Volumetric calculation using low cost unmanned aerial vehicle (UAV) approach

A A Ab Rahman1,*, K N Abdul Maulud1,2, F A Mohd2, O Jaafar2 and K N Tahar3

1Earth Observation Centre, Institute of Climate Change (IPI), Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
2Department of Civil and Structural Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
3Department of Surveying Science and Geomatic, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Malaysia

*p90513@siswa.ukm.edu.my

Abstract. Unmanned Aerial Vehicles (UAV) technology has evolved dramatically in the 21st century. It is used by both military and general public for recreational purposes and mapping work. Operating cost for UAV is much cheaper compared to that of normal aircraft and it does not require a large work space. The UAV systems have similar functions with the LIDAR and satellite images technologies. These systems require a huge cost, labour and time consumption to produce elevation and dimension data. Measurement of difficult objects such as water tank can also be done by using UAV. The purpose of this paper is to show the capability of UAV to compute the volume of water tank based on a different number of images and control points. The results were compared with the actual volume of the tank to validate the measurement. In this study, the image acquisition was done using Phantom 3 Professional, which is a low cost UAV. The analysis in this study is based on different volume computations using two and four control points with variety set of UAV images. The results show that more images will provide a better quality measurement. With 95 images and four GCP, the error percentage to the actual volume is about 5%. Four controls are enough to get good results but more images are needed, estimated about 115 until 220 images. All in all, it can be concluded that the low cost UAV has a potential to be used for volume of water and dimension measurement.

1. Introduction

Nowadays, all development work has to perform surveying process, which consists of reconnaissance and topographical tasks. The problem with conventional surveying method is related to the calculation of volume for an object or area. In short, volume is defined as the amount of three dimensional space by some closed boundary. For example, the space that a substance such as solid, liquid, gas or plasma or shape occupies. In the other hand, volume of a container is generally understood to be the capacity of the container. The current method requires a team of people, which usually consists of the surveyor, his/her assistances and a draft person to process the data, to manually perform the surveying task. This task is time consuming, requires huge cost and laborious.

It is believed that unmanned aerial vehicle (UAV) can be alternatively used for obtaining the aerial images. This can be a much better alternative to the current method and makes the surveying process becomes more efficient, less time consuming and also cost effective for small budget projects.
the use of all resources to generate the volume at the interested area is expected to be reduced using UAV. In this study, the task conducted with the UAV to calculate the volume is similar to that of the land survey method. It is anticipated that by using UAV, the surveying process can be completed with less time, cost and manpower. The common conventional method to calculate volume in surveying is tacheometry method. A study that has been conducted with this method showed that the user needs to determine which area is significant and obtain the height of the surface at that survey area [1]. All data is recorded using equipment such as total station and mini prism. After the site survey is completed, all collected data is processed using a software. Commonly, land can be represented as an irregularly shaped polygon. Different methods such as graphical method, coordinate method and planimeter can be used to determine the area of irregular polygons. Among these three methods, the most popular method is the coordinate method, which is typically applied to compute catchment area, drainage area, volume and others [2]. The volume can then be generated by a software after calculating the area and contour. The volume calculation using total station equipment requires the height on the surface or on the polygon area [3].

Nowadays, the development of the UAV has increased its potential use in surveying work. UAV is capable of performing complex tasks in limited environment, small survey area with low cost budget [4]. It has a great potential in many applications such as remote sensing, disaster effect, search and rescue, surveillance, atmospheric survey and others [5]. For this study, the aim is to highlight the UAV capability in photogrammetry to become a suitable alternative way to generate volume for surveying process, which is done by taking images at the site area.

2. Literature Review

Close range photogrammetry has close connections with other measurement techniques and also with fundamental sciences such as mathematics, physics, information sciences or biology. It has substantial relations with aspects of graphics and photographic science [6]. Its product is the sequences of images during the image acquisition. For instance, these include computer graphics, computer vision, digital image processing, computer aided design (CAD), geographic information systems (GIS) and also cartography [7]. Traditionally, close range techniques also have strong associations with the surveying methods, particularly in areas of adjustment methods and engineering surveying. There is increasing application of photogrammetry in industrial metrology and quality control [8, 9].

The data obtained from engineering design surveys are used to calculate earthwork quantities. The standard method for calculating earthwork quantities is the average end area method [10]. The area of a triangle is the surface within three sides. One of the objectives of land surveys is to determine the area of a parcel of land. There are a number of methods used for calculating areas, including the use of double meridian distances and coordinates. This is the straight forming method to calculate the volume of objects and now, digital close-range photogrammetry is an alternative method to volume calculation [11]. Time and accuracy are two important factors that reflect on the perfection of volume calculation for road project, mining enterprise, geological works and building applications [12]. In Geodetic, current surveying methods have been insufficient for volume calculation of the objects where it needs to accomplish the task in a short time or risk area. Alternatively, multiple overlapping images taken from different perspectives can produce measurements to create accurate three dimensional models of objects [13]. Information on the position of the camera is not necessary because the geometry of the object is established directly from the images [14]. With this in mind, the photogrammetry techniques will allow the user to convert images of an object into a three dimensional model. A study has shown that a minimum of two pictures of an object is needed to accomplish this using a digital camera with known characteristics (i.e. lens focal length, imager size and a number of pixels) [15]. If the user can indicate the same three object points in the two images and known dimensions, other three dimension points in the images can be determined [16]. The output of this method will then be the volume unit.
3. Material and Method

This study is split into four principle phases: Phase 1 is about preliminary study, Phase 2 is about data collection, Phase 3 is about data processing and finally, Phase 4 is about data analysis. Figure 1 depicts the stream outline of the methodology applied in this study. Flight planning is planned after the site reconnaissance stage. In this study, the site area is a water tank and the route for image acquisition is around the water tank. Images were taken at the site, which is located nearby Kolej Mawar, UiTM Shah Alam using a UAV drone. The flight altitude was set at 20m from the ground and the orientation was using the point of interest (POI) to navigate the route of the drone. The image acquisitions were taken automatically.

Figure 1: Methodology flow chart
3.1 Equipment
Phantom 3 Professional UAV, as shown in Figure 2, used for the image acquisition must be supported with a laptop and a controller. This is to ensure that any problems can be detected immediately if there is any damage or system failure during the flight mission. Checking of all hardware before starting the work is important to make sure the image acquisition process is successful. The component of UAV for this research is tabulated in Table 1.

| Components | Function |
|------------|----------|
| Drone      | Capture the images of the site area |
| Mobile     | Connected to the drone as a display view from the drone. |
| Controller | Navigate manually the flight planning during the drone fly. |

Table 1: UAV components and function

Combination of GPS and GLONASS has been utilized to make the Phantom 3 completely aware of its location to the user. It hovers more precisely, moves more accurately and locks onto the satellites faster. Through the DJI Go application, user can track its location on a live map and record its takeoff point such that the user can bring it back with the tap of a finger. The vision positioning system in the Phantom 3 literally helps to fly it. Moreover, for DJI Go application, it consists of several functions: follow me, course lock, waypoints, home lock and point of interest. For this study, the function "point of interest" is used to navigate the flight during images acquisition. Meanwhile, the flight is planned around the water tank in vertical direction with regards to the close range concept. The specification of the UAV camera is 35mm, hence the tank features can be detected by the captured images. After the data acquisition stage, the images are processed into three dimensional model using Agisoft Software.

3.2 Software
There are a lot of photogrammetric software can be used to calculate the volume of the object. In fact, the capability of these software is not only limited to calculate the volume but it can also produce three dimensional modelling application such as DEM, DSM and DTM from the aerial photo [10]. In this study, in order to obtain good results, the Ground Control Point (GCP) should be observed on the earth surface and recorded WGS84 projection. The purpose of these GCPs is to get x and y coordinates to tie with the images. In this research approach, the minimum and maximum numbers of GCPs are two and four, respectively. These coordinates were obtained from the traversing technique. The software used is a stand-alone software package that performs photogrammetric processing of digital images and generates three dimensional spatial data for use in GIS applications, cultural heritage documentation, and visual effects production, as well as for the indirect measurement of objects with various scales. Meanwhile, Agisoft software is used to perform the volume computation.

4. Results and Discussions
The developed three dimensional model appeared smoothly at the bottom of the water tank. Based on the result, the identified problem is the missing of some images during the image acquisition process. The result of the developed three dimensional model is shown in Figure 3. The volume of the water tank was calculated after the three dimensional modelling stage was successfully done. The first step to generate the volume is to select the feature or area that will be generated. The calculation of volume based on 35 images with two control points gives 4837.84 m³. Compared with the actual volume of 4027.659 m³, it seems that 35 images were not enough to get an accurate estimation. Therefore, this
step is repeated with a different number of images. Next, four control points are used with different numbers of UAV images captured to get the volume estimation.

![Figure 3: Constructed three dimensional model of the water tank](image)

From the results shown in Figure 4 and Table 2, the number of control points and UAV images will affect the results of the processed images in measuring the water tank's volume. Based on the results, it shows that increasing the number of control points gives a big improvement in the volume estimation. In similar manner, increasing the number of UAV captured images gives the same impact. However, the estimated volume is still far from the actual value of 4027.659m³.

![Figure 4: Relationship between number of UAV captured images and estimated volume](image)

In Table 2, the volume difference refers to the difference between the estimated and actual volume. From the tabulated data, it implies that having 95 UAV captured images with four control points has the lowest difference value (i.e. 185.87m³ or 5% of error). In comparison, with the same number of images but with two control points, the resultant difference between the estimation and actual volume is 810.18m³. Furthermore, the more images captured, better estimation results can be obtained.
Table 2: Error percentage comparison

| Number of UAV Images | Volume difference (m³) | Error (%) |
|----------------------|------------------------|-----------|
|                      | Two GCPs | Four GCPs | Two GCPs | Four GCPs |
| 35                   | 810.18   | 573.84    | 20       | 14        |
| 55                   | 781.28   | 521.23    | 19       | 13        |
| 75                   | 745.48   | 321.53    | 18       | 8         |
| 95                   | 585.59   | 185.87    | 14       | 5         |

5. Conclusion
This paper demonstrates the use of a low cost UAV in image acquisition process at the water tank site located near Kolej Mawar, UiTM Shah Alam. Volume of the water tank has been calculated using the Agisoft Software. All in all, the results show that having more captured images will give better volume estimation. In addition, the higher number of GCP used will also tremendously improve the estimation results. With 95 images and four GCPs, the estimation error of the water tank's volume is reduced to only 5%. It is projected that 115 to 220 images are possibly needed to get to the actual volume. From this study, it has been shown that low cost UAV has the potential to calculate the volume of water and dimension measurement.

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