Image and Geometry Analysis

Aims

1. Image preprocessing and segmentation

2. Adaptive, robust meshing or multimaterial volumes

3. Robust, general statistical shape analysis

4. Geometric analysis in biomedical simulation
Research and Software

**Seg3D**
Segmentation

**Cleaver**
Meshing

**ShapeWorks**
Analysis
Some Recent Activities

• Software
  o Seg3D
  o Shape analysis

• Applications

• Some research...
Seg3D Software

- Build as library
- Launch from within another application
- Contract with Phillips
ShapeWorks Software

• **Command-line tools** for preprocessing shape data
  o Binary segmentations and surface meshes

• **Shell scripts** of processing pipelines
  o E.g. segmentations and meshes

• **Improved/updated visualization tools** for point-based models & statistics
ShapeWorks Software

• For optimization:
  o **Constraints** on points with cutting planes and spheres for open surfaces
  o **Surface normals** as features
  o **User-defined features** for correspondence
    - Scalar values on surface mesh
  o **Code optimizations** to reduce memory footprint
  o **Shell scripts** to automate algorithmic parameter files and multi-scale optimization
Craniosynostosis Progress
[L. Kavan, J. Goldstein]

• Goals: quantitative assessment of severity of Craniosynostosis
• Experts rate severity
  o Ordinal regression in shape space
• Manuscript to J. PRS reviewed and major revision
• R21 funded
Hip Biomechanics
[w/ Anderson, Weiss]

• Extensions to full pelvis (statistical biomechanics)
• R01 renewal scored, resubmit

Harris et al, 2013
Hip Models

Dysplasia
Control
Retro
Group Mean

PCA Mode # 1
PCA Mode # 2

+/− 2 std
DeepSSM – Motivation – Scenarios

• Clinical practice – images (e.g. CT, MRI)
• Clinical/scientific shape questions
  o How does a patient differ from normal? Implications?
  o How do two groups compare? Different? How?
  o What happens to a patient over time?
• Ideal: Images -> quantitative (score), visualize
DeepSSM – Motivation

• Processing population of 3D volumes for correspondence shape analysis is hard work.
• Adding/comparing unseen samples wrt population

Proposal: a person should not need a PhD in math/CS to do shape analysis!
DeepSSM – Proposed Solution

- Regress shape parameters directly over space of images
  - Deep neural networks
Methods – Data Augmentation

Shape Space

PCA Space

n ∈ ℝ^M

Original samples
Augmented/synthetic samples

TPS Warp

s_i ∼ N(μ, Σ)
DeepSSM on LA MRI

0mm --- 12mm

0mm --- 4.3mm

0mm --- 2.2mm

mm

Training
Validation
Testing
Unseen
Severity Quantification

- Use Mahalanobis distance on PCA loadings to detect and quantify the degree of deformity from normal, i.e., the severity of metopic scans.
Craniosynostosis
[with Kavan, Goldstein, et al.]

See poster.
Femur Data

• CAM femoroacetabular Impingement (CAM-FAI)
• Performed DeepSSM and got similar results as for craniosynostosis
Conclusions

• Software
• Applications
• Some funding
  - More proposals in preparation
• Future directions
  - Easier access to analysis