Precise Measurement and 3D Modeling for Medical and Industrial Applications: Verification Tests

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Key words: Inspection, 3D modeling, 3D measurement, medical, industrial

SUMMARY

In medical (e.g. craniofacial) and industrial (e.g. inspection) applications, precise data are crucial for 3D reconstruction of objects equivalent to their original specifications. In this study, the main data for both industrial and medical applications are from close range digital photogrammetry and laser scanning techniques. This paper describes the comparison tests to evaluate the capabilities of several measurement system/software on the following aspects: data acquisition (3D point cloud), polygon, wire frame, surface reconstruction (3D solid model) and 3D measurement (linear or curve). The tests are divided into 2 parts, industrial and medical applications. In the medical application, verification of mannequin measurement was carried out using VIVID910 laser scanner system and digital photogrammetric system (DVP). The industrial application comprises of two tests: verification of MMV (Multi Mission Vessel) 3D model (using V-STARS, VIVID910, PHOTOMODELER 5.0, and AXYZ geodetic system), and the determination of surface flatness (using V-STARS, VIVID910 and NIVEL systems). 3D models were compared using RAPIDFORM software (inspection module). The outcome from this research shows the suitability of photogrammetric and laser measurement techniques for industrial and medical applications.

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1. INTRODUCTION

In medical (e.g. craniofacial reconstruction) and industrial (e.g. inspection) applications, precise data are crucial for dimensional measurement and 3D modeling (or reconstruction) of objects equivalent to their original specifications. The required precisions are within micron to cm level. In these applications, the data collection, analysis and 3D modeling require specialised measurement, software, and modeling systems.

In medical applications, craniofacial (or simply human face) is an important part of human anatomy. Human face is a complex surface, with different depth and texture. Craniofacial reconstruction requires precise modeling and measurement of human faces (Figure 1).

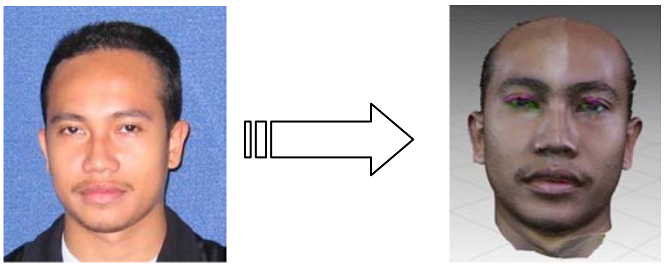

Figure 1. Measurement and modeling of human face

Industrial applications require precise dimensional measurement and the generation of three dimensional (3D) computer models of the measured objects (Figure 2).

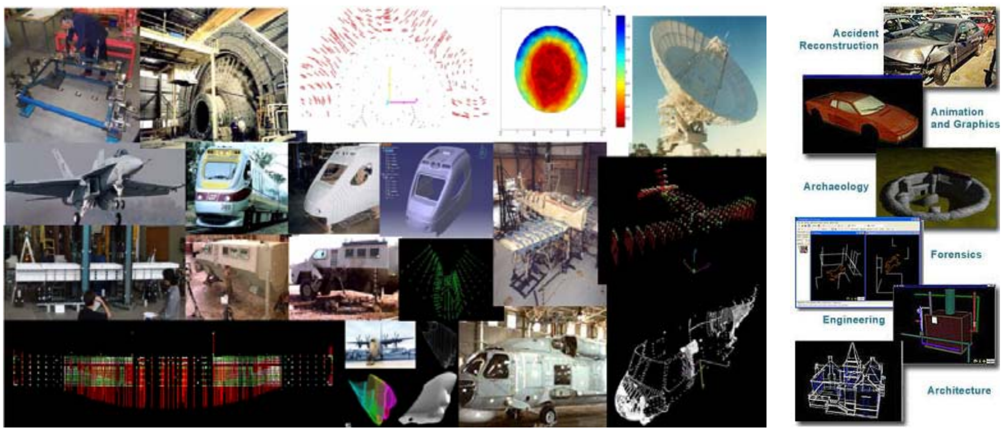

Figure 2. Industrial applications

Many precise measurement systems are available, ranging from contact (e.g. Coordinate Measuring machine or CMM) to non-contact-based (e.g. close range photogrammetric, laser scanning and geodetic systems). In this study, the main data for both industrial and medical applications are obtained from close range digital photogrammetry and laser scanning techniques (Halim, 2004). The main systems/software employed in this research are VIVID910 laser scanner system, geodetic metrology (AXYZ and NIVEL), and digital photogrammetric system/software (V-STARS, PHOTOMODELER 5.0, AUSTRALIS 6.0, DVP) (Figure 3).

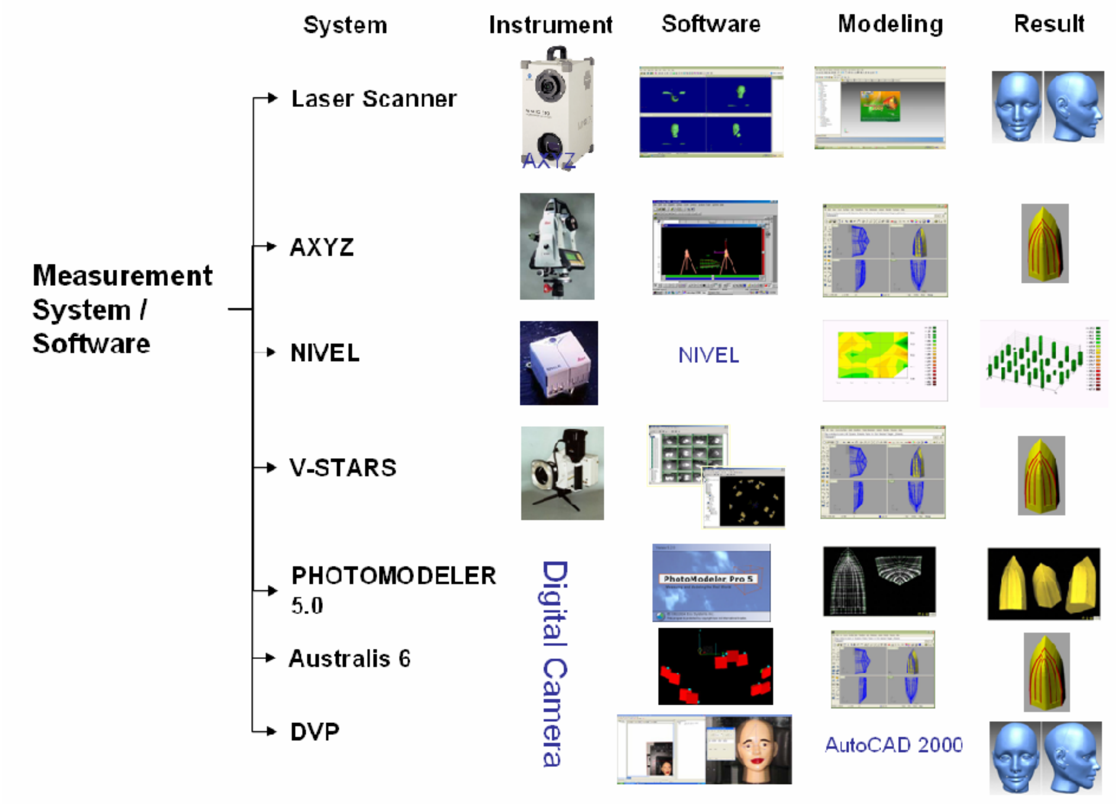

Figure 3. Measurement systems

VIVID910 laser scanner system uses a laser beam to measure an object, and has the capability to record the whole measurement in a snap (about 0.3 sec (fast mode), 2.5 sec (fine mode), and 0.5 sec (color mode)). There are 3 main advantages of VIVID910, i.e. speed, precision, and simplicity (i.e. point and shoot simplicity for consistently excellent results). The accuracy (Z, typically) of laser scanner are within 0.008 mm using fine mode. VIVID910 employs 3 types of mounted lens, depending on the object sizes and measurement distances. VIVID910 comes with Polygon Editing Tool (PET) software for real time scanning and data processing.

AXYZ is a real time measurement system using several (minimum 2) high precision electronic theodolites (i.e. TM5100A with 0.5" measurement accuracy), and the typical accuracy is 1:100,000. AXYZ system uses AXYZ software for real time operation (both data collection and data processing). However, the measurement process requires skill operator for set-up and pointing.

NIVEL measures surface flatness based on the differences of levels between 2 instruments (base and rover) via on line mode. The measurement is done using a grid method. The base is

located in a stable platform and the rover is moved to points on the grid. NIVEL software determines the flatness in real time, the results are shown in graphics and the height differences are indicated by color levels.
V-STARS vision metrology system comprises of dedicated hardware (i.e. special targets and special digital camera (INCA (INtelligence CAmera) 4.2 mega pixel)), special software (V-STARS) and special calibration technique (self calibration). The research to date deals with high accuracy off line measurement of objects using V-STARS via single camera module (Halim & Mohd Sharuddin, 2003, 2004). The typically accuracy of V-STARS is 1:100,000 or about 0.050mm on a 5.0m object. The resulted graphics from V-STARS and AXYZ can be exported into IGES and VDA format (supported by CAM software such as Rhinoceros 5.0) for real 3D visualization.

PHOTOMODELER 5.0 and AUSTRALIS 6.0 digital photogrammetric software process images from any digital camera for measurement of objects and calibration of cameras. The accuracy depends on the resolutions of the digital camera and calibration technique. For measurement automation and accuracy enhancement, PHOTOMODELER 5.0 and AUSTRALIS 6.0 employs coded targets and relative orientations targets respectively. In addition, PHOTOMODELER 5.0 has the facility for 3D modeling of objects .

Digital Video Plotter (DVP) is a stereo based photogrammetric system. This system utilizes computer with 2 monitor for data processing and stereoscopic glasses for viewing stereo images in 3 dimensional.

Several commercial 3D modeling software are used in this study such as RAPIDFORM2004 (for laser scanning data), RHINOCEROS 3.0 (for V-STARS, AXYZ and AUSTRALIS data) and AutoCAD 2000 (for DVP data). Generally, the building blocks for 3D modeling are point, line, polygon, triangle, surface and 3D solid model (rendering).

RAPIDFORM2004 software is suitable for processing 3D scan data. It is the bridge between 3D scanner and all other downstream application, including CAD, CAM, FEA, etc. RAPIDFORM2004 converts data from any 3D scanning device (such as laser, white-light, moire, CT/MRI, touch probe or any other) into high quality polygon mesh, accurate freeform NURBS surface, or geometrically perfect solid models.

RHINOCEROS 3.0 is a 3D modeling software. Among its capabilities are: generation of wireframe, generation of solid 3D model, and dimensional measurement. The step-by-step procedure for 3D modelling using Rhinoceros 3.0 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.

2. METHOD AND PROCEDURE

This section describes the comparison tests to evaluate the capabilities of photogrammetric and laser measurement system/software for industrial and medical applications. The following aspects are considered: data acquisition (3D point cloud), polygon, wire frame, surface reconstruction (3D solid model) and 3D measurement (linear or curve). The tests are divided into 2 parts, industrial and medical applications.

The adopted procedure (Figure 4) comprises of planning, data collection, processing, 3D modeling and measurement. Figure 5 and 6 show the procedures for medical and industrial applications respectively.

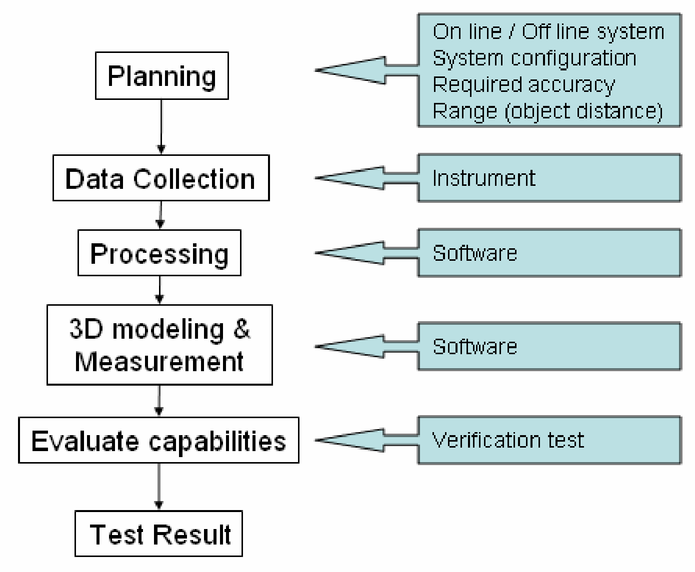

Figure 4. Flowchart of overall procedure

3. MEDICAL APPLICATIONS

In the medical application, verification of mannequin measurement was carried out using VIVID910 laser scanner and digital photogrammetric system (DVP).

The collected data from scanner and photogrammetric are processed using Polygon Editing Tool (PET) and Digital Video Plotter (DVP) software respectively. In addition, RAPIDFORM2004 software is used for 3D modeling of human faces.

The developed image capturing system (Figure 7) combines the laser scanning using Minolta VIVID 910 (L1, L2) and stereo photogrammetric (C1, C2, C3) techniques for acquiring high-resolution 3D models of craniofacial soft tissue (Zulkepli et al, 2004). The combination provides advantages in terms of rapid 3D modeling (via laser scanning) and precise measurement (via photogrammetric) (Halim et al, 2004).

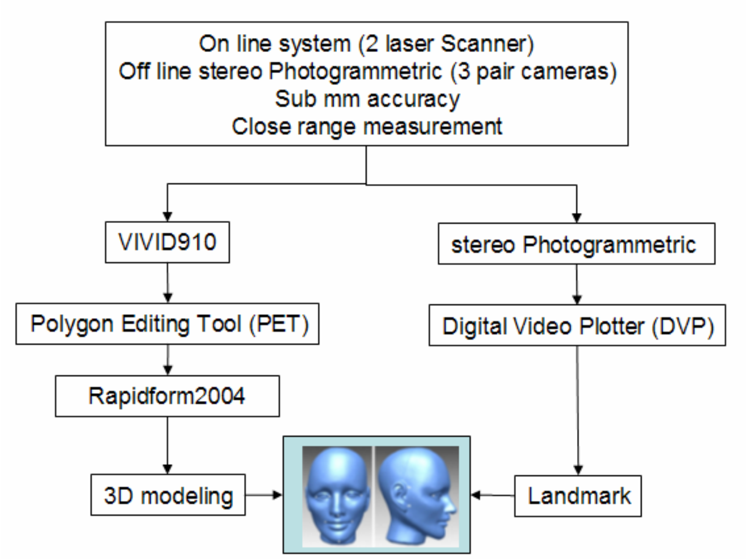

Figure 5. Procedure: medical application

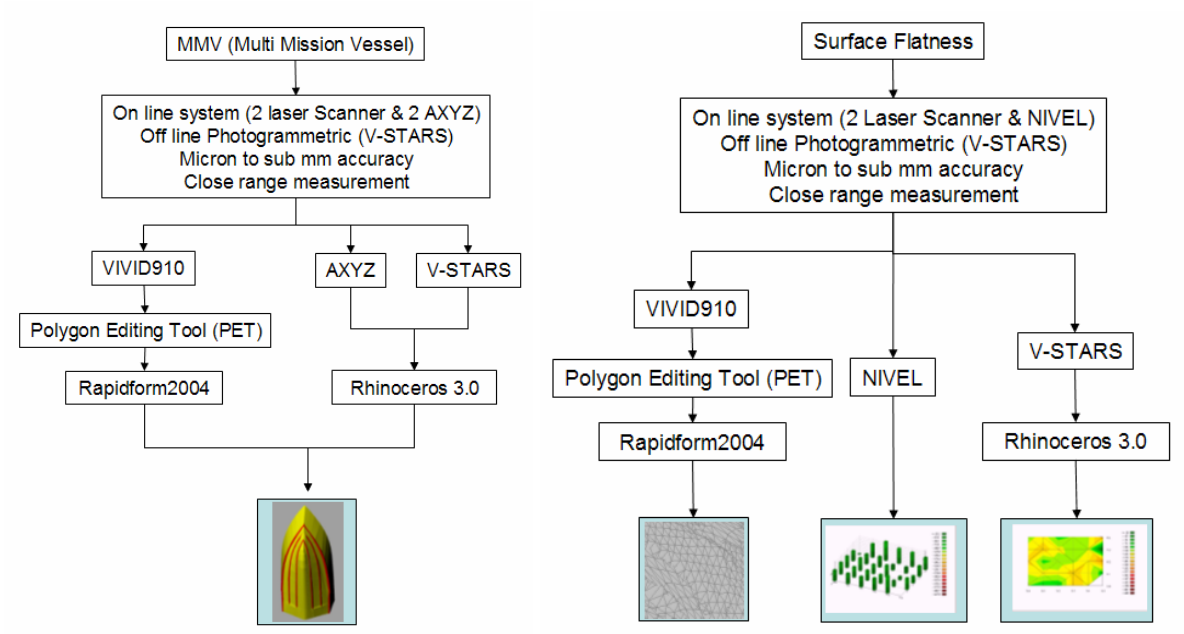

Figure 6. Procedure: Industrial application

Figure 8 and Figure 9 show the generated 3D models and measurement results. These preliminary results (Halim et al, 2004) show the differences within few mm, and mainly due to the inaccuracies of locating the anthropometric landmarks either manually (using caliper) or digitally (using DVP and RAPIDFORM).

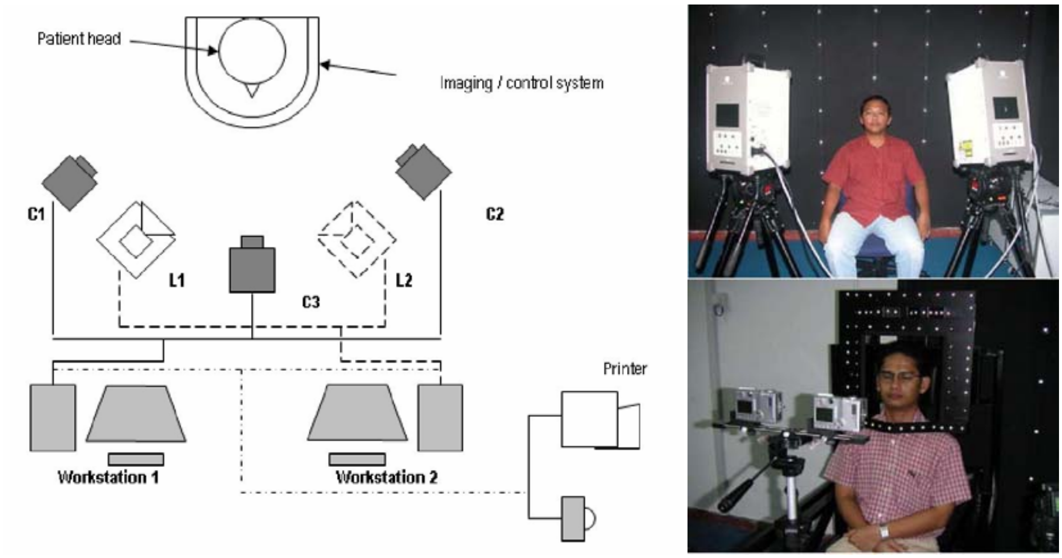

Figure 7. Data capture

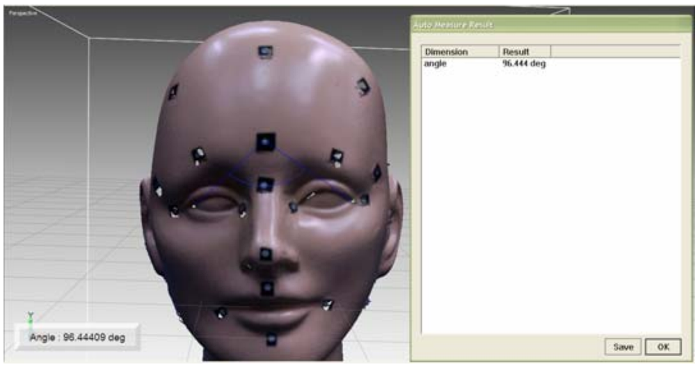

Figure 8. Results in PET and RAPIDFORM

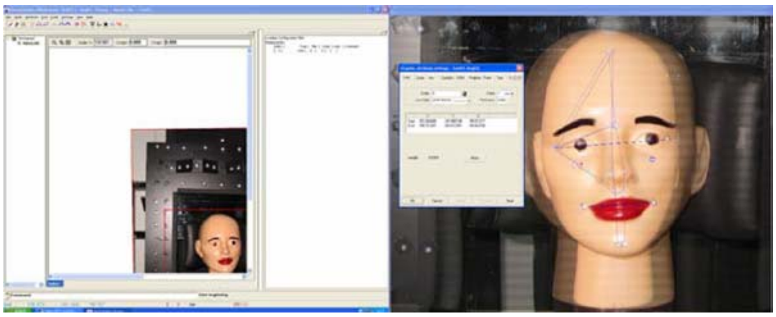

Figure 9. Results in DVP

4. INDUSTRIAL APPLICATIONS

The industrial application comprises of two tests: verification of MMV (Multi Mission Vessel) 3D model (using V-STARS, VIVID910, and AXYZ geodetic system), and the determination of surface flatness using V-STARS, VIVID910 and NIVEL systems (Figure 10).

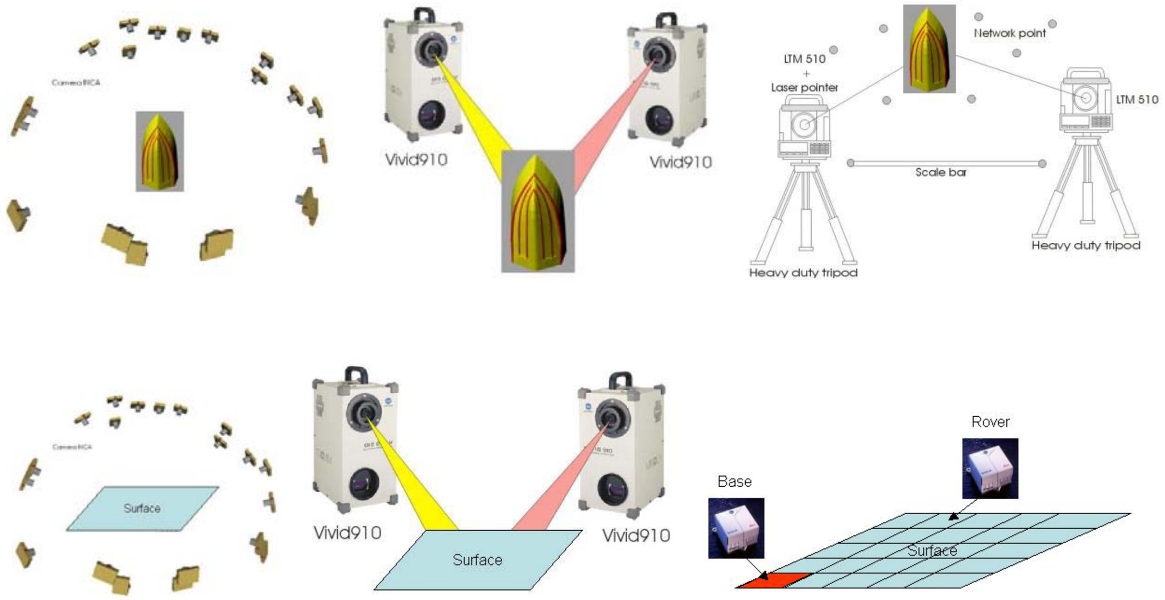

Figure 10. Data capture (V-STARS/PHOTOMODELER, VIVID910, AXYZ and NIVEL)

The generated 3D models of MMV (Figure 11) were inspected and compared using RAPIDFORM software (inspection module), and the differences (i.e. between outputs from V-STARS, AXYZ and VIVID910) were quite small. The results of surface flatness determination are shown in Figure 12.

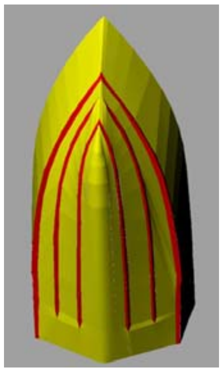

Figure 11. 3D model of MMV

5. CONCLUSIONS

This paper describes the verification tests on precise measurement and 3D modeling for specific applications (i.e. medical and industrial), using several systems (i.e. VIVID910 laser scanning; V-STARS, DVP and PHOTOMODELER photogrammetric systems; AXYZ geodetic system; NIVEL system; RAPIDFORM and RHINOCEROS software). The results between systems were quite similar. The outcome from this research shows the suitability of photogrammetric and laser measurement techniques for industrial and medical applications.

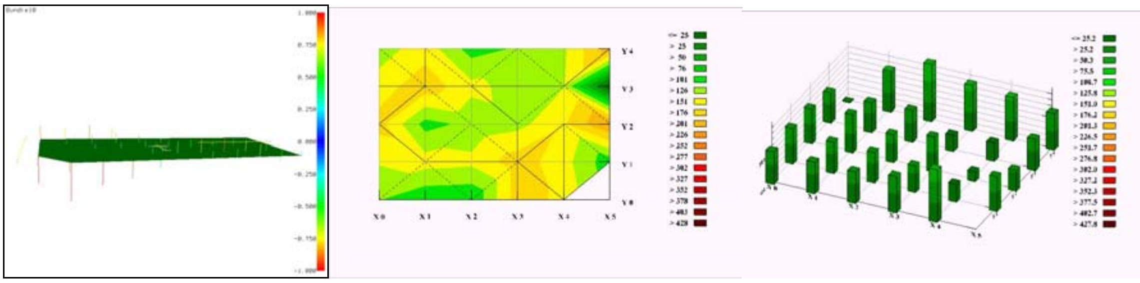

Figure 12. Result of surface flatness

ACKNOWLEDGEMENT

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BIOGRAPHICAL NOTES

Dr. Halim Setan is a professor at the Faculty of Geoinformation Science and Engineering, Universiti Teknologi Malaysia (UTM). He holds a B.Sc. (Hons.) in Surveying and Mapping Sciences from North East London Polytechnic (1984), a M.Sc. in Geodetic Science from Ohio State University, USA (1988) and a Ph.D from City University, London (1995). Currently, he is the Deputy Dean at the School of Graduate Studies, UTM. His current research interest is in precise measurement, 3D modeling, deformation monitoring, least squares estimation and industrial metrology.

Mohd Sharuddin Ibrahim holds a BSc degree in land surveying (Geomatic Engineering) from UTM in 2001 and MSc in Industrial surveying also from UTM in 2004. Currently, he is a research officer, under the supervision of Dr. Halim Setan, at the Faculty of Geoinformation

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Zulkepli Majid is a lecturer at the Faculty of Geoinformation Science and Engineering, UTM. He holds B.Sc (Hons) and M.Sc. in surveying from UTM. His current doctoral research deals with the imaging system for craniofacial reconstruction.

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