clear that the actual quality of this data is even better, because this error contains visual point interpretation error, which means that points interpreted by the operator like the highest on the building, and points later selected from the 3D dense point cloud data set, could be different. 3D point cloud data sets, created from drone images could be very useful during the construction of development plan and provide a lot of additional information. The problem is manual operator extraction of the points, and time required for this manual work.

3. The difference between measured DTM and that created from drone images is 67 m^3. The complicated relief of the territory (entry into underground garages, sudden height differences, etc.) may cause this difference. One more reason for some differences is some errors during the full automatic dense point clouds classification process. The accuracy of the DTM obtained from drone image processing is enough for use in site plans.

4. The use of the oblique and terrestrially captured images provide a more detailed model, and the information about walls is enough to interpret a buildings corner and to extract information about the buildings outline.

5. To align terrestrial images with aerial images through the identical point in both models, it is necessary to have a minimum 30 % overlap between these data. As markers, it is better to choose points on buildings roofs, since a roof is depicted on ground and aerial images in the case of lower buildings. Otherwise, the use of a special camera pole which provides the opportunity to make photos from approximately the 2nd floor is recommended.

6. From 113 photos taken from the ground, only 93 camera positions were calculated. To align ground images with each other, it is important to have a high overlap between these pictures. As one solution a fish-eye camera with a bigger observing angle could be used.

7. The use of additional oblique image sets requires reducing flight altitude in order to get more information about buildings walls.

8. Compared to the classical methods for obtaining data, the time for obtaining a detailed 3Dmodel of a city or a certain territory is much less, and takes 1 or 2 days, depending on territory size. In addition to this, high-precision Orthophotos and DTMs are created automatically in the shortest possible time. Classical measurement techniques in this case need to be applied as well, but with the use of much fewer human recourses.

9. With the use of products generated from data captured with drone imaging systems, the time for construction a site plan (1:500, 1:1000) can be 2 times reduced.

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ЗАСТОСУВАННЯ АЕРОФОТОЗНІМКІВ ДЛЯ СТВОРЕННЯ ВЕЛИКОМАСШТАБНИХ ПЛАНІВ

І. Тревого, В. Гегер, К. Лосман, О. Лісник

Охарактеризовано методи застосування аерофотознімків та знімків з мультикоптера для створення великомастшабних планів (1:500, 1:1000). Запропоновано методи покращення якості 3D моделі місцевості за допомогою використання перспективних знімків з мулькоптера та наземних, створених камерою високої роздільної здатності.

ПРИМЕНЕНИЕ АЭРОФОТОСНИМКОВ ДЛЯ СОЗДАНИЯ КРУПНОМАСШТАБНЫХ ПЛАНОВ

И. Тревого, В. Гегер, К. Лосман, Е. Лесник

Охарактеризованы методы применения аэрофотоснимков и снимков с Мультикоптера для создания крупномастшабних планов (1: 500, 1: 1000). Предложены методы улучшения качества 3D модели местности с помощью использования перспективных снимков с мулькоптера и наземных, созданных камерой высокого разрешения.

Aerial data application for construction of large-scale plans

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The methods of using aerial photographs and images from multicopter for creation of large-scale plans (1: 500, 1: 1000) are described. The methods of improving the quality of the 3D model by using drone oblique images and terrestrial, created by the high-resolution camera are proposed.