Geoinformation Science Journal, Vol. 10, No. 1, 2010, pp: 61-72

CAMERA CONFIGURATION FOR ACCURATE CRANIOFACIAL MAPPING USING PHOTOMODELER SCANNER

Nor Azira Alias, Zulkepli Majid and Halim Setan
Photogrammetry and Laser Scanning Research Group
Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia
E-mail: nazira7@siswa.utm.my, zulkepli@utm.my, halim@utm.my

ABSTRACT

PhotoModeler (Eos Systems, Inc. Canada) Scanner contains new capabilities in a module called Dense Surface Modeling (DSM). The DSM exploits photo pairs to generate massive number of 3D points, thus automatically creates a point cloud similar to the output from laser scanning technique. The DSM technology required at least two images (stereo pair) from digital cameras to generate the three-dimensional (3D) model. Camera setup is an important factor for capturing high-accuracy data because several pairs of synchronized digital cameras are needed to capture the images for craniofacial area of subject. Consequently, a research was carried out to determine an optimal camera configuration for capturing high-accuracy point cloud. The photogrammetric data captured was evaluated using the laser scanned data as the bench mark. This paper provides a detailed discussion of the designed camera configuration, the procedures to process stereo-pair images and the evaluation of the 3D model visualization reconstruction using photo-based scanned and laser scanned data.

Keywords: *Craniofacial mapping, camera configuration and PhotoModeler Scanner*

1.0 INTRODUCTION

Currently, high-accuracy and simple method has become the important thing that be considered in modeling industry especially in 3D modeling application. It was because high-accuracy method can produce the better 3D model and 3D measurement result to user in any fields. Moreover, simple method makes it the process easier and time safely and also carry out it in a cost-effective and efficient. According to Bruner *et.al* (2000) and Liu *et.al* (2000), 3D measurements with a stereo camera system are an established standard practice and are used in a wide range of different applications. In order that, digital photogrammetric approach seem to be more stunning with fast, accurate and realistic method to produce photorealistic 3D model. Mitchell and Newton (2002) has stated that history of attempts to apply photogrammetry to the measurement of the human body is almost as long as the history of photogrammetry itself. Besides, photogrammetric is also known as non-contact measurement method which suitable to use in variety of humans case studies such as craniofacial mapping applications (Chong *et. al*, 2004; Majid *et. al*, 2005; Majid and Chong, 2005; Majid *et.al* 2006), dentistry, neurology and others. With combination from PhotoModeler Scanner (PMS) and stereo cameras configuration system would be an excellent combination to achieve such accuracies in modeling and measurement for craniofacial area. Furthermore, PMS provides the tools able to create

accurate, high-quality 3D models and measurements from photographs through the process called photo-based 3D scanning.
Photo-based scanning is a new way to 3D scan based on two important components which are photogrammetric topographic Digital Elevation Model (DEM) creation and computer vision stereo matching (Walford, 2009). Through endless research to improve the efficiency of matching two images, close-range photo-based 3D scanning techniques was developed to fulfill the modern system requirements. These development techniques bring the accurate measurements and advanced matching algorithm techniques from computer vision to give new breathe for photorealistic images process. Before this, interactively visualizing and producing of 3D model and measurements has been hold on to laser scanning system that required user to have an expensive devices that is laser scanner and powerful workstation to support software for massive point clouds processing. It is impossible to handle the data processing of large amounts of point clouds by using common computer system. Due to the limitations from laser scanning system, the use of digital cameras to obtain photos which to produce 3D model result capable to overcome it. Moreover, digital cameras are available on the market, from the simple, relatively cheap, digital data format, suitable for photogrammetric system applications with the excellent lenses and high picture resolution (Tokarcyz and Mikrut, 2000).

Majid et.al (2005) have described in their research 3D point cloud created through stereo-photogrammetry, the spatial accuracy depends on the geometry of the images used, the resolution of the CCD camera and the image processing technique and mapping accuracy can be controlled simply by altering the focal length of the lens, the object distance and the pixel resolution of the CCD of the camera. However, anything involve with CCD cameras must be through calibration process to ensure it would provide accurate measurements. So, this paper initiate new development from digital photogrammetric method to generate 3D model which be capable to provide same results as laser scanner system or possibly much better, more affordable and performs high-quality visualization and measurement result achievement. Furthermore to overcome the movement real-life subjects like real human face during data capturing. So that, the system was setup with cameras synchronization to capture multiple images in very fast speed to avoid error from movement. As the explanation above, PMS is seems like a software that have capability to give user satisfaction if they use it to apply in any field of works. It was because the system is capable to solve the position and orientation of the camera when taking photos accurately through the camera calibration process. Plus ability to scan surfaces to extract dense point clouds.

The purpose of this paper is to introduce a new approach for data acquisition system in craniofacial mapping using synchronised stereo-cameras system combined with PMS software. Besides that, with comparing this new development system with well established method like laser scanner system can determine how good PMS system works to generate 3D model on human face which is live subject. Seems this system capable to provide better in 3D visualization and also can give accurate measurement with the used of high-resolution cameras. Furthermore, this development system was upgraded from previous research project but more improvise in aspect of time and efficiency. The PMS products make the processing easier and faster with automatic DSM generate modules.

2.0 DATA COLLECTING

Data collecting is carried out by using two different current close-range methods. First method from digital photogrammetry system while second method using laser scanner system. The

subjects that have been used for testing were mannequin and real human face. So, the implementation processes to be discussed referred to the system configuration to capture mannequin and human face images. There are several things need to figure out before started to collect data, as indicated in explanation below:

2.1 Digital Photogrammetric Data Acquisition System

This system is developed from incessant previous research on medical photogrammetric field to improve the quality of the data capture and produce high-accuracy results with new enhancement technology built in PhotoModeler Scanner (PMS) software. Thus, the system is built up combination of digital photogrammetric technique as a data capturing method and PMS for data processing to produce 3D model and make measurements for some craniofacial landmarks points.

2.1.1 Camera Calibration

Calibration of the internal parameters of a camera is critical for accurate measurements (Beraldin, 2004). Anything that works with cameras necessitates knowing the characteristics of the camera before apply it into the project. In order that camera calibration needed to determine interior orientation of the camera. Interior orientation is the relationship between camera-centric coordinates and image coordinates (Berthold, 2000). Usually, calibrated cameras produce five approximated parameters that can be used as a measurement device and also reduce error in measurements to achieve high accuracy results. These are the basic parameters optical, geometric and digital characteristics of the camera:

i) The perspective projection (focal length, *f*)
ii) The transformation between image planes coordinates and pixel coordinates (*x, y*).
iii) The geometric distortion introduced by the optics (*k1, k2, k3*).

Through those parameters, the world and pixel coordinate systems are related with the corresponding coordinates in the camera reference frame (**Figure 1**).

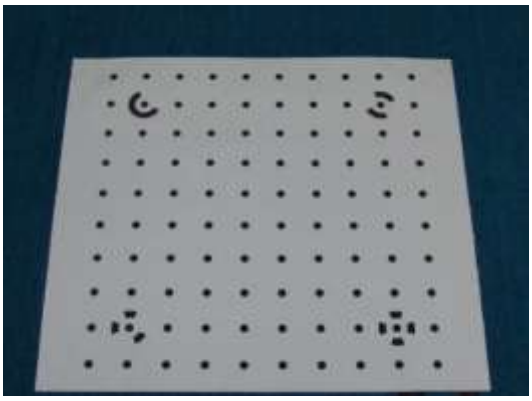

Figure 1: Standard Calibration Grid from PhotoModeler Scanner Software

In order that, PMS software was built-in already the modules to run fully automatic calibration process and all at once store the successful calibrated cameras into camera library. Meanwhile, it will automatically search the database of those cameras when images added into a project for camera matching process. The calibration was done by using PhotoModeler calibration grid that is given in PhotoModeler Scanner program files folder just like shows in **Figure 1** above. The grid need to print out suitable size referred to the subject's size itself. After that, place the calibration grid onto the floor to take the photographs. Self-calibration was used for this project because of its simplicity and easy to process. Six to twelve stereo-convergent grid calibration photos were taken to precede the cameras calibration but requisite at least two photos must be rolled in rotation 90^0 clock-wise or counter clock-wise. Besides that, strongly convinced all points contain in the calibration grid paper also appeared in calibration grid photos were captured. So, cameras stations were placed in suitable positions for make it sure covered all the points formed.

2.1.2 Cameras Synchronisation System Setup

Figure 2a, 2b, 2c and **2d** show cameras synchronized system setup which consists four, six or eight of Sony DSC-F828 SLR digital cameras to capture image of real human face and mannequin. Those cameras are high-resolution which offer a maximum of 3264 X 2448 pixels resolution which yields a file size about 3MB per image in JPG file format. Setting for all cameras must be same as the setting while camera calibration process is implemented. So, the setting could not be changed until data captured finish because to avoid errors and difficulty happen in data processing stage.

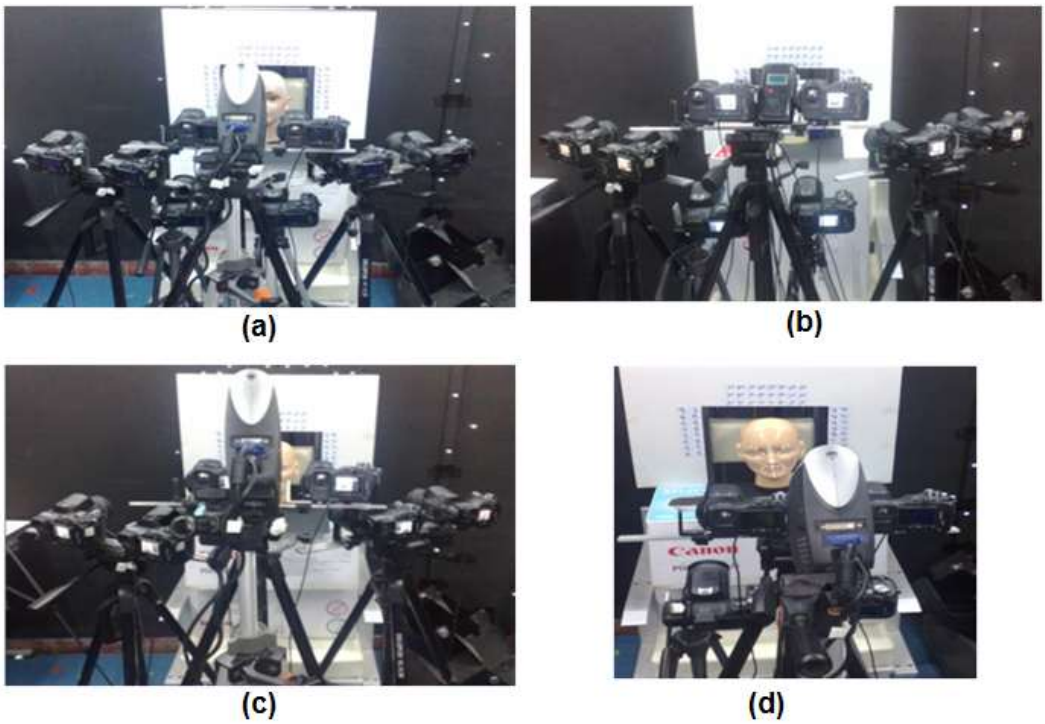

Figure 2: Setup of Camera System, (a) eight cameras with projector, (b) eight cameras without projector, (c) six cameras with projector, (d) four cameras with projector

Several set of stereo-pairs cameras were being tested in order to identify the optimal number of cameras should be used to produce the best of 3D model representation by PMS software. All the cameras configured according to the base-to-height ratios that compute already before place the cameras. The base is described the distance between cameras stations and the height is the average distance from cameras stations to the subject surface and most important the values should required the requirements of PMS in range 0.1 to 0.5. It was because, the values of base-to-height ratios whether if too small or large might influence to have a good DSM results for the 3D model. In this project, cameras base was determined at 200mm between cameras and the average distance from cameras to the subject surface determined at 700mm. So, base-to-height computed was within 0.3.

Meanwhile, those stereo-pairs cameras stations should be placed with suitable positions to ensure taken good images coverage. From previous test experience, it was noticed that ideal positions for cameras stations intended for PMS project by using mixture of stereo and convergent method. This would be helped out in coverage for images overlapping on the surface being modeled. Then, lanc controller used for controlling synchronized system to capture image simultaneously. However, the used of lanc controller might provide the accurate images without any movement because images be taken very fast less than 1 second. Other instrument also comprised with the system setup was LCD projector that being used to project visible random pattern or texture onto the subject surface during data captured. The DSM process become much easier has visible pattern or texture on images. The surface without pattern or texture applied onto it can cause the difficulties while running the modeling process by using DSM modules. The pattern or texture projected will help in creating density point clouds and well surface generated really close to the real object.

2.2 Laser Scanner System

As for comparison purposes, the laser scanner system also involved in this experimental project. This system was employed Minolta VIVID 910 3D laser scanner to scan the subject. Besides that, two techniques to acquire the data from 3D laser scanner which are using turntable or manual move by user (refer to the non-living object only). However, the laser scanner can be used one or two at the same time to scan the mannequin or human face. However, it was depending on object coverage area required to be modeled. If use only one laser can get adequate coverage of an object, it is not necessary to use two lasers.

This experimental project conducted by using two laser scanners to scan mannequin and real human face. The TELE lenses types have been chosen for both scanners to scan the images referred to the size of subjects. For human face scanned data, the fast mode has been chosen to avoid movement from the subject during scanning process and also the same mode used for mannequin. In fact, the laser scanner system need powerful workstation completed with Polygon Editing Tool (PET) software to control scanning process because of huge space required to store the scanned data and be able to process the data. Meanwhile, the use of PET is to control laser scanner during data scanning besides be able to identify distance subject from laser scanner and also can viewed the scanned images through the workstation. Actually, it is possible not use the PET to control the scanning process which means can control via laser scanner directly but the problem is cannot sure the conditions of data recorded whether scanned well or not.

3.0 DATA PROCESSING

Both systems have their compatible software to perform the data processing. The commercial software package for digital photogrammetric system is PMS software to process the photorealistic images while laser scanner used RapidForm 2004 software to process the scanned images. However, this paper to be focused more on PMS data processing nevertheless RapidForm 2004 still will be described generally.

3.1 PhotoModeler Scanner Software

PhotoModeler Scanner software has been used to process images captured by digital photogrammetric data acquisition system. Several steps need to be carried out to complete the data processing in producing 3D model of mannequin and real human face and make the measurements for each landmark points. This software special from previous version of PhotoModeler other than DSM module because provided fully automation with three new add-on modules consists of coded target, idealize and PhotoModeler Video (PMV) to make it data processing on generating 3D model more ease, high accuracy and time saving. But PMV usage is for applications where circular targets can be placed or projected on an object that is moving or changing shape. There are general steps have been carried out to model the subjects like shows in **Figure 3** below.

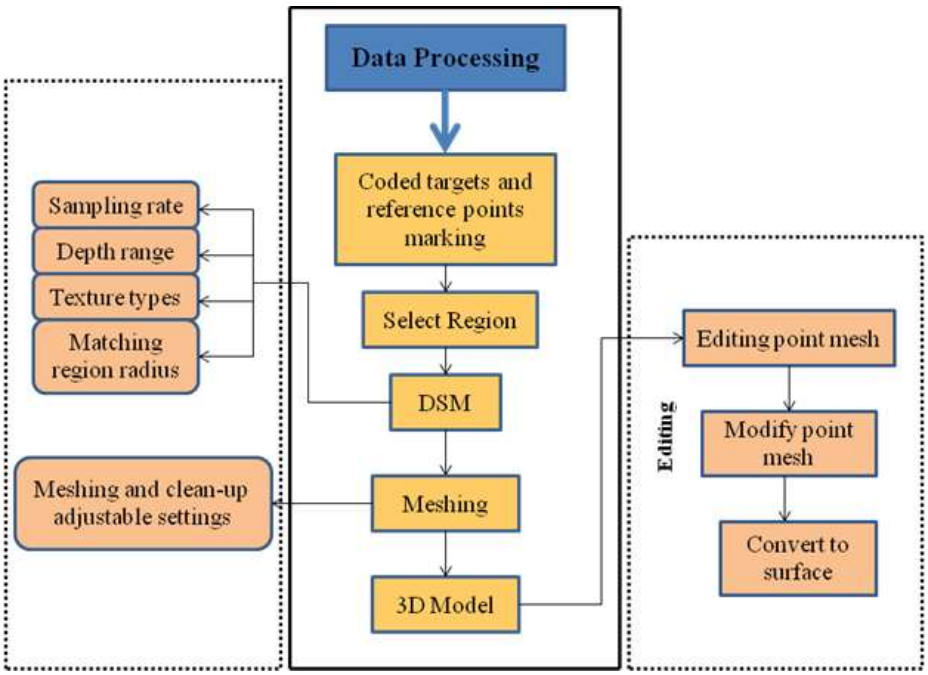

Figure 3: Flowchart of data processing steps in PMS software

3.2 RapidForm 2004 Software

RapidForm 2004 is standard software for 3D scanners. The use of Minolta VIVID 910 3D laser scanner is used to be compatible with RapidForm in order to perform creating 3D models through converts dense point clouds into triangulated polygon meshes and NURBS surface models subsequently make the measurements. In **Figure 4** below shows the data processing procedures that must be completed in RapidForm 2004.

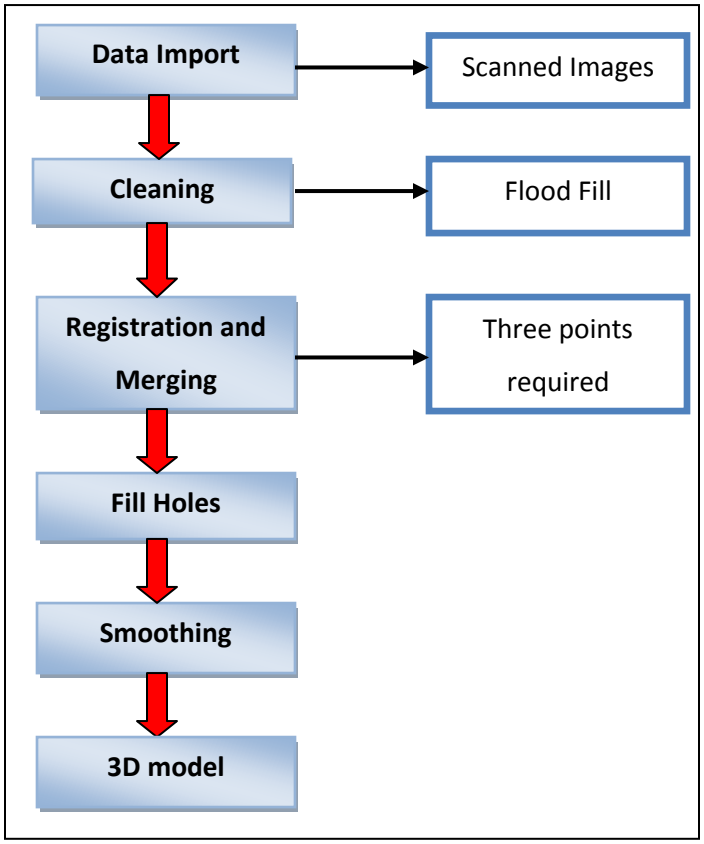

Figure 4: General procedures to generate 3D model in RapidForm 2004 software

4.0 SYSTEM EVALUATION

Evaluation was done for system involves in this study in several aspects such as 3D model visualization quality, systems cost and difficulties level to produce the output required. The increasing demand for high-accuracy and quality results expected from sensor data acquisition system makes more powerful products being invented. As the reason to know the capabilities of PMS performances on those aspects should be compared to the near system that can give similar results presentations. Besides, PMS claimed that can provide similar results as laser scanner. So, the comparison between these two systems will make to proof the statements and at the same time identify the limitations of the hardware and software used. In this paper, the comparison makes was emphasis on the texture quality of 3D visualisation, system setup and cost to build up the system.

4.1 3D Model Visualization

Three-dimensional model output from both system digital photogrammetric and laser scanning were analyses by virtue of textured colour whether close or not to the real subject. Besides that the 3D model represented also will be seen based on precise shape which less error according to the measurements particularly and general view perception. So that, 3D models products comparison was made to evaluate the capabilities of both system in effort on producing quality and better models. The results of all 3D human face and mannequin were shown in **Figure 5** from laser scanned data and **Figure 6** from PMS products below.

Figure 5: The 3D model results from laser scanner system using RapidForm 2004

Figure 6: The 3D models results from digital photogrammetric system using PMS

4.2 Comparison of Approximate Hardware and Software Cost Digital Photogrammetry System and Laser Scanner System

Digital photogrammetric system more low cost obviously compared to the laser scanning system which included hardware and software. Totally approximated cost for digital photogrammetric within RM 50,000 or maybe less to develop the system. While laser scanning system approximately cost can be reached up to RM 300,000 to set up the system. Thus, it is clearly shows that digital photogrammetric system represents more affordable and low-cost

system for the contribution on 3D modeling and measurements for craniofacial applications. But still need investigation more on the cameras configuration part to figure out the minimum stereo-pair cameras can be used to implement the data capturing process. Fewer cameras used means more lowly cost system will be produced.

4.3 RESULTS ANALYSIS

4.3.1 Discussion Performances of PMS

In aspect quality of images, PMS shows the high quality images or in other words photorealistic images captured by excellent calibrated cameras. So, it can present well-textured 3D models close to real subject. But then, need visible random pattern or texture projected on the subject's surface from LCD projector as an aid for intended generate consistent point clouds texture for that model. If non texture was projected, it can be quite difficult to get better results and at the same time construct more noises. However, other thing should to be solved out when using LCD is the resolution of light arrays projected moreover two different projector's type used simultaneously. In that case, it was better to use same type of projector because it has same resolution and make the texture projected on the face surface equivalent as good as required. If using the different projector, the images still can be processed but need a lot of filtering during 3D model creating phase. That was mean taken so much time to accomplish the images processing.

Subsequently, everything must be done follow the PMS requirements to ensure modeling process could working well such as angle of cameras position, base to height ratio, coverage area means percent of overlapping between images, cameras station arrangement and etcetera. Much overlapping between adjacent stereo-pairs images to cover all over the surface's subject could be better. In order to do that, the angles between the shots must get as close to right angles (90 degrees) as possible. If images captured not really fulfill the standard requirements will have an effect on PMS performances which is generating process did not work properly instead only can cause much errors. Then, if want to measure the distance between two anthropometry landmarks points accurately should have two clearly visible points in the images as a scale reference in the project. Due to that, must clarified the right distance length for those two points on the real surface medium. The two points could be anything that consists in system configuration such as camera base and distance between two coded targets.

However, different data acquisition systems give different level of capability to attempt get high-accuracy 3D modeling and measurement. Thus, digital photogrammetric method combine with PhotoModeler Scanner software also still have strengths and weaknesses in certain aspect while generating 3D model and make measurements. Obviously, PMS were not really performed if there any requirements not followed correctly during images captured, it can reduce the 3D models and measurements results accuracy. Other difficulties might be affected the results, the cameras synchronized system with multiple stereo-pairs cameras involved. These circumstances must have well planning to figure out suitable positions for each stereo-pair before place it in order to avoid weakness in angle between cameras positions. It probably could prepare constant platform that technically designed with exact computation followed the PMS requirements such as base to height ratio and angle between stereo-pair cameras. Hence, make the data acquisition system for PMS more systematic and ease in future research project especially for the movement objects.

5.0 CONCLUDING REMARK

The real human face and the mannequin were successfully reconstructed by using digital photogrammetry synchronized system and laser scanning system as virtual 3D models. Nevertheless, the new developed combination systems provide better results in aspect of data capturing time and easiness particularly compared to previous research or project. It was because PMS software contains fully automatic modules to implement all the stages processing in order to generate 3D models and at same time become helpful to user. The assigned technologies (instruments and software) offer a detailed and accurate reconstruction of the objects with accuracy within millimeters. But then, every system built never can avoid from pro and cons due to certain limitations come from hardware setup or cannot exactly fulfill the software requirements. Accordingly, the continuous testing should be carried out in order to improve and clarify the constant and optimum configuration for on-going research specifically in craniofacial applications. However, the used of PMS through the combination with digital photogrammetric system have high potential to go further on producing well-textured 3D model besides measurement information for craniofacial anthropometric mapping.

REFERENCES

Bruner, A.W., Fleming, G.A. and Hoppe, J.C., 2000. Comparison of three optical methods for measuring model deformation. *AIAA-2000-0835, 38th Aerospace Sciences Mtg and Exhibit.*

Beraldin, J.A., 2004. Integration Of Laser Scanning And Close-Range Photogrammetry – The Last Decade And Beyond. *The Xxth International Society For Photogrammetry And Remote Sensing (Isprs) Congress. Commission Vii, Pp. 972-983. Istanbul, Turkey. July 12-23.*

Berthold, K.P. Horn, 2000. Tsai's camera calibration method.

Chong, A.K., Majid, Z., Ahmad, A., Setan, H. and Samsudin, A.R., 2004. The Use of a National Craniofacial Database. *New Zealand Surveyor No. 294,* 2004.

Liu, T., Cattafesta, L.N. and Redeztsky, R.H., 2000. Photogrammetry applied to wind-tunnel testing. *AIAA J. 38 964-71.*

Majid, Z., Chong, A.K., Ahmad, A., Setan, H. and Samsudin, A.R., 2005. Photogrammetry And 3d Laser Scanning As Spatial Data Capture Techniques For A National Craniofacial Database. *The Photogrammetric Record 20(109): 48–68.*

Majid, Z. and Chong, A.K., 2005. Craniofacial stereo mapping: Improving accuracy with natural points. *New Zealand Surveyor No. 295.*

Majid, Z., Chong, A.K., Setan, H., Ahmad, A. and Rajion, Z.A., 2006. Natural Features for Non-contact Three-Dimensional Craniofacial Anthropometry Using Stereo Photogrammetry. *Archives of Orofacial Sciences 1 (1): 42-50.*

Mitchell, H.L. and Newton, I., 2002. Medical Photogrammetric Measurement: Overview and prospects. *ISPRS Journal of Photogrammetry & Remote Sensing, Vol. 56, pp. 286-294,* 2002.

Tokarczyk, R. and Mikrut, S., 2000. Close-range photogrammetry system for medicine an railways. *International Archives of Photogrammetry and Remote Sensing Vol. XXXIII Part B5, Amsterdam.*

Walford, A., 2009. A new was to 3D scan. *Position IT Nov/ Dec*. 2009.

AUTHORS

Nor Azira Alias is a Master candidate at the Faculty Geoinformation Science and Engineering, Universiti Teknologi Malaysia. Currently, she is pursuing study M.Sc (Geomatic Engineering) degree in Medical Photogrammetry field for Craniofacial Anthropometric Mapping Applications. She holds B. Eng (Geomatic) degree from Universiti Teknologi Malaysia.

Dr. Zulkepli Majid is a senior lecturer at Faculty Geoinformation Science and Engineering, Universiti Teknologi Malaysia. Currently, he is the head of Photogrammetry and Laser Scanning Research Group. He holds BSc.(Land Surveying) degree, M.Sc (Photogrammetry) degree and a PhD (Medical Photogrammetry) degree from Universiti Teknologi Malaysia, Malaysia. His research interests lie in the areas of Photogrammetry and Laser Scanning for various applications. His current research projects are the application of photogrammetry in forensic and assets data capture using terrestrial laser scanner.

Dr. Halim Setan is a professor at the Faculty of Geoinformation Science and Engineering, Universiti Teknologi Malaysia. He holds B.Sc. (Hons.) in Surveying and Mapping Sciences from North East London Polytechnic (England), M.Sc. in Geodetic Science from Ohio State University (USA) and Ph.D from City University, London (England). His current research interests focus on precise 3D measurement, deformation monitoring, least squares estimation and 3D modeling.