Design of Test Base for Determine Volume Accuracy

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Abstract This paper describes how the first test base for Remotely Piloted Aerial Systems (RPAS) was built. Aerial photos was done with non-metric cameras Canon 700D. Using the software Agisoft PhotoScan were created orthophotos and Digital Surface Model (DSM). Ortophotos and DSM were calculated in four variants. Computing variants are different in number of ground control points (GCP) entered. Rectangular plane coordinates of check points were read from the orthophoto maps in all variants. Heights of these points were read from DSM in all variants too. The article analyzes the accuracy of check points in all variants. These experiences are nested into the design parameters of the new test base for using in opencast mining. Proposal for a new test base must accept the conditions laid by the Czech Mining Authority for determination of the surface, area and volume, which will comply with upcoming amendment regulation No 435/92.

Keywords RPAS · Non-metric cameras · DSM

1 Introduction

RPAS are used at present in many fields of human activity. In comparison with the common manned aircraft, in some cases the RPAS is more suitable. The RPAS advantage is based on its significantly low price, low price of the sensors, high operability, versatility and adaptability. In addition, the RPAS pilot/operator training is much cheaper. The RPAS is irreplaceable in photographing small areas with Ground Sample Distance (GSD) of 1–2 cm. However if we consider the area larger than tens square kilometres, the standard manned aircraft with digital photogrammetric cameras is more efficient. Therefore it is obvious, that when

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comparing the characteristics and parameters of various means, all possibilities, advantages and disadvantages of the particular project must be considered.

RPAS with non-metric cameras are using for mapping production now. A couple of years ago, it was very difficult to determine distortions in whole area of photo. Mainly to determine the distortion of some commercial objectives—it was almost impossible due to the computer capacity. Currently, the distortion can be calculated for the whole originally non-metric image, basically pixel-by-pixel. And the picture can be transformed to a metric one. Distortion must be calculated, that the interpolation of coordinates of the picture points located between the considered points has no significant influence on the accuracy of interpolated image coordinates of these points.

Agisoft PhotoScan have solutions for determining distortions and all other internal orientation parameters of a non-metric camera, the determination of external orientation parameters of non-metric images as compared in Bartoš et al. (2014), Marčiš (2013).

2 Building the First Test Calibration Base for RPAS

To find out the achievable 3D positioning accuracy of the RPAS systems and non-metric cameras, the Research Institute of Geodesy, Topography and Cartography (VUGTK) built (by courtesy of EUROVIA CS company) a test base with 101 control points on a non-used section of the D11 highway near town of Hradec Králové in September 2013. The points were marked with white colour directly on the road asphalt surface. The marks were in shape of a 25 cm circle with two central sectors (see Fig. 1).

The highway section is oriented within the x-axis of the national coordination system, i.e. the x-coordinates change but the y-ones remain the same. The base is located in two lanes of the half of the highway section in direction Hradec Králové—Praha. Marked are the points of the outside edge of the outside lane and of the inside edge of the inside service lane with step of 10 m on 100 m section. Furthermore the points with step of 20 m on 200 m section and the points with step of 50 m on 650 m section are marked. In addition, all central points of such created images (squares and rectangles) are marked. For the point layout see Fig. 2. All other figures of the calibration base are left-turned by 90° to better comply with the A4 format of this paper.

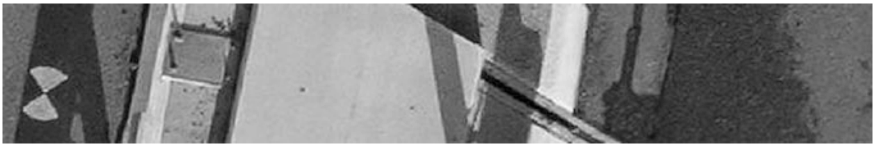

Fig. 1 Sample of ground control point

Fig. 2 Layout of ground control points

The points were surveyed twice. For the first by a terrestrial method—trigonometric coordinate determination with Leica TCA 2003 total station with respect to the national points of fundamental geodetic control. For the second by the independent GNSS technology with geometric levelling for the height determination. The national S-JTSK datum was used, regarding the GNSS technology—the S-JTSK (Křovák 2013, CR 2005 quasigeoid model) datum. The Baltic after Adjustment (Bpv) datum was used for the height determination. GNSS survey was performed twice, independently and with sufficient time interval. To determine the heights of all marked points, the very precise levelling between the 3090 point (elevation 235.066 m) and KH-055-9 point (elevation 230.875 m) was performed. The particular control points were determined by the precise levelling with respect to the points determined by the very precise levelling.

3 RPAS Test Flight

The calibration base was photographed in February 2013. The test sensing flight was intended for determination of the orthophoto positional accuracy and vertical accuracy of the digital surface model. Non-metric Canon 700D camera, size of the

Fig. 3 UAV Hexacopter G6, by courtesy of UpVision, Ltd

sensing chip CMOS 5184 × 3456 pixels (22.3 × 14.9 mm), pixel size on the chip 4.384 × 4.384 μm, with objective Canon EF 24 mm f/2.8 IS USM. The 6-rotor helicopter called UAV Hexacopter G6 was used as the carrying vehicle—see Fig. 3.

The test area was photographed with nominal GSD of 1 cm from average height above terrain of 68 m. The area was sensed in three 5-line blocks with mutual block overlap—see Fig. 4. The entire area is north-south oriented. Total of 1235 pictures was obtained with 80 % longitudinal overlap and 60 % transverse overlap. The camera was fixed with its shorter side in the flight direction. The images covered the area of ca 20 ha. Arrangement of flight stripes in the blocks in the relation to the distribution of GCP such that no rotation of the blocks. WGS84 coordinates of the image projection centres were recorded. The centres were later transformed into JTSK datum. The parameter file is one of the inputs for the photogrammetric processing with the Agisoft PhotoScan 1.0.0 build 1480 software (Agisoft Company Documents 2013). For need of the photogrammetric calculation, a total of 34 initial points were manually measured on the images. The average number of radius vectors for one initial point is 18.

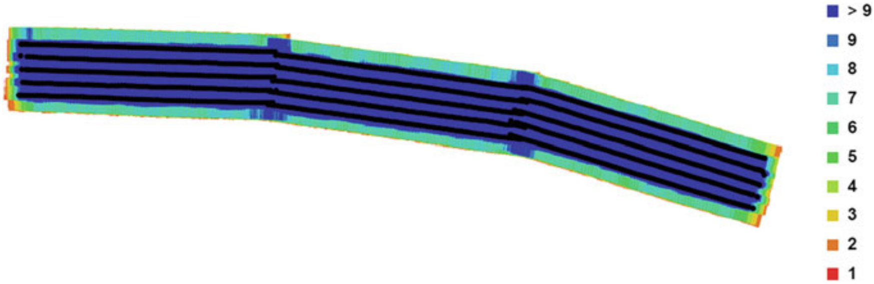

Fig. 4 Configuration of photo blocks and scale with the number beams of tie points

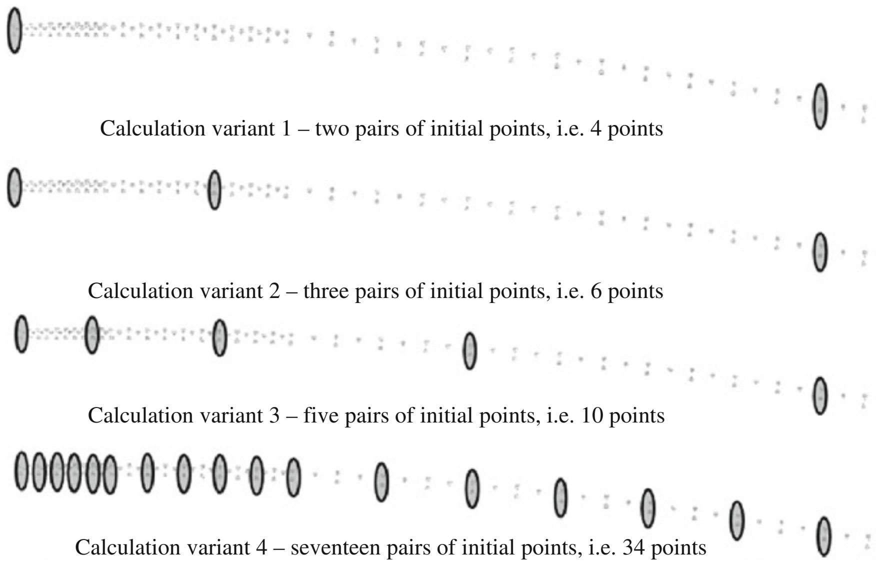

Fig. 5 Distribution of the ground control points in calculation variants

Gradually, four calculations with different number of used initial points were designed and performed. The first variant of the calculation was performed with four known initial points—two at the beginning and two at the end of the sensed area. The initial point layout of the second variant was the same as at the first one, however with two additional points inside the area. The third variant consisted of the second one with additional four points (altogether 10 points). The last variant included all 34 measured points. These points were used for calculation of residual errors on the control points in all calculation variants as the points without mean error to analyze the positional accuracy of created orthophoto and generated elevation model. The Agisoft PhotoScan 1.0.0 build 1480 was used (Agisoft Company Documents 2013). The control point coordinates were determined by the operator. He inserted on the centre of marked point in the orthophotomap a cell on the.dgn drawing with the point number, using Microstation V8i software. From the .dgn file, the numbered cells were subsequently exported to a .txt file and processed in Excel Microsoft. The point heights were determined from generated spatial model using the RoadMap software at the locations of points with zero elevation derived during identification of the marked points (Fig. 5).

Regarding the distribution of the initial points, the coordinate differences on the control points calculated in the variants 2, 3 and 4 are only irrelevantly dependent on the number of photogrammetric bases between the initial points entering the photogrammetric calculations (Table 1).

Table 1 RMSE of calculation variant

Variant description (Values of mean errors in (m) on the check points)		RMSExy		MAX		MIN		RMSEz	MAX	MIN
		Y	X	Y	X	Y	X	Z	Z	Z
Variant 1	Calculation—4 GCP input points, 96 check points	1.014	0.080	1.664	0.107	−0.361	−0.173	2.148	3.753	−0.906
Variant 2	Calculation—6 GCP input points, 94 check points	0.041	0.041	0.113	−0.020	−0.020	−0.107	0.038	0.120	−0.113
Variant 3	Calculation—10 GCP input points, 90 check points	0.015	0.015	0.040	0.036	−0.035	−0.042	0.039	0.143	−0.094
Variant 4	Calculation—33 GCP input points, 67 check points	0.012	0.011	0.032	0.025	−0.014	−0.026	0.035	0.115	−0.093

4 Proposals for Test Base Layout for Opencast Mining

In the Czech Republic, currently many mining companies consider using the RPAS devices and non-metric cameras for determination of drawn rock volume, e.g. Koliáš et al. (2014). Requirements for accuracy of the mapping and determination of the drawn rock volume can be satisfied. Systems are easy available on the market and many mapping applications and software for data processing have been developed.

On the basis of the experience with establishing the first RPAS base, determination of the relation between GSD and RMSE values in 3D position and also on the basis of experience with creating the methodology for determination of residual errors on initial and control points, it seems suitable to establish and permanently maintain a test and calibration base in area of Krušné hory foothills.

The ideal area could be between towns of Kadaň and Chomutov, particularly the area of the homogenizing disposal site of the Tušimice power plant (Figs. 6 and 7).

Fig. 6 Zone of brown coal opencast mining in Krušné hory foothills

Fig. 7 Area of homogenizing disposal site of Tušimice power plant

The RPAS calibration base should be at least of 600 × 200 × 20 m (length, height, wide) and consist of at least 48 signalized GCP spread with a regular horizontal and vertical distance. 14 of them will be entering points and 34 of them as check points, i.e. points, which will not participate in the photogrammetric processing. Before starting the works, a check sensing of the calibration base should be performed with given camera and given RPAS to assure the metrological link-up and subsequent determination of the final volume or volume decrease (mining wall) or increase (dump, pile, etc.). The base must be accessible via a public road and its description, parameters, pictures, and coordinates of initial and control points must be presented on the internet. The basic parameters for sensing the test base should be as follows. GSD 1–3.5 cm. Longitudinal overlap at least 75 %. Transverse overlap at least 50 %. Initial 14 points surveyed manually before the photogrammetric processing. Manual reading of horizontal coordinates from the orthophotomap and vertical coordinates from the digital terrain model. Final RMSE less than 1.5 × GSD in horizontal and 2.5 × GSD in vertical coordinates. If the above mentioned limits are not reached, the calculation should not be used for the volume determination. If the parameters are met, it is guaranteed, that the volume determination is with accuracy of 1 % and the error is random. These values will be further tested on known shapes (both natural and man-made) during 2015.

5 Conclusions and Recommendations

The first test base built by VUGTK is the first step of testing RPAS method for utilization in the surface mining. The tests of horizontal and vertical accuracy of photogrammetric methods, which use non-metric cameras and DPLS, represent a significant part of modern photogrammetry in the Czech Republic and are adequate alternative to the aerial sensing utilizing the manned aircraft and to both terrestrial and aerial laser scanning intended for mapping and determination of material volume in the surface mining with high accuracy. One of the main conclusions of the test described in this paper is determination of the number of initial points for number of photogrammetric bases. The test proved that to reach the horizontal and vertical accuracy of particular map points for volume determination with 1 % accuracy it is sufficient to establish one initial point for 100–120 image bases.

However this ratio can significantly change in case of using RTK methods on the RPAS board, if we know the input parameters of the centre coordinates of images made by non-metric cameras with XYZ accuracy of about 10 cm (in future also the parameters of camera rotation angles at exposition instant gained from an IMU device). In such case, only 6 initial points per the locality are sufficient. Precise parameters of the external orientation of images in the block [or at least their positions as in case of Topcon products—RPAS MaVinci (Topcon Company Documents 2014)] significantly decrease the block calculation time. Moreover, it is necessary to set the limit values for the base ration, i.e. the relation of distance between two neighbouring images to distance of the sensed object (flight elevation above the terrain), further the limit condition for the object observation angle in the image for correlation calculation, and the limit conditions and relations between the focal distance, size of the sensing sensor and size of the sensing element on the sensor. Further the relation of the limit (and needed) detail for the volume determination. It will be necessary to specify the relations between the texture type and size of used GSD with goal to eliminate, or to specify, locations unsuitable for creation of 3D model, where the insufficient texture of the object surface on the images does not enable the correlation calculation.

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