Extrapolation of Missing Craniofacial Skeletal Structure via Statistical Shape Models

Project #1 Checkpoint Presentation
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Project Overview

- **Project Goal:** Design and implement a method for extrapolating missing anatomical craniofacial skeletal structure with the use of a statistical shape model of the human cranium.

Courtesy of Dr. Chad Gordon

Courtesy of Dr. Otake
All Dependencies Met

- **Obtaining the Cranial CT Data ✓**
  - Data obtained from The Cancer Imaging Archive (TCIA) is sufficient
- **Access to Mentors ✓**
  - Scheduled and ad hoc meetings have been sufficient
- **Access to Fast Computer ✓**
  - Permission granted by Dr. Armand to use the new BIGSS lab server
Original Deliverables

- **Minimum**
  - Segmentation mask of the skeletal regions in the cranial CT images
  - Deformable registration of each CT image (or mesh) to a chosen template
  - Atlas creation and evaluation
  - Development and evaluation of anatomical extrapolation method

- **Expected**
  - Creation and evaluation of an atlas via a bootstrapping technique
  - Development and evaluation of a patient/donor similarity metric

- **Maximum**
  - Design of a method to use the estimated surface of the patient to assist in surgical planning
  - Create a system architecture for the future use of this system
Minimum Deliverable: Manually Segmented Skulls

- Manual segmentation of template CT with 3D Slicer
- Rely on deformable registration to obtain topologically consistent meshes for other images
Minimum Deliverable: Manually Segmented Skulls

- Use basic thresholding for surface distance computation between original mesh and deformed mesh and label overlap metric

CT Image Source: The Cancer Imaging Archive
Original Deliverables

• **Minimum**
  – Segmentation mask of the skeletal regions in the cranial CT images ✓
  – Deformable registration of each CT image (or mesh) to a chosen template
  – Atlas creation and evaluation
  – Development and evaluation of anatomical extrapolation method

• **Expected**
  – Creation and evaluation of an atlas via a bootstrapping technique
  – Development and evaluation of a patient/donor similarity metric

• **Maximum**
  – Design of a method to use the estimated surface of the patient to assist in surgical planning
  – Create a system architecture for the future use of this system
Minimum Deliverable: Deformable Registration Results

- Deformation fields and deformed meshes

Show in Slideshow mode for Animations

CT Image Source: The Cancer Imaging Archive
Minimum Deliverable: Deformable Registration Results (cont.)

Template

CT Image Source: The Cancer Imaging Archive
Original Deliverables

• **Minimum**
  – Segmentation mask of the skeletal regions in the cranial CT images ✓
  – Deformable registration of each CT image (or mesh) to a chosen template ✓
  – Atlas creation and evaluation
  – Development and evaluation of anatomical extrapolation method

• **Expected**
  – Creation and evaluation of an atlas via a bootstrapping technique
  – Development and evaluation of a patient/donor similarity metric

• **Maximum**
  – Design of a method to use the estimated surface of the patient to assist in surgical planning
  – Create a system architecture for the future use of this system
Minimum Deliverable: Atlas

Mode 1
mean +0.00 std. dev.

Mode 2
mean +0.00 std. dev.

Mode 3
mean +0.00 std. dev.

Show in Slideshow mode for Animations

CT Image Source: The Cancer Imaging Archive
Minimum Deliverable: Atlas (cont.)

- Leave one out surface distance computed using deformed meshes
Minimum Deliverable: Atlas (cont.)

- Should also compute surface distance using a mesh derived from manual segmentation (mode matching via PA5)

95% of variance explained by 18 modes

Expect Monotonically Decreasing Residuals

Sub-voxel?
Original Deliverables

• **Minimum**
  – Segmentation mask of the skeletal regions in the cranial CT images ✓
  – Deformable registration of each CT image (or mesh) to a chosen template ✓
  – Atlas creation and evaluation *(near completion)*
  – Development and evaluation of anatomical extrapolation method

• **Expected**
  – Creation and evaluation of an atlas via a bootstrapping technique
  – Development and evaluation of a patient/donor similarity metric

• **Maximum**
  – Design of a method to use the estimated surface of the patient to assist in surgical planning
  – Create a system architecture for the future use of this system
Slightly Updated Deliverables

- **Minimum**
  - Segmentation mask of the skeletal regions in the cranial CT images ✓
  - Deformable registration of each CT image (or mesh) to a chosen template ✓
  - Atlas creation and evaluation (*near completion*)
  - Development and evaluation of anatomical extrapolation method

- **Expected**
  - Creation and evaluation of an atlas via a bootstrapping technique
  - Development and evaluation of a patient/donor similarity metric
  - Development of a realistic patient “disfigurement”

- **Maximum**
  - Design of a method to use the estimated surface of the patient to assist in surgical planning
  - Create a system architecture for the future use of this system
Updated Task Schedule

Obtain Initial Data
Obtain Additional Data
Choose Patient Image
Research Def. Reg. For Atlas
Manual Image Seg.
Seminar Presentation
Choose Atlas Template Image
Perform Def. Reg. For Atlas
Initial PCA on Meshes
Evaluate Atlas
Develop Extrapolation
Evaluate Extrapolation
Bootstrapped Atlas Development
Develop realistic patient disfigurement
Research and Design Surgical Planning
Design Future System Architecture
Final Report, Poster

- 2/09
- 2/16
- 2/23
- 3/02
- 3/09
- 3/16
- 3/23
- 3/30
- 4/06
- 4/13
- 4/20
- 4/27
- 5/04
- 5/09

Min. Deliverable, Segmentation Achieved 3/16
Min. Deliverable, Deformable Registration for Atlas Achieved 3/10
Min. Deliverable, Initial Atlas Expected 3/31
Min. Deliverable, Extrapolation Expected 4/20
Exp. Deliverable, Realistic Disfigurement Method Expected 4/13
Exp. Deliverable, Surgical Planning Expected 5/1
Max. Deliverable, Future System Arch. Expected 5/5
Poster Session

Achieved 3/10

Expected 4/20
Summary:
About one week behind schedule, maximum deliverables at risk with any additional slips
Questions?
Minimum Deliverable: Manually Segmented Skulls

- Preliminary steps:
  - Resampling to isotropic voxels (2 mm)
  - Cropping of each CT to a uniform ROI

CT Image Source: The Cancer Imaging Archive
Manual Inspection of Registration Results (Example 1)

Registration Usable

CT Image Source: The Cancer Imaging Archive
Manual Inspection of Registration Results  (Example 2)

CT Image Source: The Cancer Imaging Archive

Registration Failed
“Realistic Disfigurement” Work in Progress

- Additive Gaussian Noise to vertex coordinates in specific region

CT Image Source: The Cancer Imaging Archive

Courtesy of Dr. Chad Gordon