Evaluation of cap design for 3D scan

Yan Luximon* and Joseli Shuk-Ling Cheung
School of Design, The Hong Kong Polytechnic University
Hong Hom, Kowloon, Hong Kong
* Corresponding author: yan.luximon@polyu.edu.hk

Keywords: 3D head scan, Cap design, CAD

Abstract

The 3D human anthropometry study has become more and more popular in design area. Human body shape can be captured by 3D scanner and surface data can be collected for further analysis. However, accuracy of the scanned data can be affected by the participant's hair, especially during head scans. A cap is normally used to compress the hair. Depending on the hairstyle and the cap design, the data at the ear region, the neck region and the top region of the head can be missing or wrong. In this study, we demonstrated the problems caused by the hairstyle and the cap design using 3D head scanners. The results indicated that a new cap design for 3D head scanning is needed in order to collect better data.

Introduction

The 3D human anthropometry study has become more and more popular over the last few decades [1-5]. Human body shape can be captured by a 3D scanner and surface data can be collected. The 3D surface data could be used in many areas including product design and animation [5-7]. However, the accuracy of 3D scans was always an issue, especially for 3D head scans. The complex shape and thick layer of hair created great difficulties for head data collection [8]. Various types of caps, including wig cap, swim cap and hairnet, were used to compress the hair in previous studies [8-10]. However, the data at ear region, neck region and the top region of the head was normally missing or incorrect depending on the hairstyle and cap design. In addition, the thickness of compressed hair also could be different due to the material property of cap. Therefore, scanned head surface varied from the scalp form that was captured from CT or MRI technology [11]. Based on these problems, different versions of the current caps were evaluated in this study. Different scan technologies also were tested in order to compare the differences of scan accuracy. The fitting and scanning results could be used to make an improvement in the future cap design.

Methodology

Participants

Ten participants were selected (five males and five females) to fit different caps with different size randomly. Their general demographic information was recorded.

Equipment

A Cyberware 3D head scanner and an Artec Eva scanner were used to collect 3D scan data. Two different types of caps were evaluated in the experiment. Both of them were commercialized caps. One is a wig cap made from Polyester material and another is a swim cap made from Lycra material.

Experimental design

All participants were tested with both caps (a wig cap and a swim cap) and both scanners. The fitting pictures and scanned files were recorded. Several dimensions measured from traditional method were compared to that from digital files. Differences were calculated and compared. Subjective perception of wearing caps was also recorded.

Procedure

Participants were asked to fill the consent form and basic information first. Their head circumferences were measured using measuring tape and caliper. The sequence of the two caps were randomly assigned. The experimenter helped the participant comb their hair and put the cap on. When scan processes from both scanners finished, the participant was questioned regarding their perception of wearing the cap. After removing the first cap, the participants' hair was combed again. Then second cap was tested with the experimenter's help.

Results

Comparisons of scans and measurements

The age of ten participants averaged 27 years old (standard deviation= 3.7 years old). Fig.1 and Fig. 2 demonstrate the scan result of the wig cap and the swim cap by Cyberware 3D head scanner and Artec Eva 3D scanner respectively. Scans from Cyberware had a lot of missing data near the ears and the back of the neck region due to the limitation of laser technology. These were the hair regions where the caps did not cover. In addition, the wig cap had some redundant material on top of the head which created some additional data points. Scans from Artec did not have so much missing data near the ears and the back of the neck region. However, it recorded the loose hair shape instead of the compressed hair shape. Both scans would affect the data accuracy greatly due to the hairstyle.

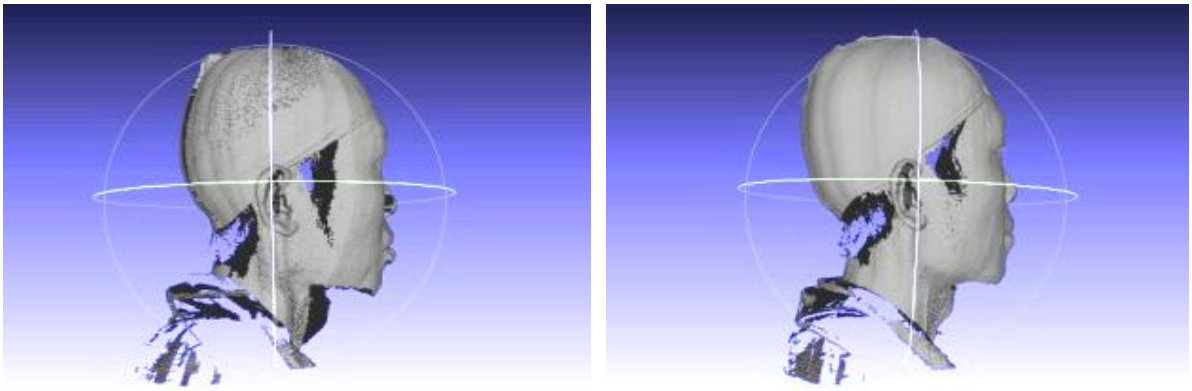
The head dimensions from Cyberware scan and Artec scan were calculated using Rapidform software. The head circumference differences between scanned files and manual measurements were compared and the result is shown in Table 1. In general, the dimensions of the scanned files from both scanners were larger than manual measurements and the wig cap from Cyberware scan gave the largest difference on average.

Table 1. Head circumference differences between scanned files and manual measurements [mm]

	The wig cap	The swim cap
Cyberware scan	16.92 ± 9.39	14.95 ± 4.14
Artec scan	13.84 ± 5.11	15.04 ± 5.95

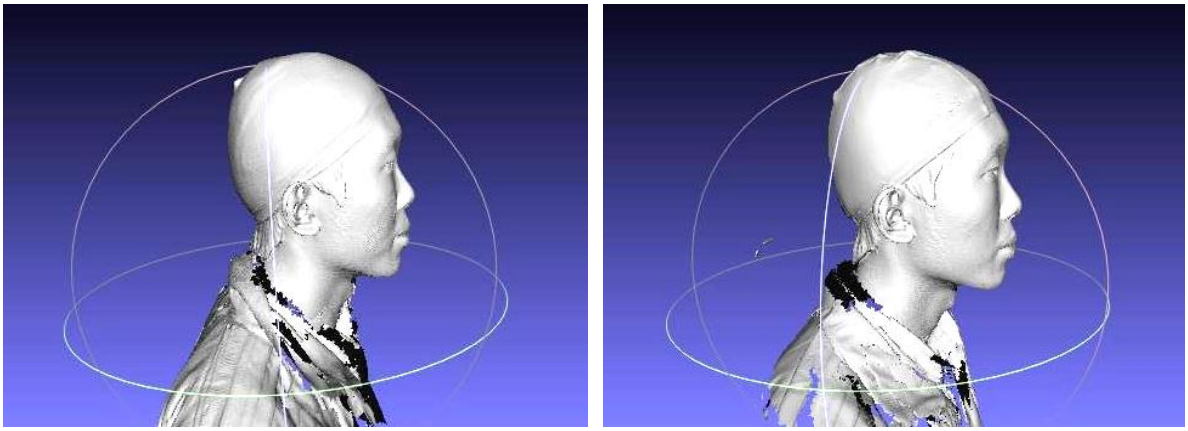
Perception

The general perception of the wig cap from participants was loose, old fashioned, but comfortable. All participants felt the swim cap was too tight and uncomfortable. 70% of participants felt pain on the forehead region since the edge of the cap was so tight and created the pressure mark there. Participants also felt the thermal condition was poor for the swim cap due to material property. In addition, females had more fitting problems with both caps due to the long hair.



(a) The wig cap (b) The swim cap

Fig. 1. The scans from Cyberware scanner



(a) The wig cap (b) The swim cap

Fig. 2. The scans from Artec Eva scanner

Conclusion & Discussion

The scan results demonstrated that the hair style could influence the result greatly, especially at the ear region and the neck region. Both of the wig cap and swim cap had similar design, therefore the missing data or incorrect area occurred at the similar location. In general, manual measurements were much smaller than that from 3D scans. The 3D scans with the wig cap from the Cyberware scanner gave the largest difference. The reason could be that the Polyester wig cap was too flexible and sheer, the hair was not compressed to the scalp well and hair through the cap could affect the data calculation. The Lycra swim cap was very strong and tight, but it was thicker and the lack of elasticity caused participants to feel uncomfortable.

By evaluating the material, fitting and the scanning outcomes of current caps, a new cap should be designed to improve the head scan accuracy. A larger coverage area, new material and gender differences should be considered during the design process. Sizing might be studied also in the further research depending on the material of the cap.

Acknowledgements

This work was financially supported by the Hong Kong Polytechnic University (G-YBBD).

References

[1] K. Robinette, H. Daanen, E. Paquet, The CAESAR project: A 3-D surface anthropometry survey", Proceedings of 2nd International Conference on 3D Digital Imaging and Modeling (3DIM'99), pp. 380-386 (1999).
[2] Z. Zhuang, B. Bradtmiller, Head-and-face anthropometric survey of US respirator users. Journal of occupational and environmental hygiene, 2(11), pp. 567-576 (2005).
[3] R.M. Ball, J.F.M. Molenbroek, Measuring Chinese Heads and Faces, Proceedings of the 9th International Congress of Physiological Anthropology, Human diversity: Design for life. Delft, the Netherlands, pp. 150-155 (2008).
[4] L. Goto, J.F. Molenbroek, R.H. Goossens, 3D Anthropometric Data Set of the Head and Face of Children Aged 0.5-7 Years for Design Applications. In N D'Apuzzo (Ed.), Proceedings of the 4th international conference on 3D body scanning technologies Ascona, Switzerland: Hometrica Consulting, pp. 157-65 (2013).
[5] Z. Zhuang, B. Bradtmiller, R. Shaffer, New respirator fit test panels representing the current U.S. civilian work force, Journal of Occupational and Environmental Hygiene, vol. 4, no. 9, pp. 647–59 (2007).
[6] C.C.L. Wang, T.K.K. Chang, M.M.F. Yuen, From laser-scanned data to feature human model: a system based on fuzzy logic concept, Computer-Aided Design, vol. 35, no. 3, pp.241–253 (2003).
[7] B. Allen, B. Curless, Z. Popovic, The space of human body shapes: reconstruction and parameterization from range scans. ACM Transactions on Graphics (SIGGRAPH'03), vol. 22, no. 3, pp.587-594 (2003).
[8] Y. Luximon, R.M. Ball, A comparison of different methods for head measurements, International Journal of Human Factors Modeling and Simulation, vol. 2, no. 4, pp.257-266 (2011).
[9] H. Seo, Y. Song, C. Kim, H. Kim, Characteristics of Korean Children's Facial Anthropometry Evaluated by Three-dimensional Imaging, Journal of the International Society for Respiratory Protection, vol. 33, no. 1 (2016).
[10] Y., Hu, Z. Zhang, X. Xu, Y. Fu, T.S. Huang, Building Large Scale 3D Face Database for Face Analysis. In: Sebe N., Liu Y., Zhuang Y., Huang T.S. (eds) Multimedia Content Analysis and Mining. Lecture Notes in Computer Science, vol. 4577, Springer, Berlin, Heidelberg (2007).
[11] S. Verwulgen, J. Vleugels, D. Lacko, E. Haring, G. De Bruyne, T. Huysmans, Thickness of Compressed Hair Layer: A Pilot Study in a Manikin, in Proc. of 7th Int. Conf. on 3D Body Scanning Technologies, Lugano, Switzerland, pp.182-189 (2016).