Extrapolation of Missing Craniofacial Skeletal Structure via Statistical Shape Models
Project #1 Mini-Checkpoint Presentation
EN.600.646 Spring 2014

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CT Image Source: The Cancer Imaging Archive
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.

CT Image Source: The Cancer Imaging Archive
Project Relevance: Face Transplant Surgery

- Restore lost functionality
- Restore appearance

Courtesy of Dr. Chad Gordon
Project Relevance: Face Transplant Surgery (cont.)

Courtesy of Dr. Chad Gordon
Extrapolation Overview

Deformed Patient ➔ Deformable Surface Registration ➔ Atlas ➔ Estimated Structure

Structure Replacement and Smoothness Restoration ➔ Estimated Structure

CT Image Source: The Cancer Imaging Archive
Deliverable Status From Last Checkpoint

• **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 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
Minimum Deliverables: Segmentation, Deformable Registration

Show in Slideshow mode for Animations

CT Image Source: The Cancer Imaging Archive
Principle Component Analysis Skin Modes

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
Leave-One-Out Skin Atlas Analysis

Mean Surface Distance Between Subject and Projected Subject vs Number of Modes Used

Max Surface Distance Between Subject and Projected Subject vs Number of Modes Used

Mean Vertex Distance Between Subject and Projected Subject vs Number of Modes Used

Cumulative Variance Explained vs Number of Modes Used
Leave-One-Out Skin Surface Distances By Modes Used
Deliverable Status From Last Checkpoint

- **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 (*Skin complete*) ✓
  - Development and evaluation of anatomical extrapolation method

- **Expected**
  - Creation and evaluation of an atlas via a bootstrapping technique
  - 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
Leave-One-Out Extrapolation Basic Test

- Out of 26 meshes choose one to leave out
- Apply “disfiguration” to left-out mesh
Deliverable Status From Last Checkpoint

• **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 (*Skin complete*) ✔
  – Development and evaluation of anatomical extrapolation method

• **Expected**
  – Creation and evaluation of an atlas via a bootstrapping technique
  – 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
• Apply random rigid transformation to disfigured, left-out, mesh
Leave-One-Out Extrapolation Basic Test (cont.)

- Create an atlas with the remaining 25 complete meshes
- Perform patient-to-atlas registration

CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00
Leave-One-Out Extrapolation Basic Test (cont.)

• Surface distance of registered atlas instance and the true surface
Leave-One-Out Extrapolation Basic Test (cont.)

- Replace the “disfigured” vertices in the patient mesh with the estimates from the atlas
Leave-One-Out Extrapolation Basic Test (cont.)

CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00
Leave-One-Out Extrapolation Basic Test (cont.)

- Surface distance of extrapolated surface and the true surface
Deliverable Status From Last Checkpoint

- **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 (*Skin complete*) ✓
  - Development and evaluation of anatomical extrapolation method (*In Progress*)

- **Expected**
  - Creation and evaluation of an atlas via a bootstrapping technique (*In Progress*) ✓
  - 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
Test Patient Head Surface

CT Courtesy of Dr. Chad Gordon
Pruning of “Non-Original” Bone

CT Courtesy of Dr. Chad Gordon
Patient-to-Atlas Registration

“Pruned” Patient Mesh

Full Skull Atlas (26 Patients)

Atlas Estimate

CT Courtesy of Dr. Chad Gordon and TCIA
Atlas Estimate Deviation From Current Patient

CT Courtesy of Dr. Chad Gordon and TCIA
Updated Task Schedule From Last Checkpoint

- **Obtain Initial Data**
  - 2/09

- **Obtain Additional Data**
  - 2/16

- **Choose Patient Image**
  - 2/23

- **Research Def. Reg. For Atlas**
  - 3/02

- **Manual Image Seg.**
  - 3/09
  - Min. Deliverable, Segmentation *Achieved 3/16*

- **Seminar Presentation**
  - 3/16

- **Choose Atlas Template Image**
  - 3/23

- **Perform Def. Reg. For Atlas**
  - 3/30

- **Initial PCA on Meshes**
  - 4/06

- **Perform Def. Sur. Reg. to Atlas**
  - 4/13

- **Evaluate Atlas**
  - 4/20

- **Develop Extrapolation**
  - 4/27

- **Evaluate Extrapolation**
  - 5/04

- **Bootstrapped Atlas Development**
  - 5/09

- **Develop realistic patient disfigurement**
  - *Expected 4/13*

- **Research and Design Surgical Planning**
  - *Expected 4/13*

- **Design Future System Architecture**
  - *Expected 4/13*

- **Final Report, Poster**
  - *Expected 4/13*

- **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 4/20*

- **Exp. Deliverable, Surgical Planning**
  - *Expected 5/1*

- **Exp. Deliverable, Bootstrapped Atlas**
  - *Expected 5/1*

- **Max. Deliverable, Future System Arch.**
  - *Expected 5/5*

- **Poster Session**
  - *Expected 5/5*
Newly Updated Task Schedule


- Obtain Initial Data
- Obtain Additional Data
- Choose Patient Image
- Research Def. Reg. For Atlas
- Seminar Presentation
- Choose Atlas Template Image
- Perform Def. Reg. For Atlas
- Perform Def. Sur. Reg. to Atlas
- Evaluate Atlas
- Perform Def. Sur. Reg. to Atlas
- Evaluate Extrapolation
- Develop Extrapolation
- Bootstrapped Atlas Development
- Research and Design Surgical Planning
- Design Future System Architecture
- Final Report, Poster

Min. Deliverable, Segmentation Achieved 3/16
Min. Deliverable, Deformable Registration for Atlas Achieved 3/10
Bone Expected 4/28
Skin Achieved 4/06
Min. Deliverable, Initial Atlas

Expected 5/1 Exp. Deliverable, Bootstrapped Atlas
Basic Capability Achieved 4/13
Exp. Deliverable, Realistic Disfigurement Method

Expected 5/4 Min. Deliverable, Extrapolation

Will not complete this semester Max. Deliverable, Surgical Planning
Will not complete this semester Max. Del., Future System Arch.

Poster Session
Newly Updated Task Schedule

Summary:
• Falling behind, as Atlas evaluation and updates have taken significant time
• Maximum Deliverables abandoned for this semester
Questions?