LAND SURVEY WITH THE HELP OF AN UNMANNED AERIAL VEHICLE (UAV) WITH 3DSURVEY

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ABSTRACT:

In this paper we present a test study of a land survey with the help of an unmanned aerial vehicle (UAV). Traditional land survey maps consist of CAD line drawings. They are produced by measuring points of interest with classical equipment, such as total stations and survey grade GNSS receivers. Unmanned aerial vehicles, however, present us with the possibility of measuring large areas just as accurately and far more elegantly than in the case of classical land surveying methods. Standard results of a UAV based land survey consist of point clouds, digital terrain models and digital orthophotos. This paper, however, does not focus on standard results, but focuses on production of line drawings based on aerial images captured by C-Astral Bramor unmanned aerial vehicle equipped with a camera and RTK GNSS navigation system. This paper describes the test dataset, data acquisition using unmanned aerial vehicle, process and methodology of producing line drawings from aerial images, control measurements performed with classical surveying equipment and accuracy analysis of UAV based measurements Those are based on ground control point errors and the comparison between aerial image line drawings and those from classical land survey measurements.

1. INTRODUCTION

Test site is an area of 30 ha in size and is located next to a highway petrol station. 679 aerial images of the test site were recorded by C-Astral Bramor UAV. In order for the results to be as accurate as possible, 9 ground control points were signalized on site, and their positions were obtained by using tachymetric and GNSS surveying method. A point cloud of the area, digital terrain model and a digital orthophoto were calculated from the aerial images with 3Dsurvey. Total station was used to measure a survey map of the area. CAD survey map of the area was drawn and this data was used as control measurements set. Second line CAD map was produced using 3Dsurvey and aerial images.

2. HARDWARE USED FOR DATA ACQUISITION

C-Astral Bramor UAV was used to record overlapping aerial images of the landslide area. The UAV is specifically designed for surveying operations. It carries a camera with a 24.3 Megapixel sensor and a modified camera lens with a focal distance of 30 mm.

Figure 1. C-Astral Bramor UAV

For georeferencing we used ground control points. To determine positions of ground control points we used a tachymetric total station Leica TC803.

Figure 2. Tachymetric ground control point – reflector mount fixed onto concrete curb

3. DATA ACQUISITION

3.1 Photogrammetric data acquisition

A UAV is used to record overlapping aerial images of the test site area. Images are recorded from 120m above ground level, with horizontal overlap of 75% and vertical overlap of 66%. Camera is set to low ISO value - ISO 100, and high shutter speed – 1/1250.

3.2 Data acquisition with total station

A team of two land surveyors was sent to the test site to produce a validation survey map of the area. They used a total station to measure 330 detail points. To measure the entire test site area they had to change the position of the total station five times and it took them four hours to complete the terrain part of the job and then another two hours of computer work to produce a CAD survey map drawing.

Figure 3. Validation survey with total station

4. DATA PROCESSING

4.1 Standard photogrammetric workflow

First part of data processing work-flow is just as any other modern digital photogrammetric technique. Software 3Dsurvey is used for processing. Aerial images are processed automatically. First, keypoints are identified in the images and descriptors are computed. These are then matched between all the images in the set. False matches are removed with the help of determination of fundamental matrix for each of image pairs. Bundle adjustment is performed, taking advantage of the sparse Levenberg-Marquardt algorithm. Positions of ground control points are taken into account to provide georeferencing. Results of the sparse Levenberg-Marquardt algorithm are parameters of inner and outer camera orientations and a sparse point cloud of 3D tie points. Sparse point cloud is then densified following a multiview stereo approach.

Figure 4. Subset of 3D point cloud

Non-terrain points are excluded from the point cloud, and digital terrain model is calculated. As final step of standard photogrammetric work-flow a digital orthophoto is calculated.

Figure 4. Part of a digital orthophoto

Accuracy assessment of generated data was performed based on ground control point errors. The following ground control point errors were observed:

	Errors [m]			
Point ID	**X**	**Y**	**Z**	**3D**
P1	0.017	0.007	-0.025	0.031
P2	-0.001	0.002	-0.009	0.010

P3	-0.005	-0.004	0.020	0.021
P4	-0.004	-0.008	0.018	0.020
P5	-0.021	0.010	-0.050	0.055
P6	-0.010	-0.000	-0.040	0.041
P7	0.007	-0.001	-0.023	0.024
P8	0.005	0.004	-0.004	0.007
P9	0.005	-0.002	0.031	0.031

Table 1. Accuracy assessment shows the mean error of 6mm in xy directions and 24mm in z direction.

4.2 Line map production

A survey map in the form of 2D or 3D CAD line maps is still the most widely used survey data type. Architects and design engineers are still reluctant to use pointclouds and digital orthophotos as a basis for their designs. What they need are clear ways to get from A to B.

3Dsurvey has the possibility to produce line drawings from original aerial images. This is a modern approach to monoplotting. It enables users to go through the list of images and draw lines. When a user draws a 2D polyline on an image, it automatically transforms 2D polyline in image coordinates into 3D polyline in world coordinates. When user moves to new images, lines drawn on previous images are reprojected onto the new images and users can snap to line endpoints and continue drawing. Basic editing tools, such as delete point and delete line are also supported. 3D lines can be at any time exported to DXF format.

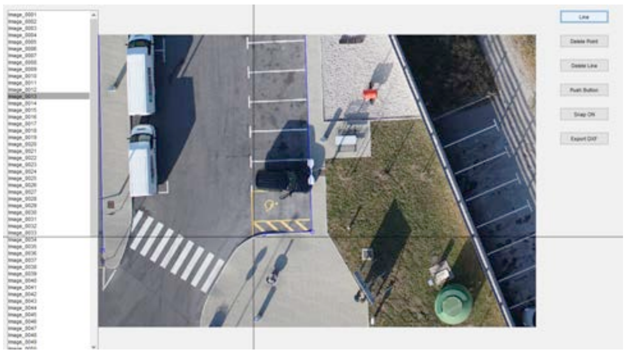

Figure 5. Producing line map from aerial images

This workflow enables a new paradigm of land surveying. Land survey maps from aerial images are produced 2 - 3 times faster than in the case of traditional surveying methods. It took us 2 hours to draw some 300 lines and points from aerial images, corresponding to survey map produced with measurements from total station.

5. ANALYSIS

We compared line survey map produced from aerial images to validation survey map measured with total station. We visualized both survey maps in CAD software and measured differences in line positions between both survey maps.

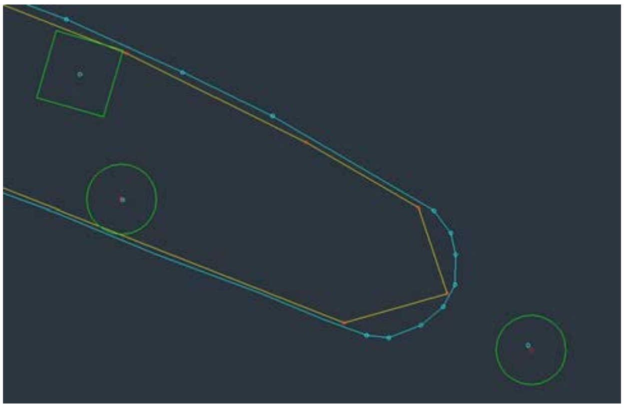

Figure 6. Part of a survey map showing aerial images in cyan, validation points in red, validation lines in yellow and validation topographic signs in green.

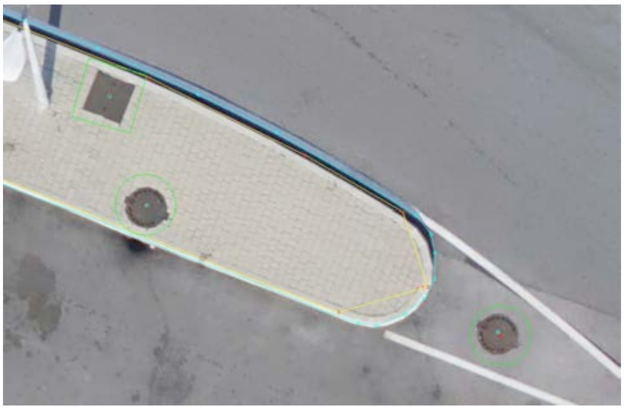

Figure 7. Part of a survey map – the above Figure 6 map with digital orthophoto overlay

To compare data from aerial images with data from the total station we followed the following methodology;

in cases of point data types (examples sewer duct covers displayed in figure 6 with green squares and circles) we took into account the vector between point measured with total station (red circle) and point obtained photogrammetrically from aerial images (cyan circle);

in cases of lines, such as curbs (yellow lines) in figure 6, we took into account the difference between point measured with total station (red circle) and point perpendicular projection of this point to line measured photogrammetrically. This is necessary, because in case of lines we must look at how far apart the lines are, not how far apart are the line endpoints are.

Accuracy analysis shows the following standard deviations of photogrammetric measurements from validation measurements made with total station: 3.4 cm standard deviation in the horizontal xy direction and 6.6 cm standard deviation in the vertical direction.

6. CONCLUSION

We believe low altitude photogrammetry can enhance classical tachymetric measurements. The technology offers the advantage in the form of fast data acquisition. While even experienced surveyors can only determine positions of approximately 3 points per minute, low altitude photogrammetry one the other hand has the ability to provide millions of points in less than an hour.

In addition, UAV based measurements are contactless which allows for highly visual representations of natural or manmade environment. They can be used to get information from places which cannot be easily (or safely) accessed, such as highways, rocky cliffs, remote locations, etc. As taking measurements does not interfere with traffic of work processes, low altitude photogrammetry can offer elegant control over quarries, landfills, highways or roads.

UAV based mapping offers a compeltely new paradigm of what is considered to be land surveying. Surveyors can map huge areas of land, and make technical and business decisions later, focusing on anything from which survey maps to produce to the question of resolution and level of detail. Furthermore, if at later stage a more detailed survey map is required, one can extract additional measurements from existing aerial images without having to do any more field work.