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

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Two Talks in One

• Parent Grant:
  3D Image Analysis and Retrieval
  (Shapiro, Brinkley, Cunningham)

• Supplement:
  Ontology of Craniofacial Development and Malformation
  (Shapiro, Brinkley, Cunningham, Cox, Heike, Hochheiser)
Analysis of Overall Head/Face Shape via Cranial Image (Distance Matrix)

- skull version: used in severity-based retrieval and pre/post-op comparisons: ongoing
- new face version: developed for analysis of midface region(s)
Analysis of Cleft Subject Data

Finding the midsagittal plane using landmark learning.

Current study to evaluate automated midsagittal plane placement

- 40 subjects (29 unilateral cleft, 6 bilateral cleft, 5 control)
- Experts will view results of plane placement from multiple views and rate the quality of plane placement
- Experts will rate the severity of each cleft for future ground truth
Grid-patch-based Asymmetry Quantification

• Once the midsagittal plane is computed, asymmetry can be quantified by looking at means of differences in local features over grid patches on the left and right sides of the face.

• Next work will be on describing and quantifying severity of clefts.

curvature score with patch:  .51
curvature score without patch: .02

score=mean curvature difference
Mouse Mandible Symmetry

SBSE-2
Asymmetry score 6.87

SBSE-7
Asymmetry score 41.43

- This methodology was developed for analysis of the midface.
- It is being tested on mouse mandibles to provide quantitative assessment and to show its generality.
Collaborations

1. Collaboration with **Seth Weinberg** (U Pitt) on analysis of data from the normative database

   - release of **automatic nose landmarks** module
   - experiments in using **deformable matching** to find 20 landmarks given a starting set
   - implementation of **Procrustes methodology** on 20 landmark points.
   - implementation of **Hutton’s dense correspondence method**
   - **comparison** of Procrustes-based classification to automated distance matrix classification
Very Preliminary Comparison Results

• 27 females, 27 males

• Hand-placed Landmarks
  – 20 Landmarks with Procrustes Imposition
  – Correctly classified instances: 90%

• Automated Pseudo-Landmarks
  – Cranial Image with 10 planes and 10 points per plane
  – Correctly classified instances: 88.8%
Collaborations

2. Collaboration with **Mahadev Satyanarayanan** (CMU) on using his OpenDiamond® Platform to develop our retrieval system.

- Improving Hyperfind GUI to allow 3D data
- Adding filters for our distance measures
- Change method of showing results to order by similarity
Diamond – Hyperfind GUI
Diamond – Hyperfind GUI
CranioGUI

• Purpose: all web-based graphical interface, no setup,
• allows people to try our modules with no overhead.
Ontology of Craniofacial Development and Malformation (OCDM)

Linda Shapiro, PI
Jim Brinkley, Project lead
What is the OCDM?

-Palate
  - Mucosa of palate
  - Submucosa of palate
  - Palatine process of right maxilla
    - Palatine process proper of right maxilla
    - Right anterior incisive foramina
    - Right posterior incisive foramina
  - Palatine process of left maxilla
    - Palatine process proper of left maxilla
    - Left anterior incisive foramina
    - Left posterior incisive foramina
  - Horizontal plate of right palatine bone
    - Horizontal plate proper of right palatine bone
    - Nasal crest of horizontal plate of right palatine bone
    - Right side of posterior nasal spine
  - Horizontal plate of left palatine bone
    - Horizontal plate proper of left palatine bone
    - Nasal crest of horizontal plate of left palatine bone
    - Left side of posterior nasal spine
  - Right levator veli palatini
  - Left levator veli palatini
  - Right tensor veli palatini
  - Left tensor veli palatini
  - Palatine part of right palatoglossus
  - Palatine part of left palatoglossus
  - Palatine aponeurosis
  - Hard palate
  - Soft palate
Purpose of the OCDM

• Act as semantic “glue” to tie together multiple forms of FaceBase data
OCDM is a collaborative project

- University of Washington
- Seattle Children’s Research Institute
- University of Pittsburgh
- Other Facebase and external projects:
  - Seth Weinberg and Mary Marazita at U Pitt
  - Yang Chai and Mouse Phenotype Committee
  - Terry Hayamizu at Jackson Labs
  - Phenotype Research Coordination Network
OCDM Use Cases

- Searching/Browsing
- Annotating Data
- Gene-Expression Display
- Ontology-Based Visualization
- Analytics
- Others under development...
Tasks

- Well-defined terms*
- Methods for annotating data with these terms
- Relations among terms*
- Query engine
- Graphical interface
- Integrate with FaceBase Hub

*Elements of an ontology
Approach

• Based on normal and developmental anatomy in Foundational Model of Anatomy (FMA)
• Augment with malformations
• Map to mouse and other model organisms
• Use existing terminology whenever possible
• OCDM as a container for separate components
Components

Craniofacial Malformations Ontology

Craniofacial Human Ontology

Craniofacial Human-Mouse Mapping Ontology

Craniofacial Mouse Ontology
Craniofacial Human Ontology (CHO)
Craniofacial Mouse Ontology (CMO)
Craniofacial Human-Mouse Mapping Ontology (CHMMO)

1-1 mapping to

Nose (Mus musculus) [CMO]

Basisphenoid bone (Mus musculus) [CMO]

1-null mapping to

Nose (Homo sapiens) [CHO]

∅
What parts of the human nose have an equivalent mouse structure?
<table>
<thead>
<tr>
<th>source</th>
<th>target</th>
</tr>
</thead>
<tbody>
<tr>
<td>ocdm:Nose</td>
<td>ocdm:Nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:External_nose</td>
<td>ocdm:External_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Dorsum_of_nose</td>
<td>ocdm:Dorsum_of_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Left_alae_of_nose</td>
<td>ocdm:Left_alae_of_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Root_of_nose</td>
<td>ocdm:Root_of_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Right_alae_of_nose</td>
<td>ocdm:Right_alae_of_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Columella</td>
<td>ocdm:Columella__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Tip_of_nose</td>
<td>ocdm:Tip_of_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Internal_nose</td>
<td>ocdm:Internal_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Right_side_of_internal_nose</td>
<td>ocdm:Right_side_of_internal_nose__Mus_musculus_</td>
</tr>
<tr>
<td>ocdm:Left_side_of_internal_nose</td>
<td>ocdm:Left_side_of_internal_nose__Mus_musculus_</td>
</tr>
</tbody>
</table>
What are all of the facial landmarks associated with the right nasal bone?
| fma:Inferior_border_of_right_nasal_bone |
| fma:Medial_border_of_right_nasal_bone |
| fma:Lateral_border_of_right_nasal_bone |
| fma:Superior_border_of_right_nasal_bone |
| fma:Rhinion |
| fma:Inferolateral_point_of_right_nasal_bone |
| fma:Nasion |
| fma:Superolateral_point_of_right_nasal_bone |
Plans

• Content
  – Expand existing
  – Malformations
  – Development

• Use for data annotation and query

• Integrate with the Hub
More Detail

• Posters
  – Mejino et al, Human components
  – Travillian et al, Mouse components and mappings
  – Detwiler et al, Queries
• Post FaceBase meeting
  – Tues June 26, 12:30-4 PM
• FaceBase Hub
  https://www.facebase.org/content/ocdm
  – Use cases
  – Current version of OCDM
  – Links to example queries