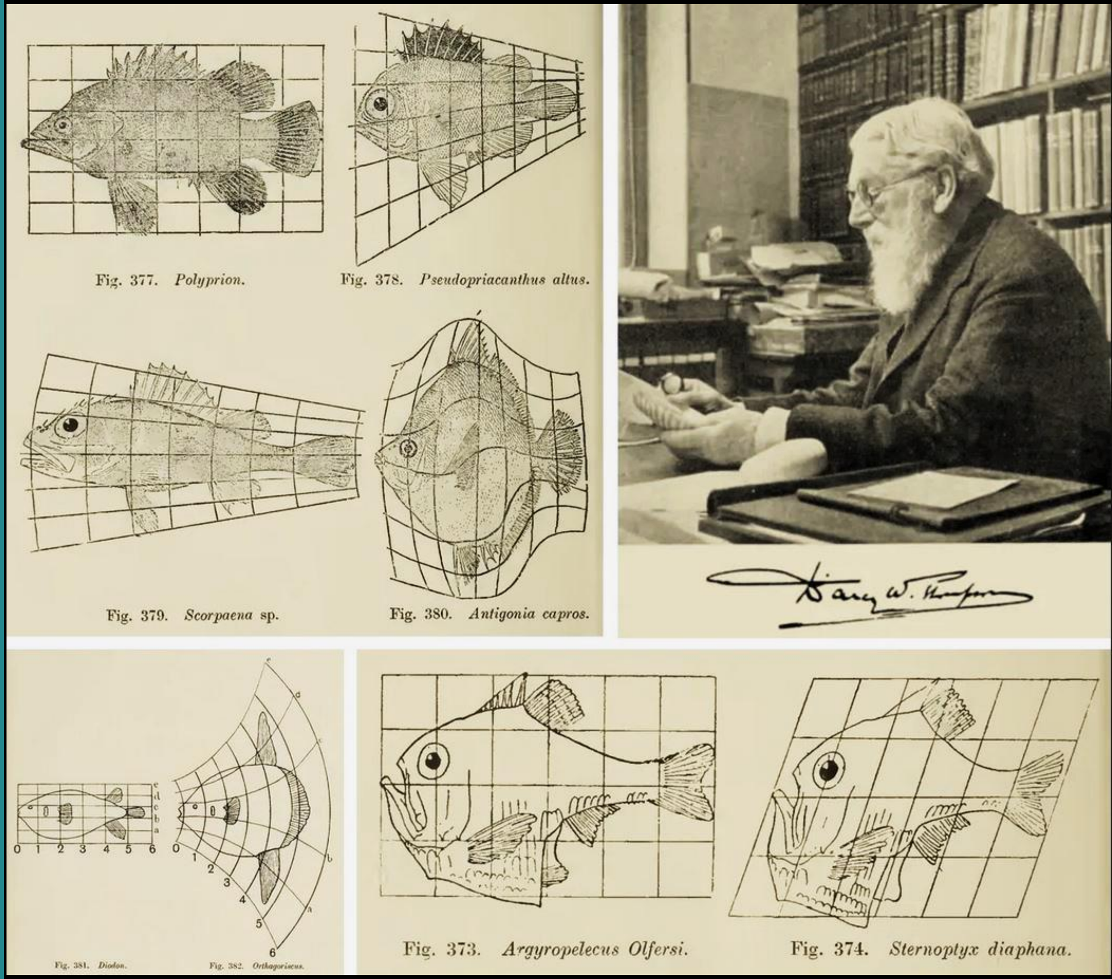
Graduate Program ARCHEO
3D Imaging and Geometric Morphometrics

2D Data acquisition

Antoine SOURON

Day 1 (23/06/2022)

D'Arcy Thompson



3D Imaging and Morphometrics Graduate Program

université de BORDEAUX

pacea UMR 5199

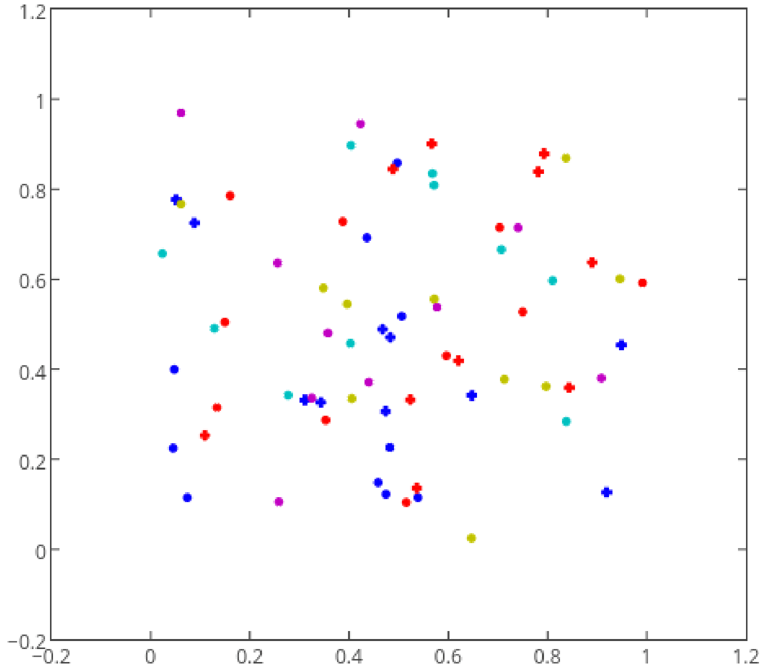
2D versus 3D: mathematics are the same!

3D Imaging and Morphometrics Graduate Program

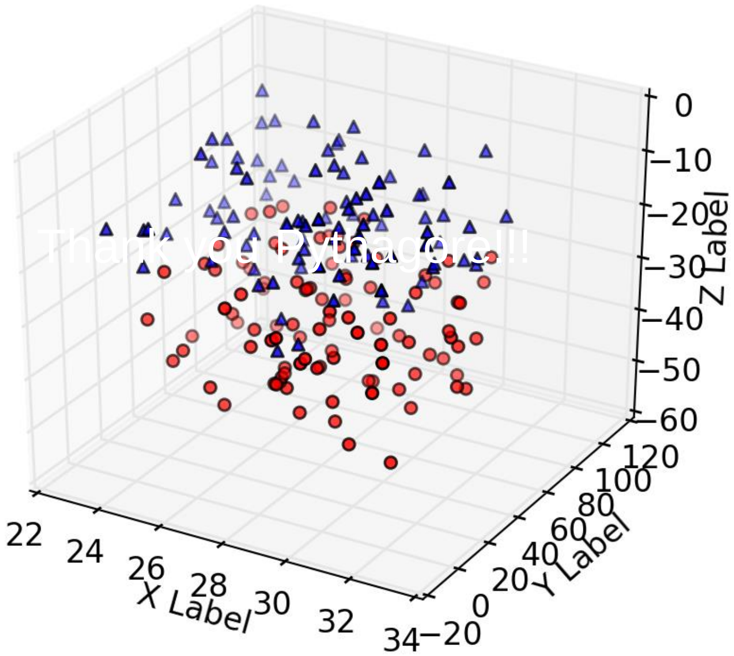
université de BORDEAUX

Principles of trigonometry

$$d_{2D} = \sqrt{(a^2 + b^2)}$$



$$d_{3D} = \sqrt{(a^2 + b^2 + c^2)}$$

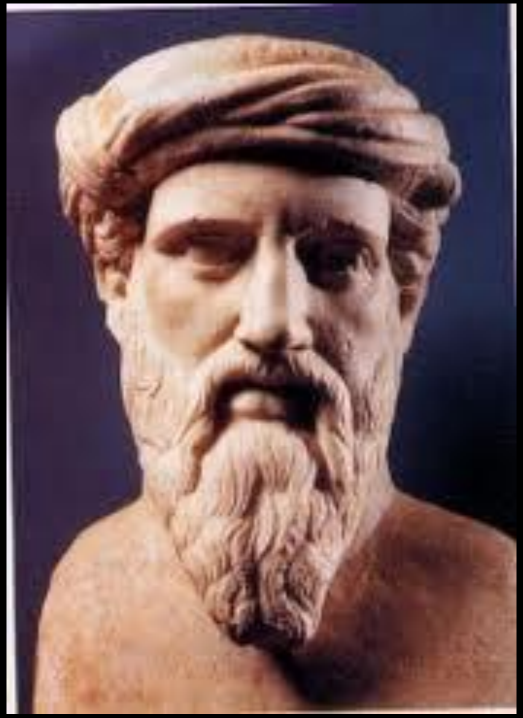


JOURNAL OF MORPHOLOGY 232:107–132 (1997)

Scaling of the Mandible in Squirrels

WILLIAM A. VELHAGEN AND V. LOUISE ROTH*
Zoology Department, Duke University,
Durham, North Carolina 27708–0325

Thank you Pythagore!!!



Slide after Luc Doyon

Types of data

	2D	3D
Landmarks	**Photographs** Projected 3D models	**Microscribe** **3D models**
Curves of semi-landmarks	**Photographs** Projected 3D models	**3D models** Microscribe
Surfaces of semi-landmarks		**3D models** Microscribe

3D models > surface scanner, CT scan, photogrammetry, microscopy...

2D data acquisition– Photography

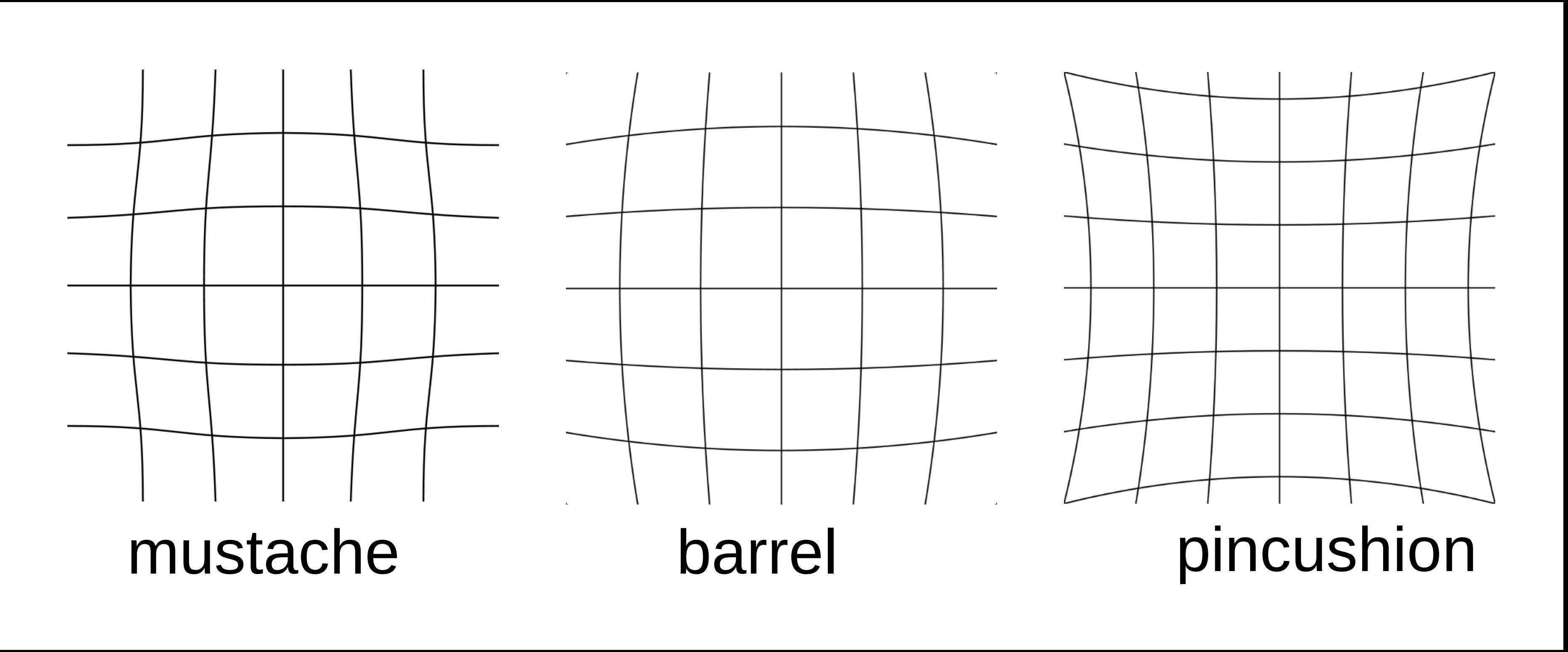
- Portable
- Fast

- Repeatability
- Only 2D

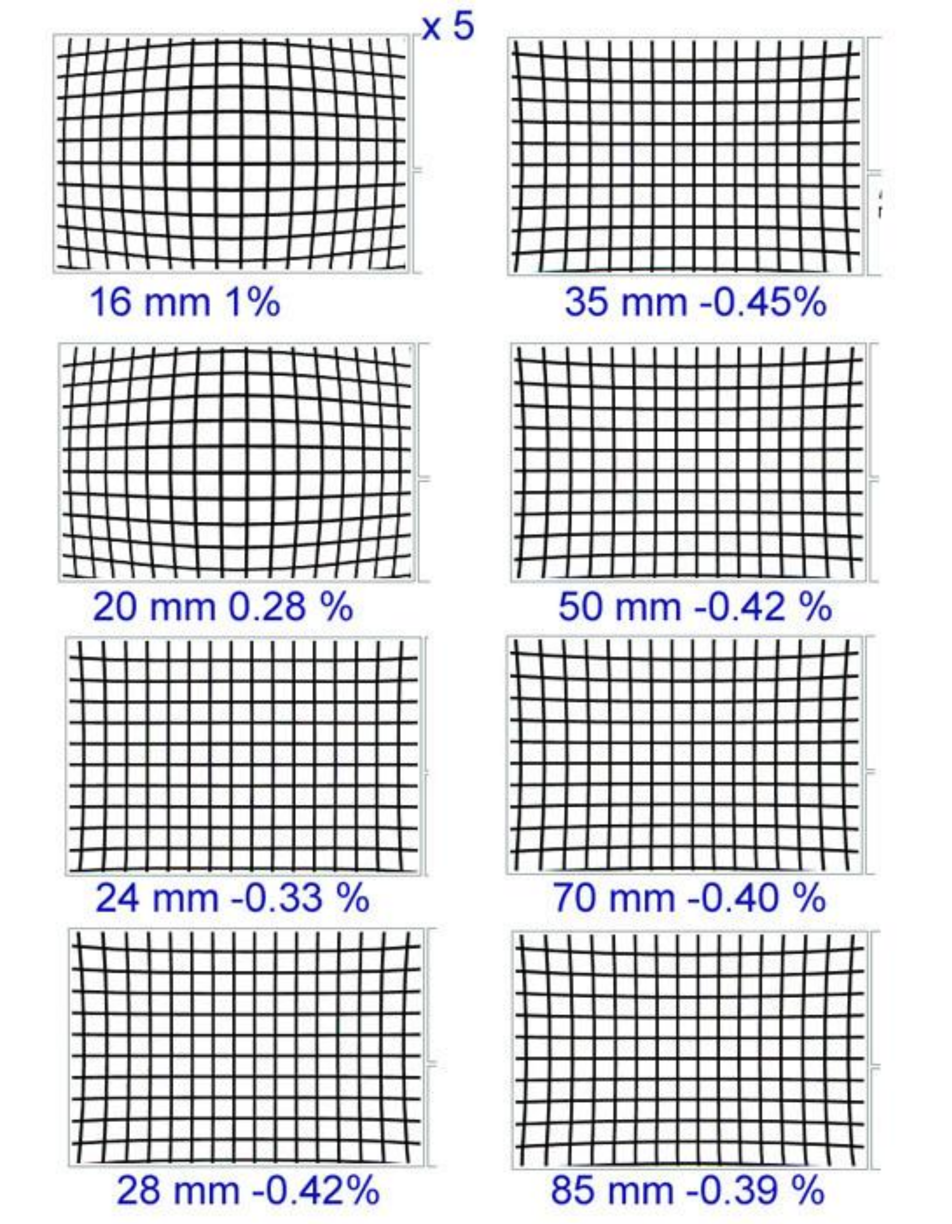
2D data acquisition– Photography

- **Stability** (use a tripod and a remote control or self-timer)
- **Lighting** (avoid flash, use oblique lights)
- **Orientation and scale**
  - camera angle, table level
  - standardized object orientation
  - scale
- **Avoid distorsion** (optical and perspective)
- **Depth of field**

Optical distorsion (> lens)



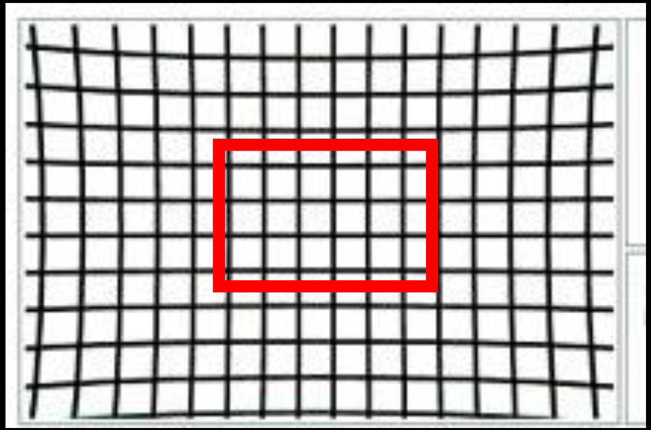
Lens distorsion in %



Zoom:
intermediate focal lengths show little distorsion

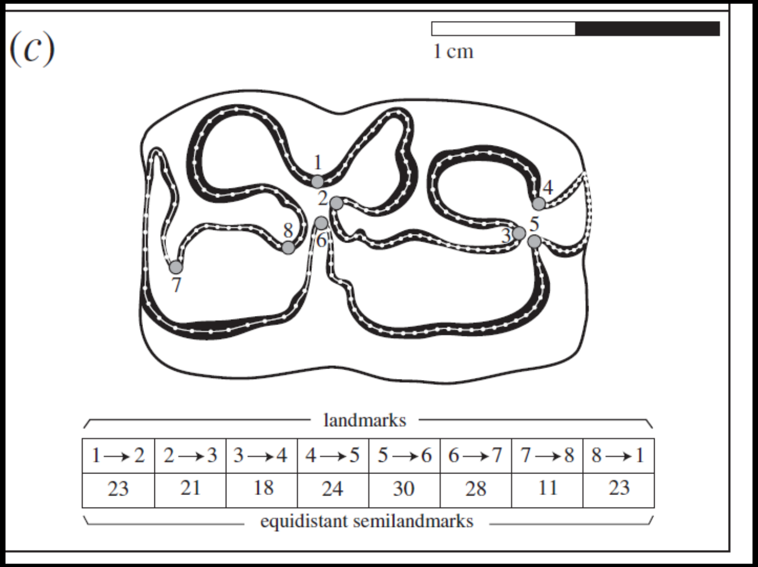
Fixed-focus length from 35 to 85 mm
=> Very little distorsion

Smallest distorsion
in the image center



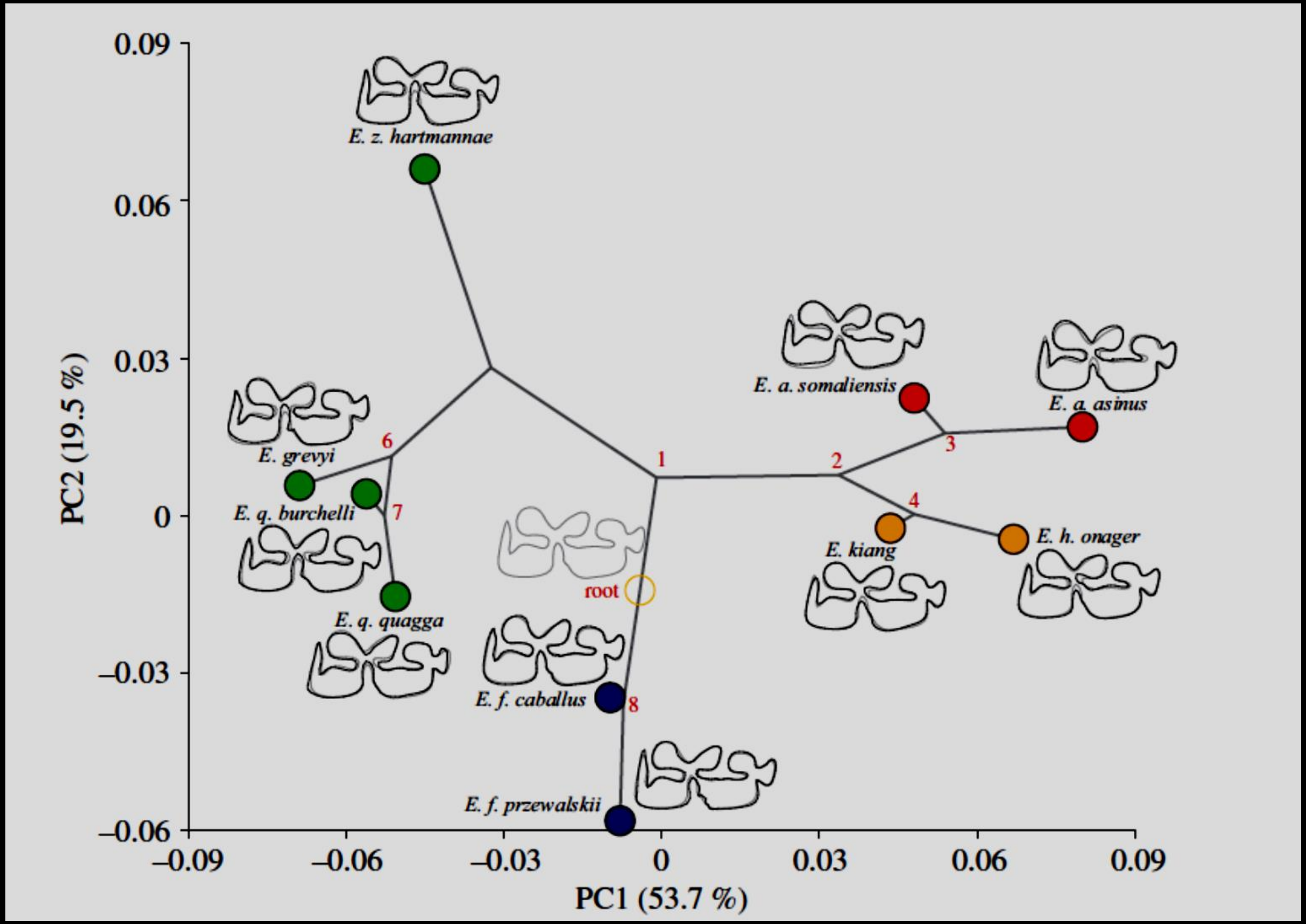
Perspective distorsion (> position of lens in relation to the object)

2D data acquisition– Photography



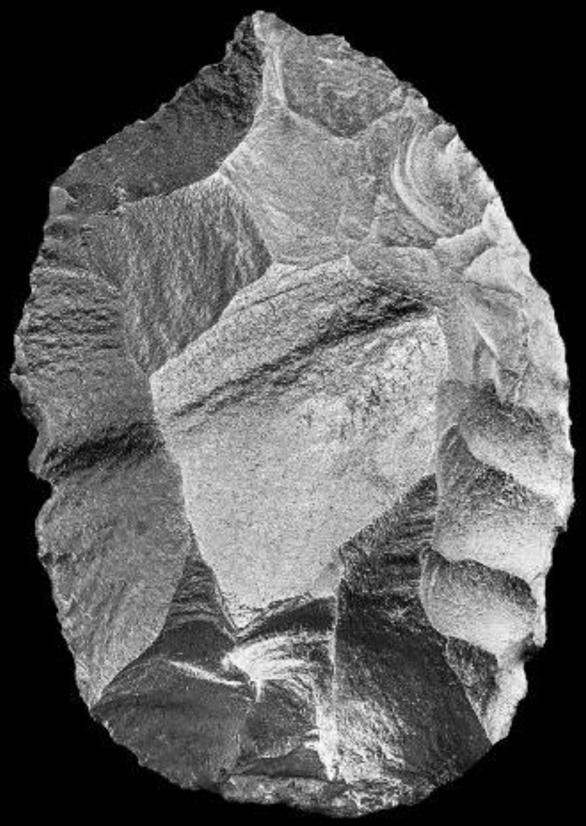
Cucchi et al., 2017

Outline analyses using landmarks and semi-landmarks curves



2D data acquisition– Photography RTI

STANDARD DIGITAL PHOTOGRAPH



ENHANCED VERSION OF RTI NORMALS IMAGE

Looten, 2022

RTI = Reflectance Transformation Imaging

> a series of photographs taken with different lighting positions

Allows highlighting of all morphological details

Relevant for engravings, surface modifications, shiny stone tools, etc.

3D data acquisition – Microscribe

Microscribe

3D landmarks

Demonstration Monday afternoon!

3D data acquisition – Microscribe

International Journal of Osteoarchaeology
Int. J. Osteoarchaeol. 21: 535–543 (2011)
Published online 22 February 2010 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/oa.1156

Comparison of Coordinate Measurement Precision of Different Landmark Types on Human Crania Using a 3D Laser Scanner and a 3D Digitiser: Implications for Applications of Digital Morphometrics

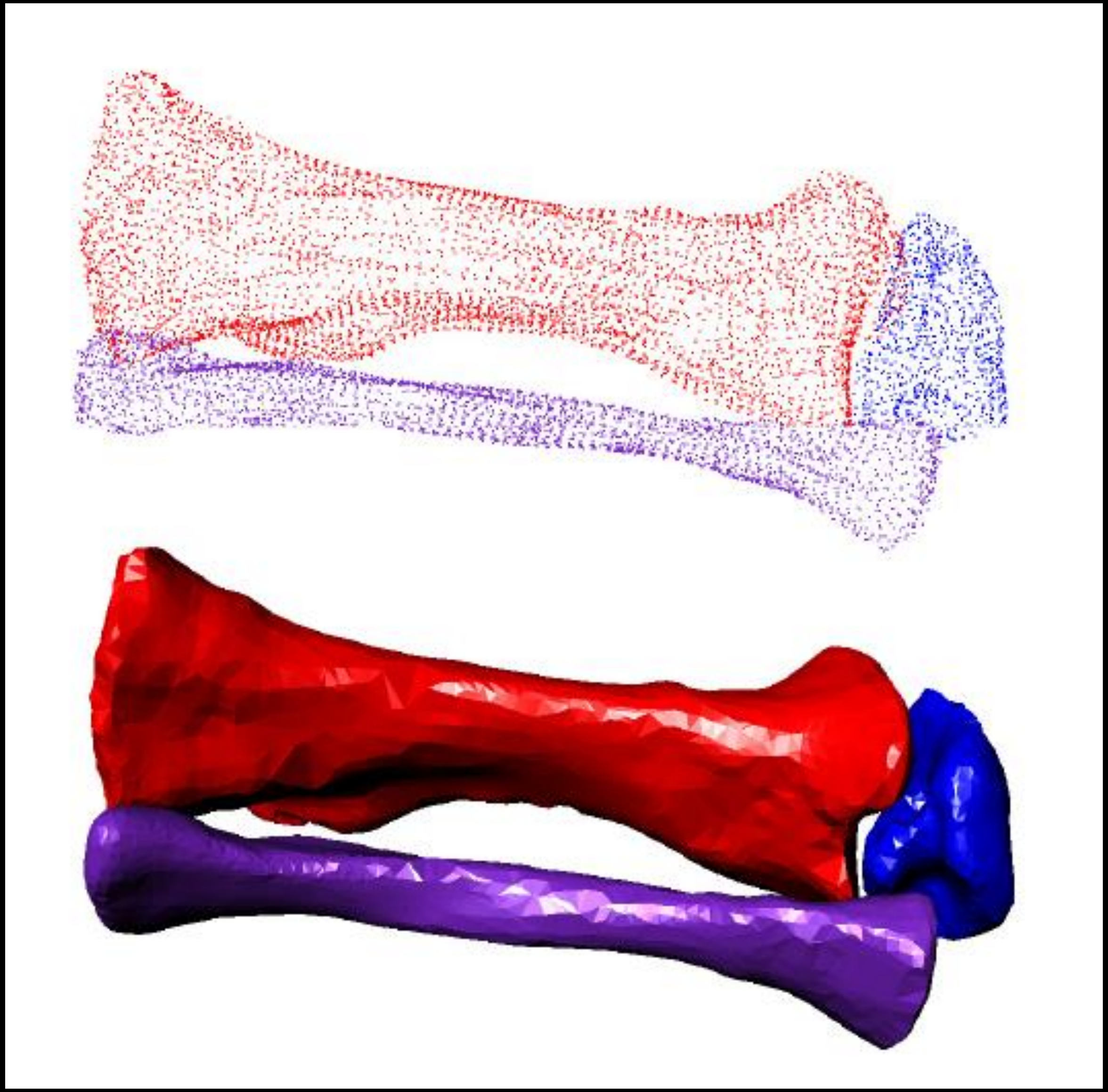
S. B. SHOLTS,[a] L. FLORES,[a] P. L. WALKER[a] AND S. K. T. S. WÄRMLÄNDER[a,b*]
[a] Department of Anthropology, University of California, Santa Barbara, CA 93106, USA
[b] Division of Biophysics, Arrhenius Laboratories, Stockholm University, 106 91 Stockholm, Sweden

Sholts et al., 2011

- Precise
- Fast

- Limited data
- Heavy
- Size of specimens limited by arm length

3D data acquisition – Microscribe



Also possible for curves and surfaces
but time-consuming

Mallison et al., 2009

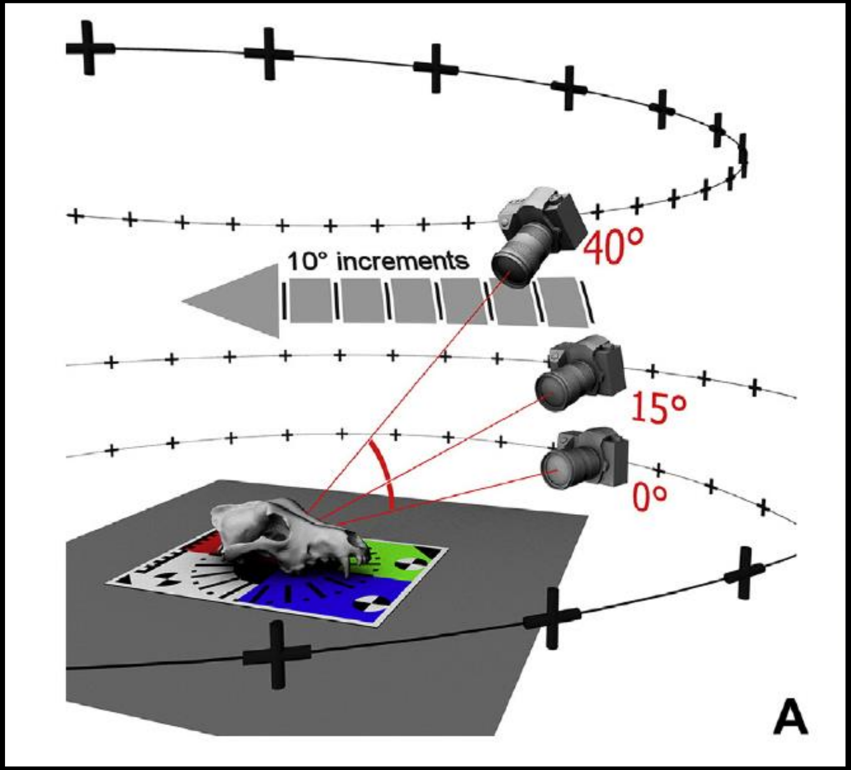
3D data acquisition – Surface scanner

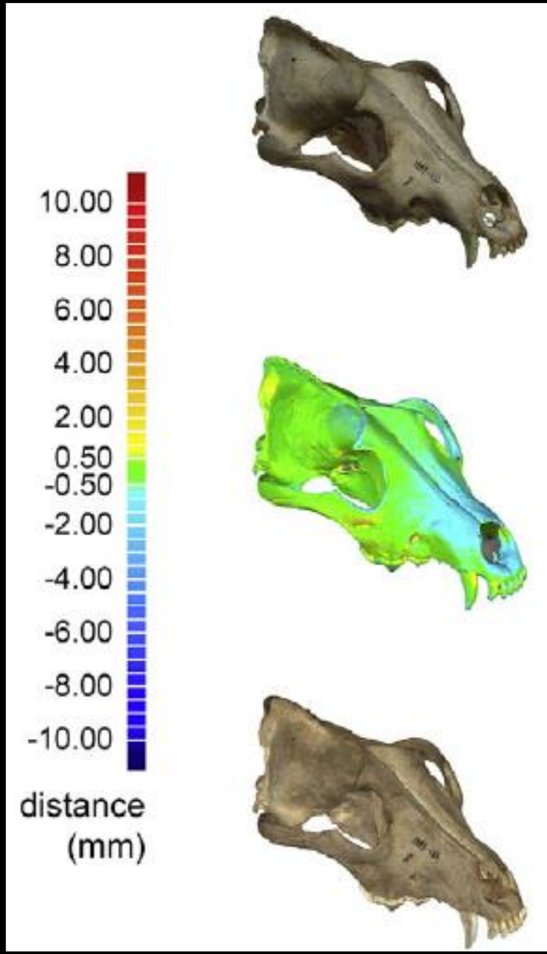
Example: NextEngine

3D data acquisition – Surface scanner

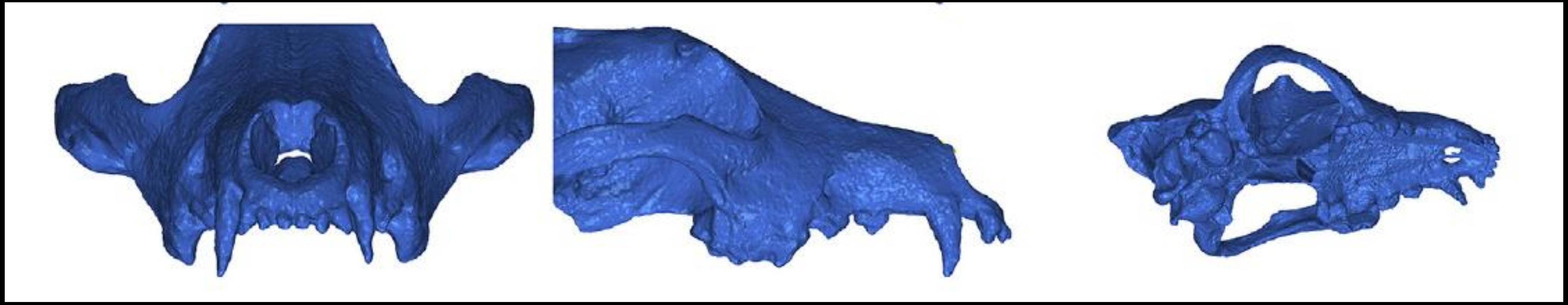
- Precise
- Light
- ± automatic
- Surface and texture

- Sensible
- Slow



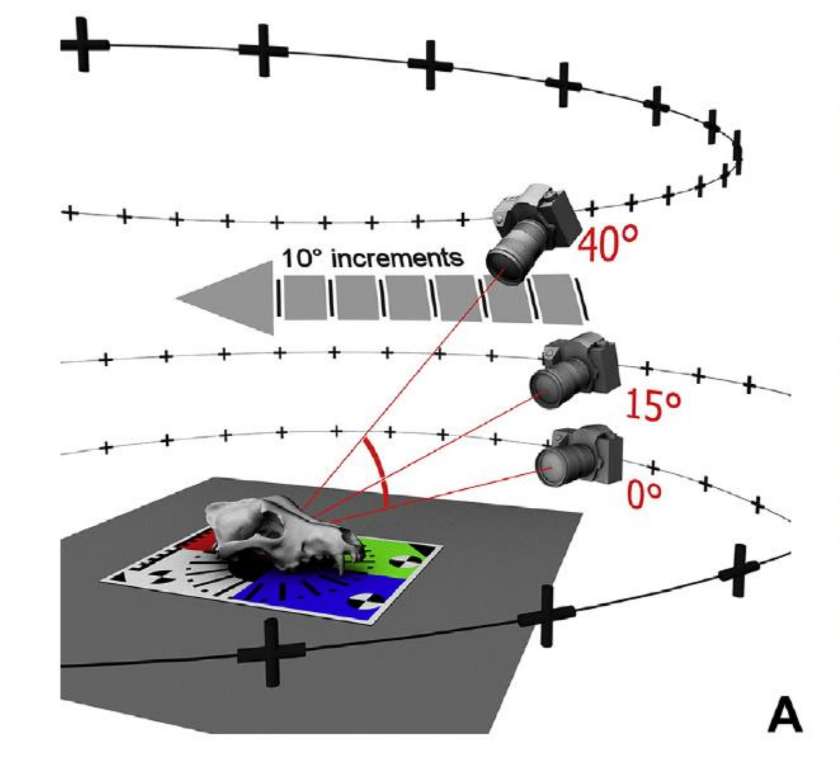


3D model
of a canid cranium



Evin et al., 2016

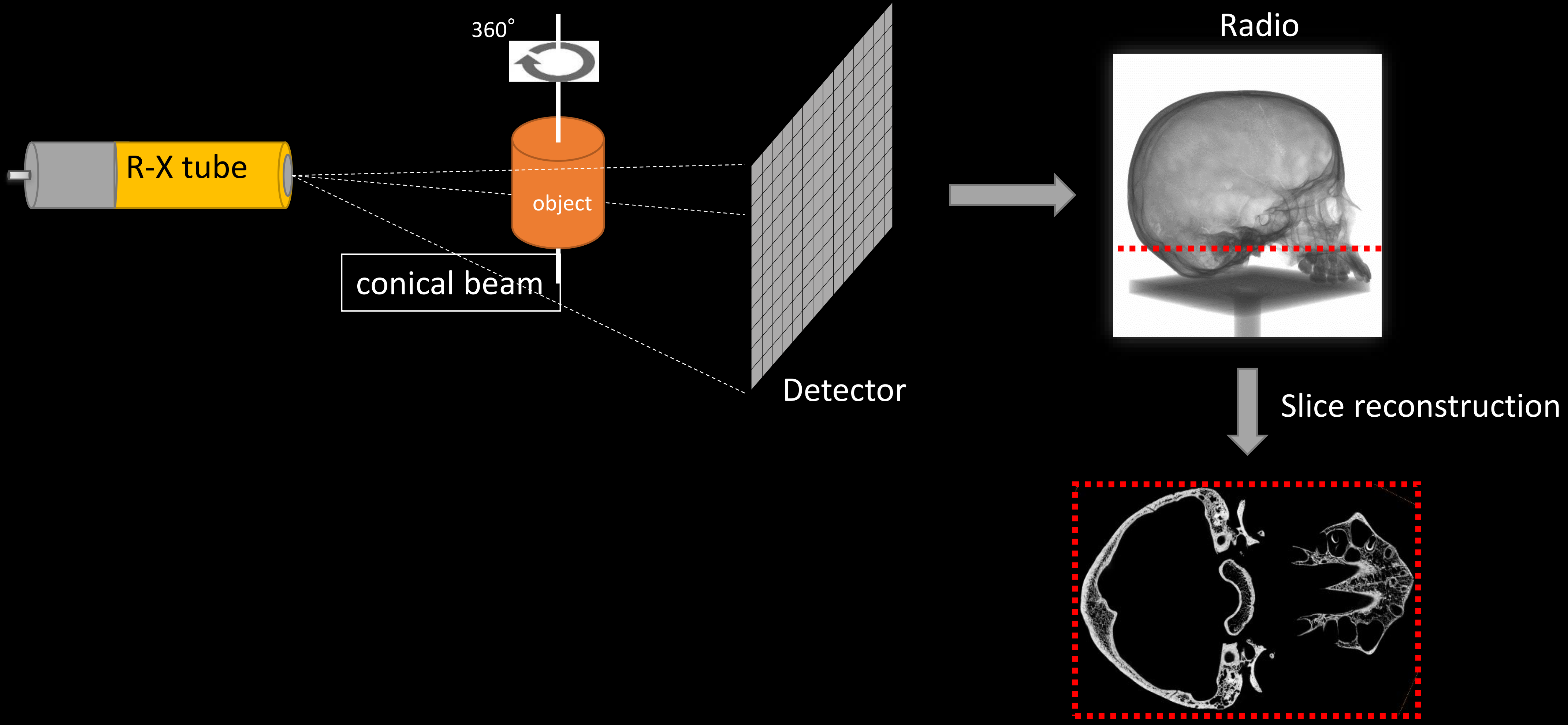
3D data acquisition– Photogrammetry



- Portable
- Surface and texture

- Repeatability
- Slow

3D data acquisition – CT scan

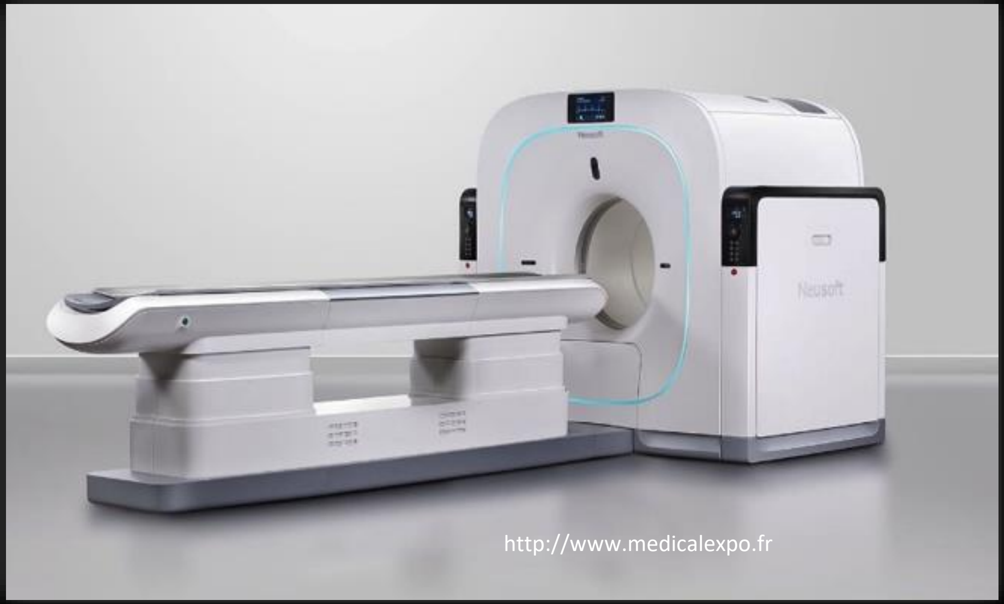


3D data acquisition – CT scan

- High-resolution
- External and inner structures

- Expensive
- Non portable

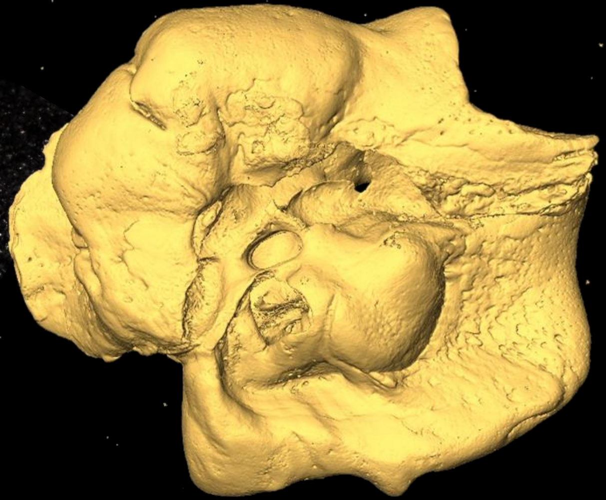
Medical CT scan

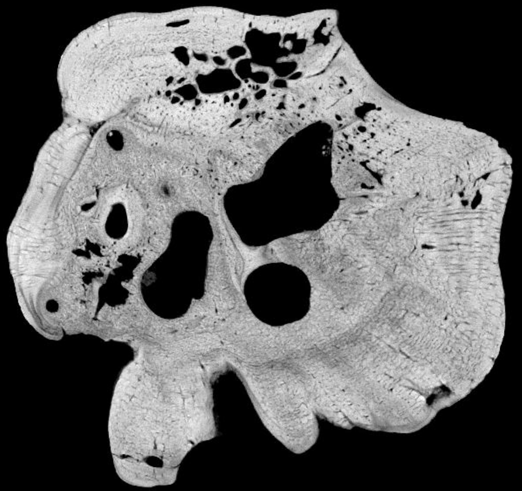


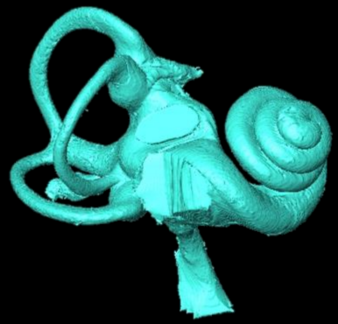
Micro CT scan

3D data acquisition – CT scan

Suid petrosal bone

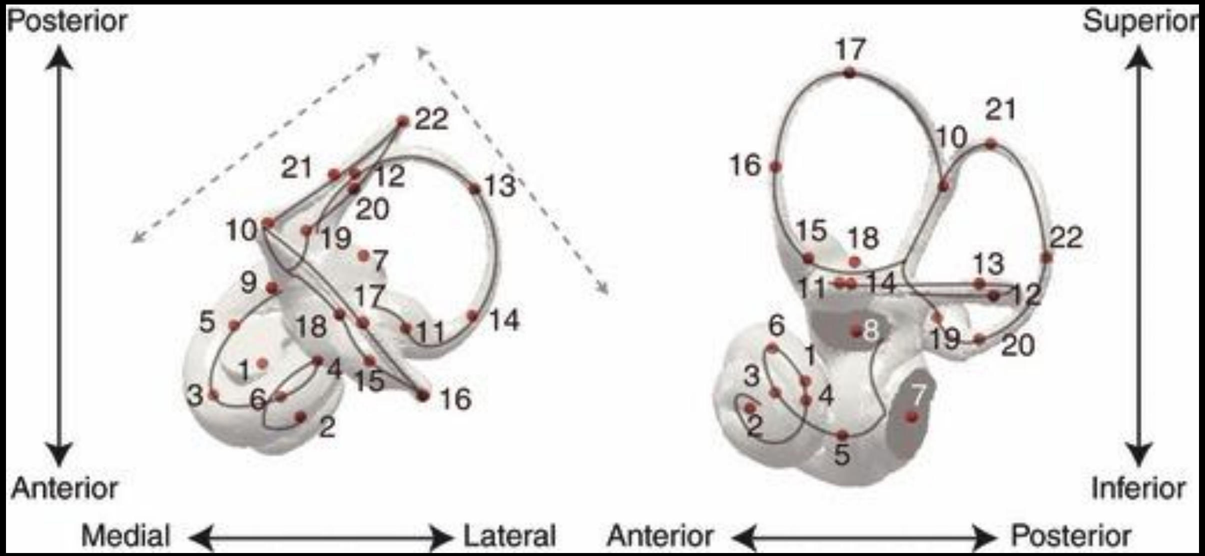






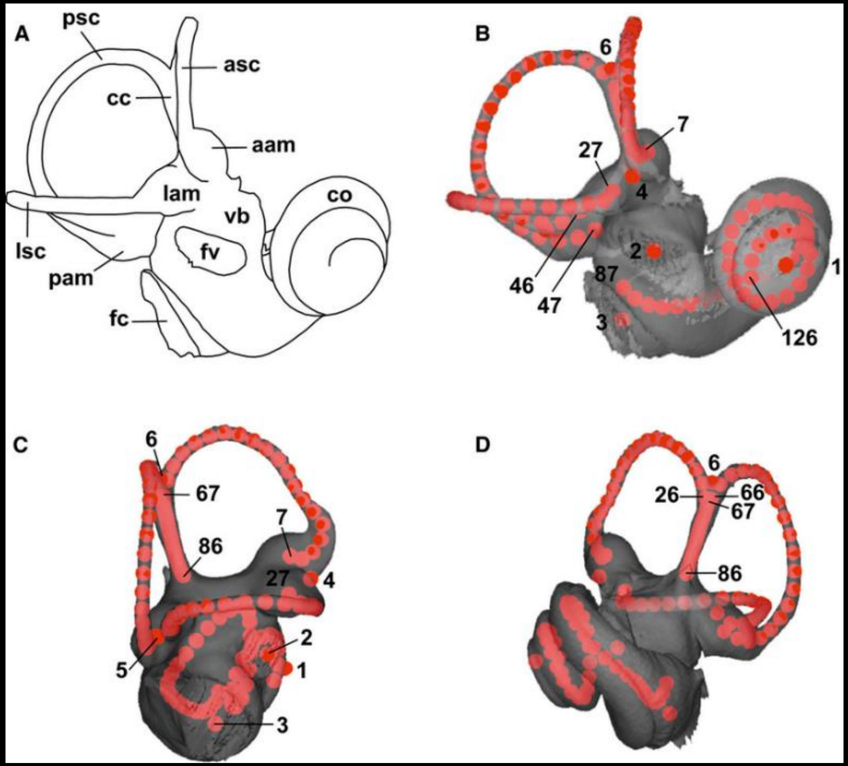
Segmented inner ear

3D landmarks



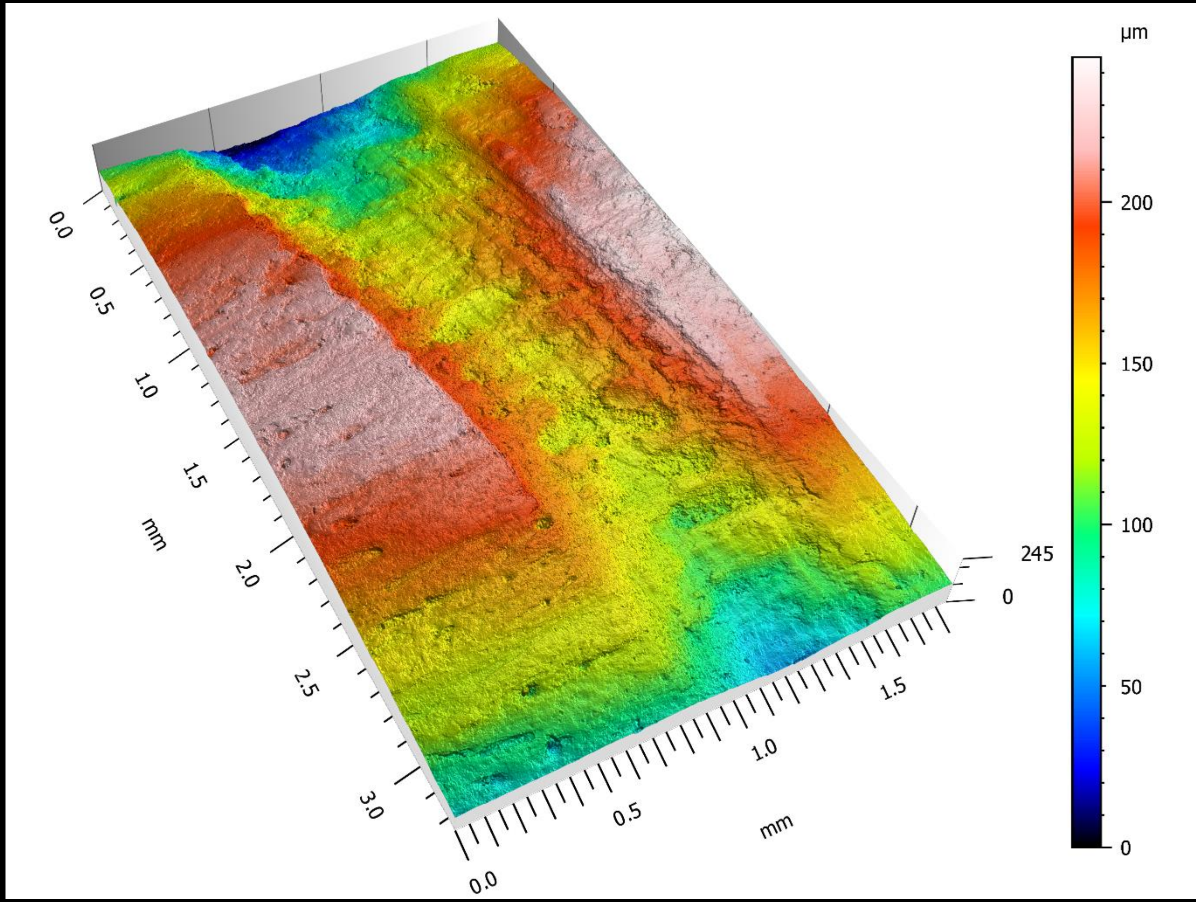
Lebrun et al., 2010

3D landmarks and curves of semi-landmarks

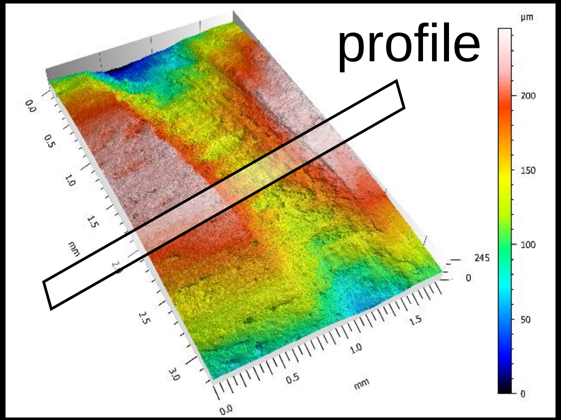


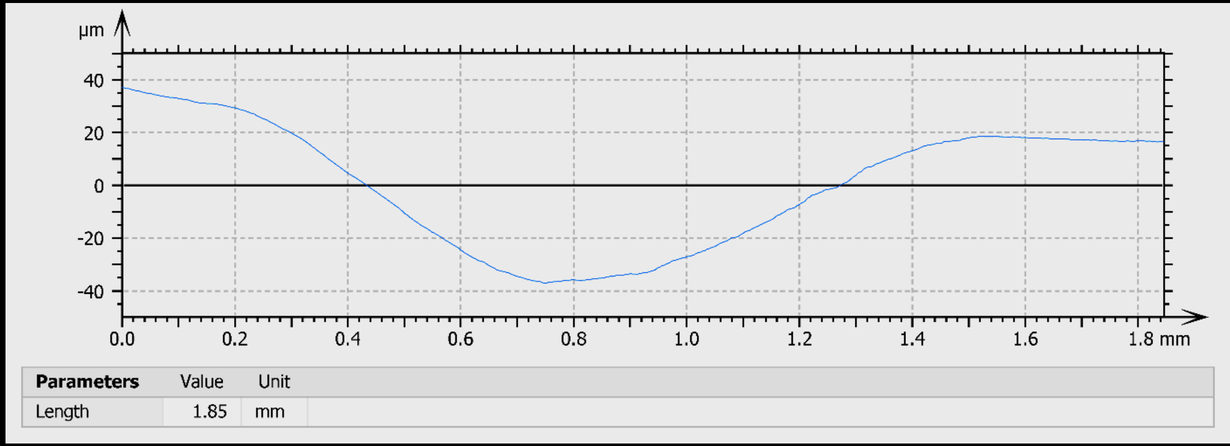
Grohé et al., 2016

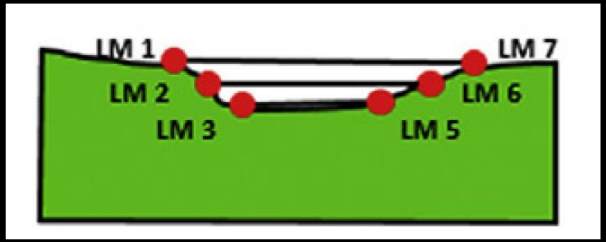
Example, confocal microscope
surface 3D with very high resolution



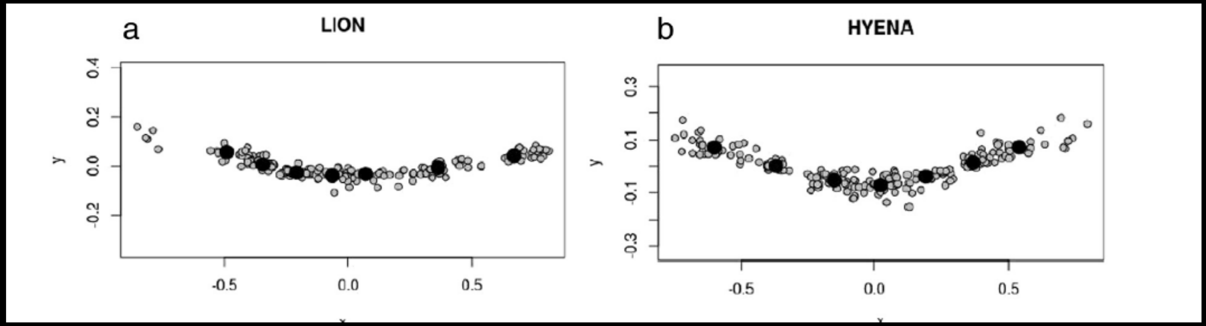
Bite mark of an extant lion on a cervid bone



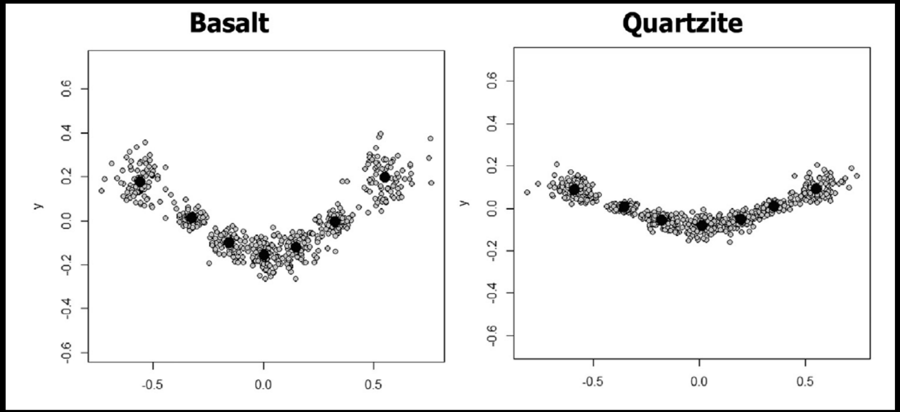




Bite marks of lions versus hyaenas



Arriaza et al., 2017



Cut marks with basalt and quarztite stone tools

Palomeque-González et al., 2017

When to use 2D morphometrics?

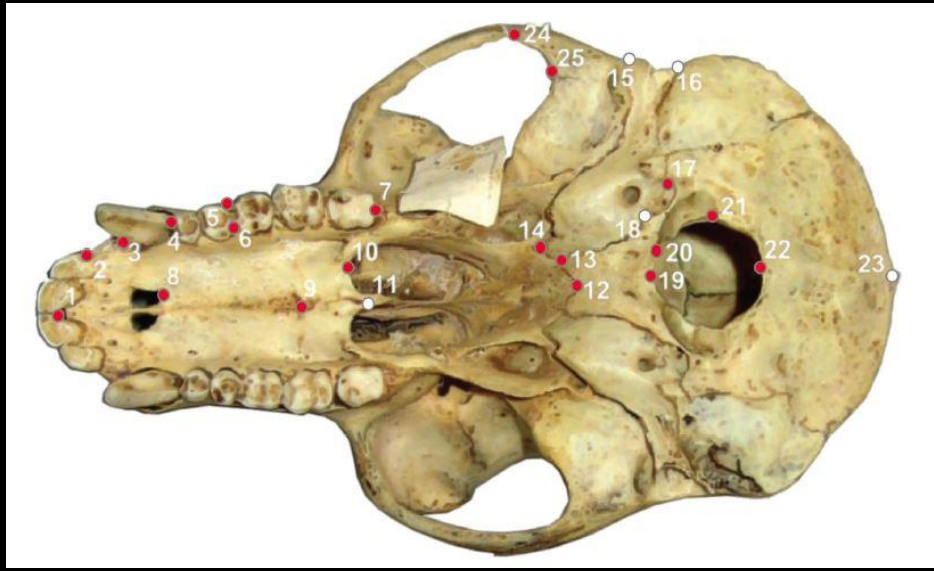
- Truly 2D objects
- Logistical limitations (lack of equipments, access to specimens...)
- Time limitations
- Large sample sizes
- Low-cost methods
- Comparability of data

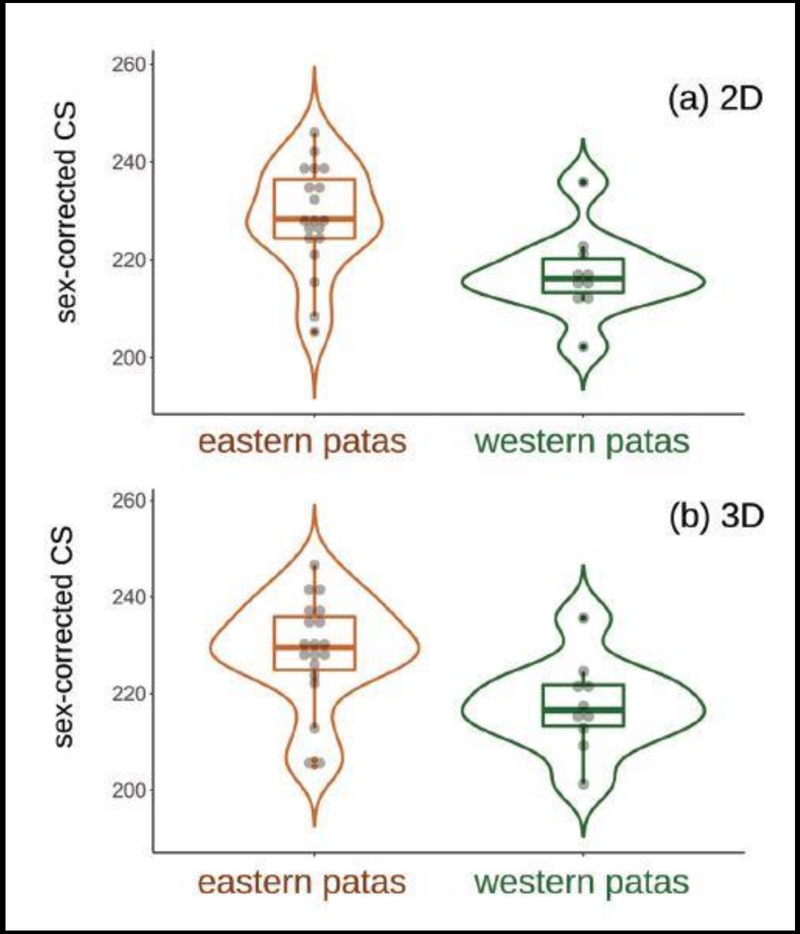
2D versus 3D

Can morphotaxa be assessed with photographs? Estimating the accuracy of two-dimensional cranial geometric morphometrics for the study of threatened populations of African monkeys

Andrea Cardini[1,2] | Yvonne A. de Jong[3] | Thomas M. Butynski[3]

« By applying a range of tests to compare ventral views of adult crania measured in both 2D and 3D, we show that, despite inacurracies accounting for up to one-fourth of individual shape differences, results in 2D almost perfectly mirror those in 3D » Cardini et al. (2021)

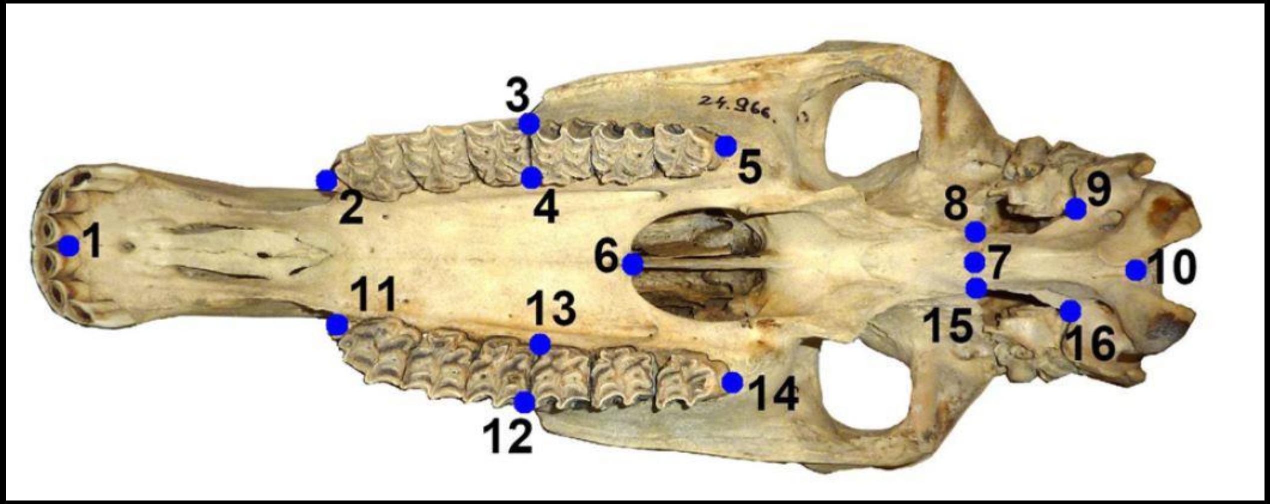


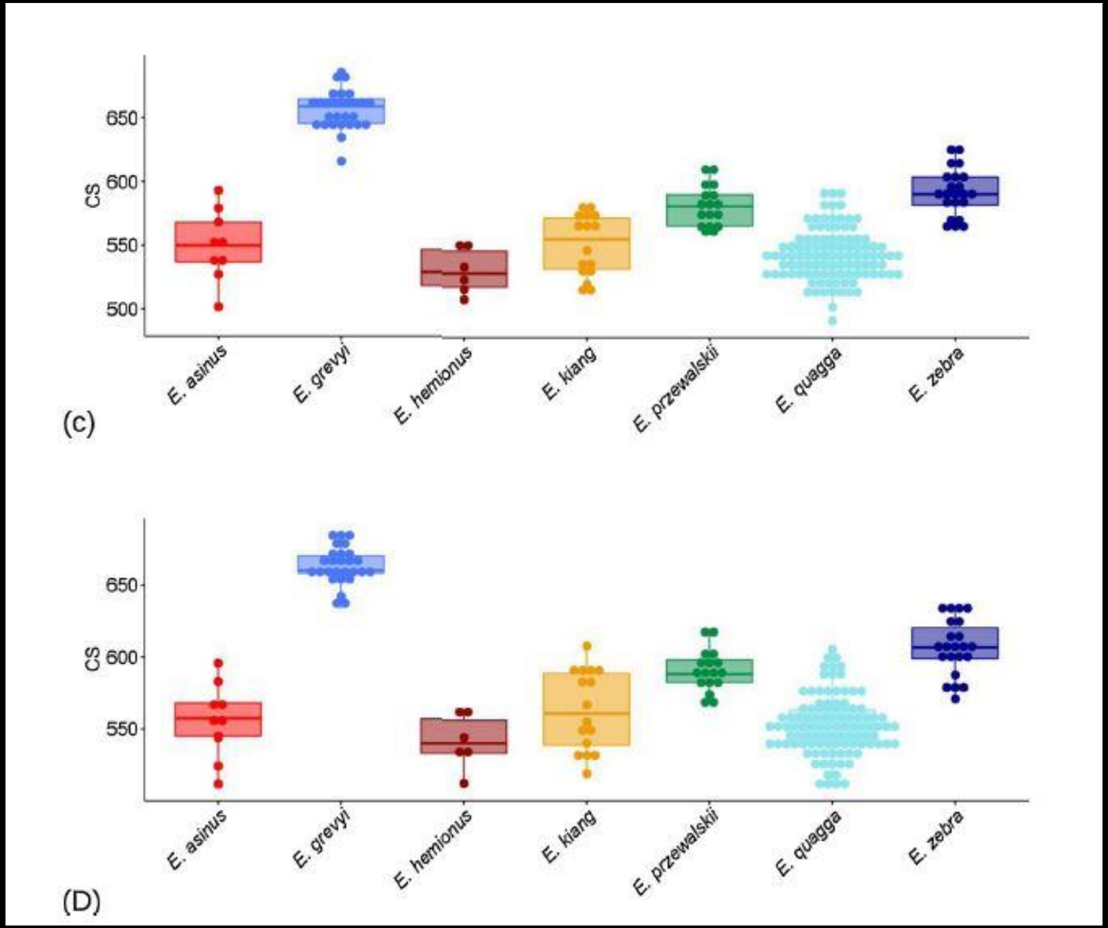


2D versus 3D

How flat can a horse be? Exploring 2D approximations of 3D crania in equids

Andrea Cardini[a,b,*], Marika Chiapelli[a]





2D

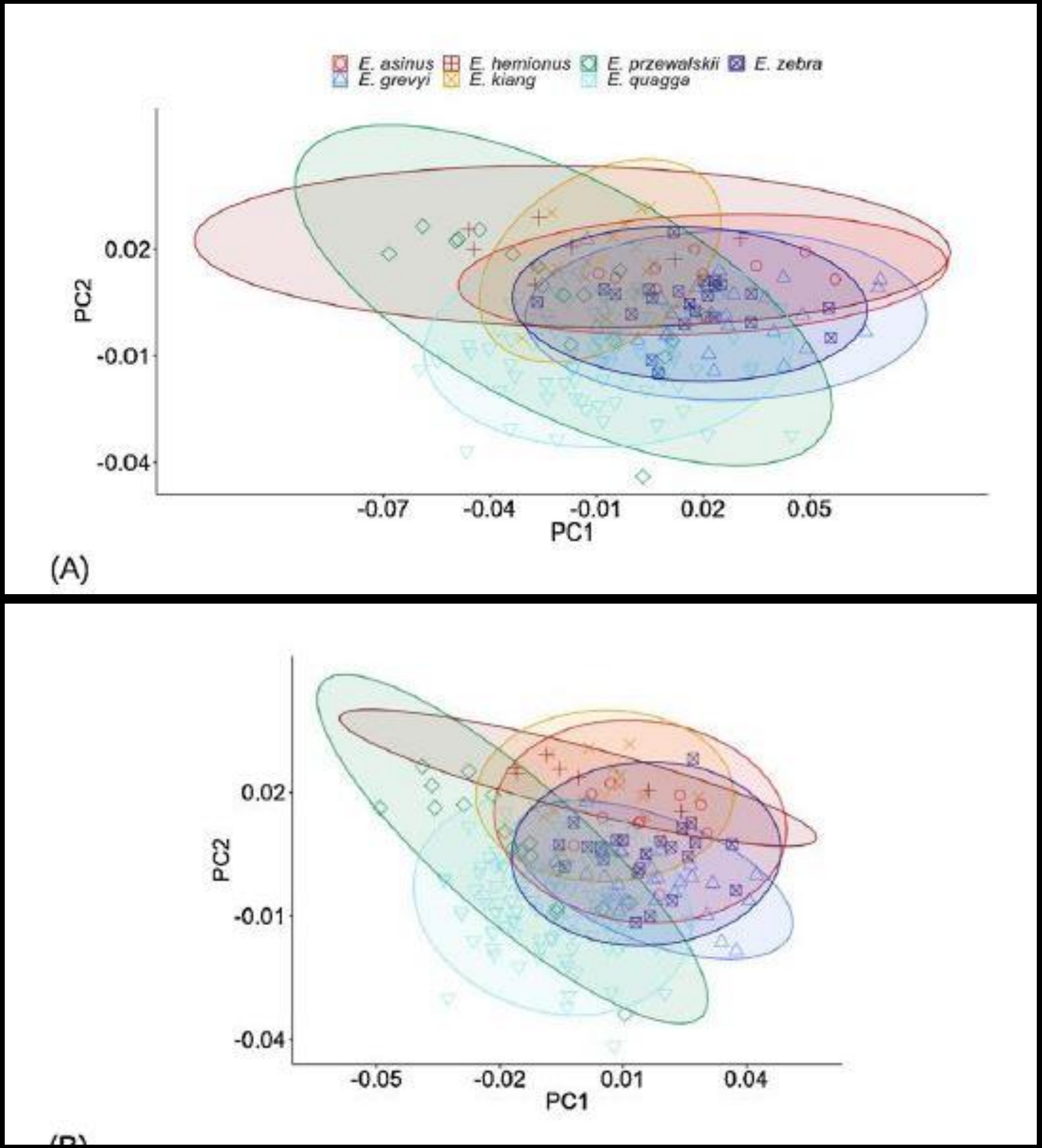
3D

Cardini & Chiapelli, 2020

2D versus 3D

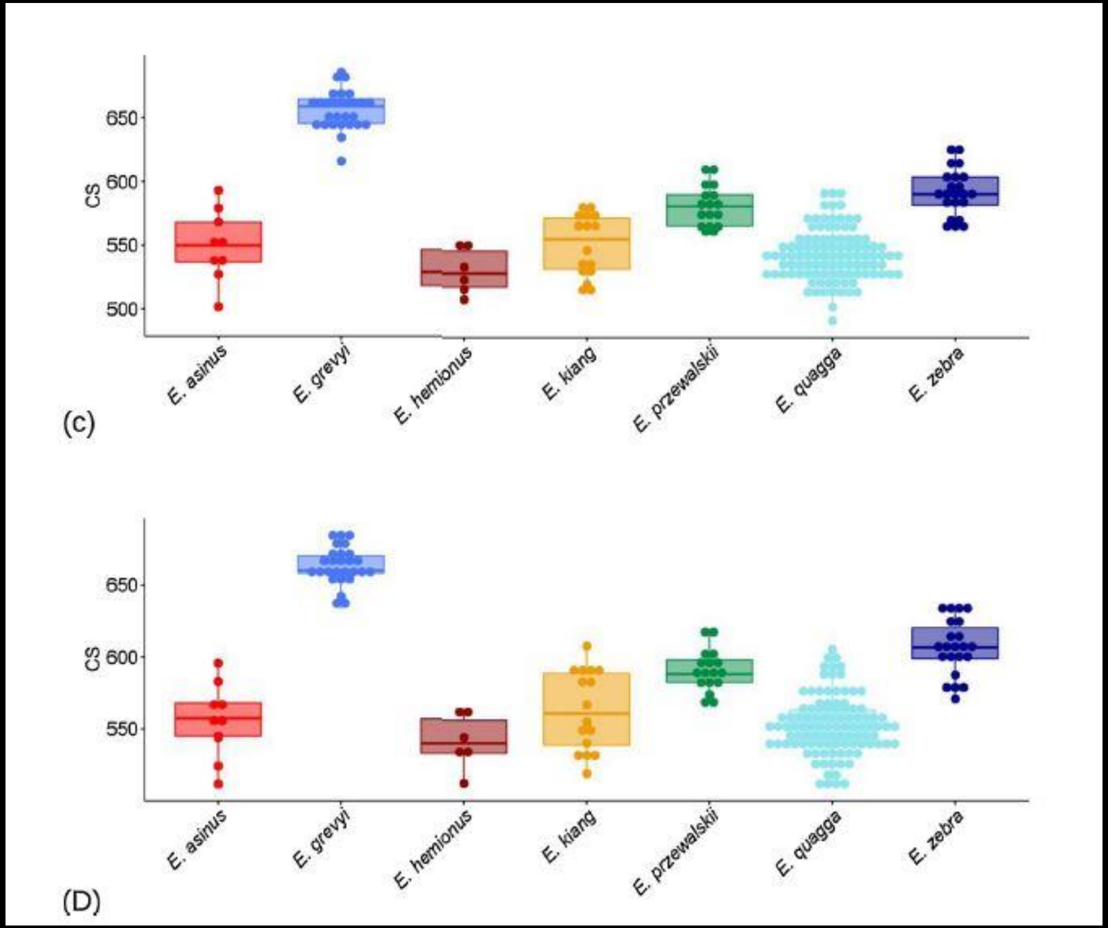
2D

3D



2D

3D



Cardini & Chiapelli, 2020

Increasing sample sizes using 2D protocols?

On the Misidentification of Species: Sampling Error in Primates and Other Mammals Using Geometric Morphometrics in More Than 4000 Individuals

Andrea Cardini[1,2] · Sarah Elton[3] · Kris Kovarovic[3] · Una Strand Viđarsdóttir[4] · P. David Polly[5]

*« the minimum sample sized [sic] required for a study varies across taxa and depends on what is being assessed, but about **25-40 specimens** (for each sex, if a species is sexually dimorphic) may be on average an adequate and attainable **minimum sample size** for estimating the most commonly used shape parameters ».*

Collecting data on large samples is usually faster in 2D than in 3D.

Repeatability and reproducibility

Repeatability = quantification of intra-observer error
Reproducibility = quantification of inter-observer errors

Error has to be much smaller than the assessed differences!!!

$\Rightarrow$ the smaller the difference (intra-specific variation, asymmetry...), the smaller the error has to be!

Repeatability and reproducibility

- Repeat data acquisition protocol several times
 (with enough time between repetition)

- Usually a few specimens repeated 5 to 10 times (choose specimens documenting the disparity within the whole sample)

- If necessary, same thing but with several observers

- Different methods to quantify or visualize variation of:
  - individual landmarks
  - landmark configurations

(see for example Cramon-Taubadel et al., 2007)

- Errors related to different steps of the protocol can be assessed independently (for example in photography)

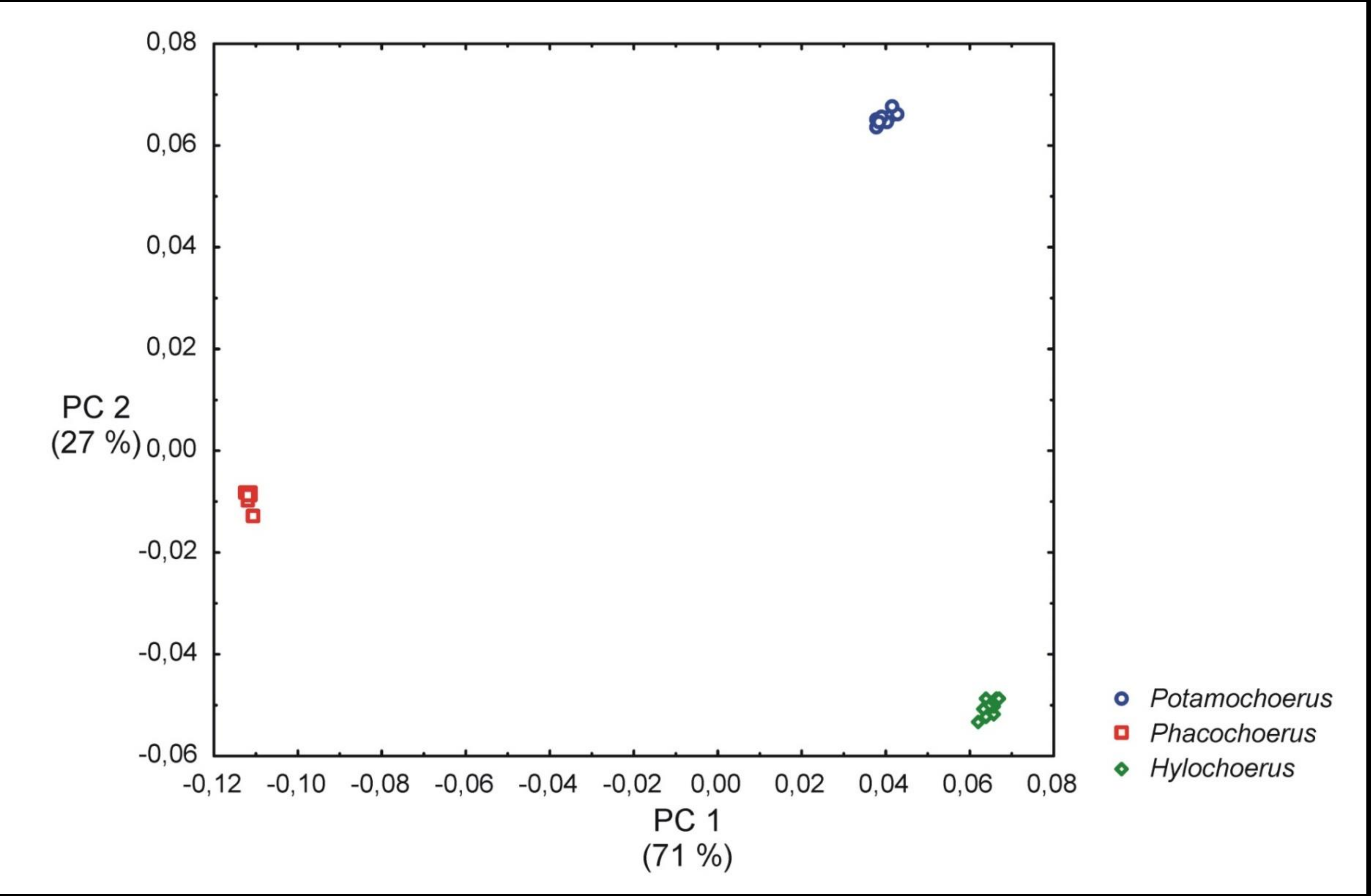
A few references to go further:

- Arnqvist, G., & Martensson, T. (1998). Measurement error in geometric morphometrics: empirical strategies to assess and reduce its impact on measures of shape. *Acta Zoologica Academiae Scientiarum Hungaricae*, *44*(1-2), 73-96.

- Fruciano, C. (2016). Measurement error in geometric morphometrics. *Development genes and evolution*, *226*(3), 139-158.

- von Cramon-Taubadel, N., Frazier, B. C., & Lahr, M. M. (2007). The problem of assessing landmark error in geometric morphometrics: theory, methods, and modifications. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists*, *134*(1), 24-35.

3D landmarks digitized on suid crania
3 specimens repeated 10 times



Souron, 2012

3D landmarks digitized on suid crania
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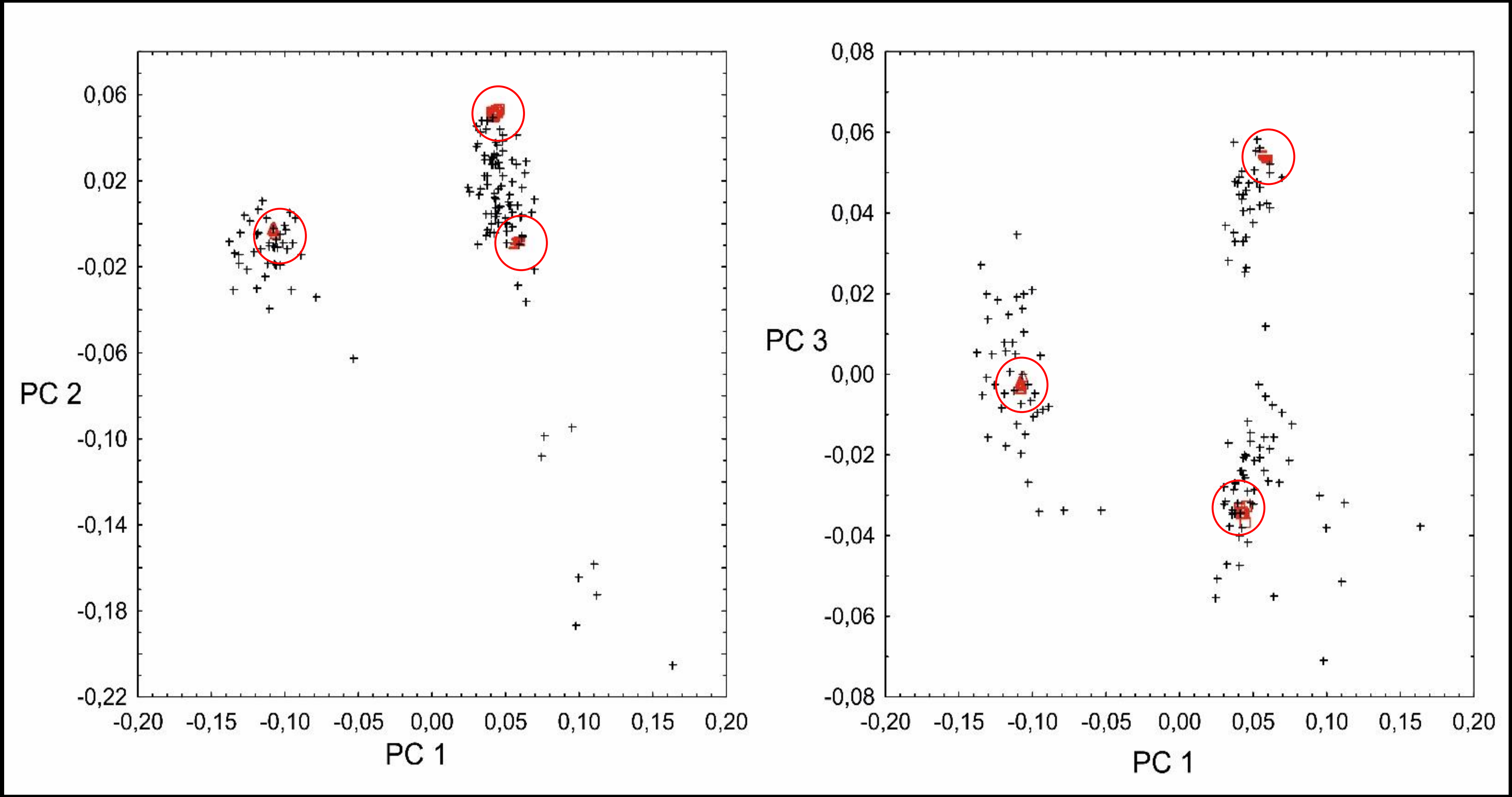
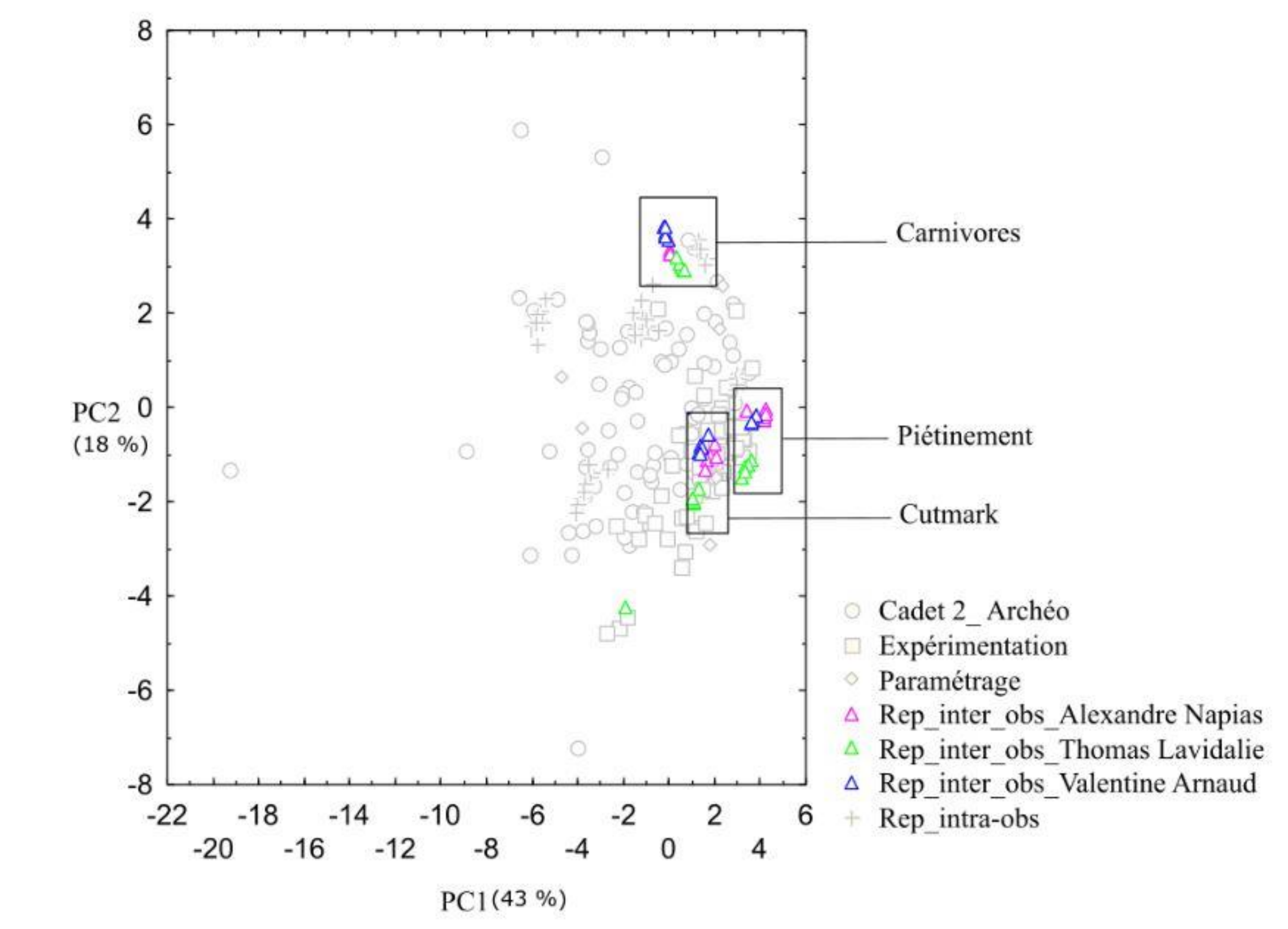


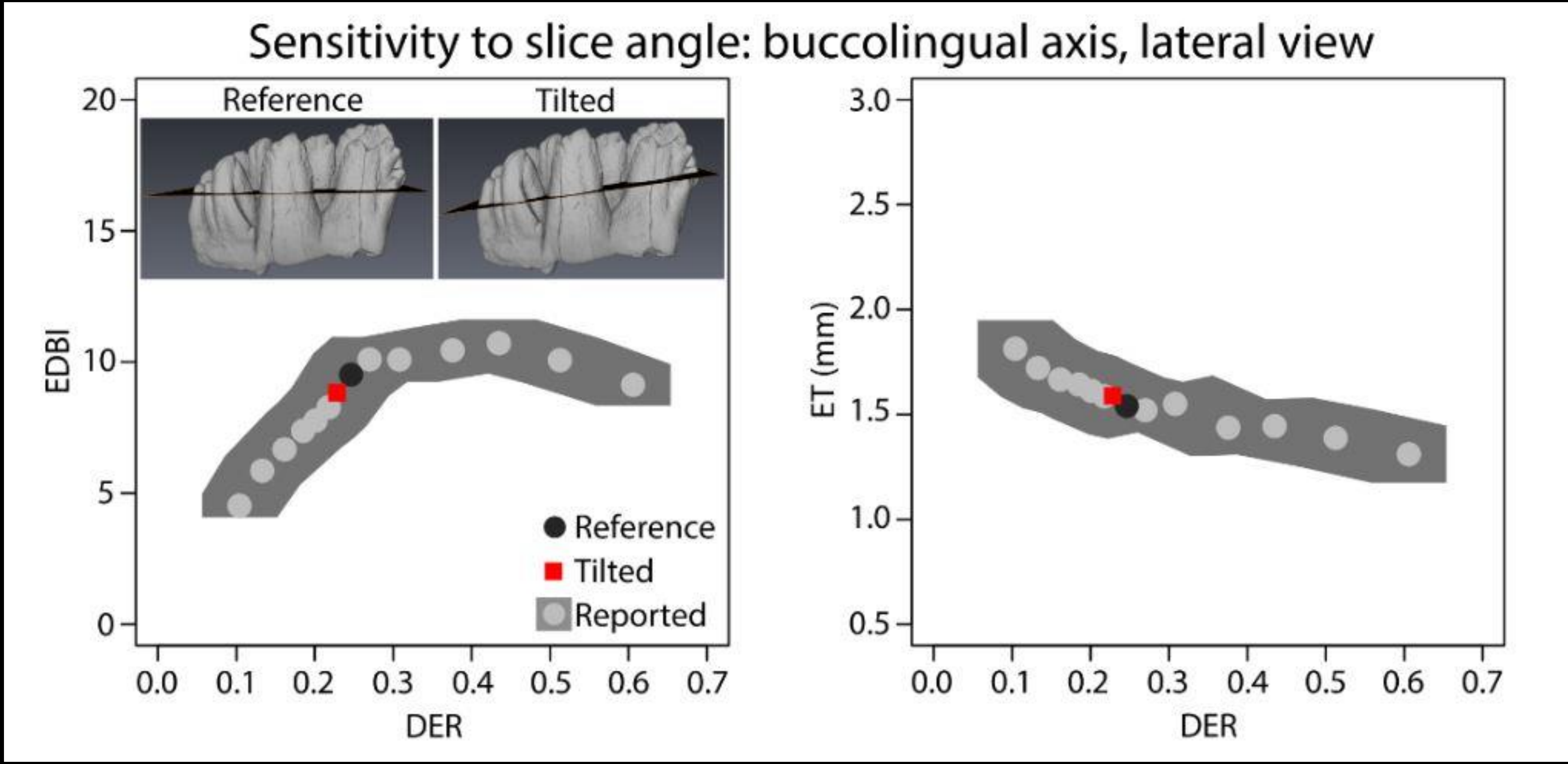
Souron, 2012

Repeatability and reproducibility



Arnaud, 2021

Sensitivity experiments for measurement error



Yang et al., 2022