QUANTIFICATION OF FACIAL MORPHOLOGY USING 3D LASER SCANNING METHOD: PRELIMINARY RESULTS

Zie Zie Azeanty Tahir, Halim Setan and Deni Suwardhi

Medical Imaging Research Group, Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia
Tel: +607-5530380
E-Mail: azeanty@fksg.utm.my

Abstract

The purpose of this study is to introduce 3-D laser scanning as a three-dimensional registration method for quantifying facial morphology and detecting changes in facial morphology during growth and development. By using 3D laser scanning method, three-dimensional co-ordinates for the bilateral landmarks Exocanthion and Cheilion and the midsagittal landmark Pronasale were determined in 20 subjects to ascertain the reproducibility of the method, and in 30 patients to detect changes in facial morphology due to growth and development. Linear and angular measurements were calculated by means of the 3-D co-ordinates in order to quantify facial morphology. During the observation period, significant changes in facial morphology were determined for the linear measurements. Advantages and disadvantages of current registration methods are discussed. It is concluded that 3-D laser scanning is suitable for 3-D registration method for quantifying and detecting development changes in facial morphology.

Key Words: *Facial morphology, 3D Laser scanning, Quantification*

1.0 INTRODUCTION

Registration methods for facial dimensions are great importance in disciplines such as orthodontics and craniofacial surgery. These methods are used to detect aberrations in morphology, to develop treatment plans and to evaluate treatment results. Furthermore, registration methods make it possible to study normal and abnormal growth and development of the face.

With anthropometrical methods, it is possible to quantify facial morphology by means of direct measurements, resulting in distances between landmarks and head circumferences. Another method is to produce plaster models, by making impressions of the object, on which measurements can be made. Fewer co-operations of subjects are needed for taking photographs. Photographic methods with which it is possible to investigate facial morphology in three dimensions are for example contour photography, stereophotography and Moire topography. In this research, another method is use such as laser scanning. Laser scanning makes use of a pair of laser beam taken with different angle. With these two laser images, it is possible to reconstruct and gives three-dimensional images of the surface of objects.

The purpose of this study is to introduce laser scanning as a three-dimensional registration method for quantifying facial morphology and detecting changes in facial morphology during growth and development.

2.0 MATERIAL AND METHODS

2.1 Sample

Close range measurement method is used for data capture, i.e. laser scanning. 3D Laser Scanning is a laser range scanning devices based on light interferometry that provides a much more automatic tool for obtaining a digital model of an existing 3D object (Alvin et al, 2002). The scanner is also useful for capturing the 3D shape of physical objects, especially those with complex geometries and free-form surfaces. The sample consisted of 78 individuals (33 females and 45 males) aged 13 to 55 years were captured using 3-D laser scanning method. The subjects were healthy and normal patients. Subjects with previous history of craniofacial trauma or congenital anomalies were not included in the sample. Subjects were informed about all procedures and gave their consent to the investigation.

2.2 Method

There are 4 steps for creating three-dimensional computer images of facial landmarks:

1) Scan the image of patient using laser scanner (Vivid 910)
2) Process the scan data using RapidForm software.
3) Identify the landmark of the face using RapidForm software.
4) Do the measurement of the landmarks taken.

In this study, the patients sit on a chair with facial muscles relaxed whereas eyes opened and lips closed for 10 second during the scanning. Two laser scanners (Figure 1) are used to capture scanned data using Polygon Editing Tools (PET) software. The scanning was performed using VIVID 910 (3D scanner operating on laser-light stripe triangulation range finder principle) and the distance of patient from the laser scanner was about 0.7 meter.

Figure 1: VIVID 910 (Laser Scanner)

The scanned data was imported to RapidForm (a professional 3D reverse engineering) software for data processing. The steps to process the scanned data are registering, merging, fill holes and smoothing (Figure 2). Registration allows you to register multiple point clouds or polygonal shells using overlapping regions. Secondly, the shells that have been aligned by registration process are merged into one united shell. During the merging process, overlapped regions between shells are removed and neighboring boundaries are stitched together with newly added polygons. The results and accuracy of shells are still maintained after merging. The fill holes operation fills holes in a model that may have been introduced during the scanning process. The operation constructs a polygonal structure to fill the hole, and both the hole and the surrounding region are remeshed so the polygonal layout is organized and continuous. Sometimes scanned data may have too much bump and detail of surface roughness in the scanning process. By smoothing the polygon model, it can reduce this roughness.

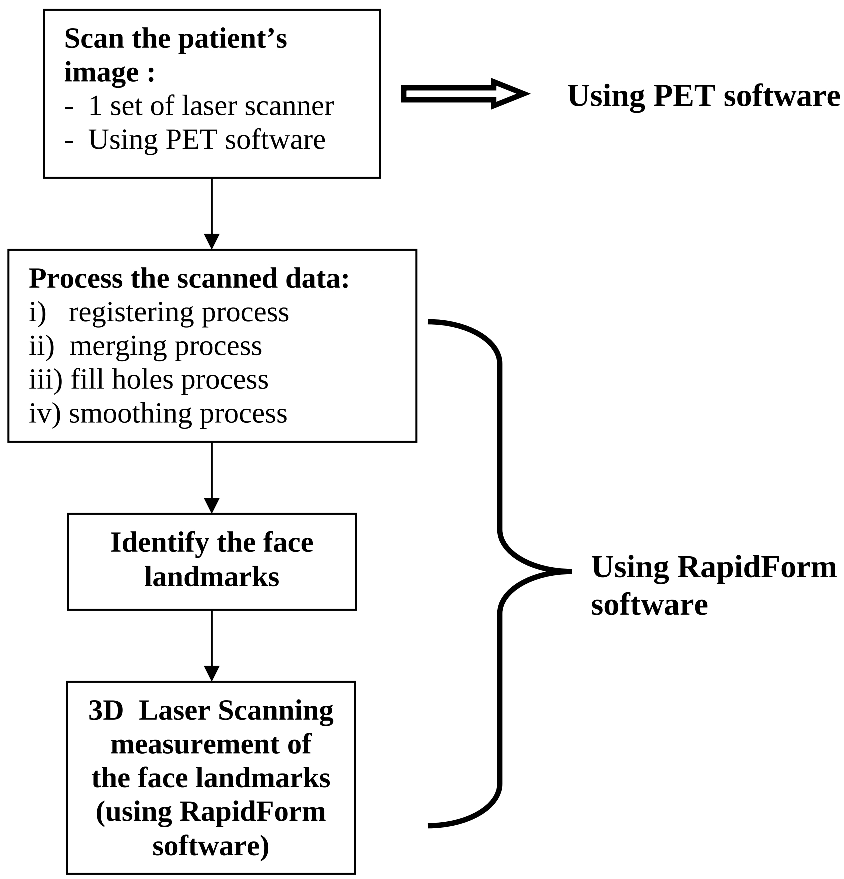

Figure 2: The flowchart to get the measurements

2.3 Collection of Three-Dimensional Facial Landmarks

There were five landmarks that were used in this study. The landmarks were selected because they are clearly recognizable and described by other authors. However, depending on the objectives of the examination, other landmarks can be included. These six sets of 3-D co-ordinates were used to calculate the distances between Exocanthion and Cheilion (P), Cheilion and Pronasale (Q), and Exocanthion and Pronasale (R) for both side of the face. Furthermore, the angles Exocanthion-Cheilion – Pronasale (A), Cheilion - Pronasale – Exocanthion (B), Pronasale – Exochantion – Cheilion (C), and between the two planes formed by Exocanthion, Cheilion and Pronasale of both sides (D) were calculated (Figure 3). All the 3-D landmarks were identifying using RapidForm software manually onto the face of the subjects. Landmarks positions were defined according to Farkas (1994a) (Table 1).

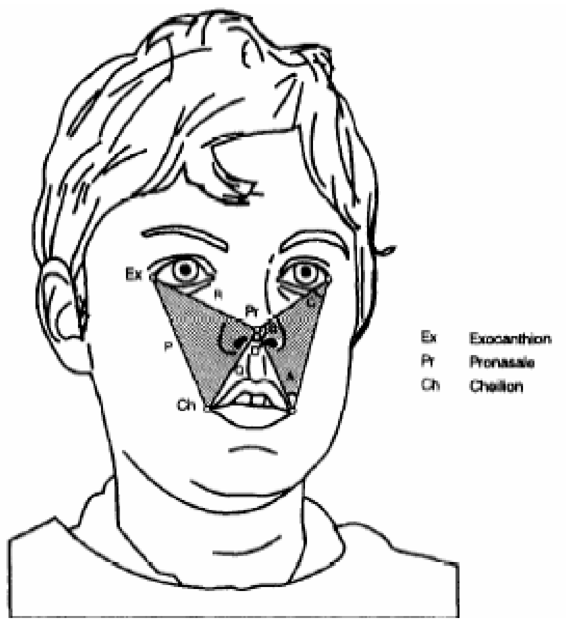

Figure 3: Schema picture including the landmarks, the distances between Exocanthion and Cheilion (P), Cheilion and Pronasale (Q), and Exocanthion and Pronasale (R). The angles Exochantion – Cheilion – Pronasale (A), Cheilion – Pronasale – Exocanthion (B), Pronasale – Exocanthion – Cheilion (C) and the angle between the two planes (D).

Figure 4: The laser scan data including the 3-D points landmarks in RapidForm software

Table 1: Summary of Landmarks definition On Craniofacial Surface

Landmark name	Initial	Description
Exocanthion	Ex	The outer corner of the eye fissure where the eyelids meet
Cheilion	ch	Orolabial The outer corner of the mouth where the outer edges of the upper and lower vermilions meet
Pronasale	prn	The most protruded point of the nasal tip

2.4 Data Analysis

To ascertain differences in facial morphology due to growth and development, 3-D coordinates landmarks mentioned above were determined in 64 normal patients with laser scanning method and the landmarks were identify manually onto the face of 3-D scanned data. The two sets of 3-D coordinates (both sides of the face) were used to calculate the distances P, Q and R, and the angles A, B, C and D. All measurements were performed in 3-D space, i.e., the position of the points relative to all 3 planes (frontal, lateral, and horizontal) was considered at the same time (no projection).

The data sets of the measurement for all distances and angles were analyzed with the aid of the analysis of variance (ANOVA) sub program of the SPSS® package. The distances P,Q, and R, and the angles A,B, and C for both sides, and D were entered as dependent variables.

Changes in facial morphology due to growth and development were analyzed with an analysis of variance (ANOVA, SPSS®) with the distances P, Q, and R, and the angles A, B, and C of both sides on age as dependents, sex as between-subject factor.

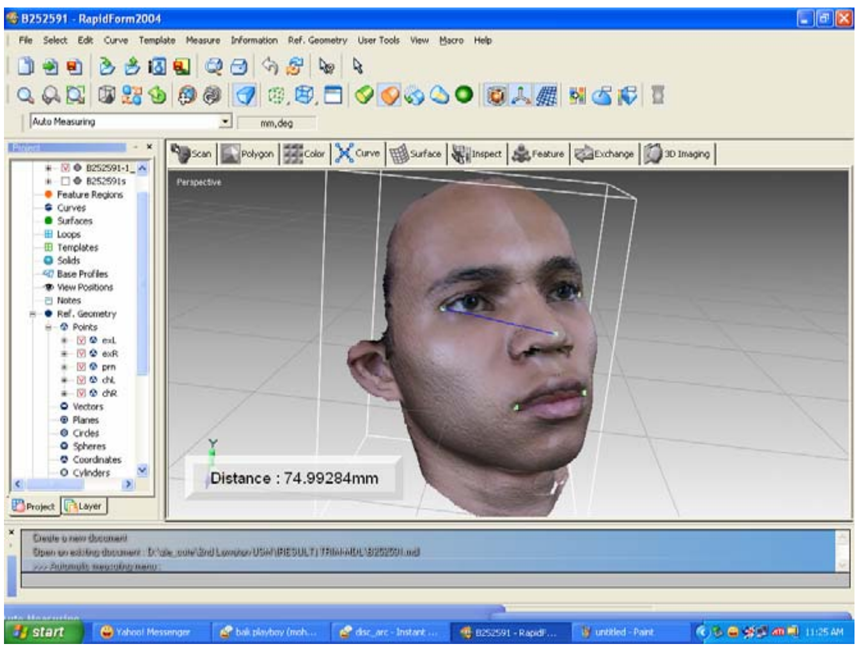

Figure 5: The distance measurement between Exocanthion and Pronasale (R) in Rapidform software

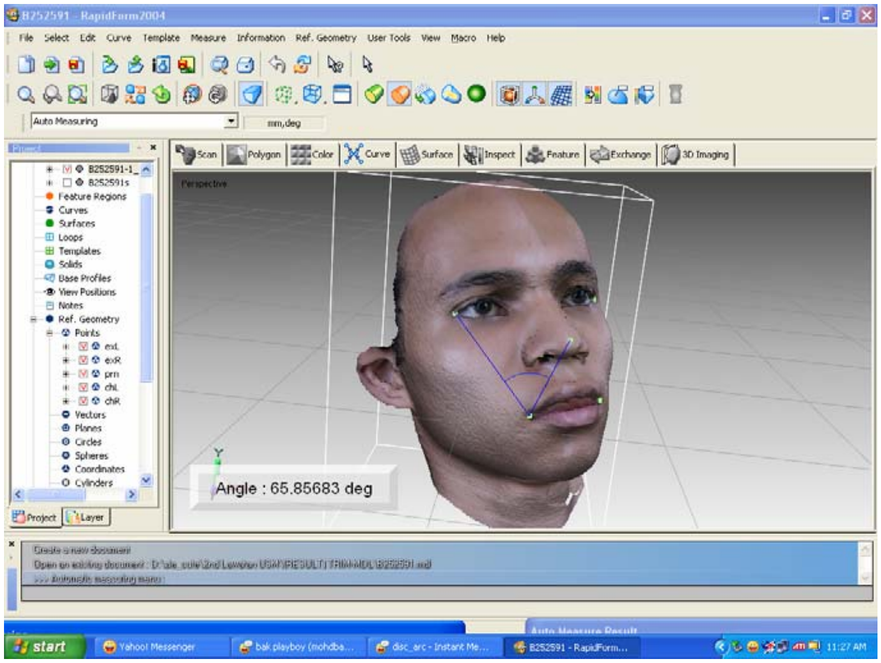

Figure 6: The angle measurement between Exocanthion – Cheilion - Pronasale (A) in Rapidform software

3.0 RESULTS

Table 2 reports mean values and standard deviations of 3-D distances and angles for different ages. The interaction effect between measurements was significant. The greatest difference is demonstrated by distance R between age 36-50 and 21-35, and by angle C between age 36-50 and above 50. The values of these differences are 5.068 mm, and 2.2162°, respectively. Figure 7 shows the distances measurement between ages while Figure 8 shows the angles measurements between ages. The measurements data taken shows that all distances and angle were increased significantly between age <14 until age 36-50, and decreased when age >50.

Table 3 reports mean values of 3-D distances and angles for male and female in ages. All distances were significantly larger in men than women. From that table, the greatest difference are between age 15-20 followed by the age 21-35.

Table 2: Mean values and standard deviation of measurements between ages

Measurement	<14		15-20		21-35		36-50		50>	
	N=20		N=26		N=19		N=6		N=7	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
R	65.4104	4.3881	66.8706	5.0582	67.1508	3.0797	72.2188	2.9663	65.3224	3.4456
P	71.9437	3.8322	73.4057	3.9043	72.8102	4.1252	79.0362	2.3902	74.4720	4.9786
Q	48.2314	4.1594	50.7368	2.9643	50.2688	3.5731	55.5137	3.6930	54.1647	9.0434
R2	64.9580	3.6584	66.4550	4.3019	66.0828	3.0876	70.2187	2.6843	65.8803	1.9528
P2	71.2961	3.6877	73.6055	4.6024	73.9552	4.6582	78.4992	2.7800	78.6676	7.2218
Q2	48.0577	4.1189	50.0119	3.2757	49.4402	4.4001	53.8273	3.4205	53.2701	6.1409
C	40.6610	2.6792	42.0298	2.2928	41.8142	3.0099	42.7897	3.3510	45.0059	8.6926
A	62.2143	3.5142	61.9892	4.1640	62.9245	2.6160	61.9855	2.3964	57.5729	3.2665
B	77.1200	4.6035	75.9810	4.4156	75.2614	4.7793	75.2132	3.0187	77.4214	11.1649
C2	40.9016	3.1059	41.4328	2.5607	40.7870	3.0305	41.9192	2.4461	41.9997	7.5719
A2	62.2973	3.0190	62.3553	5.0534	60.9697	3.0957	61.9755	5.1160	55.1874	5.7737
B2	76.8013	4.6692	76.2015	4.9434	78.2432	4.5482	76.1053	6.5860	82.8129	12.8290
D	56.5507	3.6892	58.2108	4.6066	56.9784	3.5558	55.5792	3.7287	58.2389	7.4363

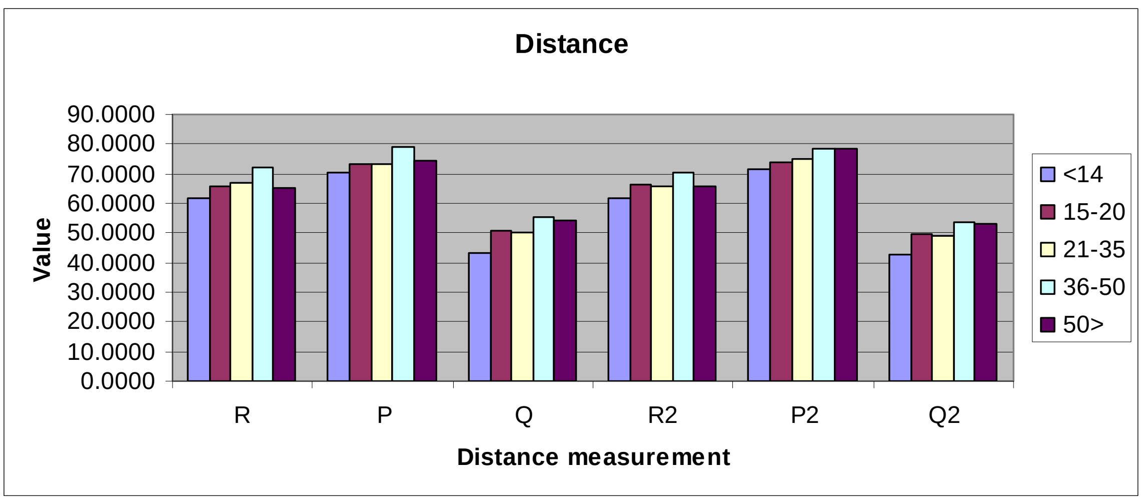

Figure 7: The distances of the measurements between ages

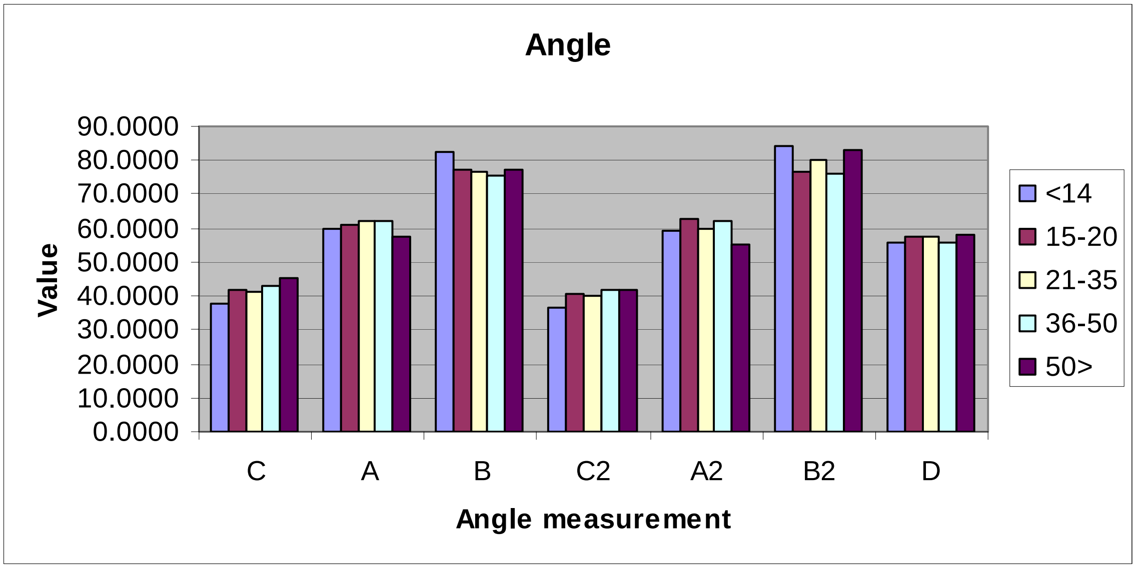

Figure 7: The angles of the measurements between ages

Table 3: The distances and angles of measurements for males and females between ages

Measurement	<14		15-20		21-35		36-50		50>	
	N=20		N=26		N=19		N=6		N=7	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
R	60.1060	63.1585	68.0236	62.5337	68.8938	65.8931	72.2188		66.4087	58.8050
P	70.4250	70.4760	73.7909	72.6070	75.7468	72.2805	79.0362		75.4333	68.7040
Q	43.4860	43.5500	51.0731	49.4702	50.6460	49.8888	55.5137		54.7850	50.4430
R2	61.0795	62.3765	68.0041	63.8250	67.6048	64.8509	70.2187		66.2268	63.8010
P2	71.8735	70.8450	73.8796	74.1617	76.8278	73.9241	78.4992		79.1173	75.9690
Q2	42.6125	42.8100	49.8417	48.9485	48.7078	49.6285	53.8273		53.8170	49.9890
C	37.8530	37.4440	42.0109	42.0007	40.5310	41.9730	42.7897		44.8743	45.7950
A	58.1885	61.9135	62.9030	58.0302	62.2225	62.0286	61.9855		57.7205	56.6870
B	83.9590	80.6425	75.0861	79.9692	77.2468	75.9985	75.2132		77.4053	77.5180
C2	36.1865	36.7820	40.8961	40.6253	38.6598	41.1764	41.9192		42.2070	40.7560
A2	57.9875	60.7430	63.1700	61.6050	60.3083	59.5503	61.9755		54.9802	56.4310
B2	85.8260	82.4750	75.9341	77.7248	81.0318	79.2733	76.1053		82.8130	82.8120
D	55.6320	55.3870	59.1369	56.9605	58.0845	57.3711	55.5792		58.3588	57.5190

4.0 DISCUSSION

The 3-Dimensional system applied in the present study uses landmark representation of the soft tissue facial surface. 3-Dimensional landmark data can be used both in conventional metric approach (angles, distances, and ratio similar to conventional cephalometric) and with other morphometric techniques. An important feature of the present imaging system is its independence from head posture (Ferrario et al, 1999).

Laser scanning is registration method to help in identifying landmark in measurement process. In principle, every object can be measured by this method. However, limitations lie in the definition of the structure to be measured. The present study demonstrated the possibilities to quantify facial morphology 3-dimensional using laser scanning method.

The result show a significant change in facial morphology due to growth and development. All linear and angular measurement had increased significantly between the ages. Age influenced the results significantly. Besides, a highly significant sexual dimorphism was found in all linear and surface measurements with male values consistently larger than female values.

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