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RESEARCH ARTICLE

THE USE OF ORTHOPHOTOS PRODUCED FROM DIFFERENT ALTITUDES IN PIPELINE PLANNING

***Mehmet Akif GÜNEN, Ümit Haluk ATASEVER and Erkan BEŞDOK**

Department of Geomatics Engineering, Erciyes University, Kayseri-Turkey

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ABSTRACT

With the developments in camera lens technology and the drop in prices of Unmanned Aerial Vehicles (UAV), orthophotos have started to be produced faster and less costly with the help of aerial photogrammetry. In addition to cultural heritage documentation, disaster area planning, precision agriculture and surveillance, UAV systems are also taking place in new and different areas such as mapping of cliff regions, roadway planning and water pipeline planning. For remote sensing systems, the distance between the target being imaged and the image obtained platform plays an important role in orthophoto and DEM production, because of changing the spatial resolution. In this paper, the images obtained from different altitude (50,100,150m) belonging to the same regionwere taken into consideration by changing the ground sample distances and an application was made to apply the water pipeline planning. The Pipeline is determined by ground control points (GCP), tie Points and user estimates where the line passes using orthophotos obtained from different altitude. Real pipeline locations, GCPs and tie point were measured using Global Positioning System (GPS)/Real Time Kinematic (RTK) method. RMSEs of GCPs were evaluated among themselves and the digitized pipelines were evaluated statistically and visually by pipelines obtained by measured pipeline.

Key words: *UAV, Pipeline, Orthophotos, GPS-RTK, Structure from Motion.*

INTRODUCTION

UAVs are preferred by researchers because they achieve high stability, produce high spatial and temporal resolution images, reduce prices and produce data faster than terrestrial methods. Vector maps produced from photogrammetric data do not contain any other special features outside the main details on the land. This may not make sense for some occupational groups in terms of the information contained in the map (Hartmann and Steup, 2013). If the orthophotos are difficult to interpret and apply to the land, they provide comprehensive information without regard to the user class in terms of containing meaningful or meaningless, permanent or temporary information related to the land. Images obtained with UAVs are processed by high-capacity computers through software selected for the purpose of the user and used as vector-based data for georeferenced-raster subsets. Orthophotos can be integrated into Geographic Information Systems and CAD systems to make various analyzes, as well as meaningful land objects can be stored in coordinate format in vector data format(Colomina and Molina, 2014). UAVs generally consist of a carrier platform with a control unit to collect data for photogrammetric purposes and a photographic machine for image capture. UAVs, which are candidates for alternative to digital-classical photogrammetric studies in the future and today, are increasingly used production of Digital Elevation Model (DEM), topographic map and orthophoto in limited areas. Influences from weather, limited flight times, easy adaptation from environmental factors, and more distorted images compared to traditional aerial images make the operation of UAVs complex. However, the resulting product is often sufficient for many studies (Ouml and mer, 2010). The quantity surveyof the pipeline accounts respond many problems such as how much pipes are laying by contractor, what kind of pipe is used and what kind of material is covered with the top of the pipe. In the quantity surveystudy made with terrestrial methods, both the time spent in the field and the cost are higher due to the time spent.When GPS-RTK systems do not get correction beyond the coverage of GPRS systems, users prefer either the classic terrestrial measurement methods (Total Station) or the DGPS method. In addition, making GPS / GNSS inaccurate results in areas exposed to intense multipath errors such as in the urban area has made it worthwhile to investigate the utility of UAV systems as an alternative to GPS / GNSS systems in some areas (Hasan *et al*., 2009; Rayburg, Thoms, and Neave, 2009). As the study area, a newly completed water pipeline was chosen for working within the Kahramanmaraş Sütçü İmam University Campus. The pipeline, grip points (tie points) and the GCPs within the bounds of the working area were used to obtain coordinates using the GPS / RTK method. The area is captured with various numbers of 50,100 and 150 m altitude by UAV with integrated 12 Mp camera. From the obtained images, 3D colored point cloud was obtained by using Tesla and CUDA GPU supported computer with Structure From Motion (SfM) method and orthophoto was produced from this point cloud. Following the details of the land that can be distinguished from orthophoto, user-assisted and manually tried to keep track of

****Corresponding author: Mehmet Akif GÜNEN,***
Department of Geomatics Engineering, Erciyes University, Kayseri-Turkey

places where pipeline passes. Possible past locations were recorded linearly in vector format. RMSE values of GCPs on orthophotos obtained from different altitudes were evaluated among themselves. In addition, pipelines generated by GPS / RTK method and pipelines digitized by using orthophotos are presented both visually and statistically to investigate UAV availability in pipelines.

MATERIALS AND METHODS

Terrestrial Measurements

GPS-RTK method was used to measure 200 mm-10 Atu pipelines in Kahramanmaraş Sütçü İmam University, which was selected as a study area, and which carries water in a closed system from Kahramanmaraş center to south villages. Measurements were made at ITRF96 datum and 2005.00 Epoch at 125 points for 3 seconds at intervals of about 10 m along the water pipe line. In addition to the line measurement, 10 points was used as GCP were measured for 5 seconds. In Figure 1, the points representing the pipeline measured by GPS-RTK method are shown on the Bing Satellite image.

Fig. 1. GPS coordinates on Bing Satellite Image

UAV and Flight planning

DJI Phantom 4 brand UAV was chosen as part of the paper. The system is suitable for additional camera installation, but its 12.4 Mp integrated camera with CMOS sensor is sufficient for operation.

The UAV, which can operate up to 6 km above sea level, is effective in generating fast results because it provides speed during image matching and dense point cloud generation in software used by GPS / GNSS information written to EXIF information. In addition to work in windy and humid environments, the DJI Phantom 4 is able to capture images from any angle with its camera gimbal which offers oblique flight and captures usable images even in extreme rattles("https://www.dji.com/phantom-4/info," 2017). The flight plan for the study area is shown in Figure 2 with minimum battery usage according to the desired sidelap/frontlap, minimum speed and working altitude. By performing flight from different altitudes, orthophotos with different spatial resolutions have been investigated on the digitization effect. Flight planning for different altitudes for the study is shown in Table 1.

Fig. 2. Flight Plan of Study Area

Table 1. Flight Planning by Different Altitude

Flight Distance (m)	50	100	150
Flight time (min)	24.32	8.14	6.40
Ground sample distance(cm/pix)	2.1	4.3	6.4
Number of Strokes of the Plane (Expedition)	2	1	1
Number of Images Captured	452	385	306
Overlap Rates (Side/Forward)	65/75	65/75	65/75
Maximum Speed (m/s)	15	15	15

As shown in Table 1, the flight height changes the groud sample distance and the number of captured images. This change changes the discriminability of small objects in the case of digitization through the generated orthophoto. Today, most software for orthophoto production uses the digital elevation model (DEM) generated from images obtained from UAVs. DEM accuracy depends on GCPs used to transform flight altitude, image angle, terrain topography, land cover, and the desired coordinate system (Baltsavias, Mason, and Stallmann, 1995; Habib, Kim, and Kim, 2007). In Figure 3, it is seen that the topography of the study area is not uniform and is in the interior of the woodland / soil area. Figure 4 shows the orthophoto generated from the images captured from the 50m altitude.

Fig. 3. Digital Elevation Model

Fig. 4. Orthophoto with high resolution

MATERIALS AND METHODS

Thanks to the precise detail identification they provide with high resolution images, the user has great convenience despite the high data size.There is a discernible object difference between high-distance captured images and close-range images.Object distinction is less in images captured with higher altitute with the same camera. GCPs are needed to correlate orthophotos with real world coordinates. With GCPs marked on the image either manually or semi-automatically, both camera calibration parameters are optimized and coordinate transformation is performed. However, it is important that the GCPs that are installed on the ground can be seen and marked in the correct place with markers on the image(Chiang, Tsai, and Chu, 2012; Hartley, Gupta, and Chang, 1992). In Figure 5, orthophoto images are shown by flying from 50,100 and 150 meters altitude, respectively, in the same region.Objects can not be selected as elevation increases as seen from here. The selectivity and color of the uncovered pipe are different from each other.Because of the altitude and the change of the projection of the sun to the earth, there are contrast differences between the orthophotos that have been caught recently (about 1.5 hours).

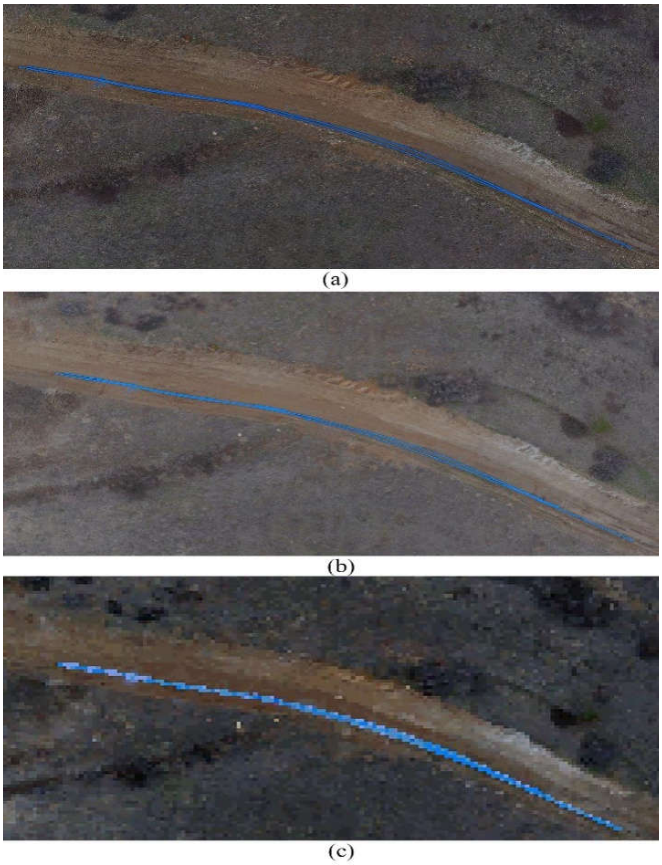

Fig. 5. Orthophoto of different altitudes a)50 m b)100 m and c)150 m

The orthophotos obtained in Figure 5 was manually traced from approximately the middle of the excavated area to follow the tie points and GCP points established in the locations where the line passes. Figure 6. shows the locations of the GCP and tie points installed to route the line from the correct location. In Figure 7, the digitized vector pipeline is displayed on orthophotos from different altitude. Point data collected by the GPS-RTK method which is accepted as reference is converted into line and the distances between them and the digitized lines are shown.

Fig. 6. Tie points and GCPs on the pipeline

These distances are the result of the user choosing the wrong detail and not having to be right where it should be. As seen in figure, the lines generated from the close images are closer to the reference line than the others.

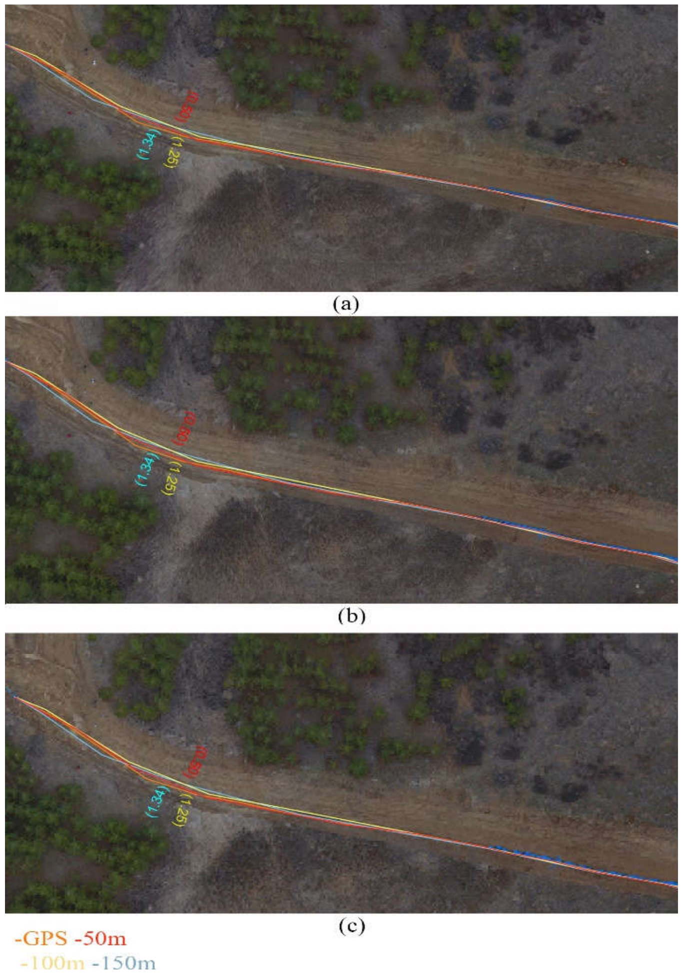

Fig. 7. Pipelines onorthophotos a) 50m b)100m c)150 m altitude

Table 2. Metric comparison of pipelines

Methods	GPS	50 m	100 m	150 m
Length (m)	1114.18	1114.80	1113.83	1115.51

The line length produced from 3 different altitudes and the metric comparison of the line length generated by the GPS method are given in Table 2. When Table 2 is examined, it is seen that the closest result is the close image. The 10 GCPs installed on the ground prior to flight are both involved in camera calibration and DEM transformation. The RMSE calculation for the GCPs where the ground is installed is given in Eq.1-4(Uysal, Toprak, and Polat, 2015).

$$RMSE_x = \sqrt{\frac{(x_{model} - x_{ref})}{n}} \quad (0)$$

$$RMSE_y = \sqrt{\frac{(y_{model} - y_{ref})}{n}} \quad (2)$$

$$RMSE_z = \sqrt{\frac{(z_{model} - z_{ref})}{n}} \quad (3)$$

$$RMSE_{Total} = \sqrt{(x^2 + y^2 + z^2)} \quad (4)$$

The RMSE values of GCPs marked on images captured at different heights are given in table 3.

Table 3. RMSE of Different Altitudes

Altitude	RMSE			
	X(cm)	Y(cm)	Z(cmm)	Total (cm)
50 m	1.99	2.46	0.77	3.26
100 m	3.20	2.75	1.35	4.43
150 m	3.62	3.42	2.21	5.45

As seen in the table, GCPs cannot be marked in the correct place because of the spatial resolution change so the flight from the 50m altitude is best.

Conclusion

This study has shown that UAV systems can be used in jobs that are done by terrestrial measurement methods such as water pipeline. And aims to reduce the cost and time spent in the field. In this context, orthophoto is produced from the images obtained from various heights by accepting the pipeline reference measured by GPS-RTK and tried to determine user-assisted pipeline from these orthophotos. It has been determined that UAV systems can be applied for pipeline metrics in the light of the obtained data. In addition, visual and statistical comparisons of orthophotos made from different heights were made. Although the problem of low battery capacity on low flights requires high data size and additional time, it has been seen that high flights have higher accuracy and produce more accurate results for photogrammetric studies.

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