A NEW APPROACH ON SLOPE DATA ACQUISITION USING UNMANNED AERIAL VEHICLE

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ABSTRACT
This study proposes a generic approach for photogrammetric survey using unmanned aerial vehicle (UAV). UAV is one of the powerful equipment that can be used to obtain the earth surface images from certain altitude. UAV can provide a high quality data for GIS analysis. In this study, two persons are needed; UAV operator and ground crew station. A complete set of fixed wing UAV with autonomous flight was used to capture image from certain altitude at the study area.UAV operator is responsible to operate UAV during flight mission especially during launching and landing while ground crew station is responsible to monitor UAV attitude during flight mission. All acquired images were processed using photogrammetric software which applied all photogrammetric stages. Two primary results were produced such as digital elevation model and digital orthophoto. Digital elevation model and digital orthophoto was generated after the aerial triangulation process based on tie point measurement and ground control points. In this study, we have generated three dimensional model based on the UAV images. It was found that, UAV images were able to provide an accurate three dimensional model for GIS presentation. This study has successfully represented the result for GIS data using UAV images. UAV can be used as one of GIS data source in the future.

Keywords: *Earth Science, Technique, Slope, GIS, UAV, Analysis*

1. INTRODUCTION

A past few years ago, Various techniques has existed to supply data for geographic information system (GIS) for example global positioning system (GPS), land surveying using total station, Light detection and ranging, terrestrial laser scanner, photogrammetry and remote sensing (Kent and Klosterman, 2007; Johnson and Wilson, 2003). Terrestrial laser scanning (TLS) is a ground-based technique for collecting high-density 3D geospatial data. It is an active imaging system whereby laser pulses are emitted by the scanner and observables include the range and intensity of pulse returns reflected by the surface or object being scanned. ALS operates by using a pulsed laser beam which is scanned from side to side as the aircraft/helicopter flies over the survey area, measuring between 20,000 to 100,000 points per second to build an accurate, high resolution 3D-model of the ground and the features upon it. The ALS scanning device is mounted at the bottom or sides of an aircraft flying along selected parallel flight paths. Previously, manned aerial photogrammetry uses film as the raw images of the earth surface but now it has been converted into digital images. Film images used analytical stereoplotter in order to determine the correct image position same as flight mission. Digital aerial images went the same processed except it has been applied using digital photogrammetric software. Manned aerial photogrammetry is widely used to classify land use at study area. Data acquisition is the most expensive stage in most project and research. Many equipments and techniques have been explored to acquire fast, accurate and low cost data. This study introduces a new technique in data acquisition for geographical information system data. A new technique of data acquisition has been discovered using unmanned aerial vehicle (UAV). UAV promises a low cost data acquisition and high accuracy data. UAV also is one of the fast platforms to acquire data at the area of interest. However, most of these techniques require high cost for data collection in GIS. Geographic information database can be represented by tabular data or spatial data. Spatial data can be obtained from the existing map or images. Spatial data can be divided into two categories such as raster and vector data. Raster data can be produced from the scanned map or digital images from specific sensor while vector data can be produced by digitizing work or vectorization processing. Tabular data is the attributes of the spatial data. Tabular data is also represented in a table form with digit and words. Recently, the spatial data and attributes are available through website (Guo et al., 2005). However, most of GIS data has its own price and usually it cannot be made public due to security reason. Internet sources need to be verified before it can be used for GIS analysis. It is because internet sources will be available in digital format and it is very important to find the main source of data creation. This is very important in order to determine the level of data quality and also metadata before it will be used for GIS analysis (Chen et al, 2011). Existing map sheet is also one of the GIS data sources and each existing map has its own content, scale and creator. The best quality of map can be used for direct measurement of some applications.

GPS is one of GIS data sources and it can collect the coordinates on the earth surface. GPS can provide the precise coordinate of x, y and z depending on the GPS specification. GPS coordinates is usually used to carry out direct georeferencing of spatial data in GIS analysis. GPS can give accurate measurement from 100 meter to 1 millimeter (Hale et al, 2007). Remote sensing data can be obtained from the satellite images which uses different types of sensor to capture image on the earth surface. Each satellite images has its own spatial resolution based on types of sensor at the satellite platform. Satellite images are captured thousand kilometers from the space and it orbits at the specific altitude. Previous photogrammetry technique obtained aerial photo of the earth surface by using manned aircraft which involved a professional pilot to navigate the proposed flight line (Eisenbeiss, 2004; Tahar et al., 2011). Manned aircraft involves huge cost and it is normally suitable for projects with large budget which involves large area, therefore, manned aircraft is not practical for small project with low budget.

This paper represents a new generic method in GIS data collection using unmanned aerial vehicle (UAV). UAV has become more popular among research in order to solve their problem especially in decision making. This study proposes a generic approach for photogrammetric survey using unmanned aerial vehicle (UAV). UAV is one of the powerful equipment that can be used to obtain the earth surface images from certain altitude. UAV was developed by military a few decades ago for surveillance and security purposes. Now UAV has been designed by civilian and researcher to improve the UAV capability for their specific application. Civilian used UAV for their hobby and many UAV has been designed using different material (Tahar et al., 2011). Most researchers have developed and designed UAV for their research and investigate the capabilities of UAV in solving their problem. UAV can be used in many applications such as archeology documentation, documentary video, national security, rescue and mapping (Eisenbeiss, 2004). This study focuses on mapping field especially using photogrammetric method. UAV has been used as a platform for image acquisition from certain altitude. UAV can be manually or autonomously controlled (Chao et al, 2010). The selection of autonomous mode or manual mode depends on the objective of the project or studies. Manual control requires an operator to operate UAV during flight mission while autonomous requires ground crew station and operator to launch and land the UAV. All acquired images were obtained by using consumer digital camera with the resolution of 4000 x 3000 pixels. Image acquisition is solely obtained from the UAV platform with the digital camera attached at the bottom of UAV.

2. MATERIALS AND METHODS

2.1 Flight Preparation

In this study, UAV flight line is designed using Lentsika software. Lentsika software requires information such as estimated coordinates at the study area, pixel size of digital image, image resolution and estimated ground resolution (Tahar and Ahmad, 2011). The estimated coordinates at the study area are obtained from Google Earth coordinates. However the interval distance between each images is calculated based on user requirement. In this study, we have calculated that each pair of images overlapped about 60 percent and side lap about 30 percent. Ground coverage area for each image is calculated based on pixel size, image resolution and scale of aerial photograph. After that, flight line file is sent to the horizon software for final inspection. Horizon software finalized the flight line of the study area and this software is also used to monitor UAV during flight mission. Figure 1 shows the flight line at the study area.

Figure 1. Flight line at the study area

2.2 Image Acquisition

Before flight mission, an operator needs to test all UAV electronic part to see if every part is functioning. This test is very important in order to avoid any problem on UAV during flight mission. An operator needs to test the electronic speed control, UAV body such as rudder, elevator and main frame, GPS onboard, camera mount, digital camera and propeller. After all tests have been done, an operator needs to find a suitable location for launching operation. In this study, we have applied autonomous flight mission to capture image at the study area. Basically, autonomous UAV needs two persons e.g operator and ground crew station. In this study, an operator is responsible to control UAV during launching and landing operation to avoid any damages on UAV. Ground crew station is responsible to design the flight line at the study area and monitor UAV attitude, battery status, number of satellite, and data link between UAV and computer at the ground station.102 images were captured to cover the whole study area. The flight mission took about 15 minutes to finish. Figure 2 shows UAV and digital camera that were used in image acquisition.

Figure 2. UAV and digital camera

2.3 Image Processing

Some of the images might have some quality problem such as blurring image and color balancing error which was caused during flight mission. These problems usually arise from the attitude of the UAV during flight. If the quality of all images were very bad, another flight mission might need to be done. However, in this study, all acquired images were in good quality and they were being preceded for the photogrammetric processing. As usual, photogrammeric technique involves many processes such as interior orientation, relative orientation, aerial triangulation and bundle adjustment. Interior orientation requires the information of camera parameters including pixel size, focal length and principal points coordinates. All of these parameters were being defined before the processing stage. Relative orientation involved image correlation algorithm in order to transfer the tie points between images. Tie points were responsible to align all acquired images in the same condition in which the images were taken during flight mission. Ground control points were established during image processing in order to project the result into local coordinate system. Ground control points were collected by using Real Time Kinematic Global Positioning System (RTK-GPS). There are two main photogrammetric results produced in this study, such as digital terrain model and digital orthophoto.

3. RESULTS AND DISCUSSION

In this study, two primary results are produced such as digital elevation model and digital orthophoto. Digital elevation model is generated after the aerial triangulation process based on tie point measurement and ground control points. Digital orthophoto is generated from an individual orthoimages for each model in the photogrammetric block. Figure 3 shows the example of DEM and digital orthophoto that was produced from UAV images after photogrammetric processing.

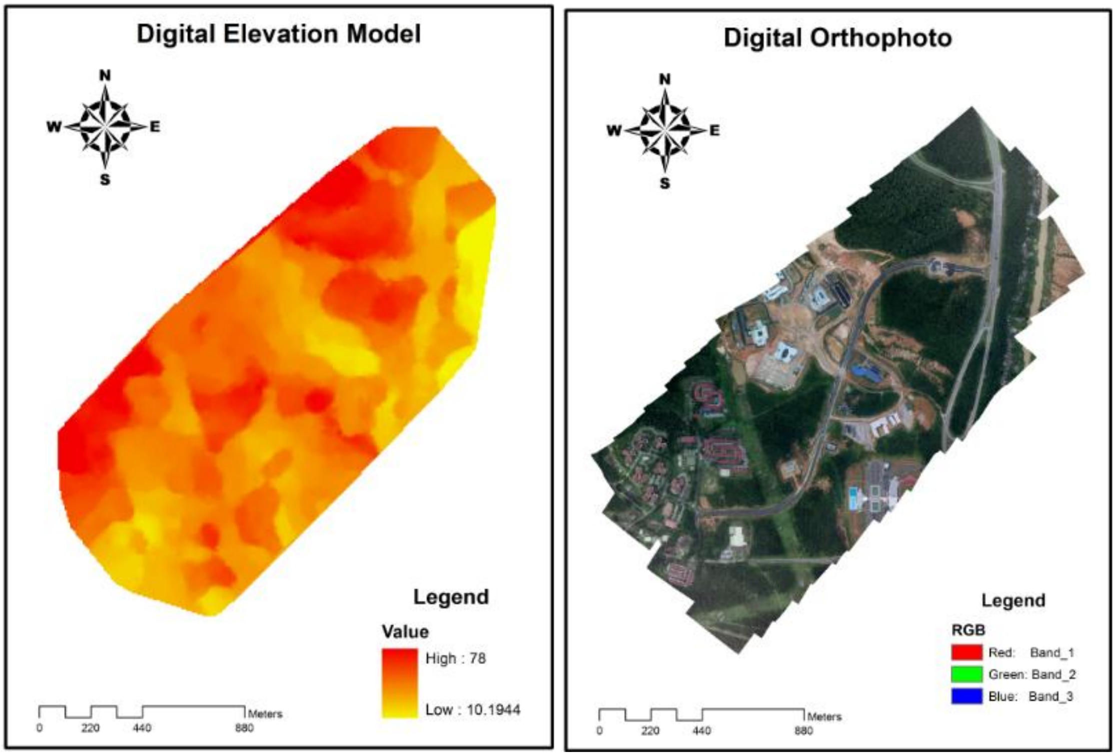

Figure 3. Primary Data : DEM and Digital Orthophoto

In GIS, primary data can provide many layers for secondary data. As a result, secondary data can be produced based on DEM at the study area. Secondary data that can be produced based on DEM are slope map, elevation map, contour map, hillshading map and aspect map. Figure 4 shows an example of slope map, contour map and triangular irregular network (TIN) as a secondary data.

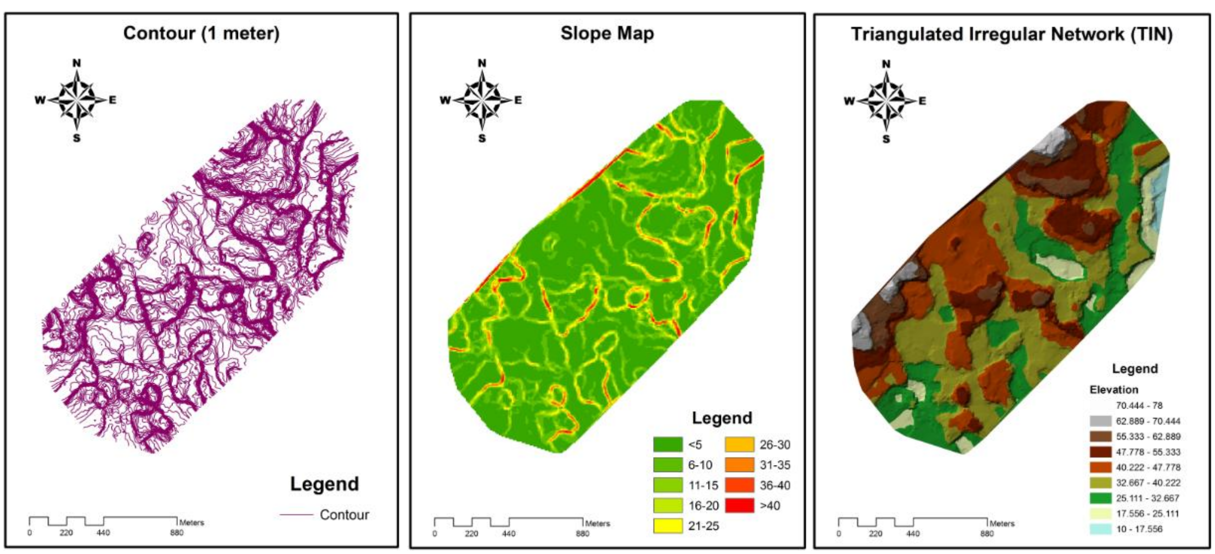

Figure 4. Secondary data : contour map, slope map and TIN

In this study, we evaluated the suitability of UAV for slope mapping. We have generated three dimensional model based on UAV images. It is found that, UAV images are able to provide an accurate three dimensional model for GIS presentation. Our results are improvement in slope mapping technique using UAV compared to previous techniques using Light Detection and Ranging (LiDAR) (Kovalev, 2006; Su and Bork, 2006; McCoy et al., 2011; Hug, et al., 2004), Terrestrial Laser Scanner (TLS) (Schurch et al., 2011; Lim et al., 2005; Schaefer and Inkpen, 2010) and manned aircraft (Ryu et al., 2005; Wu et al., 2005) for slope mapping. Previous techniques required an expensive cost in data acquisition at slope area especially for repetitive work for monitoring purposes. Therefore, this study give a solution to researcher, consultant, and worker to acquire slope data with low cost, less time and less labour needed. In this study, we have select one slope (red circle in Figure 5a) to demonstrate the three dimensional model using UAV images. The three dimensional model was developed based on digital orthophoto and digital elevatiol model consist of x, y and z coodinates. Figure 5 shows an example of three dimensional model at the study area.

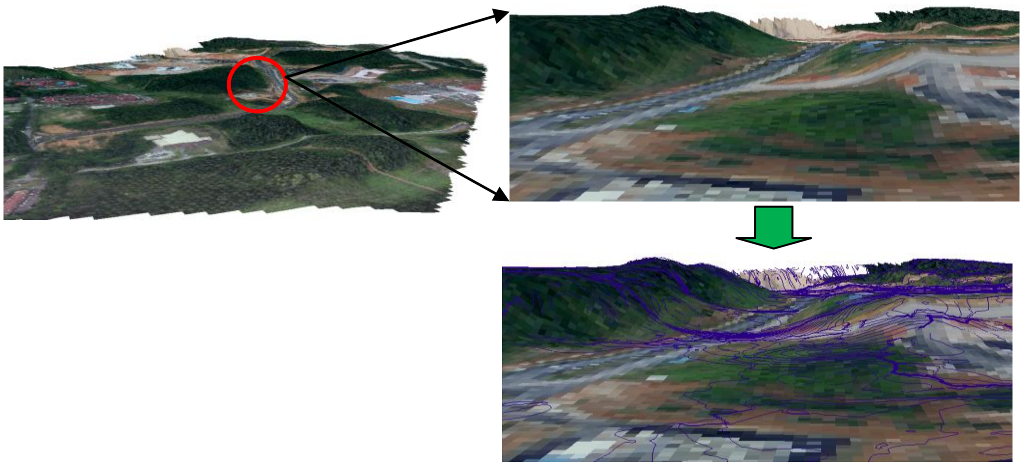

Figure 5. Superimposition of digital orthophoto, DEM and contour

Figure 5a represents the superimposition between digital orthophoto and digital elevation model of the whole study area. Figure 5b shows one selected slope was identified to determine the quality of the generated slope from UAV images. Figure 5c shows the selected slope was draped with the contour line. In graphical view, it was found that, the contour line showed the proper pattern at the slope area and at the flat area. Therefore, UAV images were capable to provide a high quality data for GIS uses. Integration between digital camera and UAV can be used to solve many problems and cases in real world such as real time mapping system (Kurz, et al., 2012), large scale mapping (Zhang et al., 2011), terrain mapping (Mitasova et al., 2009) and city modeling (Barber, et al., 2008). Previous study by Tahar and Ahmad (2011) proved that consumer digital camera able to provide high resolution data and it is support the results of this study. On the other hand, UAV has been proved as a rapid response equipment for data acquisition compared with field survey. Based on these results, there are many potential applications can be explored using UAV for example slope monitoring at landslide risk area, man-made slope assessment along roadside in highway, and determination of soil volume.

4. CONCLUSION

This study successfully represents the result for GIS data using UAV images. UAV can be use as one of GIS data source in the future because UAV images can provide high quality data for GIS analysis. More research must be done to establish UAV as a new platform in data collection especially in GIS and mapping field. In this study, we have only used fixed wing UAV in image acquisition. In the future we will investigate the capabilities of rotary UAV or known as multi rotor UAV in data collection for GIS. The comparison between fixed wing UAV and multi rotor UAV can be done in order to determine the platform in GIS data collection.

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6. REFERENCES

[1]. D. Barber, J. Mills and S. Smith-Voysey, 2008. Geometric validation of a ground-based mobile laser scanning system. ISPRS J. Photogramm. Remote Sens., 63: 128-141.

[2]. H.Y. Chao, Y.C. Cao and Y.Q. Chen, 2010. Autopilots for Small Unmanned Aerial Vehicles: A Survey. International Journal of Control, Automation and Systems, 8(1): 36-44

[3]. J. Chen, S.L. Shaw, H. Yu, F. Lu, Y. Chai and Q. Jia,. 2011. Exploratory data analysis of activity diary data: a space–time GIS approach. Journal of Transport Geography, 19: 394–404

[4]. H. Eisenbeiss, 2004. A mini Unmanned Aerial Vehicle (UAV): System overview and image acquisition. Proceedings of the International Workshop on Processing and Visualization using High-Resolution Imagery, November 18-20, 2004, Pitsanulok, Thailand, pp: 1-7.

[5]. M. Hale, P. Ramm and J. Wallace, 2007. Legal positions and Victoria's GPSnet. in *Proceedings of SSC 2007*, May 14-18, 2007 Hobart, Australia, 163–176.

[6]. H. Mitasova, M.F. Overton, J.J. Recalde, D.J. Bernstein and C.W. Freeman, 2009. Raster-based analysis of coastal terrain dynamics from multitemporal lidar data. J. Coastal Res., 25: 507-514.

[7]. C. Hug, A. Ullrich and A. Grimm, 2004. Litemapper-5600: A waveform-digitizing lidar terrain and vegetation mapping system. Int. Arch. Photogramm. Remote Sens. Spatial Inform. Sci., 36: 24-29.

[8]. I. Johnson, and A. Wilson, 2003. The TimeMap Project: Developing Time-Based GIS Display for Cultural Data. Journal of GIS in Archaeology, 1: 123-135

[9]. D. Guo, M. Gahegan, A.M. MacEachren and B. Zhou,. 2005. Multivariate analysis and geovisualization with an integrated geographic knowledge discovery approach. Cartography and Geographic Information Science, 32: 113–132.

[10]. R.B. Kent, and R.E. Klosterman, 2007. GIS and Mapping. Journal of the American Planning Association, 66(2): 189-198

[11]. V.A. Kovalev, 2006. Determination of slope in lidar data using a duplicate of the inverted function. Applied Opt., 45: 8781-8789.

[12]. F. Kurz, S. Turmer, O. Meynberg, D. Rosenbaum, H. Runge, P. Reinartz and J. Leitloff, 2012. Low-cost optical camera systems for real-time mapping applications. Photogramm. Fernerkundung Geoinform., 2012: 159-176.

[13]. M. Lim, D.N. Petley, N.J. Rosser, R.J. Allison, A.J. Long and D. Pybus, 2005. Combined digital photogrammetry and time-of-flight laser scanning for monitoring cliff evolution. Photogramm. Rec., 20: 109-129.

[14]. M. Schaefer, and R. Inkpen, 2010. Towards a protocol for laser scanning of rock surfaces. Earth Surf. Processes Landforms, 35: 147-423.

[15]. M.D. McCoy, G.P. Asner and M.W. Graves, 2011. Airborne lidar survey of irrigated agricultural landscapes: An application of the slope contrast method. J. Archaeol. Sci., 38: 2141-2154.

[16]. M. Ryu, T. Nakai, Y. Ohnishi, S. Nishiyama, T. Yano, D.H. Lee and S.K. Chang, 2005. Applying digital vision metrology to slope monitoring. Taiwan-Japan Joint Underground Investigations and Detecting Techniques Forum, Taipei, Taiwan, pp. 105-110.

[17]. P. Schurch, A.L. Densmore, N.J. Rosser, M. Lim and B.W. McArdell, 2011. Detection of surface change in complex topography using terrestrial laser scanning: Application to the Illgraben debris-flow channel. Earth Surf. Process. Landforms, 36: 1847-1859.

[18]. K.N. Tahar, and A. Ahmad, 2011. Capability of Low Cost Digital Camera for Production of Orthophoto and Volume Determination. CSPA 2011 7th International Colloquium on Signal Processing & Its Applications IEEE. Penang, Malaysia, pp. 67-71.

[19]. K.N. Tahar, A. Ahmad and W.A.A. Wan Mohd Akib,. 2011. UAV-Based Stereo Vision for Photogrammetric Survey in Aerial Terrain Mapping. Proceedings of the IEEE International Conference on Computer Applications and Industrial Electronics,. December 4-7, 2011 Penang, Malaysia.

[20]. J. Su, and E. Bork, 2006. Influence of vegetation, slope and lidar sampling angle on DEM accuracy. Photogramm. Eng. Remote Sens., 72: 1265-1274.

[21]. J.H. Wu, W.N. Wang, C.S. Chang and C.L. Wang, 2005. Effects of strength properties of discontinuities on the unstable lower slope in the Chiu-fen-erh-shan landslide, Taiwan. Eng. Geol., 78: 173-186.

[22]. Y. Zhang, J. Xiong and L. Hao, 2011. Photogrammetric processing of low-altitude images acquired by unpiloted aerial vehicles. Photogramm. Rec., 26: 190-211.