Digitizing human scalp shape through 3D scanning

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Abstract

This short paper presents a novel approach to digitize scalp shape with a combination of a scalp probing rig and 3D head scanning.

Keywords: Scalp shape, head shape modeling, 3D head scanning, head under hair

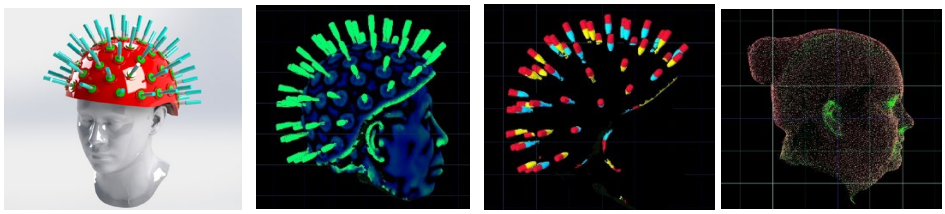
Introduction

Acquiring true scalp shape under hair, especially for females and other individuals with substantial hair, has been a challenging task for anthropologists, digital human modelers and product designers. It is not always a viable option to recruit bald headed subjects or require subjects shave their head. The most feasible way to capture scalp shape under the hair is through physical probing or digitizing. Using mechanical probes to obtain scalp shape under hair can be traced back to US Army's Personal Armor System for Ground Troops (PASGT) helmet project which used a physical probing device to read distance from the device's spherical surface to the scalp surface. Recently the US Air Force has collected female's scalp shape using a FARO Arm digitizer.

A probing process that uses physical probes or a digitizer typically requires a subject to sit still for a considerable time, which is difficult and uncomfortable and became a greater challenge under Covid safety restrictions. To improve the efficiency and acceptability, we developed a scalp probing rig with 54 adjustable probes that can be worn and fit by the subjects. After fitting all probes so they lightly touch the subject's scalp, a 3D head scanner was used to capture the image of the scalp probing rig in place. The final merged 3D image was imported to an in-house developed program to detect probes and calculate the coordinates of the probe tips. A scatter point set of the probe tips is then fed to a scalp shape reconstruction program (Morpheus-InfoSciTex) to recover the true scalp shape. This paper describes the design of the scalp shape rig, 3D scan processing methods to detect the probes' coordinates.

Methods

The scalp rig is a helmet-like shell that has 54 threaded holes to host probes. Each probe has a fixed length and consists of a cylinder section and a screw section. The end tip of the screw section is a ball shape that will contact to skin surface of the scalp. Figure 1 a) is the CAD rendering of the scalp rig assembly on a head model. The rig was 3D printed to make its weight light. When a test participant wears the scalp probe rig, each probe will be screwed to touch his/her scalp skin and the cylinder section of a probe is visible on the outside of the helmet shell. From a complete 3D image of the scalp probe rig, the coordinates of the tip point of the probes are derived from the coordinates of the end face of the cylinder section and the long axis of the probe, that is by adding an offset of the probe length to the end point of the cylinder shape in the direction defined by the probe's axis.



a) b) c) d)

Figure 1. The scalp rig and probe detection method: a) the scalp rig; b) mean curvature of the rig; c) detected candidate probe regions; d) reconstructed female scalp shape superimposed with head scan.

The detection of the probes is based on mean curvature of the 3D scan of the scalp rig. The probe shape has a high curvature compared to other parts of the scalp rig (figure 1b), which supports a mean curvature based segmentation algorithm. After the segmentation we applied the principal component decomposition to each candidate probe region to obtain their three principal axes. Three dimensional points of each region were projected to a plane defined by the centroid of the region and a normal vector of the shortest axis from three principal axes. In this way we can compute the standard deviation of the data from a fitted line as an estimator of the diameter of the candidate probes. Figure 1c shows detected candidate probes, where the end points of each probe region were computed. From derived probe coordinates on scalp surface a surface reconstruction program was used to generate the scalp shape. Figure 1d shows a superimposed a head scan with hair (red) to the reconstructed scalp surface (green).

Discussion and Conclusions

An evaluation of this rig has been conducted on a headform where scans with and without the scalp rig were taken. The mean distance between the computed probe tip points to the headform surface is -0.3073 mm (SD = 0.4886 mm). The accuracy of the detected scalp shape on human head may be affected by a

few factors such as the contact pressure of each probe to skin surface and individual's sensitivity to the probe pressure. The device has been used to collect female head shape under hair from local population.