Statistical Analysis of the Anatomy: From Digital Patient to Digital Population

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www-sop.inria.fr/asclepios/projects/Health-e-Child/ShapeAnalysis

The development of statistical tools that enable analyses of high dimensional objects can provide quantitative information on the relevant phenomena to model in order to simulate a given organ and a given pathology. We present open source tools that allow users to model biological structures for a wide range of applications.

Patient Data

Estimate Reference Geometry

Template

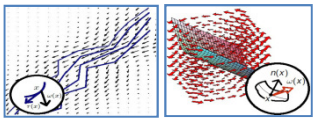
Principal Component Analysis

Deformation Modes

Statistical Analysis

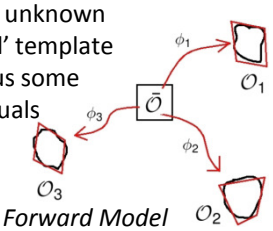
Well-Posed Statistical Framework

Currents are used to give a geometric representation of shapes - no point-to-point correspondences



Currents for curves: path integral | Currents for surfaces: flux integral

Forward model [2] used to model the set of shapes (T_i) as random deformations (φ_i) of an unknown 'ideal' template T plus some residuals (ε_i).

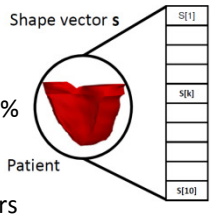


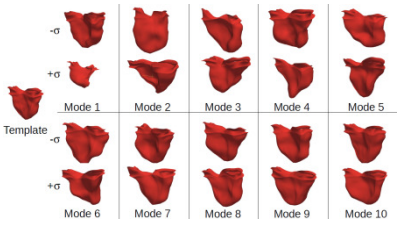
Forward Model

Large Deformation Diffeomorphic Metric Mapping (LDDMM) algorithm for non-linear registration.
- Geodesic shortest path
- Metric space on deformations
- Diffeomorphisms to preserve shape topology

Quantify Shape Variability

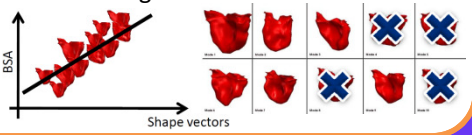
- Population – 32 Tetralogy of Fallot patients (19 males and 13 females) aged 10 – 30 years.
- 14 deformation modes capture 90% of spectral energy
- Project to a PCA subspace
- Characterize patient by 14 parameters





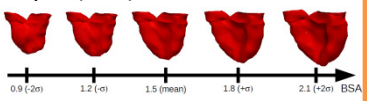
Identify Shape Descriptors

- Linear regression between modes and clinical parameter (BSA)
- Remove non-significant modes



Predict Shape

- Correlate BSA with shape – Canonical Correlation Analysis (CCA) between deformation modes and body surface area (BSA)

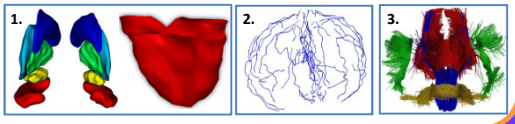


Mean RV remodelling observed when body surface area increases.

Applications

These tools are open source and freely available and will be included in the VPH toolkit. The shape analysis tools are available in the ExoShape directory, and the statistical tools are available in the ExoStat directory on the download page.

1. **Surfaces** can be used to model organs such as the heart, brain and lungs [1,4,5].
2. **Curves** can be used to model sulcal lines on the brain cortex [1].
3. **Sets of curves** can be used to model structures such as fibre bundles in the brain [1].



References: [1] Durrleman et al., MedIA 2009; [2] Allassonnière et al., JRSS 2007; [3] Valliant, Glaunes., IPMI 2005; [4] Mansi et al., MICCAI 2009; [5] Gorbunova et al., IWPIA 2009.

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Health-e-Child