

USING IN VOLUME COMPUTING OF DIGITAL CLOSE RANGE PHOTOGRAMMETRY

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ABSTRACT:

It is important to know cutting and filling volumes in many survey, engineering and mining works. Volume calculation, generally, are completed with classic surveying methods. The trapezoidal method (rectangular or triangular prisms), classical cross sectioning (trapezoidal, Simpson, and average formula), and improved methods (Simpson-based, cubic spline, and cubic Hermite formula) have been presented in the literature. Geodetic surveying methods have been insufficient for the volume calculation of the objects need to calculation of volume in a short time or in a risk areas, or unreachable areas. In this case digital close range photogrammetry is an alternative method to volume calculation. Digital close range photogrammetry is a method which has been used for 3D surveyings of objects for many years. By the development of digital techniques, digital close range photogrammetry used in many fields such as engineering surveyings, topographic surveyings, architectural surveyings, archeological surveyings, etc disciplines has become a productive, faster and an economical method. Due to the developments in digital photogrammetry and computer technology in past years, to constitute of 3D models of objects included in current research topics. In this study, performance in volume calculation of digital close range photogrammetry has been investigated. The usability degree of 3D photomodelling in volume calculation of complex figures which may not be reached and requires speed sometimes will be investigated in this study. A suitable object (stone heap) has been selected for his purpose. The volumes supplied from 3D photomodels of objects would be compared with volumes calculated from classical techniques. The results have been analyzed with respect to time, cost and accuracy.

1. INTRODUCTION

Cutting and filling volume calculation are important issues in many engineering and mining disciplines. Accurate 3D shape reconstruction and volume estimation are important in many applications, for example, erosion studies, estimation of ore removed from a mine face and terrain assessment for construction (**Schulz and Schachter 1980**).

Generally, classical methods have been used in volume computing. The trapezoidal method (rectangular or triangular prisms), classical cross sectioning (trapezoidal, Simpson, and average formula), and improved methods (Simpson-based, cubic spline, and cubic Hermite formula) have been presented in the literature (**Yanalak 2005**). Efficient volume computation in high accuracy is an important question both theoretically and practically (**Soole and Poropat 2000**).

The corrections of volume is direct proportional with the presentations of land surface in a best representation of land surface in best form is depend on the number of certain X,Y,Z coordinate points, point distributions and interpolation methods. Without doubt, in a convenient distributed and much more points provide better representation of land surface. However, much more points means much time and cost. Sometimes obtaining of geodetic points can be risky and also it can be impossible. For his reason, surface of land can not be represent correctly.

The GCPs in photogrammetric method are used to calculate the position and orientation of each camera in a stereo pair of photographs. In many cases the placement cannot be made because of inaccessibility or safety restrictions. Even if access is not a problem it is often difficult to place the GCPs in positions that allow for good visibility or distribution. Poor distribution of GCPs can result in the calculated position and orientation of the camera to have a non unique solution or variations of true position in the order of 10s of meters. The use of GCPs to calculate position adds significantly to the time and skill required for image processing particularly in the documentation and identification (**Soole and Poropat 2000**).

Usually, two persons are needed for classical measurement. Photogrammetric processing itself can be done by one person. Only ground control points (GCP) have to be signalised and measured in terrain by classical methods. However, it means just a few points in a comparison to an evaluation of all points or lines in a quarry or a mine. Therefore, photogrammetric methods are used more and more often in this case (**Patikova 2004**).

In this study, volume calculation performance of the close range photogrammetry has been investigated working on natural object practice.

2. DIGITAL CLOSE RANGE PHOTOGRAMMETRY

Photogrammetric techniques, measuring objects from photographs, have been utilized since the late 1800s. These methods are most commonly used for mapping large areas from aerial photographs. Digital close range photogrammetry is a technique for accurately measuring objects directly from photographs or digital images captured with a camera at close range. Multiple, overlapping images taken from different perspectives, produces measurements that can be used to create accurate 3D models of objects (Tüdeş 1996). Knowing the position of camera is not necessary because the geometry of the object is established directly from the images.

Photogrammetry techniques allow you to convert images of an object into a 3D model. Using a digital camera with known characteristic (lens focal length, imager size and number of pixels), you need a minimum of two pictures of an object. If you can indicate the same three object points in the two images and you can indicate a known dimension you can determine other 3D points in the images (Atkinson 1996; Cooper and Robson 1996; Lawson 1977).

The photogrammetric 3D coordinate determination is based on the co-linearity equation (Slama 1980) which simply states that object point, camera projective centre and image point lie on a straight line. 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 (Fig. 1) (Aguilar et al. 2005). Later, coordinates are measured from 3D model which is constituted by photogrammetric software.

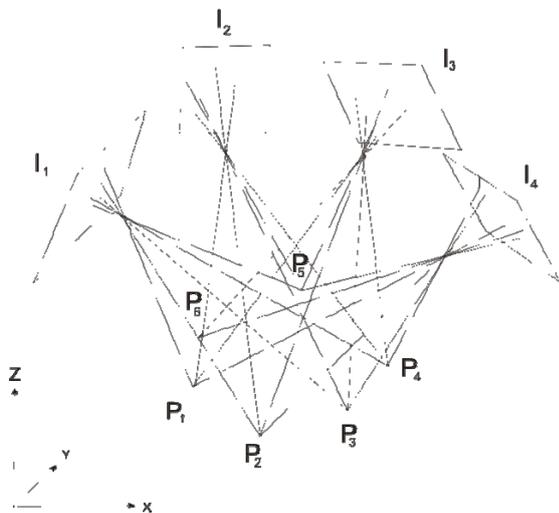


Figure 1. Coordinate of object points (P_i) by triangulating bundles of observation rays from different image planes (I_i)

Compared to classical methods, digital close range photogrammetry is efficient and rapid, significantly reducing the time required to collect data in the field. Measurements collected in less than three days in the field would have taken 10 days in a classical survey. Second, it was considerably safer. All surveyors can able to obtain precise measurements without physically accessing each measurement point. Third, the method is non-intrusive, creating minimal impact on traffic flow. Finally, the process produced a comprehensive visual

record of existing site conditions from which any identifiable features can be measured or geometrically assessed at a later date. Digital close range photogrammetric methods have been successfully applied to projects in archaeology, architecture, automotive and aerospace engineering, accident reconstruction and etc. disciplines (Atkinson 1996; Carnobell 1989).

The same process can be used to obtain dimensional measurements efficiently on inaccessible structures such as tunnels and dams, and large or complex facilities such as refineries or water treatment plants. Digital close range photogrammetric measurements can be integrated with 3D modeling and reverse engineering processes. The acquired data is infinite and the cost savings substantial (Cooper and Robson 1996; Wolf and Dewitt 2000).

3. MATERIAL AND METHOD

Current methods used for estimating volume assumes that the ground profile between the grid points is linear (based on the trapezoidal rule), or nonlinear (based on Simpson's 1/3 and 3/8 formulas). Generally speaking, the nonlinear profile formulas provide better accuracy than the linear profile formulas. However, all the methods mentioned above have a common drawback: The joints (grid points) of any two straight lines (the trapezoidal rule), quadratic polynomials (Simpson's 1/3 formula), or cubic polynomials (Simpson's 3/8 formula) form sharp corners (Chen and Lin 1991; Easa 1988).

Geodetic instruments have been used to survey point coordinates in classical methods. But in photogrammetric method, point coordinates can be obtained from 3D model of the object. The GCPs in photogrammetric method are used to calculate the position and orientation of each camera in a stereo pair of photographs.

Simpson equations have been used in volume calculation with cross sections.

$$V = \left(\frac{F_1 + F_2}{2} \right) * l_1 + \left(\frac{F_2 + F_3}{2} \right) * l_2 + \dots + \left(\frac{F_{n-1} + F_n}{2} \right) * l_n \quad (1)$$

where;

$F_{i...n}$ = cross section areas,

$l_{i...n}$ = distances between cross sections.

Rectangular and triangular prisms on object surface in volume calculation of excavation area by using trapezoidal methods volume calculation have been formed using ;

$$V = F * H \quad (2)$$

equation. In this formula, F is base areas, H also represents average heights.

In surfer 8 software, grid surfaces of object have been generated from the X,Y,Z coordinates of object surface using linear interpolation methods.

Volume values obtained from the differences between pre and post surface in excavation area. Excavation volume values for the areas that will be excavated in future are obtained from the

certain or chosen reference surface and formed surface. In this software, the volume under the $f(x,y)$ function can be determined with double integral equations (Guibas and Stolfi 1985; Lee and Schachter 1980; Surfer 8 Software; Vetterling 1988).

$$V = \int_{X_{\min}}^{X_{\max}} \int_{Y_{\min}}^{Y_{\max}} f(x, y) dx dy \quad (3)$$

In software, extended trapezoidal rules for volumes;

$$A_i = \frac{\Delta x}{2} [G_{i,1} + 2G_{i,2} + 2G_{i,3} + \dots + 2G_{i,nSutun-1} + 2G_{i,nSutun}] \quad (4)$$

$$V \cong \frac{\Delta y}{2} [A_1 + 2A_2 + 2A_3 + \dots + 2A_{nSutun-1} + A_{nSutun}]$$

Coefficients (1,2,2,2,2,.....,2,2,1),
Extended Simpson Rule ;

$$A_i = \frac{\Delta x}{3} [G_{i,1} + 4G_{i,2} + 2G_{i,3} + 4G_{i,4} + \dots + 2G_{i,nSutun-1} + G_{i,nSutun}]$$

$$V \cong \frac{\Delta y}{3} [A_1 + 4A_2 + 2A_3 + 4A_3 + \dots + 2A_{nSutun-1} + A_{nSutun}] \quad (5)$$

Coefficients (1,4,2,4,2,4,2,.....,4,2,1) ,
Extended Simpson 3/8 Rule;

$$A_i = \frac{3\Delta x}{8} [G_{i,1} + 3G_{i,2} + 3G_{i,3} + 2G_{i,4} + \dots + 2G_{i,nSutun-1} + G_{i,nSutun}]$$

$$V \cong \frac{3\Delta y}{8} [A_1 + 3A_2 + 3A_3 + 2A_3 + \dots + 2A_{nSutun-1} + A_{nSutun}] \quad (6)$$

Coefficients (1,3,3,2,3,3,2,.....,3,3,2,1) are calculated with equations.

In classical methods by means of set points on object surface and forming cross sections, excavation volume of soil has been calculated. Using surfer 8 software, object surface obtained from geodetic points and volume calculation could be accomplished. During this process the time spent and cost calculation have been also made.

Taking sufficient points placed on object, photographs of the object have been shooted with digital camera and later photogrammetric evaluation have been completed. After that, the surface of the object have been obtained and volume calculation has been made using points obtained through photogrammetric evaluation. Furthermore, the time spent and cost calculation has been made.

Lastly, calculated volume with classical methods have been compared with the calculated volume values with the photogrammetric methods and time, cost and corrections analysis have been made from these results.

3.1 Experimental Application

Artificial object has been used to evaluate of correctness of the digital close range photogrammetry in volume calculation. Artificial object is made of plaster, and has a base radius approximately 5 cm, height is approximately 9 cm and its shape is a conic (figure 2). 1000 ml beaker has been used to calculate volume of the object. First of all, beaker has been filled up to 100 ml with water and the artificial object has been submerged in the beaker and the level of water has reached 464,2 ml. Thus the volume of the object has been calculated as 364,2 ml.

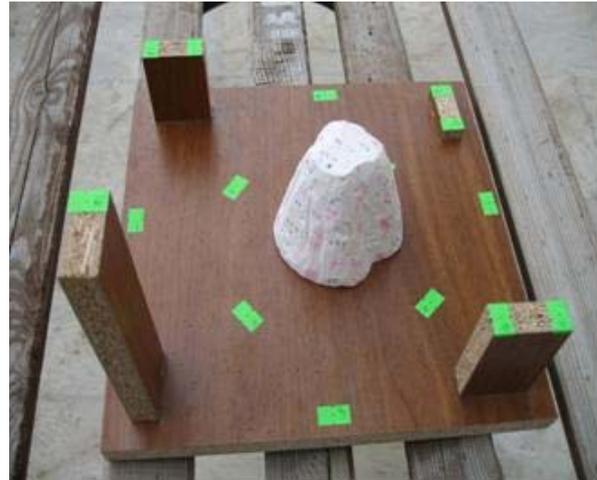


Figure 2. Artificial object and test area

A test field has been formed to survey of the control points (Figure 2). Coordinates of X,Y,Z object points have been measured with electronic total station precisely, and according to photogrammetric techniques photographs have been taken with Kodak DSC 4530 in 5 mega pixel resolution. Camera parameters have been calculated with calibration procedures. Photogrammetric evaluation of the object has been made in Photomodeler 5.0 software, using control points, photographs and calibration parameters. In this process, 541 points coordinates have been measured on the object. The point coordinates have been transferred to surfer 8 software in txt file. The volume of the artificial object has been found as 359, 527 cm³ . Besides, measured point coordinates have been transferred to Netcad software and the volume of the object has been calculated 359,701 cm³ (NetCad 2.94 Software) . The print screen of object in evaluation level can be seen in the diagram below. The volume of the object with the photogrammetric method can be as precise as 98,72 % . Photogrammetric evaluation is seen in Figure 3. 3D model of artificial object is seen in Figure 4.

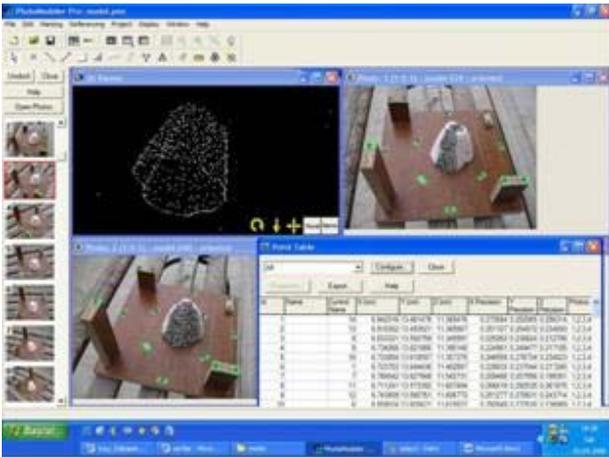


Figure 3. A view of photogrammetric evaluation



Figure 5. Stone Heap

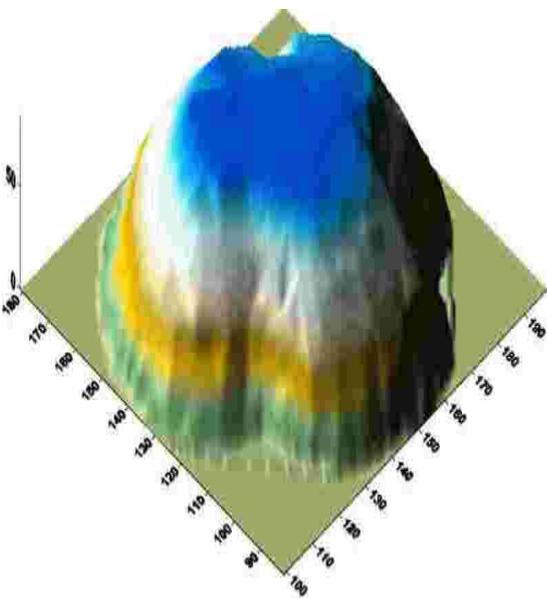


Figure 4. 3D map of artificial object

4. VOLUME COMPUTING

A stone heap has been used for volume calculation. Both classical and photogrammetric methods has been applied for the volume calculation. Volume calculation results with classical and photogrammetric methods are given in the next parts.

4.1 Object (Stone Heap)

Stone heap has 6.5 m width, 10.5 m length and 2.5 m height (Figure 5). 24 test targets (25cm*25cm) have been placed on the stone heap with proper distribution. Then, point coordinates were measured using Topcon GPT 706 electronic total station instrument.

4.1.1 Volume Computing by Classical Methods

Cross sections have been obtained with the points placed on the stone heap. According to Simpson equation, volume of the stone heap has been calculated as 46,819 m³. The same points have been transferred to Surfer 8 software and the volume of the stone heap has been calculated as 39,932 m³ from the same reference surface. Placing points on to the stone heap has taken 50 minutes and surveying points 65 minutes. Volume calculation together with cross section has taken 90 minutes and the calculation of the volume with surfer software has taken 20 minutes. Distribution of points in horizontal plane is seen in Figure 6, and 3D model of Stone Heap is seen in Figure 7.

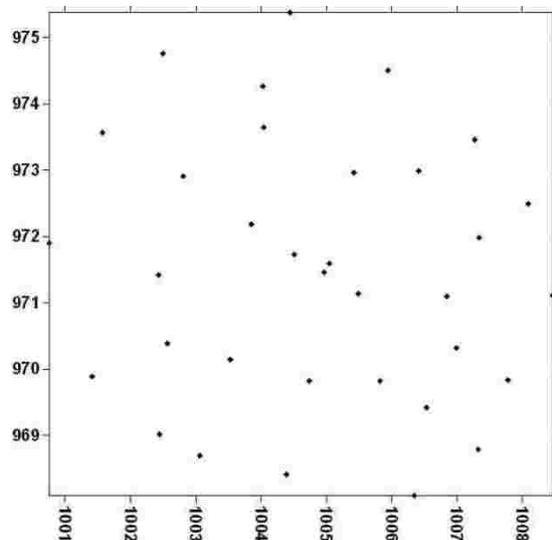


Figure 6, Location of points by classical methods

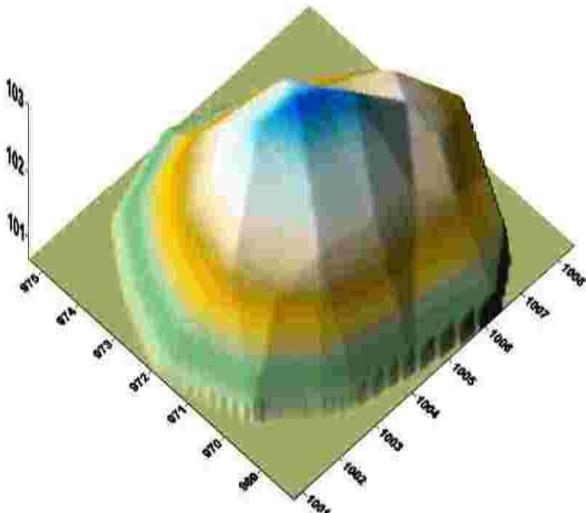


Figure 7. 3D map of object by classical methods

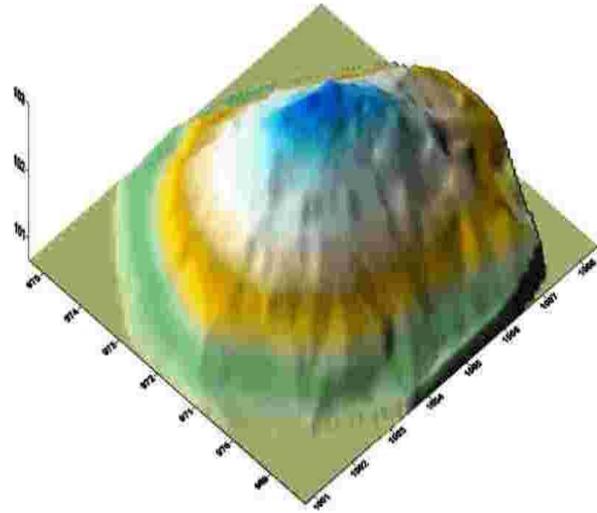


Figure 9. 3D map of object by photogrammetric methods

4.1.2 Volume Computing by Photogrammetric Methods

To carry out photogrammetric evaluation, 24 control points (25cm*25cm) in white and red have been used to make it easy to see. The coordinates of the control points have been measured with the same electronic instrument. Placing of points has taken 35 minutes and surveying has been completed in 50 minutes. The horizontal distribution of the points is seen in Figure 8.

Taking photographs has been done with Kodak DSC 4530 digital camera in 5 mega pixel resolution. Camera calibration procedures have been completed for mathematical calculations. Photographs have been transferred to Photomodeler software, photogrammetric evaluation has been accomplished 597 coordinate points have been obtained (**Photomodeler 5.0 Software**). The stage of evaluation of the photographs is given in figure 18. Photogrammetric evaluation has been made in 65 minutes. 597 control points obtained have been transferred to Surfer software and the volume of stone heap has been calculated as 42.074 m³ from the same reference surface. 3D model of Stone Heap is seen in Figure 9. Volume calculations have been done by Surfer 8 Software in 20 minutes.

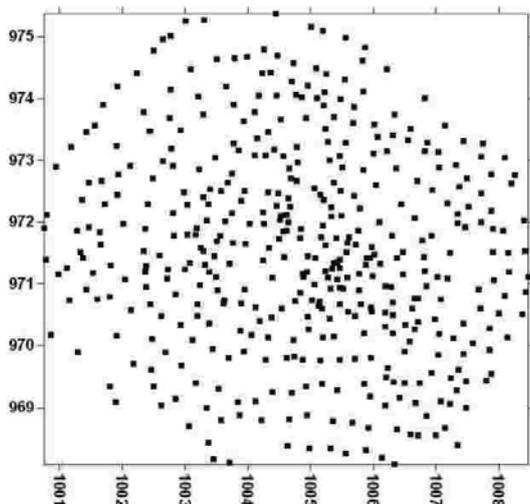


Figure 8. Location of points by photogrammetric methods

4.3 Analysis of Conclusions

Obtained volume of the object (stone heap) with classical and photogrammetric methods have been given in Table 1 and the time spent for this process has been given in Table 2.

When compared, classical method in terms of the cost, both methods have transportation cost and this cost is equivalent the both systems. Both methods have surveying process and surveying cost is equivalent both systems. 3 people are required for classical surveying but 2 people is sufficient in photogrammetric processing (**Patikova 2004**). Consequently, photogrammetric method have 33,33 % cost advantage in field works when compared with the classical method.

When experimental results examined photogrammetric method could approach 98,72 % ratio to the real value. When experimental results taken into account photogrammetric method more than 10,13 % accuracy according to cross section results and more than 5,09 % accuracy according to Surfer Software. In addition to, photogrammetric method more than 20 % cost effective.

Providing convenient distributed point on object, when the number of the points reduced about 30 %, volume variation amount is being about 1 %. However, when we eliminate characteristic trace of the land surface volume values can be change considerably (Table 3).

In photogrammetric method, the most time consuming factor is evaluation procedure stage. Maximum number of points has been surveyed to represent the best fitting of object surface. When examined table 3, surveying minimum number of points that represents the surface of the object appropriately will not affect the volume on volume scale. In this condition, time advantage will be much more height level in photogrammetric method.

5. CONCLUSION

With the development in technology, digital close range photogrammetry is affecting import degree, with the improvement of hardware and software products. Some studies can be made more economically, more accurately and faster.

Digital close range photogrammetry also can be apply very different disciplines. In this study, the situation of digital close range photogrammetry have been investigated in volume calculation . For this purpose, using both photogrammetric and classical method volume calculation have been done.

According to the results of completed study, photogrammetric method more advantageous more than 20 % in time base , more than 7,61 % accuracy base , and more than 33,33 % cost base according to classical method. Time saving will be more when we use optimal photogrammetric evaluation process according to the object shape and specifications. That is,in respect of object properties when photogrammetric evaluation have been made optimal level, time advantage could be go up. Risky places to reach or unreachable places or when required to short time to complete works, photogrammetric method have been advantageous.

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