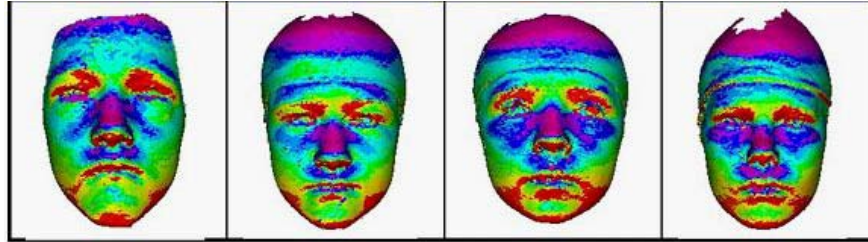




# Technology Project: Shape-Based Retrieval of 3D Craniofacial Data



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

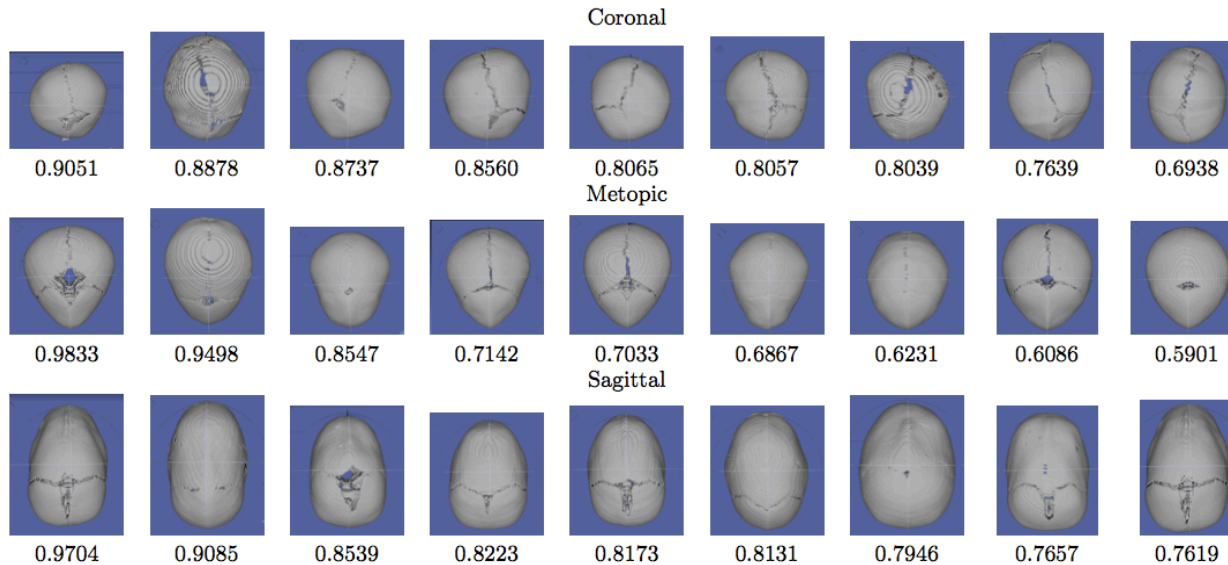
RA: Ezgi Mercan



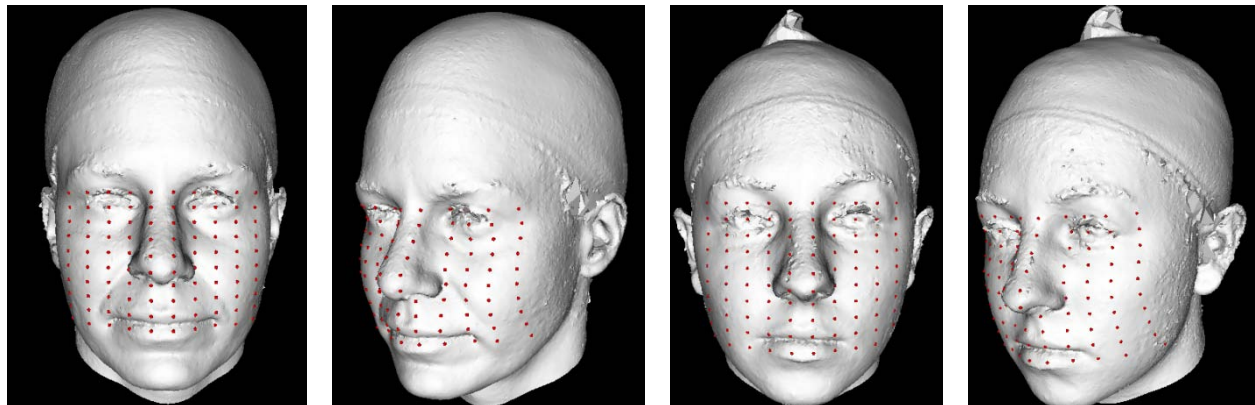
# Two Talks in One

- 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)



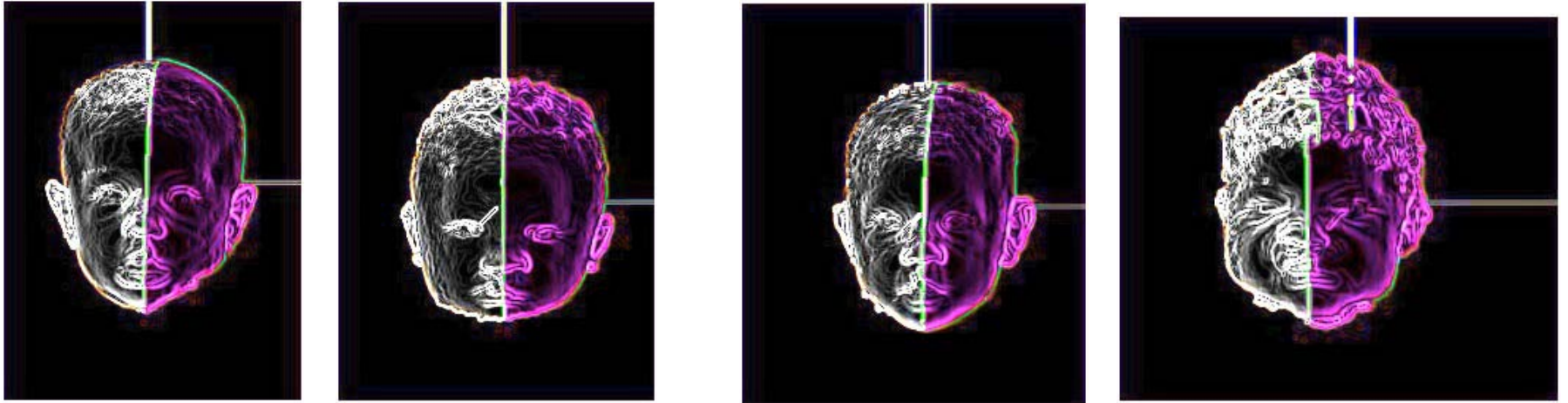
skull version:  
used in **severity-based retrieval**  
and pre/post-op  
comparisons:  
ongoing



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

# Analysis of Cleft Subject Data

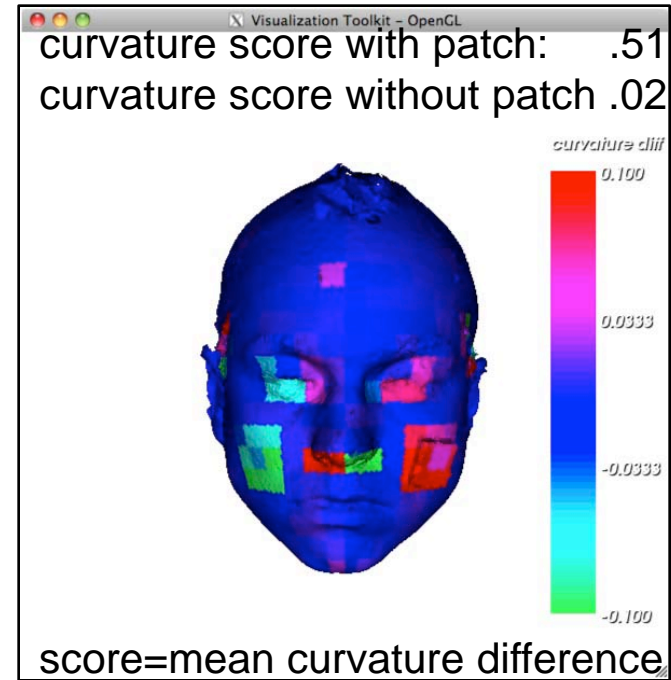
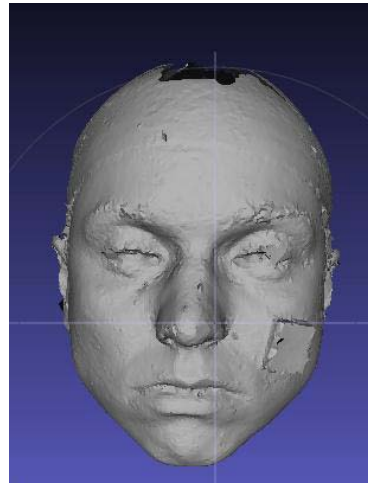
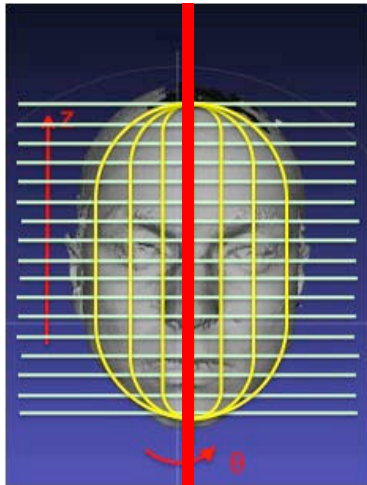
Finding the midsagittal plane using landmark learning.



**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

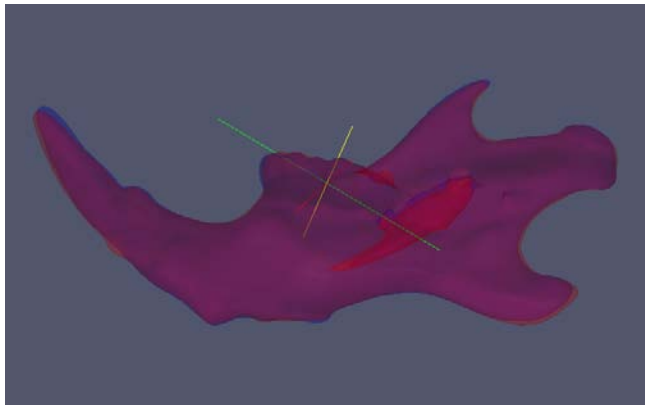


- Once the midsagittal plane is computed, **asymmetry** can be quantified by looking at means of differences in local features over grid patches on the left and right sides of the face.
- **Next work will be on describing and quantifying severity of clefts.**

# Mouse Mandible Symmetry

SBSE-2

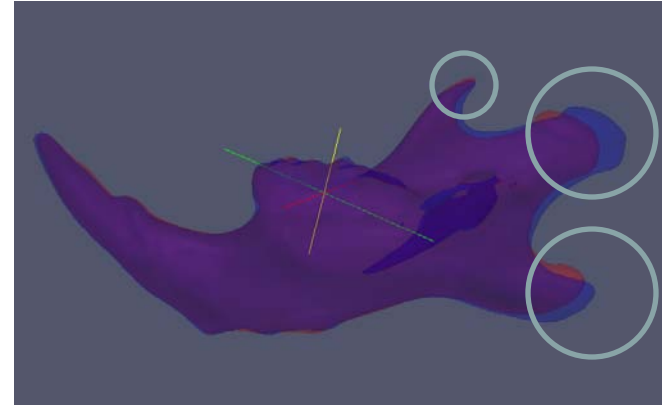
Asymmetry score 6.87



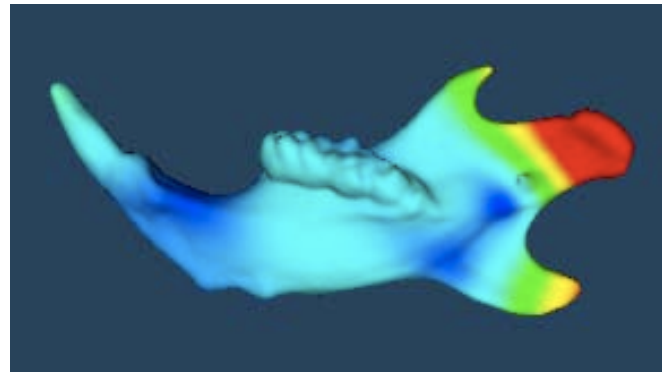
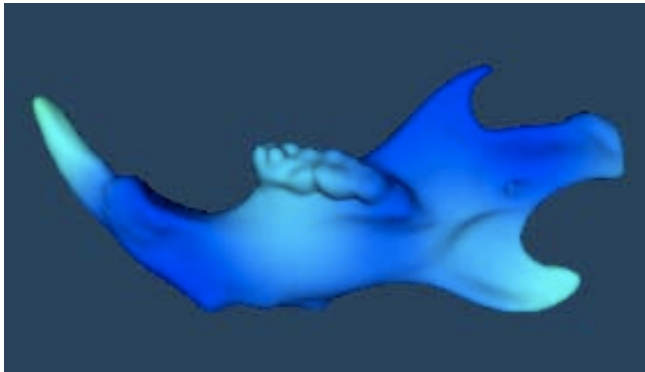
Right/left  
mandible  
overlay

SBSE-7

Asymmetry score 41.43



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

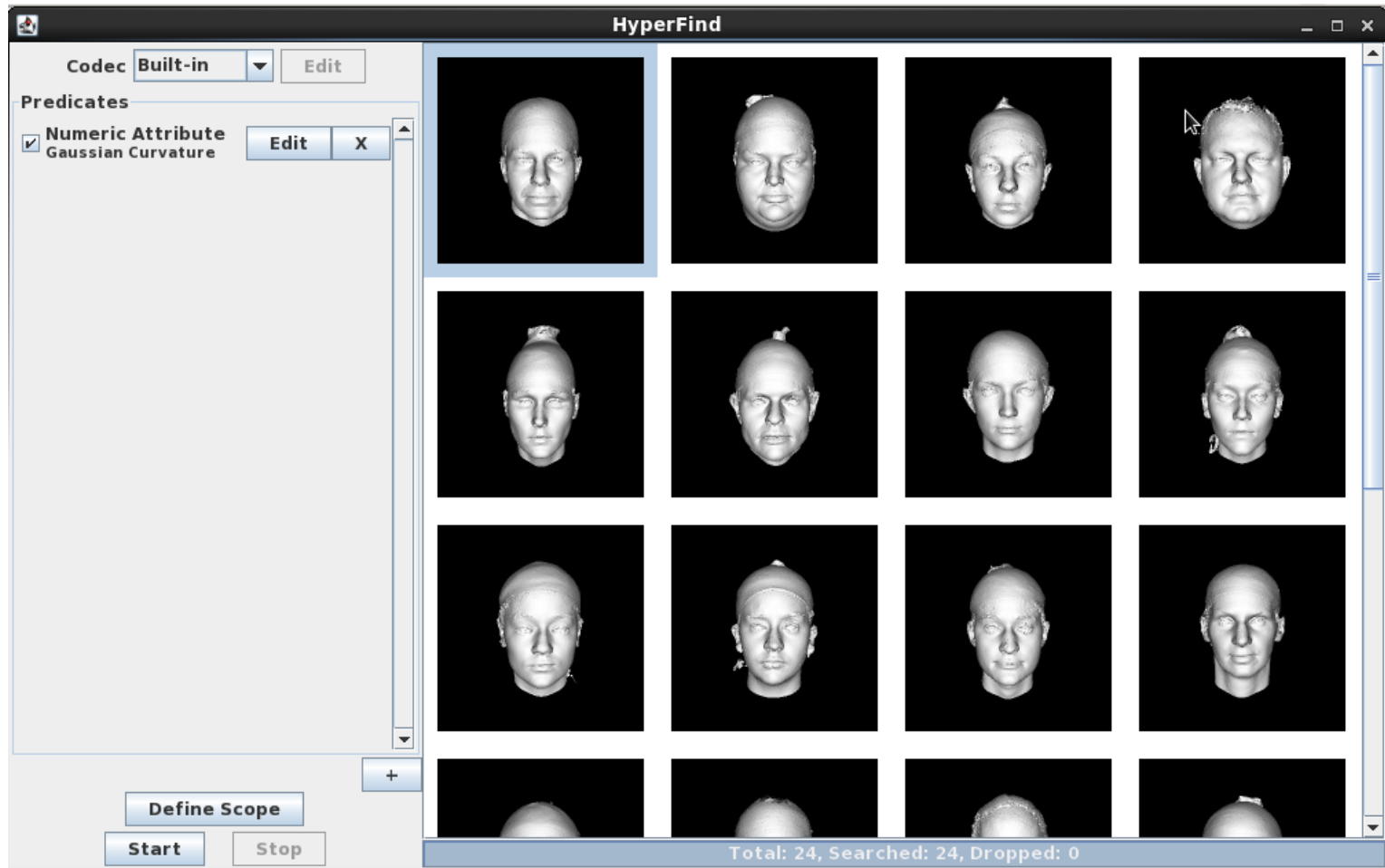
The screenshot displays the HyperFind GUI interface. At the top, the window title is "HyperFind". Below the title bar, there is a "Codec" dropdown menu set to "Built-in" and an "Edit" button. The main interface is divided into several sections:

- Predicates:** A section on the left with a checked box for "Numeric Attribute" and "Gaussian Curvature".
- Patch Results:** A central window titled "http://127.0.0.1:5873/collection/obj/2100002.jpg" showing a 3D model of a face with a red bounding box around the mouth.
- Test Predicate:** A section below the patch results showing "Gaussian Curvature" selected in a dropdown menu, with the status "Object passed".
- Example Search:** A section with buttons for "Select Entire", "Clear Patches", and "Add to Existing". Below these buttons, it indicates "1 predicate".
- Table:** A table with three columns: "Name", "Size", and "Value".

Name	Size	Value
Device-Name	10	localhost
Display-Name	49	http://127.0.0.1:5...
ObjectID	49	http://127.0.0.1:5...
_cols.int	4	300
filter.RGB_score	4	1.0
filter.THUMBNAI...	4	1.0
_rows.int	4	300
thumbnail.jpeg	4143	JPEG

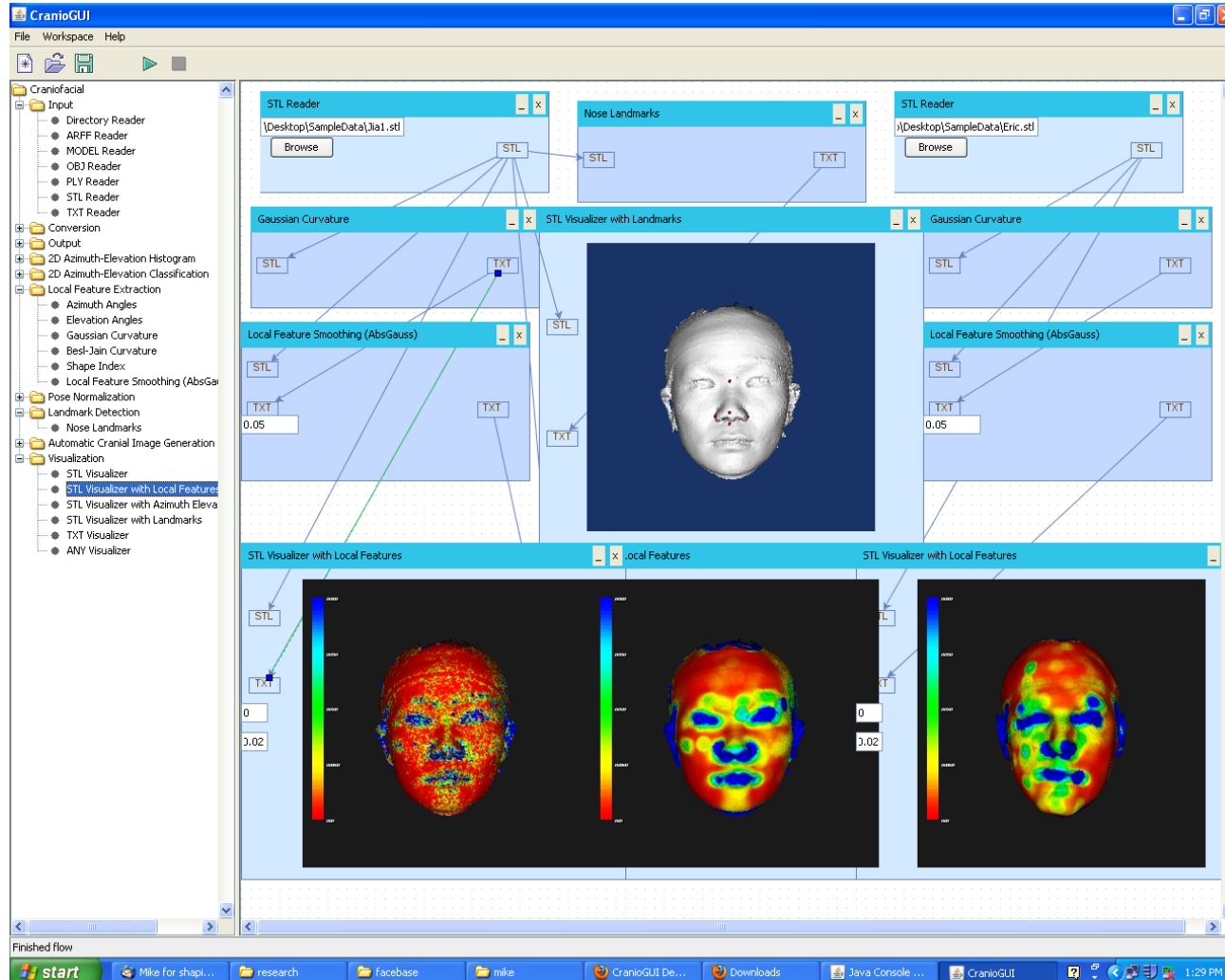
At the bottom of the GUI, there are buttons for "Define Scope", "Start", and "Stop". A status bar at the very bottom indicates "Total: 24, Searched: 24, Dropped: 0".

# 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 OCDDM?

Select navigation tree type:

## -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:

## SYNONYM:

## NON-ENGLISH EQUIVALENT:

name	language
Palatum	Latin
Palais	French
Gaumen	German

## FMAID:

## PART:

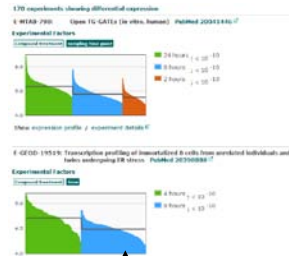
# Purpose of the OCDM

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

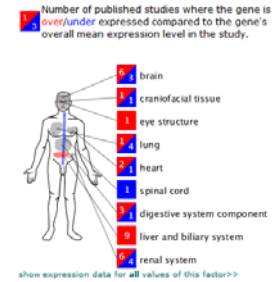
Clinical findings



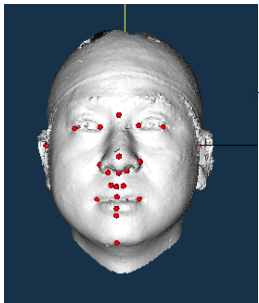
Gene expression profiles



Published genomic studies

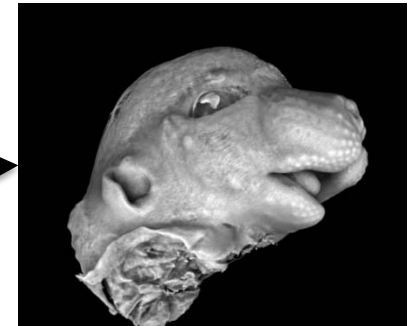


Medical imaging



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

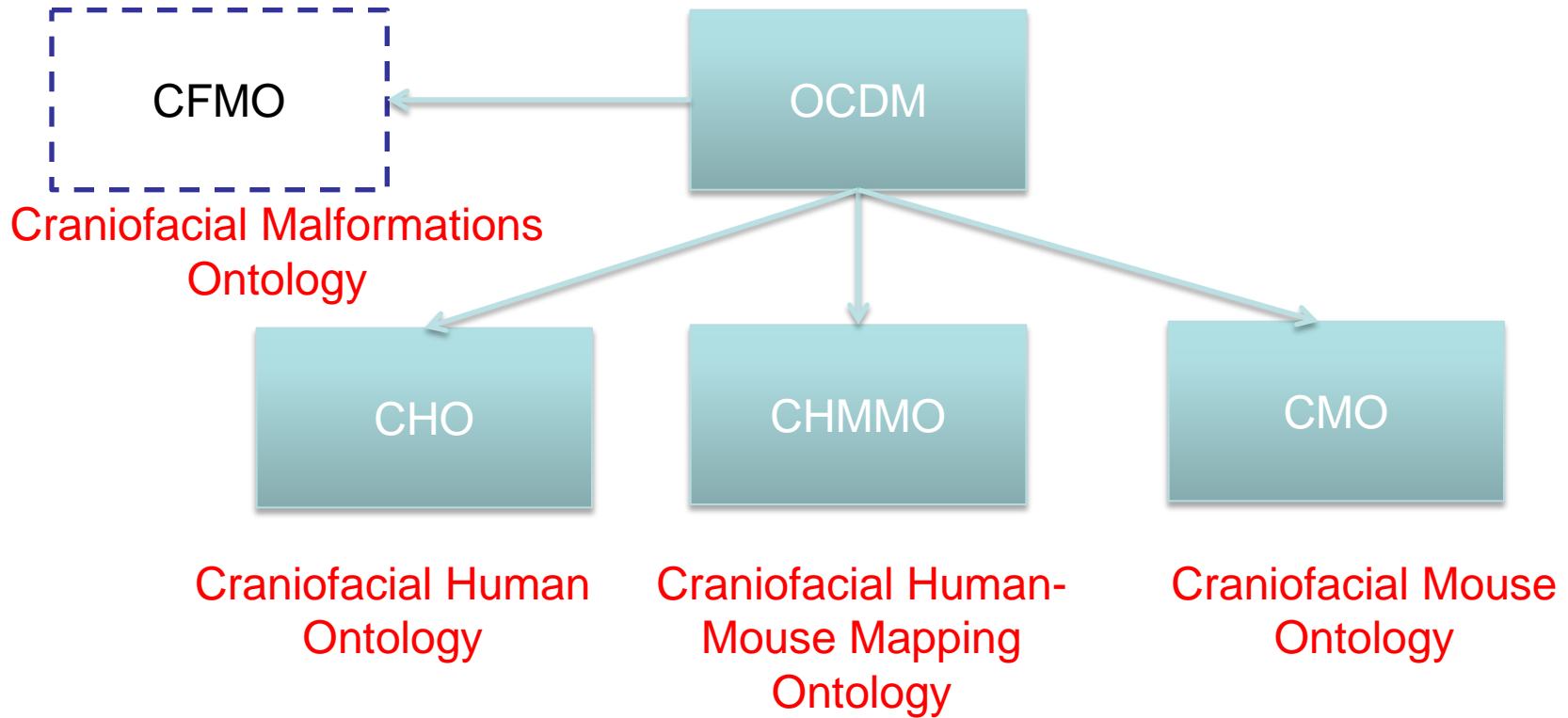
- Well-defined terms\*
- Methods for annotating data with these terms
- Relations among terms\*
- Query engine
- Graphical interface
- Integrate with FaceBase Hub

\*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



# Craniofacial Human Ontology (CHO)

**CLASS BROWSER**  
For Project: OCDM\_02\_27\_2012

Class Hierarchy

- ▶ :FACET
- ▶ :SLOT
- ▶ :RELATION
- Anatomical entity
- ▶ Parietal bone
- ▶ Sutural bone
- ▶ Irregular bone
- ▶ Organ with organ cavity
- ▶ Solid organ
- ▶ Organ system subdivision
- ▶ Portion of tissue
- ▶ Subdivision of cardinal body part
- ▶ Subdivision of head
  - ▶ Face
  - ▶ Head proper
  - ▶ Subdivision of face
    - ▶ External nose
    - ▶ Eye
    - ▶ Eyelid
    - ▶ Left side of chin
    - ▶ Left side of face
    - ▶ Midface
    - ▶ Mouth
    - ▶ **Nose**
    - ▶ Right side of chin
    - ▶ Right side of face
    - ▶ Subdivision of external nose
    - ▶ Subdivision of mouth
    - ▶ Subdivision of head proper
  - ▶ Portion of body substance

**CLASS EDITOR**  
For Class: **Nose** (instance of Subdivision of face)

**Definition**  
\*Subdivision of face which consists of the nasal skele

**FMAID**  
46472

**Preferred Name**

name	Language
------	----------

**Constitutional Part Of**

**Part**

- ▶ External nose
- ▶ Internal nose
- ▶ Integument of external nose
- ▶ Nasal septum
- ▶ Nasal skeleton

Has Boundary

Has Dimension

Has Inherent 3-D Shape

Has Mass

**Dimension**  
3-dimension

**Physical State**  
Solid

**Part Of**

- ▶ Face
- ▶ Midface

**Non-English Equivalent**

name	Language
Nasus	Latin
Nez	French
Nase	German
Nariz	Spanish

**Regional Partition 1**

**Regional Partition 2**

**Synonym**

name	Language
------	----------

**Homonym Of**

**Segmental Supply**

**Location Of**

**Systemic Part**

**Lymphatic Drainage**

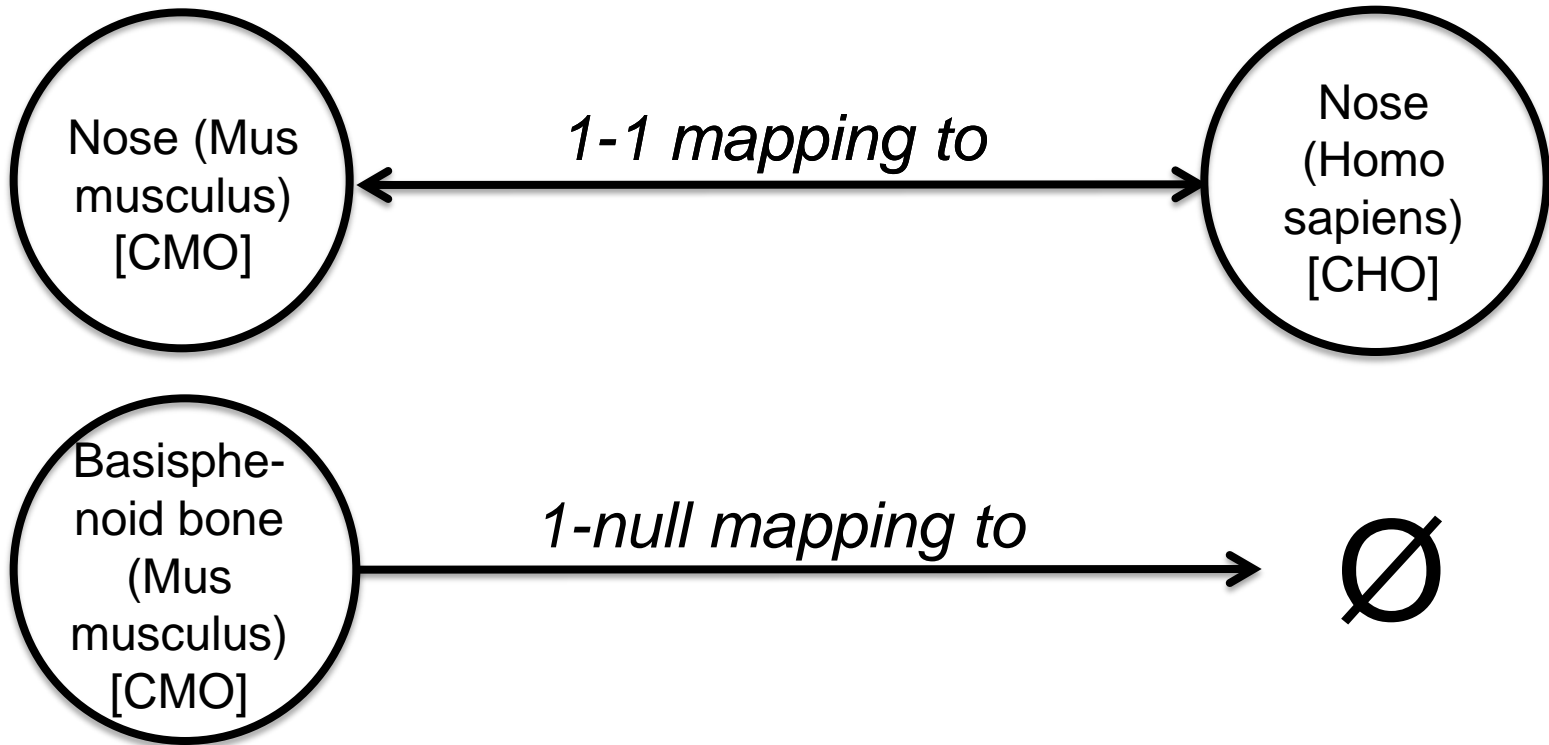
**Systemic Part Of**

**Superclasses**

- ▶ Subdivision of face



# 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_



## 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?

```
-----  
| 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 OCDDM
  - Links to example queries