Reconstruction of Cranial Surfaces from 3D Point Data

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Abstract Knowledge of the shape of the human head is paramount to the design and production of protective headwear and head-mounted equipment. Unfortunately, current practices rely on simple size measurements due to the inherent difficulty in analyzing the shape of smooth surfaces, such as the cranial region of the head. This is the second of two collaborative projects between the US Military and the FSU Geometric Morphometric Lab targeting this problem. In the first, we developed new geometric morphometric techniques to analyze male head shape in the US Military using 3D laser scans of bald male personnel. Here, we extend these methods to female head shape. However, many women are unwilling to shave their heads to obtain high quality laser scans so a new method of data collection and processing was developed. A hardware landmarking tool called a FARO arm is used to obtain facial landmarks, a line of points marking the hairline, and a set of points on the cranial region taken by parting the subject's hair. This data is combined with a full 3D laser head scan (with hair) that has corresponding facial landmarks collected via a software landmarking tool. Using a combination of the ICP algorithm and thin plate splines, we automatically remove the cranial region of the subject scan and replace it with a bald prototype cranial region that has been reshaped to exactly fit the subject's FARO data. The result is a complete head scan comprised of the subject's original facial region and an approximated cranial region.

Introduction & Background

- Morphometric analysis of human head shape is challenging due to the lack of landmarks on the smooth surface of the cranial vault.
- In a previous project, this was alleviated by developing a landmark-free method of analysis that used complete surface scans.
- 3D laser scanners were used to obtain high quality scans of bald men.
- As many women are unwilling to shave their heads, a way to approximate the surface of the scalp was needed.
- A hardware landmarking tool called a FARO arm was used to obtain 3D point data on the scalp between parted hair.
- Facial landmarks are obtained both with the FARO arm as well as in the surface scans to assist with superimposition.
- This FARO data is combined with a surface scan (with hair) and a template bald scan to reconstruct a bald version of the head.

Superimposition

- The FARO data, subject surface scan, and template bald scan all exist in different orientations, positions, and sizes.
- We use the facial landmark data to correct these differences via Procrustes superimposition.

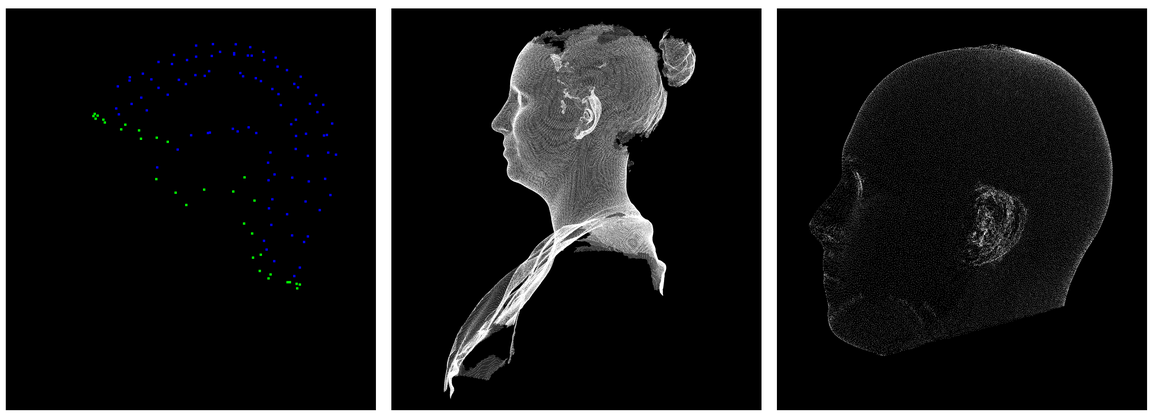

Figure 1: Left: The FARO hairline and scalp data. Center: The initial subject scan. Right: The template scan.

Mesh clipping

- An optional clipping step is applied to remove extraneous anatomical regions from the subject surface scan. This is not strictly necessary but can be useful for surface analysis after reconstruction is complete.

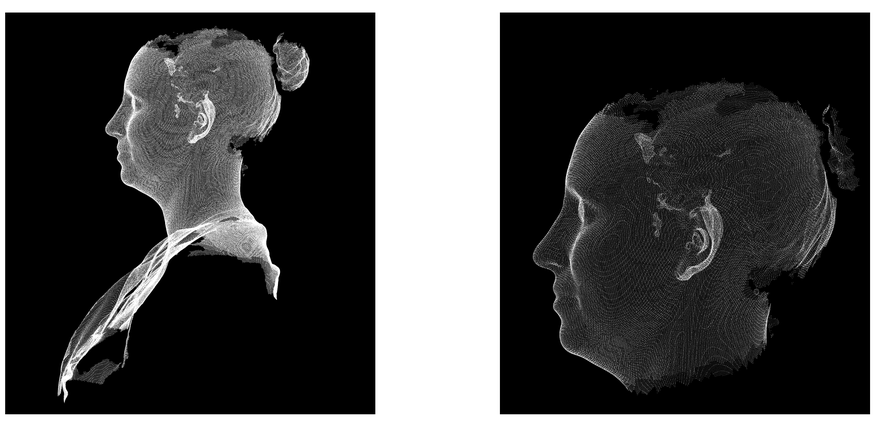

Figure 2: The subject scan before and after clipping is applied.

- We also use the hairline to delineate and remove the scalp region from the subject's surface scan.
- The FARO hairline and scalp data are superimposed on the template scan using ICP for as close a fit as possible.
- The template scalp is then separated from the rest of the scan using the hairline.

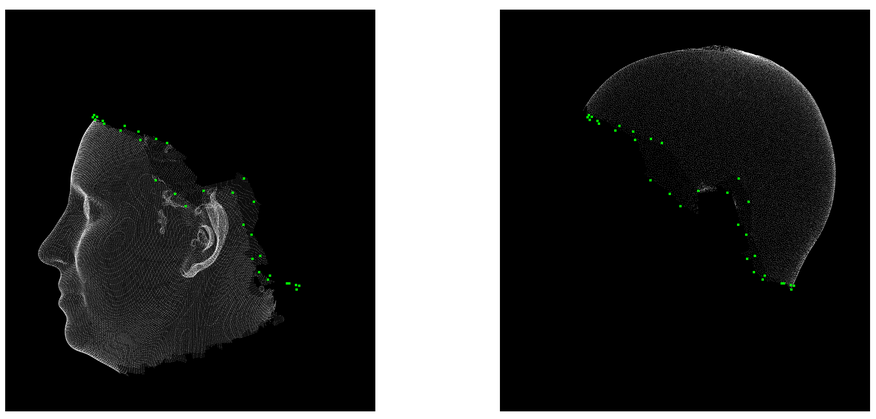

Figure 3: Left: The subject scan with the scalp removed according to the hairline (green). Right: The template scan scalp extracted according to the hairline (green).

Thin-plate splines

- The FARO hairline and scalp data are re-superimposed on the subject surface scan using the facial landmarks. The transformations applied are also applied to the template scalp to keep it aligned with the FARO data.

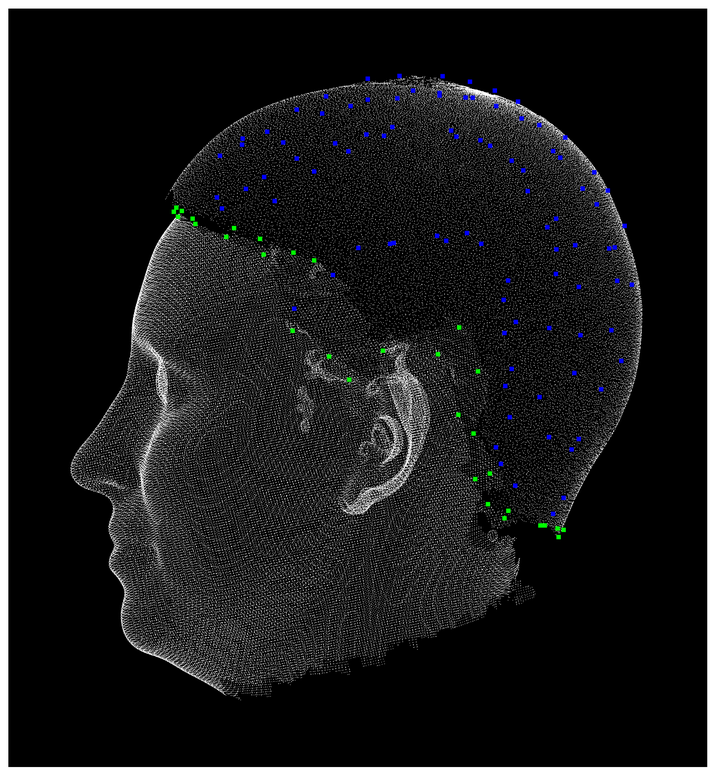

Figure 4: The subject scan facial region with the unsplined template scalp and the FARO hairline (green) and scalp (blue).

- A nearest neighbor-based correspondence between the FARO hairline and FARO scalp data and the template scalp is established.
- This correspondence is used to define the target and control points for the application of thin-plate splines.
- Transformation parameters are calculated and applied to the entire template scalp.

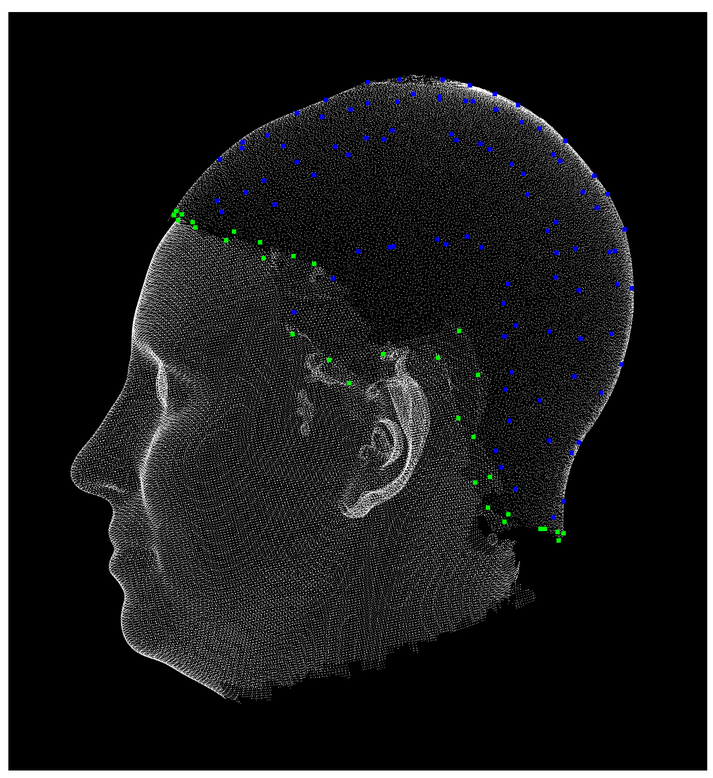

Figure 5: The subject scan facial region with the splined template scalp and the FARO hairline (green) and scalp (blue).

Results & Discussion

- The method successfully reconstructs a cranial surface from the 3D FARO points. However, there are some issues with the reconstruction.
- Significant artifacting can occur based on discrepancies between the FARO information and the surface scan information.
- One clear example of this is the back of the neck at the base of the skull. In the scanner, the subject is seated upright, while the subject leans forward into the FARO data collection head support. This difference leads to a large gap in the aforementioned region in the final scan.
- If the hairline does not adequately account for the position of the ears, they can be incomplete or missing.
- If the optional clipping step is applied to a surface that does not match well with the template surface, there may be missing patches from the clipping algorithm.
- Future work should address the above concerns.