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Technological aspects of orthophotomap generation in rapid mapping mode

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Abstract

The article presents the technical aspects of Digital Elevation Model (DEM) and Digital Surface Model (DSM) built on the basic of Very High Resolution (VHR) data to create orthophotomap in a rapid mapping mode. The final part of the paper is accuracy assessment of orthophotomap built on the same elevation models which were used in a rapid mapping way. In the article were using aerial photography's gained from digital camera *UltraCam Xp by Vexcel*. The spatial resolution of this images is 0.10 m. Example data of Gazoport in Świnoujście were processed using photogrammetry software *Agisoft PhotoScan*. The usefulness of both DSM and orthophotomap products were achieved by cross calculating mean errors. Orthophotomap created in a rapid mapping way, with minimum set of images, was built across using Ground Control Points (GCP). The source of GCP points was *the Polish Spatial Data Infrastructure Geoportal*. Check points were measured using both geoportal and Global Navigation Satellite System (GNSS) in the Real Time Kinematic (RTK) mode.

Introduction

Recently Digital Elevation Model (DEM) and Digital Surface Model (DSM) were built on the basis on satellite imageries, aerial photographs, radar data or models created through digitizing contour lines. Currently, the Light Detection and Ranging (LiDAR) and Unmanned Aerial System (UAS) are used more and more and precision of this digital models (DSM and DEM) is considerably more precise than so far used elevation (surface) models.

Detailed imagery captured from micro-UAV (Unmanned Aerial Vehicle) can produce dense point clouds using multi-view stereopsis techniques combining photogrammetry and computer vision. A very dense point cloud (< 1–3 cm point spacing) is produced in an arbitrary coordinate system using high resolution imagery. The results indicate that a georeferenced point cloud accurate to 25–40 mm can be obtained from imagery acquired from ~50 m [1]. UAV-based image capture provides the spatial and temporal resolution required to map and monitor natural landscapes (see Fig. 1).

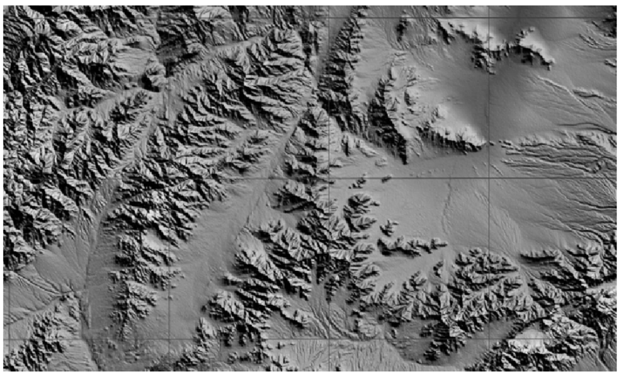

Fig. 1. Image map (flooded areas) based on Digital Elevation Model

At present, image data obtained by various registration systems (metric and non-metric cameras) placed on airplanes, satellites, or more often on UAVs are used to create photogrammetric products. The discussion of the current capabilities of automate processing of the images comes from different sources (aerial, UAV), using *AgiSoft PhotoScan* software, which was introduced by Preuss R. [6].

According to Greiwea A. Gehrkea R., Spreckelsb V. Schlienkampb A. (2013) the results for the aerotriangulation of images gaind from UAS showed the following RMSE [4]:

- Total Unit-weight: 0,31 Pixel;
- Ground X/Y: 1 cm;
- Height: 2 cm.

In this paper the complete process of creating DSM and orthophotomap was introduced. Both of this product were created on the basic of very high resolution imagery data with 0.10 spatial resolution. The orthophotomap covers a part of Gazoport area in Świnoujście.

The study was conducted across field surveying and image data processing.

GCP and ICP collecting

Surveying of ground control points were made based on RTK GNSS technologies (Fig. 2).

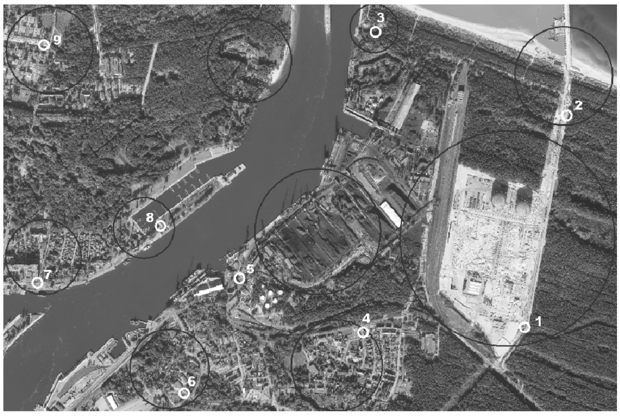

Fig. 2. Ground Control Points (GCP) collected across field surveying

These points were used as control points (ICP), due to the fact that the study of DSM and orthophotomap was taken in the form of rapid mapping. This meant that the minimum data set was used to give study with stereoscopy coverage. In addition, in order to speed up the work, control points (GCP and some of ICP) came from the *Polish Geoportal of Spatial Data Infrastructure* (Fig. 3). ICP points were measured in RTK GNSS technologies and used as a check points, in order to determine the accuracy of orthophotomap which was made as a rapid mapping study.

Fig. 3. GCP and ICP collected using Polish Geoportal of Spatial Data Infrastructure

Processing data using *AgiSoft PhotoScan* software

Agisoft PhotoScan software allows processing both LiDAR and photogrammetric data in any configuration, using image matching algorithms. The processed data can be georeferenced first or processed in the local coordinate system with this software. It is possible to process images coming from metric and non-metric camera. If there are additional data like exterior orientation and GCP (Ground Control Points), it is also possible to use self-calibration (autocalibration) function for images comes from non-metric cameras [5].

The stages of image data processing with the *AgiSoft PhotoScan* software are as follows [5, 6]:

1. Defining project (setting parameters – e.g. coordinate system, loading images);
2. Align photos using matching correlation algorithms;
3. Bulid dense cloud of object (terrain) in 3D;
4. Build mesh (reconstruction of a TIN model);
5. Build texture – the texture of a TIN model;
6. Generating DEM (DSM).
7. Generating orthophotomap.
8. Generating report.

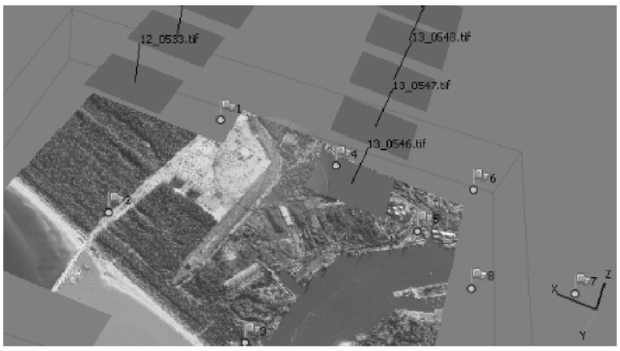

Fig. 4. Building Dense Cloud with *AgiSoft PhotoScan* software (the part of Gazoport in Świnoujście)

Orthophotomap generating

Creating the orthophotomap is possible due to the Digital Surface Model (DSM). Firstly, it follows loading images and data from camera calibration. Then, it is calculated the autocorrelation of images. The next step is to define the coordinate system and points of alignment and fixing them on the individual images. Then aerial triangulation is performed, which is possible in both cases, with and without knowledge of perspective centres. The *PhotoScan* software spatial model (DSM) is created using TIN (Triangular Irregular Network) model. Then, the mesh is textured and projected onto a plane and it is possible to get orthophoto mode. Both, orthophotomap and DEM, are possible to obtain in the area of stereoscopy coverage (Fig. 5).

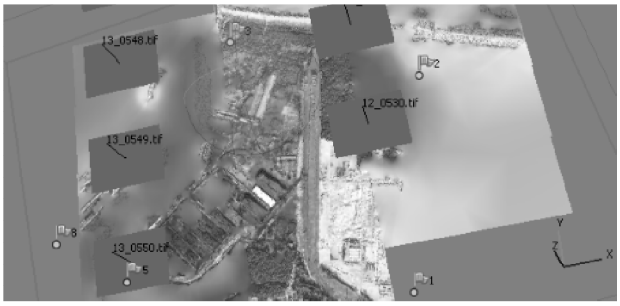

Fig. 5. Orthophotomap in the area of stereoscopy coverage

In presented study orthophotomap was performed as rapid mapping. Both, Ground Control Points (GCP) and Independent Control Points (ICP), were read out from *the Polish Geoportal of Spatial Data Infrastructure* (Fig. 6). Field surveyed Control Points are used to assess the accuracy of this rapid processing map.

Fig. 6. ICP used to assess of accuracy of orthophotomap

In this way, the accuracy of studies created without field surveying have examined using ICP. This approach of making orthophotomaps (rapid mapping) significantly reduces necessary time to produce both DSM and orthophotomap.

The next step was to analyze of the accuracy of orthophotomap. The analysis was made on the basis of:

- Independent Control Points (GNSS RTK);
- Checkpoints read out from the *Polish Geoportal of Spatial Data Infrastructure*;
- The final report is generated in the PhotoScan application protocol.

Since the real coordinates of the points used for comparison are not known, the mean errors are calculated as follows:

$$m = \sqrt{\frac{[VV]}{n-1}} \quad m_{av} = \sqrt{\frac{[VV]}{n(n-1)}} \tag{1}$$

where:

m – mean error;
m_{av} – mean error of average.

Table 1. Comparison of coordinates

No.	ICP (Geoportal)		DLT		Difference	
	X	Y	X	Y	dX	dY
1	191,319.2	682,167.7	191,319.3	682,167.6	-0.1	0.1
2	191,206.0	682,116.7	191,205.9	682,116.5	0.1	0.2
3	191,154.7	682,153.3	191,154.5	682,153.1	0.2	0.2
4	191,193.1	682,194.0	191,193.0	682,193.9	0.1	0.1
5	191,248.2	682,195.1	191,248.3	682,195.1	-0.1	0.0
6	191,294.5	682,141.8	191,294.5	682,141.8	0.0	0.0
7	191,223.5	682,152.7	191,223.4	682,152.6	0.1	0.1
8	191,227.9	682,172.1	191,227.9	682,172.0	0.0	0.1
9	191,267.2	682,138.5	191,267.1	682,138.4	0.1	0.1
10	191,270.0	682,141.6	191,270.0	682,141.5	0.0	0.1
11	191,252.5	682,112.0	191,252.4	682,111.8	0.1	0.2
12	191,302.2	682,113.9	191,302.2	682,113.7	0.0	0.2
13	191,202.2	682,181.4	191,202.2	682,181.4	0.0	0.0
14	191,192.2	682,131.9	191,192.0	682,131.8	0.2	0.1
15	191,186.7	682,133.5	191,186.5	682,133.4	0.2	0.1
16	191,282.3	682,108.7	191,282.3	682,108.6	0.0	0.1
17	191,292.9	682,116.2	191,292.9	682,116.1	0.0	0.1
18	191,173.4	682,170.2	191,173.3	682,170.2	0.1	0.0
19	191,181.3	682,174.8	191,181.1	682,174.7	0.2	0.1
20	191,249.7	682,159.1	191,249.7	682,159.0	0.0	0.1

Studied in the local coordinate system ortoimage was transformed using the DLT transformation, which is basing on the transformation (2).

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \cos\kappa\cos\varphi & -\cos\kappa\cos\varphi & \sin\varphi \\ \sin\omega\sin\varphi\cos\kappa + \cos\omega\sin\kappa & -\sin\omega\sin\varphi\sin\kappa + \cos\omega\cos\kappa & -\sin\varphi\cos\varphi\cos \\ -\cos\omega\sin\varphi\cos\kappa + \sin\omega\sin\kappa & \cos\omega\sin\varphi\sin\kappa + \sin\omega\cos\kappa & \cos\omega\cos\kappa \end{bmatrix} \cdot \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} \tag{2}$$

where:

X, Y, Z – transformed coordinates (in target system);
X', Y', Z' – source coordinates; elements of exterior orientation:
ω – transverse torsion angle; φ – longitudinal torsion angle; κ – drift angle.

The comparison of geoportal (ICP) and transformed orthophotomap are presented in table 1.

Using above data, the mean errors were calculated as follows:

- $m_x = 0.10$ m,
- $m_y = 0.10$ m,
- $m = 0.14$ m.
- $m_{av} = 0.03$ m.

The Accuracy of processing the control points (GCP) shown in the *PhotoScan* software report was within 0.2–0.5 pixel. Simultaneously, the location error (of both GCP and ICP) is 1.2 pixel size (Fig. 7). Taking into consideration that the spatial resolution (GSD) of the pixel is 0.10 m, it means that the error should be estimated at 0.12 m. This value is consistent with the errors calculated on the basis of selected ICP control points (Fig. 6, Table 1) without knowledge of perspective centres of aerial photography's (flying altitude is false and calculated).

Number of images:	6	Camera stations:	6
Flying altitude:	4.16444 m	Tie-points:	31168
Ground resolution:	0.000235112 m/pix	Projections:	74828
Coverage area:	9.95493e-006 sq km	Error:	1.21236 pix

Fig. 7. Part of the *AgiSoft PhotoScan Software* raport

Conclusions

The paper presents the fast development of Digital Surface Model (DSM) and orthophotomap of the Gazoport area located in Świnoujście. This rapid mapping process is based on minimal set of images (6 aerial photography's) to generate the stereoscopic effect based on DSM, created in a previous stage. The next step was to create orthophotomap. All processing were made in local Orto-Cartesian coordinate system without knowledge of the location of perspective centres. The coordinates of the control points GCP and ICP were read out from *the Polish Geoportal of Spatial Data Infrastructure*. In addition, to determine the accuracy of the measured control points (ICP) GNSS RTK were used. Mean errors were also calculated by the PhotoScan application itself. Position errors were of 0.14 m with a pixel size of 0.10 m. Errors calculated in *AgiSoft Photoscan* software were on the same level – 0.12 m like the accuracy of control points coming from geoportal. It means the high accuracy of photogrammetric processing and low degradation of accuracy. Preliminary results of the rapid mapping of orthophotomap are satisfactory and confirm of the high accuracy which will require further research in other areas of the test. Rapid mapping created in this way significantly reduces necessary time to produce both DEM and orthophotomap on limited areas.

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