3D MODELING AND PHOTOGRAMMETRIC MEASUREMENT PROCEDURE FOR ARCHITECTURE AND INDUSTRIAL APPLICATIONS

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Abstract

Recent developments of digital camera in terms of size of Charged Couple Device (CCD) arrays and reduced costs are leading to their application to traditional as well as new photogrammetric surveying and mapping function. Digital cameras, intended to replace conventional film based mapping camera, are becoming available along with many smaller format digital camera capable of large-scale and precise measurement application. The development in digital photogrammetry technology is inline with the development in the computer and digital technologies. This paper introduces a new procedure for 3D modeling and photogrammetric measurement using low cost digital camera (Kodak DC 290 and Olympus) and Photomodeler Pro 5.0 software. The measurement and modeling results are presented in suitable forms (i.e. dimensional plan, graphic plan and 3D model visualization), based on the needs and specification of both architecture and industrial engineering disciplines. The resulted 3D model can be exported to other formats such Autocad drawing (.dwg) and Rhinoceros file format (*.3dm). For verification, the measurement obtained was compared with tape, intersection measurement, actual plan and AXYZ Industrial Measurement System. The overall results show differences of 1.0mm-20.0mm and 0.1mm-04mm, indicating the suitability of the low cost photogrammetric system for 3D modeling and application requiring certain accuracies (millimeters to centimeters).*

1.0 INTRODUCTION

In close range photogrammetry, the distance from the camera (or cameras) is relatively close to the object (Mikhail et al, 2001). The distance range from several millimeters up to 300m (Karara, 1989). Methods of digital photogrammetry are used for modeling of objects in various areas of close-range applications. The realistic or virtual model of the objects is presently required in many types of information systems, which are concerned with various disciplines of industry, architecture, archeological and medicine.

Compared with aerial photogrammetry, close range photogrammetry and particularly architectural photogrammetry or industrial photogrammetry is not limited to vertical photographs with special camera (Adam, 1989). The methodology of terrestrial photogrammetry has changed significantly and various photographic acquisitions are widely in use (Fraser, 2002).

Consequently, digital camera are becoming standard tool for photogrammetric data acquisition, photogrammetric data processing and representation using software is now considered as routine to novel system, processing methods and results. The improvement of method for surveying historical monuments and sites is an important contribution to recording and perceptual monitoring of cultural heritage, to preservation and restoration of any valuable architectural or other cultural monument object or site as a support to architectural, archeological and other art-historical research.

This study focuses on the development of procedure for generating and measuring 3D models using low cost digital camera and Photomodeler pro 4.0 software (Eos System Inc, 2000) with different size, shape and final requirement. This paper describes the adopted photogrammetric method, the analysis and results.

2.0 TEST OBJECTS

The tested objects were Port de Santiago (A Famosa), Melaka for architecture application; Multi Mission Vessel (MMV) hull model and Proton Perdana V6 car for industrial engineering applications. This research are done with collaboration and support from Department of Museum and Antiquities, Muzium Negara Malaysia and local Licensed Land Surveyor Company (Jurukur Semasa, Melaka) and Faculty of Mechanical Engineering, UTM.

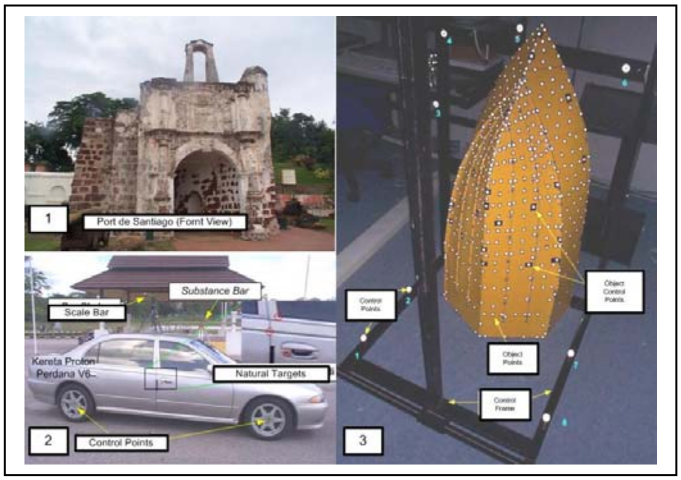

Figure 1: Test Objects

3.0 CAMERA AND PROCESSING SOFTWARE

The Kodak DC210SP and Kodak DC 290 (Figure1) is a portable, low cost non-metric digital camera (approx. price less than RM1500) with the resolution of 1.3 megapixels and 2.1 megapixels respectively. With this resolution the expected photogrammetric measurement accuracy is within several millimeters for objects with dimensions of several meters.

Photomodeler Pro 4.0 is a windows-based software (developed by Eos System Inc Vancouver, Canada) for measurement and modeling of objects using digital images. It is also known as a soft copy analytical close range convergent photogrametric software system. (Eos System Inc, 2000).

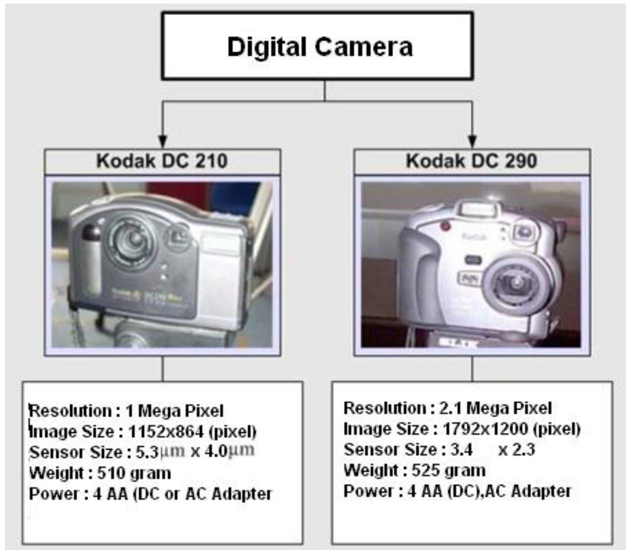

Figure 2: Digital Camera

4.0 METHOD

The procedure employed in this study is divided into two phases; in the first one, called field work phase, photographic shots of the chosen objects were taken, and enough information for its subsequent orientation and scale were collected. In the second one, known as laboratory work phase, all information collected in the field work phase were processed to obtain plans and three dimensional models from the objects (Ismail, 2004).

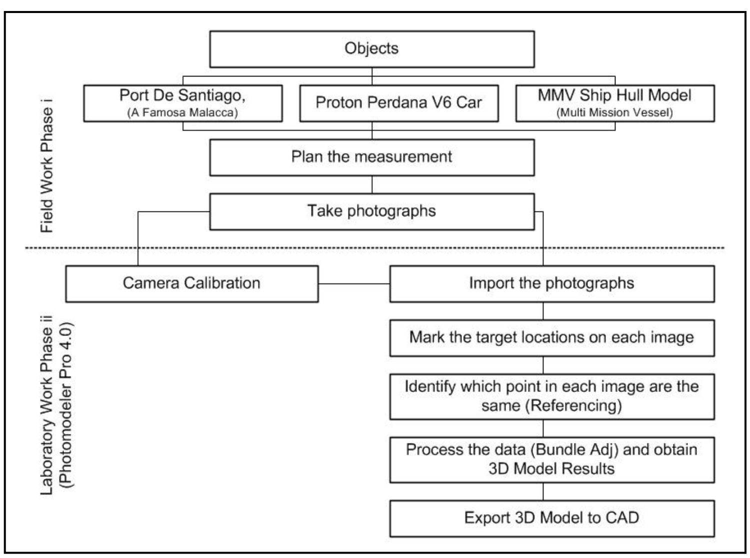

Figure 3: Photogrammetric data processing via photomodeler

4.1 Field Work Phase

It consists of the acquisition of the necessary data to able to carry out later works. This phase consists of the following processes:

4.1.1 Previous definition of pursued objectives

Before starting any documentation work it is necessary to define clearly and precisely the pursued aims and the importance of the action, and the types of the objects. Objectives that are not very precise will directly affect the laboratory work and consequently the quality of the final results.

4.1.2 Positioning and measuring of the control or network lines

They are used for the leveling, scaled and geometric definition of the fotogrammetric models. The control line direction will determine the directions of the x, y & z axes. It will be necessary to establish a series of marks, which form the scale and geometrically define the models, and must be measured accurately.

4.1.3 Carrying out photographic shots

In order to do this, cheap conventional digital camera with CCD as image sensor element are recommended. Photographic shots will be made taking into account aspects like the search of the suitable illumination of the photographed object, avoiding shades, reflections, burned photos, etc. It is recommended to use the camera on photographic tripod for the certain situation to avoid moved photos; or in its defect to make the shots with the camera supported on some stable element; it will be preferable to make the shots with elevated values of depth of field, because we will not run the risk of defocusing; each element to represent must be content in a minimum of three photos; the convergence between photos taken from different positions must have optimal values of 60 degree to 90 degree.

4.2 Camera Calibration

The focal length, sensor format size, principal point, and lens distortion parameters are obtained from the calibration results of each digital camera used. The calibration of the camera was performed using the fix focus of 8.1mm (Kodak DC 210) and 10.2mm (Kodak DC 290). The Photomodeler software contains a simple method to obtain the calibration parameters (Ismail, 2004). The test field used for the calibration is a shown in Figure 4.

Figure 4: Photomodeler Slide Calibration

4.3 Laboratory Work Phase

Once the field work completed, laboratory work begins, proceeding with the analysis and processing of the collected data. With this information saved and classified two different alternatives are considered: the information can either be filed away until the need arises to process it, or it can be immediately processed, resulting in 3D models of the original object structure. A series of successive steps will be carried out when processing this data, as briefly stated below:

i). Orientation of the photos or images. In this process the positions of the shots are calculated. In Figure 5, we can see different positions of the photographic shots.

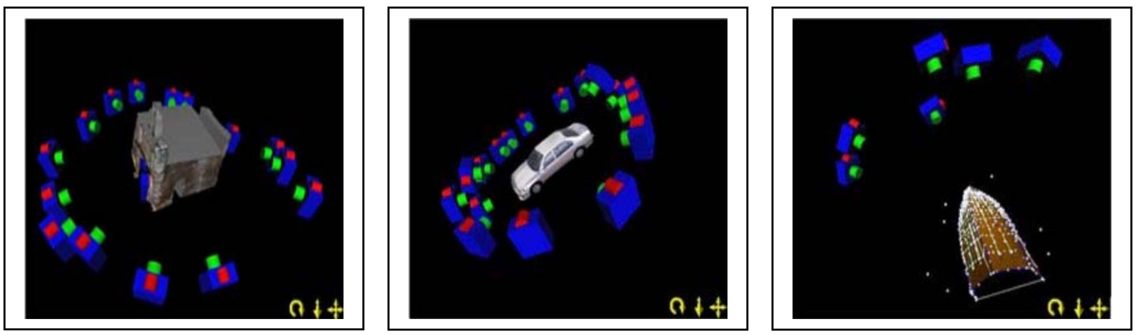

Figure 5: Position of the photographic shots

ii). Forming the scale of the model. From the direction defined by the control lines, x, y & z axis are established and so the model will be leveled. The scale is attained from the distances measured on the control point network (Figure 6).

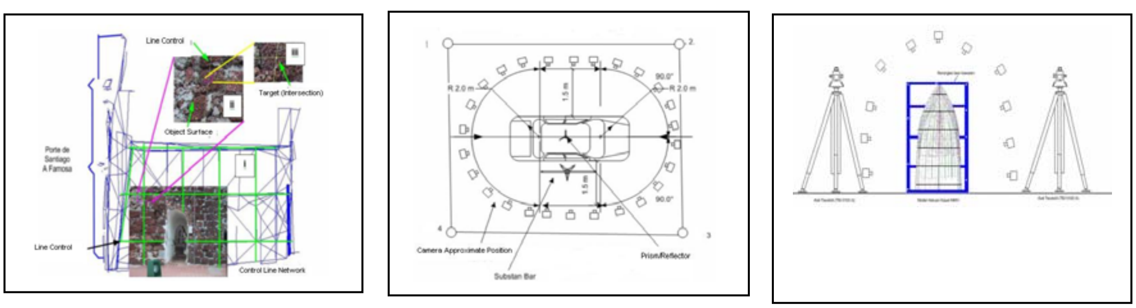

Figure 6: Scaling and network control

iii). Restoring of points, lines, polylines or other interesting graphics sources, thus obtaining numerical values, measurement and 2D and/Or 3D modes (wire frame models, surface models, texture models etc)

iv). The three dimensional models generated are now able to be exported into conventional format (*.dxf,*.3ds,*.vrml, etc)

5.0 Results

5.1 Numerical results

The results viewed provide information on the quality of the process of orientation and indicate: an average of 95% of the accuracy of the points and the quadratic composition of the averages; the average quadratic error, the average error and the maximum and minimum errors

5.2 Graphical results

The graphical results are shown by the flat representation of the model and the projections of the three-dimensional models with photorealistic textures.

In Figure 7, a representation and a profile obtained from three-dimensional points model, line and polylines are shown. Later, the three-dimensional models were transferred and processed on CAD software.

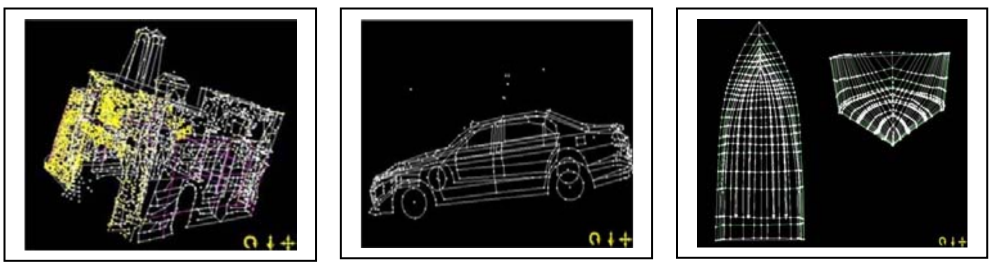

Figure 7: Representation and profile

Different renderings of photo-realistic textures have been obtained from three-dimensional surface model, such as those seen in Figure 8. These texture have been applied from photographic shots of the object itself

Figure 8: Photo-realistic textures 3D models

5.3 Verification of measurement

For the verification of the measurement results, the three measurement projects have been compared separately.

5.3.1 Port de Santiago, A Famosa Malacca

Figure 9 shows the tested object dimension both on the left and right side, and Table 1 provides the results of dimensional measurement via Photomodeler, tape measurement and theodolite intersection.

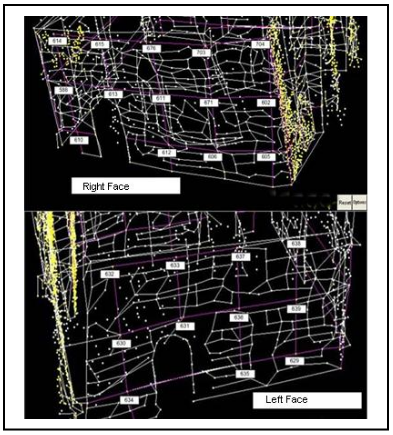

Figure 9: Control point

Table 1: Distance between control point

Line (Point-Point)	Distance (Geodetic)	Distance (Tape)	Distance (Photomodeler)
614-615	1.969	2.00	1.964
615-676	2.002	2.10	2.006
676-703	2.017	2.05	2.015
703-704	2.104	2.03	2.106
704-602	2.045	2.10	2.034
602-671	2.088	2.15	2.09
671-611	2.012	2.05	1.992
611-613	2.01	2.05	1.994
613-588	2.039	2.07	2.041
588-610	2.119	2.20	2.131
611-612	2.116	2.10	2.113
612-606	2.005	2.08	2.002
606-605	2.018	2.06	2.015
605-602	2.077	2.00	2.073
606-671	2.054	2.09	2.069
671-703	1.941	2.00	1.936
676-611	1.957	2.00	1.966
615-613	1.962	2.01	1.971
614-588	1.938	1.90	1.945
614-605	8.955	9.00	8.983

5.3.2 Proton Perdana V6 Car

Figure 10 shows the tested dimension of Proton Perdana V6, and Table 2 provides the results of dimensional measurement via photomodeler, tape measurement and standard dimensional sheet from the catalog.

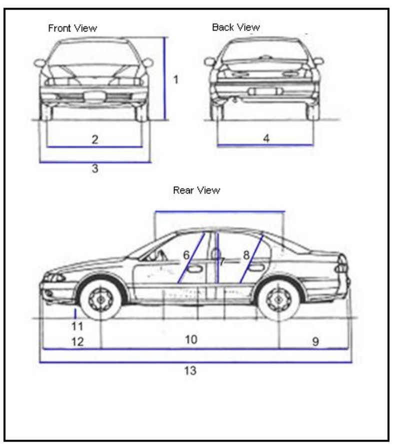

Figure 10: Tested Dimension

Table 2: Dimension Result

No	Parts	Distance (mm)		
		Tape	Photomodeler	Catalog
1	Height	1410	1405	1400
2	Width (Cen. of Tyres)	1520	1517	1510
3	Width (Rear)	1740	1735	1730
4	Width (Out of wheel cover)	1500	1503	1505
5	Window	1880	1885	1890
6	Front Door	975	978	980
7	Door Height	1160	1163	1160
8	Window back height	890	891	885
9	Distance (Tyre-Back)	1060	1063	1065
10	Distance (Tyre-Tyre)	2640	2638	2635
11	Distance (Front-Back)	4620	4615	4610
12	Distance (Floor-Ground)	150	153	150
13	Distance (Tyre-Front)	905	912	910

5.3.3 Multi Mission Vessel (MMV) Simulation Model

Figure 11 shows the MMV simulation model dimension, and Table 3 also provides the results of dimensional measurement via Photomodeler, Coordinate Measurement Machine (CMM), tape measurement and standard dimensions (actual plan).

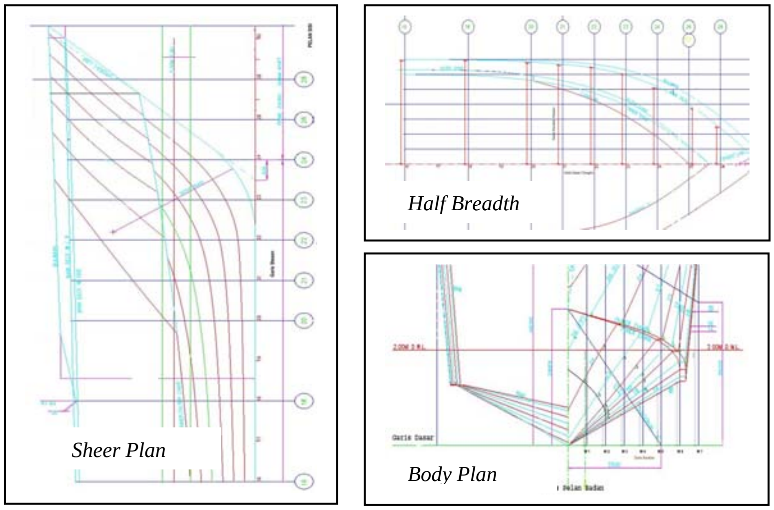

Figure 11: Body plan, Half Breadth plan and Sheer Plan

Table 3: Dimension measurement result (Sheer, Half Breadth and Body Plan)

Station Line	Distance from base line(mm)			
	Dimension (Actual Plan)	Dimension (CMM)	Dimension (Photomodeler)	Dimension (Tape)
28	320	323	324	325
28b	228	225	226	224
26	318	319	317	316
24	317	319	318	314
24b	51	52	53	55
23	315	317	316	312
22	314	319	318	320
21	312	-	316	315
20	310	-	312	313
18	308	-	308	307
16	305	-	306	304

Station Line	Distance from base line(mm)			
	Dimension (Actual Plan)	Dimension (CMM)	Dimension (Photomodeler)	Dimension (Tape)
28	175	178	176	175
26	218	215	216	220
24	355	357	353	352
23	405	400	402	399
22	450	452	450	450
21	470	-	476	480
20	485	-	488	490
18	495	-	497	500
16	500	-	502	503

Station Line	Distance from base line(mm)			
	Dimension (Actual Plan)	Dimension (CMM)	Dimension (Photomodeler)	Dimension (Tape)
W1	20	19	18	21
W2	37	38	40	41
W3	55	53	54	52
W4	73	74	76	77
W5	92	91	90	95
W6	109	110	111	110
W7	299	297	298	300

6.0 CONCLUSION

This study has focused on an architectural and industrial surveying application of close range photogrammetry using low cost digital camera and Photomodeler pro 4.0 processing software. The results obtained demonstrate the effectiveness and capability of low cost system for 3D modeling and measurement of an object with different size, shape and requirement. The measurement and modeling results were presented in the suitable forms (i.e. dimensional plan, graphic plan and 3D model visualization), based on the needs and specifications of both architecture and industrial engineering disciplines. The resulted 3D models can be exported to other formats, such as Autocad drawing (*.dwg) and 3D studio (*.3ds). For verification, the measurement obtained was compared with tape, intersection measurement, actual plan and Coordinate Measuring Machine (CMM). The overall results show differences of 0.2mm-2.5mm (MMV model), 1.0mm-9.0mm (Proton Perdana V6) and 1.0mm-20.0mm (A Famosa), indicating the suitability of the low-cost photogrammetric system for applications requiring accuracies of few millimeters to centimeters.

REFERENCES

1. Adams, L.P. (1989). Industrial Photogrammetry. *Non-Topographic Photogrammetry*. (Ed. Karara, H.M.). Fall Church, VA: American Society of Photogrammetry & Remote Sensing : 349-358.

2. Eos System Inc, (1999). *User Manual : Photomodeler Pro Version 4.0*. Vancouver, B.C. Canada.

3. Fraser, C.S. (2002). *Automated Digital Close Range Photogrammetry : New Development and Application*. International Symposium & Exhibition on Geoinformation 2002, Kuala Lumpur. October 22-24

4. Ismail bin Maarof (2004). Penjanaan dan pengukuran model 3D dengan perisian Photomodeler. MSc. Thesis, Universiti Teknologi Malaysia, Johor.

5. Mikhail, E.,Bethel, J.S & McGlone, J.C. (2001). Introduction to Modern Photogrammetry. John Wiley & Sons, Inc.