Applications of Digital Photogrammetric Systems for Dimensional Measurement and 3D Modelling

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Key words:

SUMMARY

One of the important current development in digital close range photogrammetric systems is the full automation of the measuring process. The systems range available from low to high accuracy. This study focuses on the applications of low accuracy (using normal digital camera) and high accuracy (using V-STARS system) digital close range photogrammetric systems for dimensional measurement and 3D modeling of several objects. The accuracy were checked with other systems, i.e. AXYZ and CMM. The results obtained show the practicality of both systems, with accuracy ranging from several micron (for high accuracy system) to several mm (for low accuracy system).

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1. INTRODUCTION

Digital close range photogrammetry, (or vision metrology or videogrammetry) has been successfully applied (for measurement and 3D modeling) in many applications such as animations, archeology, architecture and industrial measurement.

One of the important current development in digital close range photogrammetric systems is the full automation of the measuring process. The systems range from low accuracy(or low end) to high accuracy (or high end).

This study focuses on the applications of low accuracy (using normal digital camera and PHOTO MODELER 5.0 software) and high accuracy (using V-STARS system) digital close range photogrammetric systems for dimensional measurement and 3D computer modeling (using RHINOCEROS 3.0 software) of several objects.

2. V-STARS SYSTEM (HIGH END)

V-STARS (**V**ideo **S**imultaneous **T**riangulation **A**nd **R**esection **S**ystem) is a high-accuracy digital close range photogrammetric system. It employs special processing software (Figure 1), high-resolution intelligent camera (INCA) (Figure 2), and special targets (high contras retro-reflective coded targets, autobar, scalebar) (Figure 3 and 4) for the automation of the entire measurement process (GSI, 2002; Ganci & Brown, 2001; Ganci & Clement, 2000; GSI, 2000; Fraser, 1999; Brown, 1998). The typically accuracy of V-STARS is better than 10 ppm or 1:100,000 (i.e. about 0.050mm (or 50 micron) on a 5.0m object).

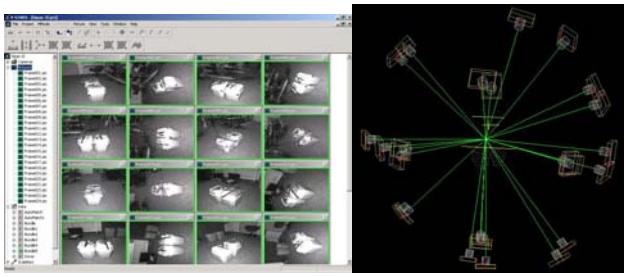

Figure 1: V-STARS software

Figure 2:Camera INCA

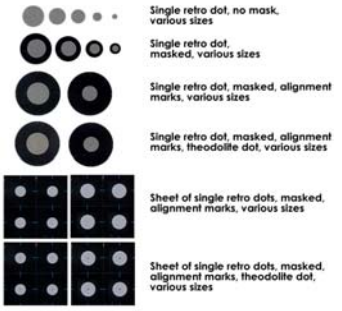

Figure 3: Retro target

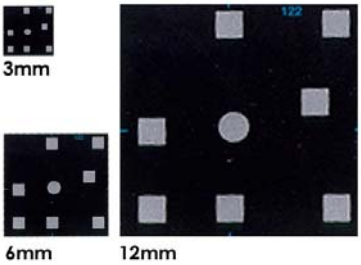

Figure 4: Retro coded target

2.1 Special Software

The V-STARS software automatically processes the images and the coordinates of points of interest computed using photogrammetric techniques and triangulations (Figure 1). There are several advantages of this processing software i.e. high accuracy (1:120,000 i.e. about 0.080mm on a 10m object) and fast (GSI, 2002; Halim & Mohd Sharuddin Ibrahim, 2004a)

2.2 Special Camera

INCA (**IN**telligent **CA**mera) has being designed for the purpose of industrial measurement application using Kodak MegaPlus with 4.2 megapixels resolution (Figure 2). INCA cameras are categorized as array matrix cameras (Fraser, 2003), and have the following capabilities: high accuracy (advanced calibrations techniques), robust, portable, easy handling, image compression up to 10% from original size and automation in measurement.

2.3 Special Target

V-STARS uses high contras retro-reflective targets (Figure 3). There are various types of retro-reflective targets. V-STARS also uses a scale bar (invar) with retro target to scale the measurement, Autobar for defining the origin of the measurement. Retro coded targets are used to control the measurement network (Figure 4). Each coded target has its own characteristic. INCA camera has the capability to recognize the coded targets after the images are taken. To get good result, it is better to get at least 4 coded in one image. For non-contact measurement, V-STARS can accept normal slide projector (dot slide) and providing accurate measurement (figure 5).

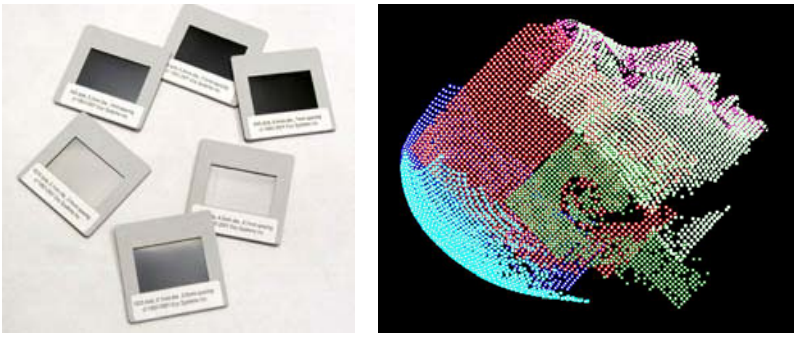

Figure 5: Non-contact measurement and its result.

This research includes the applications of V-STARS (using single camera-off line) for measurement of several models. By adopting simple measurement steps (Figure 5), the accuracy of sub-mm level is easily achievable (Halim Setan & Mohd Sharuddin Ibrahim, 2003a,2003b, 2004a, 2004b). For 3D modeling, V-STARS provides the output in *.igs (IGES) format.

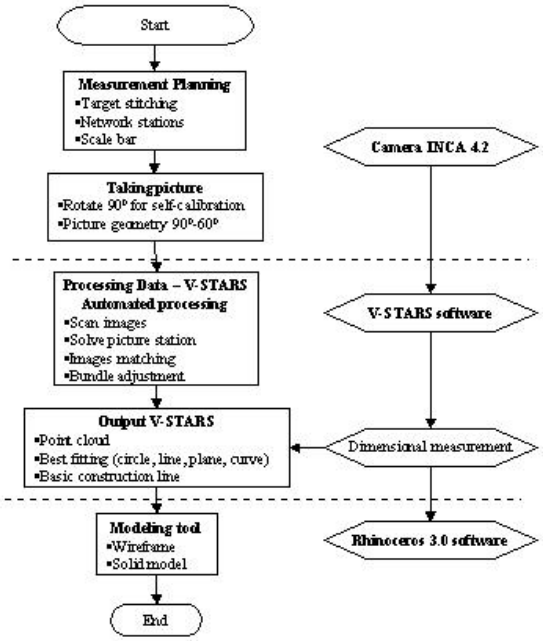

Figure 6: V-STARS measurement procedure

3. LOW END SYSTEM

PHOTOMODELER is a windows-based program that helps user to extract measurement and 3D models from photograph or images(Eos System Inc, 2003). By using a camera as an input device, PHOTOMODELER lets user to capture plenty of accurate details in very short time.

The results using PHOTOMODELER are very promising, with the average accuracy for distances between points lies in the range of 1:1700 (for 35mm, no lens distortion compensation) to 1:6500 (for metric camera) of the object's size. For the points coordinates, the average accuracy reached 1:8000 (Hanke, 1997).

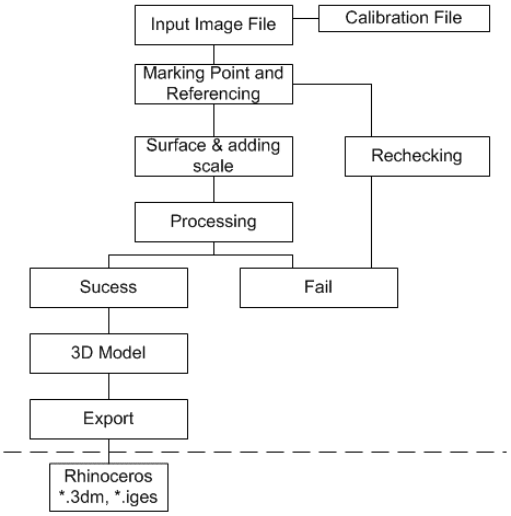

Figure 7: PHOTOMODELER processing and 3D modelling procedure

The procedure for processing via PHOTOMODELER is summarized in Figure 7. The resulted 3D model could be exported in *.3dm or *.iges for 3D modeling applications. Comparisons between V-STARS and PHOTOMODELER are shown in Table 1.

Comparison	V-STARS	Photo Modeler 5.0
Camera	INCA 4.2 megapixels	All digital camera
Software	V-STARS	Photo Modeler 5.0
Price	High	Low
Accuracy	Micron (less then 0.4 micron)	sub-mm
Target	Retro reflective	Retro Reflective, Artifical & Natural Target
Network	Coded	Retro Reflective, Artifical & Natural Target
Target recognition	Automatic	Semi-Automatic + Manually digitize
Dimensional measurement	Solid Module (geometry analysis)	3D Model
Modeling	Third party software (Rhinoceros 3.0)	3D View
Image capturing time	Less then 10 minutes	Less then 10 minutes
Data processing time	Less then 5 minutes	Depends on object or targets

Table 1: V-STARS vs PHOTOMODELER

4. 3D MODELING USING RHINOCEROS

RHINOCEROS 3.0 is a commercial 3-D NURBS (non-uniform rational B-spline) modeling program for Windows. Among its capabilities are: generation of wireframe, generation of solid 3D model, and dimensional measurement.

In this research, the developed procedure for 3D modelling using Rhinoceros 3.0 comprises of (Figure 8): Import *.igs or *.3dm data from V-STARS and PHOTOMODELER; form basic construction line (using line and polyline functions); create wireframe; create solid 3D model from wireframe; and measure for dimensional measurement (Halim & Mohd Sharuddin, 2003, 2004a, 2004b).

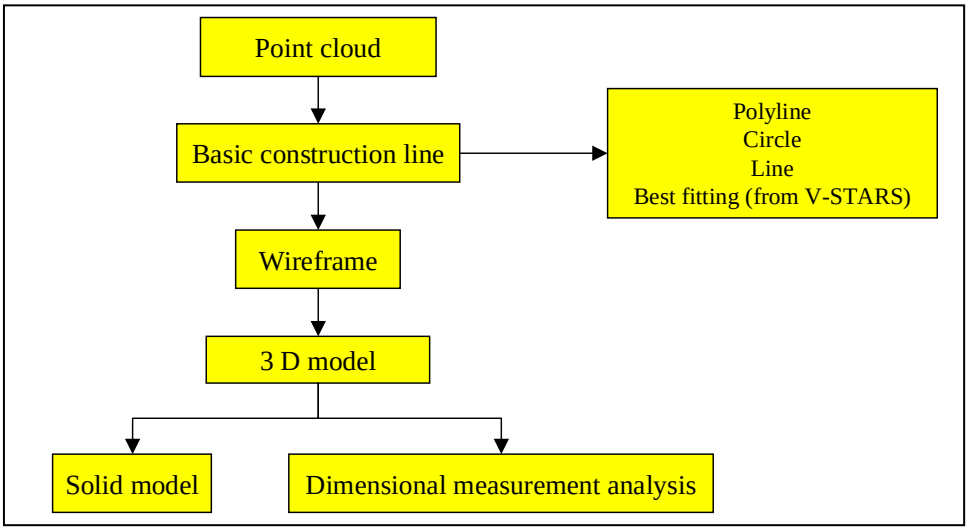

Figure 8: 3D modelling procedure

5. TEST RESULTS

A test object with retro targets are used to compare V-STARS and PHOTOMODELER. 3 scalebars are also used to check the distances. A Canon Powershot S400 digital camera (resolution of 4 megapixels) is used as input device for PHOTOMODELER.

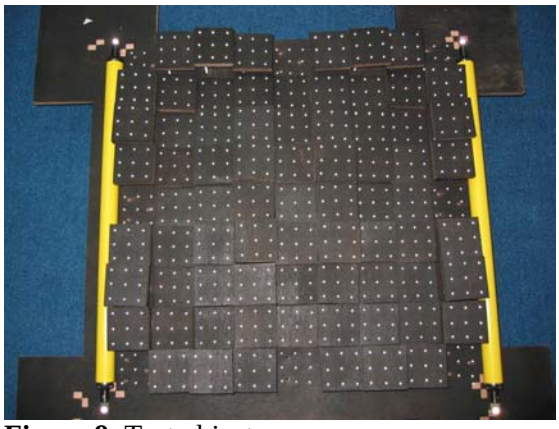

Figure 9: Test object

No.	Measurement		Actual Distance (mm)		Differences
	From	To	VSTARS	Photomodeler	
1	1	2	260.336	259.999	0.337
2	2	3	262.701	262.356	0.345
3	3	4	261.790	261.332	0.458
4	4	5	257.603	257.309	0.294
5	5	6	260.312	259.864	0.448
6	8	9	121.312	121.213	0.099
7	9	10	168.335	168.256	0.079
8	10	11	167.594	167.380	0.214
9	11	12	167.708	167.447	0.261
10	1	5	736.701	736.538	0.163
11	2	6	523.007	522.764	0.243
12	8	5	369.511	368.931	0.580
13	8	1	371.107	370.592	0.515
14	12	3	459.041	458.469	0.572
15	2	9	285.516	286.134	-0.618
16	4	9	380.873	380.472	0.401
17	14	3	582.239	582.079	0.160
18	14	5	581.947	581.733	0.214
19	13	3	621.557	621.449	0.108
20	6	13	198.706	198.470	0.236
21	1	14	259.449	259.069	0.380
22	14	9	144.598	144.461	0.137
23	13	14	199.769	199.478	0.291
24	8	13	255.752	255.475	0.277
25	6	13	198.706	198.470	0.236
26	1	6	583.489	582.597	0.892
27	11	8	118.419	118.262	0.157
28	8	3	367.198	366.736	0.462
29	13	1	447.633	447.455	0.178
30	5	2	583.312	583.055	0.257

*Actual 3D Distance = 3D Distance (Rhinoceros *.3dm)

Table 2: Differences of measurement in mm

For comparison purpose, only 30 points are selected (Table 2). The difference between V-STARS and PHOTOMODELER are between –0.6mm to 0.6mm (i.e. mm level). Scalebar distances are shown below:

Scale bar 1 (known=572.000mm): 572.000 mm (Vstars), 572.000 (Photomodeler)
Scale Bar 2 (known=572.000mm): 572.051mm (Photomodeler)

Scale Bar 3 (known=322.000mm): 322.000 (Vstars)

The results from scalebar distances show that V-STARS is very consistent, and PHOTOMODELER is capable of giving mm level accuracy.

Figure 10 summarizes the measurement configuration, results from V-STARS (point clouds), and 3D modeling via RHINOCEROS (wire frame and solid model). Results of 3D modeling of other objects are shown in Figure 11.

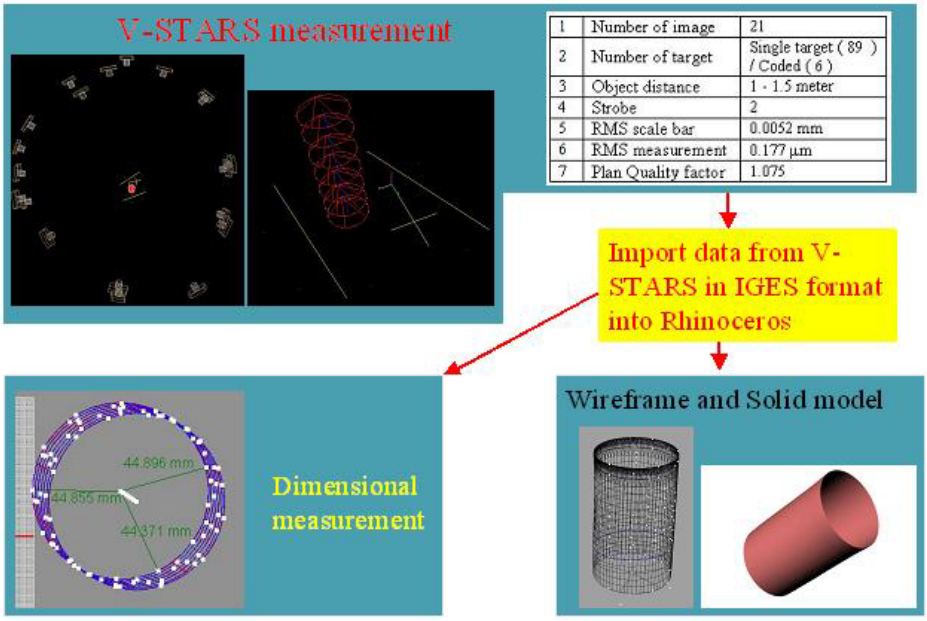

Figure 10: Measurement and 3D modeling of a cylinder

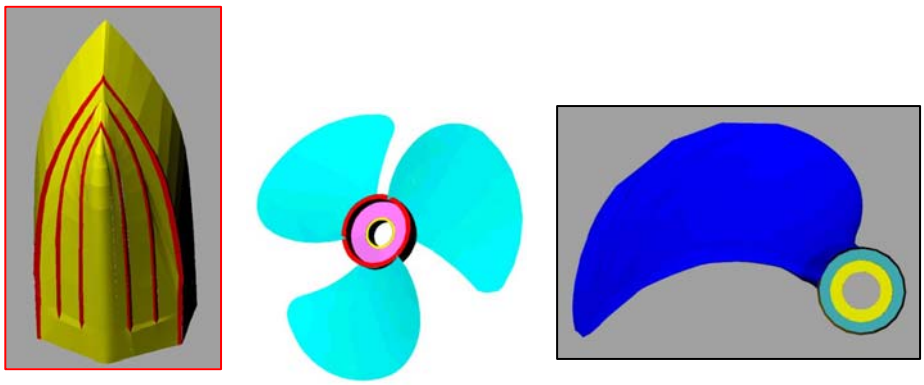

Figure 11: 3D models of a vessel, fan and propeller

To verify the accuracy of V-STARS, tests were performed with CMM and AXYZ. The differences (Figure 12) are between 0.1mm to 0.2mm (Halim Setan & Mohd Sharuddin, 2004a).

6. CONCLUSIONS

This study focuses on the applications of low accuracy (using normal digital camera and PHOTOMODELER) and high accuracy (using V-STARS system) digital close range photogrammetric systems for dimensional measurement and 3D modeling of several objects.The results obtained show the practicality of both systems, with accuracy ranging from several micron (for high accuracy system) to several mm (for low accuracy system).

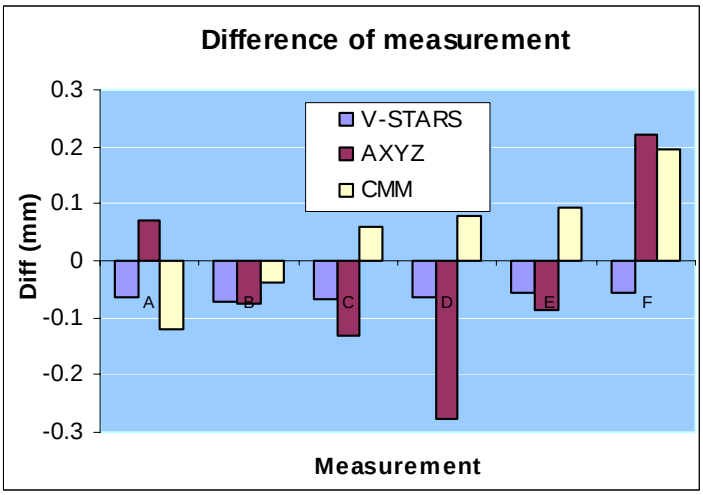

Figure 12: Analysis of accuracy: V-STARS, AXYZ, CMM

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