Morphometric Analysis of Biomedical Images

Sara Rolfe

10/9/17

Morphometric Analysis of Biomedical Images

Object surface contours

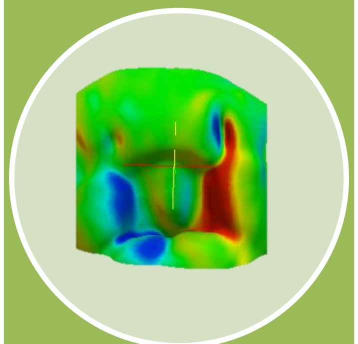
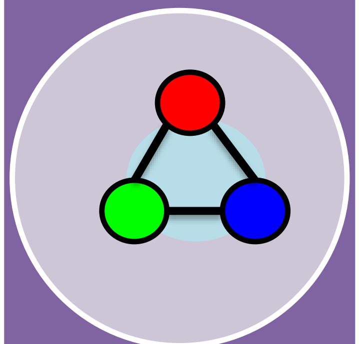
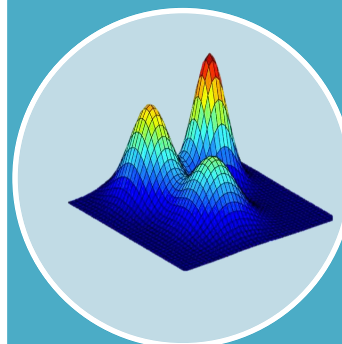


Image difference features



Compact representation of feature differences



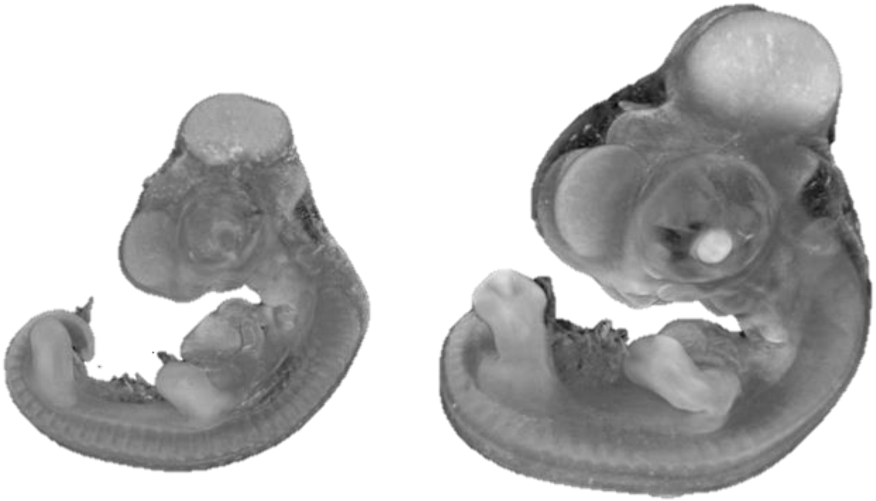
Framework to quantify, compare, and visualize image differences

Validation on multiple datasets

Framework for Morphometric Shape Analysis

Quantification and Description of Morphological Differences

- Trend towards increased use of biomedical imaging in craniofacial medicine
- Increased need for tools enabling assessment of biomedical images.
- Identify optimal treatment strategies
- Quantify genetic and epigenetic impact on phenotypes.



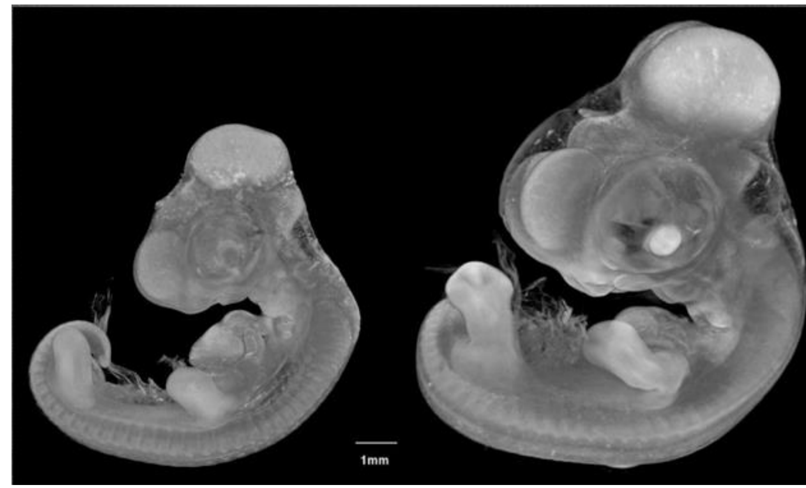
Two developmental stages of a chick embryo

Left and right mouse hemi-mandibles

Challenges in Quantifying 3D Shape Change

Traditional methods rely on landmark points

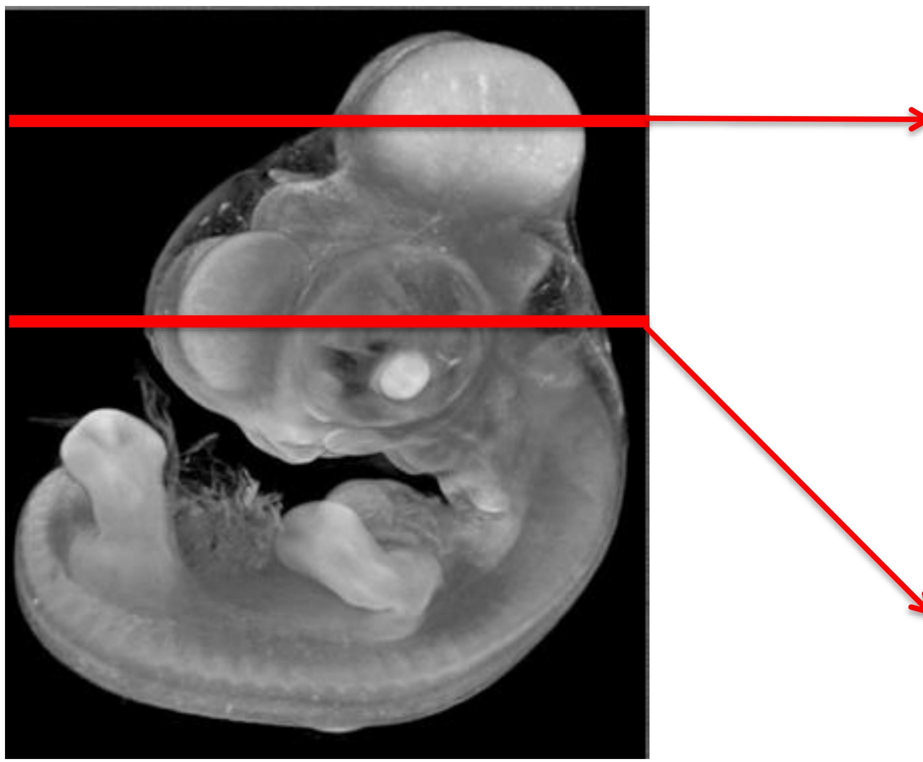
- Tedious and subject to variability
- Require locations where landmarks can be reliably placed
- Spatially sparse



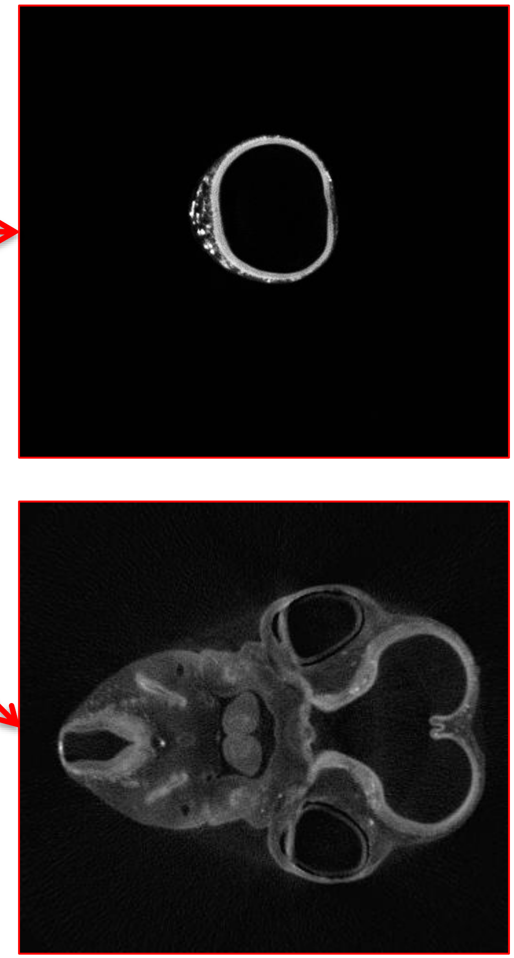
Embryonic growth

Alternative analysis technique is needed

High Resolution 3D Scan Data

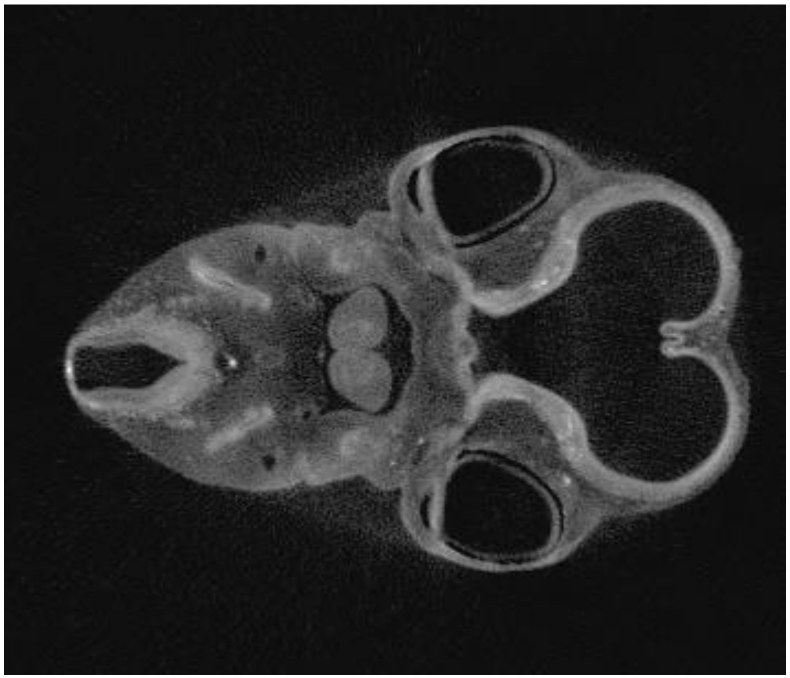


Chick embryo

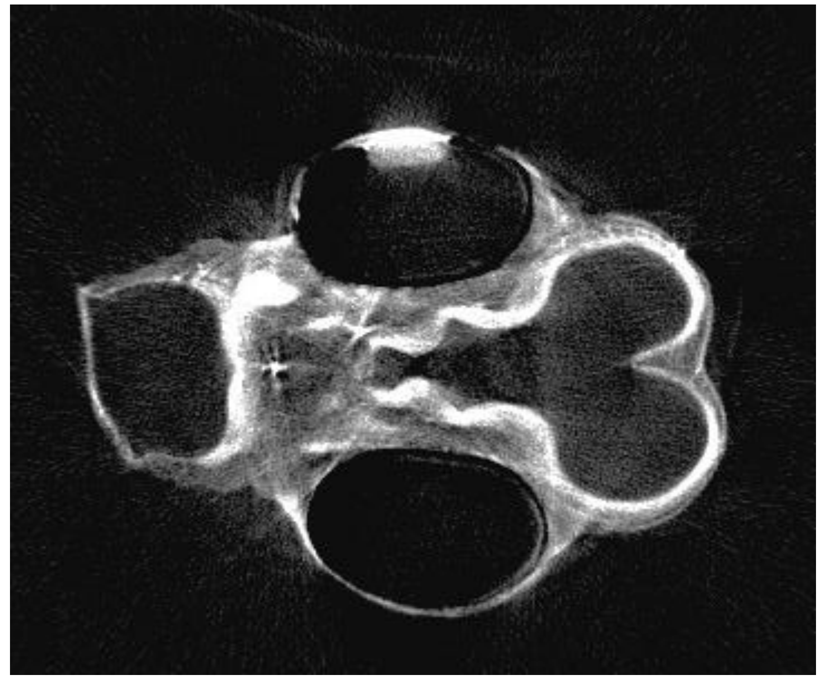


2D image slices

Problematic Scan Data

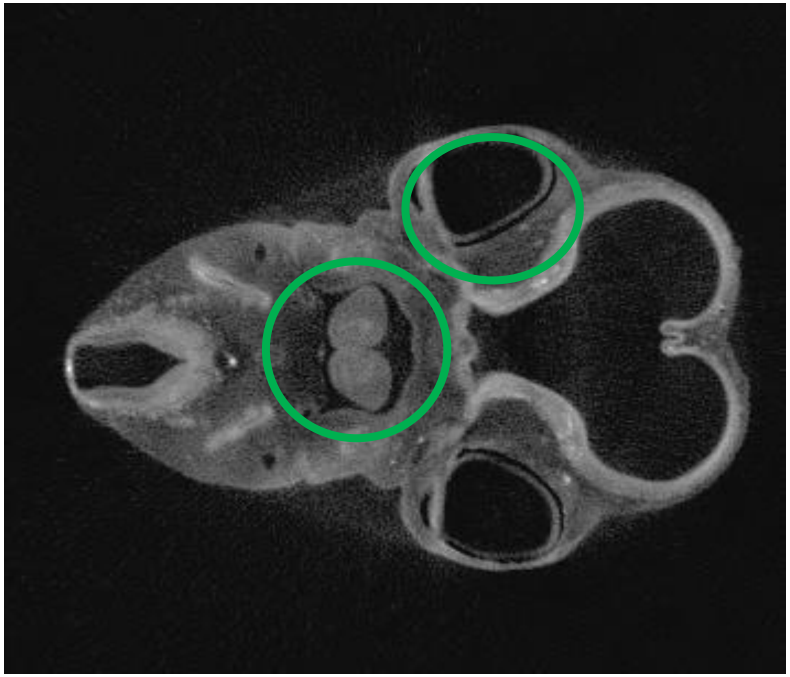


High quality image

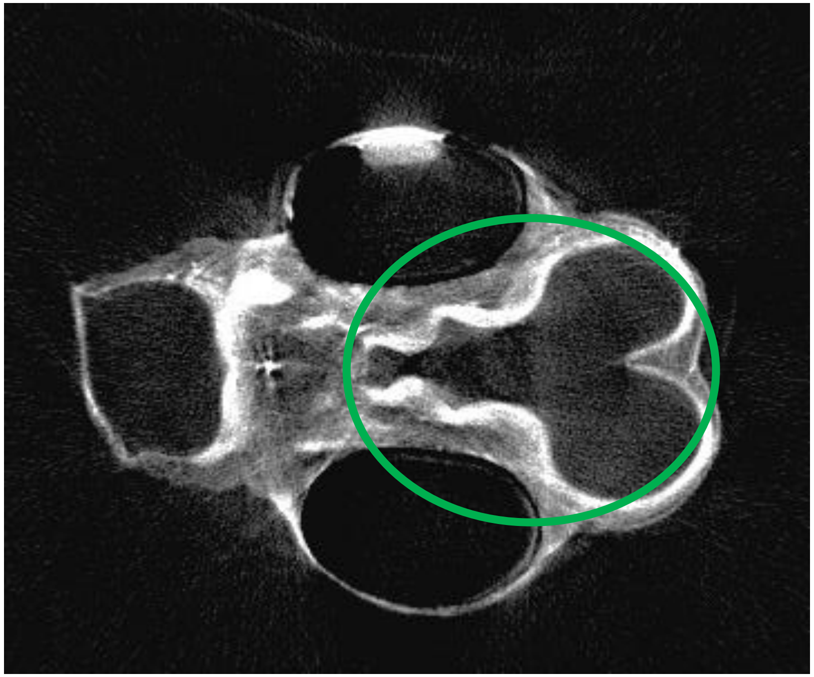


Low quality image

Problematic Scan Data



High quality image



Low quality image

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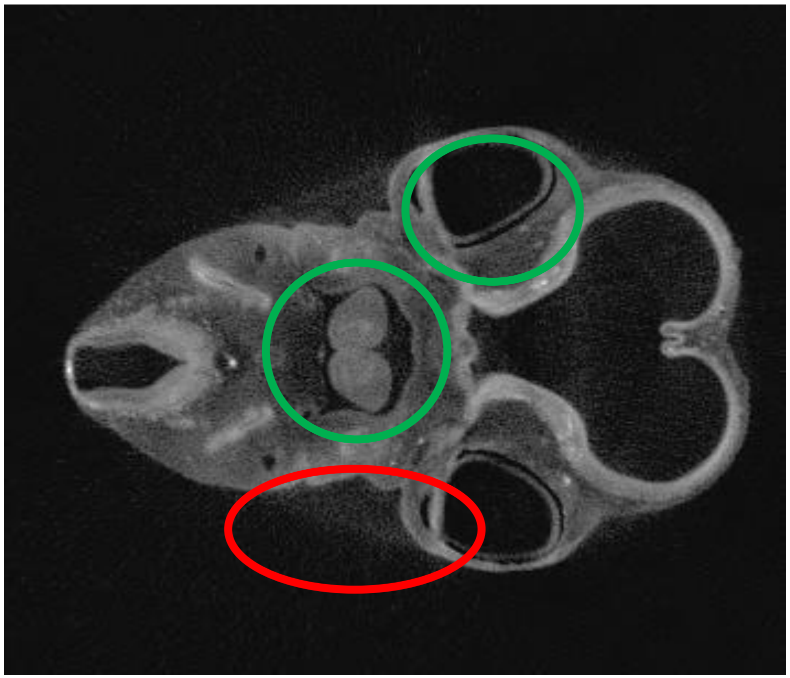
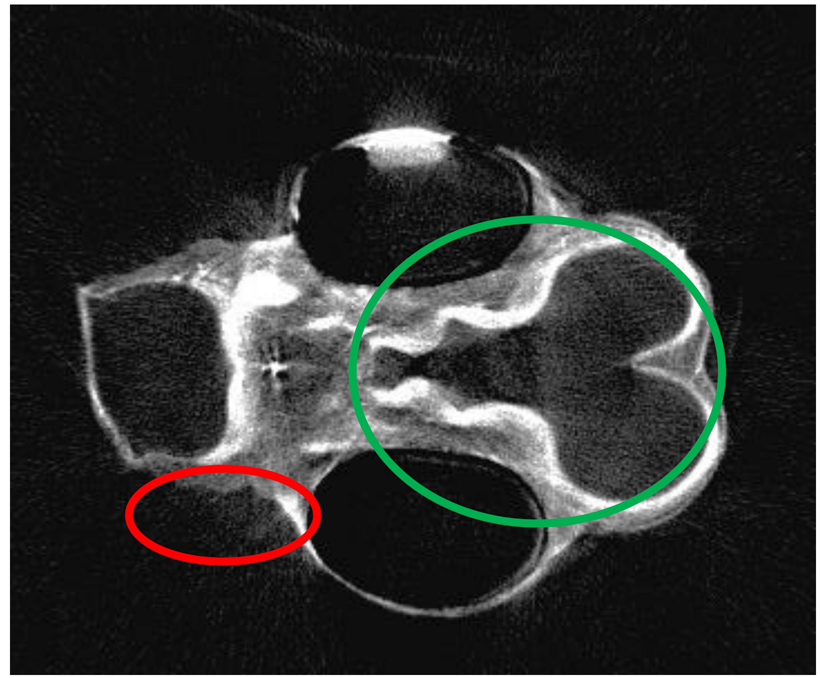


High quality image



Low quality image

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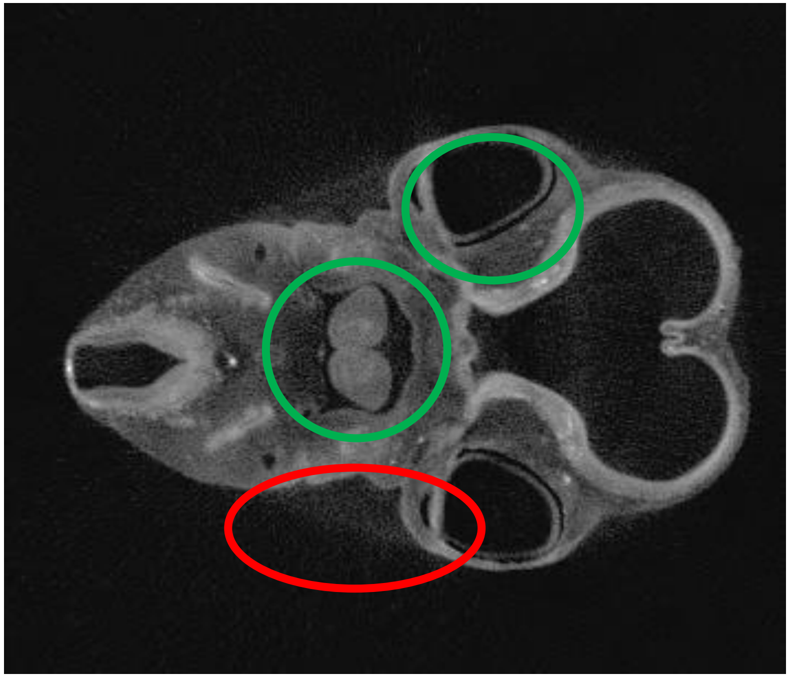
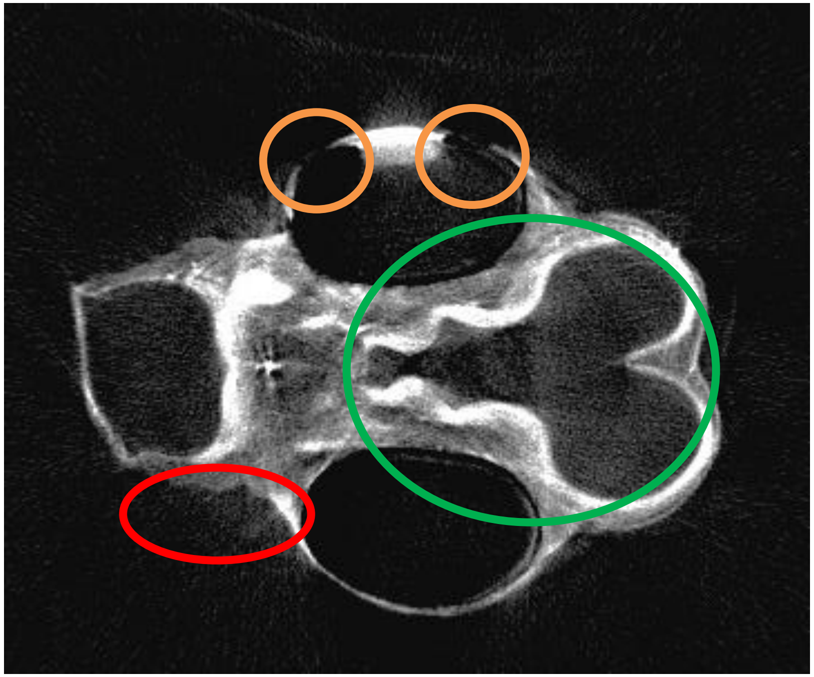
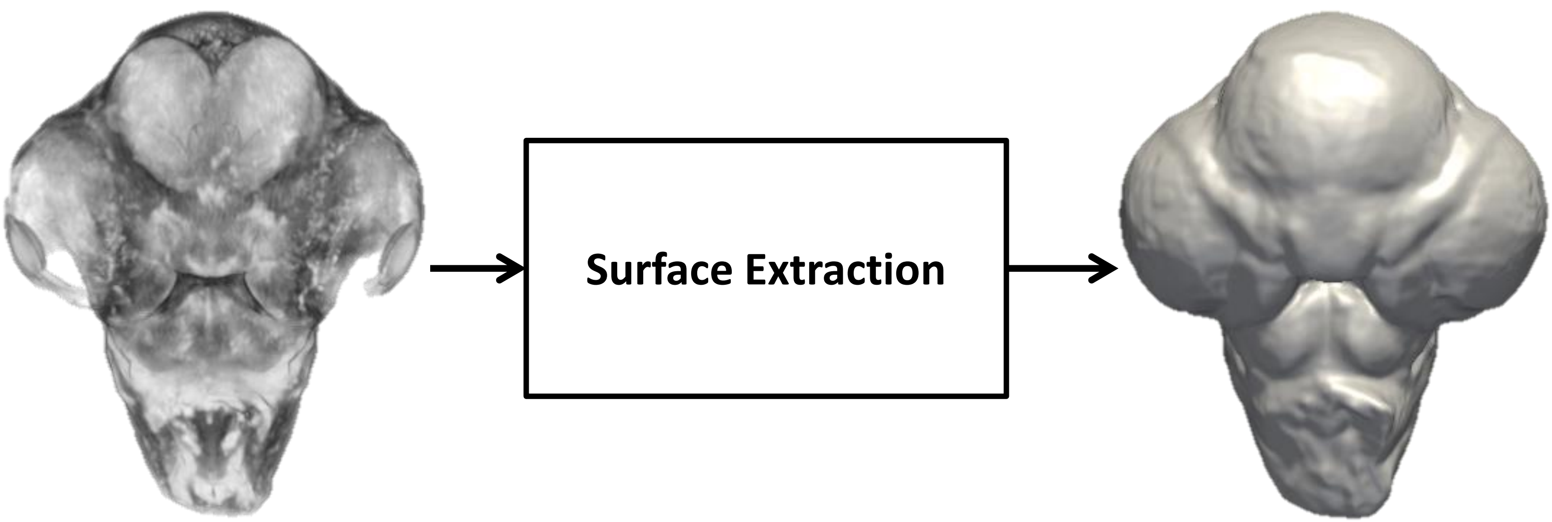


High quality image



Low quality image

Preprocessing: 3D Surface Generation

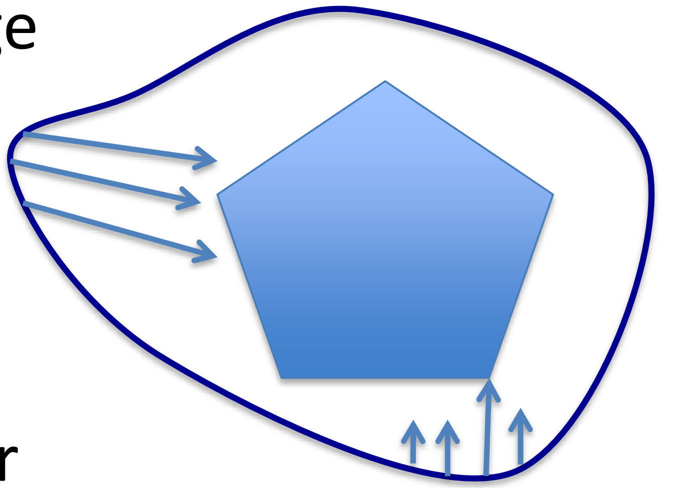


3D scan of embryo head

Surface contour of embryo head

Geodesic Active Contours

- Method for detecting image boundaries
- Start with contour approximating image boundary
- Initial contour evolved over time according to "forces" calculated from image



Snakes: Active contour models, Kass, M. and Witkin, A. and Terzopoulos, D.

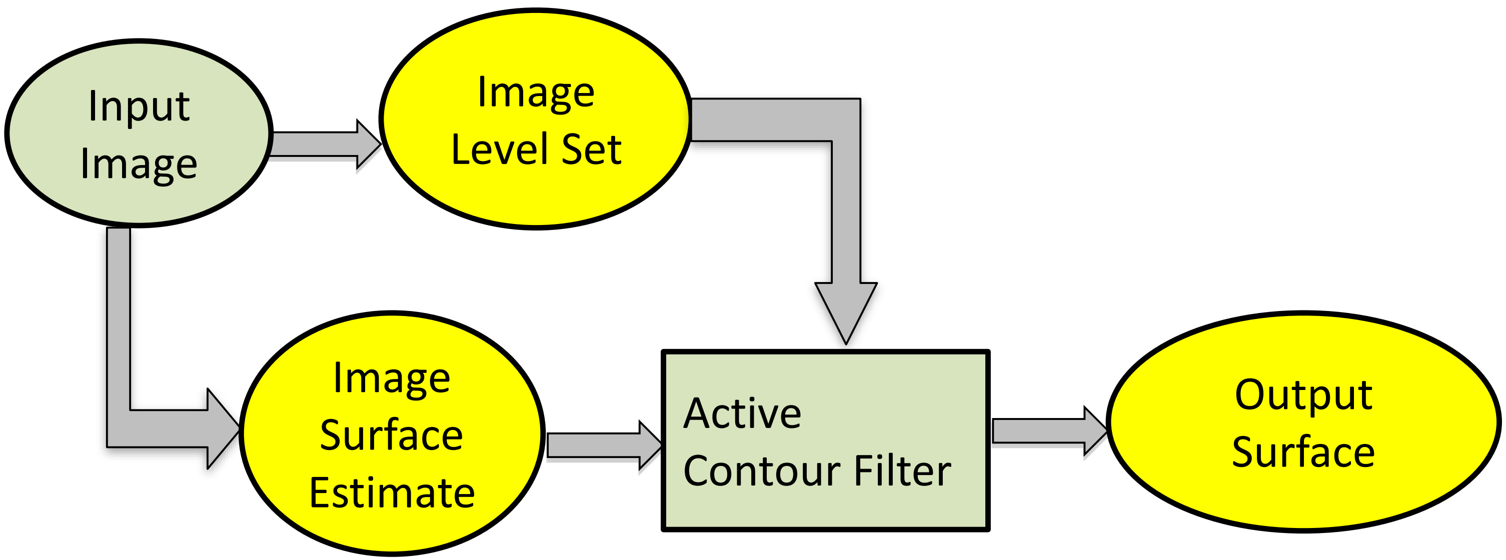
Steps for Geodesic Active Contour Algorithm

1. Model the shape with an estimated surface
2. Define energy function for surface as:

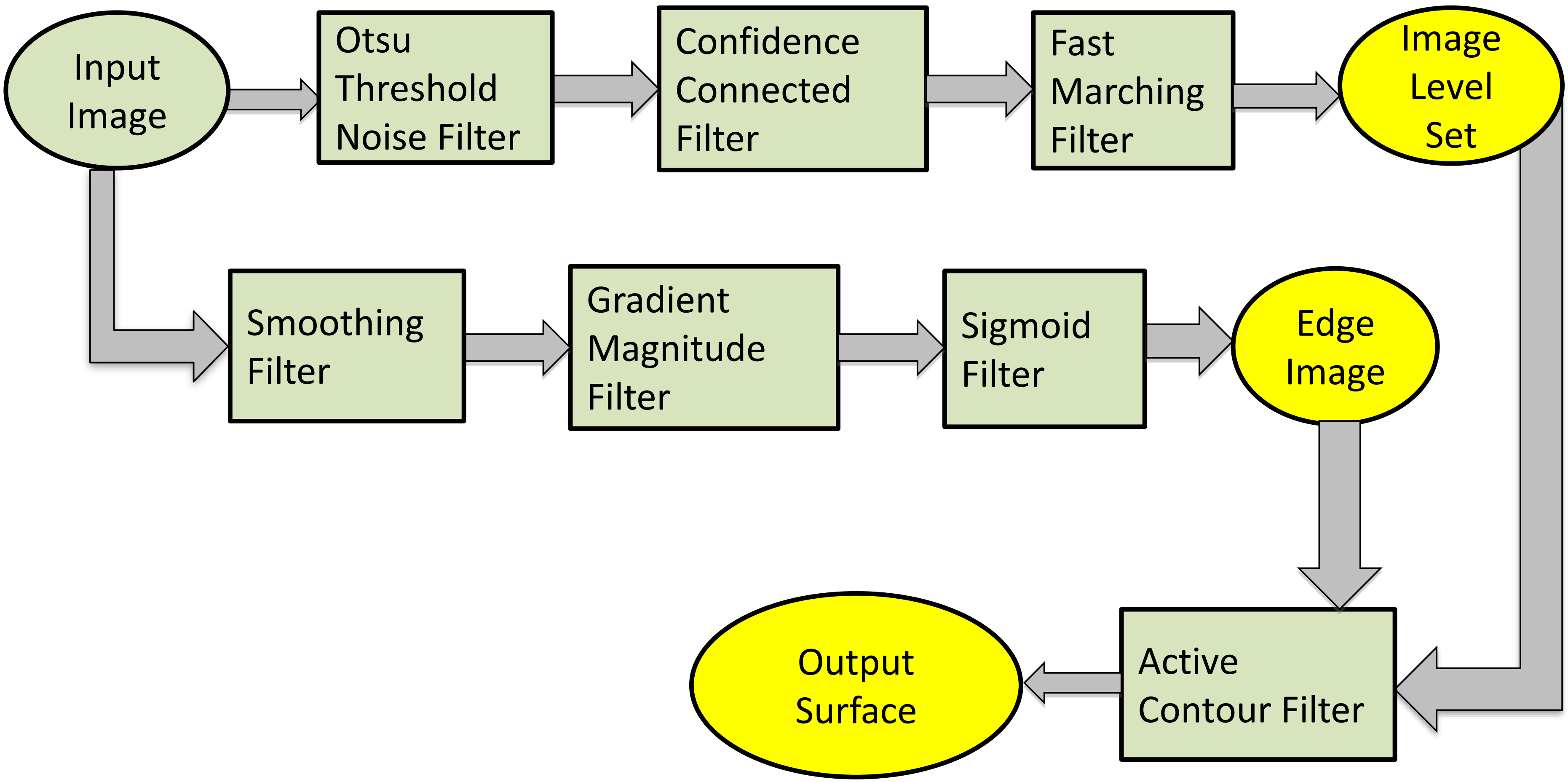
   E = Internal energy (curvature) + external energy (image edges)

3. Derive curve to minimize energy
4. Propagate curve using level set to attain minimum energy

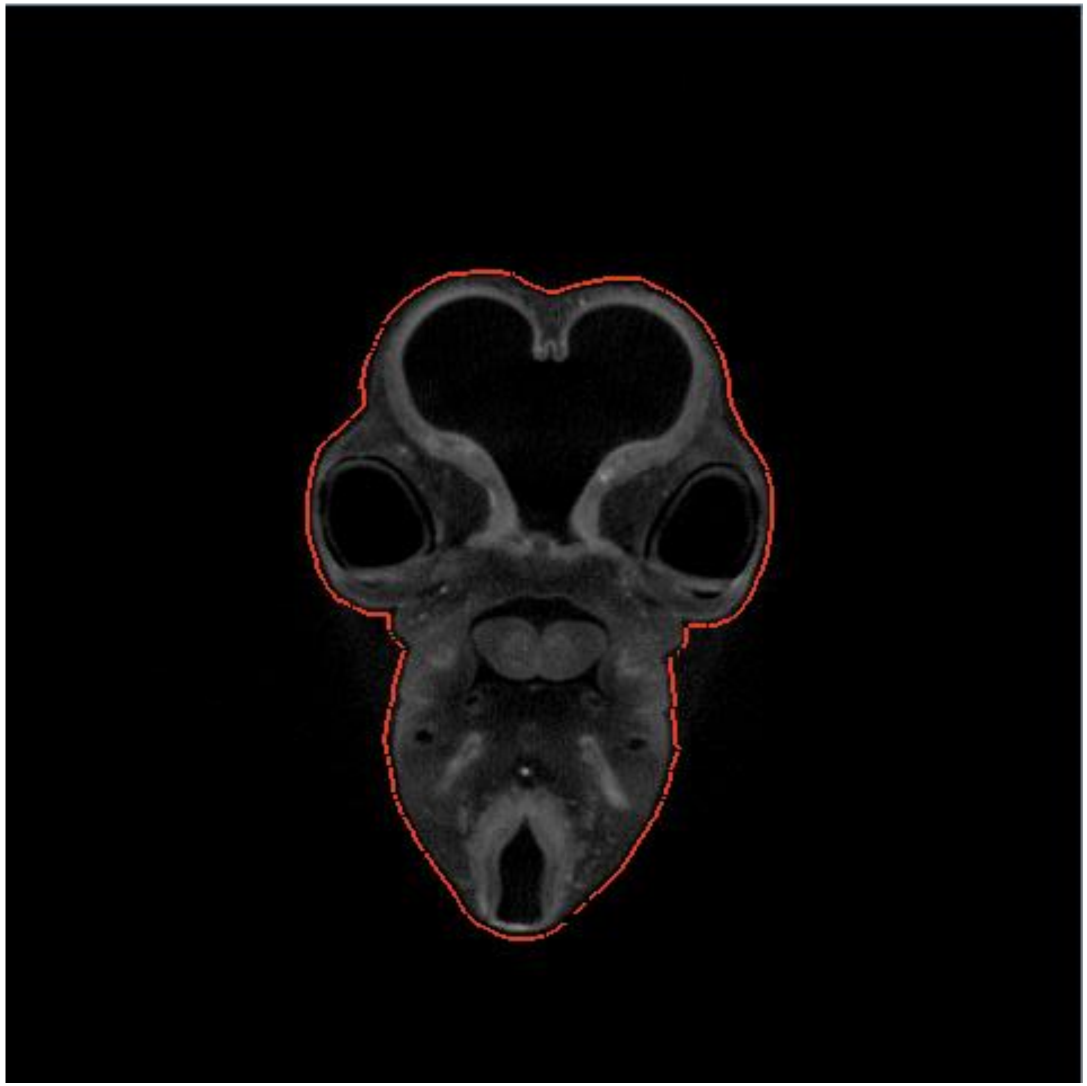
Geodesic Active Contour Implementation



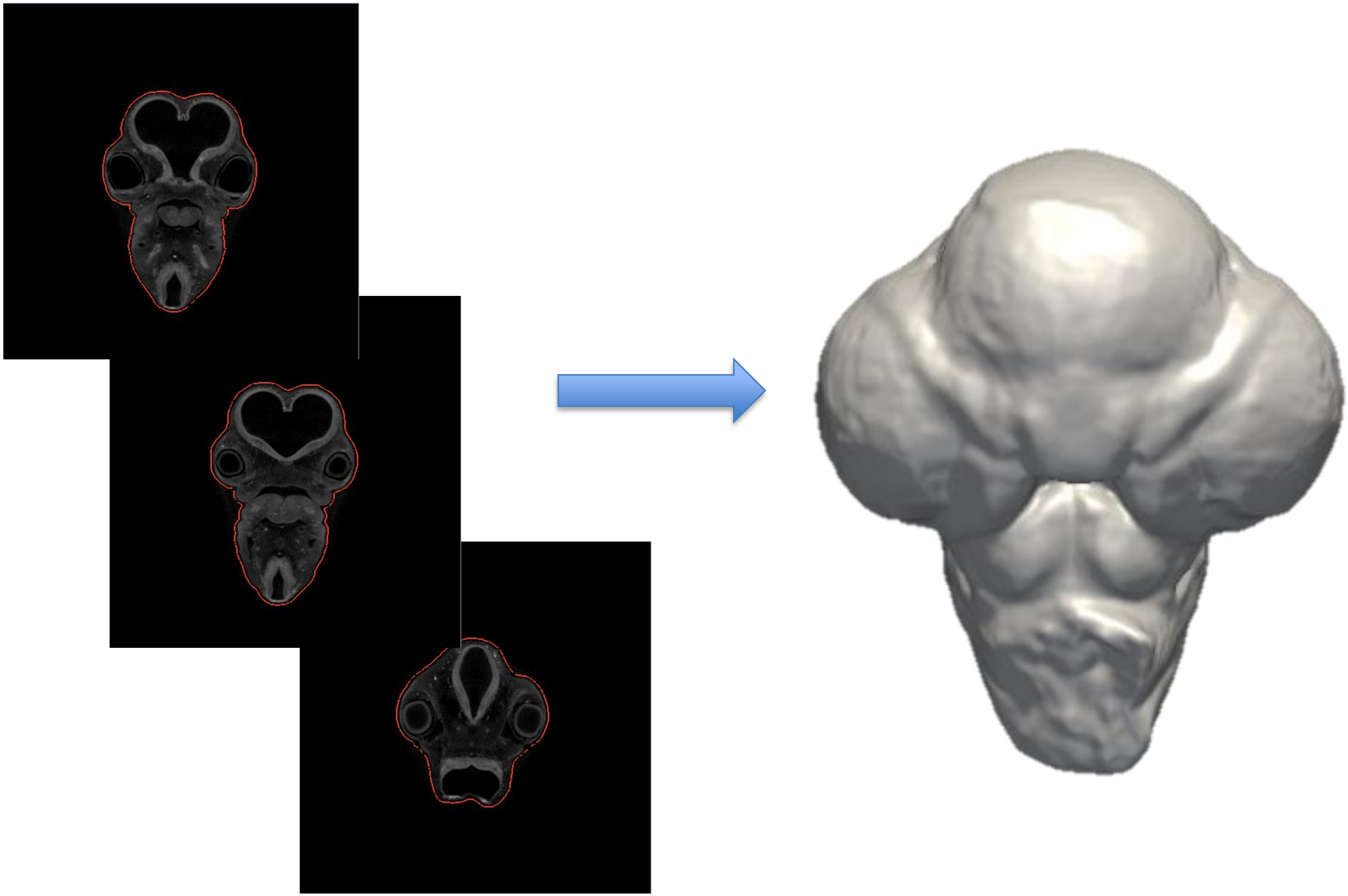
Geodesic Active Contour Implementation



2D Example

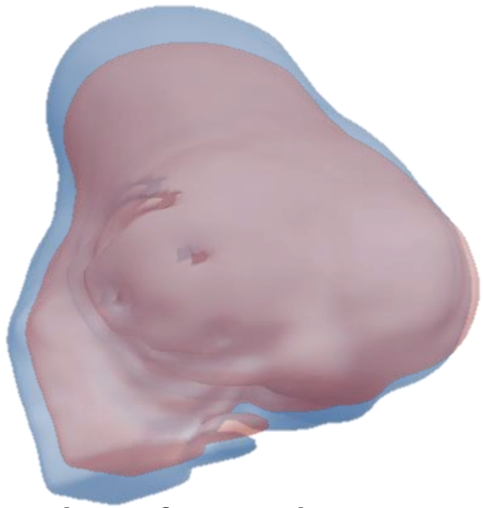


3D Surface Generation

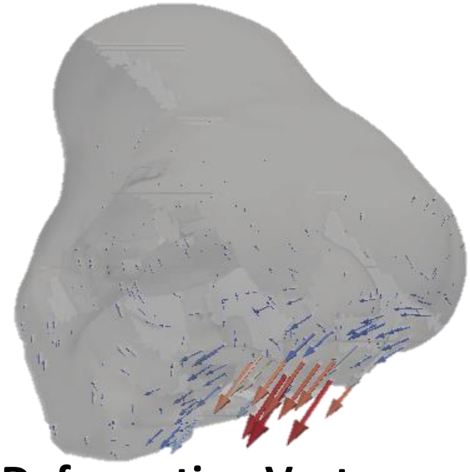


Deformable Registration

- Dense field of vectors describes transformation at each point
- Essentially provides continuous landmark data



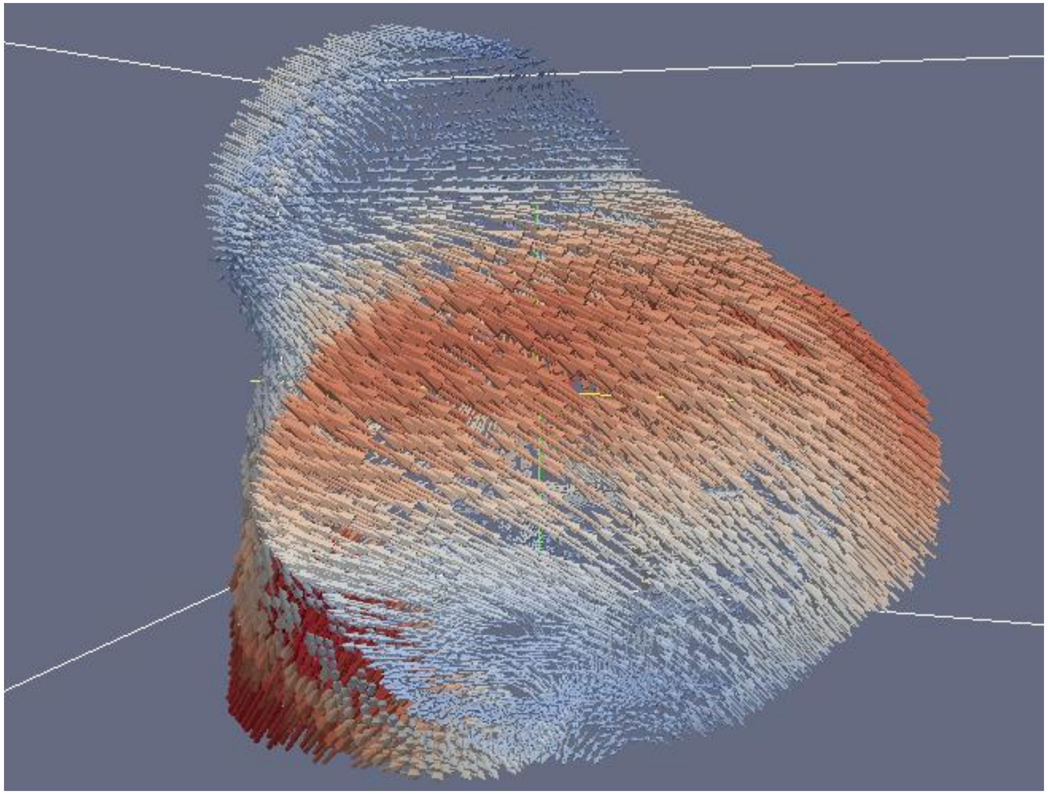
Overlay of two objects



Deformation Vectors

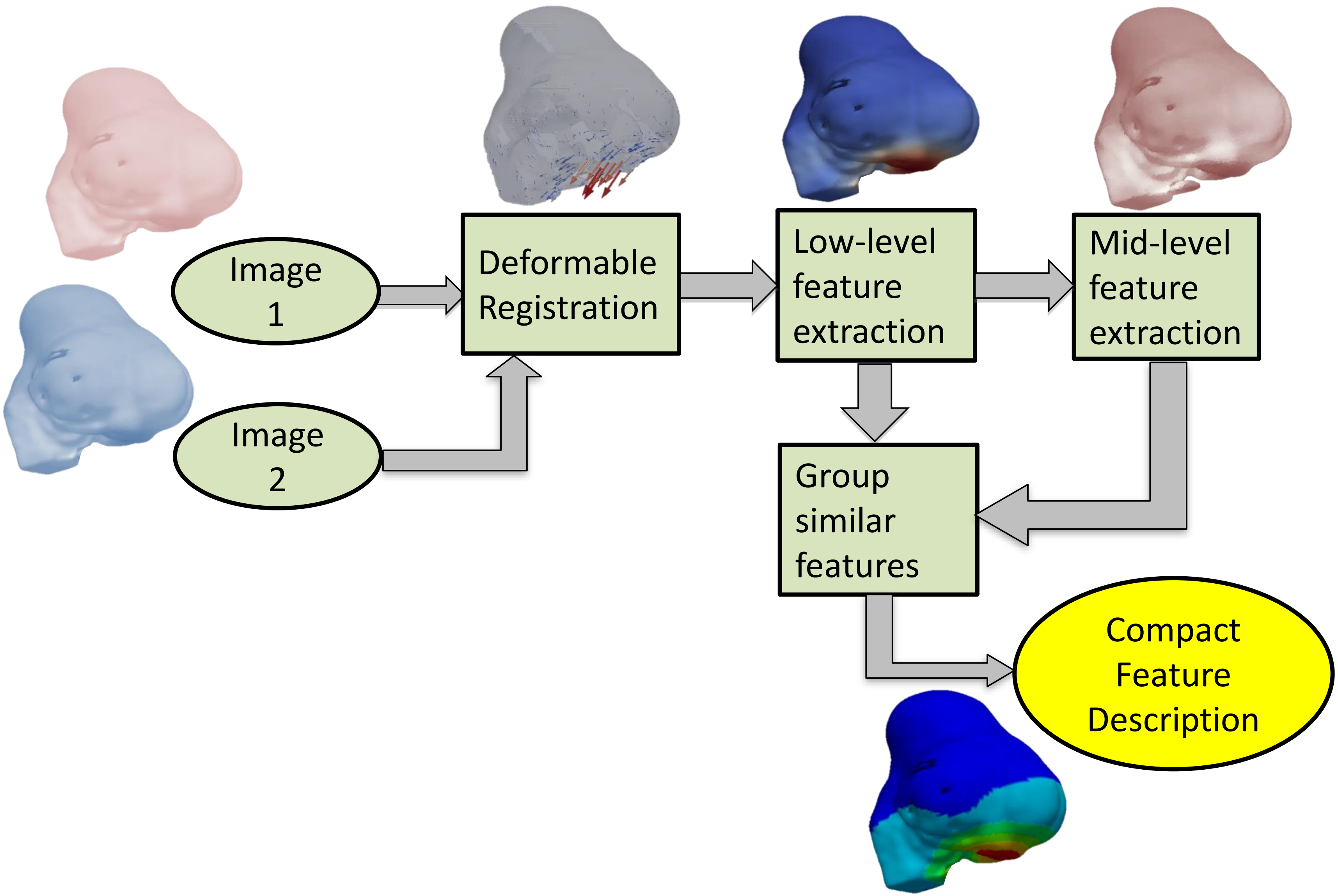
Reducing Data Dimensionality

- High resolution images can have over a million surface points
- Need to reduce this number to track meaningful differences

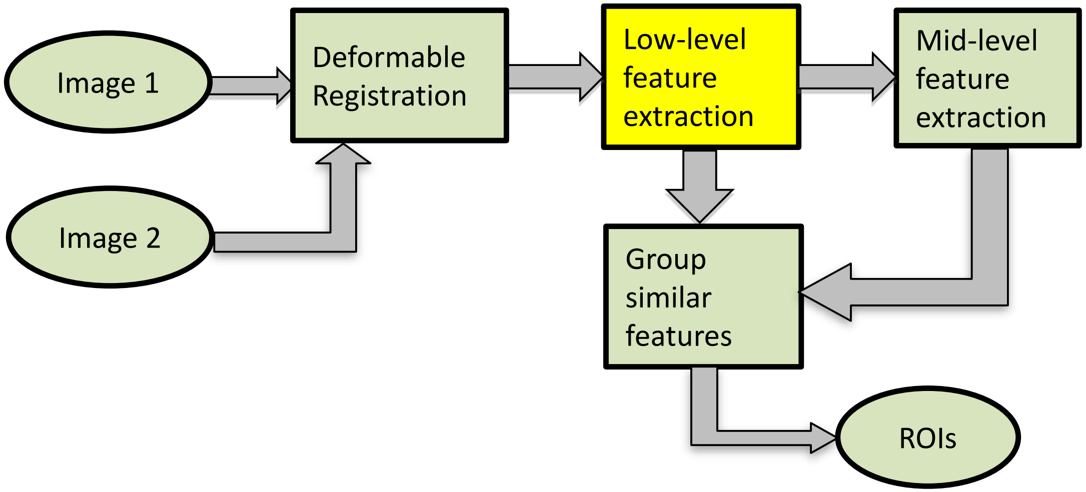


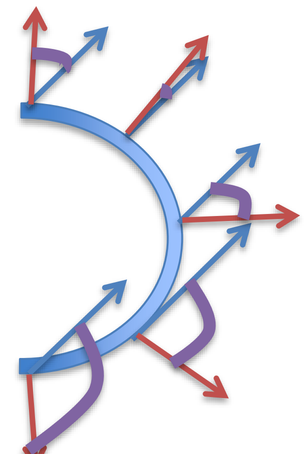
Displaying 500,000 vectors

Overview of Base Methodology



Overview of Base Methodology

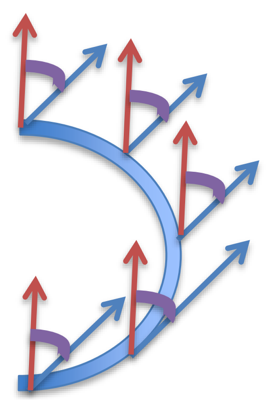




Surface normal angle

Low-Level Features

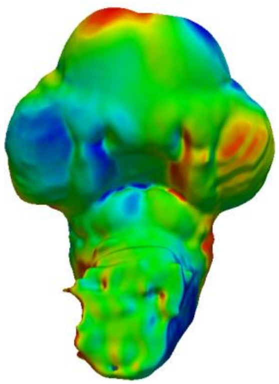
- ***Magnitude***: Vector length
- ***Normal angle***: Cosine distance from normal angle
- ***Reference vector angle***: Cosine distance from reference vector



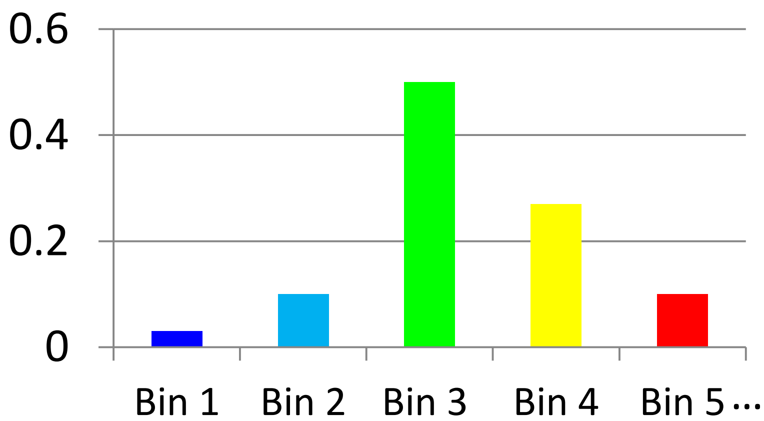
Reference vector angle

Spatiograms for Identifying Regions

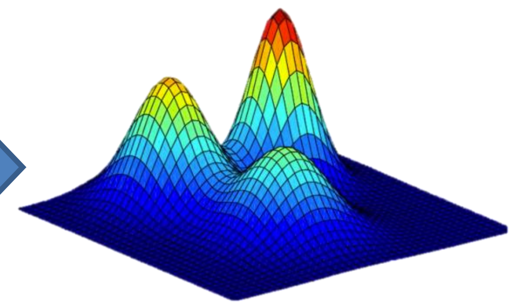
Heat Map of Feature Values



Histogram of Feature Values



Bin spatial distributions



Bins contain Gaussian distributions describing spatial position of values

Calculating the Spatiogram Distance Metric

- Based on the Bhattacharya coefficient: measures overlap between statistical samples
- Spatiograms represented as histograms with an added dimension

$$\rho(h, h') = \sum_{b=1}^{|B|} \Psi_b \sqrt{n_b n'_b}$$

B = number of bins, n_b = value of bin b

Ψ_b = spatial weighting term expressing similarity of distributions

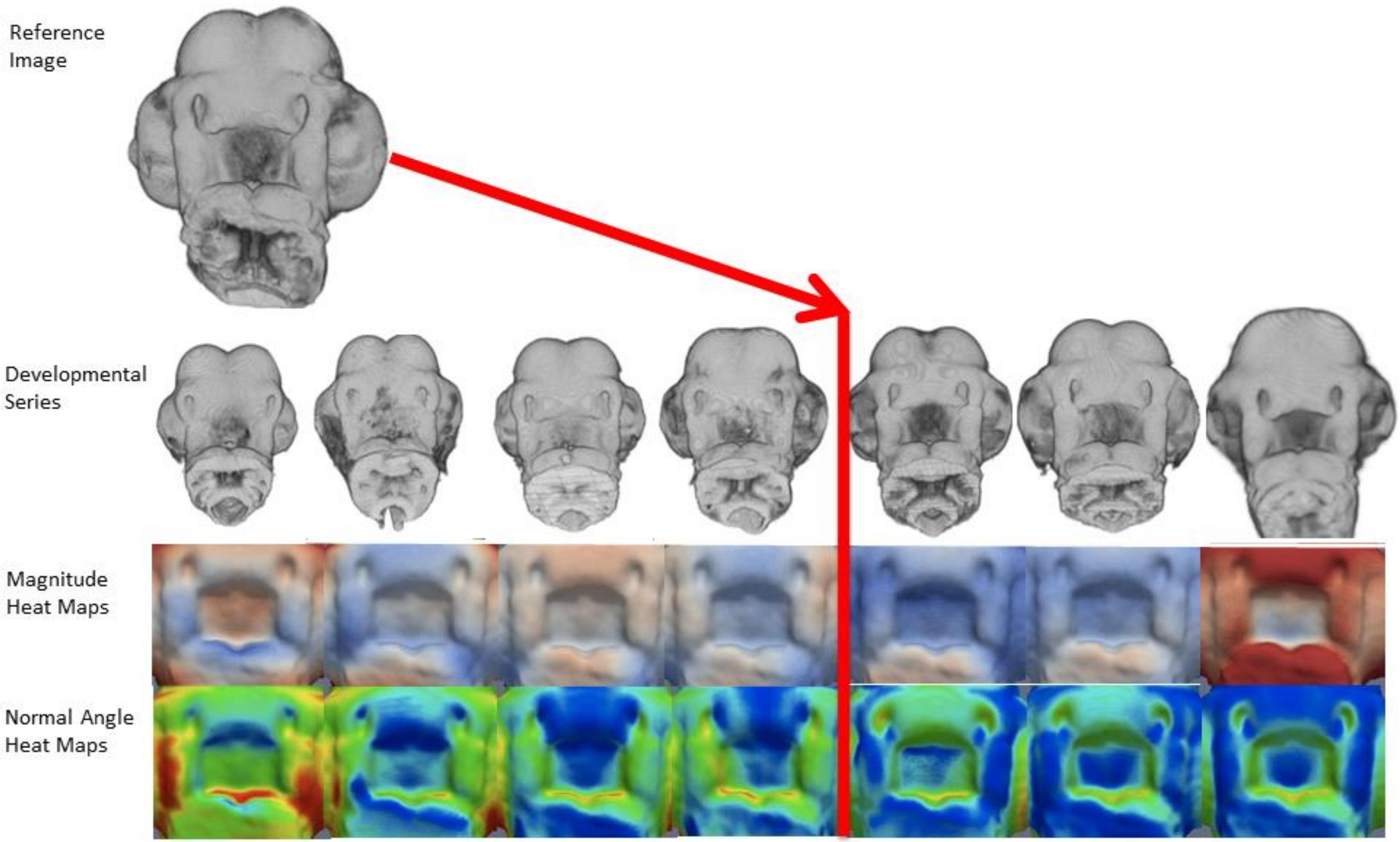
Chick Embryo Developmental Sequence

HH 19.5 HH 24 HH 24.5 HH 25 HH 26

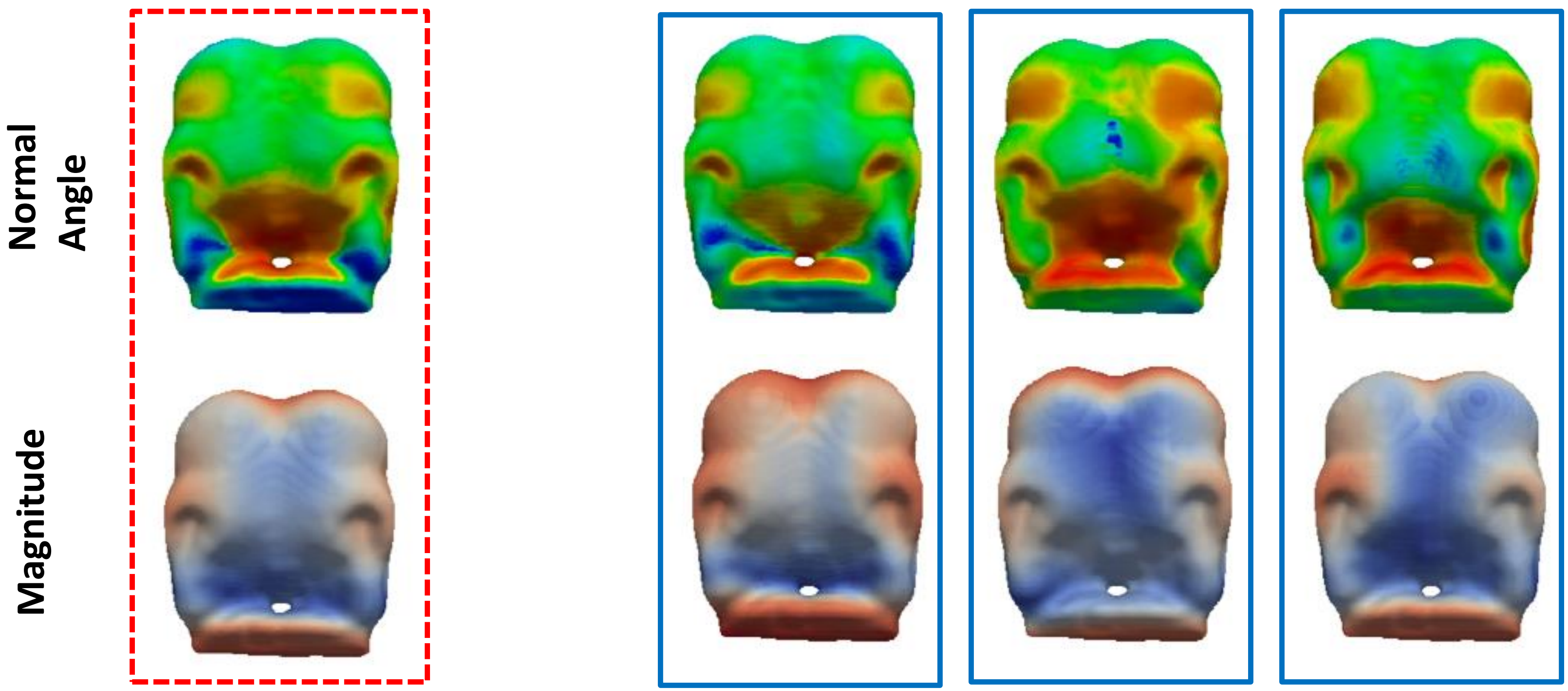
Developmental Growth Sequence

- 16 specimens
- 5 developmental stages

Application to Developmental Sequence



Retrieval of Similar Growth Trajectories



Query feature heat maps

Heat maps of top 3 ranked results

Similarity Scores: Growth Trajectory

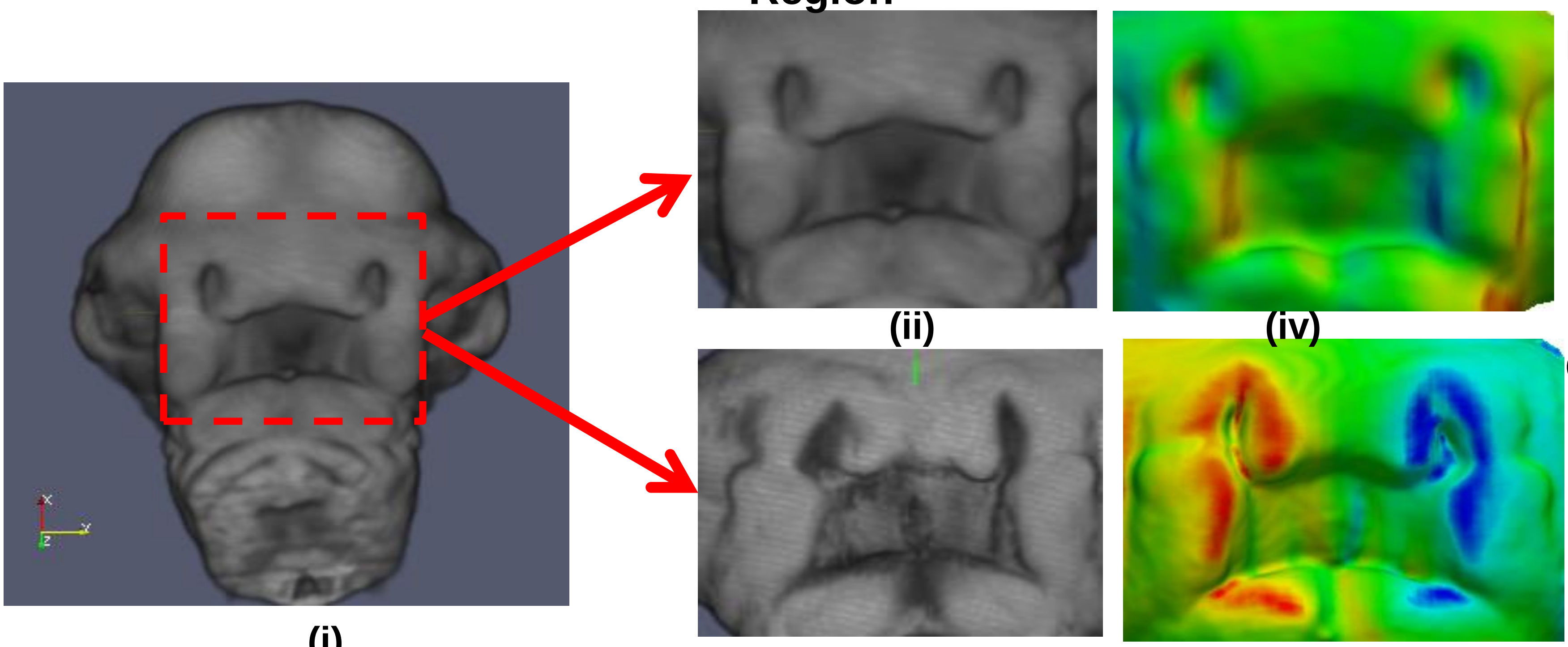
Average Score: 0.049
Close to the ideal score of 0

Developmental Stage

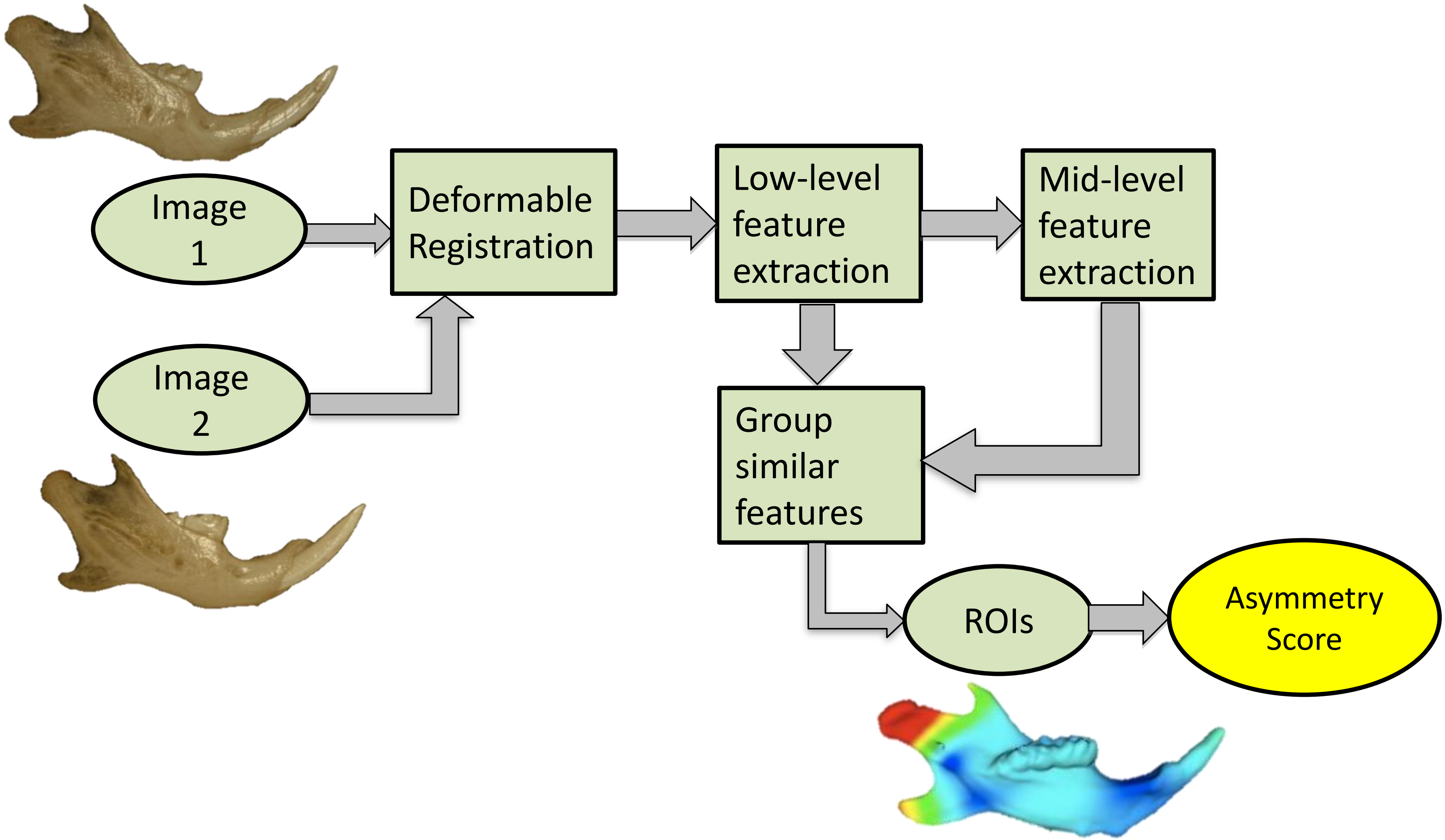
Template

	HH 24	**HH 24.5**	**HH 25**	**HH 26**
HH 19.5	0.087	0.018	0.156	0.020
HH 24	X	0.017	0.021	0.045
HH 24.5	0.044	X	0.008	0.069
HH 25	0.007	0.100	X	0.072
HH 26	0.030	0.067	0.045	X

Morphological Shape Change: Characterizing Asymmetry

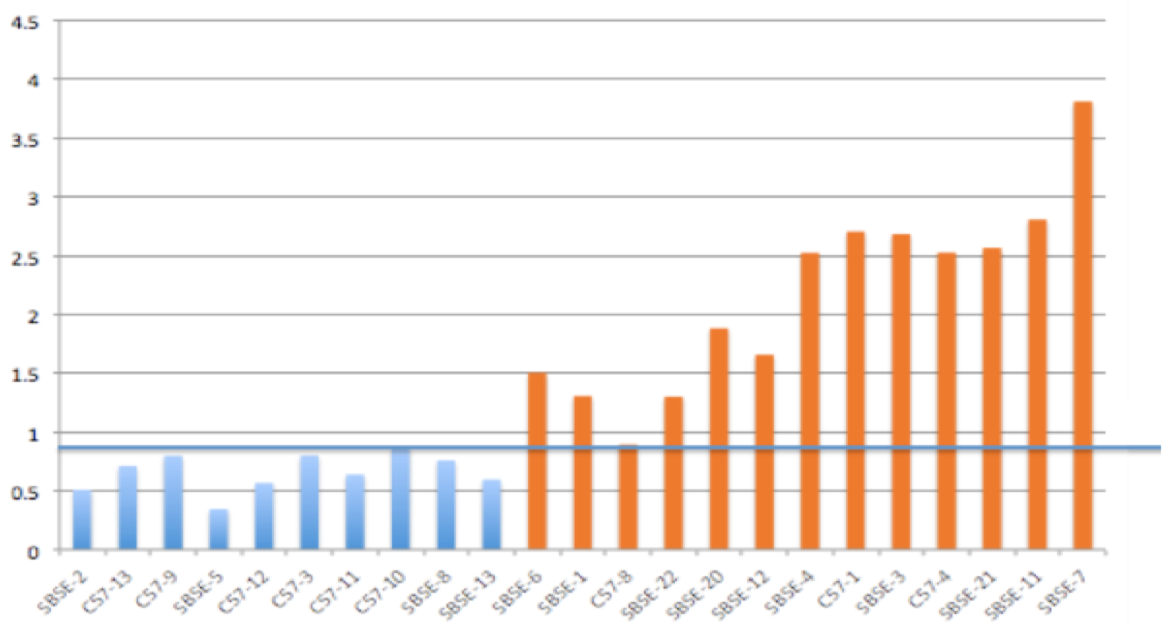


Assessing Mouse Mandible Symmetry



Assessing Mouse Mandible Symmetry

- Tool for characterizing and quantifying the asymmetry in bilaterally paired structures.
- Applied it to the two sides of the mandible of the mouse.
- Asymmetry scores compared to human expert



our
score = height

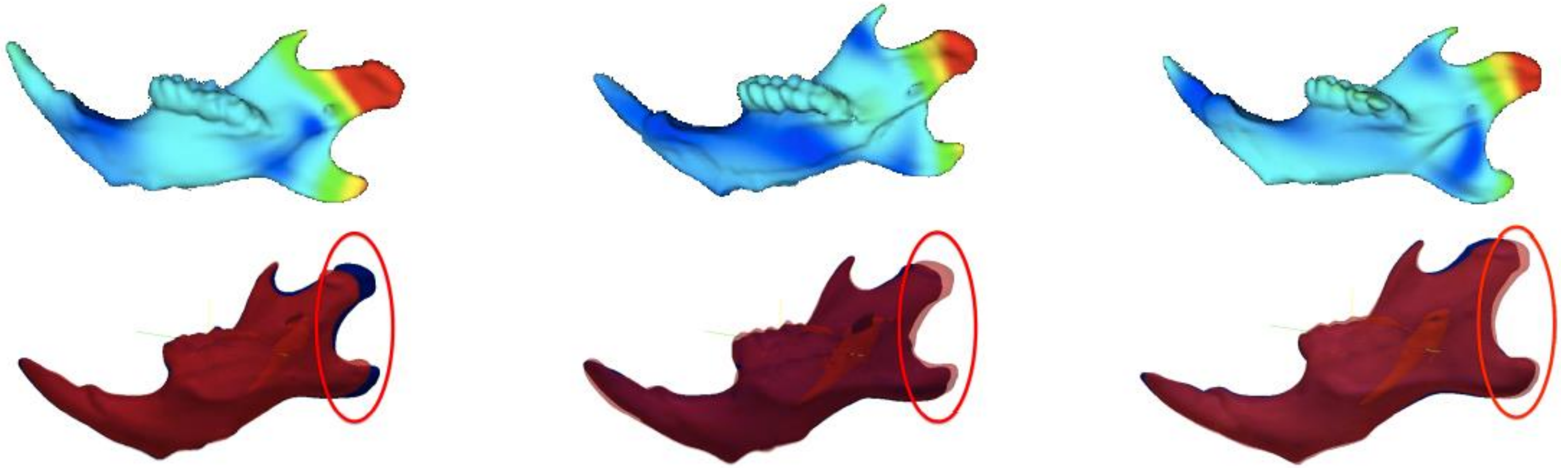
blue = normal
orange = abnormal

Correlation Coefficient = .92

Rolfe, S. M., Camci, E. D., Mercan, E., Shapiro, L. G., & Cox, T. C. "A New Tool for Quantifying and Characterizing Asymmetry in Bilaterally Paired Structures." IEEE EMBS '13 Jul 2013.

Retrieval of Specimen with Similar Morphological Shape Differences

Magnitude Sample Query



Magnitude Heat Map

Left/Right Overlay

(i) Query Image **(ii) First Result** **(iii) Second Result**

Correlation between distance from most asymmetric and expert asymmetry ranking = 0.91

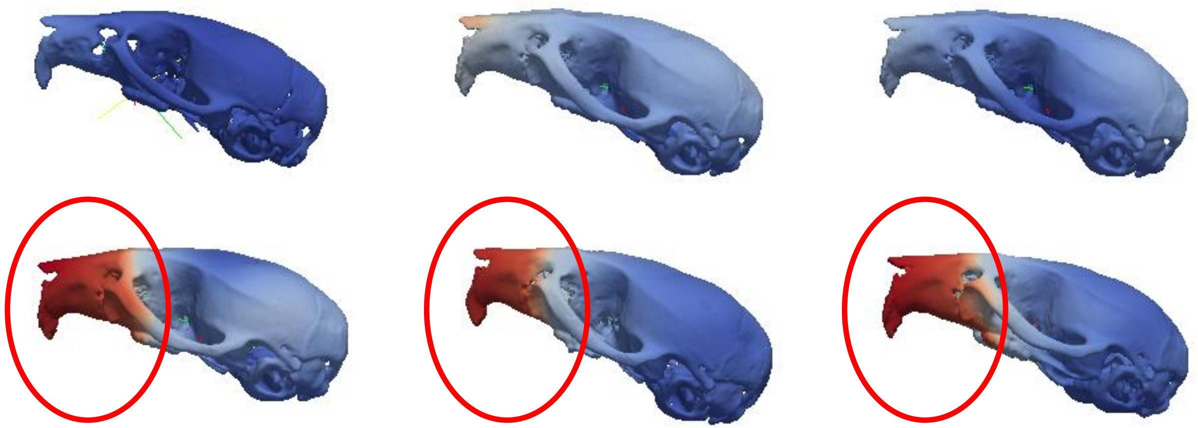
Rolfe, S. M., Camci, E. D., Mercan, E., Shapiro, L. G., & Cox, T. C. "A New Tool for Quantifying and Characterizing Asymmetry in Bilaterally Paired Structures.“ IEEE EMBS ‘13 Jul 2013.

Morphological Shape Change: Additional Applications

Magnitude Heat Maps – Mouse Skull

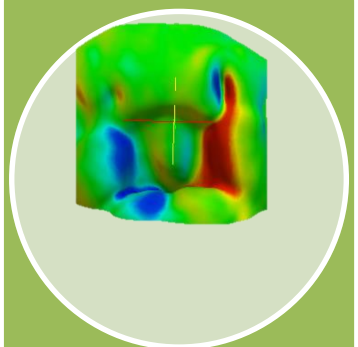
Wild Type to Wild Type

Wild Type to Mutant



Questions?

Object surface contours



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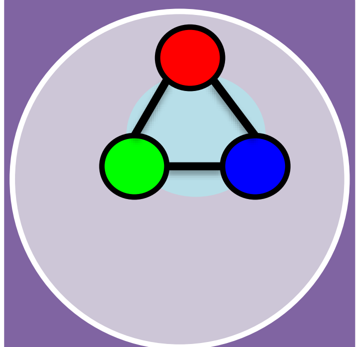

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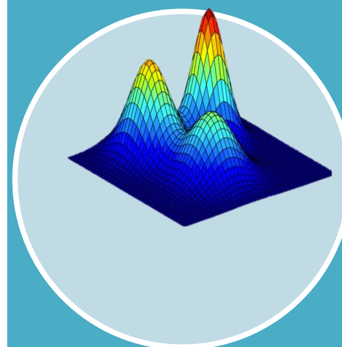

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