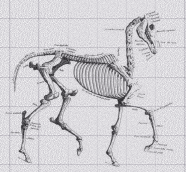
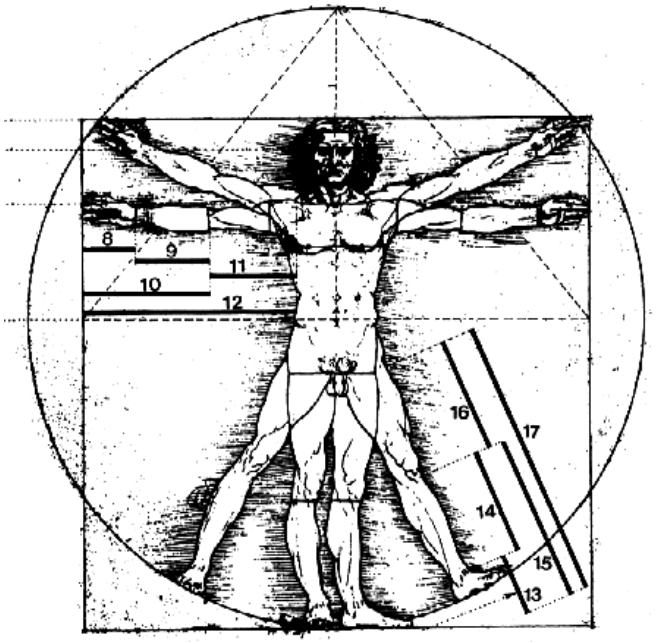
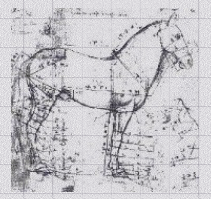


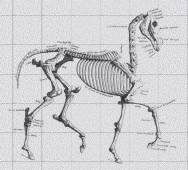
Analysis of body shape variation among different horse breeds via Generalised Procrustes Analysis

T. Druml, J. Sölkner

EAAP 2005 Uppsala

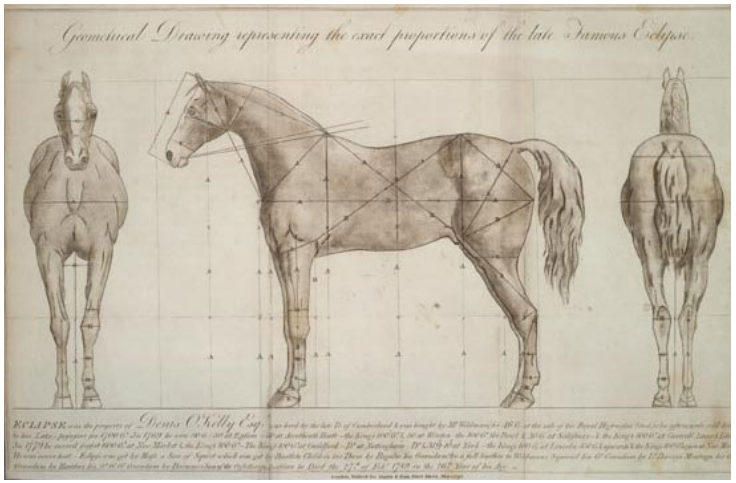






Overview

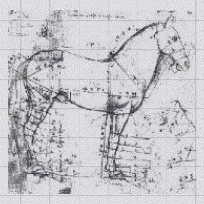
- **Traditional Morphology:**
  - Distance measurements, Circumferences, Angles,
  - Interpretation just in two dimensions: bigger – smaller, shorter – longer
  - Calculation of Indices was a trial to put single features in relationship – biological model

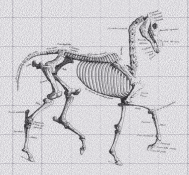


Eclipse, 1792,

fastest horse

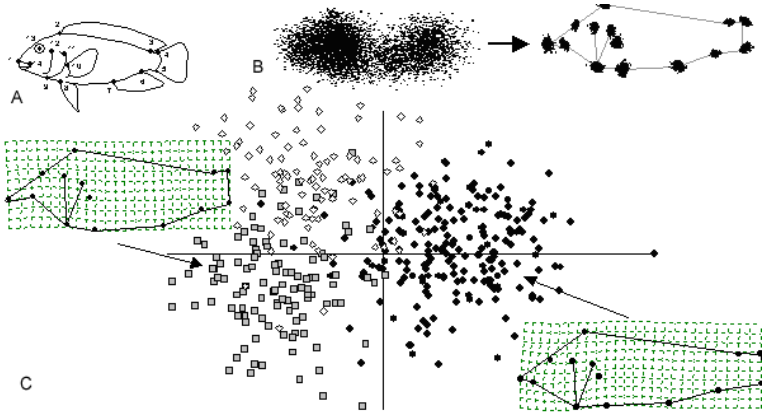
in history of racing

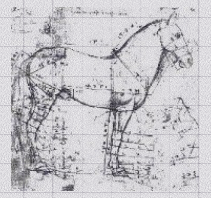


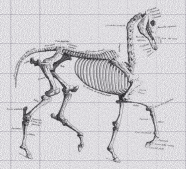


Overview

- **„Geometric Morphometrics“**
  - This methods use whole forms (specimens) avoiding the reduction to single components
  - Analysis of shape and size based on multivariate analyses of Cartesian coordinate data
  - The estimation of mean shapes and the description of sample variation of shape are carried out using the geometry of Procrustes distance.

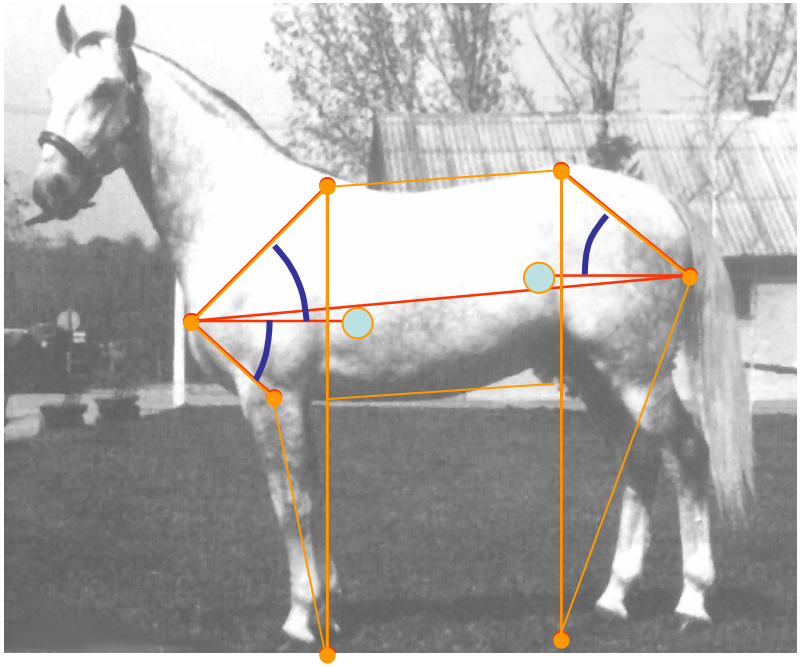


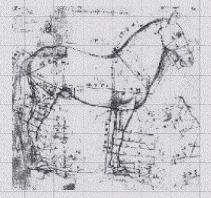


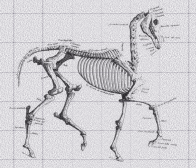


Example

- Reconstruction of horse torsi: 2 measures of height, 6 measures of distance and 3 angles
- Sin, Cos functions – calculation of 11 coordinates („landmarks“) the horse torso

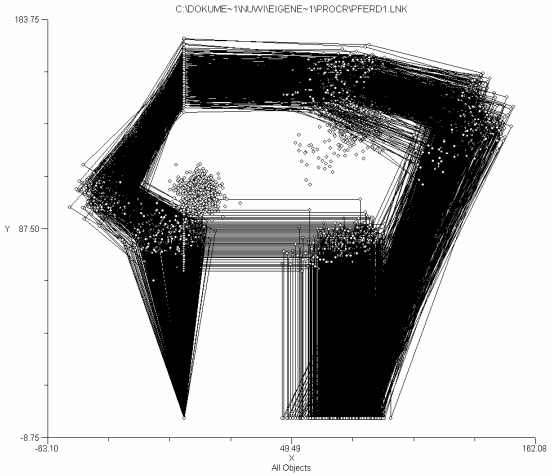


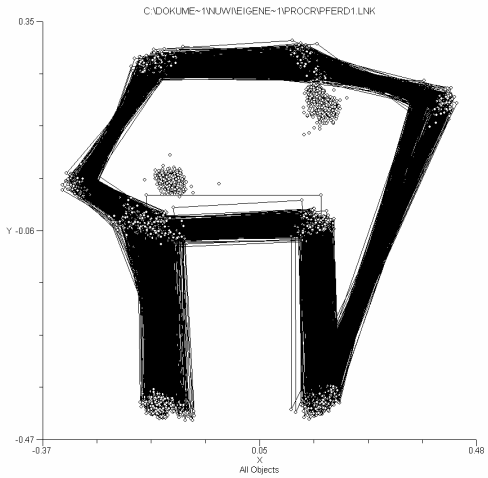


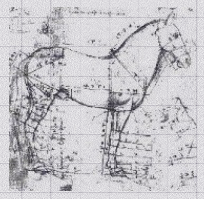


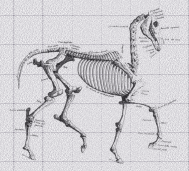
Example

- Raw coordinates of 843 horse torsi
- **„Generalized Procrustes Analysis“**
  - Reduction of orientation and variance
  - Optimal **Superimposition**
  - **Scaling** of objects to **unit size**
  - Minimum distance of the 11 landmarks



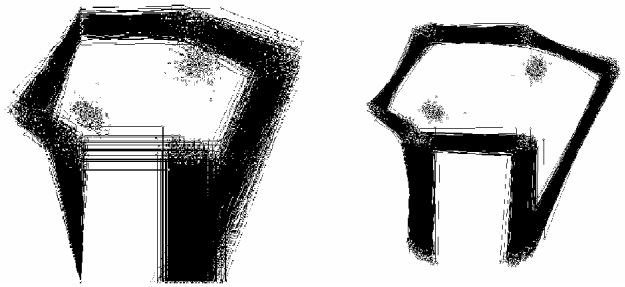


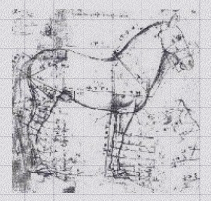


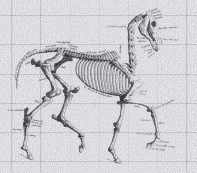


Geometric Morphometrics

- **„Procrustes Superimposition“**
  - Superimposition of all scaled forms in the centre, rotate the forms against the **mean** until the sum of squares of the „landmarks“ to the mean becomes a minimum – specimens with **Procrustes Distance.**
  - Iterative
  - Generalized Procrustes Analysis (GPA) oder Generalized Least Squares (GLS)

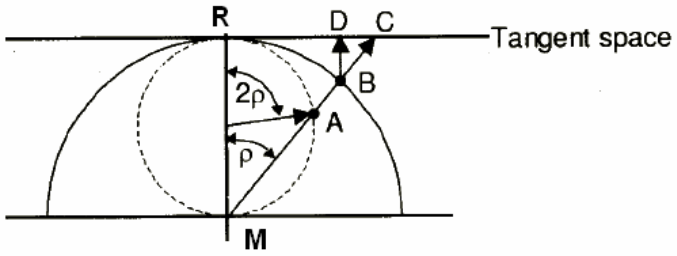


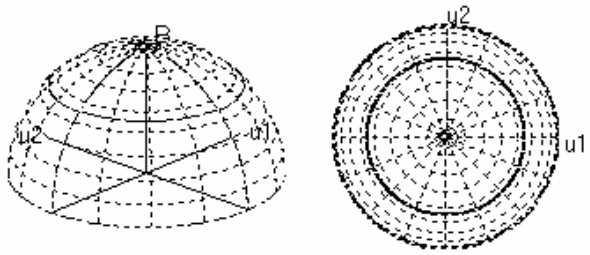


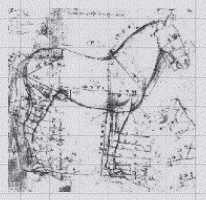


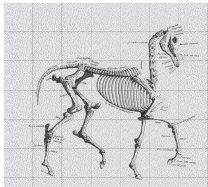
Geometric Morphometrics

- **The tangent space:**
  - „Kendall‘s Shape Space“ Concept:
    - A specimen can be defined as one point in a multidimensional Coordinate system (11x2 dimensional)
  - The **metric geometry** for statistical analysis is not in a **multidimensional** space – thus **projection on a tangent space**
    - **R** = mean form; **A** = centered form (raw coordinates)
    - **B** = scaled form (unit size 1), with procrustes distance **ρ** to mean **R**
- **Shape variables: Partial warp scores:** transformed Procrustes residuals of specimens to mean **R**

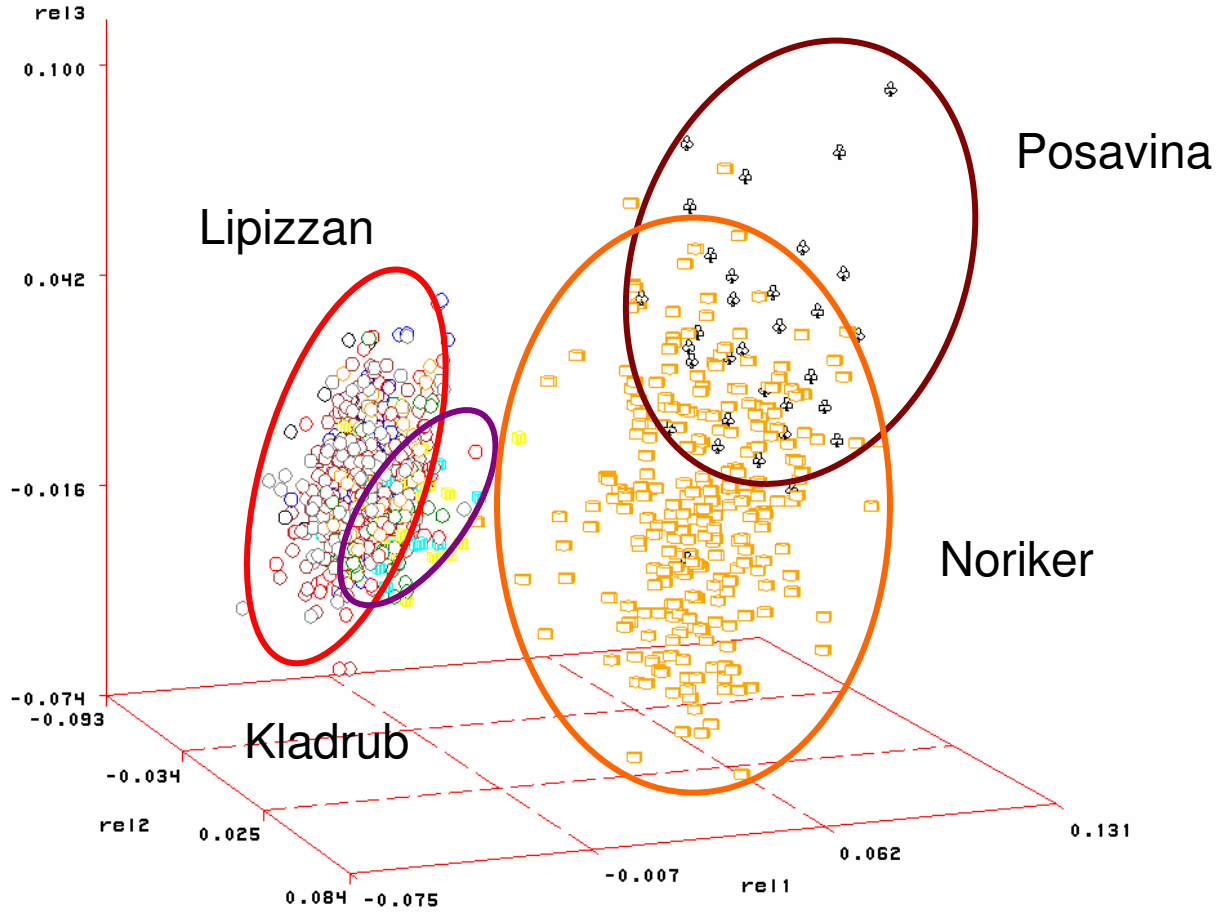


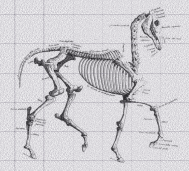






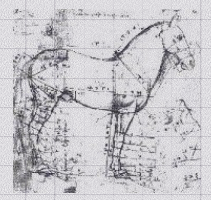
Relative Warps
Principal component analysis of partial warps

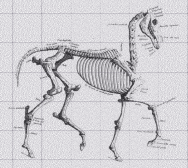




Thin plate spline

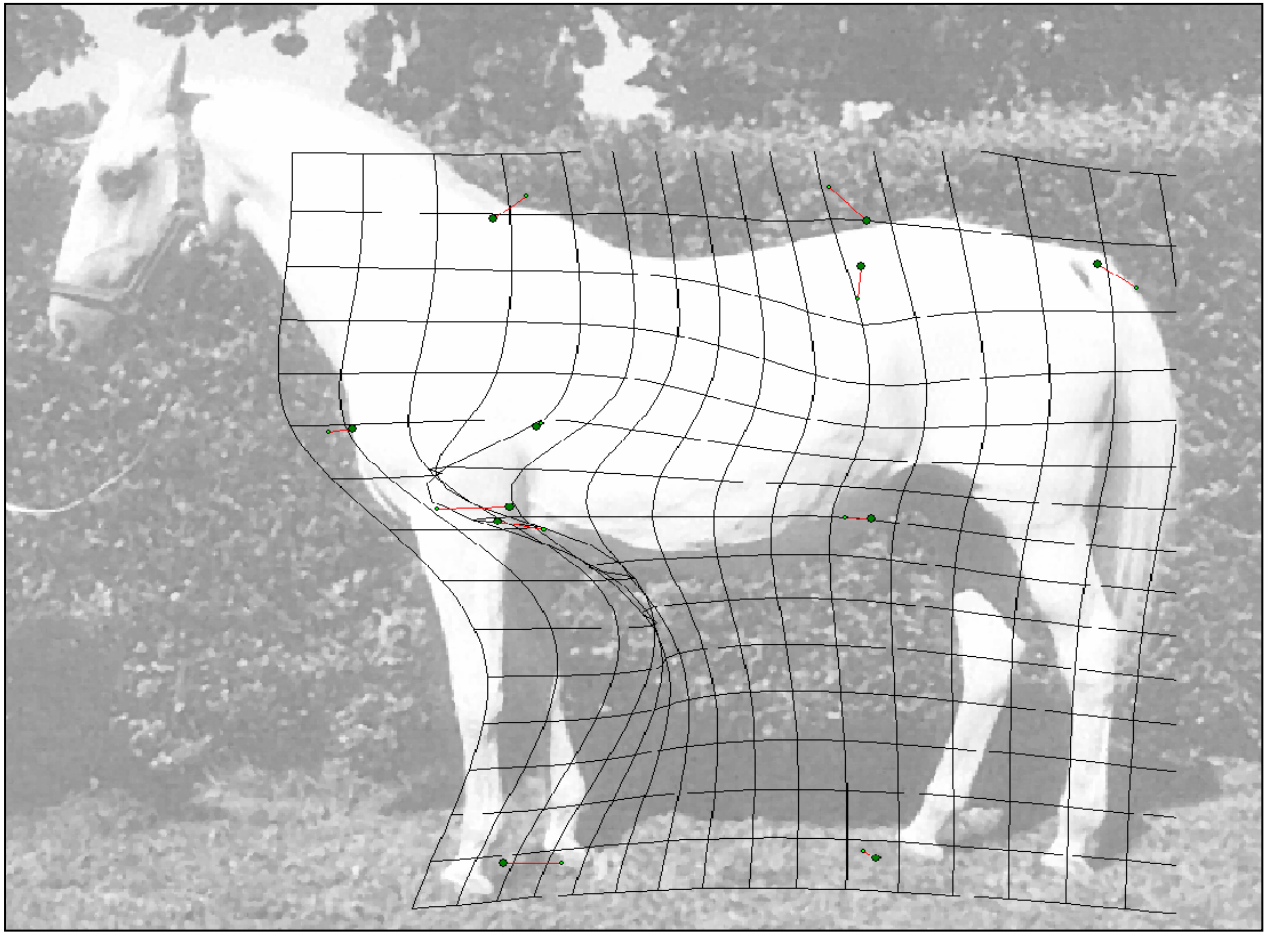
- To **visualise** and interprete the meaning of ‚Partial warp scores‘
- ‚Thin plate splines‘ are derived from engeneering techiques: physical behaviour of **thin metal sheets**
- Partial warp scores (transformed procrustes residuals) are implemented in the equation that is describing the ‚**bending energy**‘ of thin metal sheets

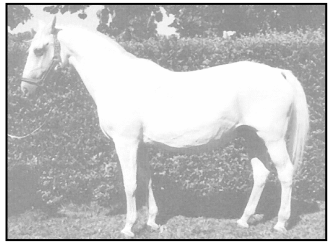


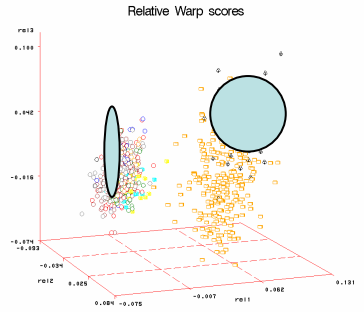


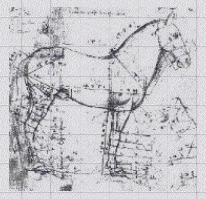
Thin plate spline

Lipizzan horse warped to the form of a Posavina



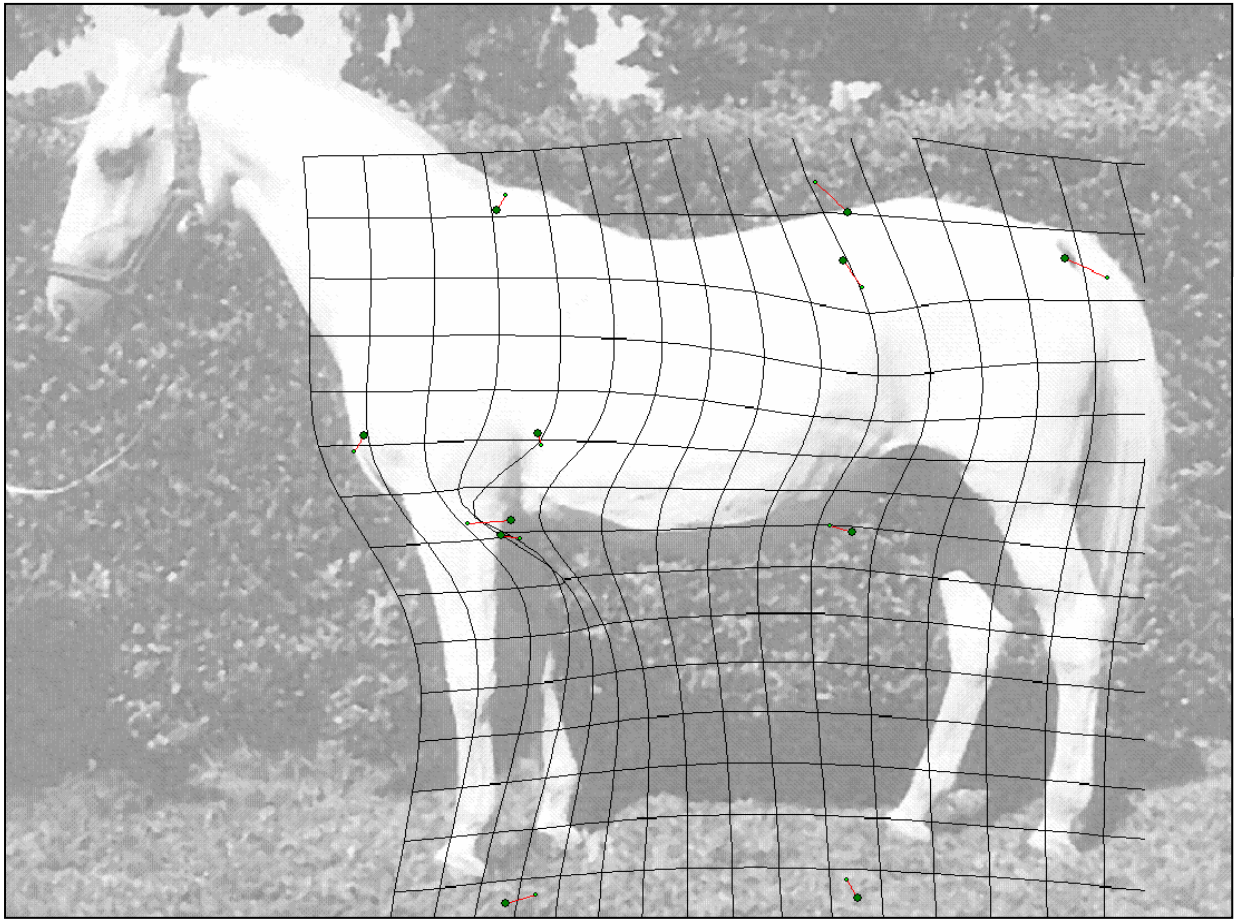


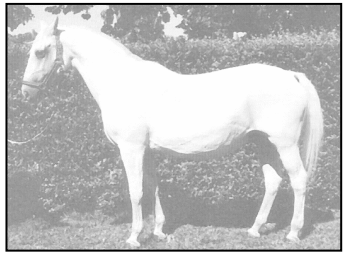




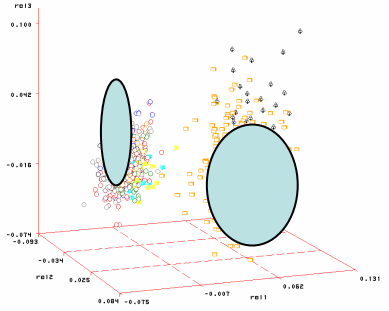
Thin plate spline

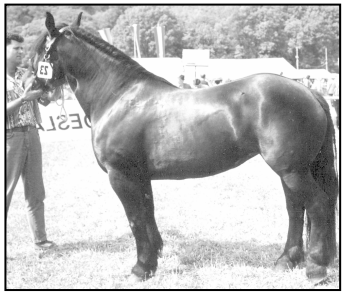
Lipizzan horse warped to the form of a Noric Horse

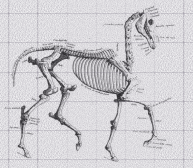




Relative Warp scores

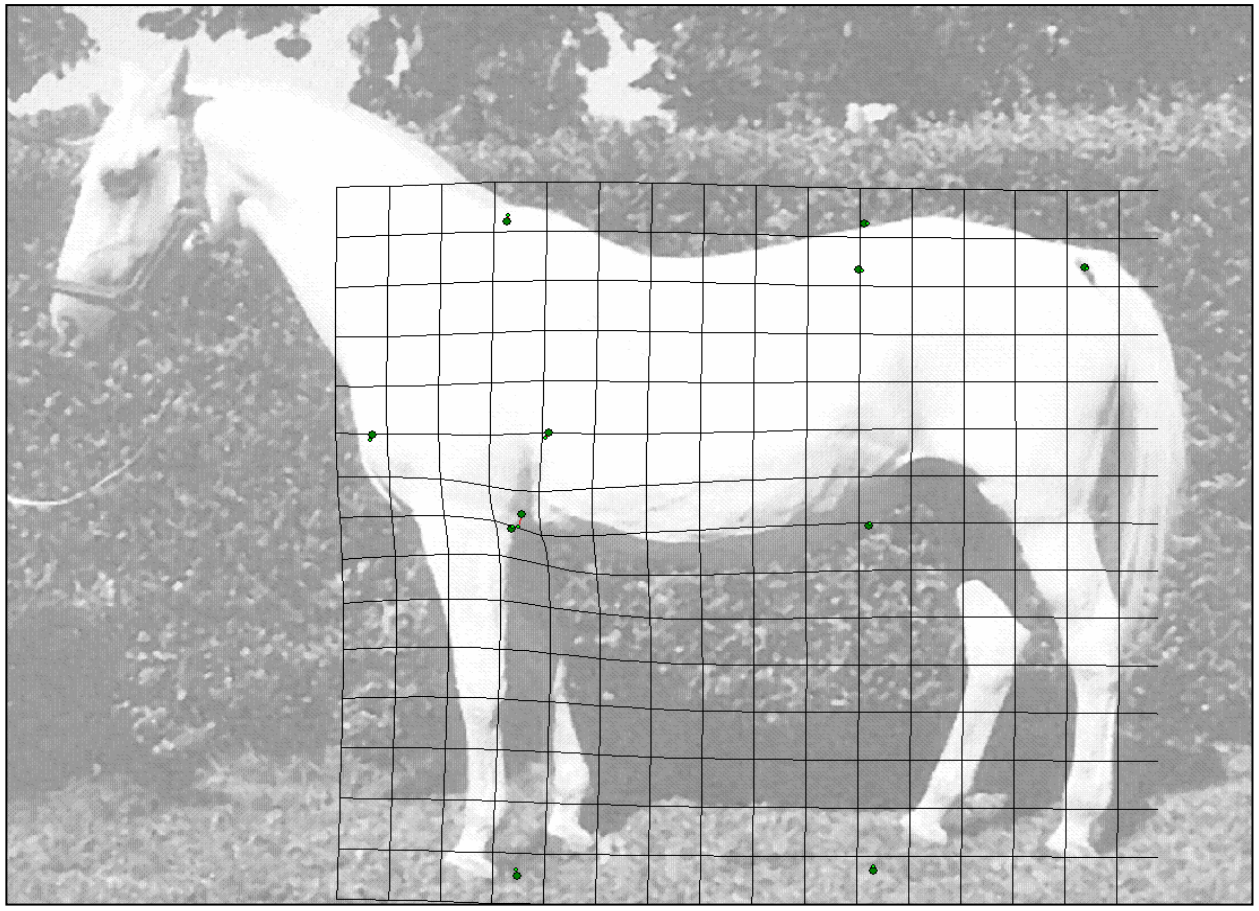


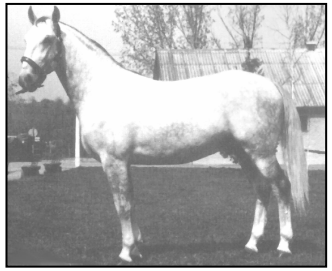


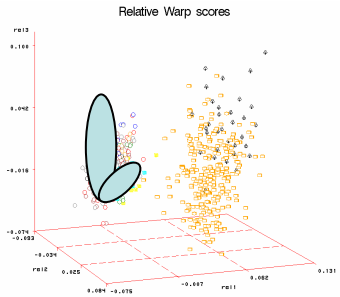


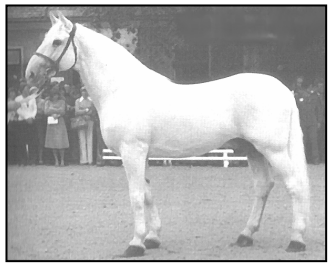
Thin plate spline

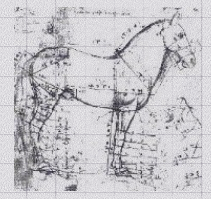
Lipizzan horse warped to the form of a Kladrub Horse





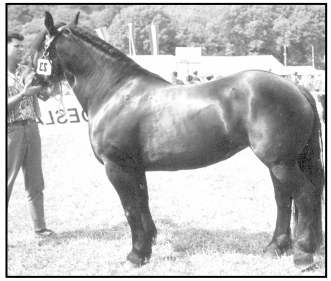


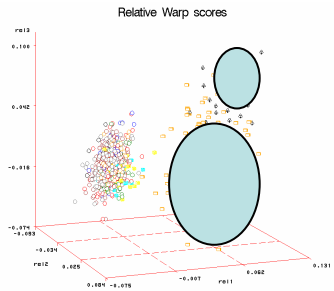


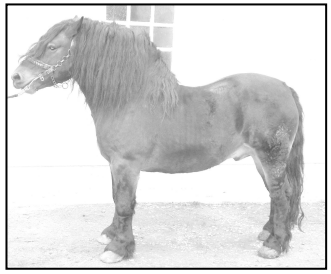


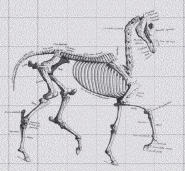
Thin plate spline

Noric horse warped to the form of a Posavina



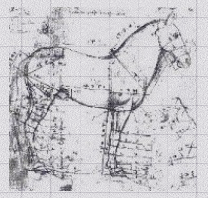


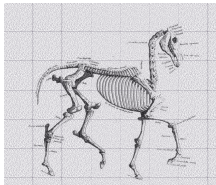




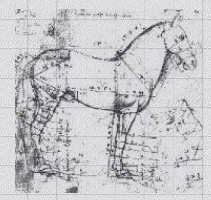
Summary

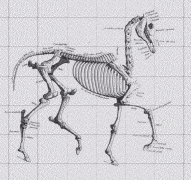
- To give an overview of a new statistical tool for analysis of morphology in animal breeding
- In this case the methodology was applied to identify differences in two types of horses:
  - Baroque horse group and Draught horse group
  - The croup and backquarter was detected to be a conservative part of body
  - Shoulder region and forequarter respond to selection and specialisation





Thank you for the attention





Software

- List of the most important software packages used:
  - TPS program series of Rohlf J.F.
    - tps-Relative warps, version 1.36 (2004)
    - tpsPLS, version 1.4 (2002)
  - MORPHEUS ET AL ©, Slice D. (1994-1999)
- Programs are available at Stony Brook hompage:

  http://life.bio.sunysb.edu/morph