The Use of Digital Image for Volume Determination Using Digital Close Range Photogrammetric Method

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***Abstract*- Calculation of excavation and filling volumes is an important issue in engineering works especially in earthwork project. Various surveying methods can be used in the determination of volume in civil engineering field. At present practice, volume estimation is based on measurement carried out by land surveyor. Close range photogrammetry offers comprehensive approach in various fields such as engineering surveying, architecture and archaeology. The need of the estimated location of target point information has been carried out in previous research for volume calculation where it consumed time for field data acquisition. In this study, attention is given to the coordinate and relative orientation method that is available in Australis software for volume determination. For relative orientation module, the estimated coordinate of the target point is not required. The test of this study is based on physical model and actual object. The result of the computed volume from close range photogrammetry data is compared with the conventional method to determine the accuracy of volume. In this study, the volume accuracy achieved is greater than 90%. This study proved that close range photogrammetry is successfully used for the application of volume computation.**

Keywords: **Volume Determination, 3D Model, Close Range Photogrammetry**

I. INTRODUCTION

Volume determination is an important issue in many engineering and mining disciplines. Also in these disciplines cost estimation is an essential component of infrastructure project. Accurate estimation could assist project managers to choose adequate alternatives and to avoid misjudging of technical and economic solutions. The accuracy of volume estimation increases towards the end of the project due to detailed and precise information. Conventional method for volume determination is based on surveying method which consists of data acquisition on site. This method is tedious and time consuming which often relied on weather factor that concerned with the project progress work. Nowadays alternative studies could be used for volume estimation. The recent development in computer technology has brought about innovation in 3D measurement technology [1]. Close range photogrammetry is the technology evolved from the rapid development in hardware and software. For this reason, the photogrammetric method which utilises non-contact method could be used for volume estimation and many other applications. For example, close range photogrammetry method can be considered suitable d useful in surveying object that cannot be physically measured or contacted [2].

Generating volume depend on how best the land surface could be represented and the number of 3D coordinates (XYZ) of targeted points, point distribution and interpolation methods. The total volume of target points is the quantity of whole surface and based on a reference surface. In recent years, the desired accuracy can be obtained when the objects are measured accurately from classical photographs or from digital images captured by close distance/range with camera [1],[2],[3]. In the study carried out [2],[3], they concluded that the photogrammetric method is 21.89% faster, 12.83 % more accurate, and its cost is 33.33% less, on the average, compared to the classical method . In this study, volume calculation performance of the close range photogrammetry has been investigated based on natural object using consumer-grade digital camera. [4] stated that digital cameras are not only used by professional photographers but it can be used for photogrammetry applications.

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Digital Close Range Photogrammetry

Digital close range photogrammetry is a technique for accurately measuring object directly from photographs or digital images captured with a camera at close range. Multiple, overlapping, images taken from different perspectives, make possible measurements that can be used to create accurate 3D models of objects. Knowing the position of the camera is not necessary because the geometry of the object is established directly from the images. Close-range photogrammetry (CRP) applications, most of them has an object-to-camera distance of less than 300 m [5],[6]. Close range photogrammetry is the reconstruction of object simultaneously from several images and the images are acquired at different perspective. In CRP, the best possible perspective is used to ensure suitable geometry of intersecting rays and strong network. The determination of the 3D coordinates from a definite point is achieved through the intersection of two or more straight lines in bundle adjustment process. The essence of the photogrammetric bundle adjustment is illustrated in Fig. 1. Bundle triangulation is concerned with the reconstruction of 3D shape where an array of targets is imaged in a convergent network of four sensor stations [7]..

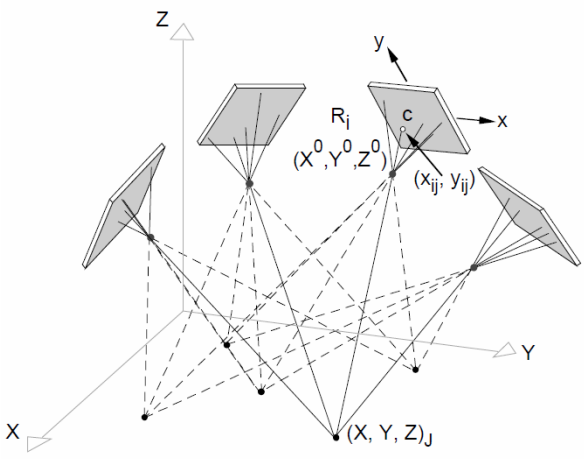


Fig. 1 The concept of bundle triangulation

The photogrammetric 3D coordinate determination is based on the collinearity equation which simply states that object point, camera projective centre and image point lie on a straight line (Fig. 2)[8]. The equation describes transformations from object space (X, Y, Z) to image coordinates (x, y). The determination of the 3D coordinates from a definite point is achieved through the intersection of two or more straight lines. Therefore, each point of interest should appear in at least two photographs [9]. Later, the 3D coordinates are measured from 3D model which is constituted by photogrammetric software. Fig. 2 shows the basic equations relating the location of a point in the photo coordinate system and ground position.

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} x - x_o \\ y - y_o \\ -f \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} = \begin{bmatrix} X - X_L \\ Y - Y_L \\ Z - Z_L \end{bmatrix}$$

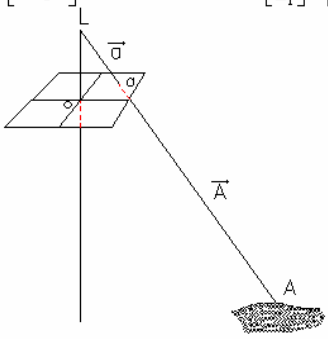


Fig. 2 Collinearity condition

where,

X_A, Y_A, Z_A Ground coordinates of point A

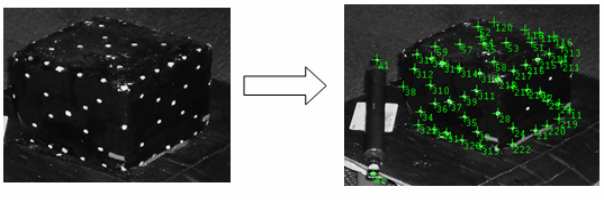
X_L, Y_L, Z_L Exposure station coordinates

In this study, the usefulness and performance of digital close photogrammetry photogrammetry and geodetic method (i.e using total station) in volume computations are investigated. For this purpose, an artificial model and natural hill were selected and the volume of the objects were calculated from the data obtained using photogrammetric method and geodetic method.

II. METHODOLOGY

A. Artificial Object

Artificial object has been used to evaluate the correctness of digital close range photogrammetry method in volume calculation/determination. Artificial object is a concrete block which has dimension: width 145mm, height 145mm, length 145mm and its shape is a cube (Fig. 3(a)). Manual calculation is used to calculate the volume of the object. First of all, the artificial object has been measured their dimension using a ruler which the values are constitute to volume calculation. Thus the volume of the object has been calculated as 3048625 mm^3.



(a) (b)

Fig. 3 Photogrammetric process on the images

Digital images of the concrete block were acquired using consumer grade Olympus T10 digital camera with 12 mega pixel resolution and taken at three different distances from the digital camera to the concrete block (Table 1). The purpose of this approach is to find out at what distance accurate volume could be obtained using the close range photogrammetric method. The images of the block were acquired using convergent configuration method. Geometry arrangement of convergent network for minimum of four camera station positions is required in the procedure to acquire digital images around the object. 3D coordinates (XYZ) of object points have been measured manually using a ruler. In this study, the digital camera was calibrated to determine the interior orientation parameters using close range photogrammetric software known as Australis 6.04 [10]. For photogrammetric evaluation, 100 control points in white circle (1mm radius) is sticked on the concrete model. The digital images were processed with relative orientation and coordinate processing technique which are available in Australis software. Fig. 3(b) shows the convergent network for the concrete model after data processing using Australis software.

B. Natural Object (Small hill)

In this study, a natural object i.e small hill was also used for volume determination using both the close range photogrammetric and geodetic methods. The volume obtained from the geodetic method was used as a reference value. The size of the small hill is approximately about 24m length, 3m height and 13m width. On the small hill targets were placed around the small hill. The target is in the form of circle and the size is 10mm in white with black background. It was designed in such a way to make it easy to identify during data processing. Then all the target points were surveyed using Topcon GPT 706 electronic total station instrument for producing 3D coordinates. The small hill is shown in Fig. 4. For field work 22 digital images were captured around the object (Fig. 5). Then Australis software converts JPEG image to TIFF format (Fig. 4) for establishing and calculating the 3D coordinates (XYZ) of targeted points. A total of 32 targets were placed randomly on the hill surface which cover different part of the surface of the hill.

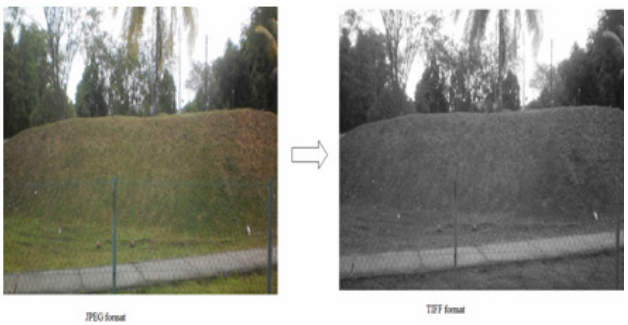


Fig. 4 Image format

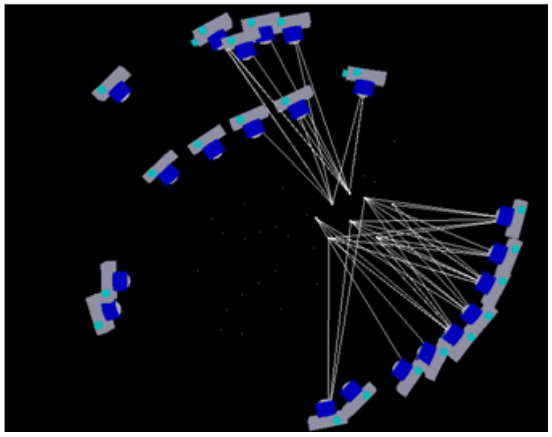


Fig. 5 Camera Station

IV. RESULTS

A. Artificial Object

For the artificial object (i.e concrete block), the manual measured average dimensions were used to determine the volume. The volume of the concrete block was also determined using processed data from Australis software (relative orientation and coordinate methods). The actual concrete model volume calculated using basic formula model is 3048625 mm^3 and is used as a reference. At the same time, volume based on processed data from Australis software was also used to determine the volume of the concrete block. Table 1 shows the results of difference in volume calculation between relative orientation and coordinate methods compared to the volume determine manually.

TABLE 1 VOLUME CALCULATION FOR THE CONCRETE MODEL

Method/ Distance	0.5m	1.0m	1.5m	% of difference		
				0.5m	1.0m	1.5m
Volume relative orientation method (mm^3)	3040884	3053350	2881589	0.250	0.155	5.479
Volume coordinate method (mm^3)	3064318	2868006	2951375	0.514	5.924	3.190
			Accuracy	99%	95%	95%

B. Natural Object (Small hill)

For the small hill, all the 3D coordinates obtained using total station were transferred into Surfer 8 software to calculate the volume. Figs. 6 to 8 showed the generated 3D surface from close range photogrammetric method (i.e relative orientation (RO) and coordinate methods) and total station method respectively. In this case, the volume from the total station was used to represent real geometry and served as a reference value. Table 2 shows the results of volume

accuracy for close range photogrammetric method and geodetic method (i.e total station).

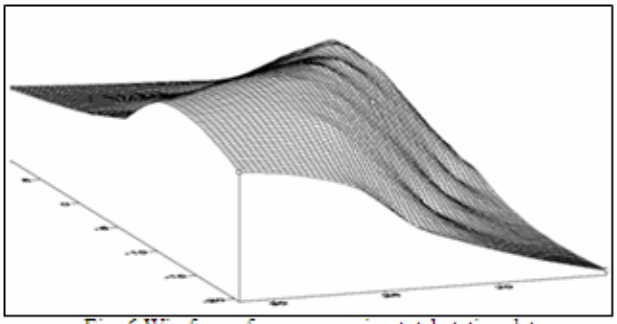


Fig. 6 Wireframe from processing total station data

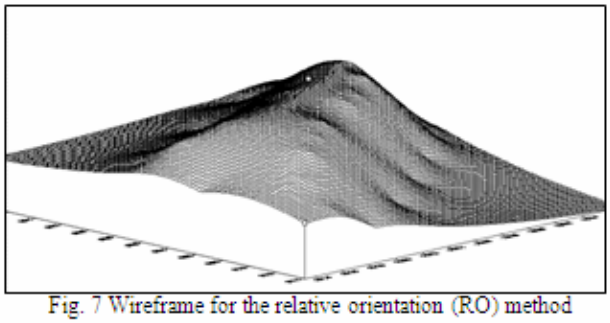


Fig. 7 Wireframe for the relative orientation (RO) method

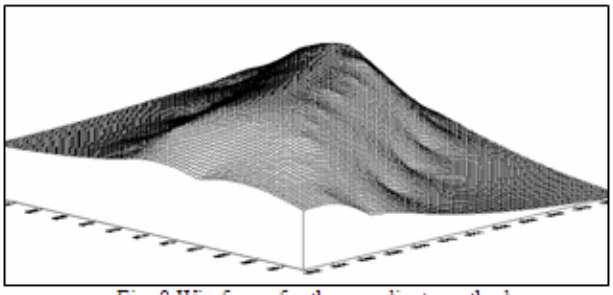


Fig. 8 Wireframe for the coordinate method

Vol calculation method/ Measurement method	**Total Station**	**Coordinate Method with Australis**	**Relative Orientation Method with Australis**
Net Volume(m^3)	1129.726	1241.015	1058.171
Different(m^3)		111.288	71.555
% of different		**9.851**	**6.334**

IV. CONCLUSION

The results achieved in the two case studies demonstrated that close range photogrammetry method with convergent image configuration can support volume determination. This finding is significant for volume estimation using consumer-grade digital camera since this method can be an alternative methods in volume estimation The degree of similarity between volume calculation of *Relative Orientation* (RO) and *Coordinate* methods in Australis software were evaluated by analysing accuracies in the 3D object space achieved using consumer-grade digital camera. The achievement of the RO and *Coordinate* method of extracting 3D object space coordinates using digital camera data are represented by DEMs generated using Surfer 8 software. Volume derived using Surfer 8 software provide an appropriate measure to assess the accuracy of volume determination using the RO and *Coordinate* methods in Australis software. Comparison of the accuracies revealed that consistency in volume estimation for both methods which achieved more than 90 percent in accuracy.

V. ACKNOWLEDGEMENT

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