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RESEARCH ARTICLE

High-accuracy Cloud Point Scanning Method based on a Dual Laser 3D Scanner for Head Profile

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Abstract The purpose of this study is to investigate the efficient method of collecting 3D cloud points of head profile Malaysian. The objective of the research is to analyse the head anthropometric data with having the accuracy of the computations in several typical settings characterized by time-consuming, resolution levels and computed cloud point file sizes with eliminating artefacts. This case study approach is a statistical analysis and comparison of existing manual anthropometric and digital landmark measurements. This research is also dedicated to determining the relative accuracy of anthropometric head profile measurement using a 3D scanner to digitally generate a cloud point 3D file. In addition, the scanned cloud point 3D file is to be measured, and the degree of closeness of the manual anthropometric method to the absolute true value can be calculated. Participants were among Universiti Teknologi Malaysia's students. They volunteered to share their head profile to collect anthropometric data. The steps of process procedures were conducted by setup a 3D handheld scanner, creating and collecting data from manual anthropometric measurement, scanning and reconstructing head profile, editing scan data and parameters, creating mesh data and transferring data to the software Geomagic, and carrying out data analysis and comparison by using Minitab. Thus, the analysis of variance and the standard deviation is conducted by using Minitab. Three sample objects were specified and analysed, their parameters in the registration process and the relative accuracy of the measurement data. As result, data comparison between the percentage errors of high detail, medium detail and low detail for each set of different fixed time runs. The high detail setting, which gives the average absolute difference, achieves the highest accuracy size (0.02mm) within the given nine-time frames. In comparison, the highest average absolute difference for low detail given 1.04mm, the second was medium detail given 0.97mm and the third was high detail given 0.93mm. Based on the overall data observation, the three sets of detail resolution settings at different fixed times contributed to the measurement with an average absolute difference between 0.02mm and 1.04mm. The accuracy of data can be optimized between the processing time and the typical settings of the resolution. The overall data measurement was analysed and the best time-consuming 3D scanning is shown in the figure, each resolution of a typical setting is between 210 seconds and 240 seconds. The purpose of carrying out this experiment is intending to reduce the scan-time consumption of 3D scanning, to minimize the variability and closer to well-perform anthropometric measurement data that has high accuracy. In conclusion, the accuracy of the 3D scan model is affected by the time processing and the typical settings of the resolution during the head contour scan. Therefore, optimum typical settings of the 3D scanner can help users minimise the impact of time-consuming and quality issues on the final 3D head profile scanning model.

Keywords: 3D scanning, Anthropometric, Data measurement, Ergonomics

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Introduction

In the field of the modern manufacturing industry, nowadays, 3D scanning is one of the advanced technologies that can bring benefits to a range of industries and end-users. Data collection from constructing a digital 3D model that is used in many industries for enhancing their design and production process. In some case studies, medical device manufacturers are preferred to use a 3D scanner to visualize their patient’s head, body, or outer organs with absolutely harmless. For instance, medical device manufacturers are provided with all useful data about the devices that have the necessary quality for fast 3D scanning, which can be finally applied and used in patients. The quality of the products or equipment that is measured and produced in the production industry plays an important role. Thus far, most manufacturers are always seeking a shorter time to collect and analyse a large amount of data with higher accuracy and repeatability. Hence, identifying important factors and proposing effective measurement methods will help manufacturers improve their competitiveness in the global market and economic value [1].

Furthermore, Malaysia's anthropometric data has become more and more important for designing ergonomic products that can meet consumer satisfaction. Because most of the final products are designed according to American or European standard sizes and designed following their anthropometric data. Currently, 3D scanning technology has appeared in a non-contact method, which digitally captures the outline of a person's head through dual laser scanning technology. Other than that, the cloud point-based anthropometric data can be used for designing consumer products that involve ergonomics factors and design guidelines. To develop a high-accuracy data system, this advanced acquisition technique can be used to collect individual anthropometric data digitally [2]. The objective of this research is to analyse the head anthropometric data with having the accuracy of the computations in several typical settings characterized by time-consuming, resolution levels and computed cloud point file sizes with eliminating artefacts likely spikes and holes occur.

In this case study and experiment, operators were using a handheld 3D scanner as the main experimental equipment. The reason for choosing the handheld 3D scanner is this device offers the advantage of obtaining 3D scanning data from an entire object needed, especially for capturing a profile from a human’s head shape. In addition, the function of a handheld 3D scanner needs to consider its resolution, accuracy of data, portability, repeated scanning process for a large number of cloud point objects, and other factors. Therefore, this research is to figure out the optimal setting performance of the handheld scanner to obtain better results in the 3D scanning process of the head profile.

The scope of the research was covered for determining overall head landmarks localization, pose variations, unconstrained environment, and variation of head profile in a different population of Malaysians.

Anthropometry Measurement

Accuracy refers to how the closeness of the analysed concentration between the result of a measurement and a true value. However, all measurements must have some concern of uncertainty that may incur from a variety of factors. The error analysis is well known as an activity of evaluating the uncertainty associated with a measurement result.

Statistical analysis of the differences between digital measurement data and artificial anthropometric measurement data by calculating the average, standard deviation, and standard error using descriptive statistics. As mentioned by Catapan *et al*. [3] these anthropometric measurements of the human head may differ for individuals, especially for size measurement of head circumference. According to studies by Kopecký *et al*. [4], anthropometric measuring tools such as the spreading calliper can be used to measure human head such as head length, head width, the width of the head and so on.

In this section, researchers figure out the relative accuracy of anthropometric head profile measurement using a 3D scanner to digitally generate a cloud point 3D file. In addition, the scanned cloud point 3D file is to be measured, and the degree of closeness of the manual anthropometric method to the absolute true value can be calculated. Anthropometric measurements of the head are having of two types:

Figure 1. Use The Spreading Caliper To Measure Head Profile While Manual Anthropometric Measurement Process [4].

a. Manual Anthropometric Measurement (Direct contact)

This is done with an anthropometric instrument, which can accurately measure the contour of a person's head. As shown in Figure 1, some basic anthropometric instruments are very commonly used, such as anthropometric callipers and soft tape. For anthropometric measurements, the size is collected by subtracting the maximum value observed when using the instrument, and it needs to be pressed hard during the measurement. Determine the size of the human head by using defined anthropometric landmarks as shown in Figure 2, especially for points with longer lengths or longer widths.

b. Landmarks Measurement (Non-contact)

This process is very much similar to manual anthropometric measurements. A method of generating cloud point types for landmark measurements using a 3D scanning system. It brings the benefits of physical contactless and non-invasive digitization of human face landmarks. The landmark high cloud points can be measured with anthropometric measurements of the Head Circumference, Head-width, and Head-length from a generated 3D facial landmark model. These landmarks are suitable for use as a point-to-point guide for major anthropometric measurements to obtain high-precision 3D cloud points of the head facial model. The aim is to fabricate a 3D soft head facial template that can be captured the accurate shape profile of the face features, and based on conducting a statistical analysis of the human head data from provenance trials.

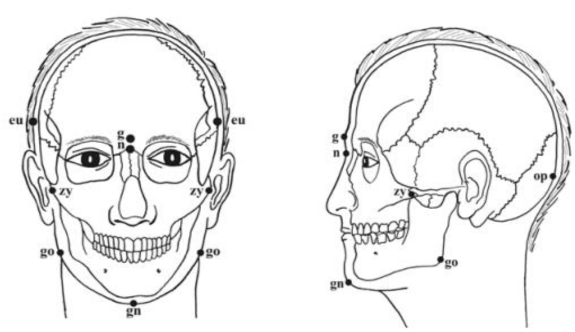


Figure 2. Anthropometric landmarks of the head [4].

Excellent performance in the use of anthropometric instruments, it has thorough knowledge and strict compliance with standardised measurement methods, prior professional training, sufficient experience and the use of established measurement procedures. Therefore, it also plays an essential role in the acquisition of objective data that were needed for the evaluation of the variability of the human body and physical condition of an individual. Anthropometric data of the following subjects were collected in this study:

i. Head Length (Point Glabella to Point Opisthokranion)
ii. Head Width ((Point Left Euryon to Point Right Euryon)

By using anthropometric tools, which may be extended callipers, sliding callipers and soft metres, it was an accurate and standardised anthropometric instrument designed to measure height, length, width and circumference to determine the size of a person's head. A good static posture can measure a person's head area more. Therefore, to study the measurement of the human head was carried out from the length (Glabella-Opisthokranion), the width (left Euryon-Right Euryon), the height of the head and the surroundings. Some sample sizes were measured to calculate the average absolute difference and percentage error.

Tools and Platforms

In this section, researchers used the spreading calliper to measure the head length and head width. When measuring the head length and head width, the tips of the spreading calliper must be pressed firmly and the dimensions were taken by subtracting the highest value observed. The action and activities differences between manual measurement and digital measurement are listed in Table 1 below:

Table 1. The details of the measurement device.

Terms / Description	Manual Measurement	Digitally Measurement
Devices	Spreading calliper (Anthropometric instrument)	Point to Point measurement in Geomagic software's features (Anthropometric landmarks)
Approach	Direct contact during the measuring process	Contactless during the measuring process
Cost	Normal	High
Training	On-duty training is needed.	Require to attend training courses.
Data Transfer	Take a set of data recorded from paper writing work to Excel lists	Scan from a physical object and saved as cloud point 3D files which are editable and compatible

For undertaking anthropometric measurements by using 3D technology in Johor, Malaysia, a target individual student aged 20 – 29 years old was part of the study proposed. To create a list of anthropometric measurements. Mankind Head of data profiles from a fast data captured and good quality of head profile digitalization. The steps of the process procedure for the 3D scanning experiment was listed below:

(a) Set up hardware and software for the 3D handheld scanner.
(b) Create and collect data from manual anthropometric measurements.
(c) Scan and reconstruct a head profile of the respirator by using a handheld scanner.
(d) Edit scan data and adjust parameters (if necessary).
(e) At the end stage of scanning, it must clean up data from scanning, create mesh data, and proceed post-processing via third-party software – Geomagic.
(f) Carry out data analysis and comparison by using the software Minitab.

Figure 3 shows the process sequence of capturing cloud points data from a human head profile. Firstly, the device of the scanner was completely set up with a connection. For scanner settings, a set of calibration and alignment was required for ensuring the high accuracy of data collection under a repeatability 3D scanning mode.

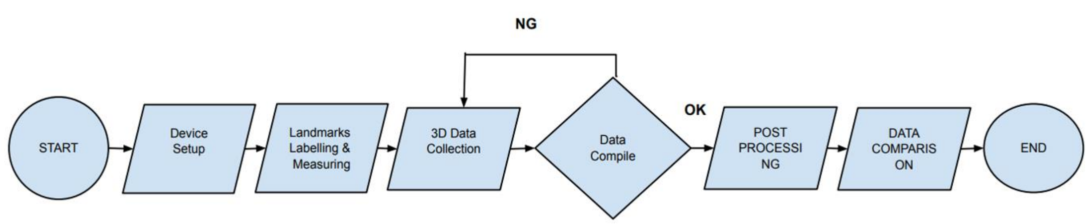


Figure 3. Flow of Process for 3D Head Profile Scanning.

Parameter Setting for Registration Process

The factors that control the 3D laser scanner are scan-time processing and resolution settings. Figure 4 shows the function of settings in capturing Model 1. Therefore, it also plays an essential role in the acquisition of objective data that were needed for the evaluation of the variability of the human body and physical condition of an individual.

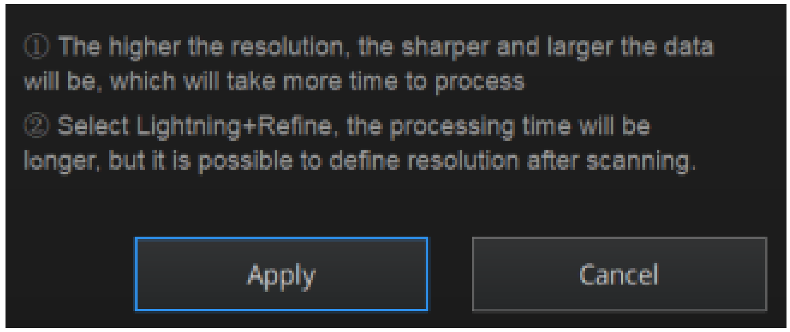


Figure 4. The Feature Settings of EINSCAN PRO.

Object preparation

After being familiar with the 3D scanner operating process, measuring standard procedure and specified allocation of head landmarks were determined. As standard procedure, each dimension was measured three times and the average of the numbers was taken from the respondent. In Figure 5, the respondent has been explained this experiment's scope and objectives before inviting him as a participant in this study of the experiment.

For archiving the human head profile's 3D scan and printing application, Geomagic Design X's mesh processing tools helped to build the 3D model through the entire scan alignment, merge and mesh optimization process. In normal practice, the process of scan data, mesh preparation, solid modelling and CAD file exporting were required during tasks of reverse engineering. Instead of 3D modelling from 2D sketch, 3D Scanner & Geomagic software was assisted to build up the object's features with the method of rapid manufacturing applied.

Data Processing Workflow

A human head profile 3D cloud points represented a rapidly extracting permits detailed facial geometries collection. It can be used for build-up as a mesh from a 3D scanner to Geomagic software by generating triangles between points, the CAD files known as OBJ or STL files. Those files can generate the visualization of a human head profile in reverse engineering to make a CAD model application. Data Importing, Mesh Buildup Wizard Application, Level of Optimization, Final CAD Model, CAD Files Converting, Performance Measurement in Geomagic.

Therefore, the scanning of the mankind head profile was done by using an EinScan Handheld 3D scanner. In general, the 3D model of the head profile has been worked seamlessly in a 3D metrology software which is Geomagic Design and it is imported into CAD software for developing a sample mock-up for the prototype model.

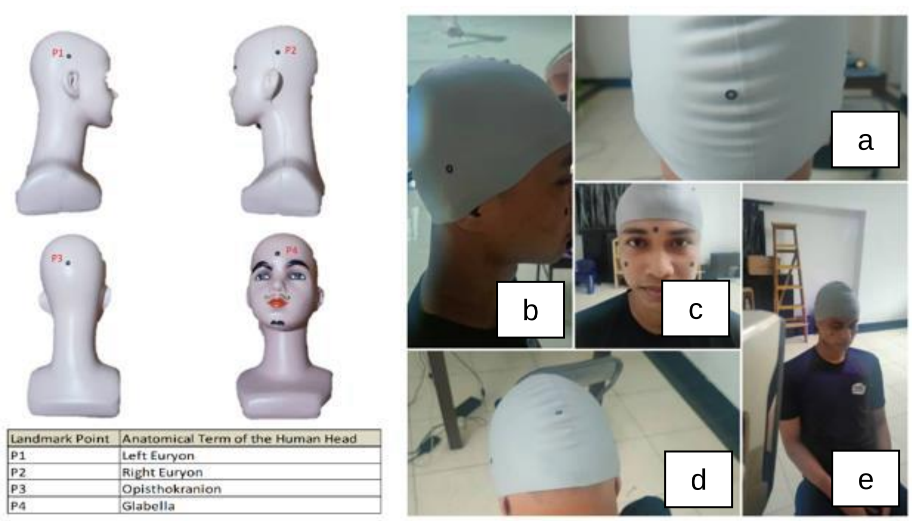


Figure 5. The setup labelling of landmarks for participant. (a) Glabella-P4, (b) Left Euryon-P1, (c) Opisthokranion-P3, (d) Right Euryon-P2, (e) EINSCAN PRO-3D Scanner.

Performance Measurement in Geomagic

Before CAD model importing, the accuracy model of head profile scanned 3D data is quite important to apply tools for measurement. To ensure the mankind head profile was successfully scanned and captured most of the features from the original object. As shown in Figure 6 below, the mankind head profile scanned model had digital measurement and was compared to the anthropometric head profile measurement.

Excellent performance in the use of anthropometric instruments, thorough knowledge and strict compliance with standardized measurement procedures, requires well-trained skills and experienced operators in the process of anthropometric data collection. And then, a comparison between manual anthropometric measurement and digital anthropometrics was proceeded to figure out the statistical analysis results as proof of differential needed.

Figure 6. The comparison between the physical head & 3D model head profile.

Results and Discussion

An experiment of running model 1 with different parameter settings was conducted for the human head profile 3D scanning. Since similar pattern diagrams are displayed in all settings, the analysis is explained in detail using the different parameter settings of the 3D scanner. Each detail has proceeded with a set of fixed times which are 30 seconds, 60 seconds, 90 seconds, 120 seconds, 150 seconds, 180 seconds, 210 seconds, 240 seconds, and 300 seconds respectively. Table 2 below shows the data collection of model 1, which was run 27 times in a total of running numbers. The factors that control the 3D laser scanner are scan-time processing and resolution settings. In addition, the 30 seconds scan data was ignored because the object does not completely scan in the complete head shape outline and the landmark coordinates cannot be obtained.

It can be seen from the experimental results obtained by the datasheet that the average difference of some measured values is larger or smaller. The analysis of all combinations of anthropometric indicators with different parameter settings, and researchers introduced the possibility and reason for this error during the experiment. For instance, some landmarks are also difficult to repair because there is some fat accumulation under the skin surface or too short time of scanning duration has been produced.

Optimum Typical Settings & Data Table Analysis

In 3D scanning, the optimization of the accuracy data for human body measurement includes consideration of time processing and resolution settings. An efficient processing method minimizes the unconstrained environments and unconstrained poses of objects [5]. The accuracy of data can be optimized between the processing time and the typical settings of the resolution. The data were collected and shown in Table 2. Therefore, the accuracy of data measurement was analysed, and the best time processing and resolution of typical settings were analysed. During 3D scanning data collection, the scanning speed affected the accuracy of the data measurement and it is shown from the result estimation of ANOVA analysis for model 1.

$$H0: t1 = t2 = t3 = t4 = t5 = t6 = t7 = t8 = 0$$

H1: ti ≠ 0 for at least one i

F-Test Two-Sample for Variances (Glabella - Opisthokranion)		
	P1 - P2 (Glabella - Opisthokranion)	*L1 - L2 (Glabella - Opisthokranion)*
Mean	190.825	190.6475
Variance	0.283695652	0.770836957
Observations	24	24
df	23	23
F	0.368035873	
P(F<=f) one-tail	0.010042674	
F Critical one-tail	0.496419613	

F-Test Two-Sample for Variances (Left Euryon – Right Euryon)		
	P3 - P4 (Left Euryon – Right Euryon)	*L3 - L4 (Left Euryon – Right Euryon)*
Mean	164.4375	163.8720833
Variance	0.158967391	0.437547645
Observations	24	24
df	23	23
F	0.363314471	
P(F<=f) one-tail	0.009295661	
F Critical one-tail	0.496419613	

Figure 7. The Hypothesis test by using Microsoft Excel.

Initially, researchers also used Microsoft Excel's Data Analysis tools to test the hypothesis that different time-consuming 3D scans did not affect the anthropometric accuracy data. Since the significant level = 0.05, the researcher rejects H0 and summarizes that time consumption of 3D scans in the anthropometric measurement significantly affects the anthropometric accuracy data. As shown in Figure 7, the computer excels output reports a series of P-values for the test statistic that is smaller than 0.05. Since the P-value is considerably smaller than the significant level = 0.05, researchers have strong evidence to summarize that H0 is not true.

Table 2. The setting for Model 1.

Run	Fixed Time Consuming (A)	Resolution (B)	Calipers Value (Glabella - Opisthokranion) in mm, P3-P4	Calipers Value (Left Euryon – Right Euryon) in mm, P1-P2	Measurement Result (Glabella - Opisthokranion) in mm, L3-L4	Measurement Result (Left Euryon – Right Euryon) in mm, L1-L2	Average Absolute Difference in mm	Percentage Error, %	Clsoud Point File Size Megabytes (MB)
1	30 seconds	High Detail	191.5	165	NG	NG	N/A	N/A	26.6
2	30 seconds	Medium Detail	191.5	165	NG	NG	N/A	N/A	27.1
3	30 seconds	Low Detail	191.5	165	NG	NG	N/A	N/A	22
4	60 seconds	High Detail	191.5	165	191	163.89	0.81	16%	39.4
5	60 seconds	Medium Detail	191.5	165	191.18	163.38	0.97	17%	38.9
6	60 seconds	Low Detail	191.5	165	191.6	163.77	0.56	17%	38.8
7	90 seconds	High Detail	191.5	165	191.14	163.5	0.93	16%	44.9
8	90 seconds	Medium Detail	191.5	165	191.24	163.39	0.94	17%	32.8
9	90 seconds	Low Detail	191.5	165	191.22	163.2	1.04	17%	31.2
10	120 seconds	High Detail	191	164	190.26	163.37	0.69	16%	43.3
11	120 seconds	Medium Detail	191	164	190.71	163.43	0.43	17%	43.3
12	120 seconds	Low Detail	191	164	191.12	163.43	0.22	17%	42.2
13	150 seconds	High Detail	191	164	191.88	164.11	0.5	17%	76.3

Run	Fixed Time Consuming (A)	Resolution (B)	Calipers Value (Glabella - Opisthokranion) in mm, P3-P4	Calipers Value (Left Euryon – Right Euryon) in mm, P1-P2	Measurement Result (Glabella - Opisthokranion) in mm, L3-L4	Measurement Result (Left Euryon – Right Euryon) in mm, L1-L2	Average Absolute Difference in mm	Percentage Error, %	Clsoud Point File Size Megabytes (MB)
14	150 seconds	Medium Detail	191	164	191.11	164.12	0.12	16%	55.1
15	150 seconds	Low Detail	191	164	191.2	164.04	0.12	17%	34.8
16	180 seconds	High Detail	191	164	191.17	164.42	0.29	16%	46.2
17	180 seconds	Medium Detail	191	164	190.64	162.6	0.88	17%	46.1
18	180 seconds	Low Detail	191	164	190.78	162.2	1.01	17%	46.1
19	210 seconds	High Details	190.2	164.5	190.46	164.27	0.02	16%	98.1
20	210 seconds	Medium Detail	190.2	164.5	190.58	164.72	0.3	16%	75.9
21	210 seconds	Low Detail	190.2	164.5	190.68	164.36	0.17	16%	38.1
22	240 seconds	High Detail	190.2	164.5	190.57	164.79	0.33	16%	40
23	240 seconds	Medium Detail	190.2	164.5	190.66	164.72	0.34	16%	40
24	240 seconds	Low Detail	190.2	164.5	190.57	164.2	0.03	16%	36.5
25	300 seconds	High Detail	190.2	164.5	188.66	164.42	0.81	15%	86.8
26	300 seconds	Medium Detail	190.2	164.5	188.67	164.17	0.93	15%	84.5
27	300 seconds	Low Detail	190.2	164.5	188.44	164.43	0.91	15%	22

Remarks:
[1] "P" stand for Point-to-Point manual anthropometric measurement.
[2] "L" stand for Point-to-Point digital anthropometric measurement.

Landmark Point	Landmark Point	Anatomical Term of the Human Head
P1	L1	Left Euryon
P2	L2	Right Euryon
P3	L3	Opisthokranion
P4	L4	Glabella

In Figure 8, the accuracy of data measurement is analysed. About the recommended time processing and resolution of typical settings are analysed. In the process of 3D scanning data acquisition, the scanning speed affects the accuracy of data measurement, which can be seen from the two-way mixed ANOVA analysis of model 1. In the table platform of MINITAB, the first column (C1-T) was set as the running numbers, which fixed settings of time-consuming and is known as a within-subjects factor. The column of C2-T was set as the time-consuming 3D scanning. This set of fixed times was run with 60 seconds, 120 seconds, 150 seconds, 180 seconds, 210 seconds, 240 seconds, and 300 seconds respectively and they were set from No. 4 to No. 27. The reason for ignorance for data information of No. 1, 2, and 3 were caused the 30 seconds scanning time does not enough time to scan to generate the full 3D model cloud point of the head profile during the 3D scanning process. The third column (C3-T) of the table was set for a group of between-subjects factors which have independent settings of the 3D scanner. These group factors are High Resolution, Medium Resolution and Low Resolution, this is the features of the EinScan 3D scanner and its classic options in Scan mode from the device settings. The selection of scan mode is affected the 3D scanned data effectiveness, size object and scan range consideration.

For the table column of C4 and C5 represented the number of distance landmark point-to-point of Glabella – Opisthokranion (P3-P4) and Left Euryon – Right Euryon (P1-P2) were measured respectively. All of them were measured by using a manual anthropometric instrument and their unit of measurement is in millimetres (mm). Next, the values of the column of C6 and C7 were measured from the Geomagic Software platform and its scanned head profile generated 3D models. For digital anthropometric results, researchers can obtain data from scanned head profile objects through point-to-point performance measurements in Geomagic, as shown in Figure 6. The keywords of "L3-L4" stand for the digitally anthropometric measurement between Glabella and Opisthokranion and the keywords of "L1-L2" stand for the digital anthropometric measurement between Left Euryon and Right Euryon. And, the unit of digital measurement is also in millimetres (mm).

Based on the parameters given above, researchers started to calculate the result values of the mean absolute difference (C8) and percentage error (C9). The last column C10 was given to them to select the lighter file size of the cloud point 3D model once researchers had the optimization data results between scan-time consuming and resolution settings of the 3D scanner itself. And then, researchers start to compile all data parameters by using the advanced statistical calculator from the MINITAB software, such as Two-way ANOVA, Main Effects Plot, Interactions Plot, Analyze Factorial Design and so on.

MINITAB - MINITAB001-AADVSRE.MPJ - [Worksheet 1 ***]

File Edit Data Calc Stat Graph Editor Tools Window Help

↓	C1-T	C2-T	C3-T	C4	C5	C6	C7	C8	C9	C10
	Run	Time Consuming	Resolution	P3-P4 in mm	P1-P2 in mm	L3-L4 in mm	L1-L2 in mm	Avg Absolute Difference in mm	Percentage Error, %	Megabytes (MB)
1	4	60 seconds	High Details	191.5	165.0	191.0	163.9	0.8	16	39.4
2	5	60 seconds	Medium Details	191.5	165.0	191.2	163.4	1.0	17	38.9
3	6	60 seconds	Low Details	191.5	165.0	191.6	163.8	0.6	17	38.8
4	7	90 seconds	High Details	191.5	165.0	191.1	163.5	0.9	16	44.9
5	8	90 seconds	Medium Details	191.5	165.0	191.2	163.4	0.9	17	32.8
6	9	90 seconds	Low Details	191.5	165.0	191.2	163.2	1.0	17	31.2
7	10	120 seconds	High Details	191.0	164.0	190.3	163.4	0.7	16	43.3
8	11	120 seconds	Medium Details	191.0	164.0	190.7	163.4	0.4	17	43.3
9	12	120 seconds	Low Details	191.0	164.0	191.1	163.4	0.2	17	42.2
10	13	150 seconds	High Details	191.0	164.0	191.9	164.1	0.5	17	76.3
11	14	150 seconds	Medium Details	191.0	164.0	191.1	164.1	0.1	16	55.1
12	15	150 seconds	Low Details	191.0	164.0	191.2	164.0	0.1	17	34.8
13	16	180 seconds	High Details	191.0	164.0	191.2	164.4	0.3	16	46.2
14	17	180 seconds	Medium Details	191.0	164.0	190.6	162.6	0.9	17	46.1
15	18	180 seconds	Low Details	191.0	164.0	190.8	162.2	1.0	17	46.1
16	19	210 seconds	High Details	190.2	164.5	190.5	164.3	0.0	16	98.1
17	20	210 seconds	Medium Details	190.2	164.5	190.6	164.7	0.3	16	75.9
18	21	210 seconds	Low Details	190.2	164.5	190.7	164.4	0.2	16	38.1
19	22	240 seconds	High Details	190.2	164.5	190.6	164.8	0.3	16	40.0
20	23	240 seconds	Medium Details	190.2	164.5	190.7	164.7	0.3	16	40.0
21	24	240 seconds	Low Details	190.2	164.5	190.6	164.2	0.0	16	36.5
22	25	300 seconds	High Details	190.2	164.5	188.7	164.4	0.8	15	86.8
23	26	300 seconds	Medium Details	190.2	164.5	188.7	164.2	0.9	15	84.5
24	27	300 seconds	Low Details	190.2	164.5	188.4	164.4	0.9	15	22.0

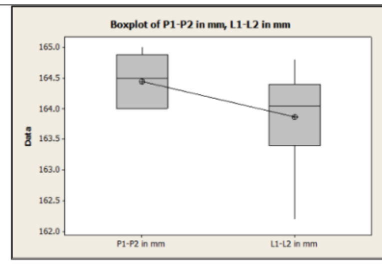
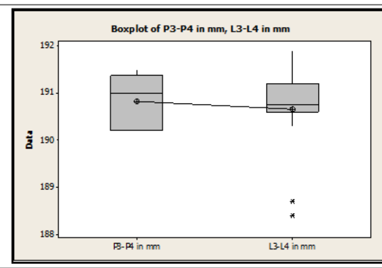
Figure 8. Table MINITAB of Model 1.

Comparison Between Cloud-based Method & Caliper-based Method

Run model 1 with different parameter settings. Since similar pattern graphs were displayed in all settings, the analysis was explained in detail using the different parameter settings of the 3D scanner. Three detail resolution settings have been made. The settings were High Detail, Medium Detail and Low Detail of the 3D scanner's settings were carried out during the cloud point data collection. Each detail has proceeded with a set of fixed times 60 seconds, 90 seconds, 120 seconds, 150 seconds, 180 seconds, 210 seconds, 240 seconds, and 300 seconds respectively.

It can be seen from the experimental results obtained by the T-test that the average difference of some measured values was small or large. Table 3 shows the analysis of all combinations of anthropometric indicators with different parameter settings, and researchers introduced the possibility and reason for this error during the experiment. Because 30 seconds scan-time consuming was too short to capture and reconstruct a whole profile of the head.

Table 3. Two-Sample T-Test from Means and Standard Deviations

No.	Results	Diagram
1.	**Two-Sample T-Test and CI: P1-P2 in mm, L1-L2 in mm** Two-sample T for P1-P2 in mm vs L1-L2 in mm N Mean StDev SE Mean P1-P2 in mm 24 164.437 0.399 0.081 L1-L2 in mm 24 163.871 0.659 0.13 Difference = mu (P1-P2 in mm) - mu (L1-L2 in mm) Estimate for difference: 0.566667 95% CI for difference: (0.248092, 0.885241) T-Test of difference = 0 (vs not =): T-Value = 3.60 P-Value = 0.001 DF = 37	
2.	**Two-Sample T-Test and CI: P3-P4 in mm, L3-L4 in mm** Two-sample T for P3-P4 in mm vs L3-L4 in mm N Mean StDev SE Mean P3-P4 in mm 24 190.825 0.533 0.11 L3-L4 in mm 24 190.654 0.874 0.18 Difference = mu (P3-P4 in mm) - mu (L3-L4 in mm) Estimate for difference: 0.170833 95% CI for difference: (-0.252025, 0.593692) T-Test of difference = 0 (vs not =): T-Value = 0.82 P-Value = 0.419 DF = 38	

In Figure 9, the High Detail had the greatest file size of cloud point data in IGES format. There is a similar comparison of data results between the percentage errors of high detail, medium detail and low detail for each set of different fixed-time runs. The high detail setting, which gives the average absolute difference, achieves the highest accuracy size (0.02mm) within the given nine-time frames. In comparison, the highest average absolute difference for Low detail given 1.04mm, the second was Medium Details given 0.97mm and the third was High details given 0.93mm. Based on the overall data observation, the three sets of detail resolution settings at different fixed times contributed to the measurement with an average absolute difference between 0.02mm and 1.04mm.

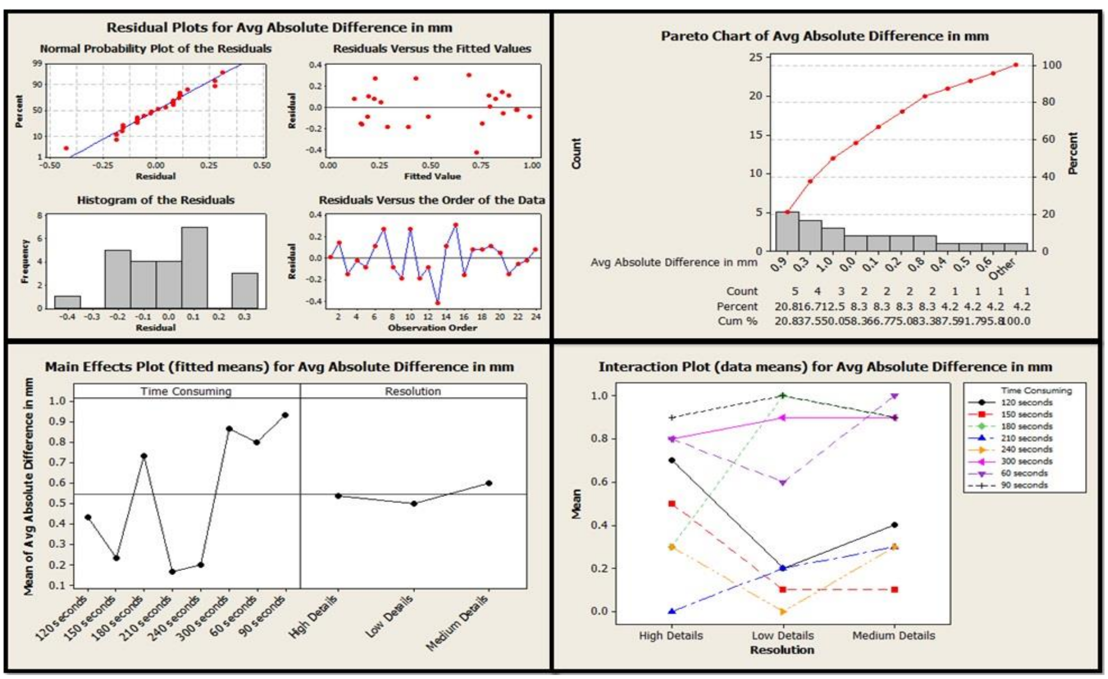


Figure 9. The Analysis of Variance for Model 1.

Run model 1 with different parameter settings. Since similar pattern diagrams were displayed in all settings, the analysis is explained in detail using the different parameter settings of the 3D scanner. In addition, this experiment adopts the interaction method of factorial design, with 120 seconds, 150 seconds, 210 seconds, 240 seconds, and high details in time, and runs the parameters at the resolution of medium and low details respectively.

During 3D scanning data collection, the scanning speed had been affected the accuracy of the data measurement. Figure 5 shows the estimation of ANOVA analysis for model 1. These figures show that as data collection takes time, the observed variance with high-precision dimensions tends to increase. The accuracy of data can be optimized between the processing time and the typical settings of the resolution. The overall data measurement was analysed. According to the best time-consuming 3D scanning shown in the figure, each resolution of a typical setting is between 210 seconds and 240 seconds.

In general, the best parameters in the 3D scanning process can be used to control errors in the final 3D model. An excellent 3D scanner with the best features to scan the most complex human head contours into a 3D model application. This research application of 3D scanners can provide the advantages of relatively efficient time-consuming processes and high-precision anthropometric data of 3D human head profiles. The most effective method to improve and optimize the process required to study its process control and experiment design of 3D scanning on an object of head profile. The purpose of carrying out this experiment is to reduce the scan time consumption of 3D scanning, to minimize the variability and closer to the well-perform anthropometric measurement data that has high accuracy.

Conclusions

In conclusion, the accuracy of the 3D scan model is affected by the time processing and the typical settings of the resolution during the head contour scan. Although the outline of a human head is one of the most complex objects in a 3D model, it has complex functions, non-rigidity, and the time required to perform body measurements. By using 3D laser technology and scanners, it can help users capture external measurements of complex head profiles.

Meanwhile, an optimum typical setting of the 3D scanner can help users minimise the impact of time-consuming and quality issues on the final 3D head profile scanning model. This research proposes a function that can generate meshes and surfaces by using Geomagic Studio software to generate a cloud-based 3D model of a head profile. Therefore, the output can be exported in a compatible CAD format and can be read by other commercial reverse engineering applications.

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