Advances in Forensic Anthropology

Technology Transition Workshop

Improving Forensic Facial Reproduction Using Empirical Modeling

During this session, attendees will learn of an approach for forensic facial reproduction that uses empirical modeling. The process of using a portion of the known landmarks traditionally accessed for facial reconstruction prediction, while also incorporating the effect of body mass index (BMI) in the empirical model, will be described. Unlike current forensic facial reconstruction techniques that use average facial tissue depths from a population sample of individuals, the technique applied during this workshop session will use a non-parametric empirical model to predict facial tissue depths that are unique to each cranium. Attendees will discover that this technique also has potential to predict facial features like the eyes, nose, and ears. The purpose will be to learn to use this technique to generate more accurate facial reconstructions, thus improving forensic facial reconstruction by enhancing the accuracy of the prediction of soft tissue thickness.

Technology Transfer Session 2: Tissue and Bones Measurements Hands-on

The second portion of the Technology Transfer Session 2 will be tissue and bone measurements. The primary focus of this hands-on session will be to ensure attendees' understanding of the developed software program which will be utilized to predict soft tissue thickness from surface models generated from the CT segmentation process. Attendees will be guided through a step-by-step demonstration of the software program, leading to the completion of an accurate prediction of soft tissue thickness that can be used later for clay reconstruction.

Tissue and Bone Measurements Hands-on

The registration and morphing software, iMF, is developed by the Center for Musculoskeletal Research (CMR) in the Biomedical Engineering Department at The University of Tennessee, Knoxville. The software registers any skull to the base skull model; this method is called affine transformation. This allows the user to see the locations of the base or template skull with the fiducial markers registered with the skull to be measured by rigidly aligning the two skull surface models and putting them on the same scale. After a male skull in the database and the base male skull with the fiducial markers are registered to one another, an elastic deformation is used to stretch the database skull to fit the base skull. The elastic deformation tries to match the 32 total fiducial markers on the base skull to the correct craniometrical locations on the database skull, where the soft tissue thicknesses will be measured.

iMF user interface is divided into five parts: (1) Two Dimensional Axial Viewer, (2) Two Dimensional Sagittal Viewer, (3) Two Dimensional Coronal Viewer, (4) Three Dimensional Viewer, and (5) Toolbar Area as shown in Figure 1.

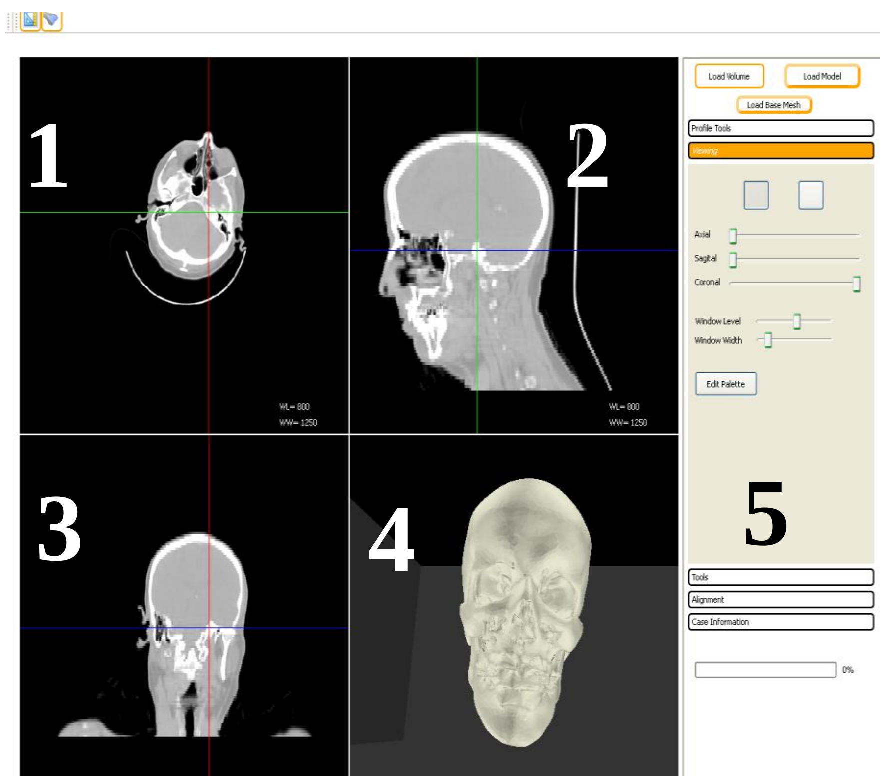

Figure 1 iMF user Interface

Loading Dataset

Before any tissue or bone measurements can be made, a single skull's DICOM image set must be loaded into iMF Along with the DICOM image volume of a particular subject in the database, the subject's surface mesh model must be loaded into iMF.

After the DICOM volume and surface model have been loaded, the iMF home screen displays the DICOM volume in three different views (axial, sagittal, and coronal). In the lower right quadrant of the home screen, the surface model of the segmented bone is correctly placed within the DICOM volume as shown below.

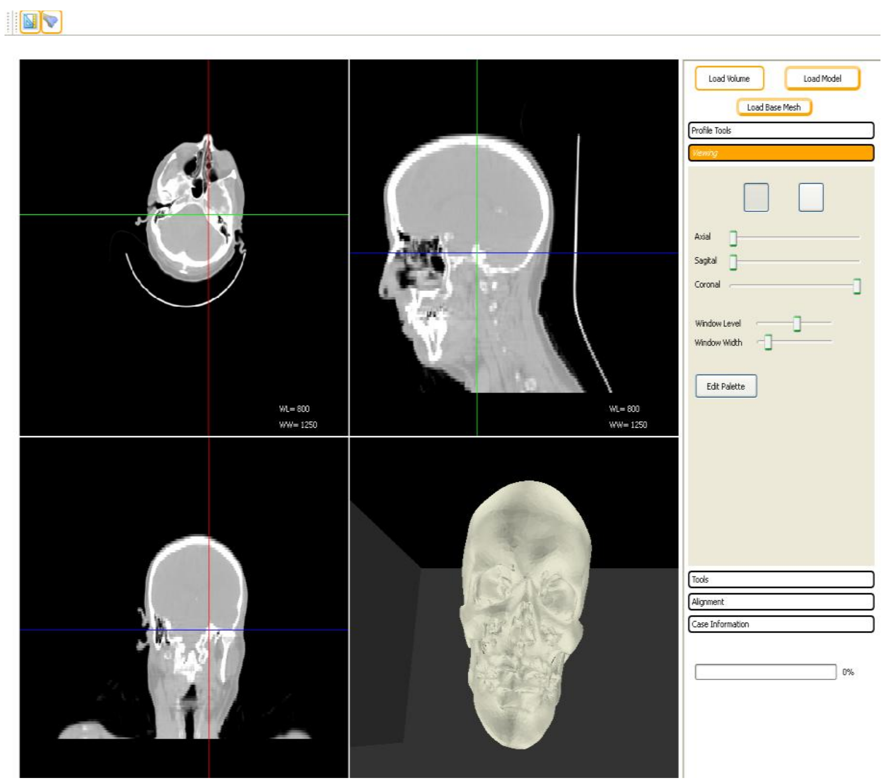

Figure 2 Loaded volume and surface model

Registration

The next step in using the iMF software is to load the base mesh model and register it to the previously loaded surface model. The registration method used in iMF for the cranium consists of four steps: scaling, rigid alignment, affine transformation, and morphing. The surface model scaling step attempts to align the new surface model mesh with base mesh model and then scales the base mesh to match the dimensions of the new mesh model. The second step in the registration and deformation process is a rigid alignment of the base model to the new model. The rigid alignment is performed using a standard vertex-to-vertex iterative closest point (ICP) algorithm. The ICP algorithm works to minimize the distance between a set of points from the

100,000 triangles that make up the base surface model and the new surface model. The algorithm continues to compute the closest point then compute the registration and then apply the registration until the root mean square error between the base model and the new model falls below a set threshold. The third step is to perform a general affine transformation without iteration. The affine transformation method is used to align the base model with new model using 12 degrees of freedom (rotations, translations, scaling, and shear). After the affine transformation, the linear transformation limits have been reached; therefore, another method must be used to register local portions that are still distant from one another. The last step is a morphing or warping process that tries to create new points on the surface of the new model that has similar local spatial characteristics as the base model.

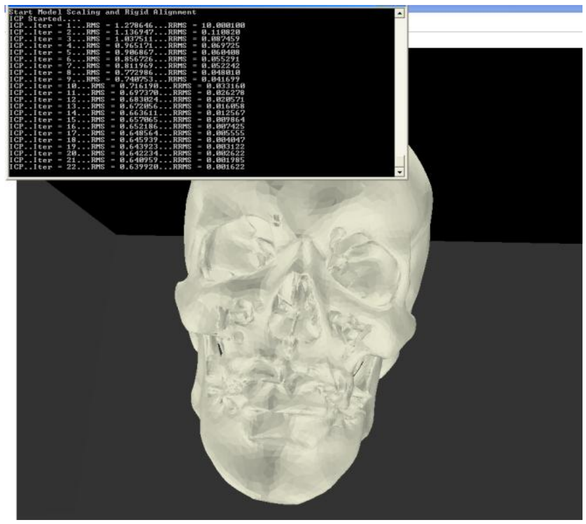

Figure 3 Performing registration

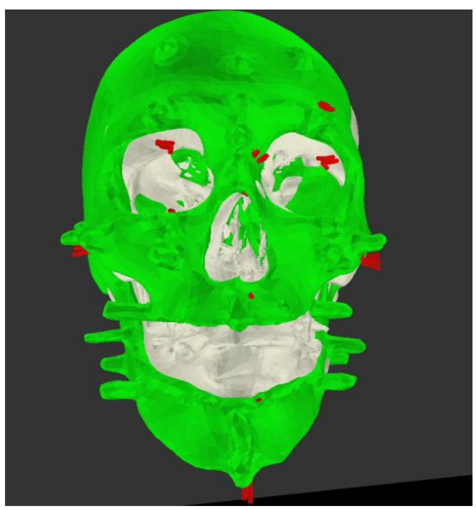

Figure 4 Registered base model and new model

Measurements

The next step in using iMF to calculate the tissue and bone measurements is to select the craniometrical location to measure the tissue thickness and bone thickness. In iMF under the "Profile Tools" tab, one can select the "Pick" button. This allows the user to pick any number of points on the new surface model where a measurement will be made.

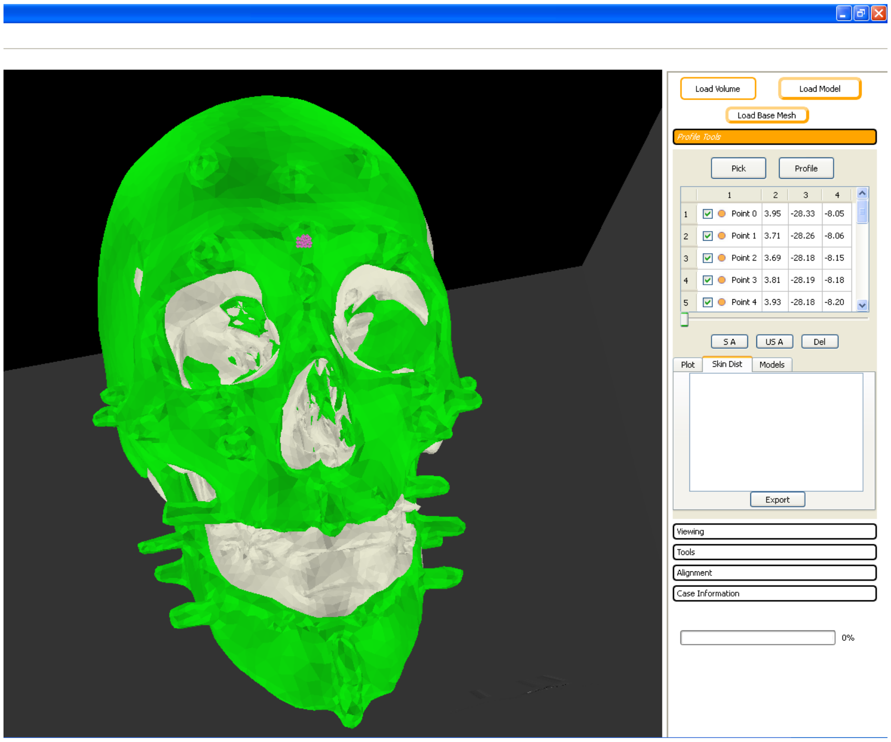

Figure 5 Picking bone thickness areas

To help ensure the most accurate measurements possible, about 20-40 points are picked at each location. This will allow for an average bone thickness to be calculated from the 20-40 points for a single location on the skull. The bone thickness measurement for each point is computed by selecting the profile button in iMF after all points have been picked for a single location. iMF computes the bone thickness for each selected point by finding the distance (in centimeters) from the point picked on the model's surface along the normal direction in the direction into the cranium until the surface model at that location ends.

The next step is using the surface model measurement tool, which allows the user to measure any linear distance on the segmented cranium model. The distance tool also allows for any angle to be measured on the skull. These measurements are used as possible predictors in the kernel regression model. Table 1 shows a list of the 5 measurements. These skull landmark distance measurements can be used to help differentiate between Caucasian and African American by almost 90%, based on data from the University of Tennessee's Anthropology Department. These particular measurements were chosen due to their ability to be measured easily from CT images in iMF, as well as their ability tobe measured by a forensic anthropologist physically on the skull.

Table 1 Ancestry measurments

1.	**Basion – Prosthion**
2.	**Basion – Nasion**
3.	**Orbit Height**
4.	**Nasal Breadth**
5.	**Biauricular Breadth**

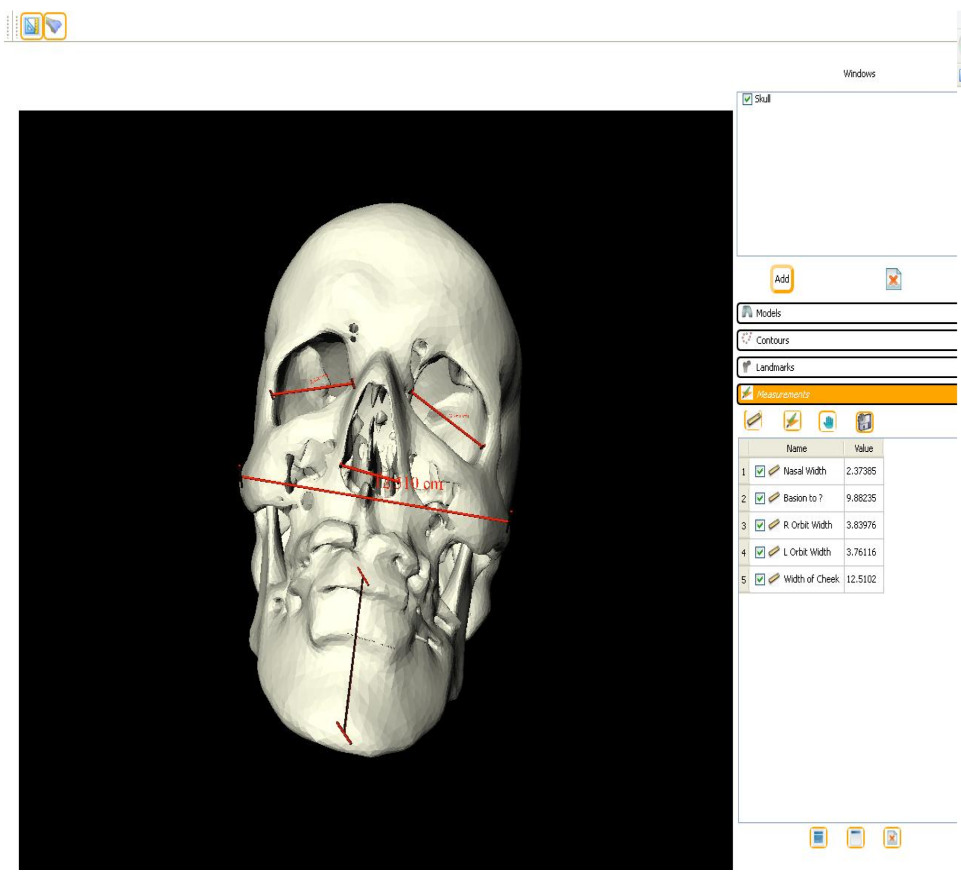

Figure 6 Ancestry measurements user interface

The first measurement is the Basion to Prosthion distance as shown in Figure 7. The next bone measurement is the Basion to Nasion distance as shown in Figure 8. The third bone measurement is the Orbit height which is the maximum height from the upper to lower orbital borders perpendicular to the horizontal axis of the orbit. Figure 9 shows the Orbit height measurement in iMF.

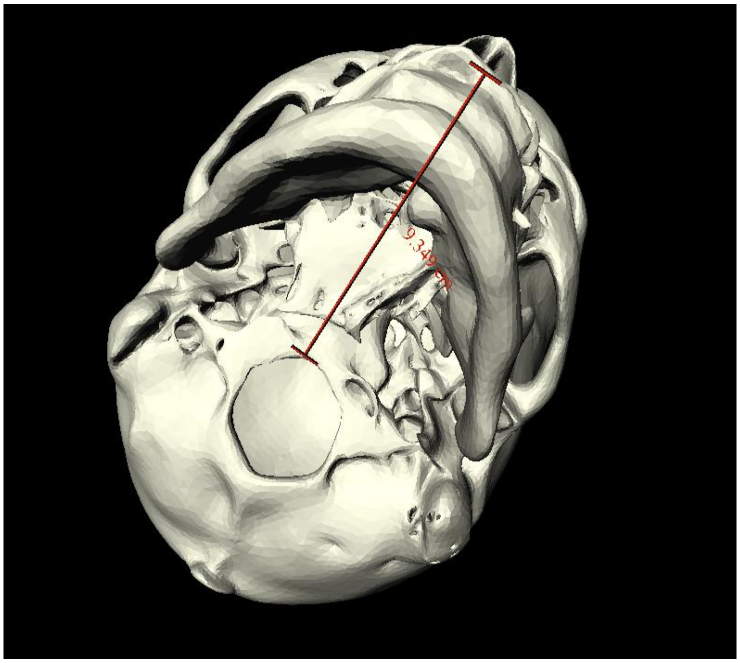

Figure 7 Basion to Prosthion distance

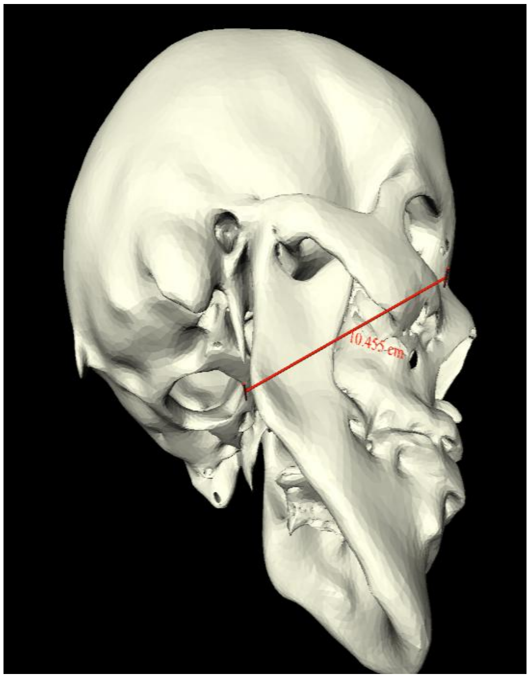

Figure 8 Basion to Nasion distance

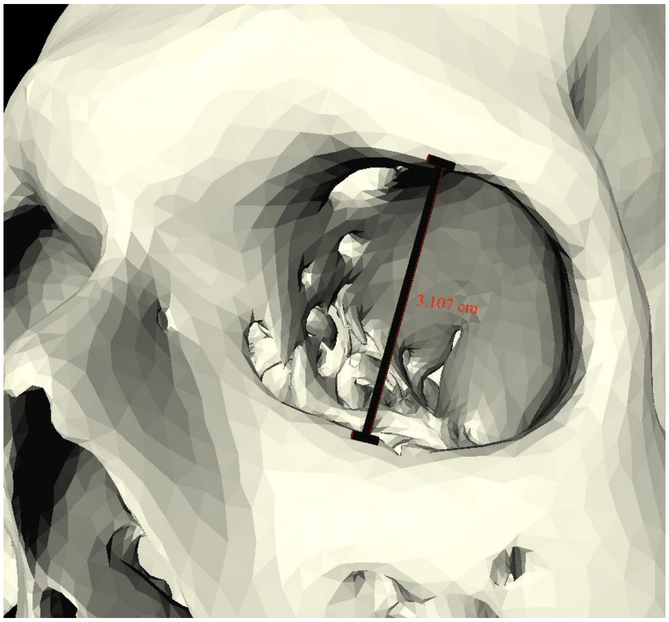

Figure 9 Orbit height

The fourth bone measurement is the Nasal Breadth. The Nasal Breadth is defined as the maximum breadth of the nasal cavity which can be seen in Figure 10.

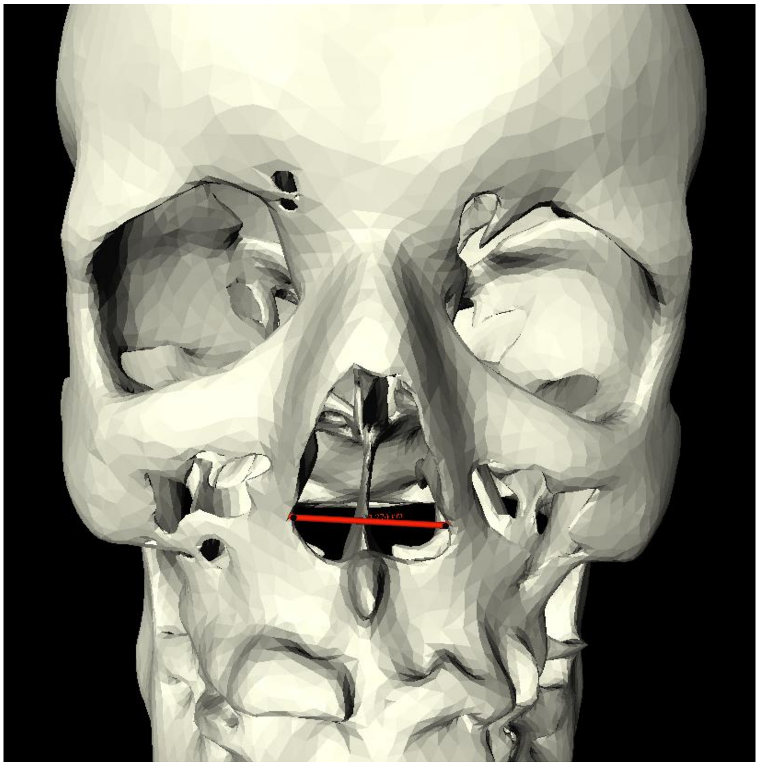

Figure 10 Nasal breadth

The fifth and final bone measurement is Biauricular Breadth. This distance is defined as the least breadth across the roots of the zygomatic processes, which is the porion landmark. The porion landmarks are located just above the ear openings on each side of the skull. Figure 11 shows the measurement in iMF.

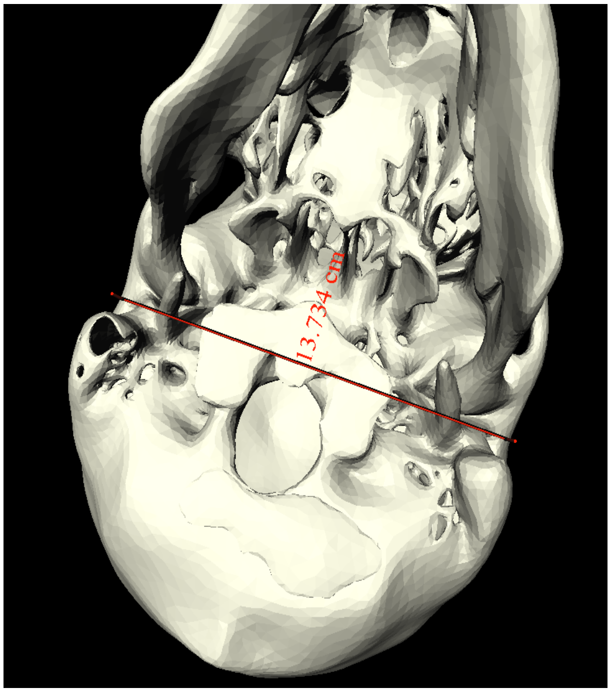

Figure 11 Biauricular breadth

Upon completing the measurements and point localization for bone thickness, pressing the "Predict soft tissue" button in the toolbar area displays the results of the predicted soft tissue thickness from the kernel regression model at the localized locations. These soft tissue thicknesses can be used instead of the table data to build a clay model for the deceased's skull.