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Automated Landmarking through Point-cloud Alignment and Correspondence Analysis

Arthur Porto

Seattle Children's Research Institute

Seattle Children's
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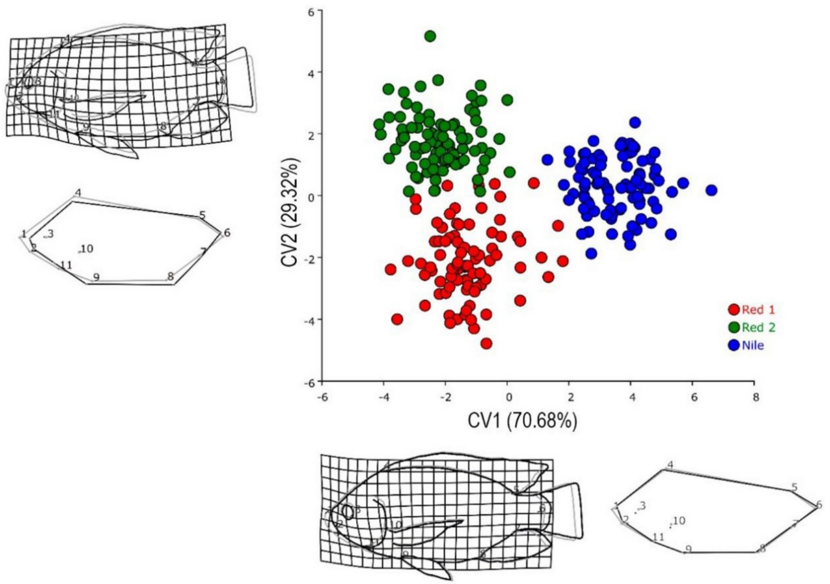
SLICERMORPH

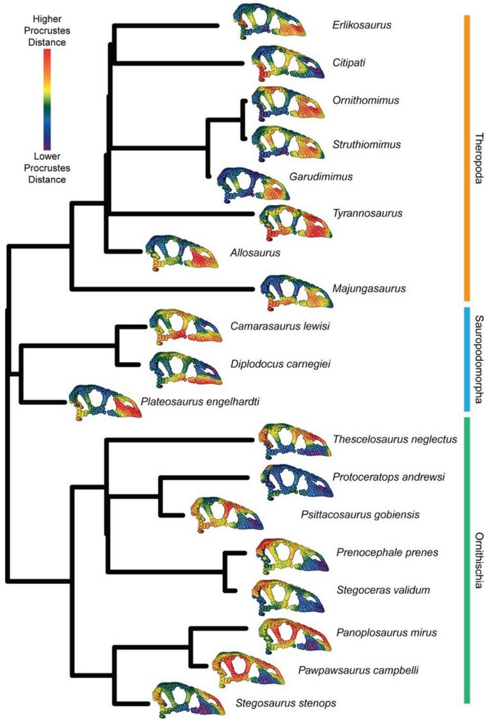
Morphometrics – EcoEvo

Morphometric analysis is widely used in ecology and evolutionary biology

Plasticity



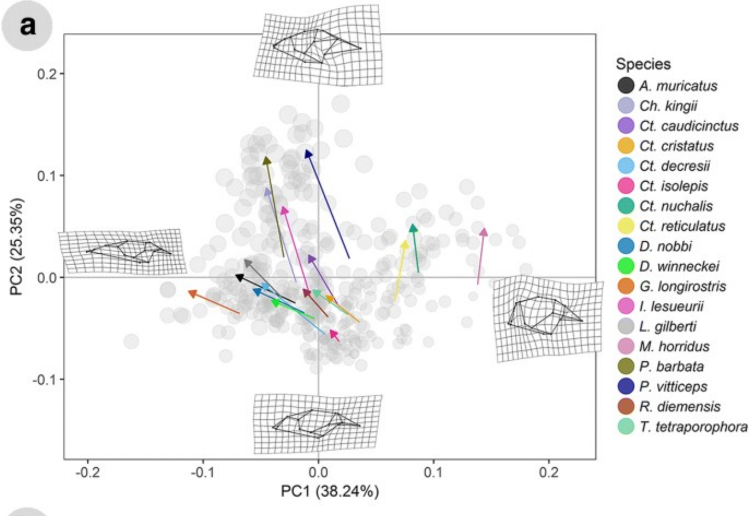
Montoya-Lopez et. al., 2019



Evolutionary change

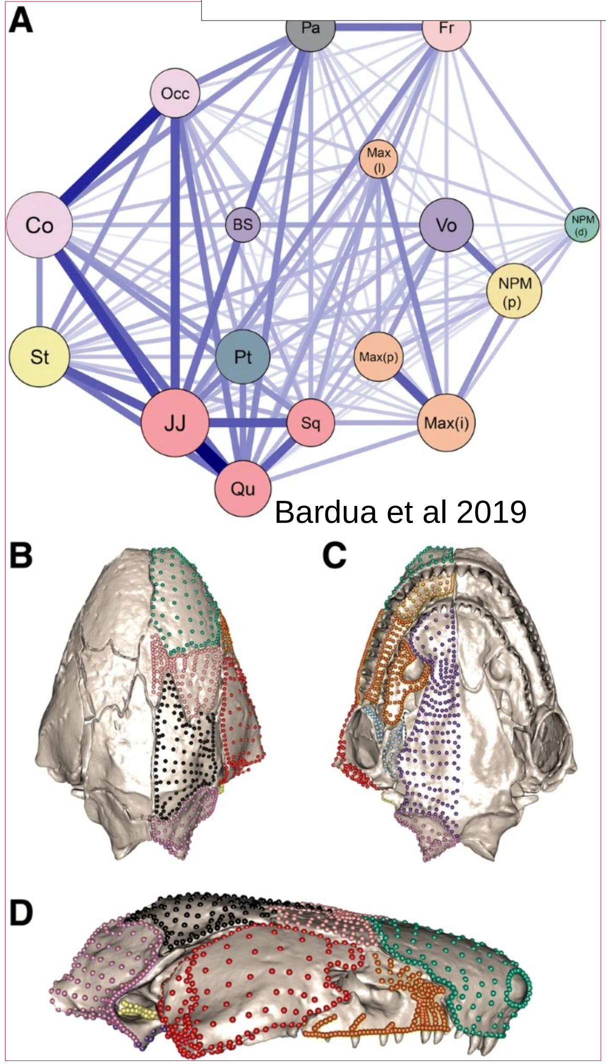
Felice et. al., 2020

Ontogeny

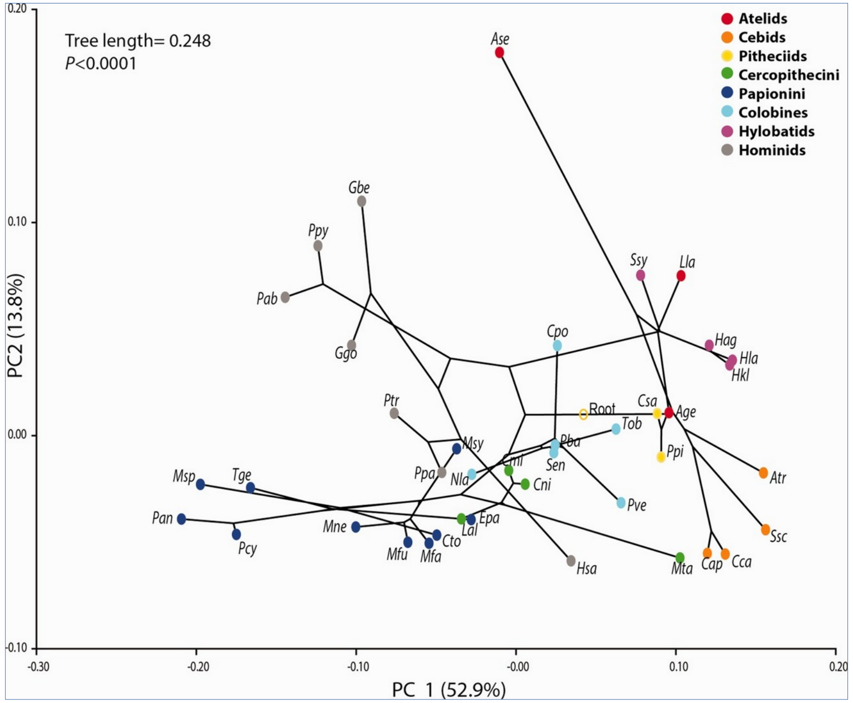


Gray et. al., 2019

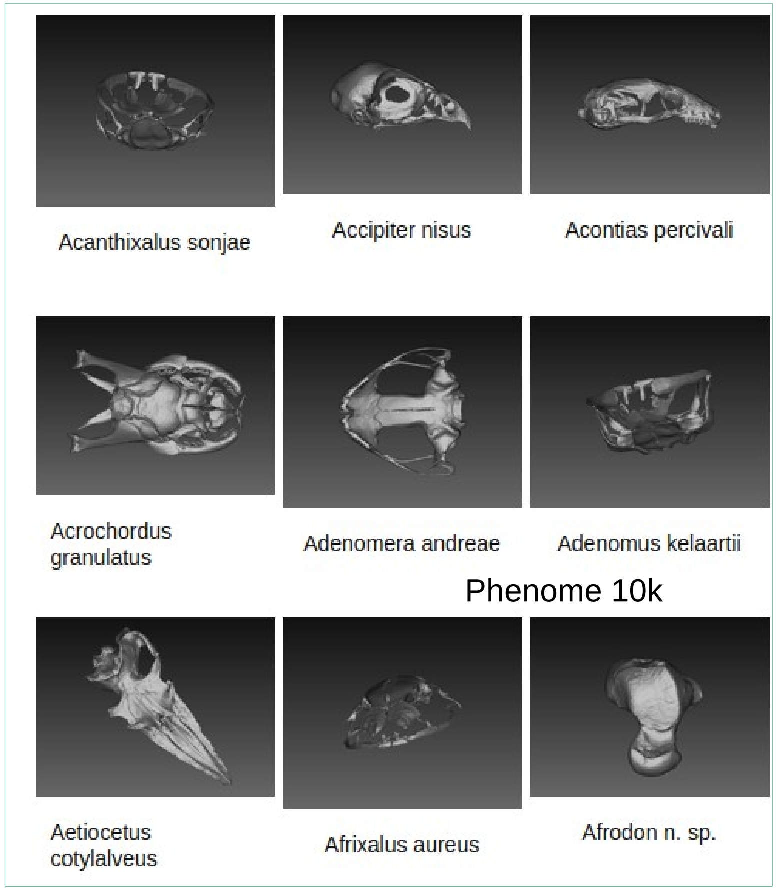
Advances – Analysis, Data and Imaging



Modularity and Integration



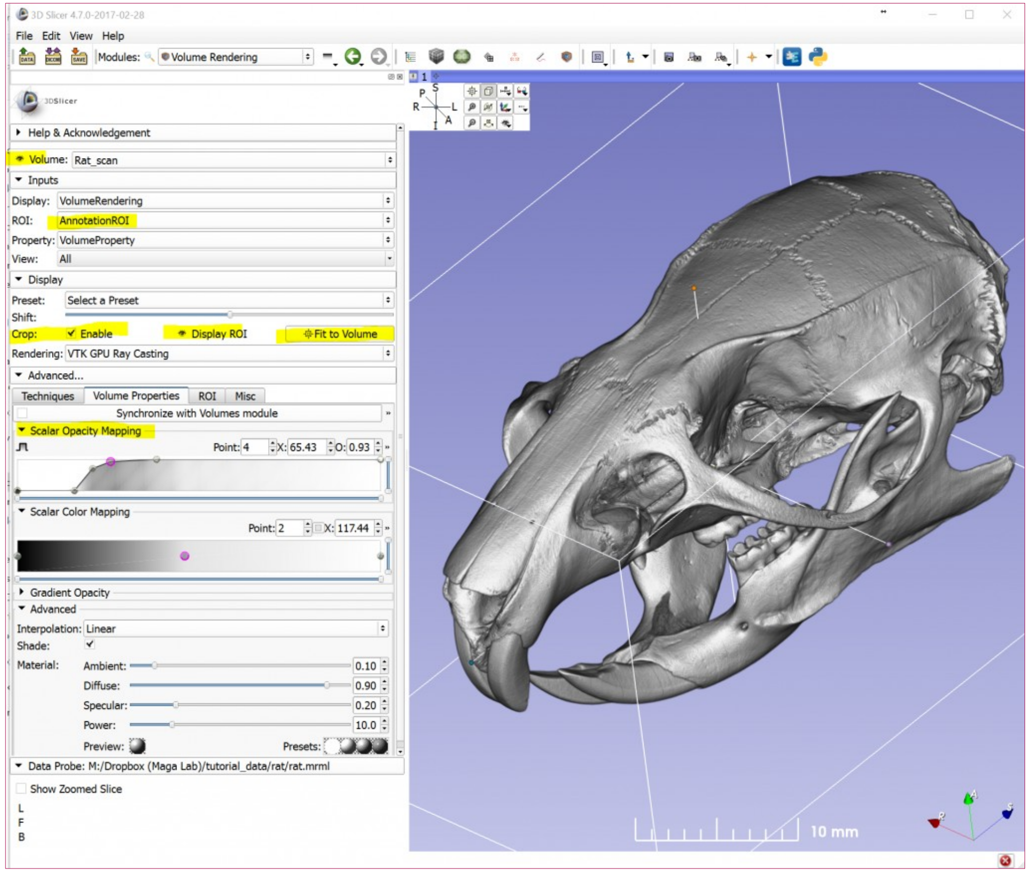
Phylogenetics And Evolutionary Models



Public Databases and High res. images

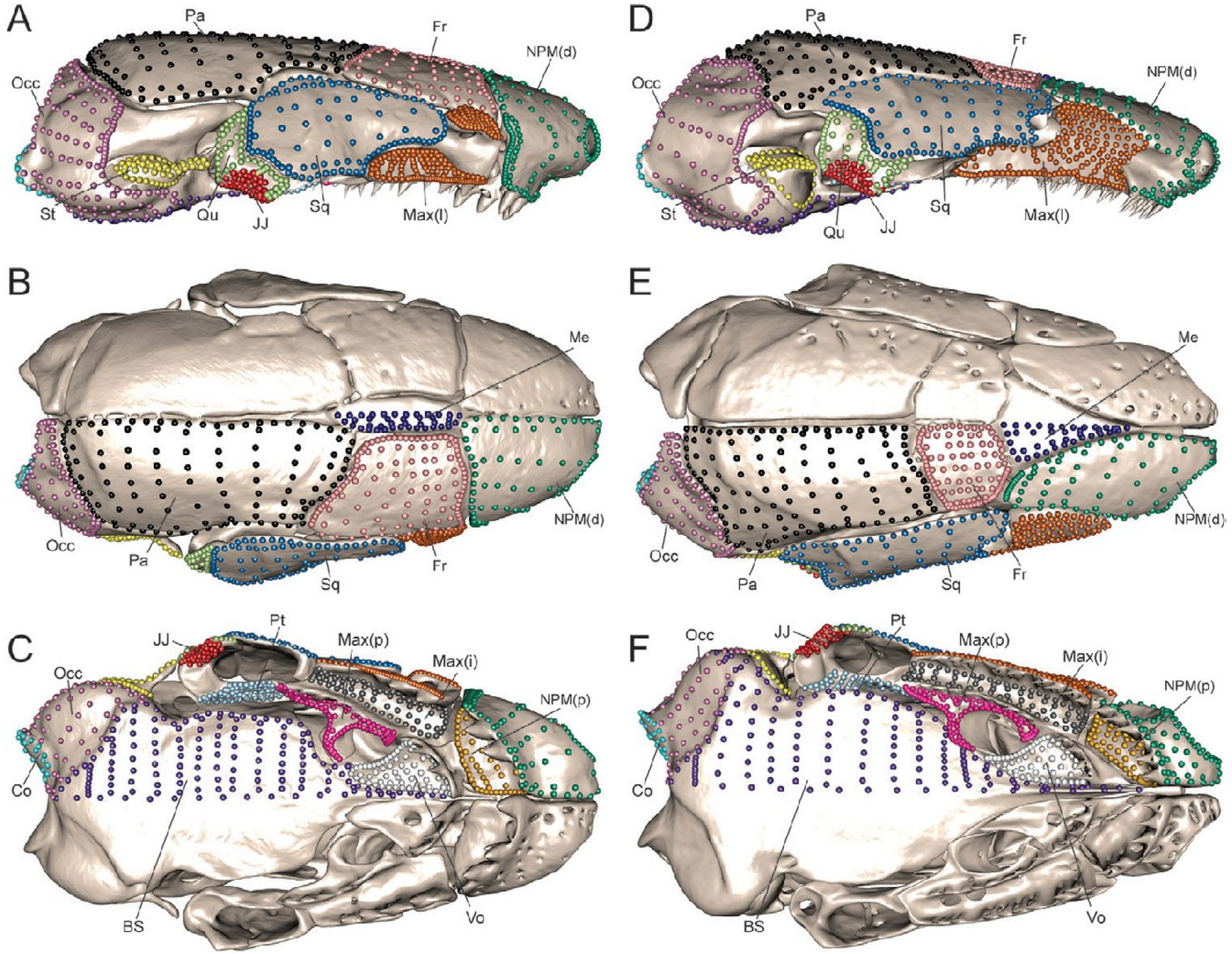
Data collection – Still largely manual

e.g., digitizers



e.g., software

Time consuming



66 (type 1)
+
336 (sliding)
+
736 (semi)

Marshall et. al., 2019

Intra- and inter-observer error

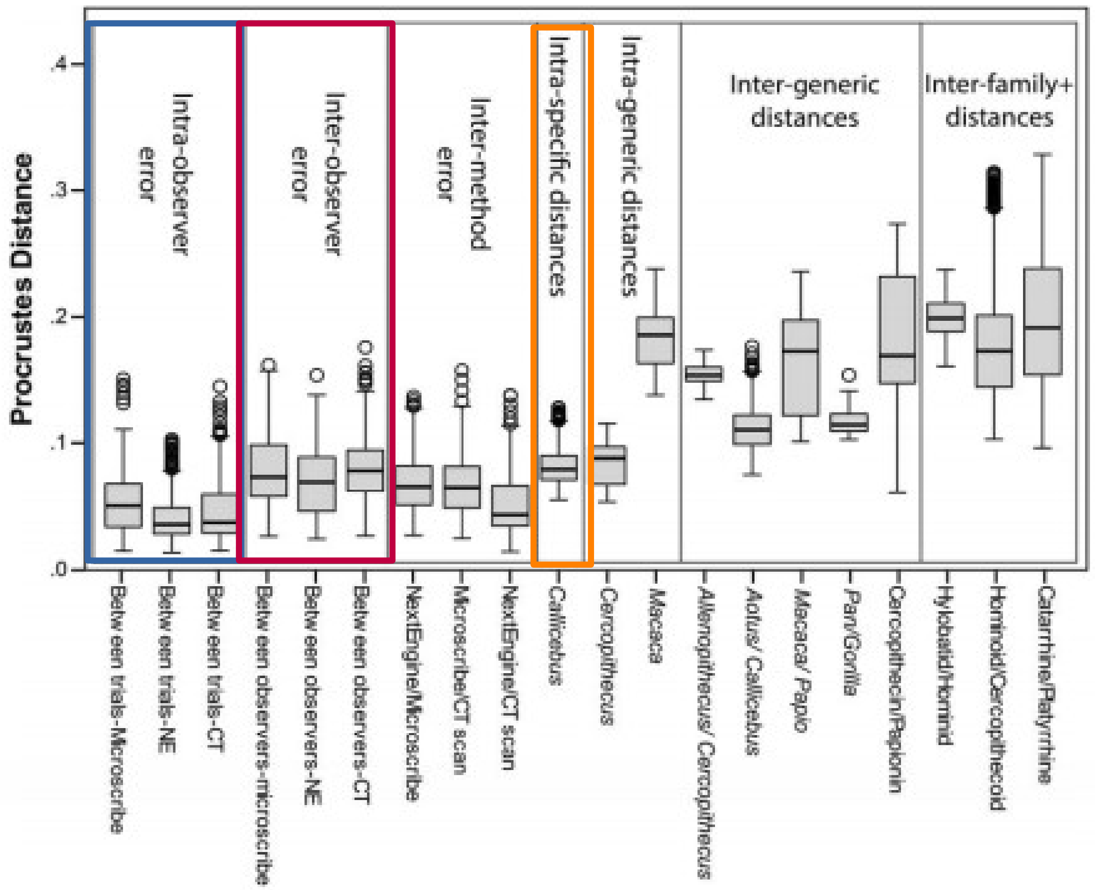
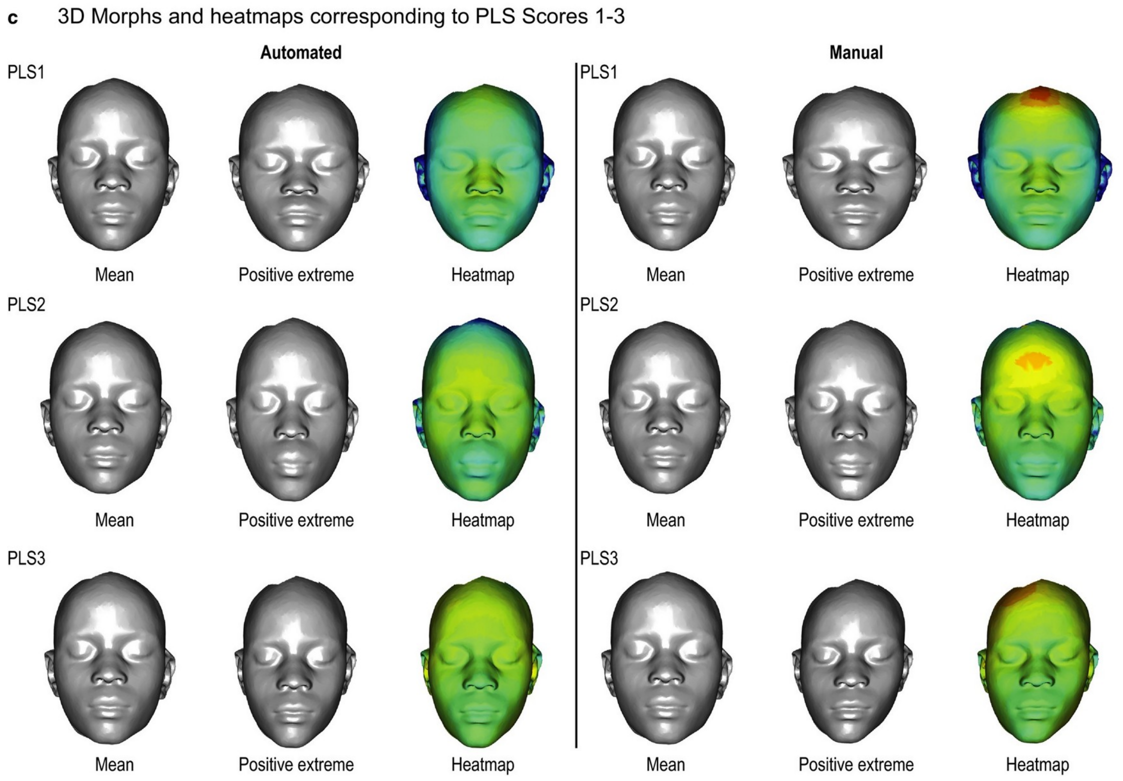


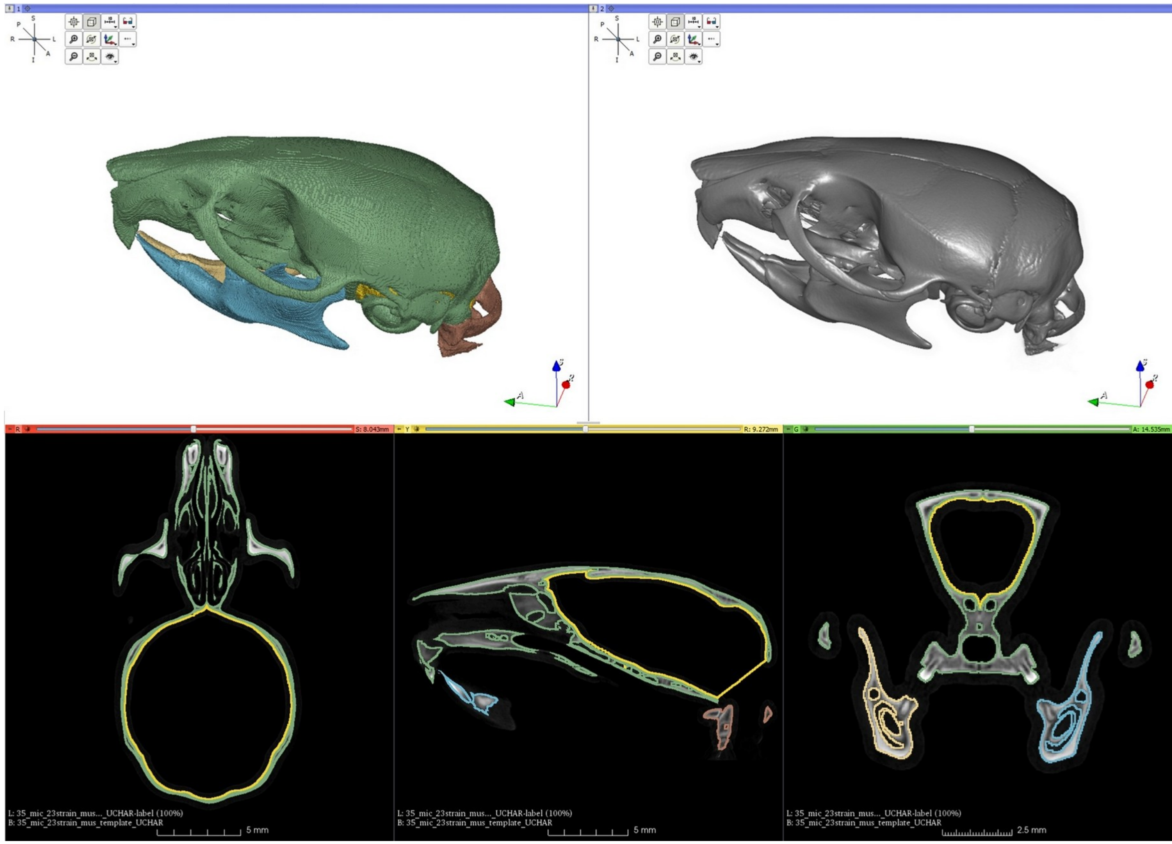
FIGURE 4 Box plot of Procrustes distances within and among observers, methods, and taxa. Darkened bars represent the median value for each group, boxes show the interquartile range (25th to 75th percentile), and the whiskers extend to 1.5 times the interquartile range. Outliers are designated by circles

Robinson and Terhune, 2017

In contrast with biomedical research



Li et al. "Rapid automated landmarking for morphometric analysis of three-dimensional facial scans." Journal of Anatomy (2017).



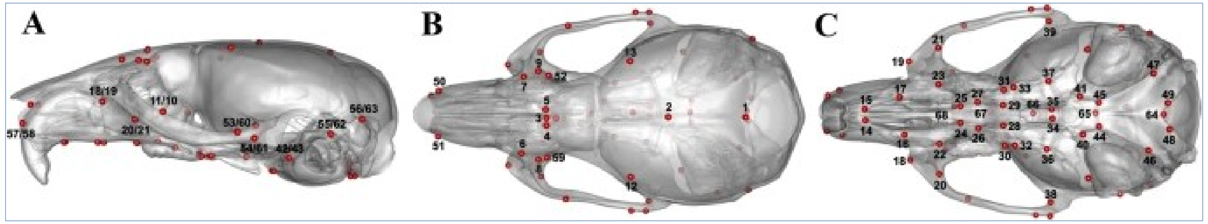
Maga et al. A population level atlas of Mus musculus craniofacial skeleton and automated image-based shape analysis. Journal of Anatomy (2017)

Ecology and Evolution - Challenges

* Lack of comparable resources

    - <u>Personnel</u>: imaging scientist

    - <u>Hardware</u>: automation = as much as 10 CPU/hours per specimen



e.g. Devine et al 2020

* System-specificity

    - Algorithms: species-specific and hard to generalize

Our attempt

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Intuitive

Users with no prior experience in image analysis could use it

Lightweight

Run in minutes (much less time than manual digitization)

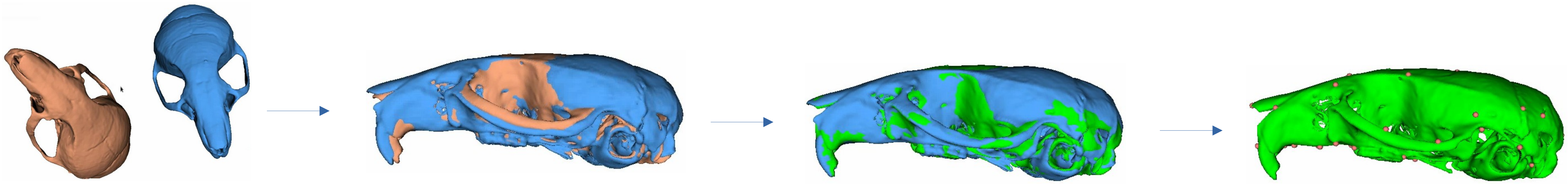
General

Can be applied to any structure of interest, given some limitations in the degree of shape variation

In many ways, it is similar to traditional methods

Registration

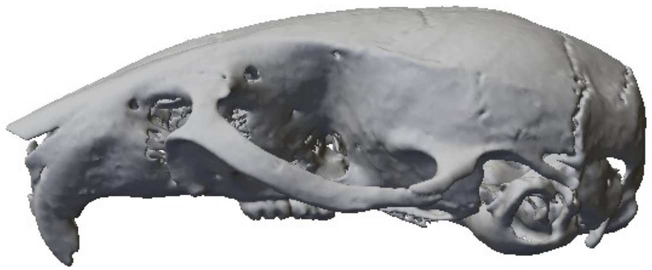
is the process of finding the optimal transformation to maximize correspondence across specimens

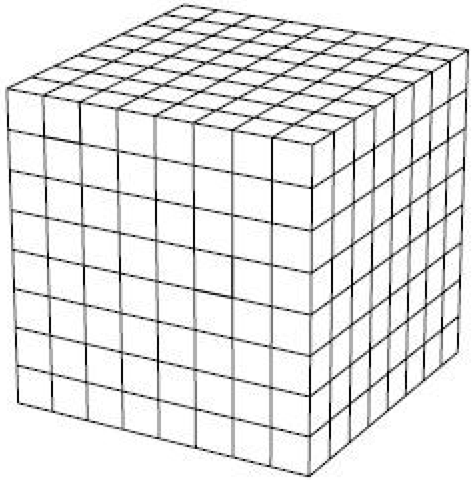


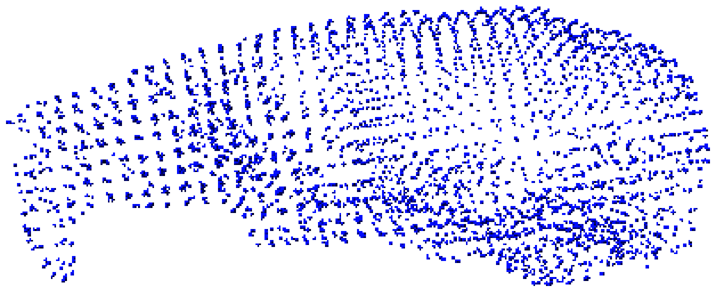
But it is also different

Key aspect

Sparse representation can be used to find for alignment







Voxel size = 0.8 mm

Mesh

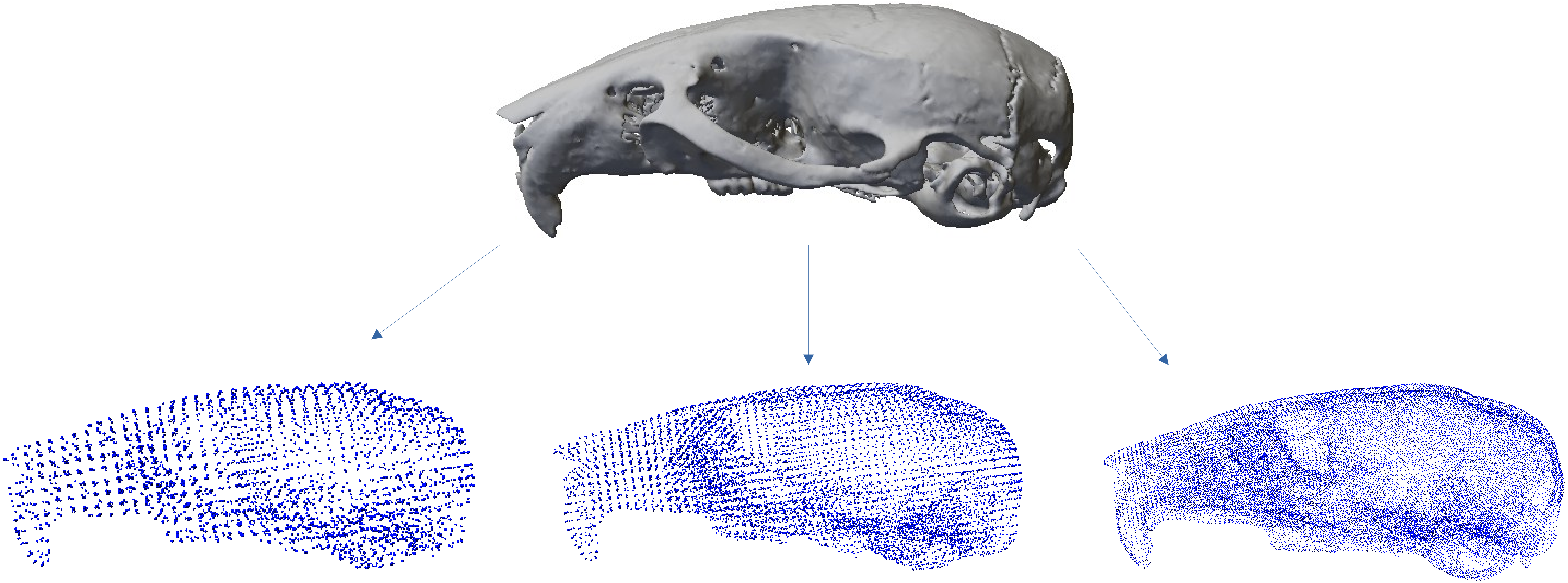
Voxel Grid

User-specified

Point-cloud

But it is also different

How sparse? User has control over it



Voxel size = 0.8 mm

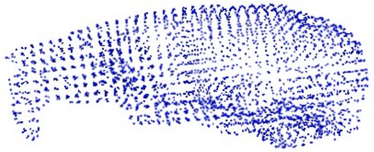
Voxel size = 0.6 mm

Voxel size = 0.2 mm

Once pointclouds are obtained

Source

Target

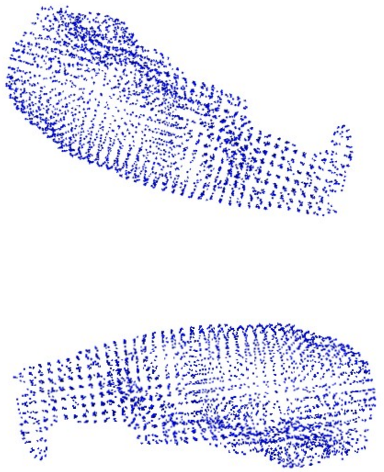


Pointclouds

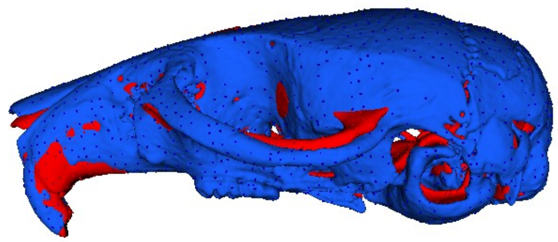
3 steps

From the user point of view

Rigid

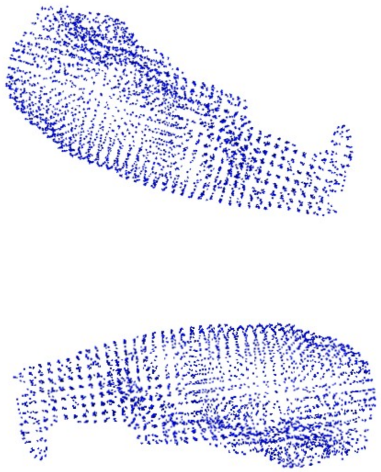


Pointclouds

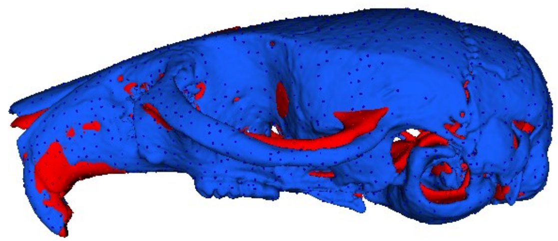


Rigid registration

Rigid



Pointclouds



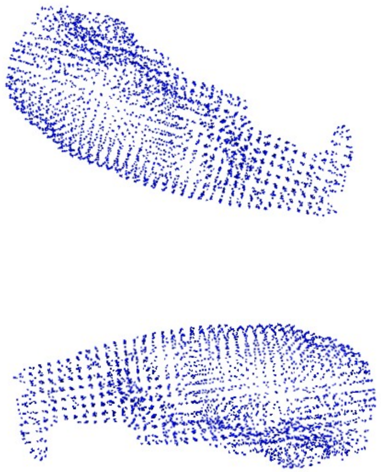
Rigid registration

Global registration = Finds the initial (rough) alignment (FPFH-based RANSAC)

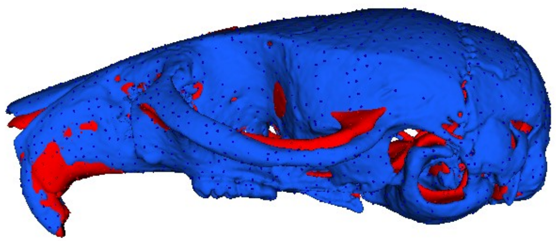
+

Local registration = Refines the rough alignment (point-to-plane ICP)

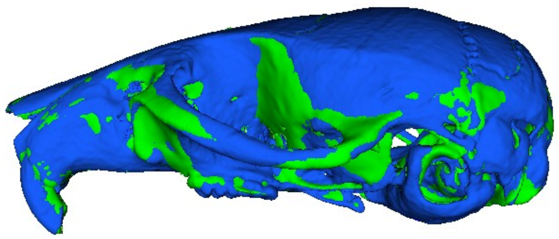
Deformable



Pointclouds

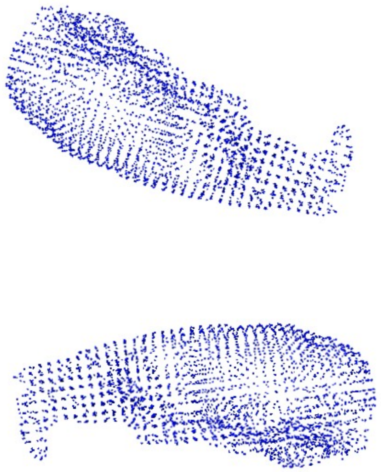


Rigid registration

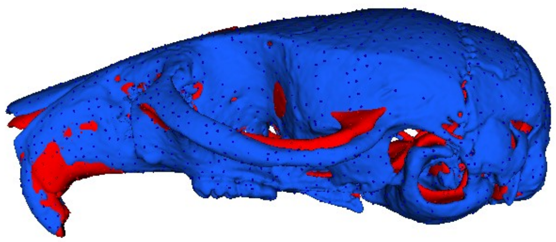


Deformable registration

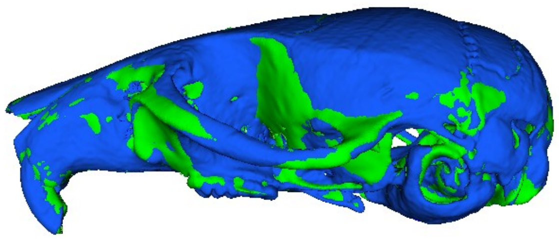
Deformable



Pointclouds



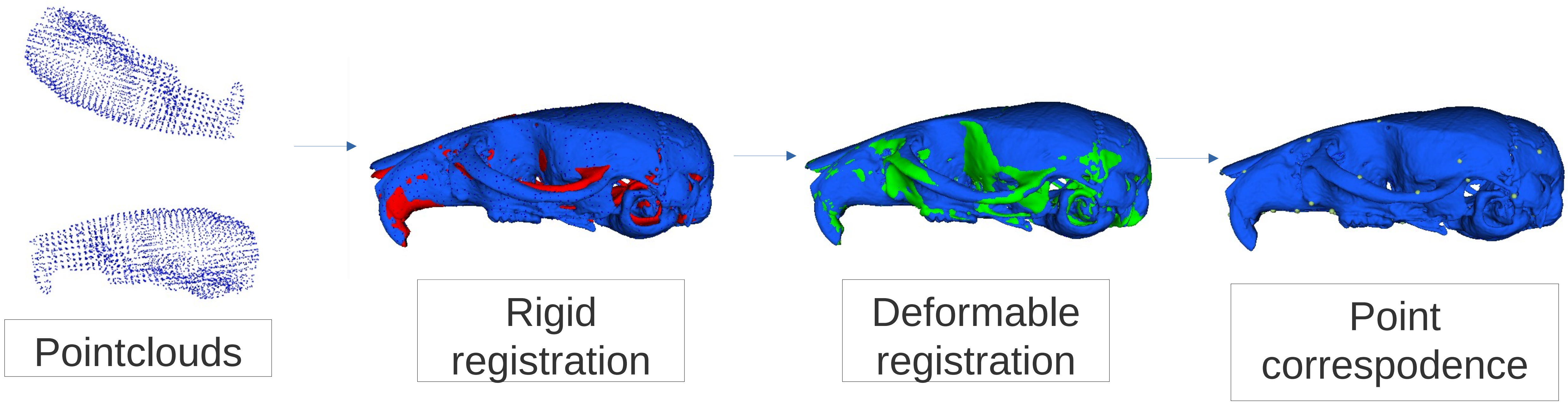
Rigid registration



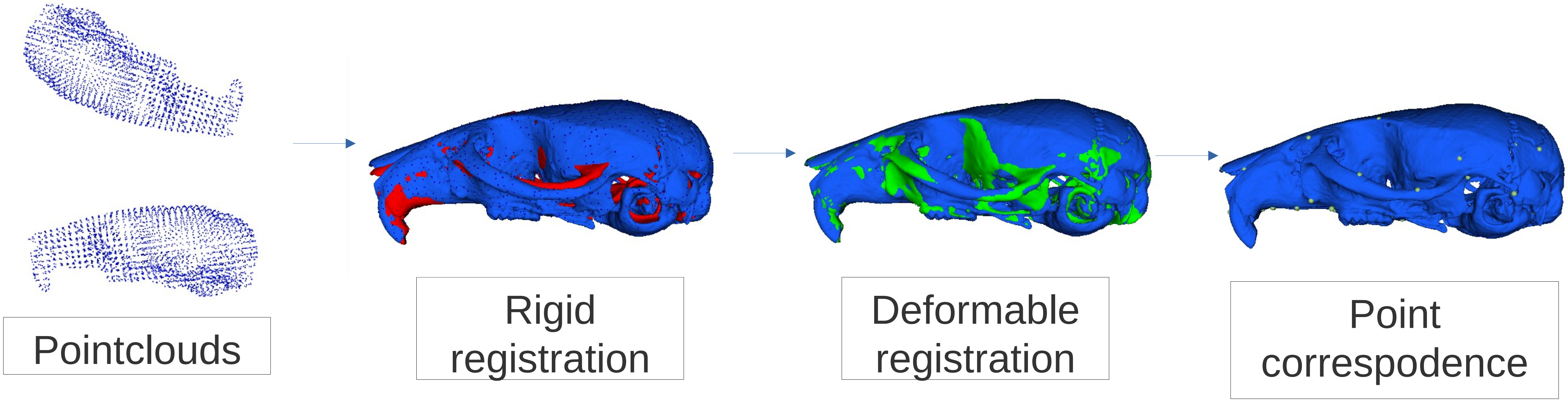
Deformable registration

Finds the deformation necessary to closely align one pointcloud to another, given some constraint (Coherent Point Drift)

Deformable


Pointclouds
Rigid registration
Deformable registration
Point correspodence

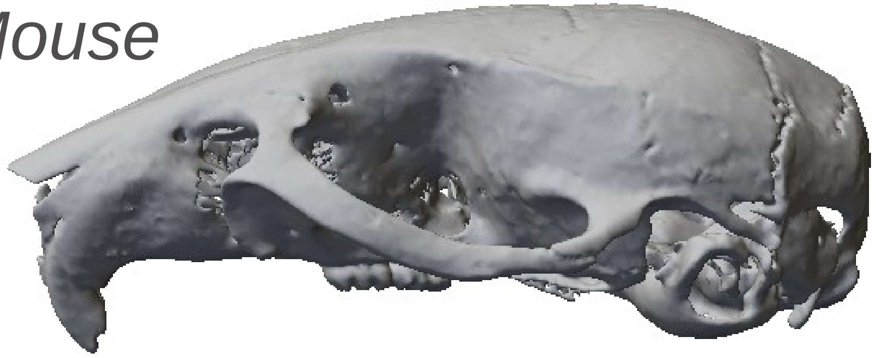
Deformable

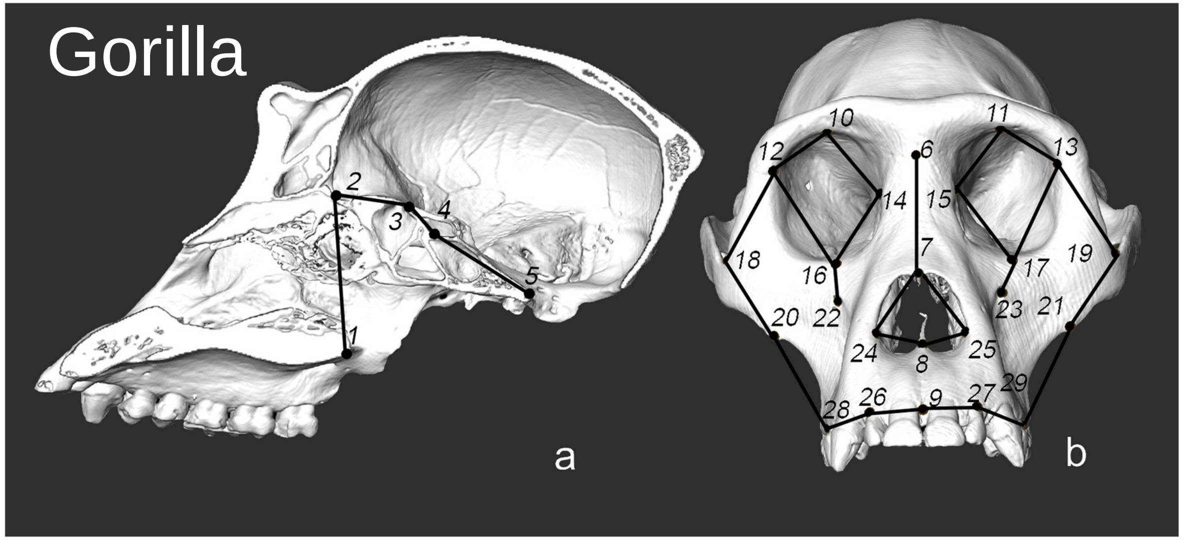


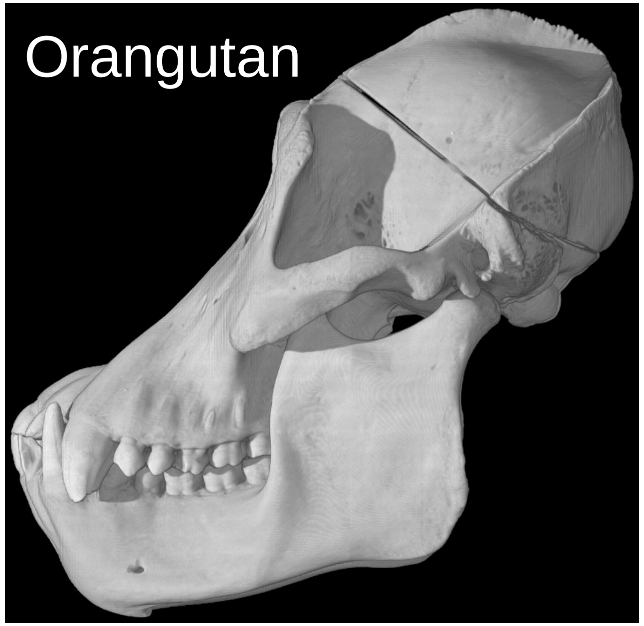
Transfer the landmark positions from the source to the target mesh

So far - Four datasets

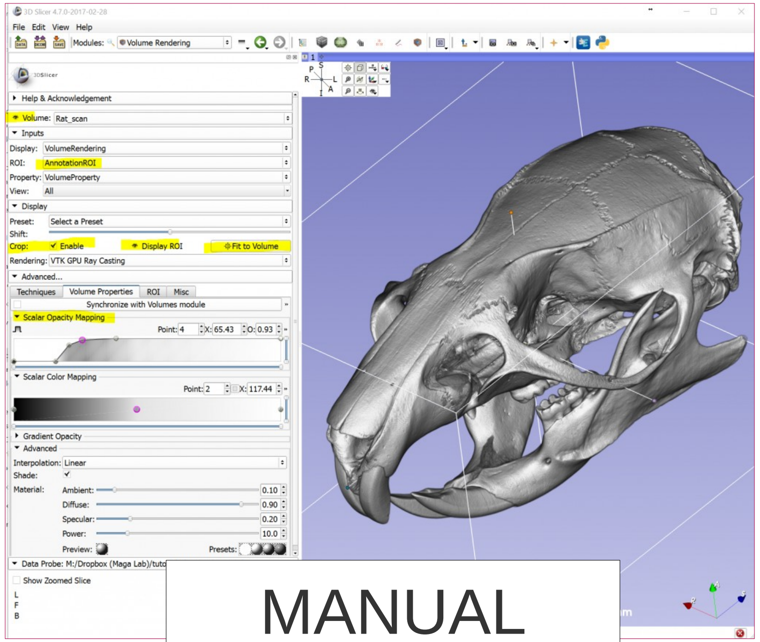
Mouse







Method comparison

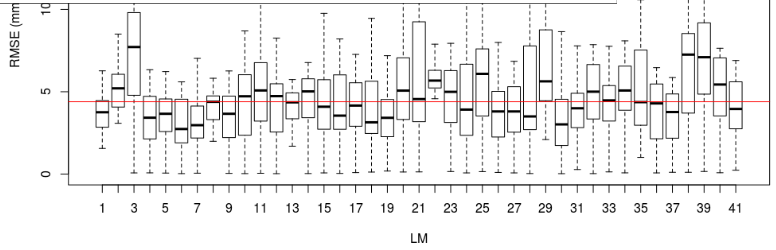


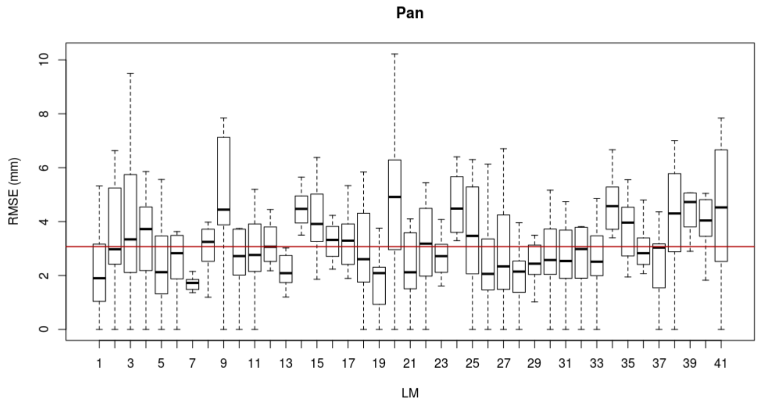
MANUAL

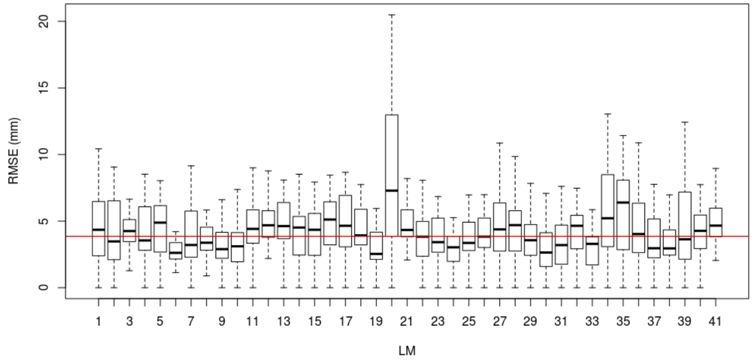
VS

ALPACA

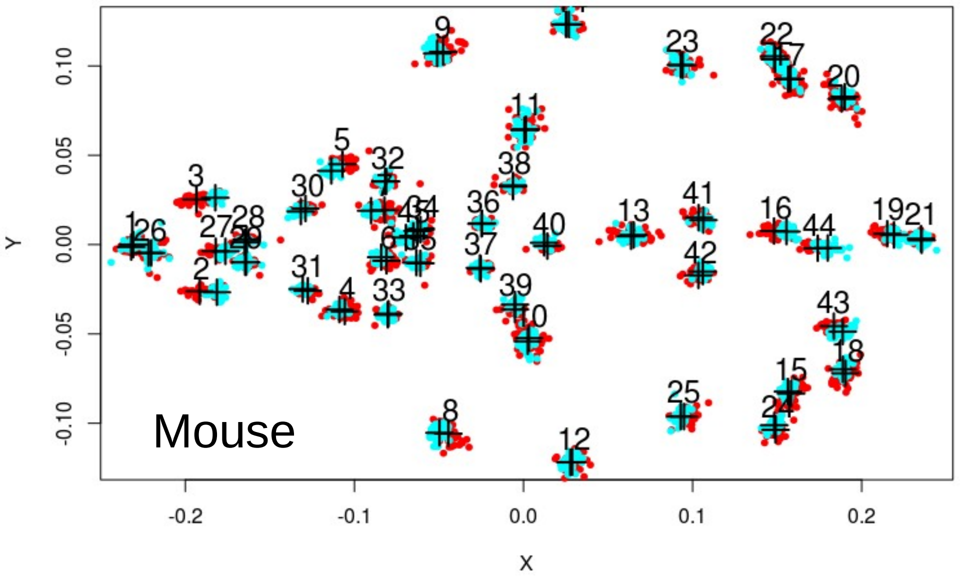
Method comparison – Euclidean space

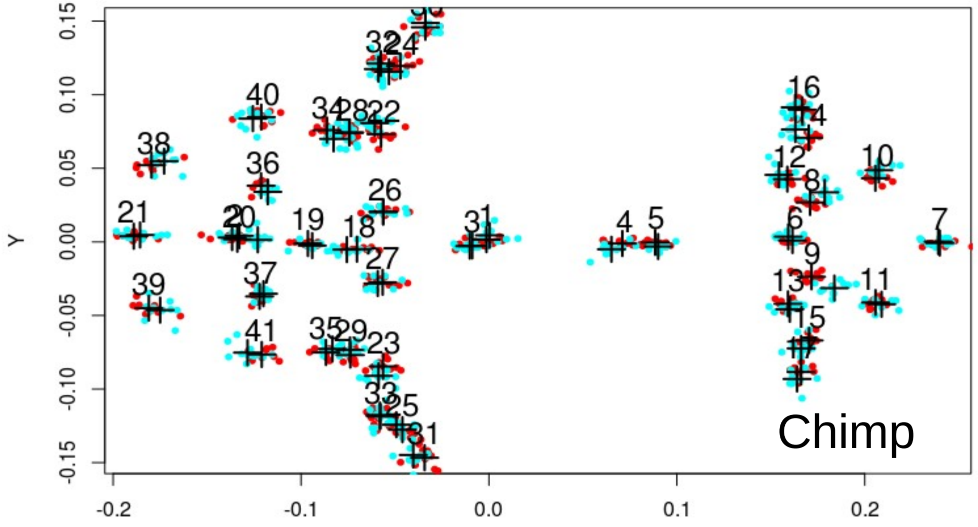


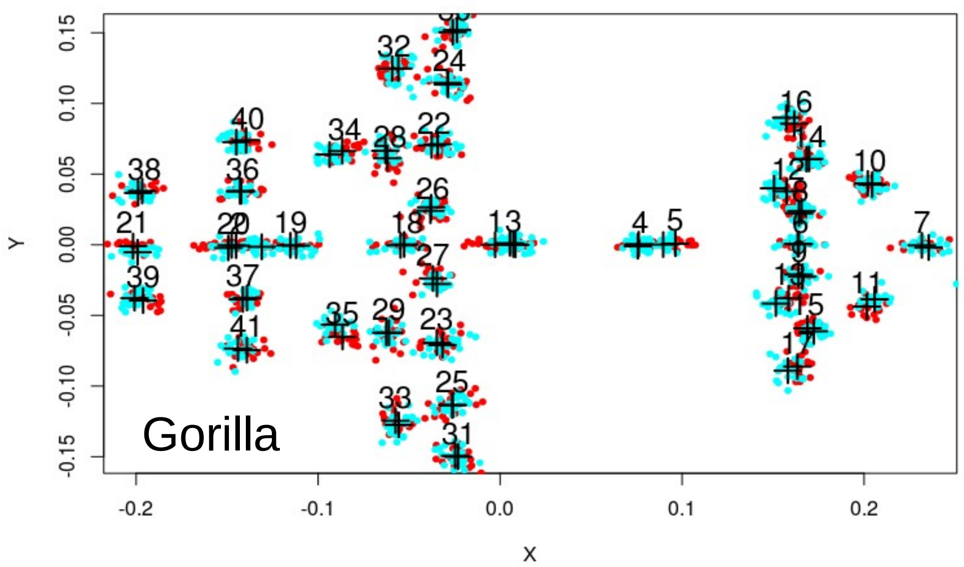


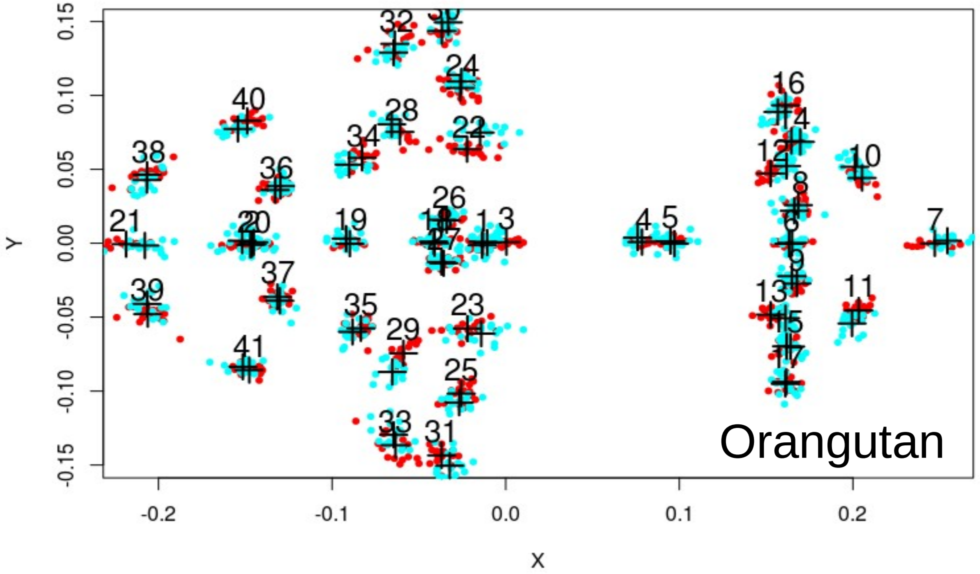


Method comparison – LM configurations

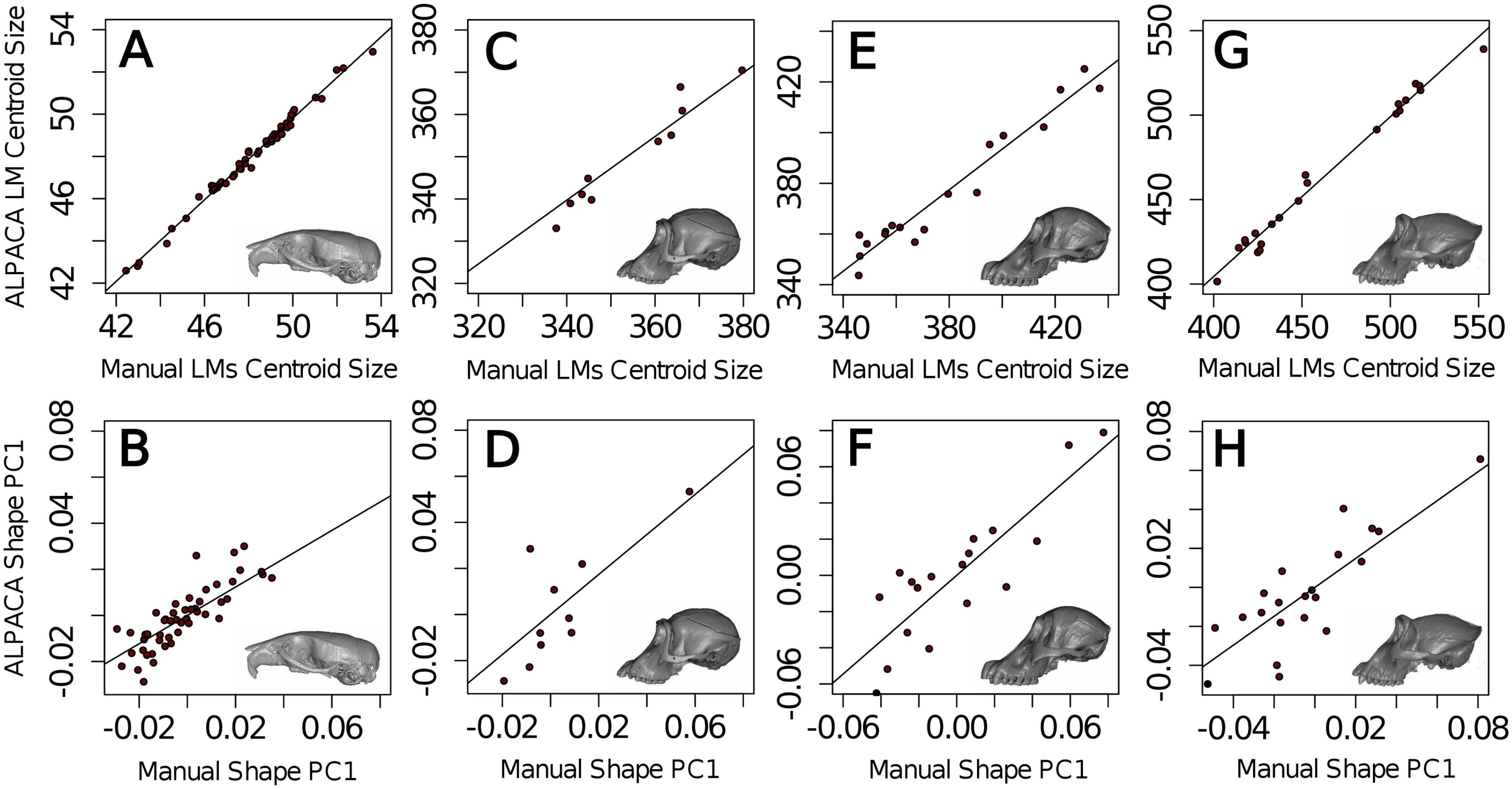




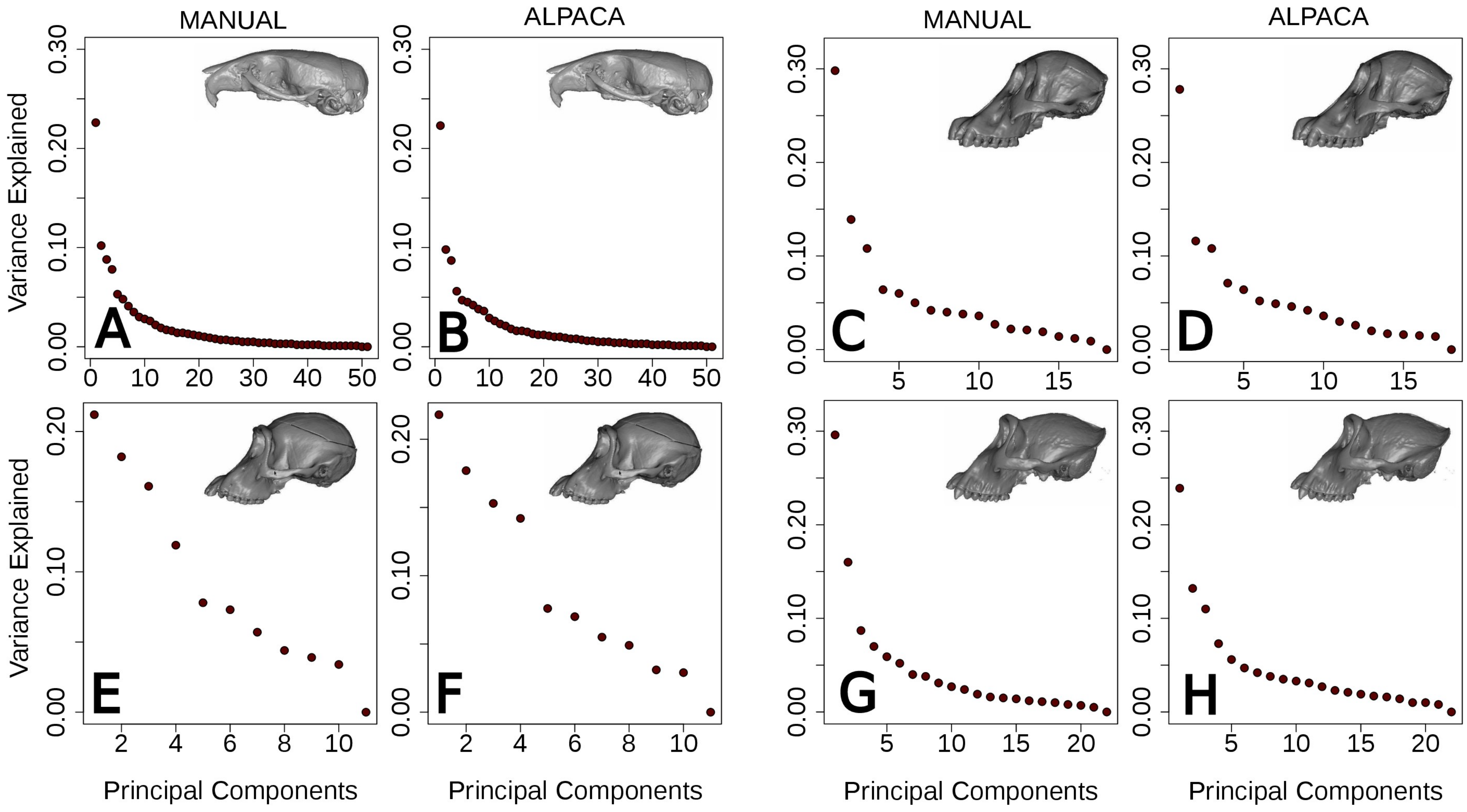




Method comparison - Centroid Size and PC1



Method comparison – Scree plot



But we are counting on you to really test it ..

** Please try with your own datasets and let us know how it goes **

If you have trouble, we are here to help.

The greater the use, the better the tool will become

But we are counting on you to really test it ..

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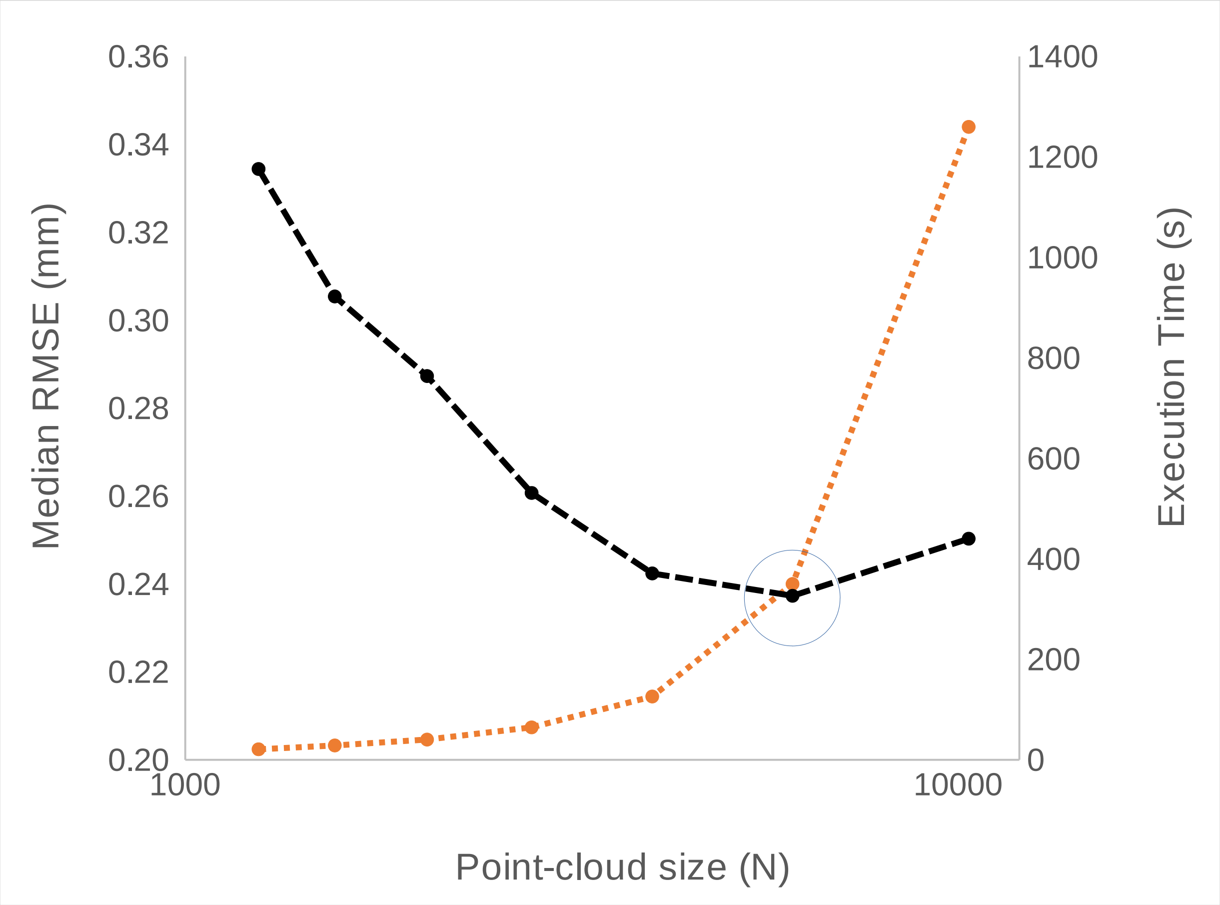
<u>Short term improvements – Next 4 weeks</u>

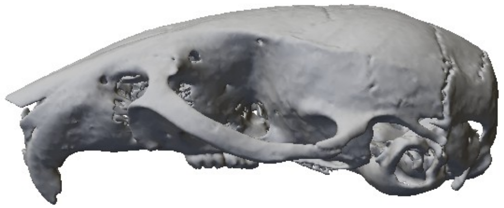
1) Add scaling option
    * User will have the option to scale the source mesh to match the target one
2) Voxel size will be inferred directly from the mesh
    * No need to choose subsampling voxel size

A few practical considerations

Accuracy x Resources

* First tip : Aim for 5,000 to 6,000 points



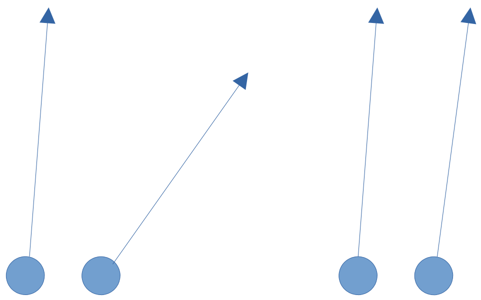


N=62 specimens

Deformable – Structure specific

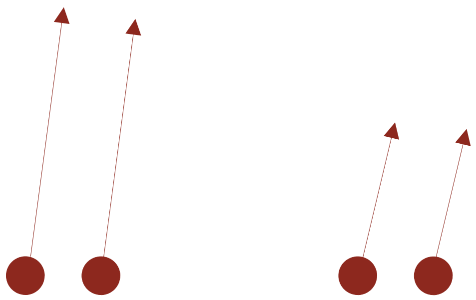
The deformable step has two regularization parameters (α and β) . These parameters will typically have to be modified to better serve your own needs.

Motion coherence



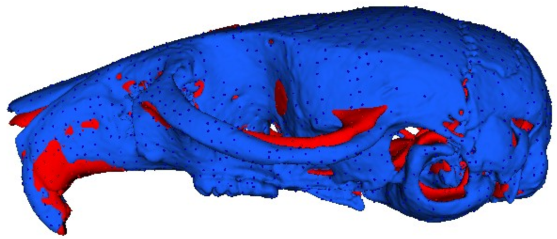
Small β   Large β

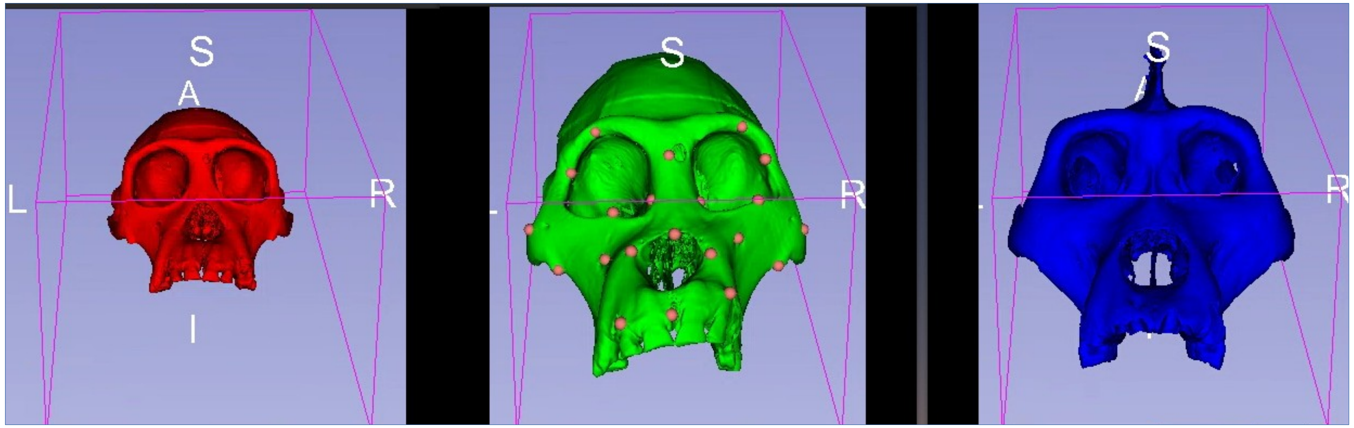
Displacement



Small α   Large α

Deformable – Structure specific





Small β =2

Large α = 2

Large β = 14

Small α = 0.05