Standardization of head orientation according to the Frankfort horizontal and midsagittal plane

1) Purpose

To get familiar with the concept of standardization of head orientation, and to carry out such a standardization on a facial surface scan.

2) Introduction

Standardization of skull orientation (e.g. for craniometry or roentgencephalometry) is traditionally carried out relative to the so-called Frankfort horizontal plane (FHP) and the midsagittal plane (MSP). The FHP is a plane through three points in the normal skull: the upper margin of the opening of the left and right external auditory canals and the lowest point on the lower margin of the left orbit. The MSP is a plane that divides a normal head into left and right halves. In practice, the MSP is often defined as the plane passing through the midpoint between the ear points used for the FHP determination, and being perpendicular to the FHP. A standard orientation of a skull according to this system involves rotating the skull such that the MSP is vertical and the FHP is horizontal. In addition, the MSP is oriented in space, typically such that the skull is facing in the direction of one of the Cartesian coordinate axes. Modifications to this system may be made in special cases. Such modifications include using the right orbit instead of the left if the right orbit is abnormal, or an average of left and right orbits if both sides are abnormal. Figure 1 shows an illustration of the standard orientation of a surface representation of a skull from a CT scan of a head. In the case of a surface scan of a head, where the bone structure is not readily identifiable, a modified FSP may be defined using soft-tissue ear points and e.g. nasion or the tip of the nose (or an average of these two) instead of the lower orbit point. A similar system may be defined in other body parts, e.g. in the mandible using e.g. condyle points and symphysis. In mouse skulls, a similar reference system may also be defined.

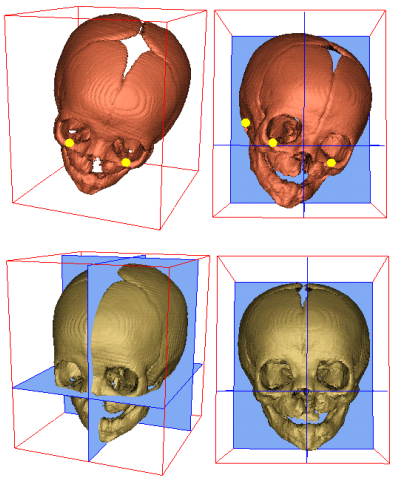

Figure 1. Illustration of the standardization of the orientation of a skull surface according to the FHP/MSP system. Upper two images: Before orientation. Yellow dots indicate location of landmarks used for orientation. Lower two images: After orientation.

One way of carrying out the orientation correction is to first define the three landmarks used for the definition of the MSP and FHP planes in a target coordinate system, and then to determine the rigid transformation needed in order to make the original landmarks (in the source coordinate system) coincide with the new target landmarks. Finally the transformation is applied to the skull. The situation is illustrated in Figure 2. In the figure, pR, pL and o represent the three landmarks: right ear, left ear and orbit, respectively. pR', pL' and o' are the same landmarks after drawn in a target coordinate system. The target coordinate system is here chosen such that the three landmarks fall in the z-y plane (defining the FHP), with the left ear point at a larger x-coordinate than the right ear point, and the orbit point at a smaller y-coordinate than the ear-points (the skull facing negative y direction). The construction of the target landmark coordinates may be carried out as follows: 1) The midpoint between pR and PL (m) is determined. 2) dm is computed as half the distance between pR and pL. 3) pR' = [m_x-dm, m_y, m_z], 4) pL' = [m_x+dm, m_y, m_z], 5) di is computed as the perpendicular distance from o to the line between pR and pL. 6) p is determined as the closest point on the line pR-pL from o. 7) di2 is the distance between pR and p. 8) o' = [pR_x+di2, m_x, m_z].

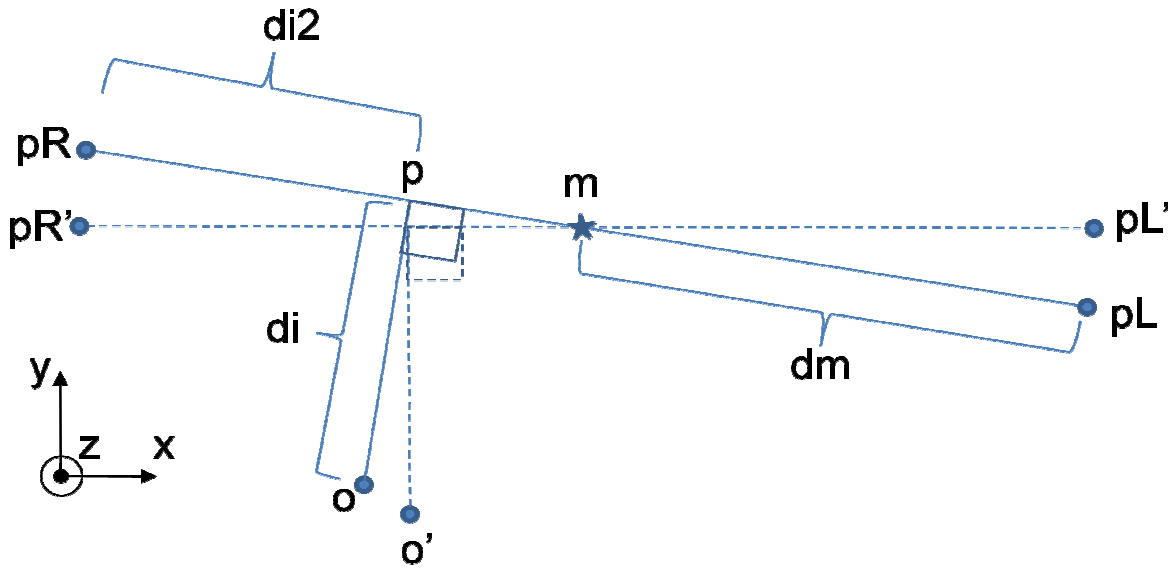

Figure 2. Illustration of landmarks and coordinate systems used for standard orientation of a skull.

3) Standard orienting a single face surface by use of the menus

Start landmarker and load a surface: File->Load(New)->SurfaceFile
(choose e.g. the file named tron.vtk)

Set four landmarks as follows (see Figure 3) (see Box 1 about how to set landmarks)

Landmark no.	Location
0	right ear
1	left ear
2	nasion
3	tip of nose

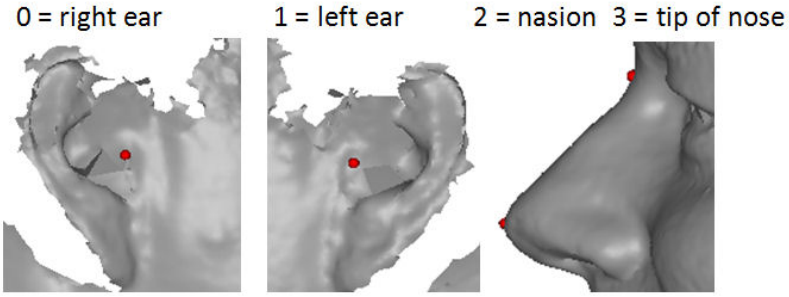

Figure 3. Illustration of location of the four landmarks.

To set landmark no.0: click left mouse in surface window, move cursor to the desired landmark location, then press keyboard "p". Wait until a red sphere appears. Change the location by moving cursor and pressing "p" repeatedly until satisfied.
To set landmark no.1: move the "Landmark #" slider to position "1", then repeat the above step.

Box 1. Manual landmarking in landmarker.

Carry out the orientation: Edit->StandardOrientFace
This will open up the Standard Orientation Menu (Figure 4).

Press "Compute Transformation".
Press "Transform Landmarks" and see what happens in the surface window.
Press "Transform Surface" and see what happens in the surface window.
You can use the adjacent "Undo" buttons and then carry out the transformations again etc.

Figure 5 illustrates the process.

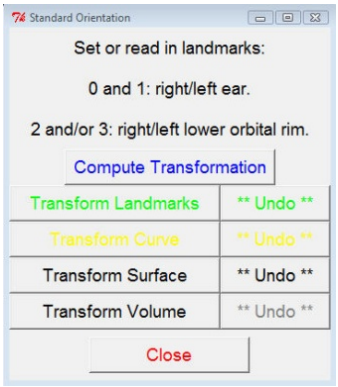

Figure 4. The Standard Orientation Menu.

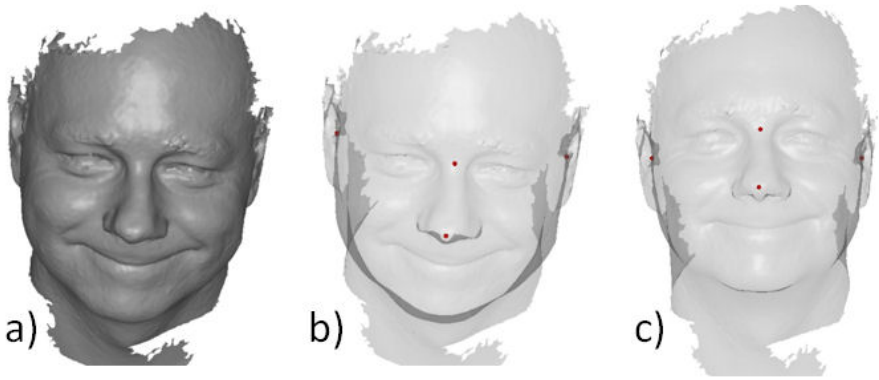

Figure 5. a) Surface before orientation. b) Transparent surface with four orientation landmarks. (To change surface transparency: Settings->SurfaceColor and change the Opacity slider.) c) After orientation. Note that ear landmarks now fall on a horizontal line (they have the same y-coordinate). Note also that the mid-point between nasion and tip of nose also fall on the horizontal line between the ear points.

Save the oriented surface: File->Save->Surface (choose a name; e.g. tron_ori.vtk)
(Make sure you select *.vtk in the "Save as type:" entry.)
(Note: you have to type the extension (.vtk) in the "File name:" entry.)

Exit landmarker: File->Exit