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Research On the Standard Operation Procedure of Mobile 3D Scanner

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Abstract

Background: For the past few years, 3D facial imaging technology has been widely used as preoperative evaluation and surgery design for plastic and cosmetic surgery. Compare to the stationary scanner, handheld scanner is more portable and mobile, which leads to a higher demand for the operator manipulation. The aim of this study is to search and improve the standardized procedure of handheld 3D scanner, in order to collect preferable data and improve treatment accuracy.

Methods: Artec Eva 3D scanner was used to scan the subject head-face area. By altering the distance and angle between the scanner and subject, changing the scanner movement patterns and tracks, and modifying the light and background, multiple images were collected and analysed. By comparing the differences between generated images and the amount of software errors, the best operation procedure for mobile 3D scanner was concluded.

Results: With adequate light, the optimal distance between scanner and subject (working distance) was 80cm, and the scanner was 5cm above the subject head. The scanner was stabilized on a tripod with wheels and scans following an arc track. The optimal scanning time was 8s, which was easy to control and could keep the integrity of collected images at the same time.

Conclusion: By the comparative study of light, background, distance, angle and scanner movement pattern, we found that handheld scanner with standardized operation procedure can stable the scanning results and improve the collection efficiency and accuracy.

Keywords: Accurate Treatment Method; Facial Scanning; Mobile 3D Scanner; Standardized Operation

Introduction

For the past few years, 3D facial imaging technology has been more and more widely used as preoperative evaluation and surgery design for plastic and cosmetic surgery [1]. Currently, the two most popular types of 3D scanners are handheld and stationary. Compare with the stationary type, handheld scanner is more portable and mobile. It's capable of scanning through any body part, body position and environment. However, due to the strong flexibility of handheld scanner, how operator manipulating it will distinctly affect the result [2]. Some researchers have mentioned the operation procedure of 3D scanning, yet their studies are not systematic enough. In order to more efficiently collect the integrated 3D facial information, meet the needs for research and operation of plastic and cosmetic surgery, and reduce postoperative issues, this research used a type of mobile 3D scanner, conducted a comparative analysis with data collected from different operation procedures. The aim of our study is to investigate the best scanning effect and operation method, to form a standardized procedure for mobile 3D scanning.

Methods and Procedures

Materials

Equipment: Laser 3D scanner (Artec eva m 3D scanner, point accuracy 0.1mm) (Artec3D, Santa Clara, CA, USA 95054), computer (16G RAM, i7 Quad-core four threads, graphic cards, NVIDIA Q-line professional graphics card), and scanning program (Geomagic software is used in Step 2 data processing) (Geomagic, Morrisville, NC, USA).

Subjects

Research subjects were chosen from the medical staffs (three male and four females, age 19-65). All subjects have normal development and body features, no history of trauma or facial surgery, no facial deformation or defect.

Methods

Scanning condition

No obvious shadow on the subject face; white clear background; the scanning distance between the subject and the scanner is 80cm.

Scanning method

Scanner is stabilized on tripod with wheels

The scanner is fixed on tripod with wheels. The lenses of the scanner should be 5cm higher than the subject's head and the scanning distance should be 80cm. The scanner moves from one side of the external ear to the other side following a 180-degree arc track. When returning, the scanner should be 30cm below the chin, following the same arc track with 30-degree elevation angle.

Scanner is held in hand

Considering the stability and scanning range of handheld scanner, we designed multiple operation methods.Handheld method: One hand supports the bottom of the scanner, the other hand lifts the scanner, tightly bend the forearm. In order to observe the difference of scanning method, two more specific operation procedures were designed:

a. Holding the scanner in hand, scan through a 180-degree arc track which is parallel or slightly higher than the subject's head-face area. When returning, lower the height and following the same track with designated elevation angle.

b. Holding the scanner in hand, vertically move the scanner up and down as well as horizontally scan 180 degree following the facial outline at the same time, forming a zigzag pattern.

Scanning time

We chose four scanning speeds in our study. The scanner finished scanning in 3s, 8s, 14s and 30s. Pairwise compare the vertices and grid information of the generated images, to select the best scanning speed.

Results

Scanning time

The data collected from four different scanning times (3s, 8s, 14s and 30s) were compared in pairs, and vertices and grid information of generated image were analysed using repeated measures ANOVA. Our results showed that when the scanning time is 3s or 8s, the grid and point information is significant and the image is clear and integrate (Table 1,2).

Factor		F	P
Factor 1 Error (Factor 1)	Level 1 and Level 2	30.294	.002*
	Level 2 and Level 3	4.438	0.08
	Level 3 and Level 4	1.64	0.248

Table 1: Factor 1 is the vertex. Level 1 to 4 represents 3s, 8s, 14s and 30s respectively. Compare 3s with 8s, 8s with 14s and 14s with 30s, we found that only the difference between the vertices of 3s and 8s has statistically significance (P=0.002<0.05). The *P* values of other groups are all over 0.05.

Factor		F	P
Factor 2 Error (Factor 2)	Level 1 and Level 2	29.137	.002*
	Level 2 and Level 3	4.093	0.09
	Level 3 and Level 4	2.923	0.138

Table 2: Factor 2 is the grid information. Level 1 to 4 represents 3s, 8s, 14s and 30s respectively. Compare 3s with 8s, 8s with 14s and 14s with 30s, we found that only the difference between the grid information of 3s and 8s has statistically significance (P=0.002<0.05). The *P* values of other groups are all over 0.05.

Scanning method

According to the study result listed in (Table 1,2), we chose 8s as our scanning time and investigated the difference between two scanning methods. Vertices and grid information collected are demonstrated as follows (Table 3-6). The vertices and grid information are all higher in tripod group than handheld group in all seven samples.

Number	Methods	
	Handheld	Tripod
1	2.5	3.3
2	1.9	2.7
3	1.6	2.6
4	2.6	4.3
5	2.5	2.3
6	1.5	1.8
7	2	2.3

Table 3: Vertices results (value*10^6).

Variable	Subject amount	Average	Standard deviation (SD)	Paired t value (*P* value)
Handheld	7	2.086	0.4525	
Tripod	7	2.757	0.8203	0.027

Table 4: Comparison of vertices information between handheld group and tripod group (value*10^6).

Number	Methods	
	Handheld	Tripod
1	4.5	6.2
2	3.5	5
3	2.9	4.8
4	4.9	7.8
5	4.5	4.1
6	2.8	3.2
7	3.6	4.2

Table 5: Grid information results (value*10^6).

Variable	Subject amount	Average	Standard deviation (SD)	Paired t alue (P value)
Handheld	7	3.814	0.8295	
Tripod	7	5.043	1.5274	0.026

Table 6: Comparison of grid information between handheld group and tripod group (value*10^6).

Discussion

Scanning lighting, background and other objective conditions

Lighting

Non-contact 3D scanner has the advantages of fast scanning and the availability to reproduce the detail colour and texture of human soft tissue. However, it has higher requirement for the condition of subject surface and lighting [3]. Although the scanner is equipped with flashlight which has an exposure time of 0.2 millimetre second, when we scanned the same object under natural daylight or lamplight with same location and same working distance, the later method generated better images with higher colour authenticity and clearer demonstration of details like canthus. Considered the dependence of scanning on lighting, lack of illumination may cause scanning defect or lack of details. To avoid these issues, we provided additional lighting at 45 degrees with professional LED (1600lm). Our result showed that additional side light can help to better present three-dimensional organs such as ears and mandibular. Junjuan Wang et al. also reported that supplementary light can be used to improve image quality [4]. One thing that worth notice is that, while the lighting need to be enough, overexposure should be avoid since it will increase the amount of noise and affect the image quality.

Background

Handheld 3D scanner has no restriction on background condition, but too much colour is still inappropriate. Recommend using white or black or other single colour to reduce unnecessary background information and avoid redundant post-production editing [5]. In our study, both clear wall with no background and black background did not affect scanning results.

Scanning distance

Our results showed that the best distance between the scanner and the scanning subject head-face area is 80cm. At this distance we can capture the clearest and most detailed images. If the distance is too far, details will be missing; while if it is too close, scanner cannot analyse the feature overlap points very well, which will cause software error and loss of trace. Yet some researchers reported difference scanning distance, mostly smaller than 50cm [6].

Study subject requirements

The light reflection properties of study subjects can also affect the information collected from non-contact 3D scanner. There are occlusions when scanning those dark hollow parts with shadow, such as hair, pore and complex slot (nostril, auditory meatus, et al.) [4]. To solve these issues, additional light and change of scanning angle can be used for those complex curved surfaces such as nostril, chin and alar [7]. Bush suggested that the most accurate result can be achieved when subject head is at the centre of the scanning, and orbit meatal line forms a 10-degree angle with the horizon [8].

The differences of scanning movement and trajectories

After investigating the optimum lighting, background, study subject and other objective conditions, we tested the potential effect of different scanner movement and trajectories on the scanning result. We tried several movement patterns, including asking the subject to spin around when scanning; however, most subjects could not control the exact spinning time and speed, so we decided to use tripod with wheels to perform the arc track. By following this arc track, scanning was more stabilized and confluent, and could also collect more information. Our results suggested that for the beginners, standardized procedure should be setting the scanner on a tripod, scanning from one side of subject external ear to the other side following a 180-degree arc track, then lower the height and scanning back following the same track with an elevation angle. Dehua Zheng et al. also demonstrated that different scanning angles, including horizontal and vertical angles will cause surveying error [9].

The determination of scanning time

Considered the requirement of scanning speed, we showed that the appropriate scanning time is 3s and 8s. Finish scanning in 3s was the fastest but the image was not clear enough; and it was also hard to control the time. Yet when we increased the scanning time to 30s, there was no significant improvement in the image quality, so we suggested that the most suitable scanning time should be 8s. There are other researches in agreement with our results. They show that using an average scanning time of 10s can improve the resolution to 0.01mm [10]. This is also better than the 0.9mm resolution suggested by Moss in his 3D non-contact measurement system of facial reconstructive surgery [11].

Conclusion

Artec eva m handheld 3D scanner can better achieve the depth information and colour texture of the scanning subject. It has the advantages of fast scanning speed and good reproduction of colour and texture of human soft tissue. However, it has higher requirement of the subject surface condition and lighting. Our study results demonstrate that the standardized procedure of mobile scanning should be:

a) Adequate natural daylight, white or black background.

b) The distance between scanner and subject: 80cm, 5cm higher than the head.

Scanner should be stabilized on tripod with wheels, scanning starts from one side of external ear to the other side following a 180-degree arc track. When return, lower the scanner to 30cm below the chin and follow the same arc track with a 30-degree elevation angle. The scanning time should be kept around 8s to ensure the best result.

Handheld scanner can precisely scan detailed facial organs such as ear, chin and nasal ala. The data collected from scanning can help doctors to accurately measure and locate human facial features, and perform individualized preoperative evaluation [6]. To better ensure the quality of collected information and the resolution of generated image, operators can hold the scanner longer at those organs which are hard to scan clearly (such as ear and nasal ala), and can also slightly change the angle. For most well-collected primary data, using the method discussed above can achieve a favourable result. However, for some undesirable data which may be caused either by the inappropriate scanning distance, or subject massive trembling which leads to facial misalignment, professional software is required to perform post processing such as integral registration and grid simplification.

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