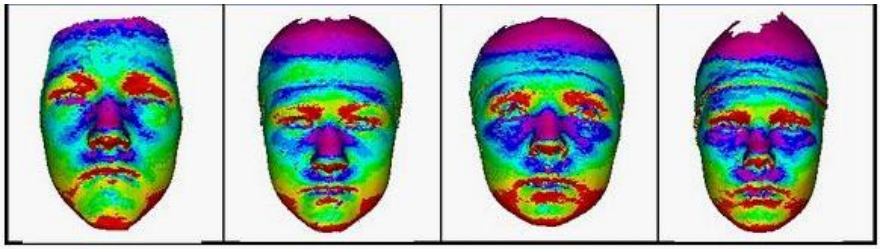
Technology Project: Shape-Based Retrieval of 3D Craniofacial Data



PI: Linda Shapiro, Ph.D.

Key Personnel: James Brinkley, M.D., Ph.D.,
Michael Cunningham, M.D., Ph.D.,
Carrie Heike, M.D., Timothy Cox, Ph.D.
Harry Hochheiser, Ph.D.

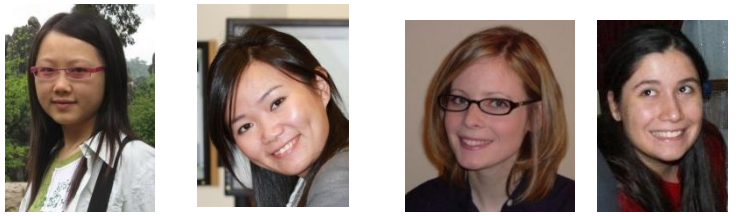
Postdoc: Ravensara Travillian, Ph.D.

RA: Shulin Yang, MS

RA: Jia Wu, MS

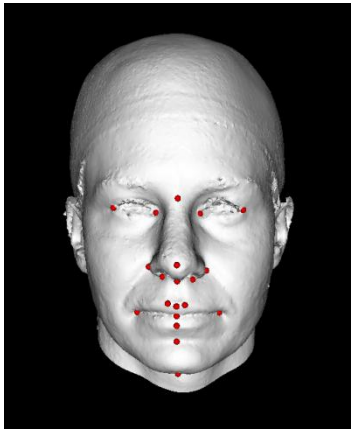
RA: Sara Rolfe, MS

RA: Ezgi Mercan

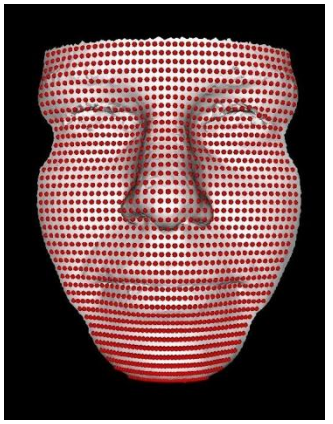


Aims

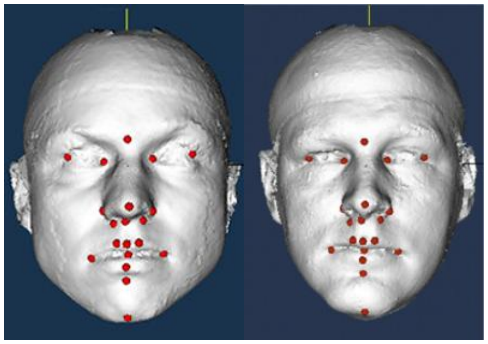
- Software tools for craniofacial analysis (we have lots of these; available in CranioGUI)
- Quantification of similarity between faces (we use distance measures)
- Organization for retrieval (using Diamond)
- Prototype system for similarity-based retrieval (under development)



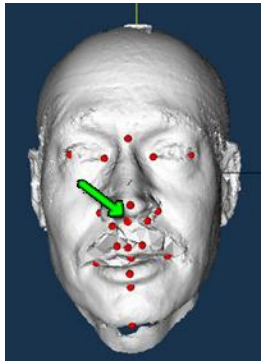
Result 1: Pseudo-Landmarks



- New *fully-automatic* method for computing pseudo-landmarks on 3D meshes
- Experiments run on Seth Weinberg's Facial Norms Database comparing gender classification results on
  - Seth's hand-labeled anatomical landmarks
  - our pseudo-landmarks at different resolutions (automatic)
  - Hutton/Hammond dense pseudo-landmarks (requires hand labeling and correspondence)
  - Claes pseudo-landmarks (requires hand labeling and correspondence)
- Pseudo-landmarks in general classified better than landmarks and our method is much faster than the others
- Paper accepted for IEEE Eng. in Medicine and Biology



Result 2: Autolandmarking

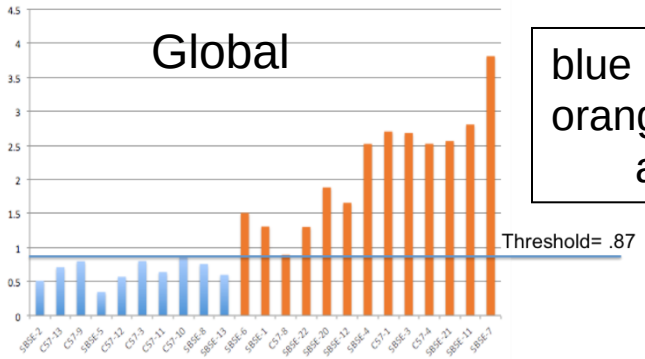


- Method for automatically detecting an arbitrary number of anatomical landmarks on a 3D face mesh.
  1. Geometric method finds an initial set of 17 landmarks on the target mesh.
  2. These are used to initialize a deformable matching method from a template mesh to the target mesh.
  3. Using the resultant correspondence, the required landmarks are transferred from the template mesh to the target mesh.
- Experiments were run on 115 3D facial meshes of normal adults from Seth Weinberg's Facial Norms Database.
- Our method has an average error of 2.64 mm over the 115 heads and is superior to prior published methods in the literature.
- Paper accepted for IEEE Eng. in Medicine and Biology

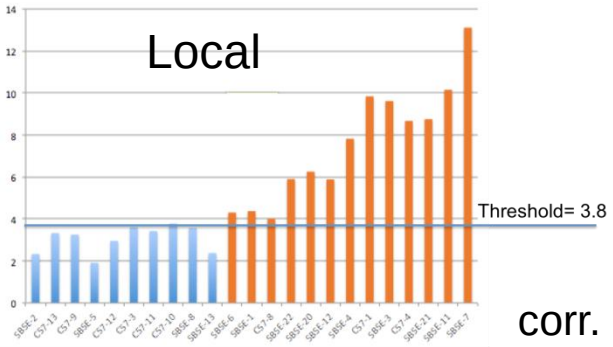
Result 3:Shape Analysis through Optical Flow Vectors

- New tool for characterizing and quantifying the asymmetry in bilaterally paired structures.
  - Deformable registration produces a dense vector field correspondence
  - Deformation vectors have properties: deformation vector magnitude and the cosine distance between the deformation vector and the surface normal vector.
  - Vectors are clustered to detect regions of asymmetry
- Applied it to the two sides of the mandible of the mouse.
- Asymmetry scores compared to human expert (order=ranking)

our score = height



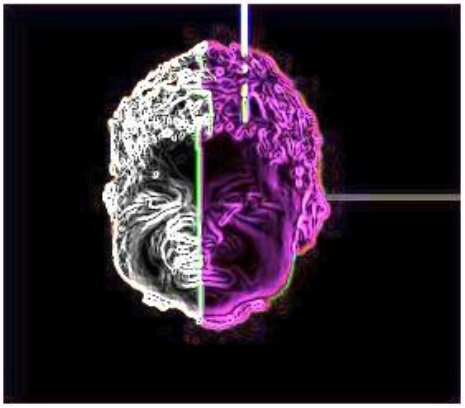
blue = normal
orange = abnormal



corr. = .92

corr. = .91

- Paper accepted for IEEE Eng. in Medicine and Biology
- Current work on chick embryo images: multiple ages, w/wout cleft



Ongoing: Analysis of Cleft Subjects

- Ongoing cleft study with Dr. Raymond Tse and Dr. Carrie Heike at Seattle Children's Hospital.
- 49 3dMD images (9 bilateral, 35 unilateral, 5 control)
- Ongoing evaluation of our symmetry plane finder (published last year)
- Once plane of symmetry is found, our grid-patch method quantifies differences in left and right sides based on radius, angle and curvature.
- Initial experiments to classify left vs. right unilateral clefts are 100% accurate.
- Final year's work is on investigating other computable features of clefts.

Ongoing: Content-Based Image Retrieval

- Developed a web application for content-based retrieval of 3D face meshes using Satya's Diamond system from CMU (part of HUB).
- Adding features to the system (automatic landmarks, pseudo-landmarks) so we can run multiple kinds of retrievals in controlled tests.
- Plans to test features in a face retrieval task that will involve whole-face and facial-feature similarity, using Seth Weinberg's Facial Norms Database.
- Will have 2 kinds of evaluation
  - human evaluators (limited due to IRB)
  - comparison to retrievals using computationally expensive dense correspondence method with Procrustes distance.

Ongoing: CranioGUI

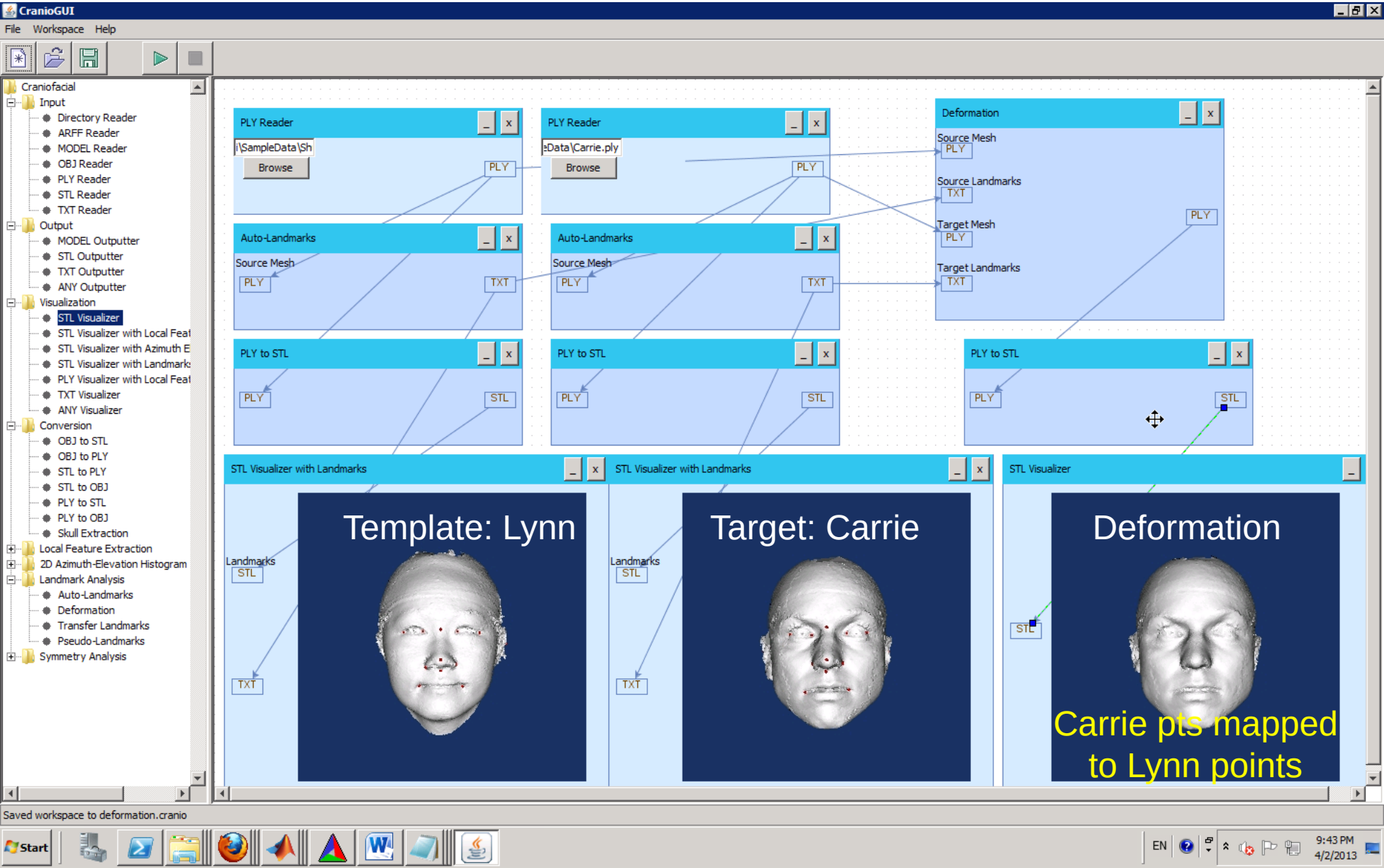
- We developed CranioGUI to allow people to try our software without downloading and in an interactive environment.
- It runs on our server in client-server mode; users can upload their own images and download results.
- We've added a page of source code in the same tree structure as the CranioGUI modules, so users can take the source code of modules they want (but the VTK library is required; we can help you with that).
- We've added multiple new modules
  - some specifically for those of you who wanted points
  - some that produce our more advanced features

New Modules

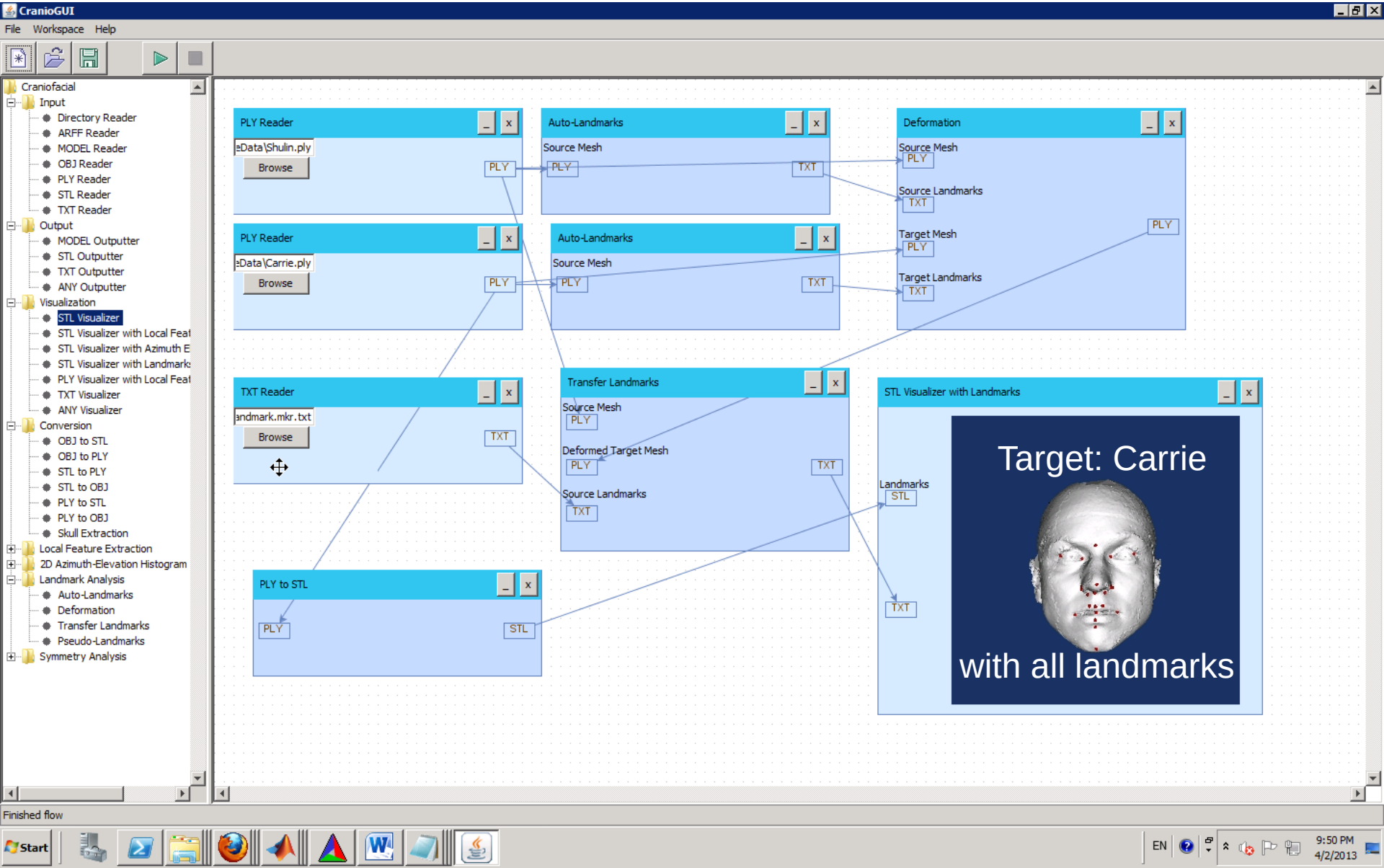
- PLY reader, PLY visualizer, STL-PLY and PLY-STL conversion (needed for some modules)

- Landmarks
  - Automatic landmarks from geometry (finds 17)
  - Deformation (maps target image to a template image using the automatic landmarks)
  - Transfer-Landmarks (transfers 24 landmarks from the template to the target)
  - Pseudo-Landmarks

Autolandmarking and Deformation Modules



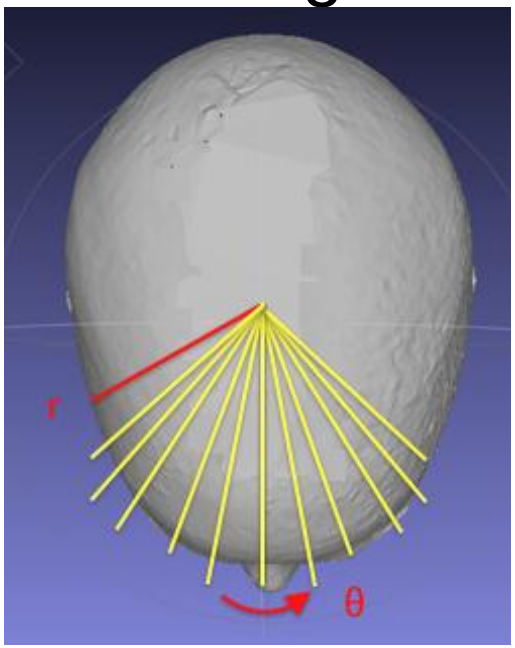
Transfer of Anatomical Landmarks: Template to Target

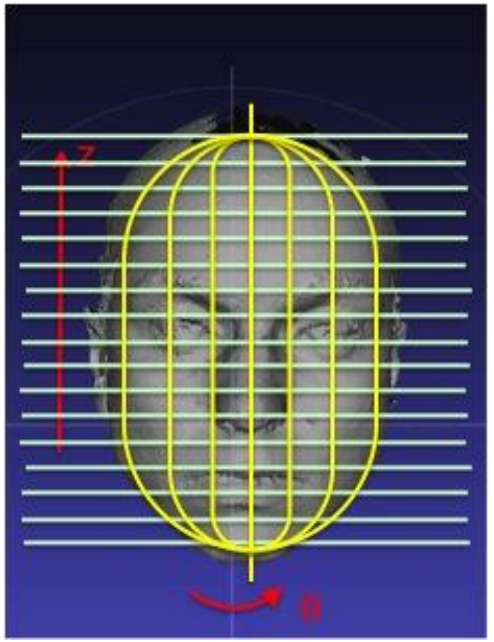


New Modules

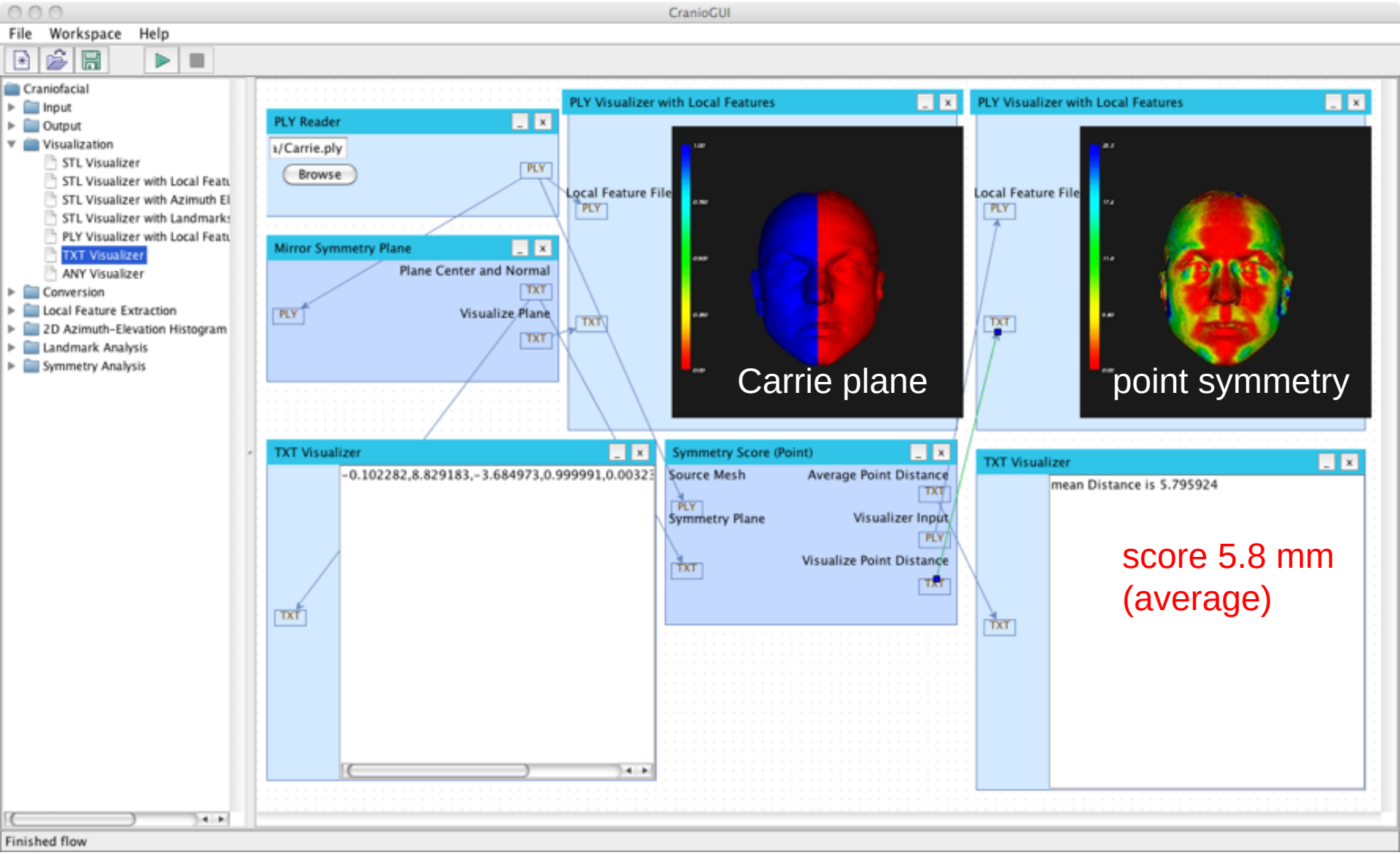
- Symmetry
  - Mirror symmetry plane
  - Symmetry score from points
  - Symmetry score from grid cells
    - Radius
    - Angle

    (between surface normal vectors)
    - Curvature

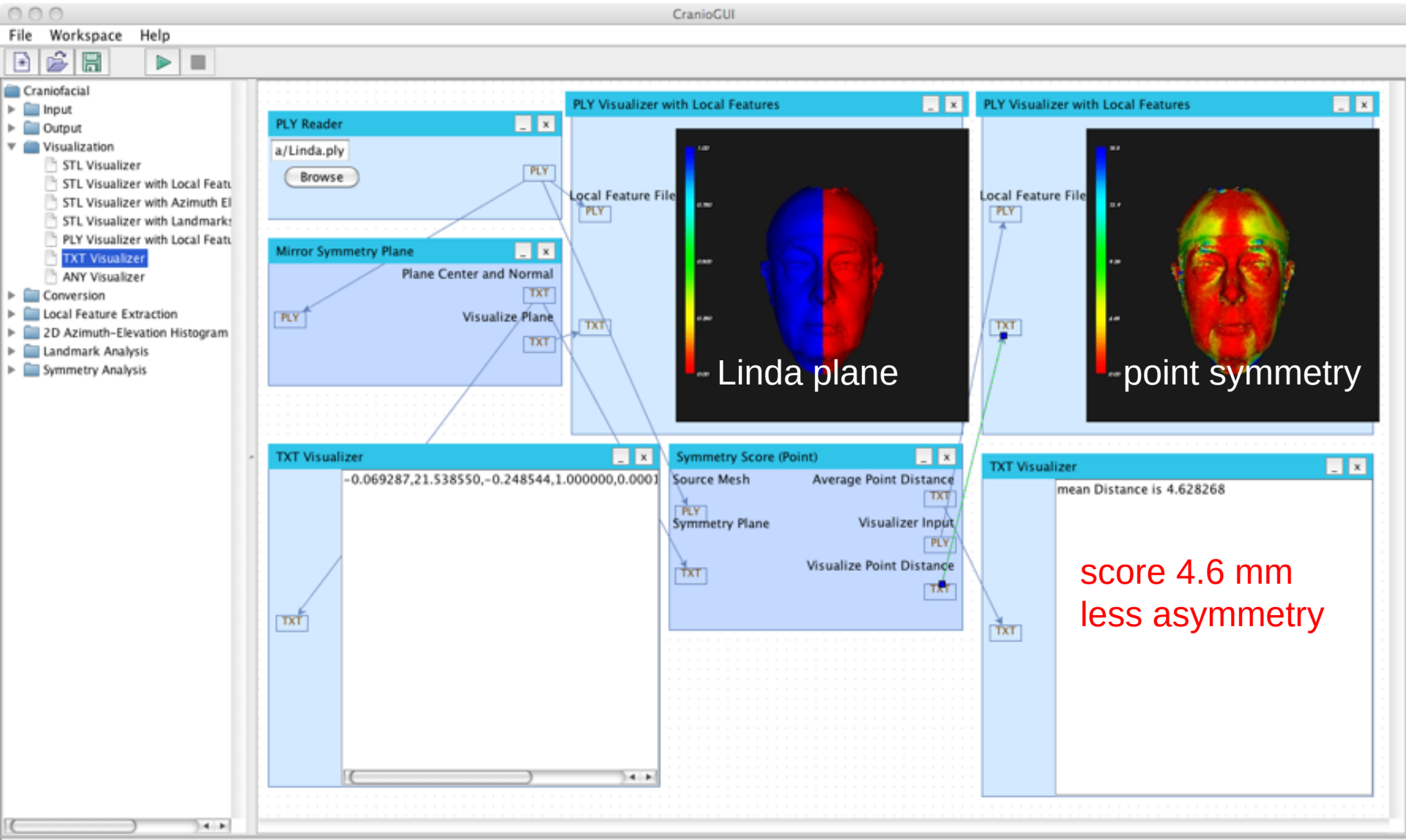




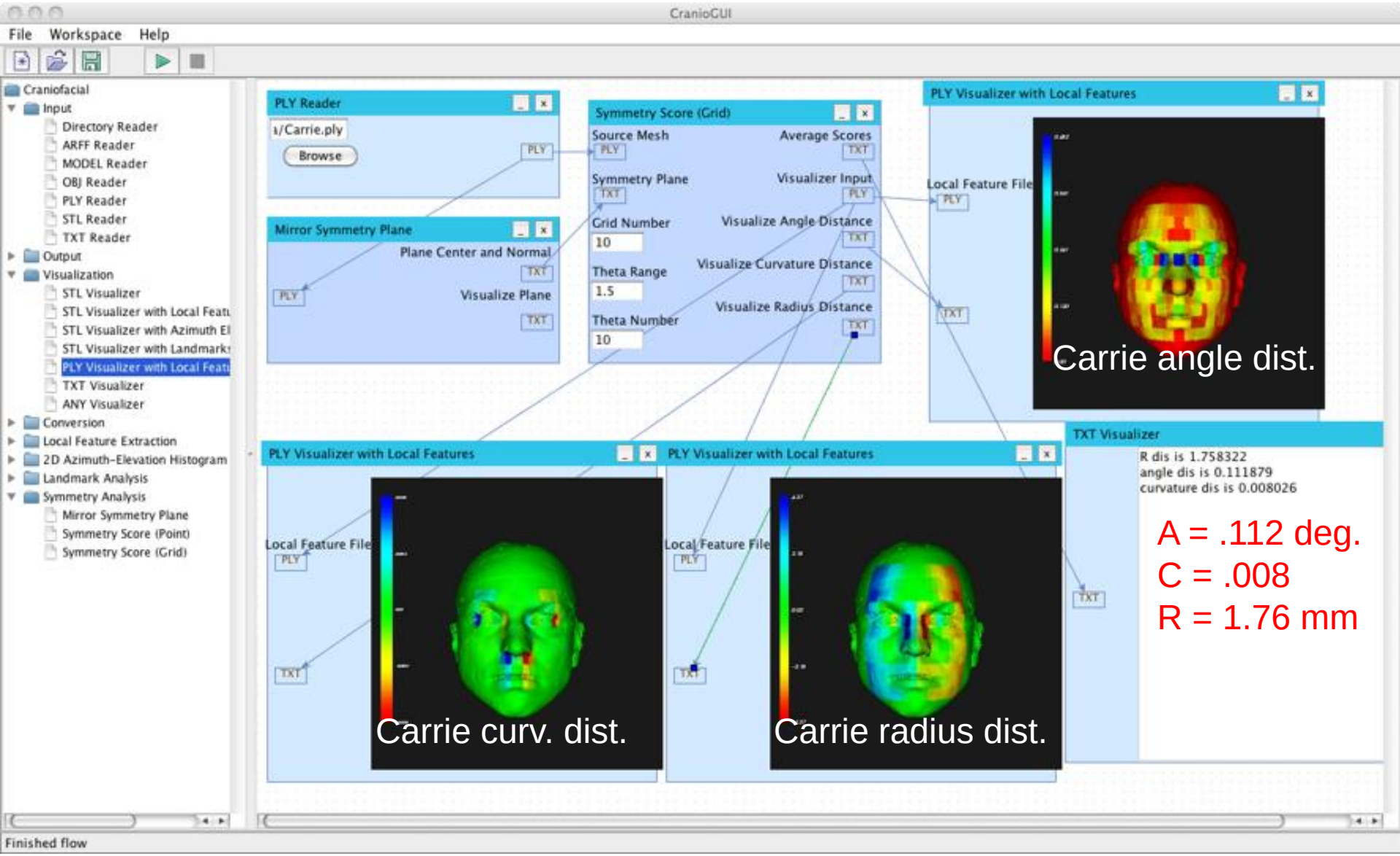
Symmetry Plane and Symmetry Score from Points



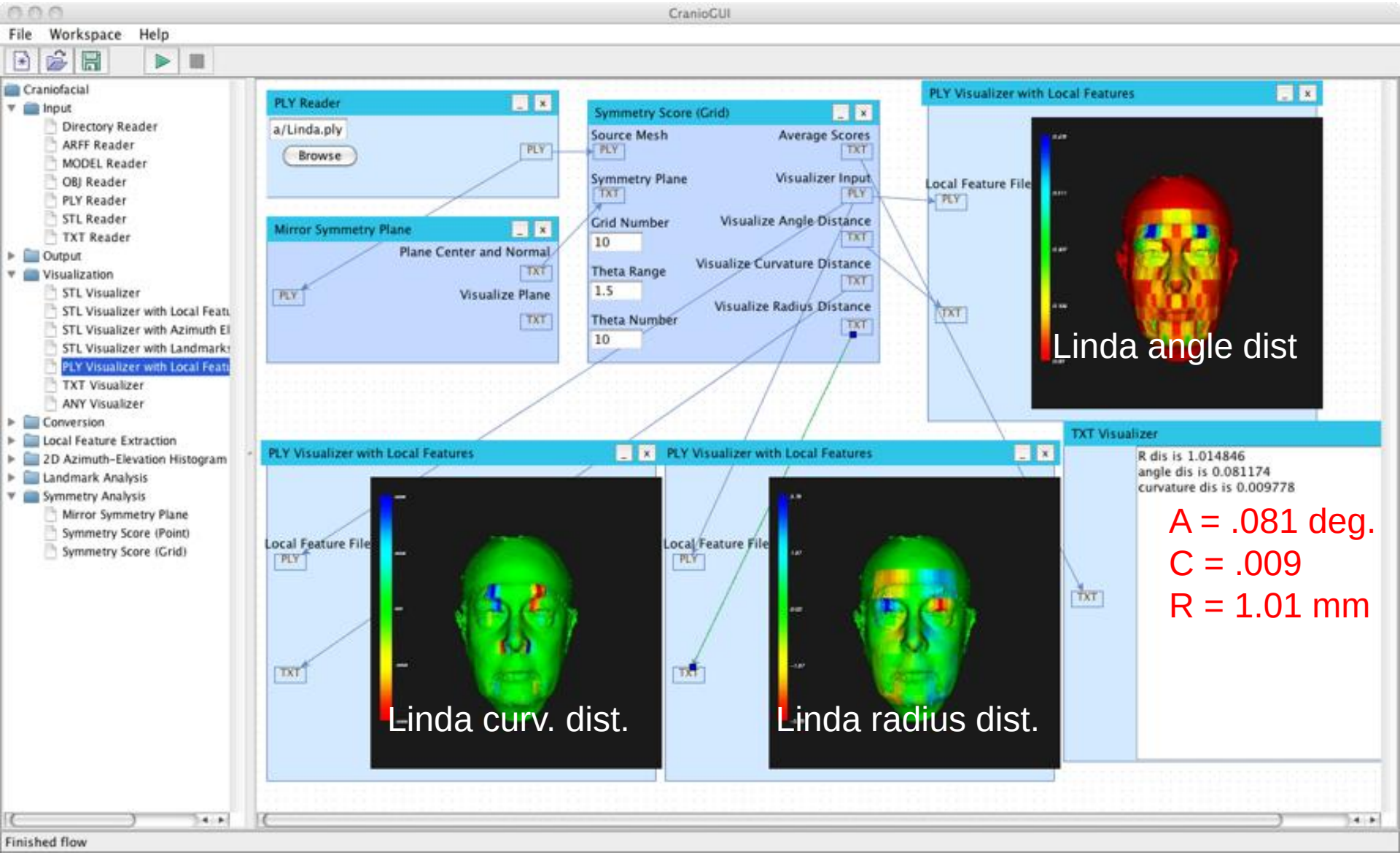
Symmetry Plane and Symmetry Score from Points



Symmetry Plane and Symmetry Score from Grid Cells



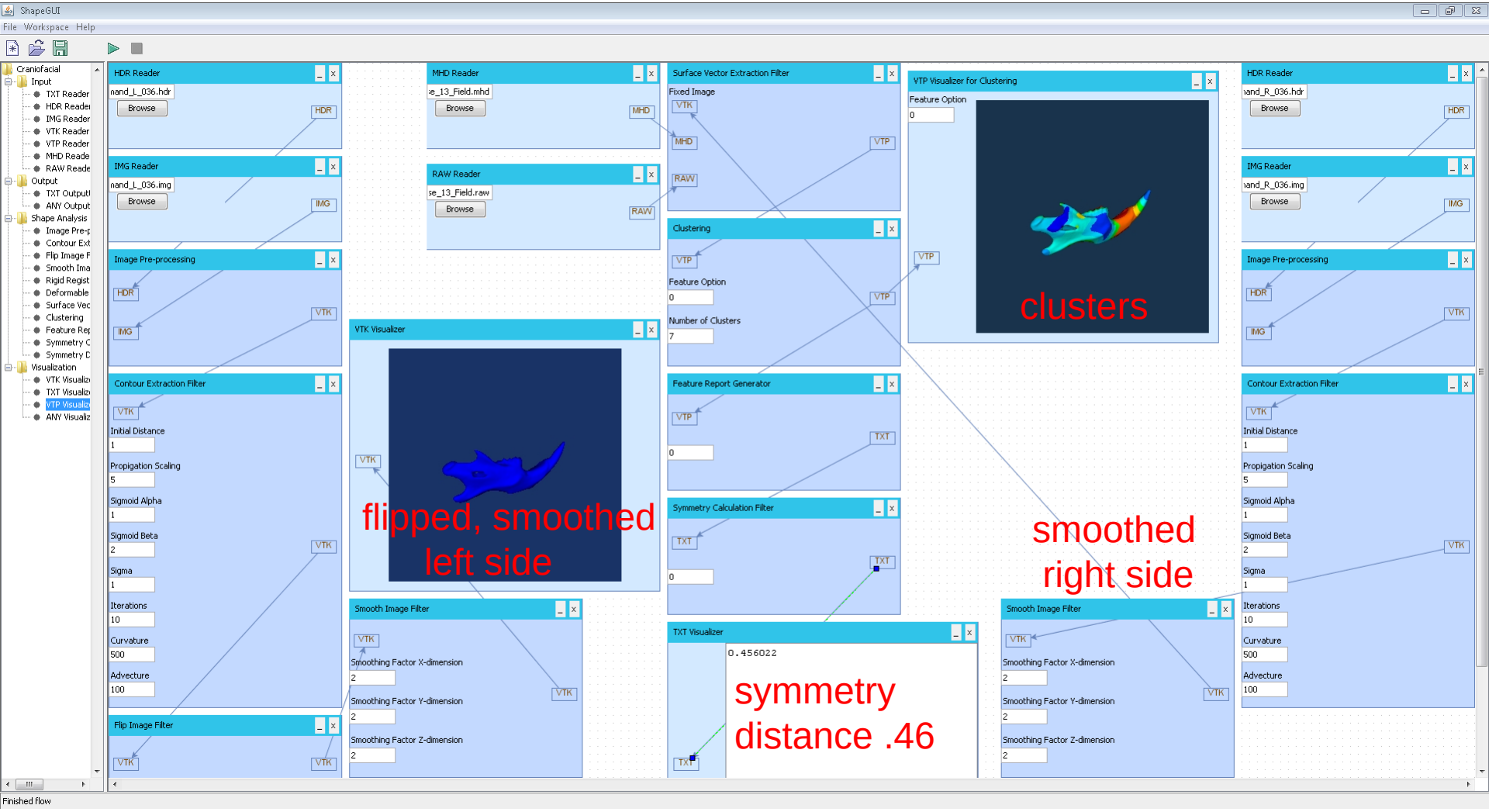
Symmetry Plane and Symmetry Score from Grid Cells



ShapeGUI

- A new GUI to show a separate set of modules for our animal (chicken and mouse) work.
- Data comes from micro-CT scans.
- Current demo is on mouse mandible data.
- Has modules from low-level preprocessing and smoothing through registration and comparison through deformation vector analysis.

Comparing Left and Right Sides of a Mouse Mandible



Supplement: Ontology of Craniofacial Development and Malformation

- OCDM use cases have been extended, re-categorized, and cross-linked for comparison and extraction of common themes. https://www.facebase.org/ocdm/wiki/use-cases
- Workflow has been established for creating and exporting OCDM content. OWL file is used for queries. Modules and queries will be covered by Jim Brinkley.
- Content on adult human and mouse, developing human and mouse, malformations of human and mouse, and some mappings between them have been created.
- A web client for visualization of the OCDM has been developed and is under continued improvement. https://www.facebase.org/content/ocdm.