ShapeWorks

The tutorial
Correspondence Pipeline

Align → Antialias → Distance Transform → Initialize → Optimize → Align

Preprocessing

PBM Algorithm
Command Line Tools

Align → Antialias → Distance Transform → Initialize → Optimize → Align

Preprocessing

Seg3D/ITK → ShapeWorksGroom

PBM Algorithm

ShapeWorksRun

Analysis: PCA, Group differences → ShapeWorksView
ShapeWorksGroom

Command line collection of preprocessing filters

Syntax

ShapeWorksGroom torus.preprocess1.params isolate hole_fill center auto_crop
ShapeWorksGroom torus.preprocess2.params antialias fastmarching blur

Basic filters available

- isolate
- hole_fill
- antialias
- fastmarching
- blur

DEMO: torus example
Example tori shapes from population parameterized by $r$ and $R$
ShapeWorksRun

Command line tool to initialize and optimize particle positions on shapes in the ensemble

Syntax

ShapeWorksRun torus.correspondence.params

Notable parameters

• # particles
• adaptivity
• alignment

DEMO: torus example
Correspondences overlaid on 3 of the input shapes
ShapeWorksView

GUI to visualize correspondences and perform statistical analysis

Syntax
```
ShapeWorksView torus.analyze.params
```

Notable parameters

- Reconstructed shapes
- Modes of variation
- Group differences (not in demo, only if 2 populations are available)
Modes of variation captured by the correspondence model.
The first (top) and second (bottom) modes capture the shape variation consistent with the generative model.
Recent Work†

†M Datar, Y Gur, B Paniagua, MA Styner, RT Whitaker, “Geometric Correspondence for Ensembles of Nonregular Shapes,” MICCAI 2011
Challenges of Nonregular Shapes

Fig: Incorrect correspondences near sharp features when (a) points with different tangent spaces interact, (b) nearby points sampling different parts of the surface interact, (c) optimization is based only on point positions on different shapes

- Geodesic distances
  - computed using intermediate triangular meshes
  - pre-computed between vertices [Fu, et. al†]
  - otherwise computed using two-layered Barycentric interpolation

- Surface normal entropy
  - penalize divergence from “mean” in the space of surface normals
  - helps disambiguate correspondences near convoluted features

Mean differences between normal and ischemic groups (blue => expansion, yellow => contraction)
Top: PBM*, Bottom: proposed method

- Study shape differences between normal and ischemic LV wall segmented at end diastole (ED)

- Results
  - Group mean differences significant with \( p\text{-value} < 0.01 \)
  - Shape changes spatially consistent with previously published results

* M Datar, Y Gur, B Paniagua, MA Styner, RT Whitaker, “Geometric Correspondence for Ensembles of Nonregular Shapes,” MICCAI 2011
Nonlinear Growth Model

Fig: Replacing linear regression model with nonlinear Gompertz model for optimization

Estimate Gompertz model parameters

Optimize correspondences

\[ z = \mu + \epsilon, \epsilon \sim \mathcal{N}(0, \Sigma) \]

Replace covariance w/ residual

\[ z = f(t) + \tilde{\epsilon}, \tilde{\epsilon} \sim \mathcal{N}(0, \hat{\Sigma}) \]

Estimate regression coefficients (linear)

\[ f(t) = a + bt \]

Varying asymptote*

Varying delay*

Varying speed*

\[ y(t) = ae^{be^{ct}} \]


Fig: Progression of growth at three time-points from neonate – 4 years

Mixed Effects Model

Mixed Effects Model: Trends

Group trend

Individual trend

Pairwise Distance Features

Pairwise interparticle distance (Euclidean/Geodesic) as a feature for correspondence optimization

Fig: Initial results from study of cortex shapes. Two examples from the population with correspondences overlaid. Note that correspondences are not good near the top of the cortex, suggesting the need for additional features (e.g. curvature) to be included.
Thank you!

Questions?