Effect of the accuracy of 3D head scanners in product design development

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ABSTRACT

Human head needs to be protected from any risk as multiple sensory organs are located there. Hence it is very important to design products with a high level of comfort and fit in order for the product to perform its function. With the advancement of 3D scanning facilities, it is possible to acquire highly accurate and precise surface contour which can be used for designing customized products. With the availability of wide range of 3D scanners, it is necessary to evaluate the user experience of products developed from different scanners based on their accuracy and precision in scanning. The aim of this study is to investigate the effect of accuracy of three 3D scanners in product designing and evaluating user's comfort and fit parameters for the developed products. Participants were scanned using three different 3D scanners (Artec Eva 3D scanner, Cyberware 3030 color scanner and Structure sensor scanner). A mask frame was developed from every scan and then 3D printed for evaluation. The individuals were made to evaluate the designed mask frame to understand their comfort and fit experience. Based on the responses from the participants it was found that the mask frame developed from the scan acquired from Artec Eva 3D scanner was found to be the most comfortable one and had the best fit. The scans acquired from Cyberware 3030 color scanner had missing data and was reported slightly dissatisfaction on fit. The scans from the Structure sensor lacked precision and fine details, and the frame got the lowest rating at comfort level.

Keywords: 3D Scanners, Head and Face, Product Design, Comfort, Fit

1. Introduction

Human head needs to be protected from any risk as brain and multiple sensory organs are located there (Zhuang and Bradtmiller, 2005; Waugh and Grant, 2010). To ensure that the designed product for the head and face region serves its purpose of protection, a close fit with a good level of comfort is necessary. In order to achieve that, designers require anthropometric data which is usually acquired by traditional measurement techniques like using scale, tapes or callipers (Quant and Woo, 1993; Farkas, 1994; Yokota, 2005; Vasavada et al., 2008). However, traditional techniques are not very reliable and can include human error (Fourie et al., 2011; Shah et al., 2016). With the advancement in 3D technology, it has been easier for the designers to acquire more accurate 3D anthropometric data of human head and face. Most commonly used technique for development of 3D head and face model involves usage of 3D scanners to record the head and face contour (Plooij et al., 2011). The scanned head model can be used to develop a wide range of customized products with computer aided designing and computer aided modelling technology. There are wide range of 3D scanners available nowadays, having different accuracy and precision ranges. This variation in the accuracy and precision of the 3D scanners would affect quality of acquired data, therefore leading to differences in the designed products. There is a need of understanding of how much the accuracy and precision of the 3D scanners affect the product design.

Comfort and fit are two of the most important parameters considered by users while buying any product (Dias, 2003). Hence it is necessary to understand user experience of comfort and fit and how it varies with respect to the accuracy of the scanner. This paper tries to address this question by testing customized 3D printed mask frames designed based on the scans acquired from three head scanners and evaluating their comfort and fit experience.

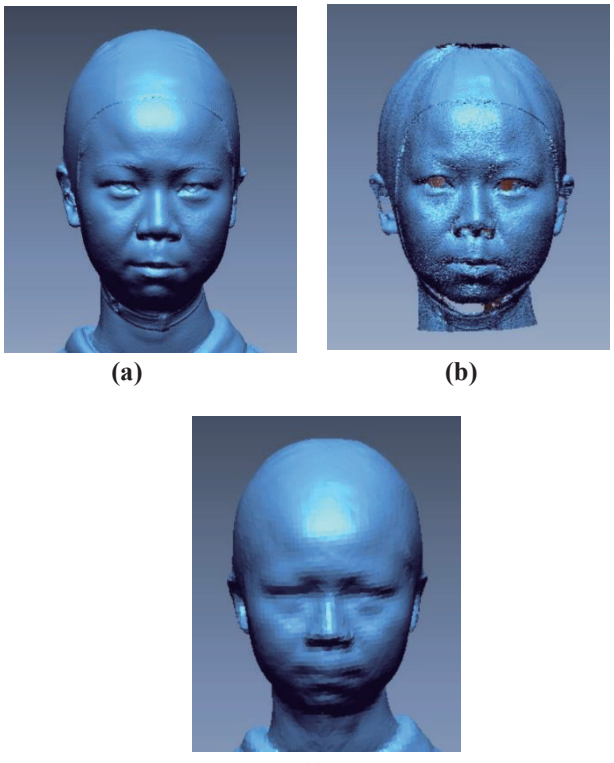
2. Method

2.1 Participants

Three Chinese individuals (2 females and 1 male) with an average age of 25 years voluntarily participated for the study. Participants were informed about the study protocol and a written consent was acquired from each participant. All the participants had no facial abnormalities or lesion.

2.2 Procedure

The study incorporated three of commonly used head 3D scanners: Artec Eva 3D scanners, Cyberware 3030 color scanner and Structure sensor. Scans were acquired in a random order from all three scanners for all the participants as shown in Figure 1. All scans were post processed using dedicated software.



(a) (b)

(c)

Figure 1. 3D scan acquired from (a) Artec Eva 3D scanner (b) Cyberware 3030 color scanner (c) Structure Sensor

The missing regions in the Cyberware scan were filled using the Meshmixer software. A template for mask frame was designed using Meshmixer which was projected on the acquired scans as shown in Figure 2. The facial contour in the overlapping region of the projected mask template and the face scan was acquired using Boolean Intersection function in Meshmixer. This facial contour was used to develop a customized mask frame based on the scan data. Therefore, each participant got three deigned mask frames. The masks were then 3D printed using ABS material as shown in Figure 3.

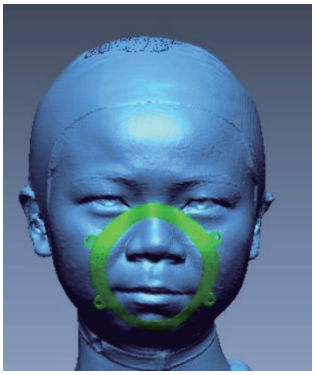


Figure 2. Designed mask frame

Figure 3. A sample 3D printed mask frame

The participants were made to wear all the three mask in a random order for five minutes and then they were made to answer a short questionnaire based on their comfort and fit experience and they were asked to rate the masks accordingly.

3. Results

As shown in Figure 1. (a) the scans acquired from Artec Eva scanner were very precise and accurate (Precision of Artec Evan 3D scanner=0.05mm). They

had detailed contour and shape of complete head and face region. Cyberware 3030 color scanner is a laser scanner whose scans had an accurate facial contour data but lacked information in shadowed regions like the back sides of nose, ears, area beneath the chin and top part of the head as shown in Figure 1. (b). The scan from Structure sensor was very crude and lacked precisions (Precision of Structure sensor = 0.5mm) as shown in Figure 1. (c).

The mask frames developed from Artec Eva 3D scanner were rated to be moderately comfortable (5.7 on average for a 7-point Likert scale). Also the participants were satisfied with the fit of the mask frame and found it to be satisfied (4.3 on average for a 5-piont Likert scale). None of the participants felt any discomfort while wearing the mask frame developed from Artec Eva 3D scanner. The participants felt a bit of pressure and tightness in the nose region because of the close fit.

The participants rated the mask frame developed from the scan acquired using Cyberware 3030 color scanner to be better than neutral (4.3 on average) for comfort level. The participants were dissatisfied with an average of 2.7 regarding the fit of the mask frame. All the participants reported of having problem in the nasal region. They found bad fit on the sides of the nose and there was some empty space where the mask did not make contact with the corresponding region on the nose. This may have been caused by the missing data in the scan from the Cyberware 3030 color scanner and interpolation technique may not be able to provide a good gap filling for this area. In addition, the participants found the fit in the facial region to be good but problems occurred in the chin area.

The mask frame developed from Structure sensor were rated neutral (4 on average) for comfort level. Two of the participants felt discomfort while wearing the mask frame. All the participants felt issues in the mask frame at the nasal region where they found it to be very tight. The participants rated a bit higher than neutral (3.3 on average) with the fit. All the participants found the mask frame to be smaller and felt the mask was causing some pressure on the soft tissues in that region. This might have been caused as the facial contour data acquired from the scan was not highly accurate. Also the scan acquired smoothed the fine details in the regions where there was a sharp change in the facial morphology.

When the participants were asked to rank the mask based on the comfort level, all the participants rated mask frame developed from Artec Eva 3D scanner to be the best. When asked about their experience with respect to fit parameter, two participants rated the mask frame developed from Artec Eva scanner to be the best while one participant preferred the frame developed from Structure sensor.

4. Discussion

Products designed related to the head and face and mostly used for the purpose of protection, medical reasons or appearance. The products need to have a close fit with the body in order for the product to serve their purpose. Based on the results of the study it is evident that the users prefer the products developed from 3D scanners with high accuracy and precision (Artec Eva 3D scanner) as the product is more comfortable and has a better fit. Hence scanners with higher accuracy and precision can be used to develop wide range of products for the head and face. Even though the laser 3D scanners like Cyberware 3030 color scanner have missing data, the comfort level is still positive but the fit has issues at missing data region. The gap filling technique could be an important factor for product development. However, the 3D scanners with a low accuracy such as Structure sensor demonstrated the lowest evaluation (neutral) at level of comfort, but a positive evaluation for satisfaction of fit. This suggests that low accuracy scanner still is suitable to be used for designing the products with lower requirement on fit and comfort.

Currently, this study only tried to evaluate the mask frame which is only affected by the shape and contour in the nose and face region. In order to have a better understanding the effect of accuracy on the 3D scanners a wider range of products related to different regions of the head and face need to be studied for a larger group of users belonging to different age and gender.

5. Conclusion

Products related to the head and face require a close fit for them to conduct their desired function. Hence the fit is of utmost importance. Product fit varies based on the properties of the scanner when the product is designed based on 3D scan file. In order to understand the effect of scanners' accuracy on

the level of comfort and fit experienced by users based on the designed products, three head scanners were studied. The reviews of the participants provided details about the problems and limitations of the products designed from every scanner. The results revealed that the products developed from the scans acquired from 3D scanners with high accuracy and precision were evaluated to be better than the ones developed from lower accuracy scanners in terms of the level of comfort and fit.

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