

Establishment of 3D Model with Digital Non-Metric Camera in Close Range Photogrammetry

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ABSTRACT

The use of three dimensional computer graphics and visualization techniques is becoming more and more popular, because these techniques visualize more realistic object models than graphic based object models. However, in most application of 3D modeling and visualization, large and complex 3D models data are required. The basic data source of 3D modeling of regular or irregular surfaced objects are known (or calculated) point coordinates. Obtaining 3D model of the irregular surfaced objects need plenty of points to represent the surface exactly. These points can be easily obtained both traditional methods and from the measurement of the photographs. the production of 3D object in cloud points depend on the sampling rate and taking many captures. In this case, an object of face-shaped clay was used and a 3D object is performed with (5563) 3D points with sampling rate (1 mm). The smaller sampling rate results in longer processing and more points. This case could be beneficial in documentation of cultural and historical heritage in a digital library in observing the variation with time.

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الخلاصة

أن استخدام المخططات ثلاثية الابعاد و تقنيات المرئية سيصبح اكثر شعبية واكثر شهرة وذلك لان هذه التقنيات تظهر نماذج الاجسام بصورة اكثر واقعية وفي نفس الوقت فأنه اكثر تطبيقات النماذج ثلاثية الابعاد تتطلب بيانات كثيرة ومعقدة. ان مصدر البيانات الاساسي للنماذج ثلاثية الابعاد وللأجسام ذات السطوح النظامية و الغير نظامية يعرف ب (أو يحسب على اساس انه) احداثيات نقطة. ان الحصول على نموذج ثلاثي الابعاد للأجسام ذات السطوح الغير نظامية يحتاج نقاط كثيرة لتمثيل ذلك الجسم او السطح بدقة عالية. هذه النقاط يمكن ان نحصل عليها بسهولة بالطرق التقليدية وطرق المسح التصويري. أنتاج جسم ثلاثي الابعاد بنقاط كثيفة يعتمد على نسبة

الاعتيان وألنقاط عدة لقطات للجسم . في هذه الحالة استخدم جسم مصنوع من الطين على شكل وجه وقد تم تمثيل هذا الجسم بنقاط ثلاثية الابعاد كثيفة بلغت (5563) نقطة وبنسبة أعتيان (1ملم). بنسبة الاعتيان الصغيرة أدت الى معالجة طويلة ونقاط كثيرة . هذه الحالة مفيدة لتوثيق التراث التاريخي و الثقافي في مكتبة رقمية ومتابعة التغيرات الزمنية التي تحدث عليها .

INTRODUCTION

The term photogrammetry means the process of measuring images on a photograph. An integrated digital Photogrammetry system is defined as hardware/software configuration that produces photogrammetric products from digital imagery using manual and automatic techniques. Nowadays, there is an increasing demand for full three dimensional data of planning, architecture, archaeology, environmental analysis, civil engineering, tourism, computer animation, historical preservation, mechanical inspection, and ship construction [1].

To depict the real condition of the object, and to measure 3D of all the corners of the structure, particularly the inaccessible points, creation of accurate 3D models are very much necessary. Recent years have seen a number of developments in geometric modeling of historical monuments in 3D, especially their structural details and textures [2].

Close Range Photogrammetry is a measurement technology that can be used for the extraction of 3D points from the images; further, these points are useful for the accurate 3D modeling and visualization. Digital Photogrammetry derives all the appropriate measurements from the images itself rather than measurements directly from the objects. Due to the digital data flow, photogrammetry has now become an efficient alternative to the classical building measurement and reconstruction methods [3]. This paper discusses the various 3D model generation techniques and shows the advantages of photogrammetry techniques for measurements. For the present project, an experiment has been conducted to check the accuracy of the 3D model generated using the photogrammetric technique. The complete orientation and calibration is done automatically or manually based on the images only. The objects selected are the artificial object face-shaped made of clay.

PHOTOGRAMMETRIC PROCESSING

Office work is a subsequent stage to field work. Office work serves the purpose of processing previously gathered information. It is carried out in two stages: one involving the storage of data contained on the index cards and the other involving data processing. In the first stage a database must be created in order to speed up the management of information. In the second stage, 3D models reproducing the original structure on a fixed scale are obtained by means of a digital photogrammetric station. into the following stages:

INNER ORIENTATION

This operation entails the reconstruction of perspective rays in conditions similar to their formation within the photographic camera, using the values obtained in the calibration process (radial and decentring lens distortion, focal length and position of the principal point). By means of inner orientation we can get rid of errors arising from the use of non-metric cameras. The camera calibration has been done using the Camera Calibrator software included in the Photomodeler version 6.0 digital photogrammetric station. The method used by this software is the self-calibrating bundle adjustment, which requires taking some previous shots of a calibration grid [6] in order to obtain the inner orientation parameters of the camera.

EXTERIOR ORIENTATION

In this stage the rays generated in the inner orientation process are positioned in relation to the ground in the very same position adopted at the moment of exposure of the photographs. The photogrammetric coordinates for a minimum of five points shared by another photograph already orientated or to be orientated in the same process must be measured. As ground control points are not available, the system will carry out a free network adjustment. This includes two operations arranged in sequences known as relative and absolute orientation.

EXTERIOR RELATIVE ORIENTATION

The evaluation of the exterior orientation elements of one camera with regard to the photo coordinate system of another is known as relative orientation. The simultaneous intersection of at least five pairs of homologue rays distributed through the model is enough for the remaining points to intersect as well, according to perspective geometry. The rays' equations are calculated analytically and the relative orientation parameters can be calculated applying the collinearity conditions to the homologue rays (vectors defining the projection of every ground point on the photographs) for each pair of photos. Adopting the coordinate system based on the first Picture (origin in the centre of projection, X- and Y-axes on a plane parallel to the plate, and the Z-axis in the direction of the principal axis), the relative orientation solves the problem of calculating the relation between the photogrammetric coordinate system and the model coordinate system by means of the collinearity condition.

EXTERIOR ABSOLUTE ORIENTATION

Once the model has been established, we must adjust it to the ground coordinate system by means of absolute orientation. The z-axis is established from the direction defined by the plumb lines and this is how the model is leveled. The scale factor is attained via the distances measured on the plumb lines by means of a simultaneous bundle adjustment. Then we proceed to a new adjustment which ensures correct leveling, orientation and scaling of the 3D model. The transformation equations for the photogrammetric systems (x, y, z) to the ground coordinate system (X, Y, Z) are similar to the ones used in relative orientation:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = s \times M \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} \quad \dots (1)$$

Where: (X, Y, Z) ground coordinate system; (x, y, z) model coordinate system; M (Ω, Φ,κ) rotation matrix; (T_x, T_y, T_z) translation distance; and s scale factor.

DESCRIPTION OF DIGITAL CAMERA

The two primary types of digital cameras used in this paper are Nikon (COOLPIX AW100 with resolution 16 megapixels), its zoom (5-25) mm and SANYO (E1075, resolution 10 megapixels), with zoom (5.7-17.1) mm. The shapes of these cameras are shown in figure (1) and (2) respectively, and their main characteristics of these cameras are illustrated as follows in two tables (1) and (2) respectively.



Figure (1) Nikon Coolpix AW100 [3].



Figure (2) Sanyo (E1075) [4].

Table (1) Camera's Main Characteristics (Nikon) [3].

Type	Compact digital camera
Effective Pixels	Approx. 16 mega pixels
Image Sensor Size	1/2.3-in.type CMOS :Approx. 16.79 million pixels, (6.4286×4.8214) mm.
Pixel Size	0.00139 mm;
Lens Mount	5x optical zoom. Nikkor lens
Focal Length	(5-25)mm (angle of view equivalent to that of 28-140 mm)

Recording pixels	(1) Large:	Approx. 16 mega pixels (4608 × 3456)
	(2) Medium:	Approx. 8.00 mega pixels (3264 × 2448)
	(3) Small:	Approx. 3 mega pixels (2048 × 1536)
	(4) RAW:	Approx. 16 mega pixels (4608 × 3456)
Focusing Modes	Focus range (from view) ,focus-area selection	
Focusing range	Approx. 50cm. (1ft-8in.) to ∞ (W); approx. 1m. to∞ (T)	
Shutter Speeds	1/1500sec. to 1secs.	
Depth-of-field preview	Enabled with depth-of-field preview button	
Image type	JPEG	

Table (2) Camera's Main Characteristics (SANYO) [4]

Type	Digital Camera	
Effective Pixels	Approx. 10 mega pixels	
Image Sensor Size	(6.4125x4.8094) mm	
Pixel Size	0.00175mm;	
Lens Mount	3x optical zoom lens	
Recording pixels	(1) Large:	Approx. 10.00 mega pixels (3664 × 2748)
	(2) Medium:	Approx. 5.00 mega pixels (2048 × 1536)
	(3) Small:	Approx. 2.00 mega pixels (1600 × 1200)
	(4) RAW:	Approx. 10.00 mega pixels (3664× 2748)
Focusing Modes	Multi zone –center- selected area	
Shutter Speeds	1/2000sec. to 2secs.	
Depth-of-field preview	99% by LCD	
Image type	JPEG	

PROCESS OF DEVELOPING 3D MODEL FROM IMAGES

The following sub-sections discuss the process for developing the 3D Model from digital images by using PhotoModeler software on the case study project.

Selection of Data Analysis Software and Importing the Images

With rapidly increasing capabilities of digital cameras and personal computers in recent years, some photogrammetry software's are made available. These products can analyze images from any source. Photomodeler Pro, one of the consumer software products has been used successfully throughout this research. First, the images are transferred from the cameras to the computer by using USB flash drive. Before pictures can be transferred (copied) to computer, the supplied software must be installed. Then the Photomodeler software is started, and the

images are selected and imported into the program for analysis. Next, the user associates each image with its specific, previously calibrated camera.

Object preparation and scene arrangement

Before taking photos, the first step is preparation of an object it is accomplished by deploying special markers on object in purposeful manner. Finding proper strategy of marker deployment is an important matter, it helps to find an optimum workflow between amount of work in item preparation, time of calculation and detailed result in point cloud.



Figure (3) Coded targets, a) 8 bit, b) 10 bit, c) 12 bit.

The second stage of the analysis is scene arrangement – placing object between special coded targets. Using these symbols provides the possibility of automatic mutual photograph oriented during the later computing. Every coded target has unique shape, its unique digital representation, recognized by software tool, see Figure (3). Sample model, placed on an arranged scene, ready for photographing is shown on Figure (4).



Figure (4) Artificial object with coded targets.

Mark the Target Locations in Each Image

Data analysis begins by marking the locations of the targets in the images. The xy coordinates of the centroid of each elliptical target projected while dots in this case, must be marked as accurately as possible in each image. Targets are high contrast circles placed in a scene or on an object to provide an accurate sub-pixel point marking. Coded targets are circular targets with some additional bits that can be automatically recognized by PhotoModeler during the marking process.

Identify Points in the Images Referring to the Same Physical Point

The second step of the data analysis is to match the marked points in one image with their corresponding points in the other images. This process is called referencing the points. When a point is initially marked on an image, it is assigned a unique identification number. When a marked point on one image is referenced to a marked point on another image, the software reassigns the same identification number to both points indicating they are the same physical location on the

structure. In the beginning of the data analysis, the user must perform this referencing operation automatically or manually until a certain minimum number of points (at least six) are referenced on all photos, at time the user processes the data. When these calculations are completed, the user returns to the referencing phase. At this point, automatic helper tools are available to speed up the process. These tools appear as a result of the initial processing of the data, which yields the spatial location and orientation angles of the cameras. In figure (5) the viewer shows small camera icons at their locations and orientations relative to targets with calculated 3D coordinates, displayed as small dots. Now the images are said to be oriented.

Scaling and Orientation

After imported photos are taken with coded target to the Photomodeler, code target can be used to (Translate/Scale/Rotate) project. This type of coordinate system transformation is defined based on coded targets. There are three components that define the conformal transformation were defined by coded targets. For example code target number (1) in the grid of coded target is used to define the translation that has arbitrary value for the x, y, and z equal (0, 0, 0). Often the translation point is the origin (0, 0, 0) but it could be any coordinate value. The known distance between two coded targets used to define the scale in the model so that they can be determining absolute measurements in study model. Finally use the coded targets to define the axes of the coordinate system of the model as in the example, see figure (5).

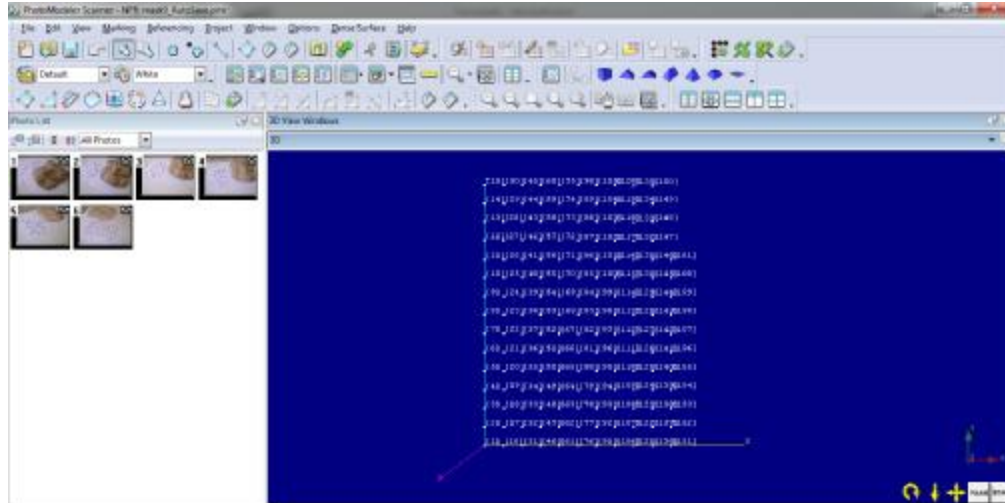


Figure (5) Using code targets to define Translate/Scale/Rotate.

Code target ID1 defines the Translate, and the distance between two ID'S (1, 15) defines the scale, the two ID'S in x-direction used to define X-axis and the two ID'S in the y-direction used to define Y-axis. The first axis that was defined becomes the 'dominant' axis. The two active axes should be close to right angles. When the coordinate system is computed, PhotoModeler calculates the exact secondary axis at 90 degrees to the dominant axis based on the plane defined by the two axes.

Creating Dense Surface Model (DSM) Project

Dense Surface Modeling is a search algorithm that uses an existing pre-oriented project and pairs of photos from that project to search for image patches that look alike. This search is done in a regular grid-like manner, so a grid of 3D points is computed. When a good match is found between two photos, the orientation and camera data allow the program to compute the correct 3D location of the surface point corresponding to the image patch. With proper orientation and stereo overlap, a DSM or point cloud of 3D values can be created, edited, and converted to a triangulated mesh for export and advanced modeling and design. The basic steps of the DSM process are:

1. Start with an oriented, idealized, high-quality project with low residuals and at least two or more camera stations with suitable base-to-height ratios.
2. Define the extents of the search using Trim Tool to mark the area of interest on the images. It is possible to choose the area outside or inside the trim to create the 3D model.
3. The DSM algorithm first collects the pairs of photographs to be processed. Each pair of photographs overlaps is checked.
4. The algorithm searches along a row of the destination image using an $N \times N$ patch of imagery from the source image. Wherever it finds a good match it records it. The search range is controlled by the depth range parameters. The step size in the source image is defined by the sampling rate parameter. The sampling rate controls the distance between each point of the point mesh. The smaller value is set the longer time DSM processing takes, but the further point mesh can be generated and the quality increases by the increasing number of points. In this case, the sampling rate is set equal(1mm), by this value the number of the points mesh will be generated equals to (5563) points, these points are saved as a TXT file.
5. If more than one pair of photographs is being run, the results of each point cloud are then registered and merged into one cohesive point cloud.
6. The meshing steps and converting the point cloud into a triangulated mesh surface as in figure (6) below.

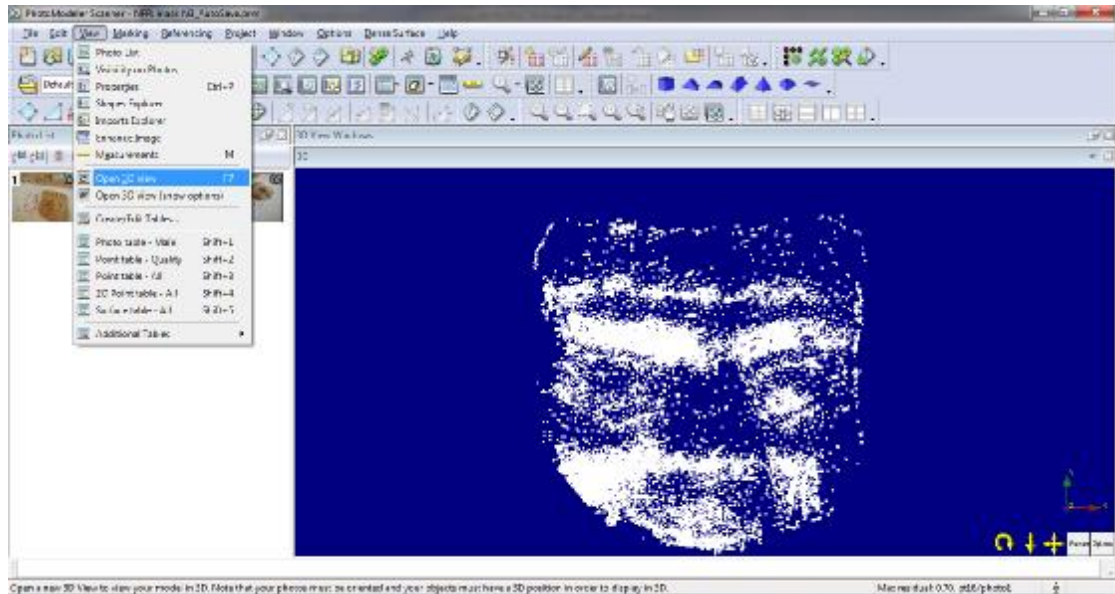


Figure (6) The 3D-points mesh.

7. A TXT file can be exported to many programs like AutoCAD or surfer. It's exported to a surfer program to produce a contour map for the object, as in figure (7).

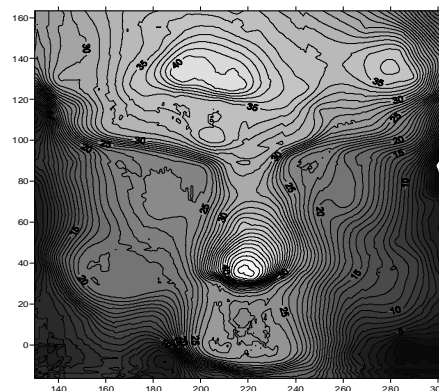


Figure (7) Derived contour map. The contour interval is 1.0mm.

The image pairs will be used to create the dense surface. It is necessary to choose a pair with a low angle between both images, suitable base-to-height ratio, low root mean square error (RMS), and small distance of the sampling rate, In this object the maximum residual equals to (0.70 pixel). By clicking Execute the point, mesh begins. The resulting 3D point mesh can be viewed under the task View by clicking Open 3D View. Now a new window, which includes the generated point meshes showed up. In the 3D View Options dialogue box, Point Mesh has to be enabled as surface type to make the point cloud visible.

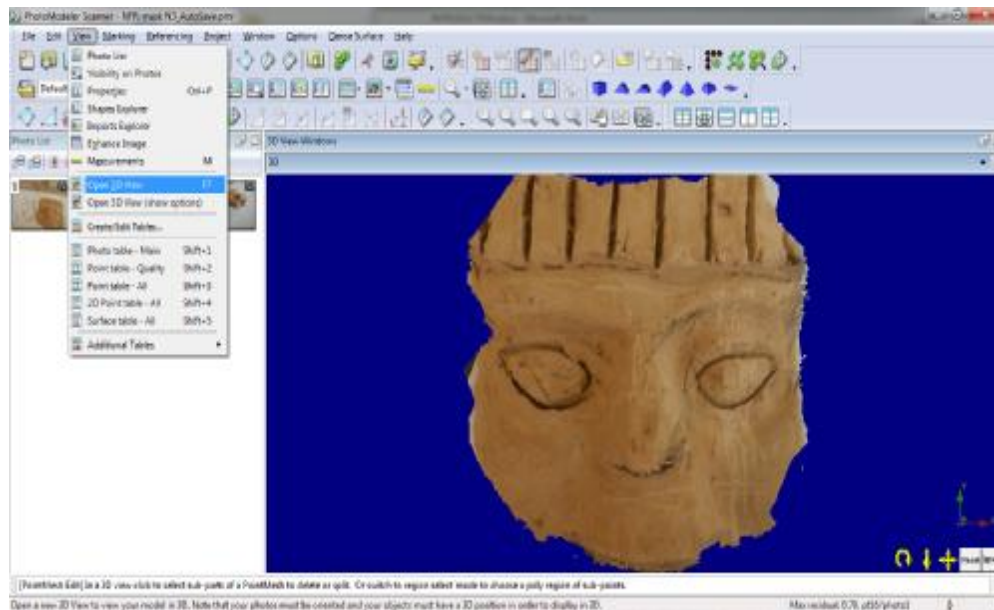


Figure (8) the 3D-point (Stereomodel) with textures displayed in 3D-view.

Further, it is possible to change the display style into quality textures which visualizes the object with a more detailed surface by taking values from the source image Figure (8). In the last step, the point cloud got meshed with triangulations between the points. Therefore, the point cloud got marked by clicking on it with the right click. Here it is possible to activate the triangulation. Now a certain surface has been generated which finally makes a proper 3D model out of the 3D point cloud. The coordinate points of the 3D point mesh are saved as a TXT file.

CONCLUSIONS

Nowadays, both visual and scientific applications of 3D modeling are increasing day by day. 3D modeling products are using in many variety discipline. With the improving hardware and software 3D modeling studies can be done much more easily and fast. In this paper, the role of digital close range Photogrammetry in the obtaining of 3D model was investigated. It can be seen that, in the completed study from model, obtaining of the data with Photogrammetry is quite accurate and quite fast. Close range Photogrammetry software and a consumer degree digital camera are sufficient for this works. All studies can be completed only using photographs. That is, this is a noncontact technology. For this reason, photogrammetric method can be considered in risky places. It also can be consider to survey of directly unmeasurable objects. This is the must safe method from the point of this view. One of the main features of photogrammetric methods is the short length of time required on-site to carry out measurements. Office work during the evaluation stage is actually longer.

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