Extrapolation of Missing Craniofacial Skeletal Structure via Statistical Shape Models

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Courtesy of Dr. Otake
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. Otake
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 Discontinuity Removal

Cadaver CT Courtesy of Dr. Otake
Extrapolation Overview (cont.)

Deformed Patient → Deformable Surface Registration → Atlas → Estimated Structure

Utilize CIS I PA5

Structure Replacement and Discontinuity Removal

Cadaver CT Courtesy of Dr. Otake
Extrapolation Overview (cont.)

Atlas Creation Derived From Prior Art

Cadaver CT Courtesy of Dr. Otake

Extrapolation Overview (cont.)

Deformed Patient → Deformable Surface Registration → Atlas → Estimated Structure → Structure Replacement and Discontinuity Removal

*Thin Plate Spline Extrapolation of Displacement Vectors Between Patient and Estimate*

Cadaver CT Courtesy of Dr. Otake
Prior Work From Forensics Community

Source: Senck, Sascha, et al., Virtual Reconstruction of Very Large Skull Defects Featuring Partly and Completely Missing Midsagittal Planes

Additional Work

• Development of a method to incorporate this structure estimation into surgical planning
  – Integration into APL Face Surgery?
• Design of a future system architecture
  – For example, enabling the automatic identification of a potential donor

Intra-operative strategy
• Navigation with optical tracker performed concurrently on both donor and recipient
• Hard tissue navigation involving tracking guides and lines of osteotomy
• Soft tissue navigation via mapping vessels and nerves
• 3D visualization of the surgical progress
• Intra-operative plan updates and biomechanical assessment during the surgery

Figures Courtesy of Ryan Murphy, JHU APL
Initial Set of Six Cadaver Heads

20120808 Female  Center slice  20120815 Female  20120813 Female

20120808 Male  DRR(AP)  20130607 Male  20130607 Male

Cadaver CT Courtesy of Dr. Otake
• **Disclaimer:** 2 minute segmentation & model
  - Simple threshold, connected components, Marching Cubes

Data Source: https://wiki.cancerimagingarchive.net/display/Public/Head-Neck+Cetuximab
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
Dependencies

• **Obtaining the Cranial CT Data**
  – We have an initial set of 6 cadaver head CT images from Dr. Otake
  – The Cancer Imaging Archive (TCIA) has two datasets with head CT images of 77 and 91 patients, respectively; the data is freely available with no usage restrictions
  – If TCIA data is insufficient, then we can request additional data from Dr. Armand, however it may require IRB approval.
  – If neither of these plans work, then the fallback would be to use existing pelvis CT data.

• **Access to Mentors**
  – A recurring weekly meeting with Dr. Otake has been scheduled
  – Schedule meetings with Dr. Taylor, Dr. Armand, and Ryan Murphy as needed

• **Access to Fast Computer**
  – Ask Dr. Armand for permission to use the new BIGSS lab computer
  – Fallback is to use personal computers
Management Plan: Basics

- Program Manager: Robert Grupp
- Two Weekly Recurring Team Meetings
  - More as needed
- Weekly Recurring Meeting Scheduled with Dr. Otake
  - Meetings with Dr. Taylor, Dr. Armand, and Ryan Murphy as needed
- Source Code and Document Control via LCSR Git Lab
Management Plan: Key Milestones

- **March 2**: All data obtained and pre-processed as needed
- **March 10**: Manual segmentation of all images complete
- **March 12**: Deformable registration for atlas creation complete
- **March 21**: Initial atlas created and evaluated
- **April 2**: Extrapolation algorithm complete and evaluated
  - *Minimum deliverables achieved*
- **April 13**: Bootstrapped atlas created and evaluated
  - *Expected deliverables achieved*
- **April 13**: Compatibility metric between donor and patient complete
  - *Expected deliverables achieved*
- **April 25**: Surgical planning tool design complete
- **May 1**: Future system architecture complete
  - *Maximum deliverables achieved*
- **May 9**: Poster session
Reading List

• Craniofacial Surgery Background
Reading List (cont.)

• **Atlas Creation**
  
  
  
  
  
• **Deformable Registration (for Atlas Creation)**

• **Surface Interpolation**

• **Forensic Anthropology**
Questions?
Face Transplant Surgery, March 2012

Source: University of Maryland Medical Center (https://umm.edu/programs/face-transplant/media-resources)
Face Transplant Surgery, March 2012 (cont.)

Source: University of Maryland Medical Center (https://umm.edu/programs/face-transplant/media-resources)