A Tutorial on

Computation of Face Asymmetry in *landmarker*

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Purpose: Computation and visualization of the asymmetry of a surface scan of a face.

Requirements:
- *landmarker* version 2.0.4 (or higher) running on Microsoft Windows computer platform.
  (Go to http://www.lab3d.odont.ku.dk/landmarker/download_landmarker.html to download and install *landmarker*)
- your surface file needs to be in stl or vtk format.

Example computation of face asymmetry

There are two steps involved:
A. Landmarking of your face surface, and
B. Computation of asymmetry.

A) Landmarking of your face surface

1) Start *landmarker*

2) File->Load(New)->SurfaceFile

For this tutorial, choose the surface named *tron.stl* that is included in the *landmarker* distribution (Figure 1).

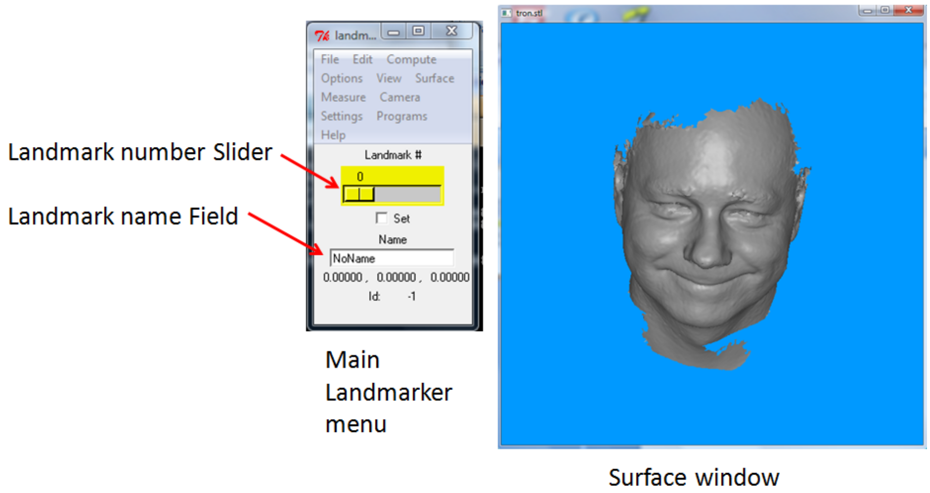

Figure 1. *tron.stl* surface file loaded in *landmarker*.

3) Set landmarks according to the landmarks shown in Figure 2 by following the 2 steps below. If you wish, you can inspect the landmarks in 3D by starting a second (simultaneous) *landmarker* application and load the surface file *face_template.vtk* and landmark file *face_template.log* (Use File->Load(New)->SurfaceFile followed by File->Load(New)->LandmarkFile)

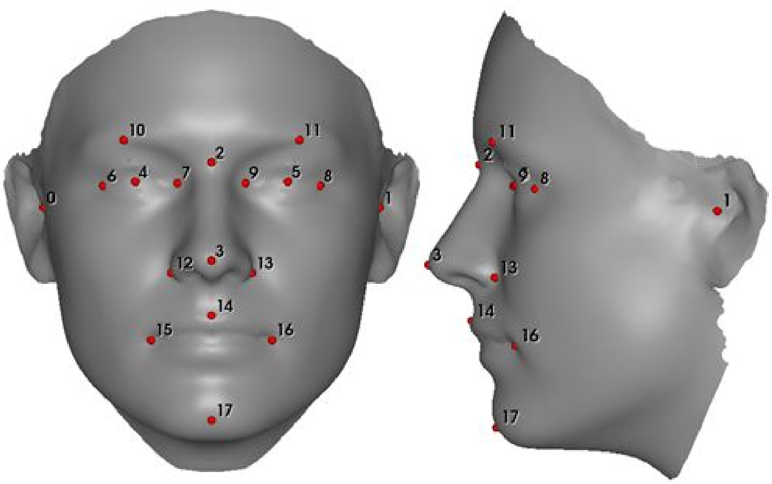

Figure 2. The "template" surface with 18 "template" landmarks. Note numbering of landmarks starting from 0.

Step 1. Load the sequence of landmark names: File->Load(New)->LandmarkNamesFromFile and select the file *face_template.log*. This will load only the names of the landmarks you are going to place. The names will appear in the Name field in the *landmarker* main menu (see Figure 2) as soon as you touch the "Landmark #" slider (see Figure 1).

Step 2. Place the landmarks.

TIP: During landmarking it is good practice to rotate and zoom in/out the surface model frequently in order to get a good 3D impression of the anatomy for optimal recognition of landmarks.

Place the first landmark (landmark number 0) by moving the landmark number slider to position 0 (unless it already is at this position), then rotate and zoom the surface to get a good view of the right ear. Point the cursor to the location where tragus and helix meets, then press keyboard character “p”. A green landmark sphere will appear on the surface underneath the cursor. Adjust the position of the landmark by repeatedly moving the cursor and pressing “p” until you are satisfied.

Place the second landmark (landmark number 1) by advancing the landmark number slider to position 1, then repeating the above procedure of placing a landmark.

Place subsequent landmarks analogously.

Save your landmarks. Finally, when all 18 landmarks have been landmarked, save the landmarks in a landmark file: File->Save->LandmarkFile (save it as tron.log). (Note that you MUST specify the .log extension in the FileSave dialogue.) (If you are unable to landmark a particular landmark (e.g. due to noise/missing data in a part of your surface) you just skip this landmark.)

After you have saved your landmarks, close the *landmarker* application.

B. Computation of asymmetry

1) Start a new *landmarker* application.

2) Load your surface and the landmarks you saved above in part A.
File->Load(New)->SurfaceFile (select tron.stl)
File->Load(New)->LandmarkFile (select tron.log)

3) Open the Face Asymmetry menu:
Compute->Face Asymmetry
The menu is shown in Figure 3 (some help appears if you press Help->ShowHelp)

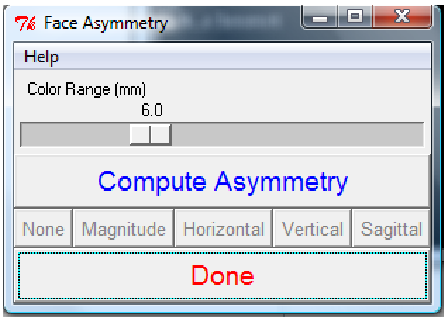

Figure 3. The Face Asymmetry Menu

4) Press the “Compute Asymmetry” button.

This will do three things to your surface:

I. The surface (tron.stl in the example) is aligned in a least-squares manner to a fully symmetric landmark configuration (it can be found in the file face_template.log) and is shown in Figure 2). (The aligned surface will be written to disk as tron_ori.vtk and tron_ori.log.) An image of the aligned dataset is also saved: tron_ori_front.jpg (this is shown in Figure 4).

Figure 4. The aligned surface and landmarks.

II. The symmetric template surface (seen in Figure 2) is deformed to the input surface (tron.stl) by use of thin-plate-splines (TPS) guided by the landmarks, followed by closest point deformation.

[The deformed template surface can be found in the file named tron_template_tps_cp.vtk). An error estimate of the matching is provided in the file tron_template_tps_cp_clr.clr which is an ASCII text file listing errors (closest point distance between deformed template and the original surface) in mm. It may be loaded as a surface color file on top of the deformed template: File->Load(New)-> SurfaceFile-> tron_template_tps_cp.vtk followed by File->Load(New)->Color(.clr)File.]

Images of the error are also saved: tron_template_tps_cp_front.jpg, tron_template_tps_cp_left.jpg and tron_template_tps_cp_right.jpg (Figure 5).

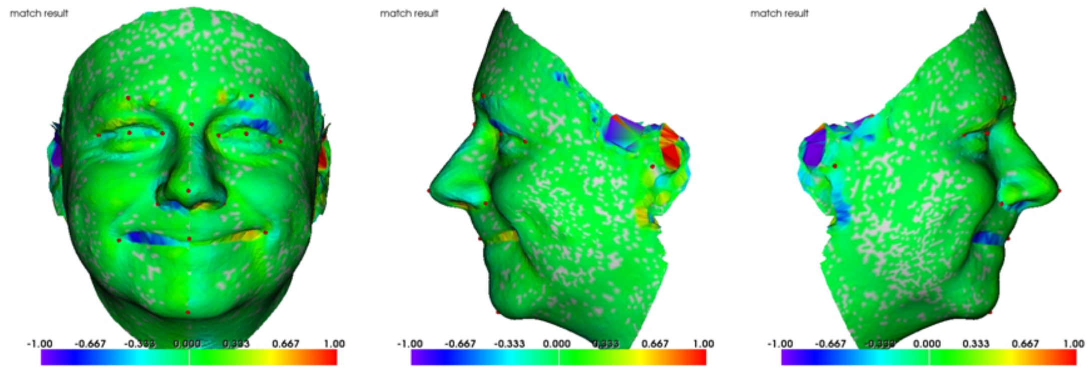

Figure 5. Spatial distribution of matching error (in mm). Range is from -1 to 1 mm. White and green indicate very small error.

III. Asymmetry computation. The template is constructed in such a way that there is detailed point correspondence between left and right side of the face. This information about left-right correspondence is carried along to the surface under study by means of the template matching. Asymmetry is computed based on the knowledge of point correspondence, and is defined in the following way: The amount of asymmetry **A** is the length of the 3D vector from a point on the right side of the face to the anatomically corresponding point on the left side of the face, after a mirroring across the mid-sagittal plane (MSP) has been carried out. (Note here that the MSP is defined in terms of the orientation procedure described under I above.) The definition of asymmetry is illustrated in Figure 6.

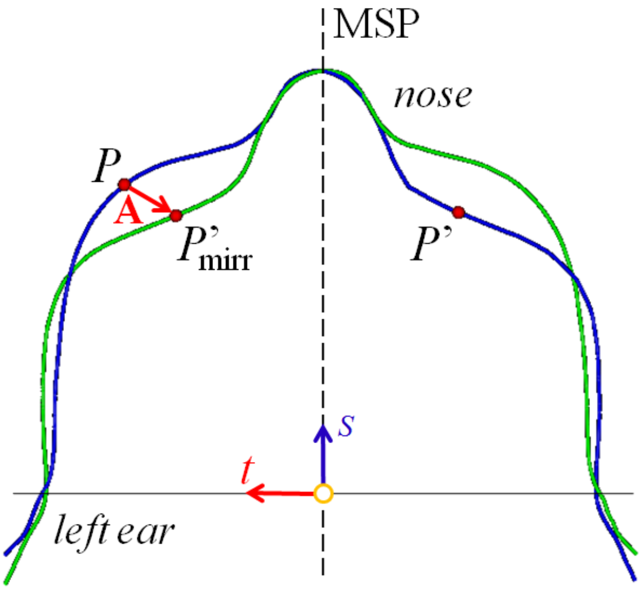

Figure 6. Schematic illustration of the definition of asymmetry used in the Face Asymmetry program. The blue outline represents an axial cross-section through an asymmetric face at the level of the nose. *t* and *s* indicate the transverse and sagittal directions, respectively, drawn as arrows from an origin halfway between the ears. *P* marks a point on the left side of the face, *P'* marks the anatomically corresponding point on the right side of the face. The green outline is the same cross-section after the face has been mirrored across the MSP (dashed line). P'_{mirr} marks the location of P' after the mirroring. The asymmetry **A** is defined as the vector between *P* and P'_{mirr}. The template deformation process assures that *P* and *P'* are anatomically corresponding points on the left and right side of the MSP, respectively.

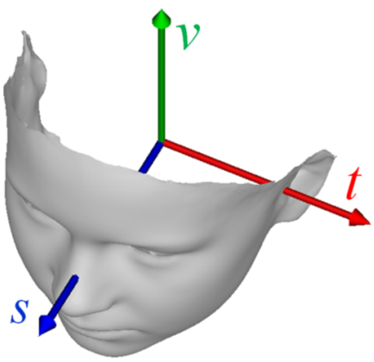

Figure 7. Coordinate system used in the determination of asymmetry. The coordinate axes t, v and s coincide with the Cartesian coordinate axes x, y and z, respectively, and represent the transverse, vertical and sagittal directions in the face.

The asymmetry is computed in terms of the amount of asymmetry (length of the vector), as well as the x-, y- and z-components of the vector (determining the asymmetry in the transverse, vertical and sagittal directions, respectively; Figure 7).

The result is presented in 3D as color coded asymmetry shown on the deformed template. You may rotate, zoom and inspect the result (Figure 8). When the computation is finished, the face is shown in 3D and color coded according to the amount of asymmetry. Note that the negative and positive asymmetry values (blue and red colors) are used on the right and left side of the face, respectively (this highlights the location of the MSP).

You can switch between the different types of asymmetry by pressing the buttons in the Face Asymmetry menu (Figure 8).

You may probe the actual asymmetry values by pointing to a location on the surface and pressing keyboard character ‘p’, then the probed asymmetry value appears in the Main Menu (Figure 8).

You may change the range of the color display by moving the “Color Range” slider, then pressing one of the buttons (Figure 8).

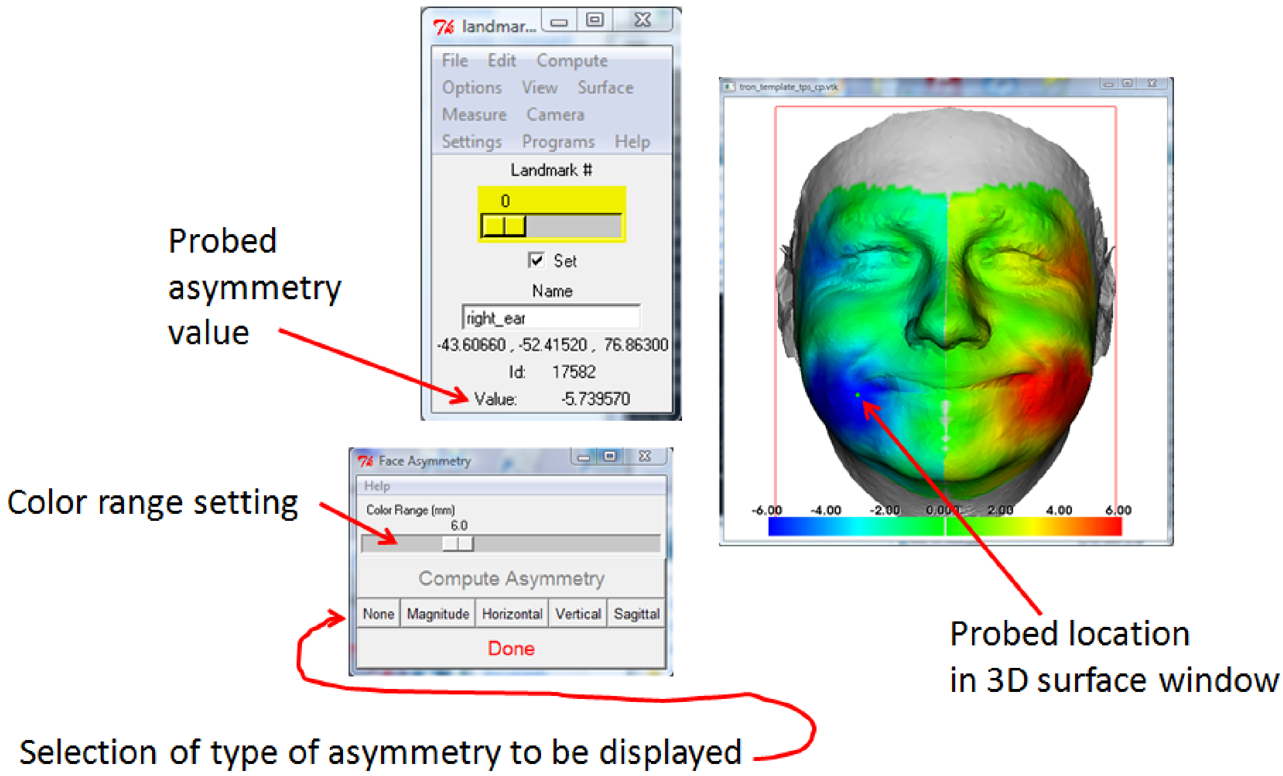

Figure 8. Display of the result of the asymmetry calculation.

The asymmetry results are saved as .clr files (that may be loaded in landmarker on top of the surface at a later time). The color files are named as follows: tron_template_asy_ho_a.clr, tron_template_asy_ho_x.clr, tron_template_asy_ho_y.clr and tron_template_asy_ho_z.clr, where the letters a, x, y and z indicate the amount as well as directions of the asymmetry.

In addition, snapshots of the asymmetry results are saved as jpg images. These are displayed in Figure 9.

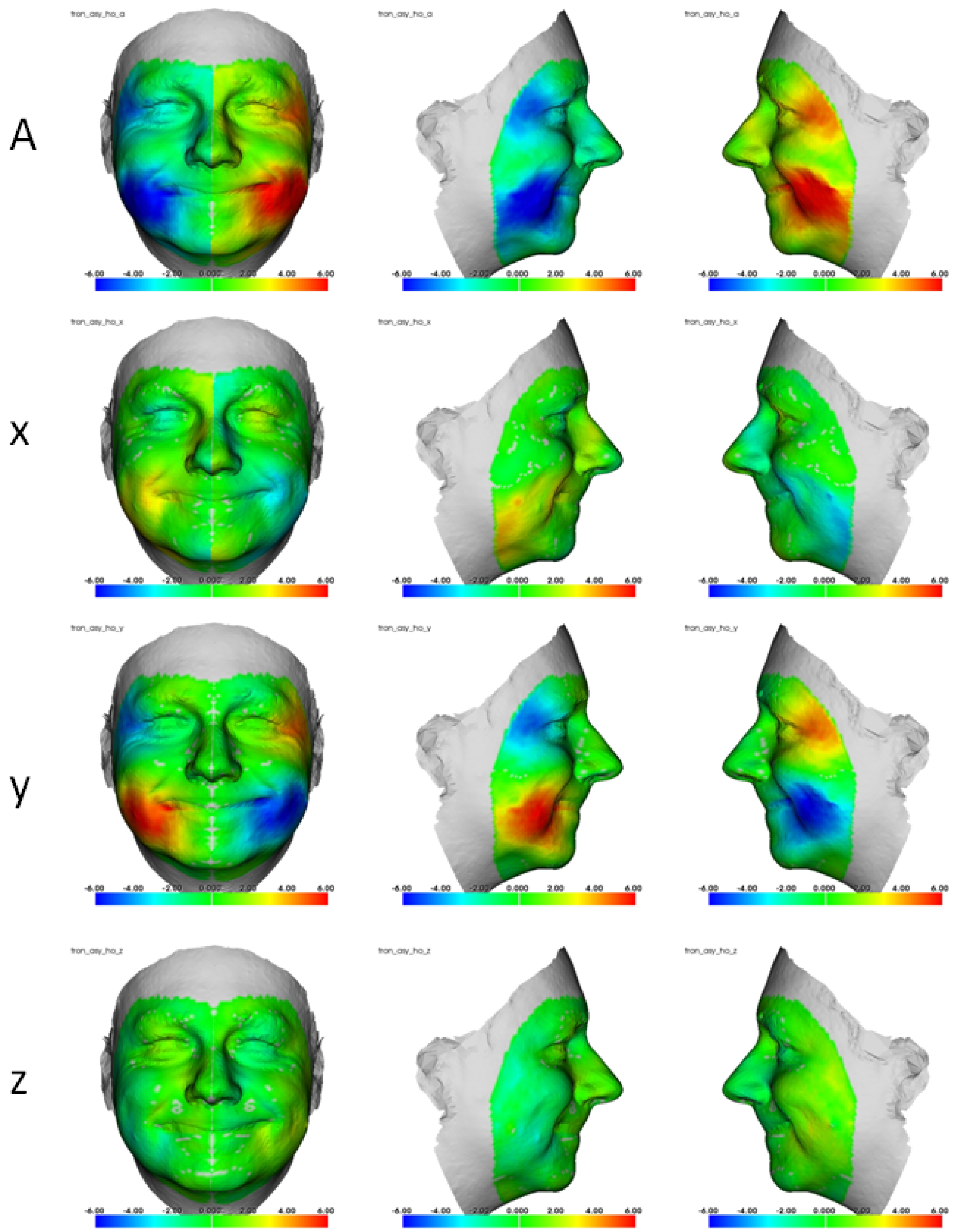

Figure 9. Asymmetry results. x-, y- and z-components correspond to asymmetry in the transverse, vertical and sagittal directions, respectively.