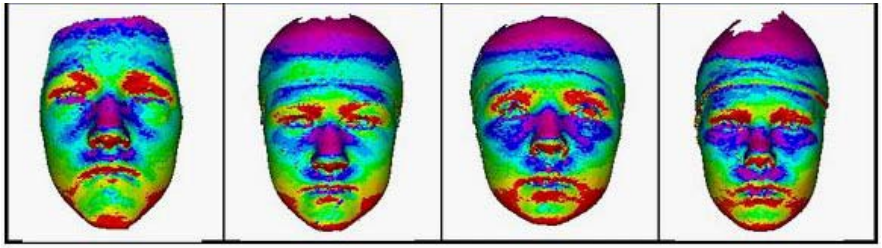
Technology Project: Shape-Based Retrieval of 3D Craniofacial Data



PI: Linda Shapiro, Ph.D.

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

Postdoc: Ravensara Travillian, Ph.D.

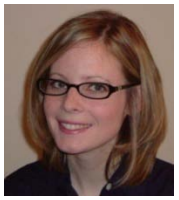
RA: Shulin Yang, MS

RA: Jia Wu, MS

RA: Sara Rolfe, MS

RA: Ezgi Mercan






Two Talks in One

- Parent Grant:

  3D Image Analysis and Retrieval

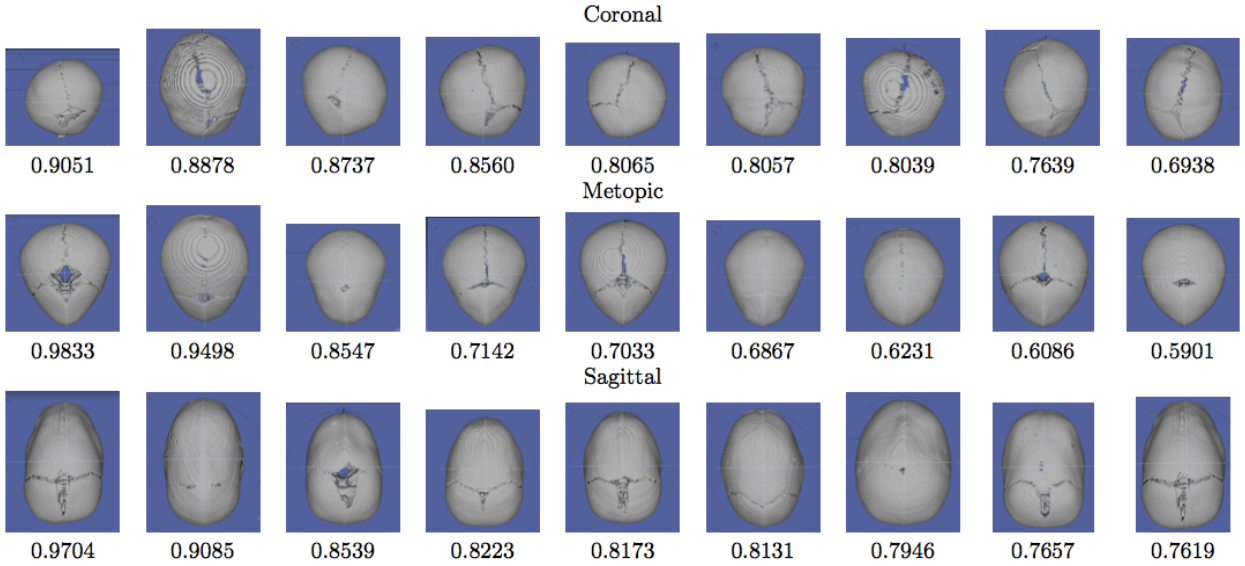
  (**Shapiro**, Brinkley, Cunningham)

- Supplement:

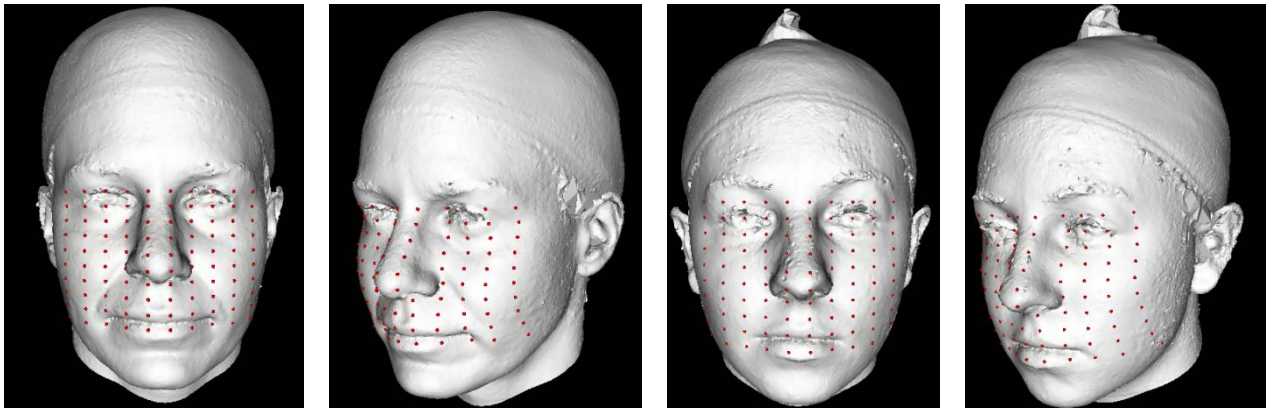
  Ontology of Craniofacial Development and Malformation

  (Shapiro, **Brinkley**, Cunningham, Cox, Heike, Hochheiser)

Analysis of Overall Head/Face Shape via Cranial Image (Distance Matrix)



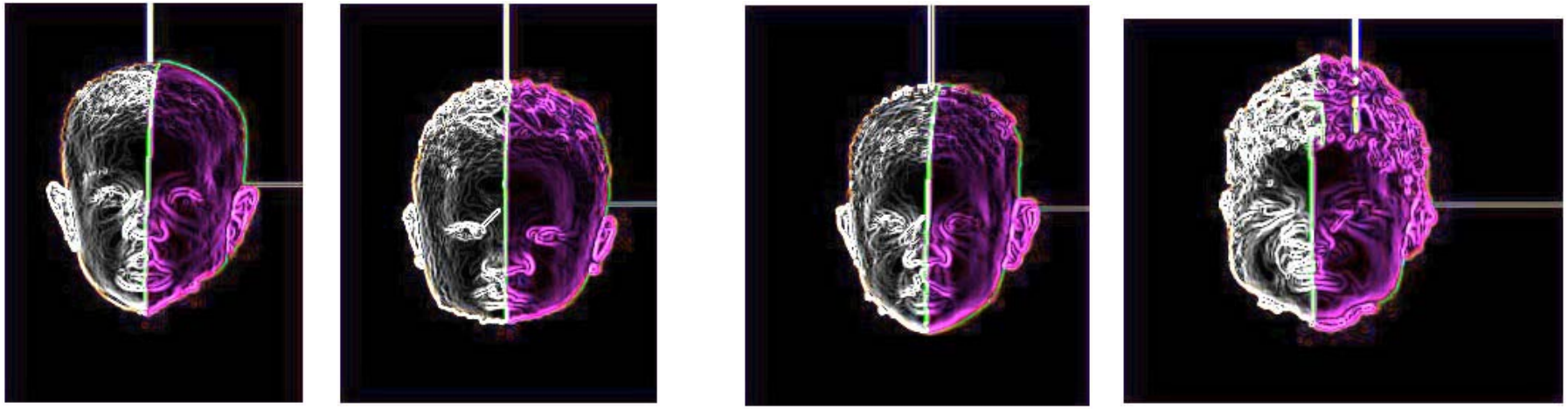
skull version: used in severity-based retrieval and pre/post-op comparisons: ongoing



new face version: developed for analysis of midface region(s)

Analysis of Cleft Subject Data

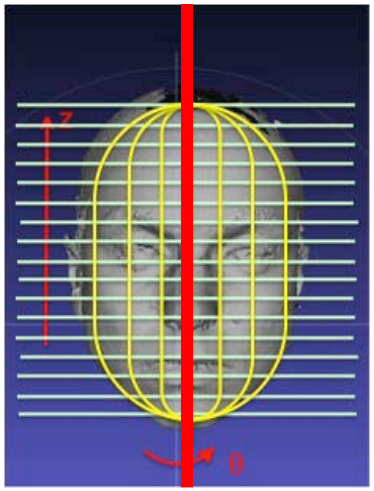
Finding the midsagittal plane using landmark learning.

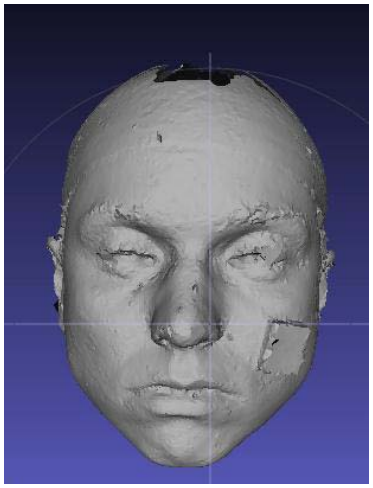


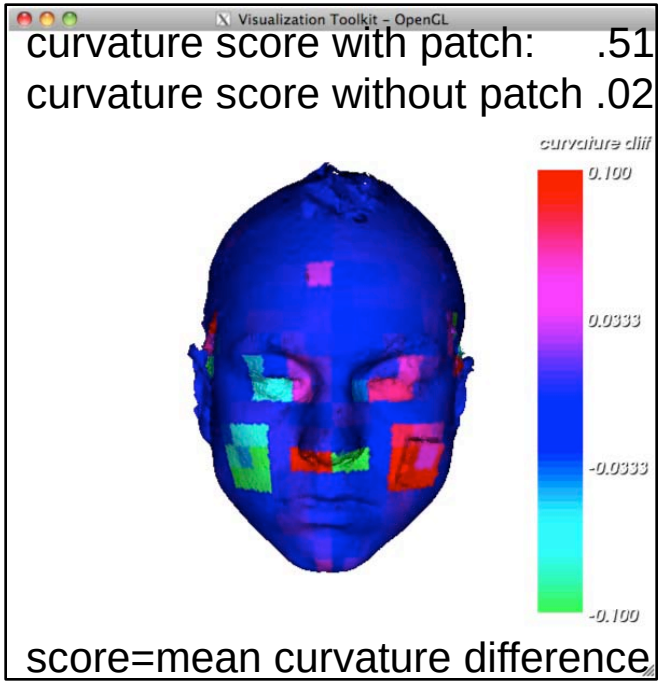
Current study to evaluate automated midsagittal plane placement

- 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

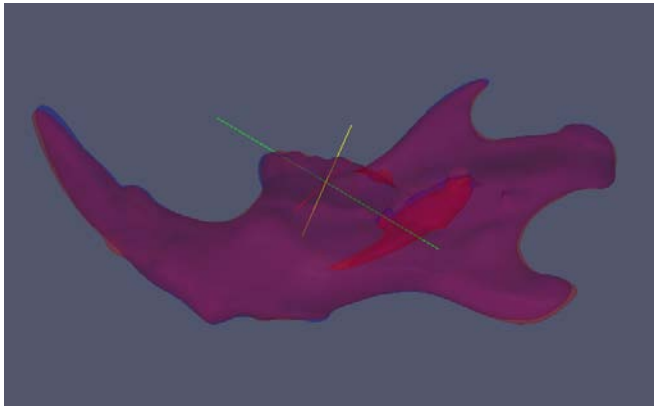
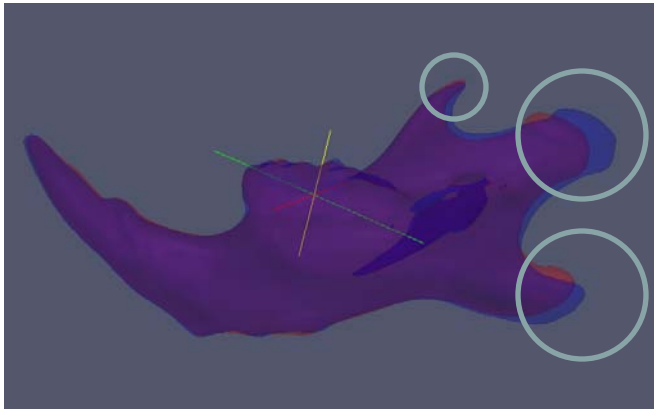
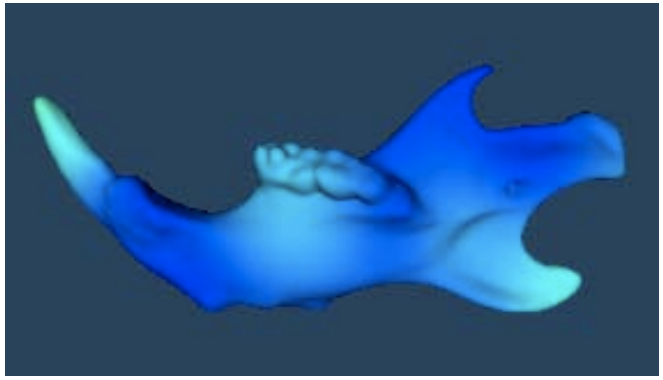
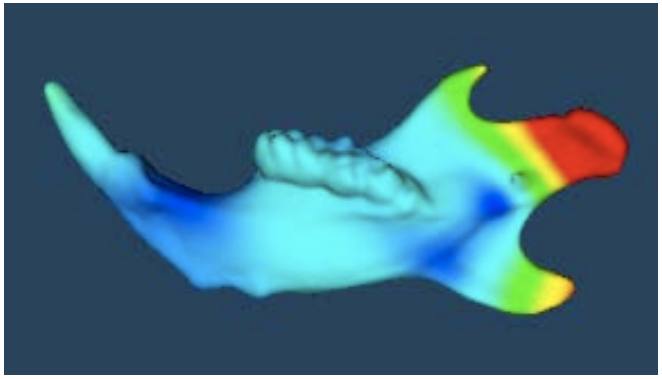






- Once the midsagittal plane is computed, asymmetry can be quantified by looking at means of differences in local features over grid patches on the left and right sides of the face.
- Next work will be on describing and quantifying severity of clefts.

Mouse Mandible Symmetry

	SBSE-2 Asymmetry score 6.87	SBSE-7 Asymmetry score 41.43
Right/left mandible overlay		
Deformation vector magnitude		

- 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

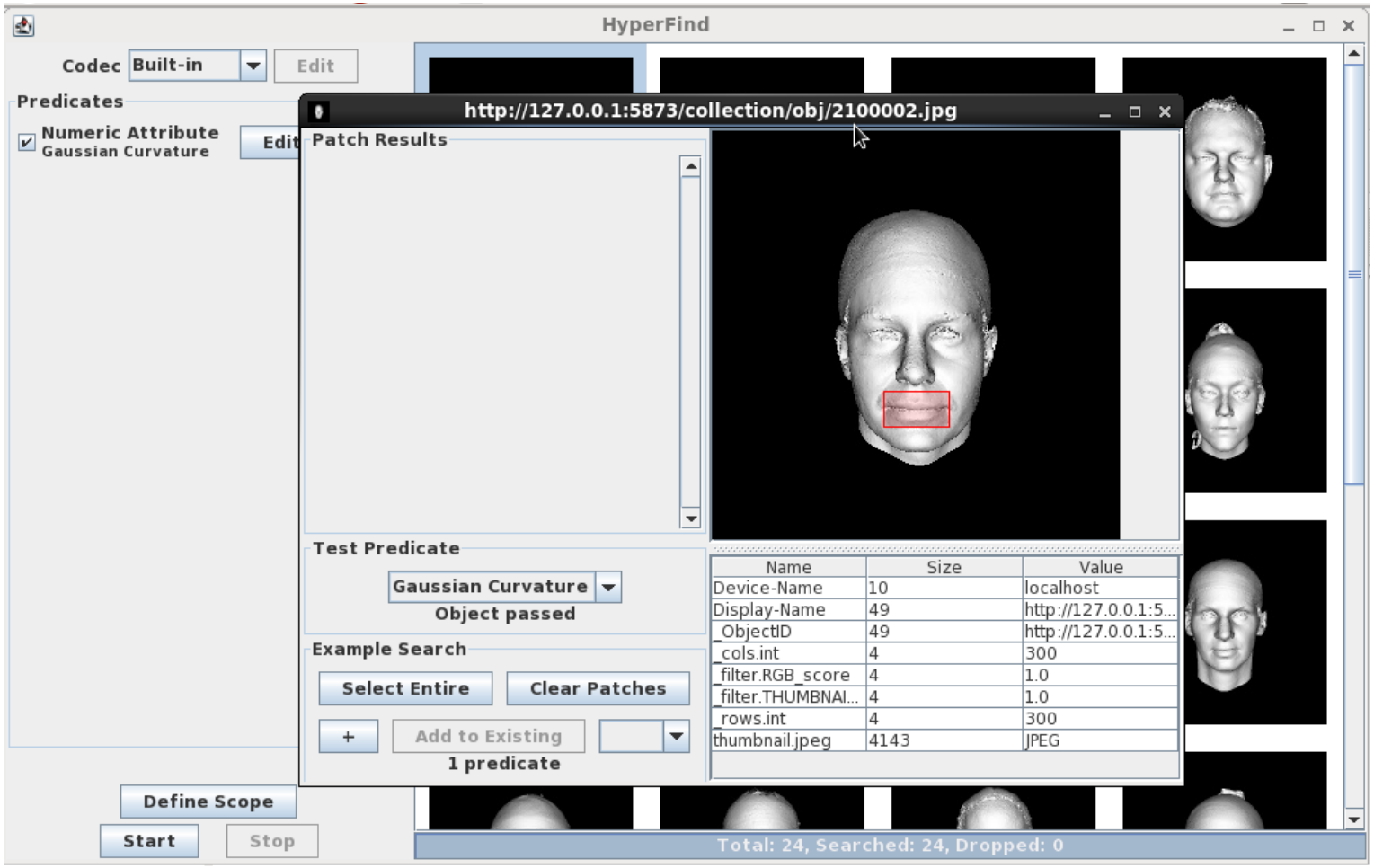
- 27 females, 27 males
- Hand-placed Landmarks
  - 20 Landmarks with Procrustes Imposition
  - Correctly classified instances: 90%
- Automated Pseudo-Landmarks
  - Cranial Image with 10 planes and 10 points per plane
  - Correctly classified instances: 88.8%

Collaborations

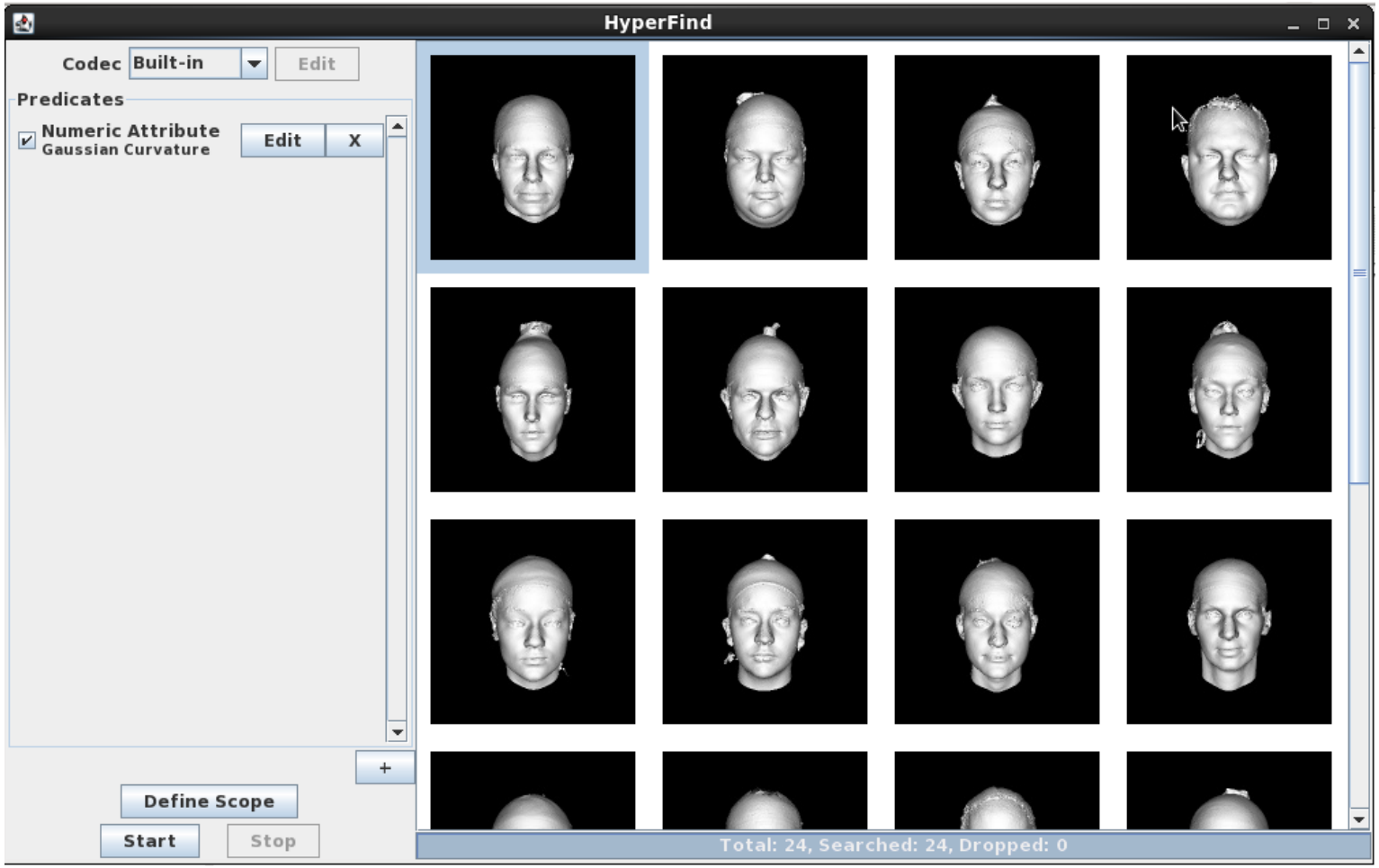
2. Collaboration with **Mahadev Satyanarayanan** (CMU) on using his OpenDiamond® Platform to develop our retrieval system.

   - 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

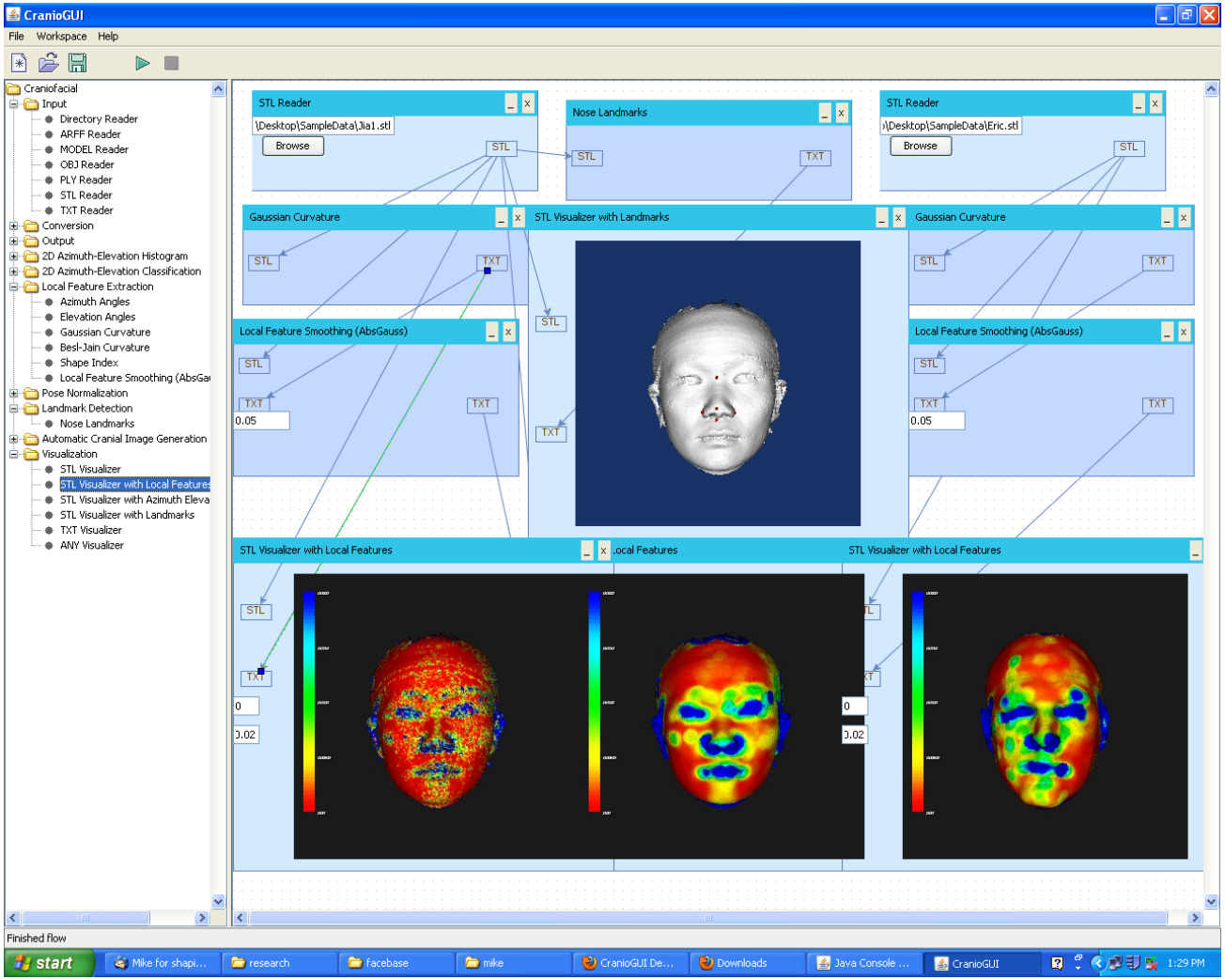


Diamond – Hyperfind GUI



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 **Search**

Select navigation tree type: part

- **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

PREFERRED NAME:

Palate

SYNONYM:

Oral roof

Roof of mouth

NON-ENGLISH EQUIVALENT:

name	language
Palatum	Latin
Palais	French
Gaumen	German

FMAID:

54549

PART:

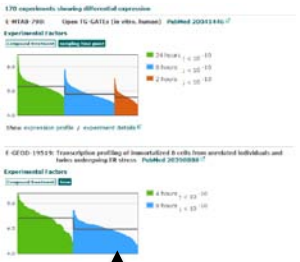
- Mucosa of palate
- Submucosa of palate
- Palatine process of right maxilla
- Palatine process of left maxilla
- Horizontal plate of right palatine bone
- Horizontal plate of left palatine bone
- Right levator veli palatini

Purpose of the OCDM

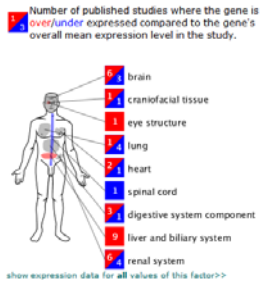
- Act as semantic “glue” to tie together multiple forms of FaceBase data

Clinical findings

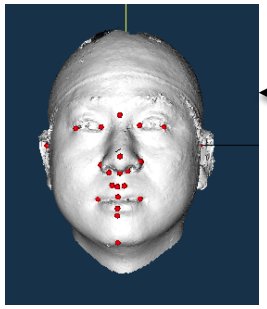
Gene expression profiles



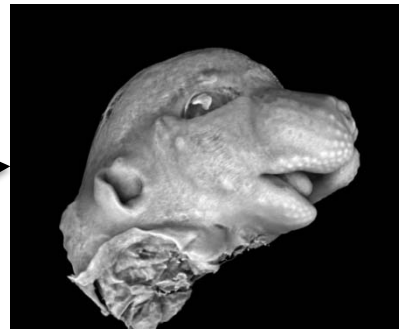
Published genomic studies



Medical imaging



OCDM



FaceBase repository

Model organism studies

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

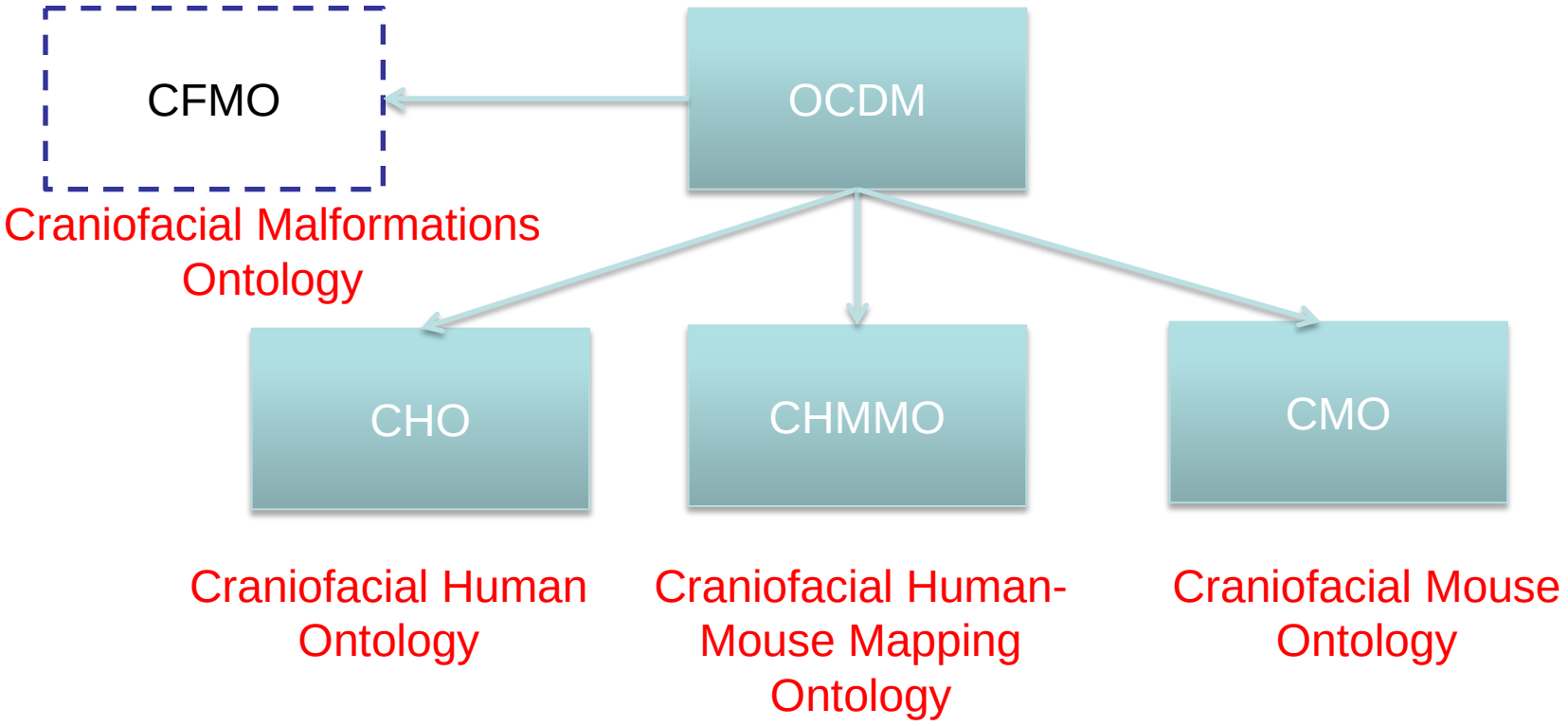
- Well-defined terms*
- Methods for annotating data with these terms
- Relations among terms*
- Query engine
- Graphical interface
- Integrate with FaceBase Hub

*Elements of an ontology

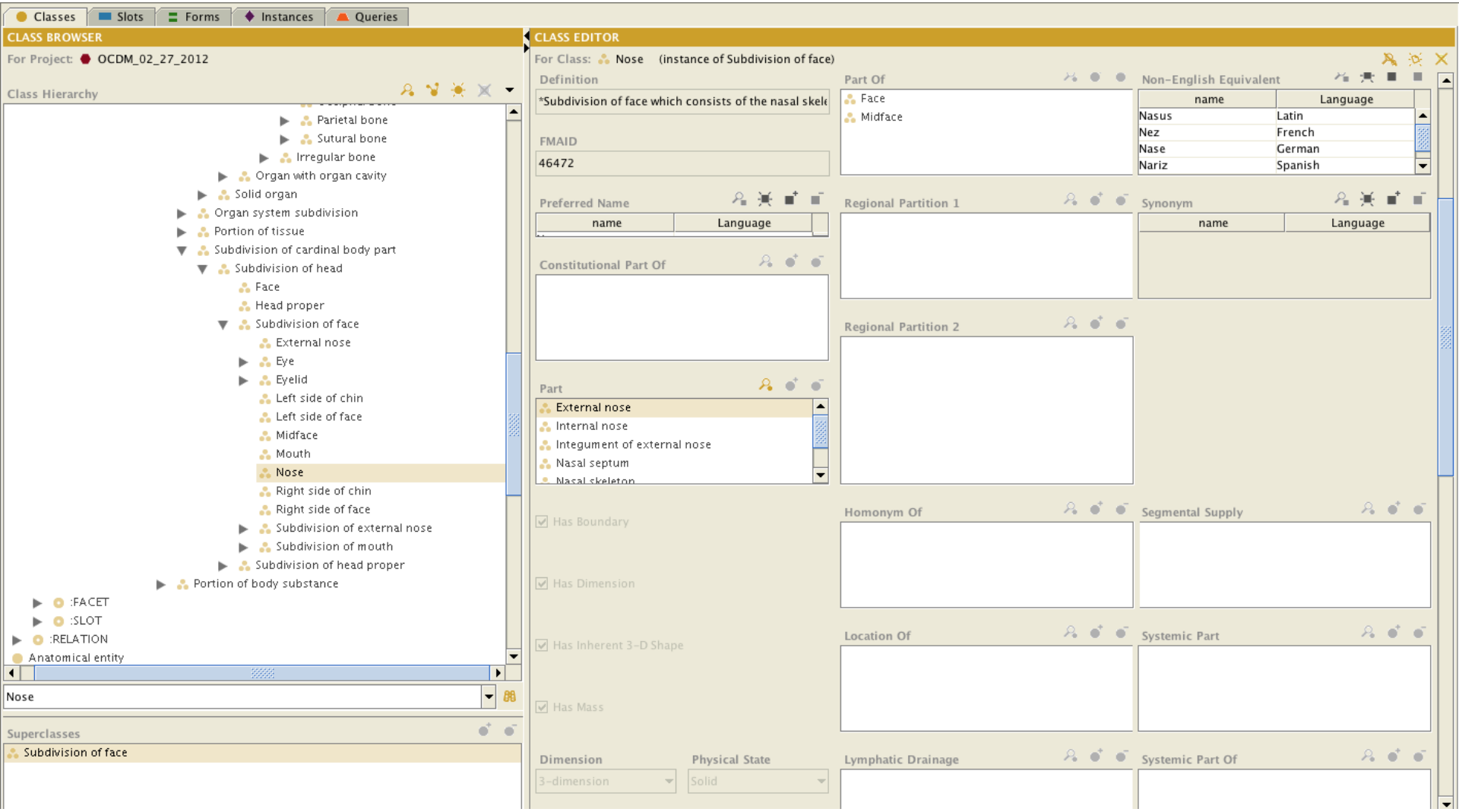
Approach

- 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

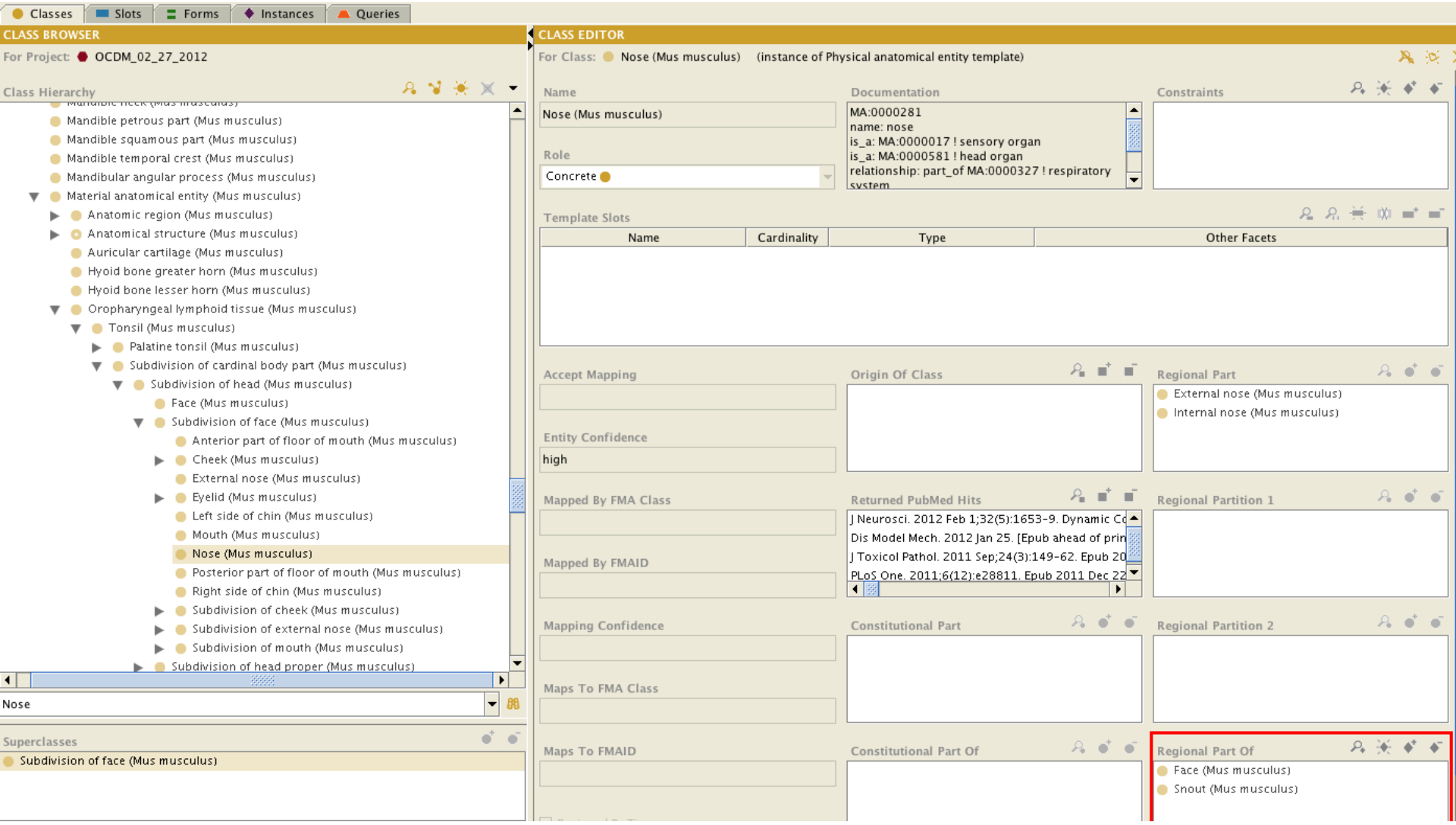
Components


CFMO
OCDM
Craniofacial Malformations Ontology
CHO
CHMMO
CMO
Craniofacial Human Ontology
Craniofacial Human-Mouse Mapping Ontology
Craniofacial Mouse Ontology

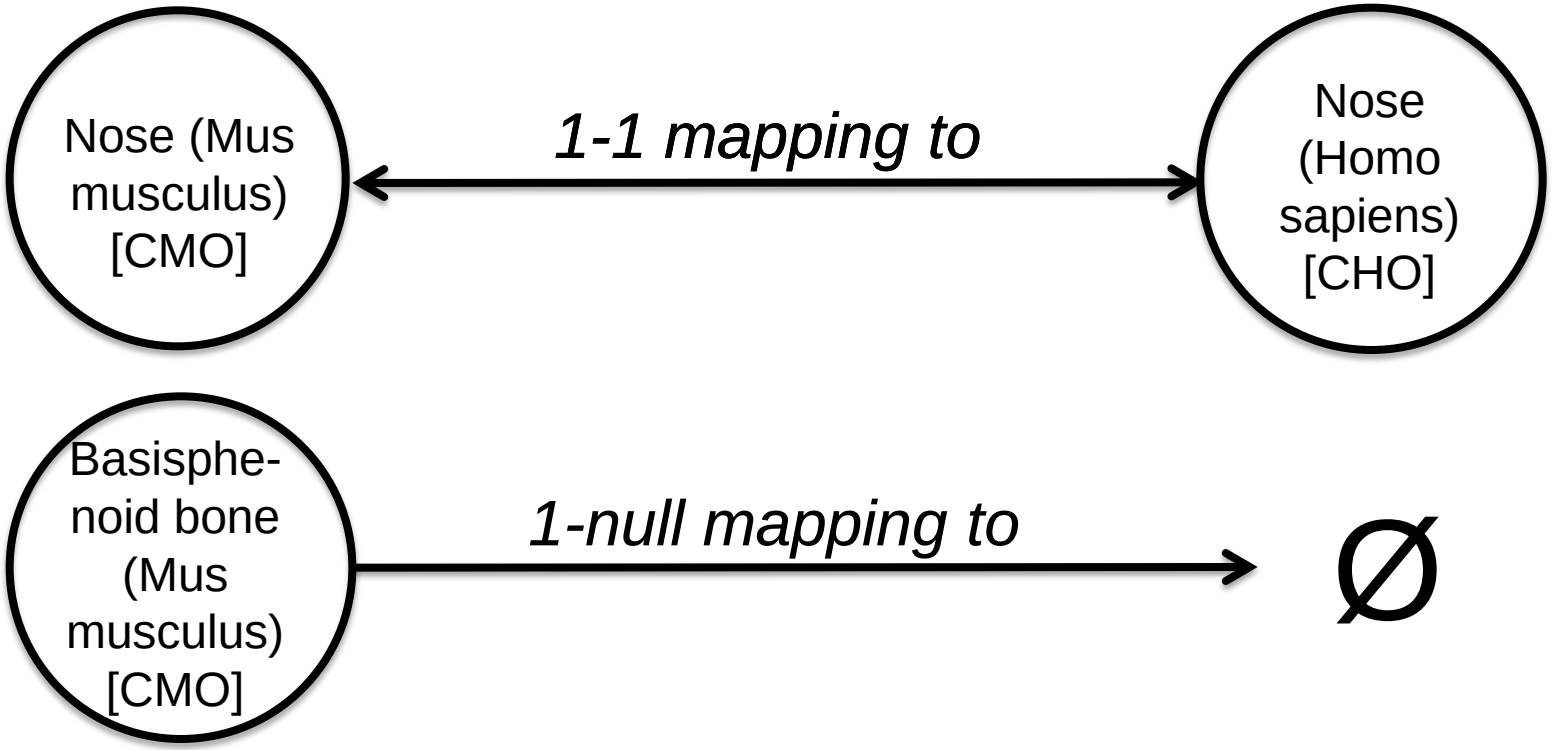
Craniofacial Human Ontology (CHO)



Craniofacial Mouse Ontology (CMO)



Craniofacial Human-Mouse Mapping Ontology (CHMMO)



Query Integrator

Login

Manage Search Edit User Help

Title

Query to test Protege OWL export of OCDM

Description

This query finds all of the parts of the nose and then finds their mappings to mouse structures.

Query

```
PREFIX rdfs:<http://www.w3.org/2000/01/rdf-schema#>
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl:<http://www.w3.org/2002/07/owl#>
PREFIX ocdm:<http://www.owl-ontologies.com/Ontology1330451109.owl#>

SELECT distinct ?source ?target
FROM <http://purl.org/sig/ocdm>
WHERE
{
   ocdm:Nose (ocdm:regional_part|ocdm:constitutional_part)* ?source.

   ?x ocdm:source ?source.
   ?x ocdm:source_species ?source_species.
   ?x ocdm:target ?target.
   ?x ocdm:target_species ?target_species.
   FILTER (str(?source_species) = "human" && str(?target_species) = "mouse").
}
```

What parts of the human nose have an equivalent mouse structure?

Language vSPARQL

Execute

source	target
ocdm:Nose	ocdm:Nose__Mus_musculus_
ocdm:External_nose	ocdm:External_nose__Mus_musculus_
ocdm:Dorsum_of_nose	ocdm:Dorsum_of_nose__Mus_musculus_
ocdm:Left_ala_of_nose	ocdm:Left_ala_of_nose__Mus_musculus_
ocdm:Root_of_nose	ocdm:Root_of_nose__Mus_musculus_
ocdm:Right_ala_of_nose	ocdm:Right_ala_of_nose__Mus_musculus_
ocdm:Columella	ocdm:Columella__Mus_musculus_
ocdm:Tip_of_nose	ocdm:Tip_of_nose__Mus_musculus_
ocdm:Internal_nose	ocdm:Internal_nose__Mus_musculus_
ocdm:Right_side_of_internal_nose	ocdm:Right_side_of_internal_nose__Mus_musculus_
ocdm:Left_side_of_internal_nose	ocdm:Left_side_of_internal_nose__Mus_musculus_

Query Integrator

Login

Manage Search Edit User Help

Title

demonstration craniofacial landmark query

Description

This query starts at a structure (currently right nasal bone) and traverses paths that lead to related landmarks. But these paths contain other results that would not be considered landmarks as well. So the query then filters to just those results that are lines or points.

Query

```
PREFIX rdfs:<http://www.w3.org/2000/01/rdf-schema#>
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl:<http://www.w3.org/2002/07/owl#>
PREFIX fma:<http://purl.org/sig/fma/>

SELECT ?x  FROM <http://purl.org/sig/craniofacialfma>
WHERE
{
   # process path pattern that leads from structure to associated landmarks
   fma:Right_nasal_bone (fma:bounded_by/fma:regional_part*)+ ?x.

   # filter results to just those that are landmarks (lines and points)
   ?x rdfs:subClassOf+ ?super.
   FILTER (?super=fma:Anatomical_line || ?super=fma:Anatomical_point).
}
```

What are all of the facial landmarks associated with the right nasal bone?

Language vSPARQL

Execute

x
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