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Thank you!
geometric morphometrics

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slides adapted from David Polly – Intro to GMM lecture
Announcements

• May 5th is redefined day (go to your Friday classes), so no presentations

• Final Project (2 options) – 10% of final grade
  – Turn in a video of your final project (around three minutes, these will be posted on my webpage)
    (e.g., http://www.kindealabs.com/)
  – Turn in a manuscript for critical review and feedback.
Schedule for today

• My presentation
  – on geometric morphometrics

• Presentation on geometric morphometrics
• Demonstration on geometric morphometrics

• BREAK
• Tutorial on geometric morphometrics
what are morphometrics?
Morphometrics

• Quantitative measurement and analysis of morphological traits
Geometric morphometrics

- Quantitative representation and analysis of morphological shape using geometric coordinates instead of measurements
the major goal

• to measure similarity and dissimilarity
types of geometric representation

landmarks

3D surfaces

outlines


Definitions

- **Landmark** – any point described with cartesian coordinates \((x, y, z)\) used to represent the shape of a structure.
- **Landmark (2)** – any point that can be placed on a biologically or geometrically homologous point on the structure.
- **Semi-landmark** – a point that is placed arbitrarily using an algorithm, often by defining endpoints at biologically homologous points and placing a specified number points between them.
Landmarks

- Landmarks are coordinate points used to represent a shape
- They are quantified as Cartesian coordinates \((x,y,[z])\)
- At least 3 are required (two points make a line)
- Example analyses: Relative Warps (PCA of landmarks), Euclidean Distance Matrix Analysis (EDMA) of distances between landmarks
Outlines

- Outlines are perimeters delimited by many points
- They are quantified as Cartesian coordinates \((x,y[,z])\), often converted to angles
- Many points are required to represent a shape
- Example analyses: Semilandmarks, sliding semilandmarks, Eigenshape (PCA of outline), Fourier analysis
Surfaces

- Surfaces are the 3D surface of an object
- They are quantified as Cartesian coordinates ($x,y,z$)
- Many points are required to represent a shape
- Example analysis: Eigensurface (PCA of surfaces), sliding semilandmarks
Advantage to geometric representation

• Results can be presented visually as a “shape” rather than tables of numbers
• Data are easily collected from digital photographs
• Size is mathematically removed from the analysis to focus on pure shape
Present results graphically

Difference in shape of mandibles of shrew and marmot

Example of visualizing the difference
Traditional morphometrics mixes size and shape

The size of the animal affects all measurements so that primary morphometric difference between two taxa is size rather than shape.
Geometric morphometrics removes size by rescaling

Shapes are enlarged or reduced to achieve a standard, equal size. Coordinates of rescaled landmarks show difference in relative position only.
Disadvantages of geometric representation

• Size is completely absent from the analysis, and size may be biologically relevant

• Only single rigid structures can be easily analyzed
Size is biologically important and is perhaps of interest in a morphometric analysis.
Size and shape may behave differently therefore, size or shape may be relevant for different analyses
Size and shape may behave differently therefore, size or shape may be relevant for different analyses.
Only single rigid structures can represented with geometric morphometrics
Steps in a geometric morphometric study

1. Study design
2. Data collection
3. Data standardization
4. Analysis
5. Results interpretation
Steps in a geometric morphometric study

- Study design
- Data collection
- Data standardization
- Analysis
- Results interpretation

landmarks outlines surfaces
Steps in a geometric morphometric study

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Translate, Rotate, and Scale
-Procrustes is a popular method for doing this
-there are lots of ways to standardize
Steps in a geometric morphometric study

1. Study design
2. Data collection
3. Data standardization
4. Analysis
5. Results interpretation

Calculate scores (multivariate ordination), usually PCA or Relative Warp Analysis
- do anything we have talked about in class thus far
- and so much more
Steps in a geometric morphometric study

- Study design
- Data collection
- Data standardization
- Analysis
- Results interpretation

Each new variable corresponds to a shape, understand what that shape and how it varies with variables of interest.
How do you choose landmarks (or outlines, or surfaces)?

1. The data must reflect a hypothesis
2. The data must represent the shape adequately
3. Landmarks must be present on all specimens
Measurement Error and Sample size

1. Measurement error (ME) always exists in any collection of data, but ME doesn’t matter if it is substantially less than the differences you want to measure.

2. Sample size required for a particular study depends on the within-group variation relative to differences between groups.
How many specimens do I need?

- Depends on the question being addressed
- Depends on the error in your data
- You need more specimens when the differences you want to measure are small compared to the variation within your group (natural or due to error)
- For sexual dimorphism in skulls of humans or other primates, 10 individuals of each sex might be enough
- For differences in genetic strains of mice where the mutation doesn’t obviously affect the skeleton, 50 individuals of each strain is more realistic
- For species that belong to different families or orders, 1 specimen per species is almost always sufficient
What morphometrics can’t answer for you..

• Morphometrics does not tell you what the effects ‘large’ or ‘difference’ or ‘shape’ mean (These are definitions you must supply and your results depend upon them)

• Morphometrics does not tell you whether you unwittingly have two unrecognized groups in a single sample (Although comparison with known groups may help such an endeavor)

• How to identify cladistic characters (For the first two reasons combined)
Examples of available software

Digitizing landmarks and outlines: tpsDIG, ImageJ, R

Superimposition: Morpheus (plus integrated in some below), R

Outline analysis: Eigenshape, PAST, R

MANOVA: Statistica, PAST, R

Discriminant functions, CVA: Statistica, PAST, R

Principal components analysis of landmarks: tpsRELW, PST, R

Construction of trees: PHYLIP, PAUP, NTSYSpc, PAST, R

Simulations: Mathematica, R

Links and downloads at SUNY Stony Brook morphometrics site: http://life.bio.sunysb.edu/morph/
Equipment: 2D outlines and coordinates

High-quality digital cameras

(resolution doesn't matter as much as the possibility of lens distortion: test your camera first by photographing a piece of graph paper and looking for “fish eye” distortion)

Calipers or scale bar
Equipment: 3D outlines and coordinates

Reflex Microscope for collecting 3D landmarks, outlines and measurements (good for objects the size of a cat skull down to things about 2-5 mm long)

Microscribe robotic arm for collecting 3D landmarks and measurements (good for objects the size of a human skull down to a rat skull)
3D Surfaces

Microscan Laser scanner for scanning surfaces (good for objects the size of a cat skull down to ones about 2-3 cm long)

NextEngine laser scanner (good for objects the size of a horse skull down to a single tarsal bone)
3D Surfaces