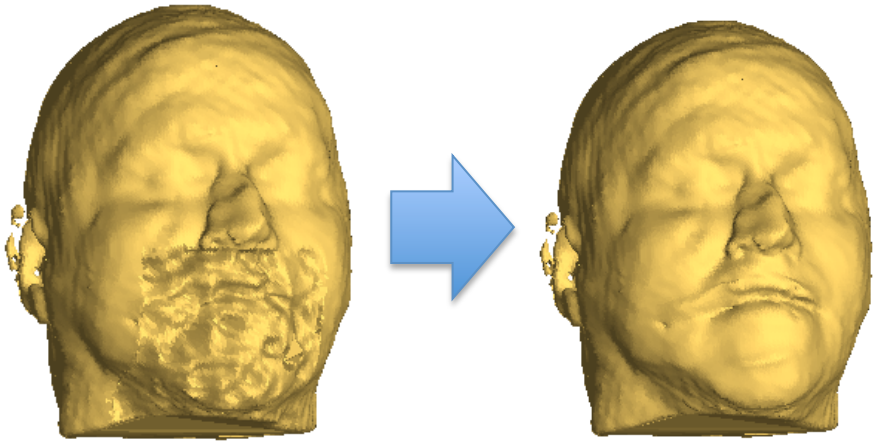
Extrapolation of Missing Craniofacial Skeletal Structure via Statistical Shape Models

Project #1 Mini-Checkpoint Presentation

EN.600.646 Spring 2014



CT Image Source: The Cancer Imaging Archive

Robert Grupp

Hsin-Hong Chiang

Dr. Yoshito Otake (Mentor)

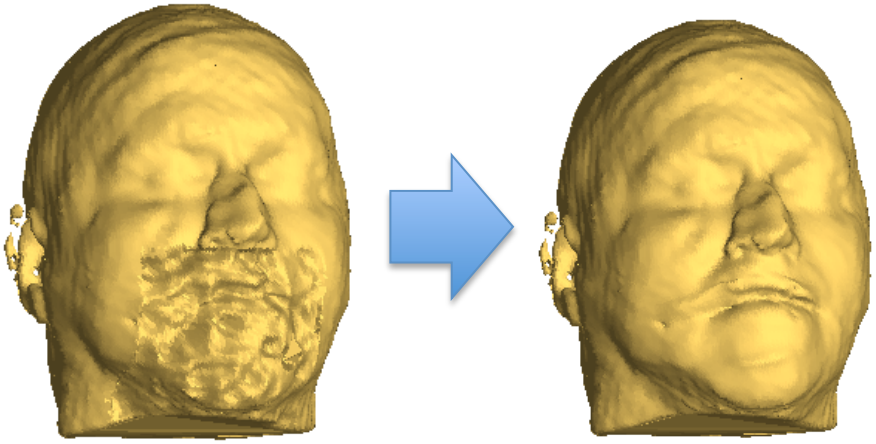
Ryan Murphy (Mentor)

Dr. Russell Taylor (Mentor)

Dr. Mehran Armand (Mentor)

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.

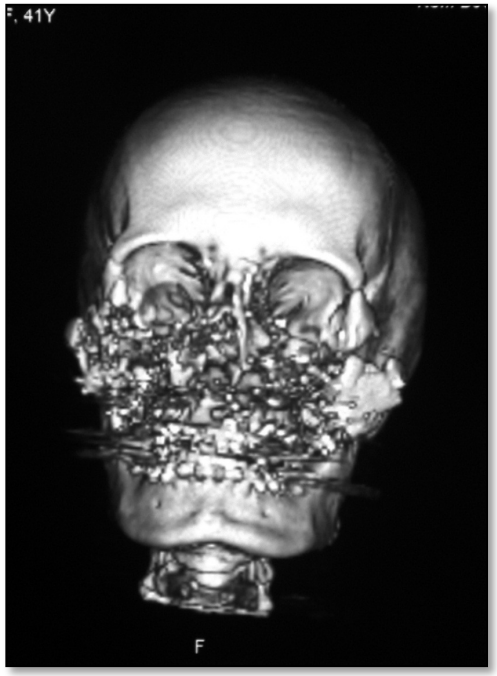


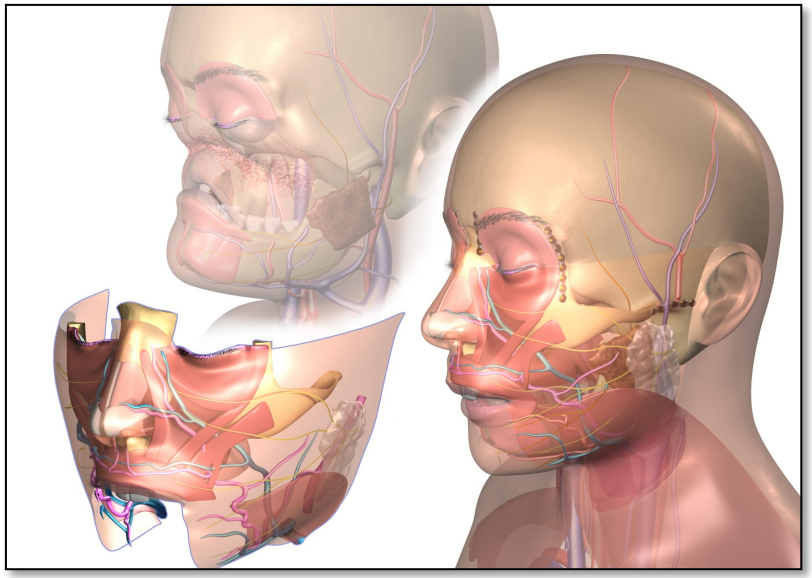
CT Image Source: The Cancer Imaging Archive

Project Relevance: Face Transplant Surgery

- Restore lost functionality
- Restore appearance

Courtesy of Dr. Chad Gordon

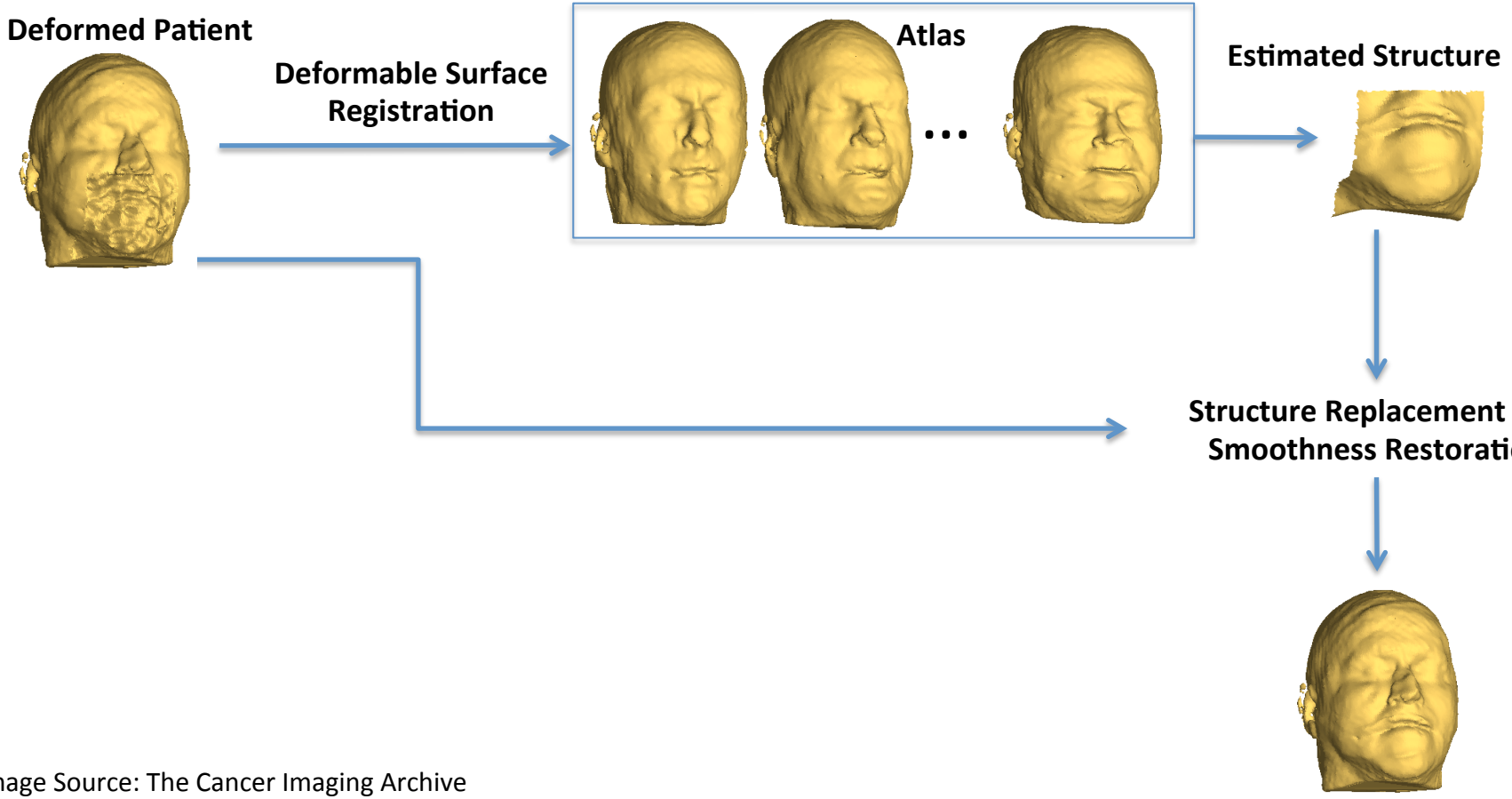




Project Relevance: Face Transplant Surgery (cont.)

Courtesy of Dr. Chad Gordon

Extrapolation Overview

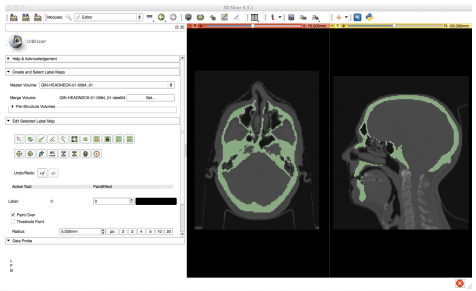


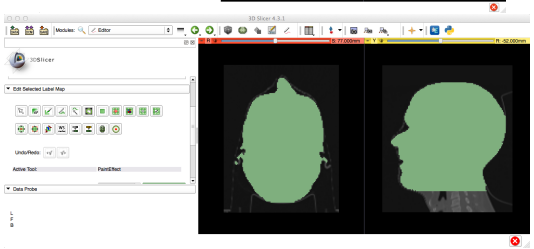
CT Image Source: The Cancer Imaging Archive

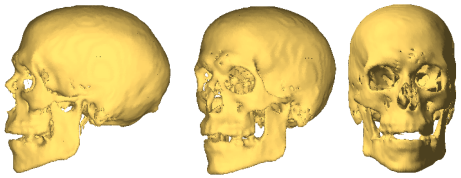
Deliverable Status From Last Checkpoint

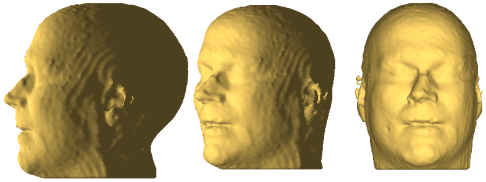
- **Minimum**
  - Segmentation mask of the skeletal regions in the cranial CT images ✓
  - Deformable registration of each CT image (or mesh) to a chosen template ✓
  - Atlas creation and evaluation (*near completion*)
  - Development and evaluation of anatomical extrapolation method
- **Expected**
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

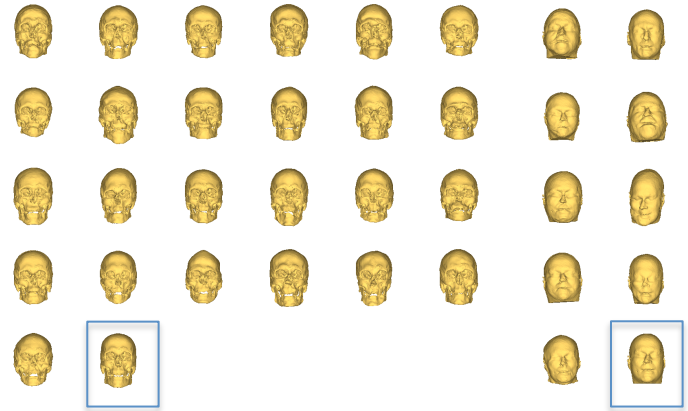
Minimum Deliverables: Segmentation, Deformable Registration

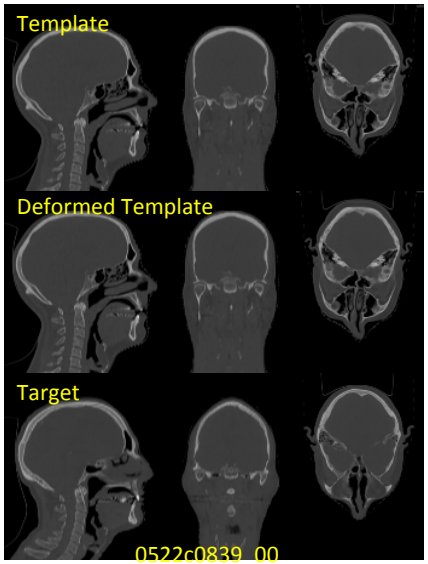


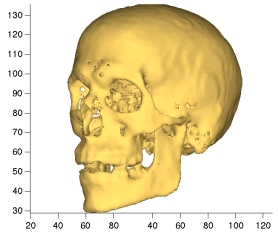


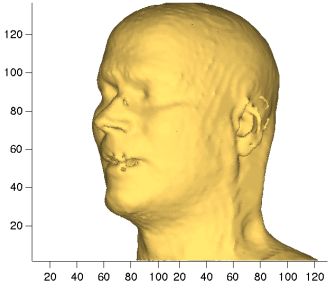








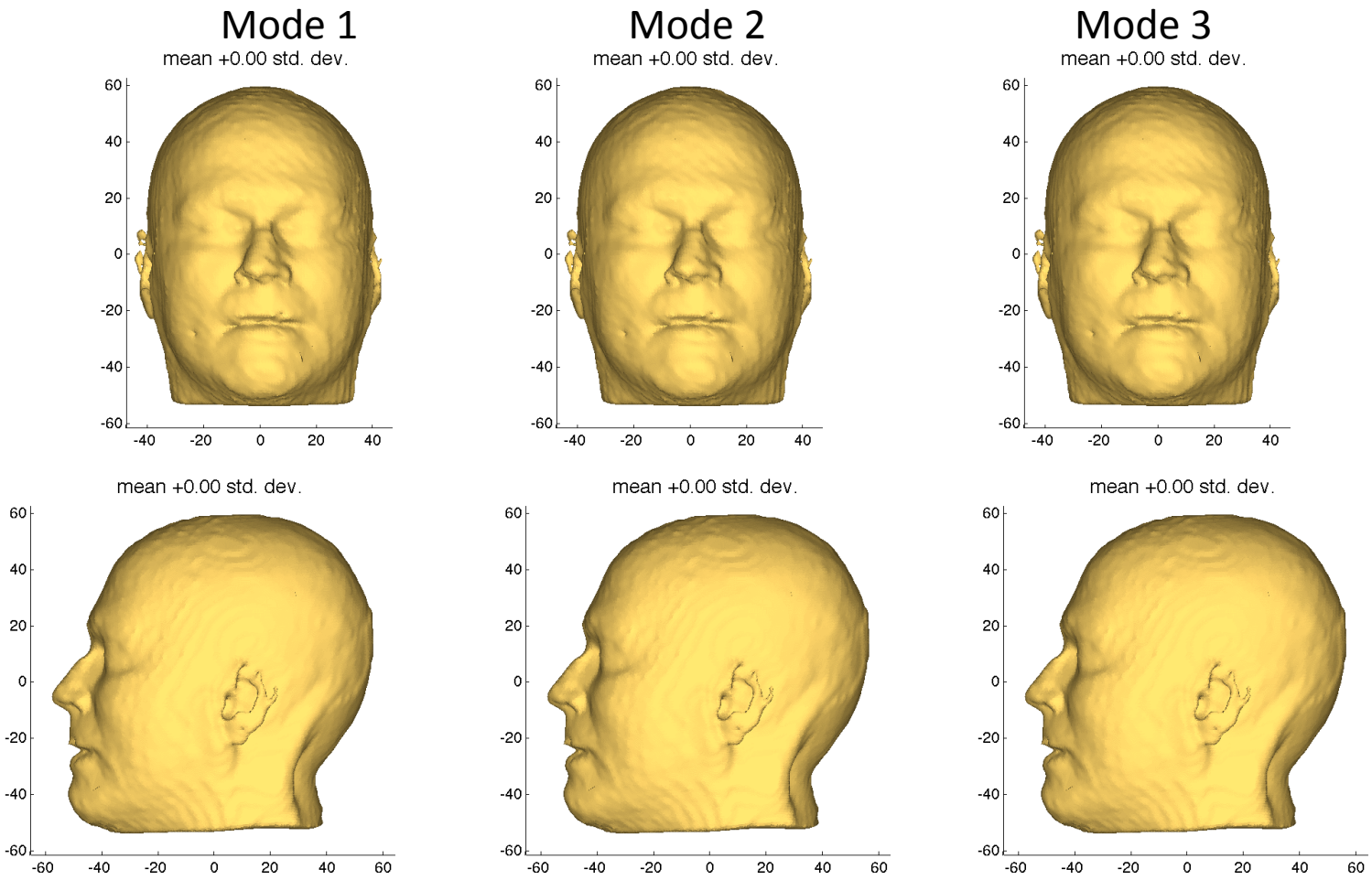




Show in Slideshow mode for Animations

CT Image Source: The Cancer Imaging Archive

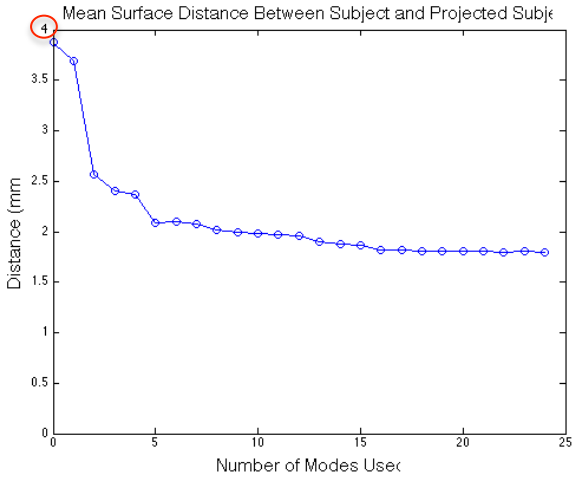
Principle Component Analysis Skin Modes

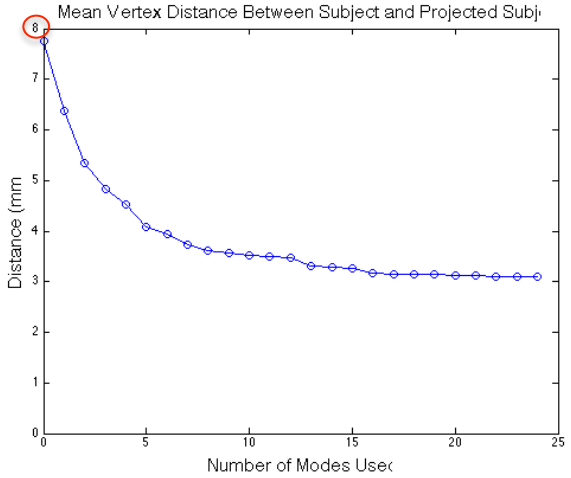


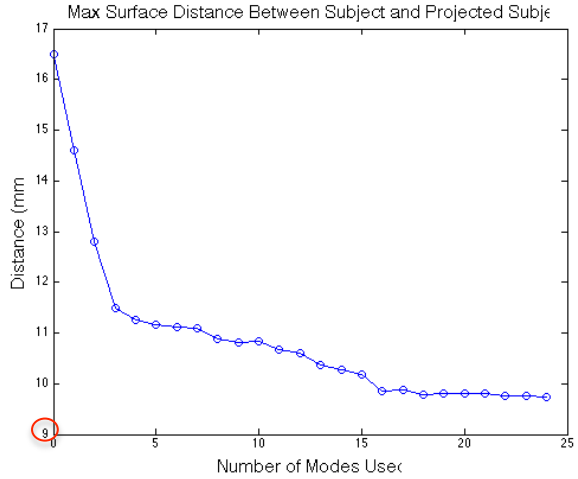
Show in Slideshow mode for Animations

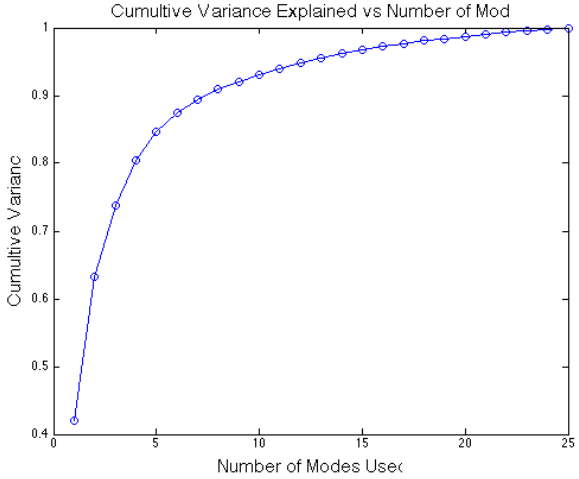
CT Image Source: The Cancer Imaging Archive

Leave-One-Out Skin Atlas Analysis

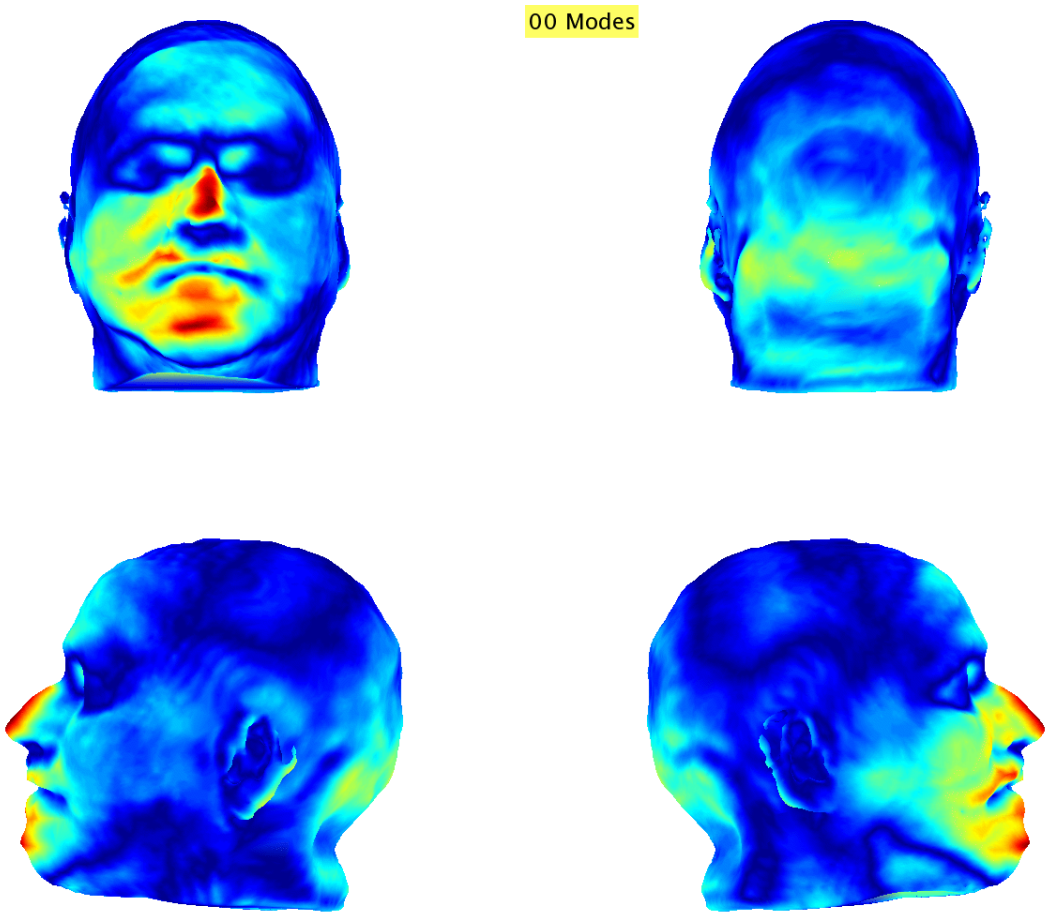








Leave-One-Out Skin Surface Distances By Modes Used



Show in Slideshow mode for Animations

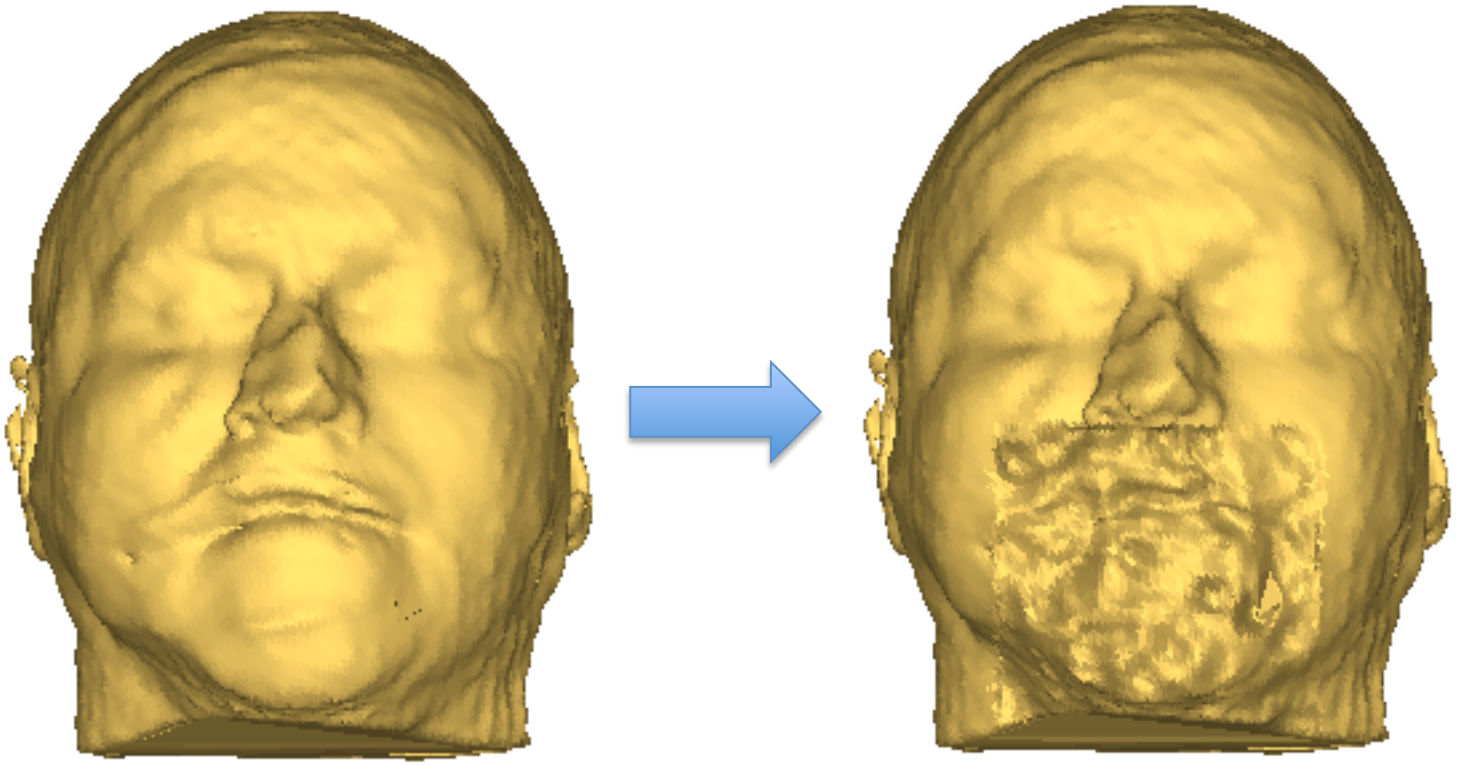
CT Image Source: The Cancer Imaging Archive

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 (*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



CT Image Source: The Cancer Imaging Archive

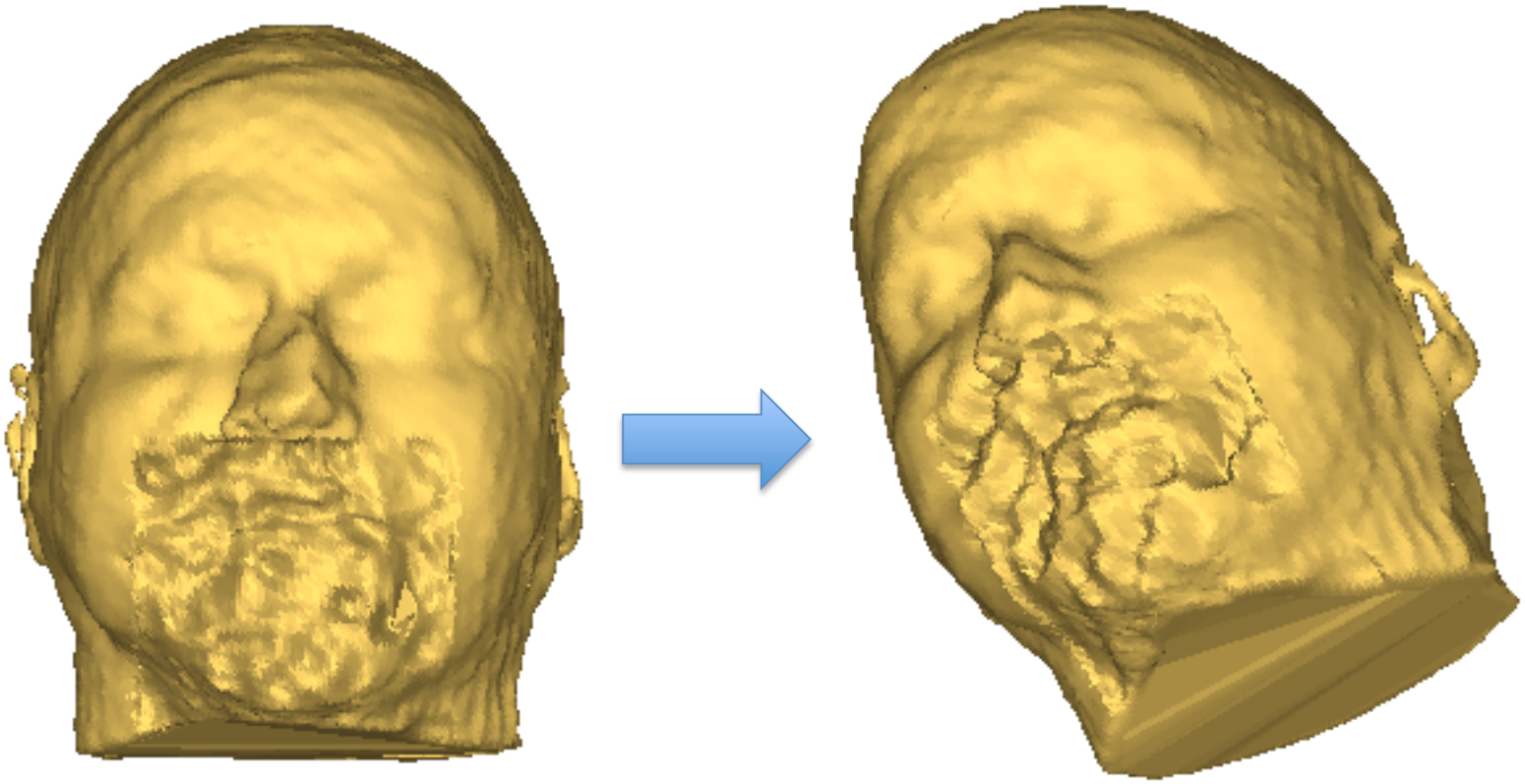
Patient ID: 0522c0009_00

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 (cont.)

- Apply random rigid transformation to disfigured, left-out, mesh

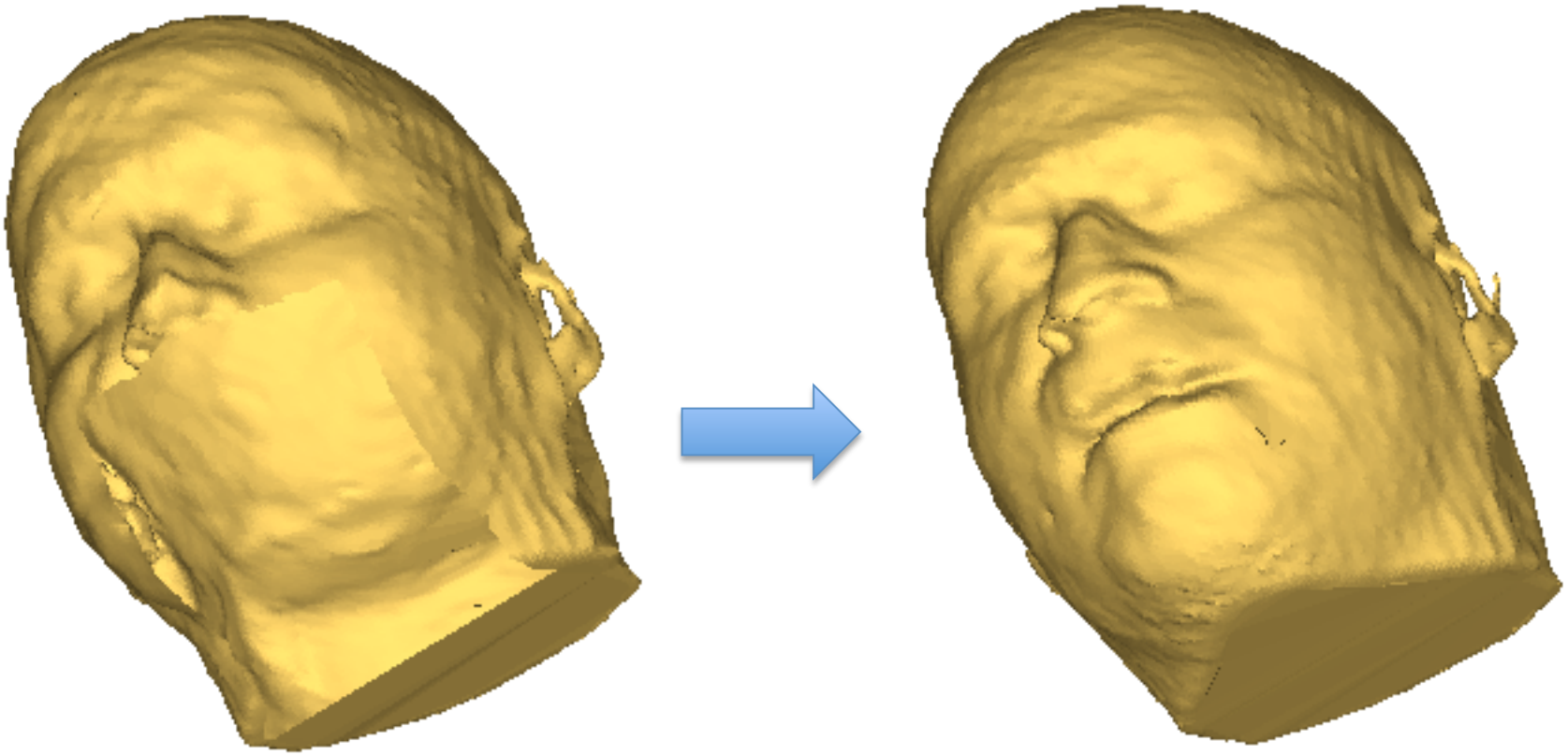


CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00

Leave-One-Out Extrapolation Basic Test (cont.)

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

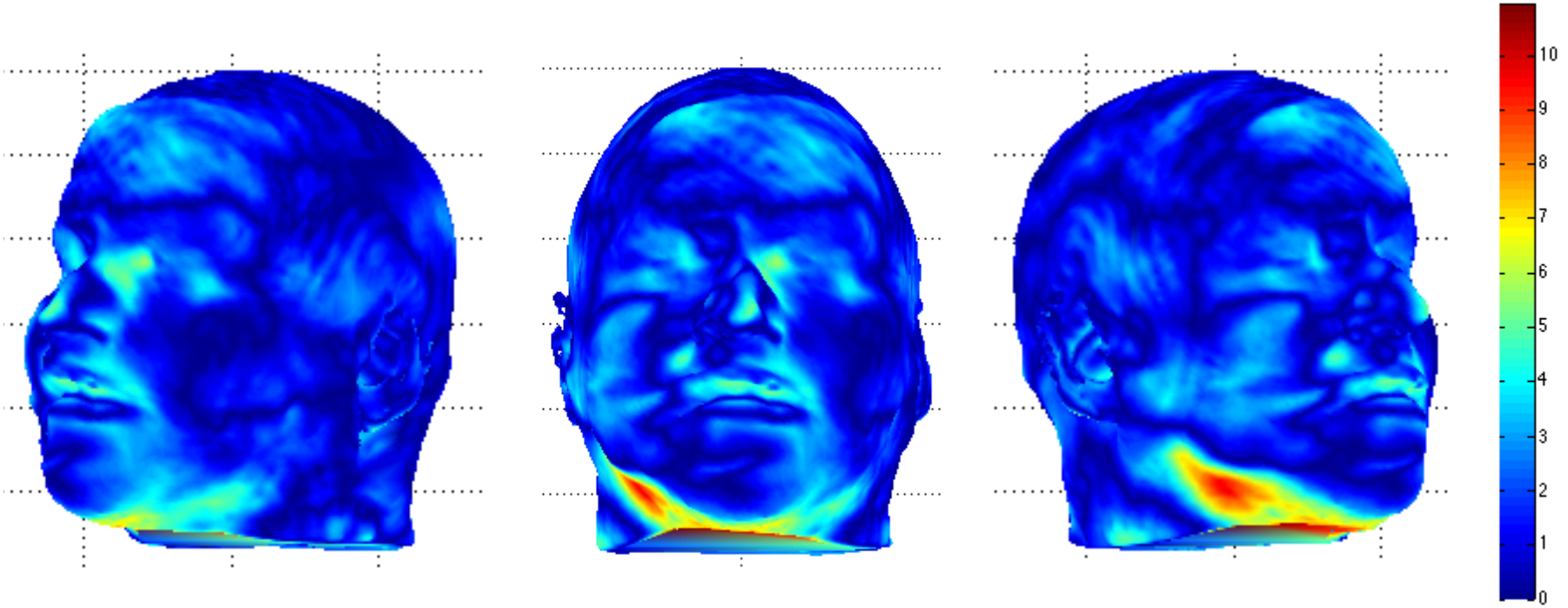


CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00

Leave-One-Out Extrapolation Basic Test (cont.)

- Surface distance of registered atlas instance and the true surface

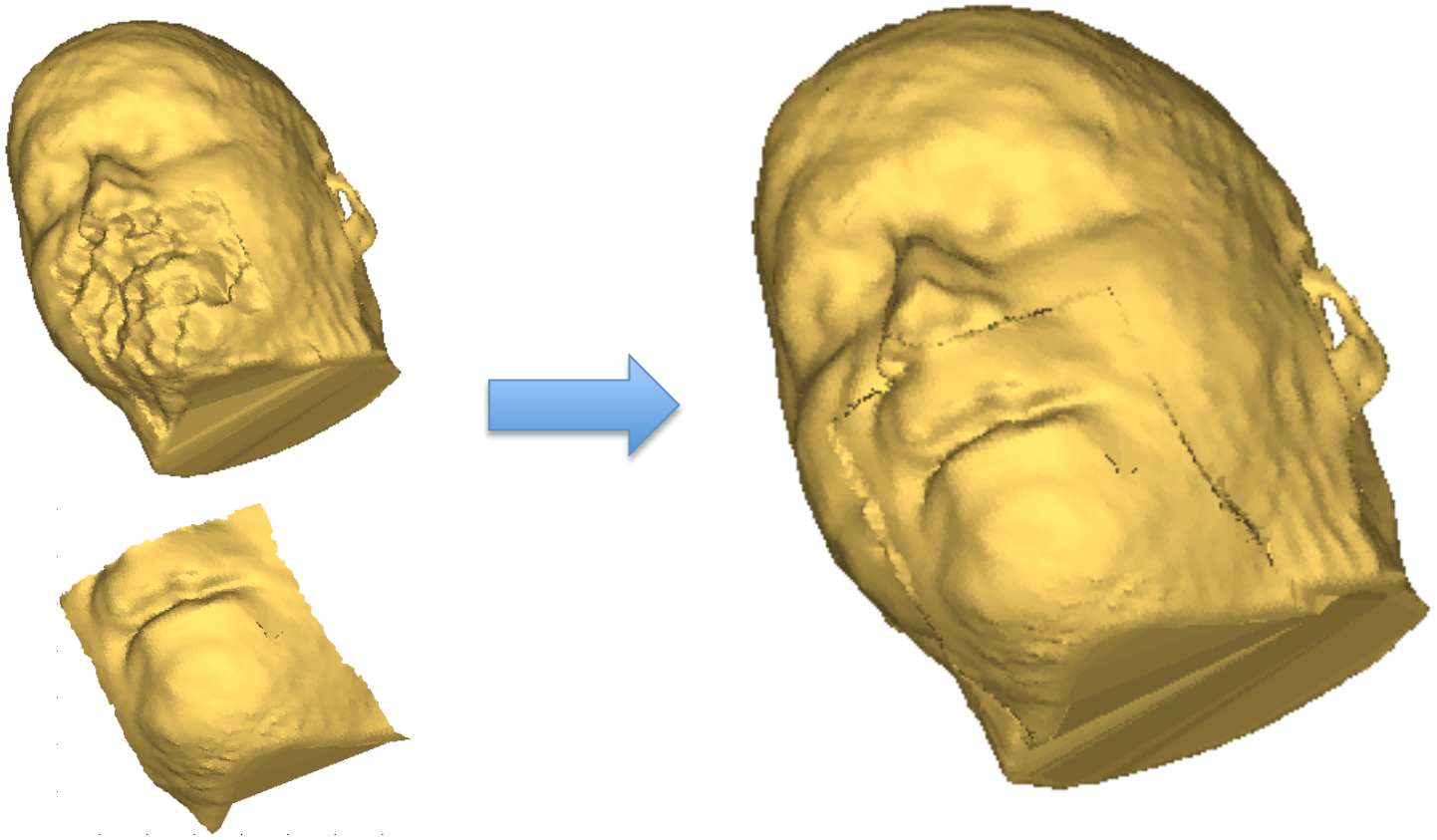


CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00

Leave-One-Out Extrapolation Basic Test (cont.)

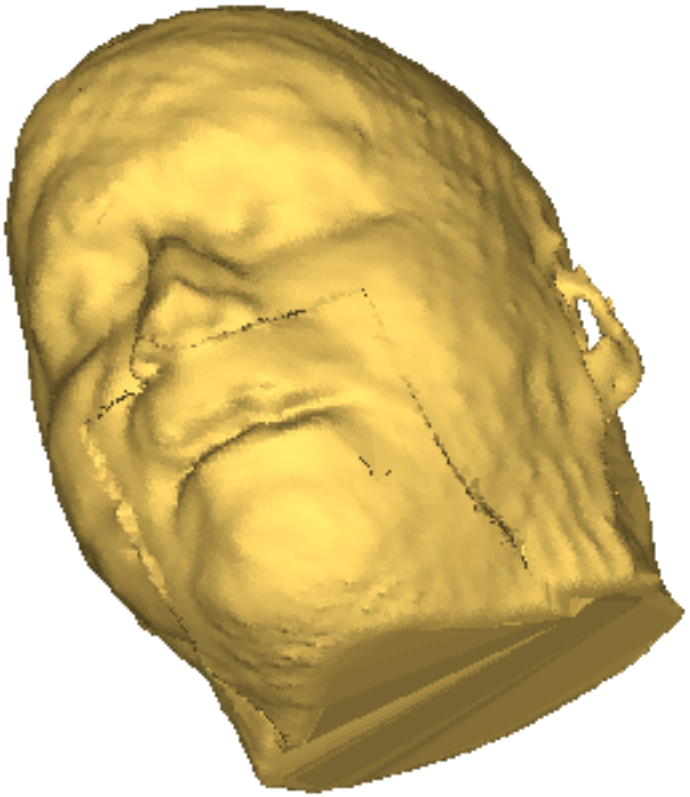
- Replace the “disfigured” vertices in the patient mesh with the estimates from the atlas

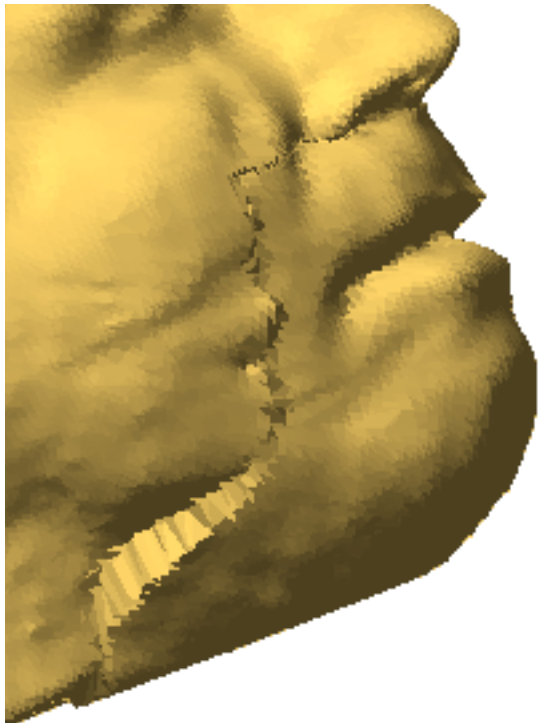


CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00

Leave-One-Out Extrapolation Basic Test (cont.)



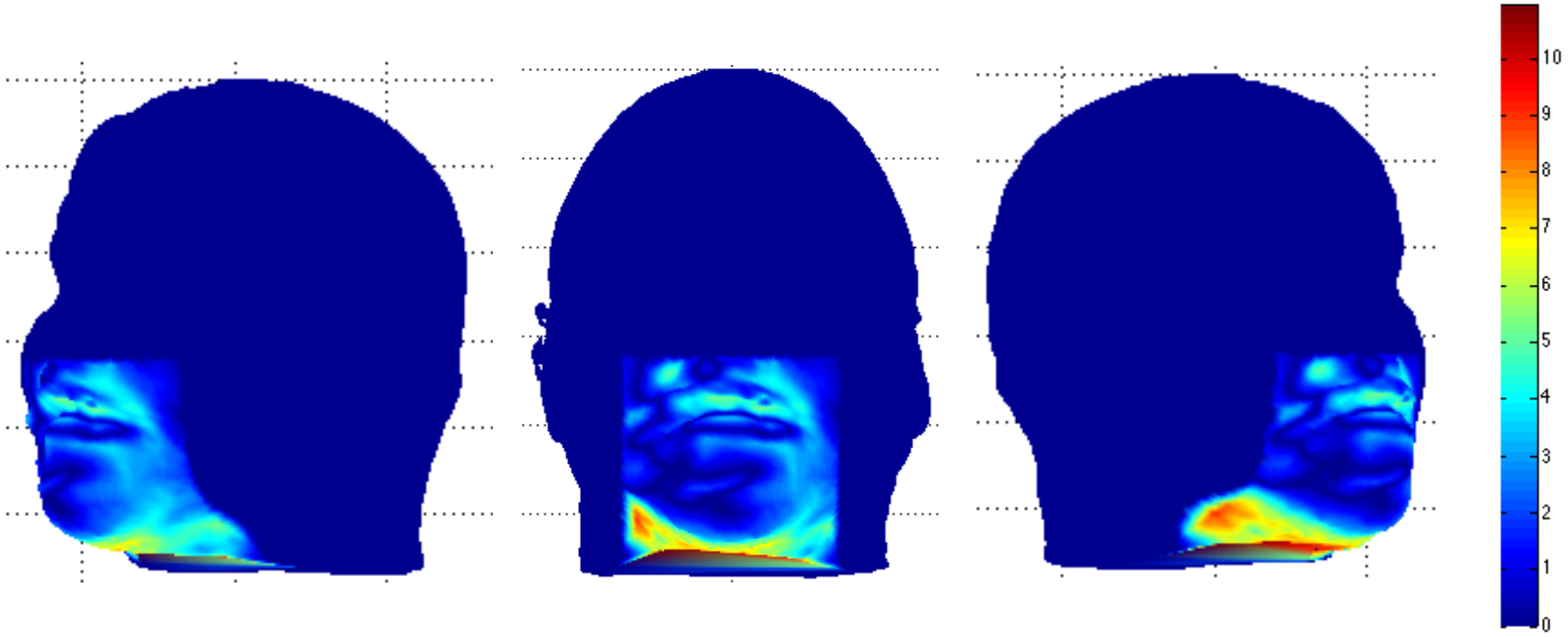


CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00

Leave-One-Out Extrapolation Basic Test (cont.)

- Surface distance of extrapolated surface and the true surface



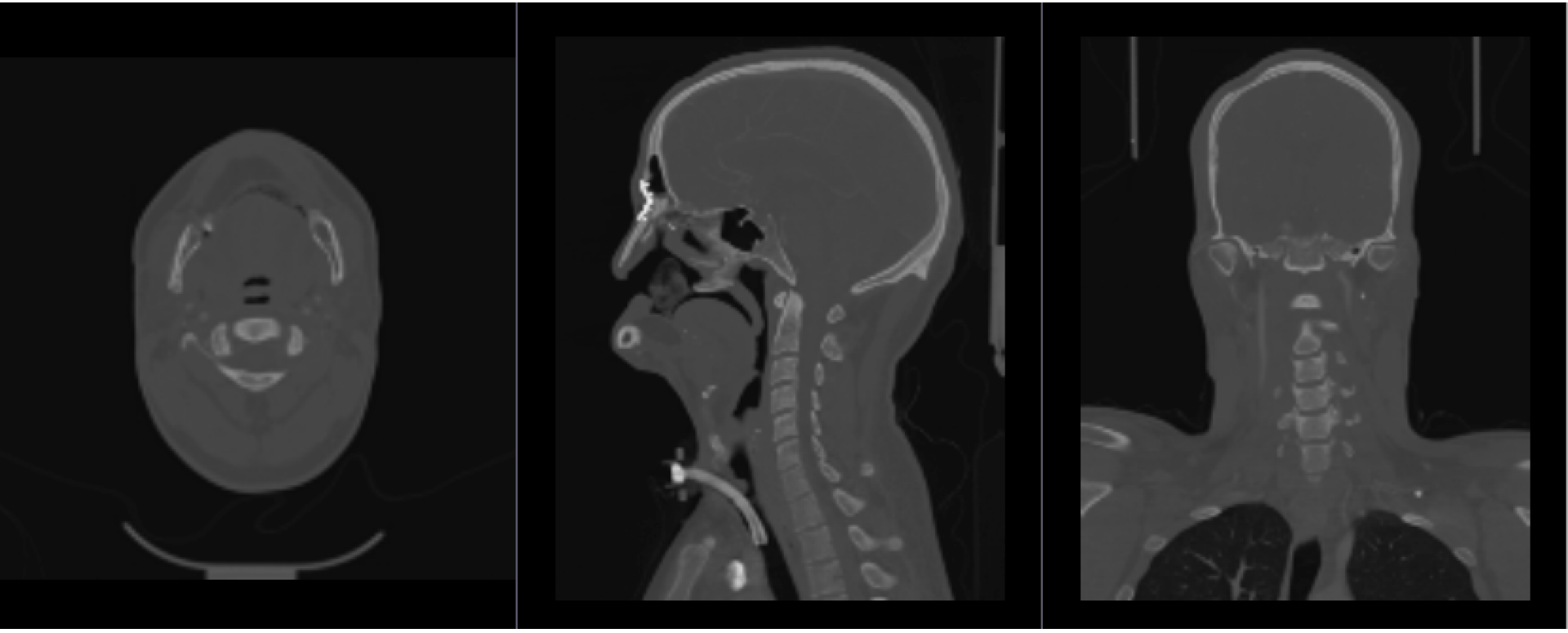
CT Image Source: The Cancer Imaging Archive

Patient ID: 0522c0009_00

Deliverable Status From Last Checkpoint

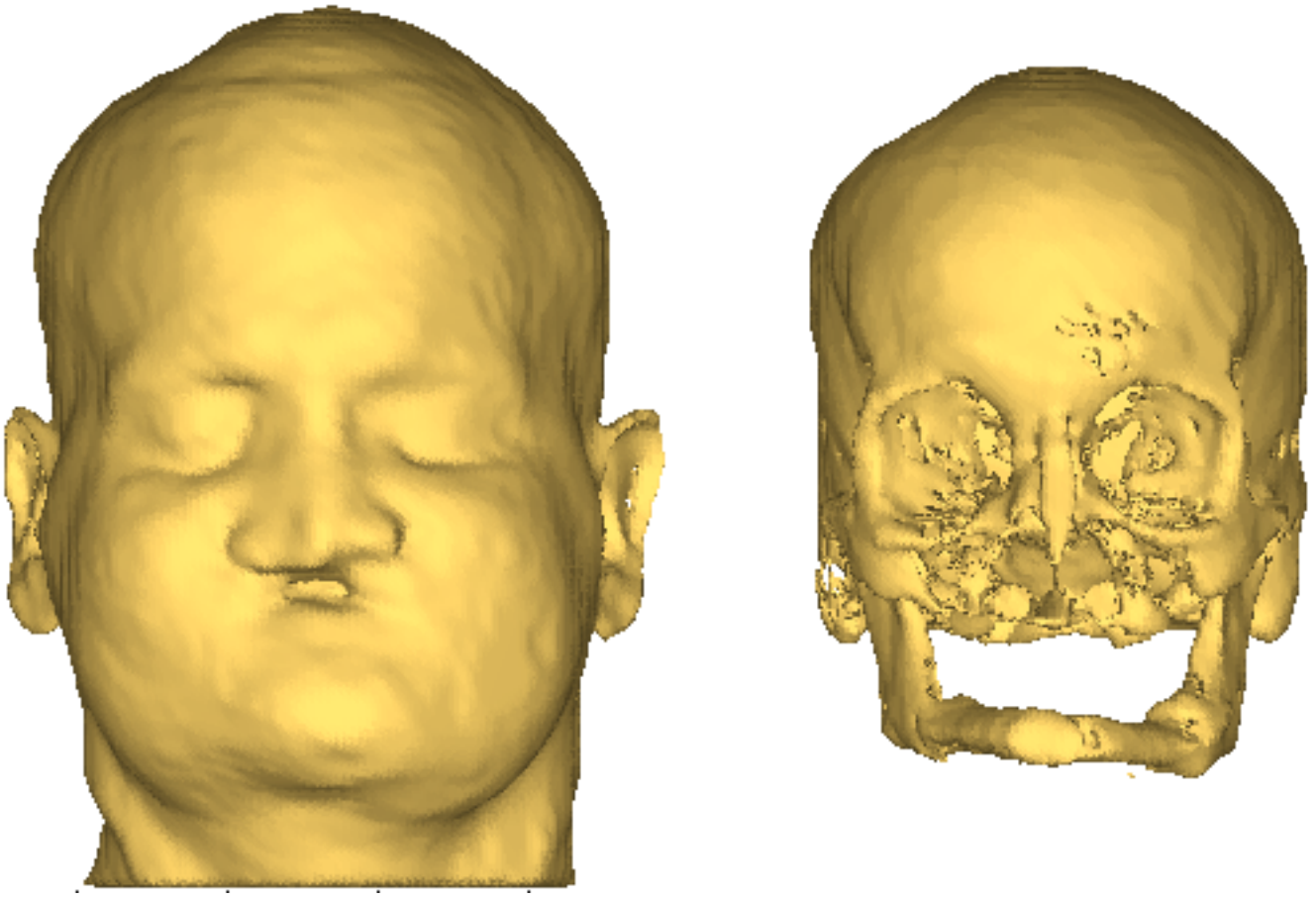
- **Minimum**
  - Segmentation mask of the skeletal regions in the cranial CT images ✓
  - Deformable registration of each CT image (or mesh) to a chosen template ✓
  - Atlas creation and evaluation (*Skin complete*) ✓
  - Development and evaluation of anatomical extrapolation method (*In Progress*)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



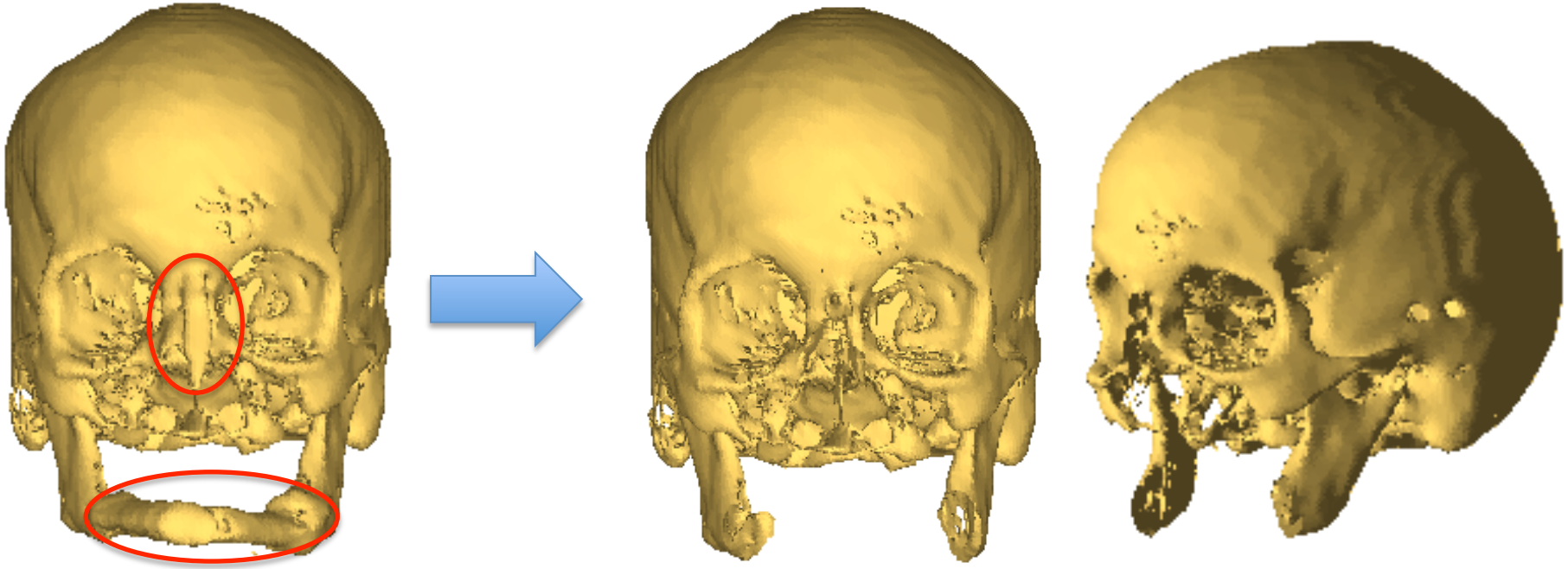
CT Courtesy of Dr. Chad Gordon

Test Patient Head Surface



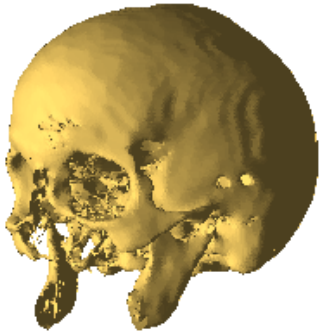
CT Courtesy of Dr. Chad Gordon

Pruning of “Non-Original” Bone

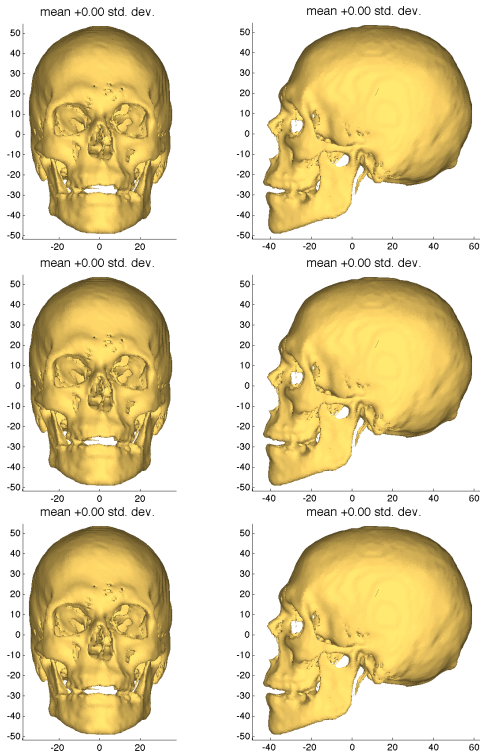


CT Courtesy of Dr. Chad Gordon

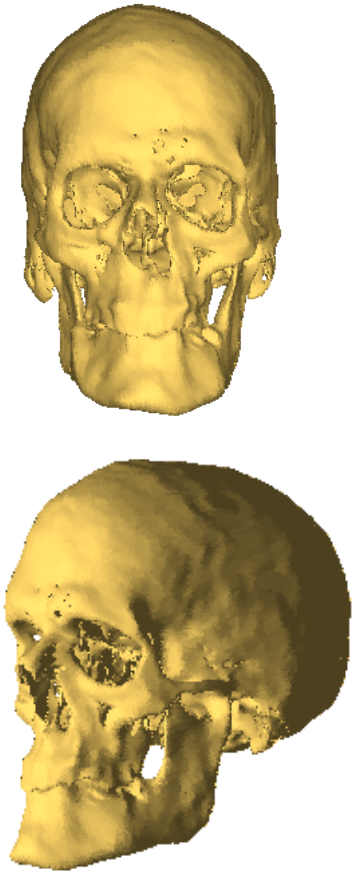
Patient-to-Atlas Registration



"Pruned" Patient Mesh



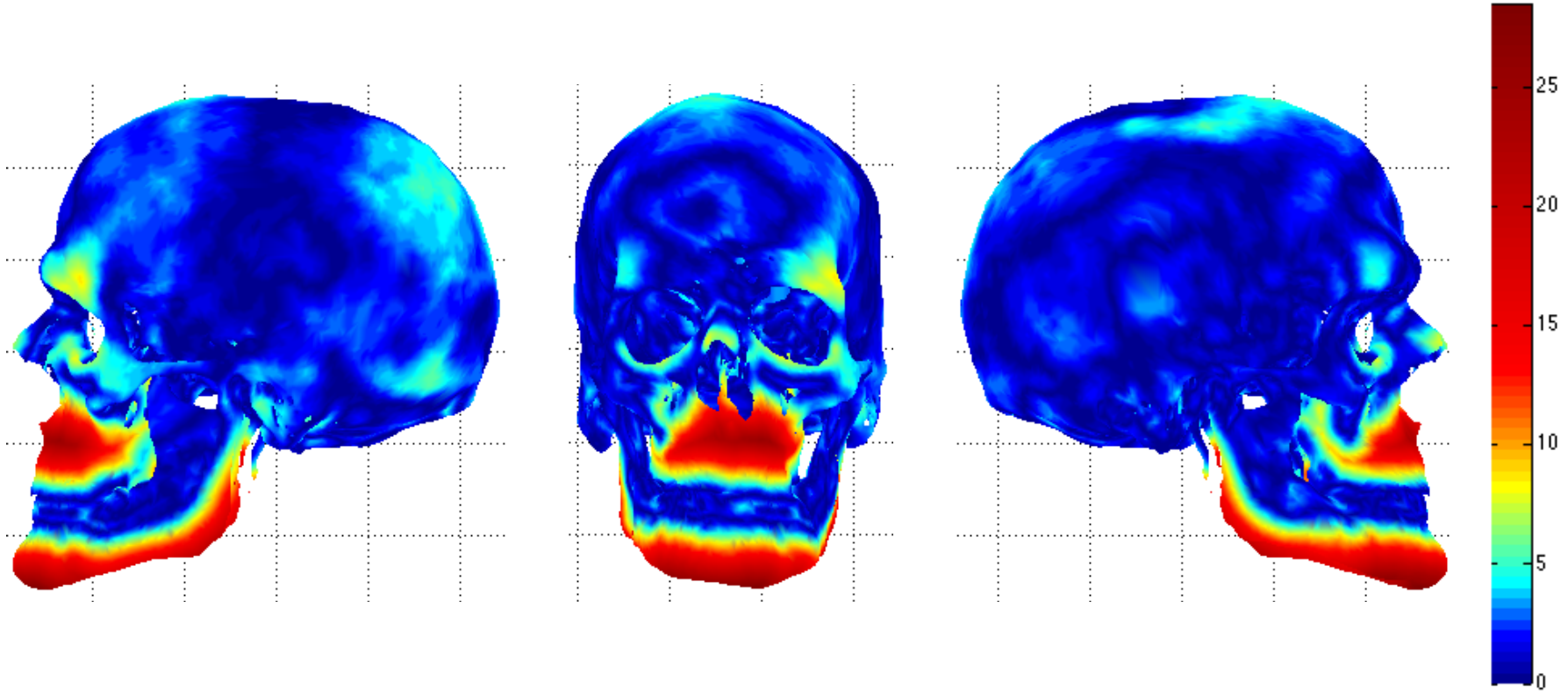
Full Skull Atlas (26 Patients)



Atlas Estimate

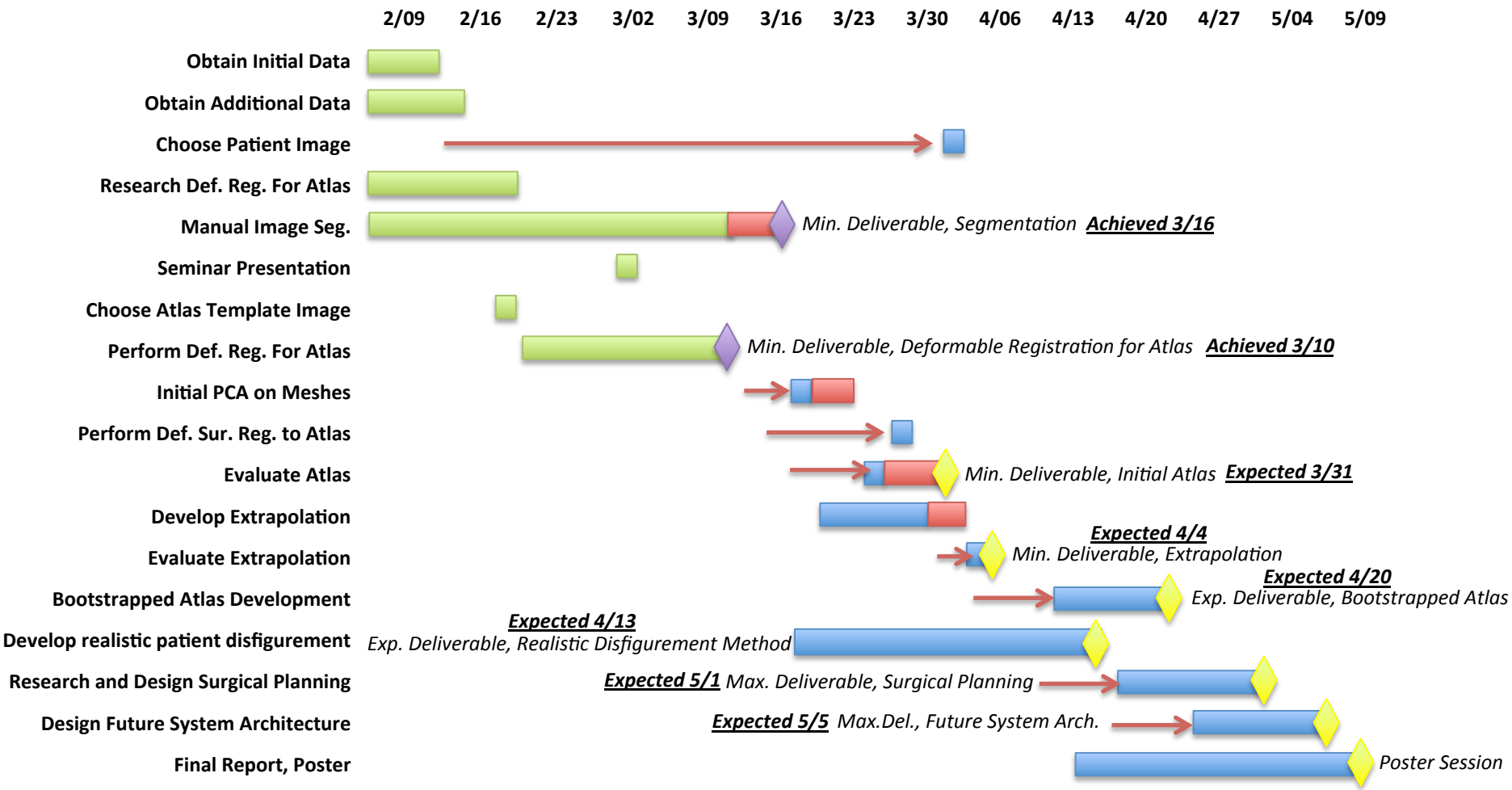
CT Courtesy of Dr. Chad Gordon and TCIA

Atlas Estimate Deviation From Current Patient

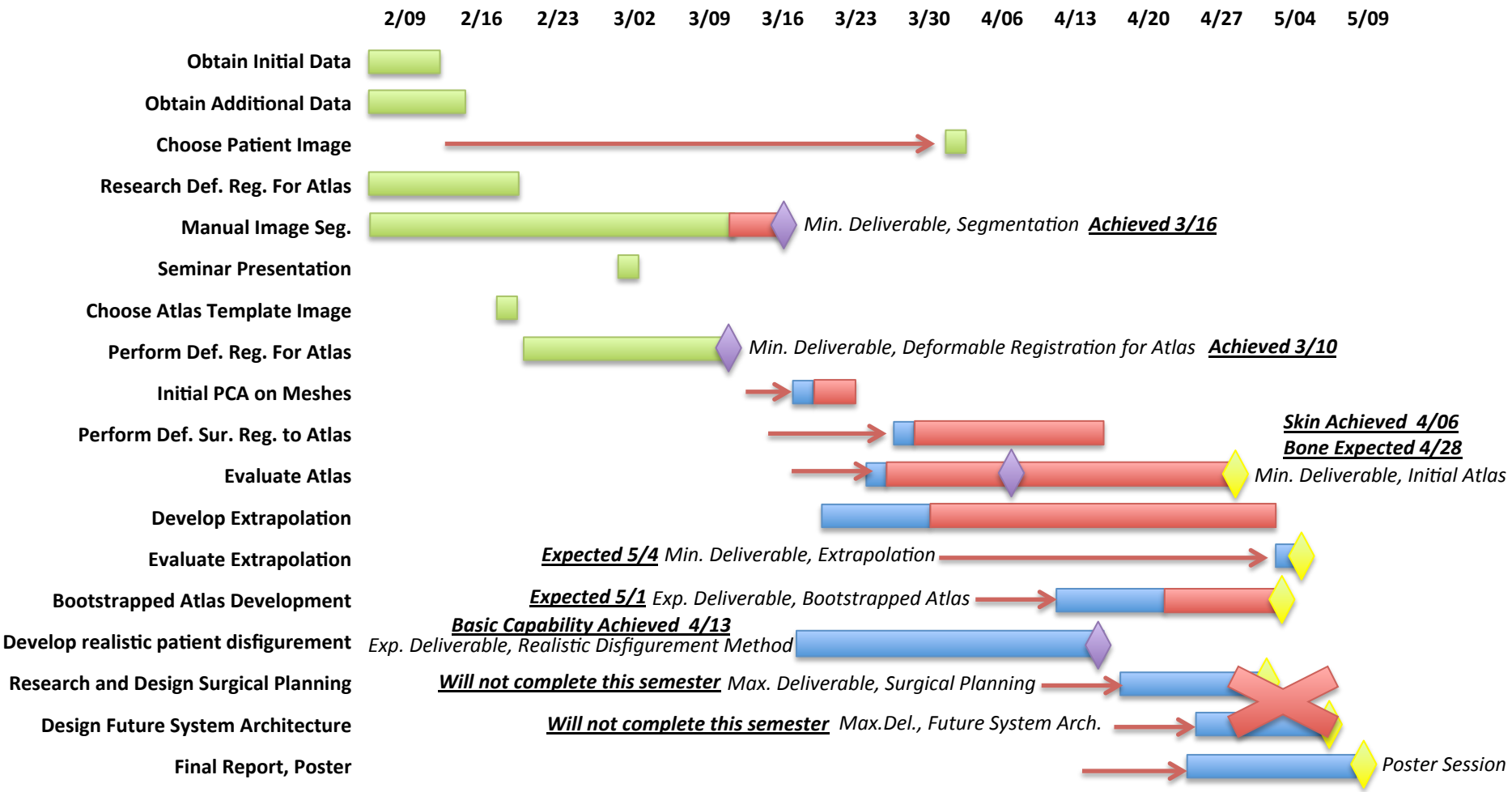


CT Courtesy of Dr. Chad Gordon and TCIA

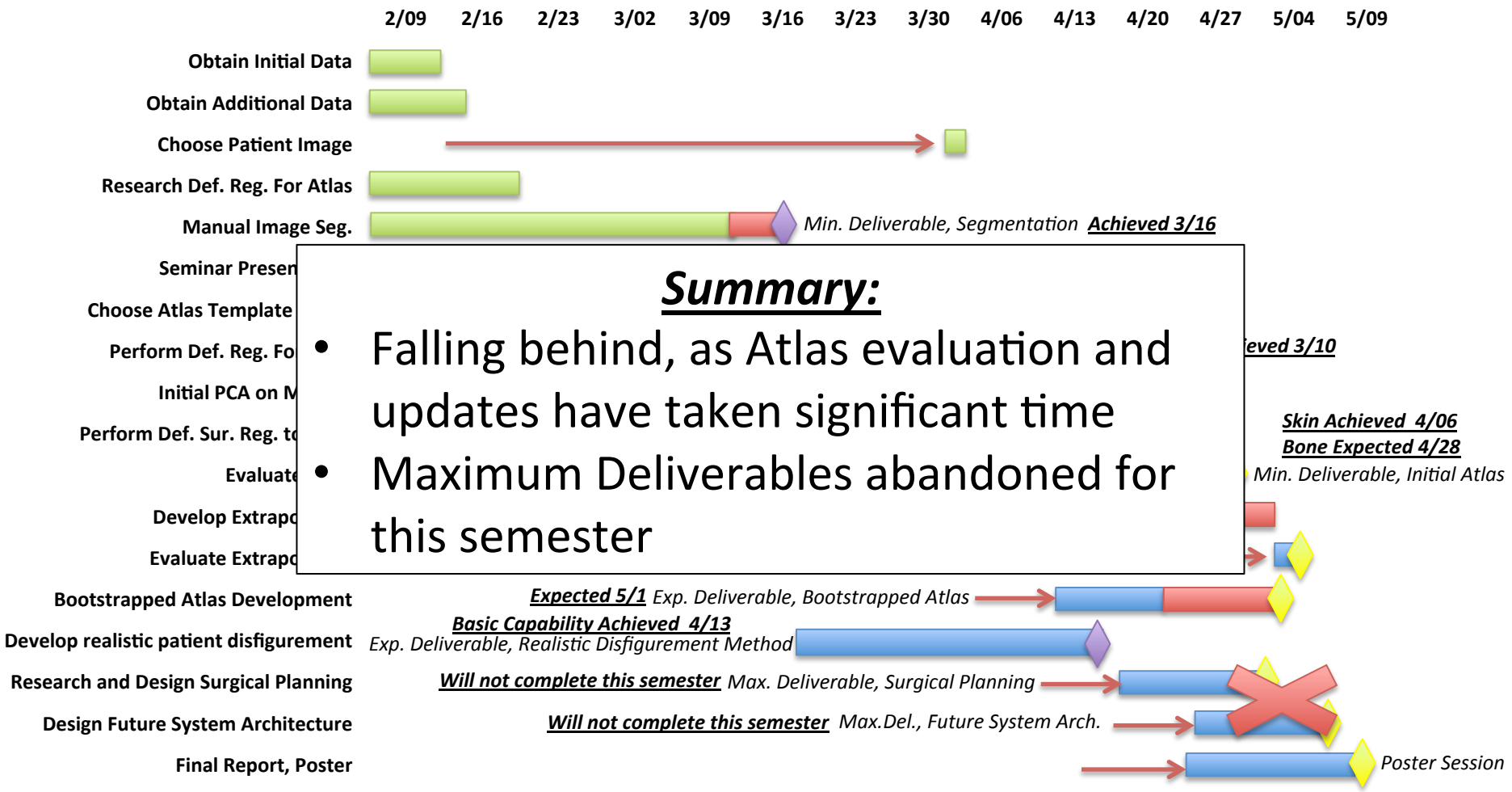
Updated Task Schedule From Last Checkpoint



Newly Updated Task Schedule



Newly Updated Task Schedule



Summary:

- Falling behind, as Atlas evaluation and updates have taken significant time
- Maximum Deliverables abandoned for this semester

Questions?