Proceedings, 11th FIG Symposium on Deformation Measurements, Santorini, Greece, 2003.

PRECISE MEASUREMENT AND 3D MODELLING FOR INDUSTRIAL APPLICATIONS

Halim Setan & Mohd Sharuddin Ibrahim

Department of Geomatic Engineering
Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia(UTM)
81310 UTM Skudai
Johor, Malaysia

Abstract

Many industrial applications require precise dimensional measurement and three dimensional (3D) models. The industrial measurement systems could be divided into geodetic (e.g. V-STARS and AXYZ systems) and non-geodetic (e.g. CMM system) methods. The V-STARS system is an enhanced (and portable) digital close range photogrammetric system for precise 3D coordinate measurement using special high-resolution digital cameras intelligent camera (INCA), special target (high contras retro-reflective) and special software, for the automation of the entire measurement process. The typically accuracy of V-STARS is better than 10 ppm, i.e. about 0.010mm on a 1.0m object. This research concentrates on the precise dimensional measurement (using V-STARS with single camera) and 3D modeling (using Rhinoceros 2.0 software) of several test objects. By adopting simple measurement procedure, the accuracy of sub-mm was easily achievable. The results from V-STARS were also verified with AXYZ and CMM.

1. Introduction

Many industrial applications require precise dimensional measurement and three dimensional (3D) models. The industrial measurement systems could be divided into geodetic and non-geodetic methods (Figure 1). The geodetic methods are usually non-contact, and comprise of the teodolite/total system (e.g. AXYZ system) or close range photogrammetric system (e.g. V-STARS system). The non-geodetic methods use contact measurement, and vary from simple direct tape measurement to the sophisticated Coordinate Measuring Machine (CMM).

This research concentrates on the precise dimensional measurement using close range digital photogrammetric system (V-STARS) and 3D modeling of several test objects. The research approach is summarized in Figure 2, with the emphasis on measurement planning, taking picture (using single INCA 4.2i digital camera), data processing (using V-STARS/Solid), and 3D modeling (using Rhinoceros 2.0 evaluation copy).

Figure 1- V-STARS, AXYZ and CMM systems

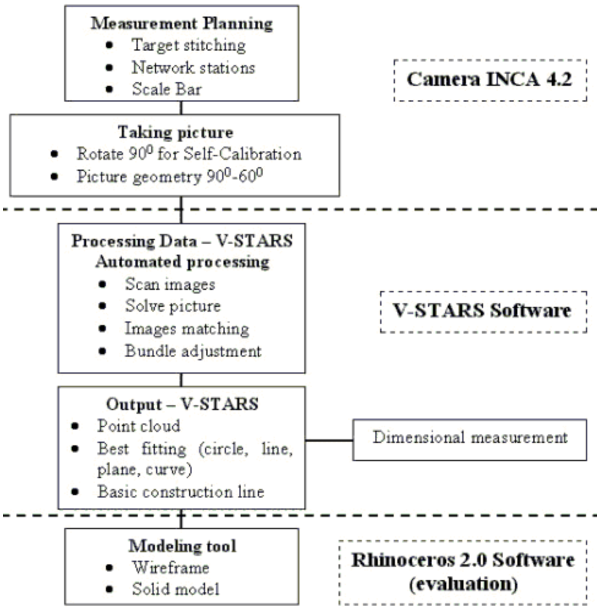

Figure 2- The research method

2. V-STARS

In recent years, faster and more powerful computers have led to the development of more comprehensive and sophisticated measurements that have increased accuracy and improved the measuring process. V-STARS (**V**ideo **S**imultaneous **T**riangulation **A**nd **R**esection **S**ystem) is an enhanced (i.e. high precision, fast, fully automated) and portable digital close range industrial photogrammetric measurement system for precise 3D coordinate measurement using high-resolution digital cameras (instead of film cameras). V-STARS uses special intelligent camera (INCA), special target (high contras retro-reflective) and special software for the automation of the entire measurement process. The typically accuracy of V-STARS is better than 10 ppm, i.e. about 0.050mm on a 5.0m object. The system is developed by Geodetic Services Inc (GSI) USA, and has been applied in many industrial applications (Brown, 1998; Fraser, 1999; Ganci & Brown, 2001; Ganci & Clement, 2000; Ganci & Brown, 2000; Leica Geosystem, 2002; GSI, 2002).

In industrial applications, the non-geodetic methods via Coordinate Measuring Machine (CMM) requires a stable platform throughout the measurement. V-STARS offers several advantages over CMM due to its ability to work in unstable measuring environments (GSI, 2002).

The V-STARS software processes the images automatically and computes the coordinates of points using photogrammetric techniques and triangulations (Figure 3). Among the main characteristics of V-STARS are: portable, high accuracy (to 1:120,000 or about 0.080mm for a 10m object), non-contact, measurement automation, fast results (real time or within minutes), minimal temperature effect (due to fast data capture), versatile in confined spaces, and flexibility.

V-STARS at UTM uses INCA (**IN**telligent **CA**mera) with 4.2 megapixels resolution, suitable for industrial measurement applications (Figure 4). The main features of INCA are: high accuracy (using advanced calibrations techniques), stable, robust (and works in unstable environments), portable, easy handling, image compression (up to 10% from original size), and measurement automation.

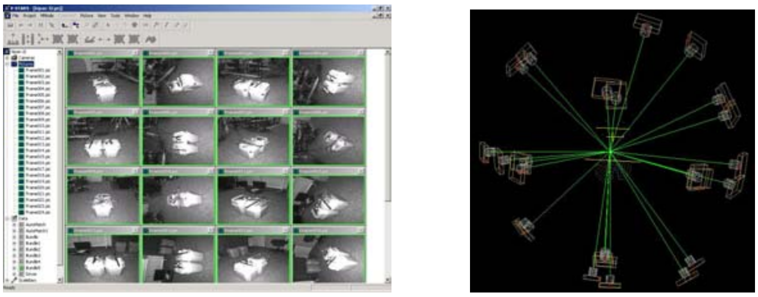

Figure 3- V-STARS software

Figure 4- INCA 4.2

Prior to data capture using INCA, retro targets are placed on the objects. The targets (Figure 5) comprises of retro dot targets (for measurement) and coded targets (for automation during processing). The data is then immediately transferred to a notebook computer, and automatically processed using V-STARS. For 3D modeling purposes, V-STARS exports the graphics data in Initial Graphics Exchange Specification (IGES or *.IGS) format (Figure 1). IGES is an ANSI-standard format for digital representation and exchange of information between CAD/CAM systems.

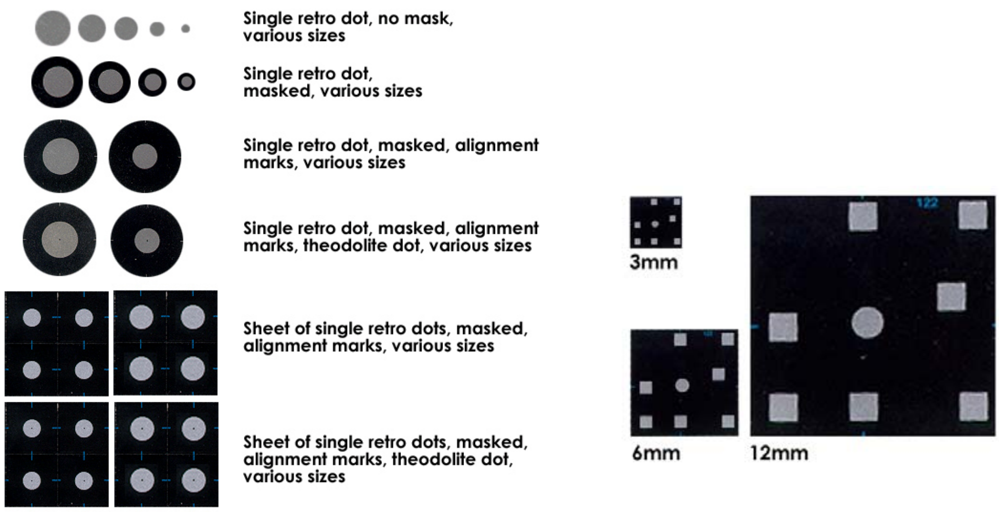

Figure 5- Retro and coded targets

3. Rhinoceros 2.0

Rhinoceros 2.0 is a commercial 3D modelling software. Among its capabilities are: generation of wireframe, generation of solid 3D model, dimensional measurement. The step-by-step procedure for 3D modelling using Rhinoceros 2.0 comprises of: Import IGES data from V-STARS, create wireframe (using line and polyline functions), create solid model from wireframe, and measure for dimensional measurement.

4. Measurement and procedure

In this research, the following 3 measurement tests (of several models) were carried out:

a) Comparison of accuracy between V-STARS, CMM (coordinate Measuring Machine) and AXYZ (high precision electronic theodolites).
b) 3D modeling of a cylinder.
c) Modeling of other objects.

In all these tests, the following were adopted/used: single INCA 4.2 (off-line), software (V-STARS and SOLID), autobar (for automatic initial coordinates determination), specially designed circular retro targets (diameter 4mm), coded targets (for network automation), invar scale bar (for scaling the measurement). The distances between camera and objects vary from 1.0m to 1.5m, following the diameter of targets and distance relationship (Figure 6).

During data processing using V-STARS, the following criteria were used for quality control of the results: RMS of measurement less than 40 microns, plan quality factors between 1 to 2.

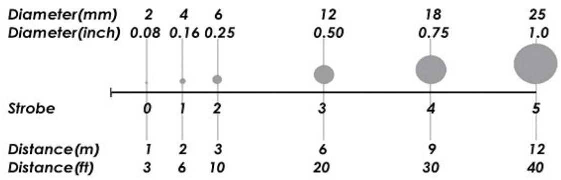

Figure 6-Relationship between target size and distance

The complete procedure (Halim & Mohd Sharuddin, 2002) with simple measurement steps (from data capture, data processing and modeling) is summarized in Figure 2.

5. Results

The relevant results are discussed in sections 5.1 to 5.3 respectively.

5.1 Comparison of accuracy

In the first test, a cylinder with roughly 45 mm radius was measured using 3 systems, i.e. V-STARS, AXYZ and CMM. The cylinder was divided into 7 sections (Figure 7). Table 1 shows the estimated radius of the cylinder. The differences between all 3 systems are between 0.1mm to 0.6mm, indicating that all systems are highly precise (Figure 8). The results from V-STARS and AXYZ are very similar, with 65% within 0.050mm (Figure 9). V-STARS is the fastest (although off-line mode) amongst the 3 systems. Moreover, both V-STARS and AXYZ are more practical than CMM due to their mobility.

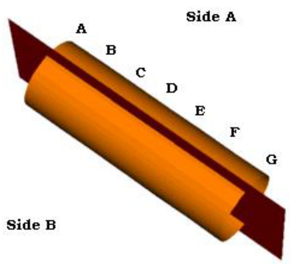

Figure 7 Cylinder measurement

Radius	Comparison measurement to determined radius of cylinder using V-STARS, CMM & AXYZ (mm)						
	V-STARS	AXYZ	CMM		Diff from V-STARS		
			Side A	Side B	AXYZ	CMM (A)	CMM (B)
A	44.592	44.449	45.192	45.176	0.143	-0.600	-0.584
B	44.563	44.428	45.048	45.194	0.135	-0.485	-0.631
C	44.571	44.575	44.939	45.136	-0.004	-0.368	-0.565
D	44.569	44.633	44.856	45.026	-0.064	-0.287	-0.457
E	44.565	44.776	44.787	45.058	-0.211	-0.222	-0.493
F	44.556	44.585	44.752	45.059	-0.029	-0.196	-0.503
G	44.556	44.278	44.754	44.854	0.278	-0.198	-0.298

Table 1- Radius of cylinder

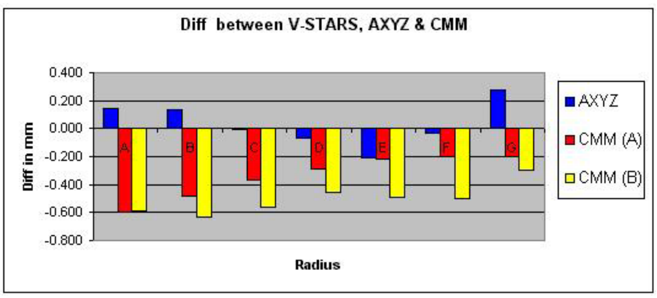

Figure 8- V-STARS vs AXYZ vs CMM

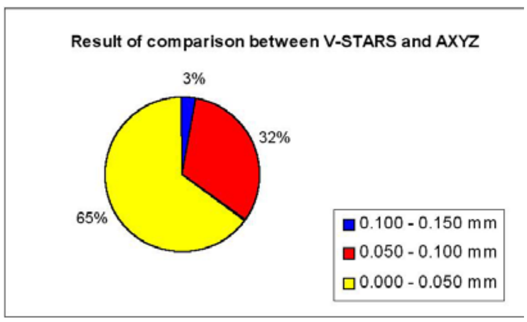

Figure 9- V-STARS vs AXYZ

5.2 3D modelling

The second test used the V-STARS data from the first test (i.e. the same data), with the emphasis on 3D modeling of the cylinder. This test used 21 images and more than 90 targets. The results from V-STARS are saved as graphic data in IGES format. Using Rhinoceros 2.0 (evaluation), 3D modeling, measurement and visualization are much more easier and faster than CAD. Figure 10 illustrates the measurement configuration, summary of results from V-STARS (point clouds), and 3D modeling (wireframe and solid model). The root mean squares (RMS) of the measurement with V-STARS is 0.18 µm.

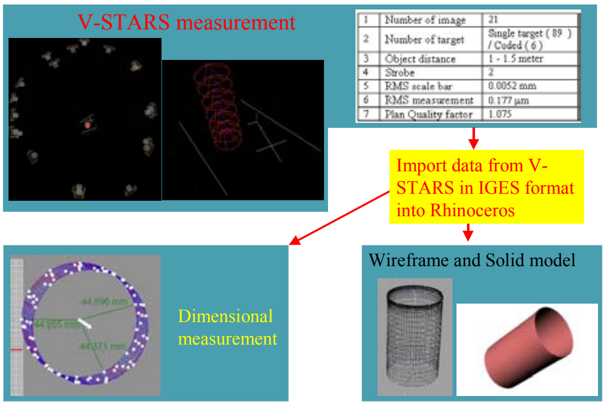

Figure 10- Measurement and 3D modelling

5.3 Modelling of other objects

The third test was carried out in collaboration with Marine Technology Laboratory, UTM. The task was to generate a 3D model of a vessel model (roughly 1m by 0.5m) using V-STARS. 65 images and more than 100 targets were employed, with measurement RMS of 0.37 µm. The results are shown in Figure 11.

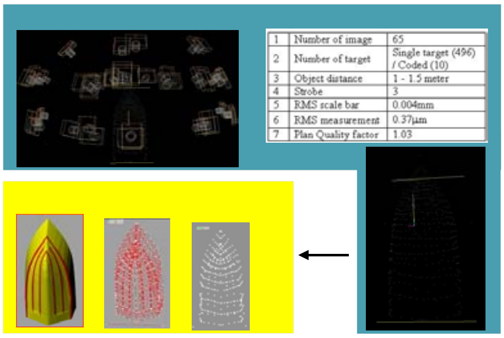

Figure 11- Modelling of a vessel model

Measurement and modeling of two other objects (i.e. fan and propeller) are illustrated in Figure 12.

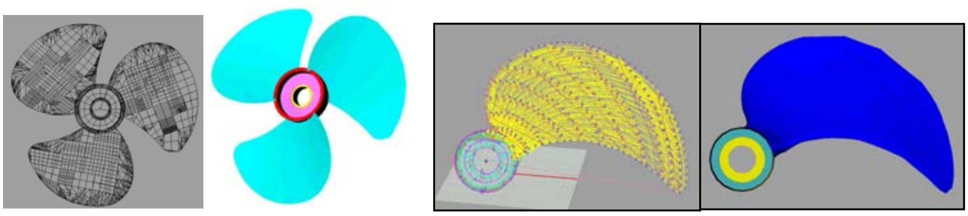

Fig 12 - Modeling the fan and propeller

6. Conclusions

V-STARS measurement system is suitable for high precision industrial measurement applications due to the following factors: special camera (INCA), special target (retro-reflective) and special software (V-STARS) for the automation of the entire measurement processing.

This research concentrates on the applications of V-STARS/S and Rhinoceros software for measurement and modeling of several objects. By adopting simple measurement procedure, the accuracy of sub-mm is easily achievable.

The typically accuracy of V-STARS is better than 10ppm, i.e. about 0.010mm on a 1.0m object. Accuracies of the measurement from this study are between 0.18μm to 0.37μm. The results from V-STARS were also verified with AXYZ and CMM.

Output from V-STARS in IGES format is useful for 3D modelling and dimensional measurement purposes. In this study, 3D modeling of several objects were carried out successfully using Rhinoceros 2.0 software (evaluation copy).

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provides special setting for generating the *.dmp files, which contain the necessary information (especially variance covariance matrix) for deformation detection purposes.

Consequently, an interface program called CONVERT was developed, for linking STARNET and our in-house deformation detection software (GPSAD2000 and DEFORM99). It is hoped that surveyors might be beneficial from the integration of STARNET with other software for deformation surveying applications.

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