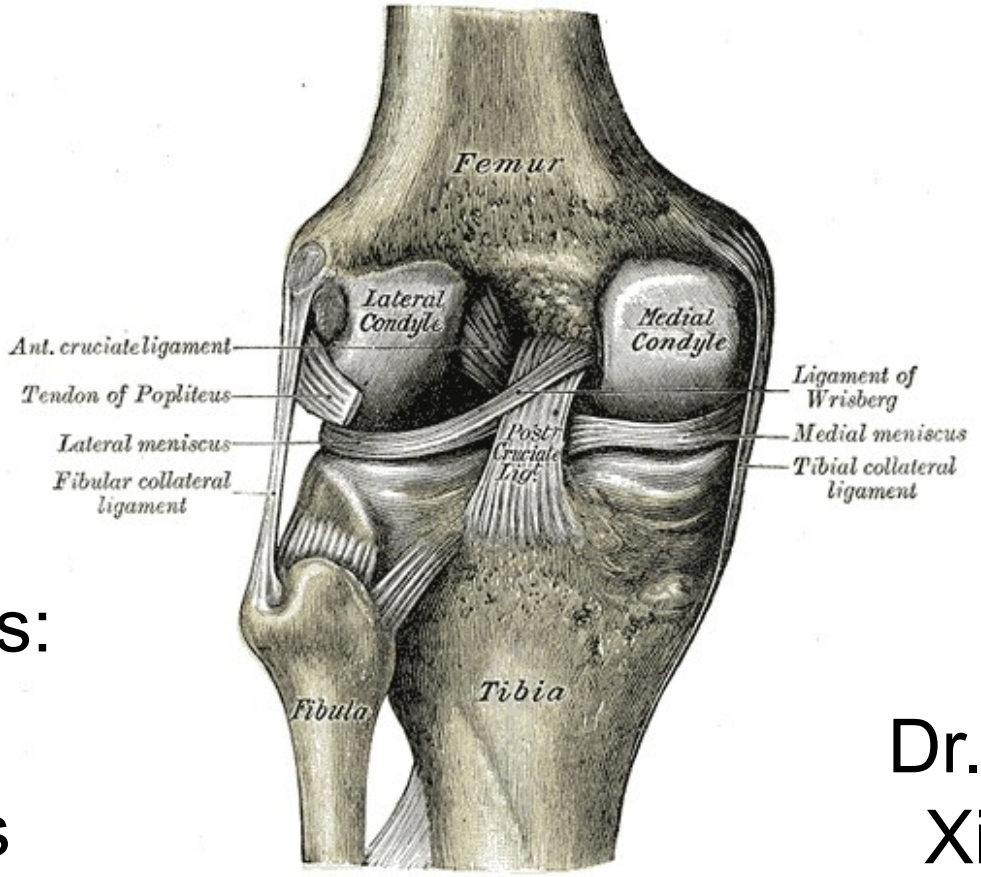
Statistical Atlas of the Knee



Henry Gray, Anatomy of the Human Body, 1918
http://www.bartleby.com/107/93.html

Team Members:

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Ceylan Tanes

Mentors:

Dr. Russell Taylor
Xin Kang (Ben)

ERC | CISST

LABORATORY FOR Computational Sensing + Robotics
THE JOHNS HOPKINS UNIVERSITY

Project Overview

- Improve and automate the statistical atlas building pipeline developed by Dr. Gouthami Chintalapani at the Johns Hopkins University
- Build a statistical atlas of the knee using CT images

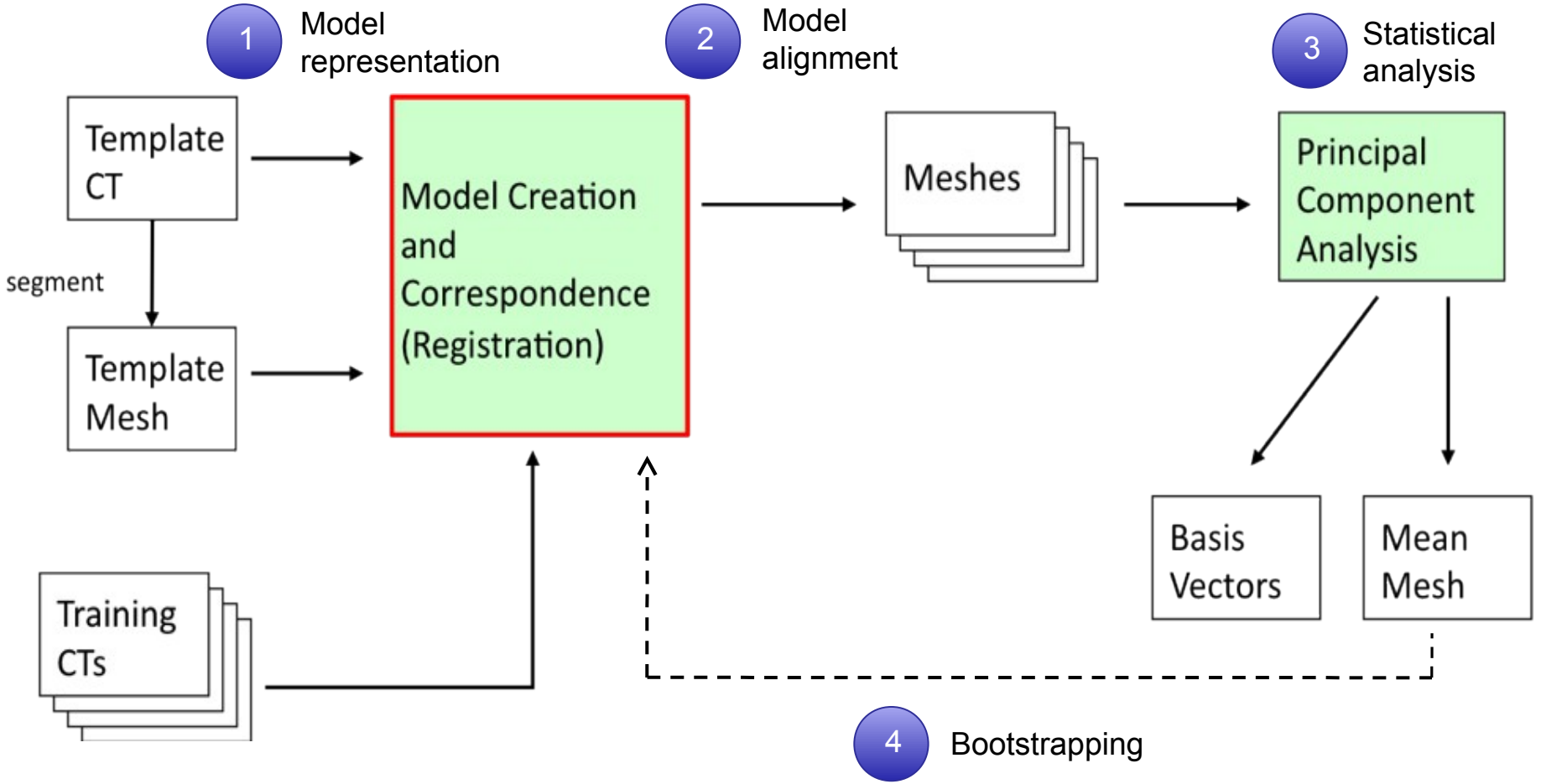
Milestones & Progress

Milestone	Status	Planned date	Date accomplished
Preliminary atlas	Done	2/25	2/25
Tetrahedral mesh of femur and tibia	Done	3/27	3/25
Automated pipeline	Done	3/27	3/27
Knee atlas		4/24	
Estimate bone tunnel locations after ACL surgery		5/6	
Joint segmentation – registration method (maximum deliverable)		5/15 (?)	

Dependencies

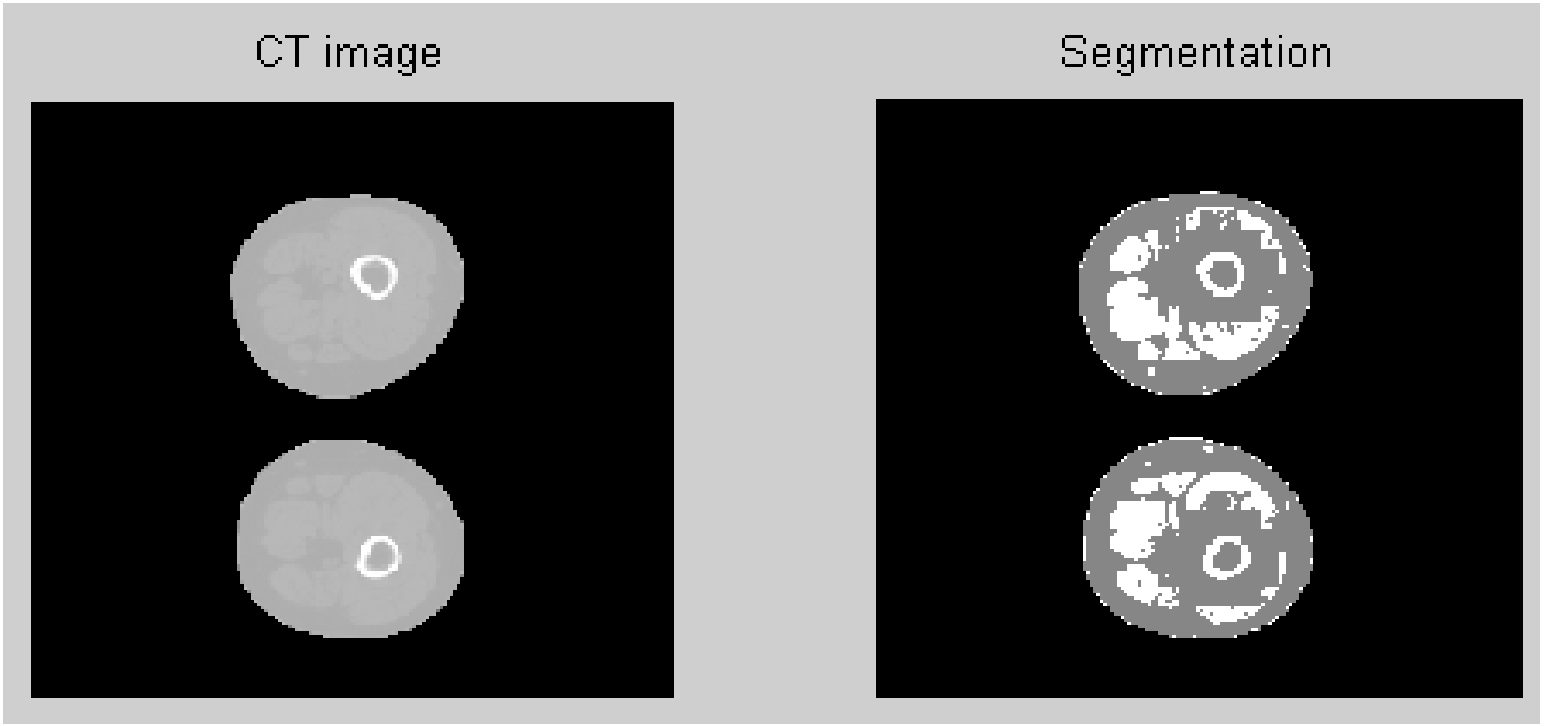
- No unresolved dependencies
- Data
  - IRB approval for patient dataset
  - Hong Kong cadaver dataset
- Software
  - ITK-SNAP, FANTASM, Mjolnir, MATLAB, Analyze
- Computer and linux account on server

Basic Atlas Construction Process

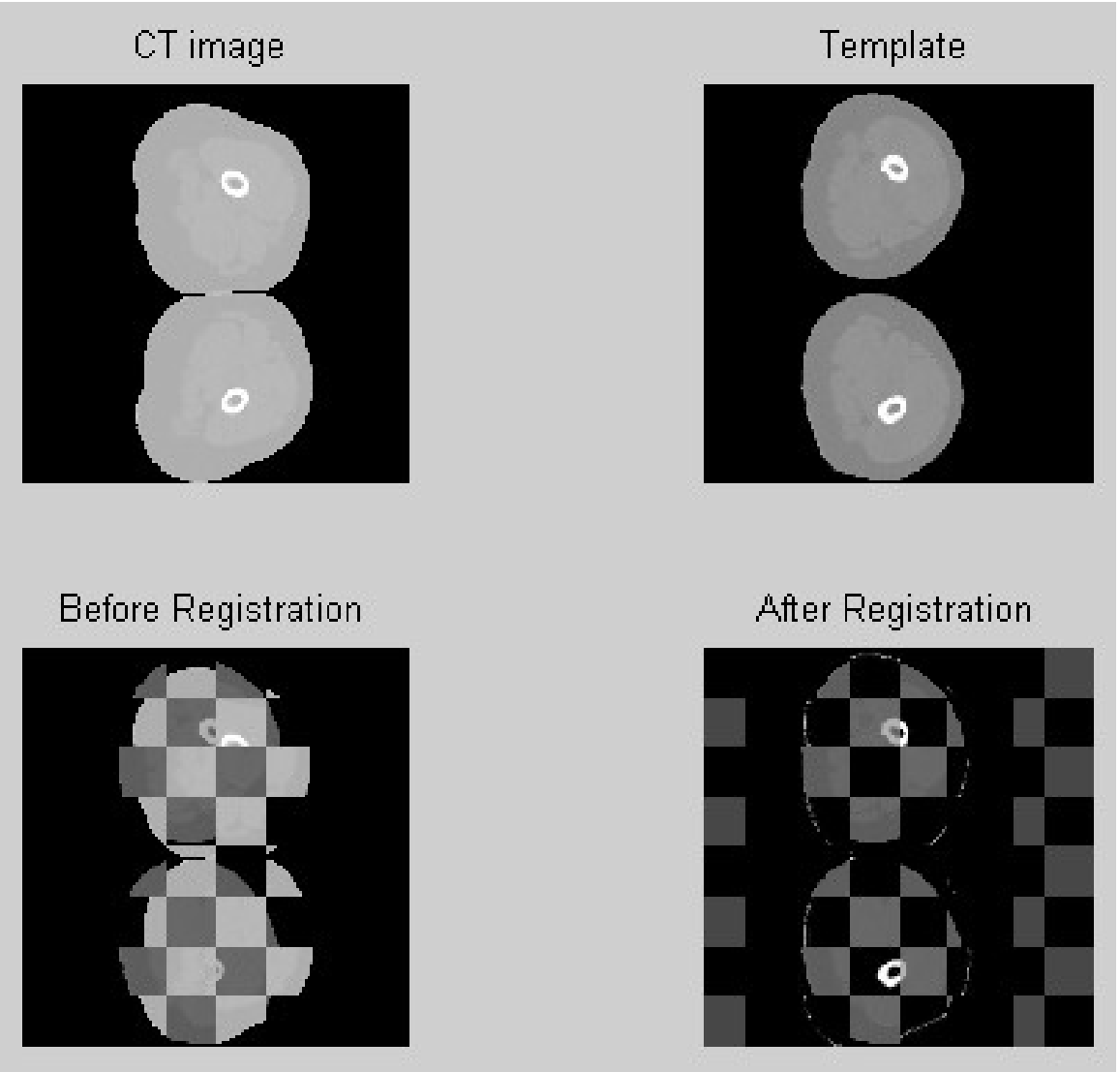


from G. Chintalapani's PhD dissertation

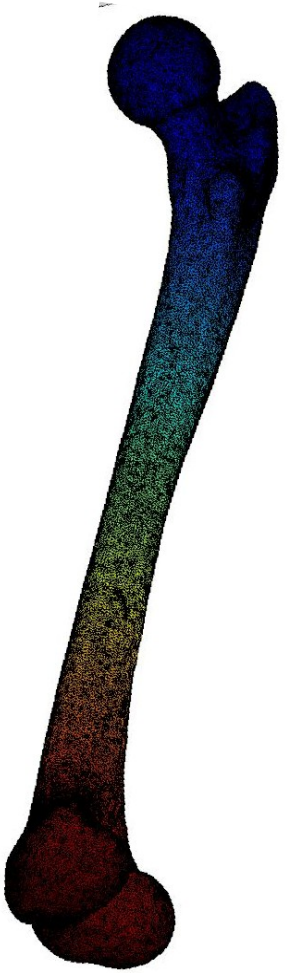
FANTASM Results

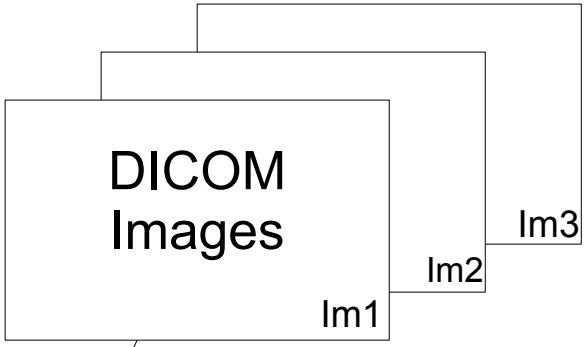


Mjolnir Results



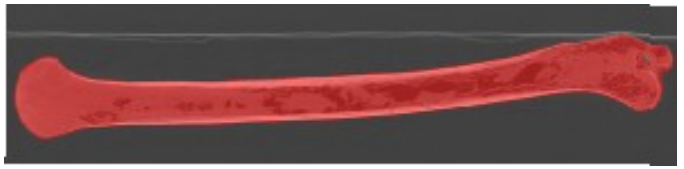
Tetrahedral Mesh Creation





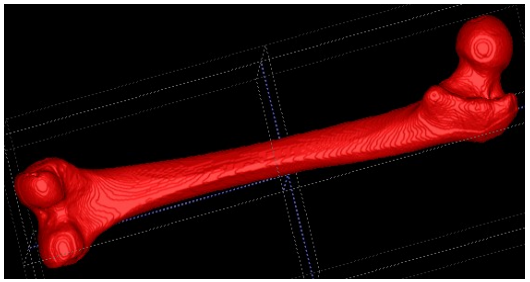
Tetrahedral mesh

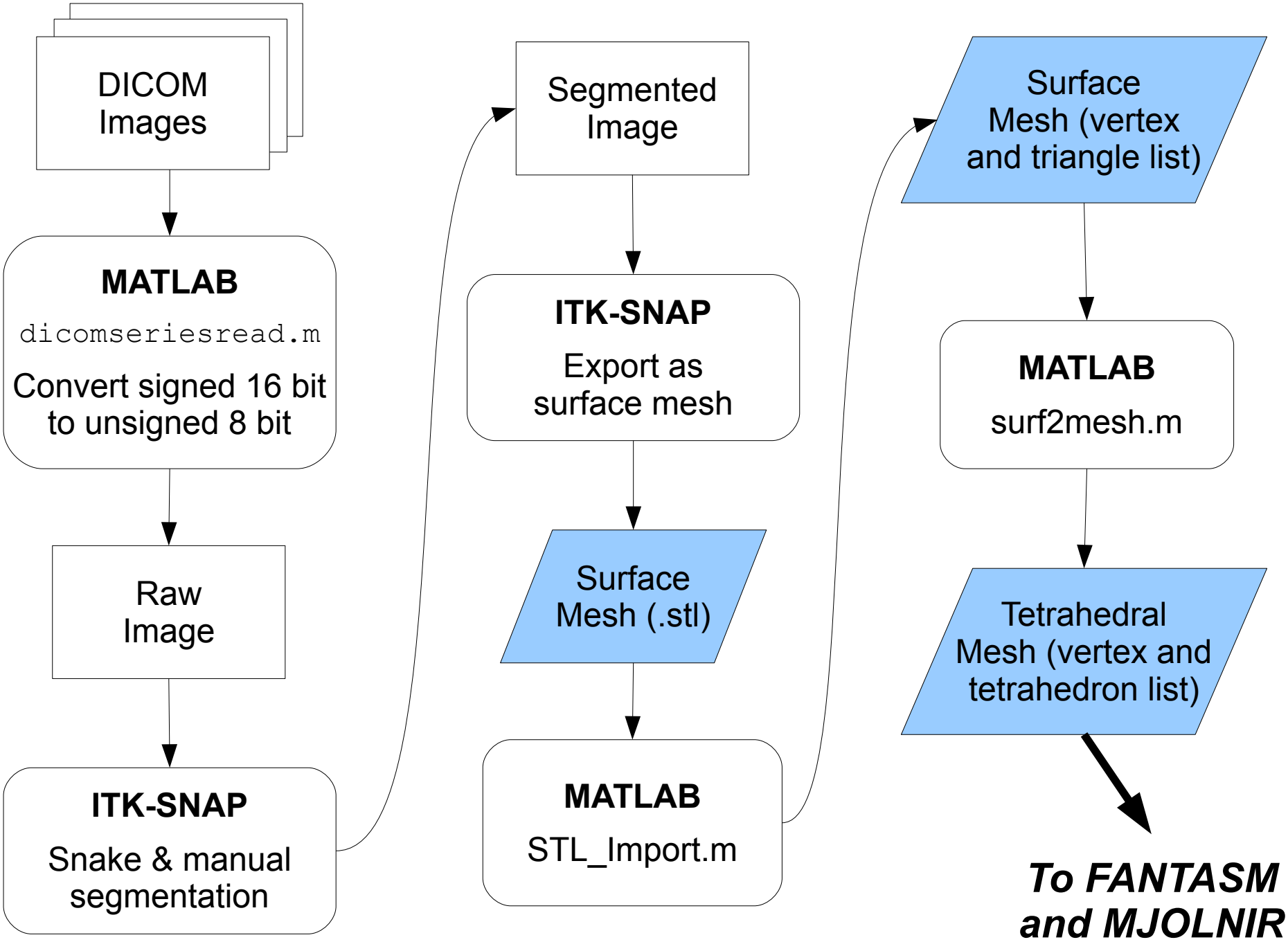
Raw Image



Surface mesh

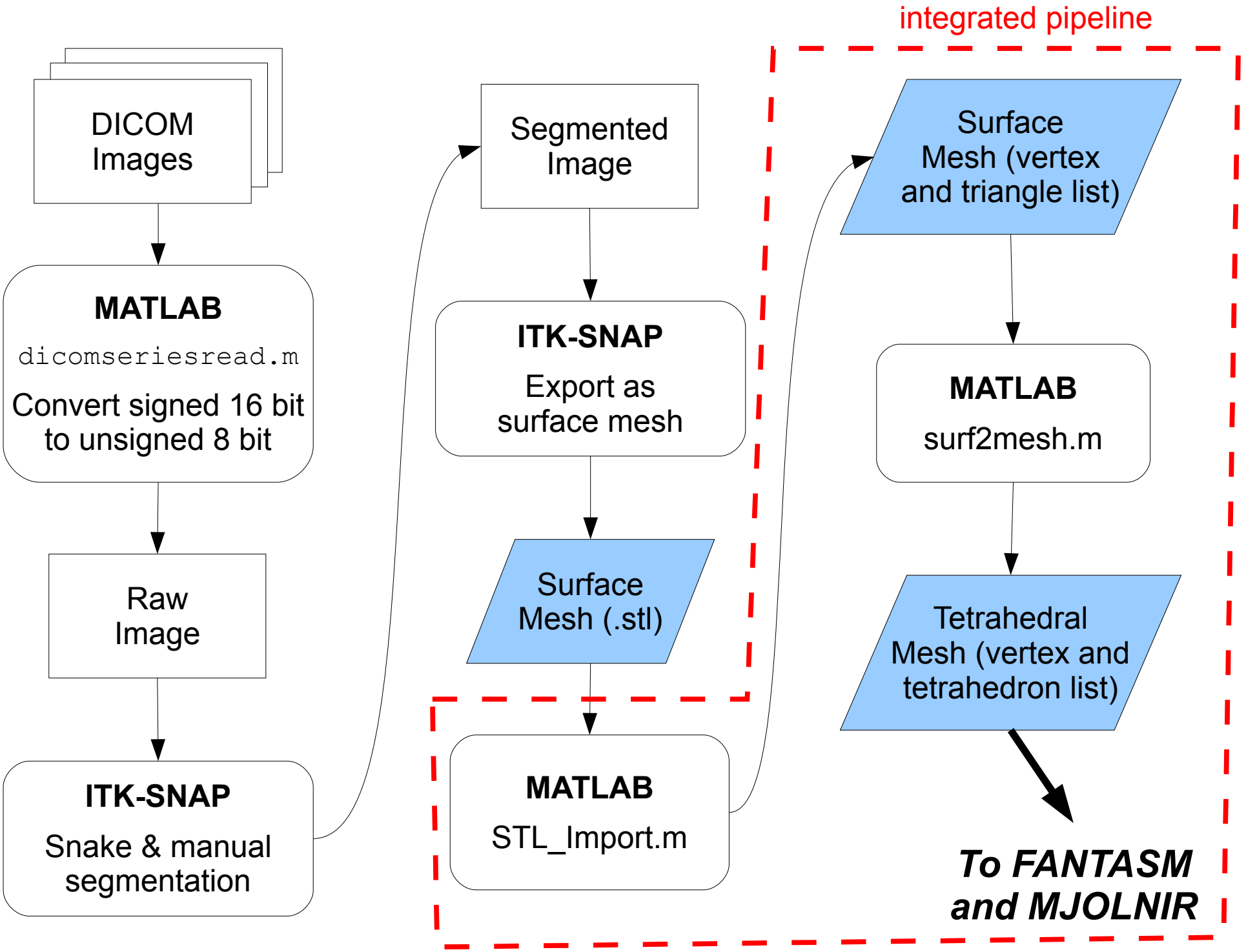
Segmented Image




DICOM Images
MATLAB
dicomseriesread.m
Convert signed 16 bit to unsigned 8 bit
Raw Image
ITK-SNAP
Snake & manual segmentation
Segmented Image
ITK-SNAP
Export as surface mesh
Surface Mesh (.stl)
MATLAB
STL_Import.m
Surface Mesh (vertex and triangle list)
MATLAB
surf2mesh.m
Tetrahedral Mesh (vertex and tetrahedron list)
To FANTASM and MJOLNIR

Integrated Pipeline

- MATLAB script that integrates the components
- Calls necessary shell scripts
- Runs on the stomach server, visualization is possible with the use of X11
- Inputs: template image, surface mesh, patient images
- Outputs: registered instances of all images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Pipeline Comparison

Original Pipeline

- Create labelled raw binary volume
- Use `tetsplit` to generate the tetrahedral mesh
- Convert results to CISST text mesh format

Improved Pipeline

- Generate surface mesh using ITK-SNAP
- Load the surface mesh into MATLAB, and use iso2mesh package to generate the tetrahedral mesh

Multiple Atlas Registration

- Separate meshes for femur and tibia:
  - Since knee is a pivotal hinge joint, femur and tibia of the patient are unlikely to be perfectly in line when the CT images are acquired
  - Need separate atlases for femur and tibia (and for left and right leg)
  - Will perform multiple atlas registration when doing post-surgery evaluation

What's next?

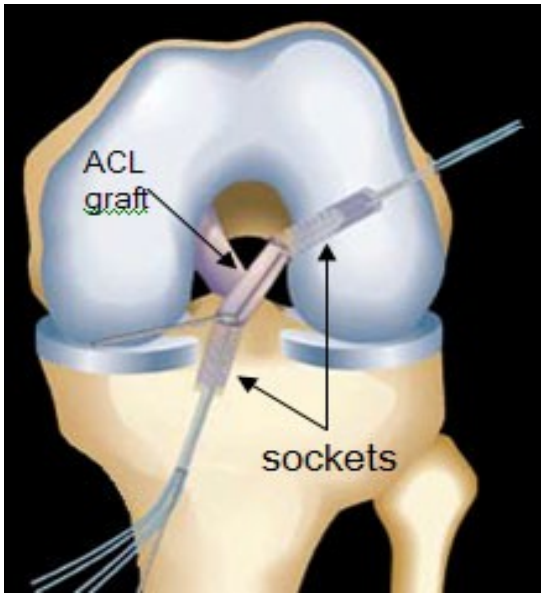
Milestone	Status	Planned date	Date accomplished
Preliminary atlas	Done	2/25	2/25
Tetrahedral mesh of femur and tibia	Done	3/27	3/25
Automated pipeline	Done	3/27	3/27
Knee atlas	Currently working on preprocessing patient images, preliminary FANTASM results	4/24	
Estimate bone tunnel locations after ACL surgery	2D to 3D registration algorithm implemented by Ben	5/6	
Joint segmentation – registration method (maximum deliverable)	Working on MATLAB code	5/15 (?)	

Knee Atlas

- Use segmentation results from the cadaver dataset to facilitate the segmentation of the patient images
- Non-rigid coupled registration and segmentation between cadaver mean image and template patient image

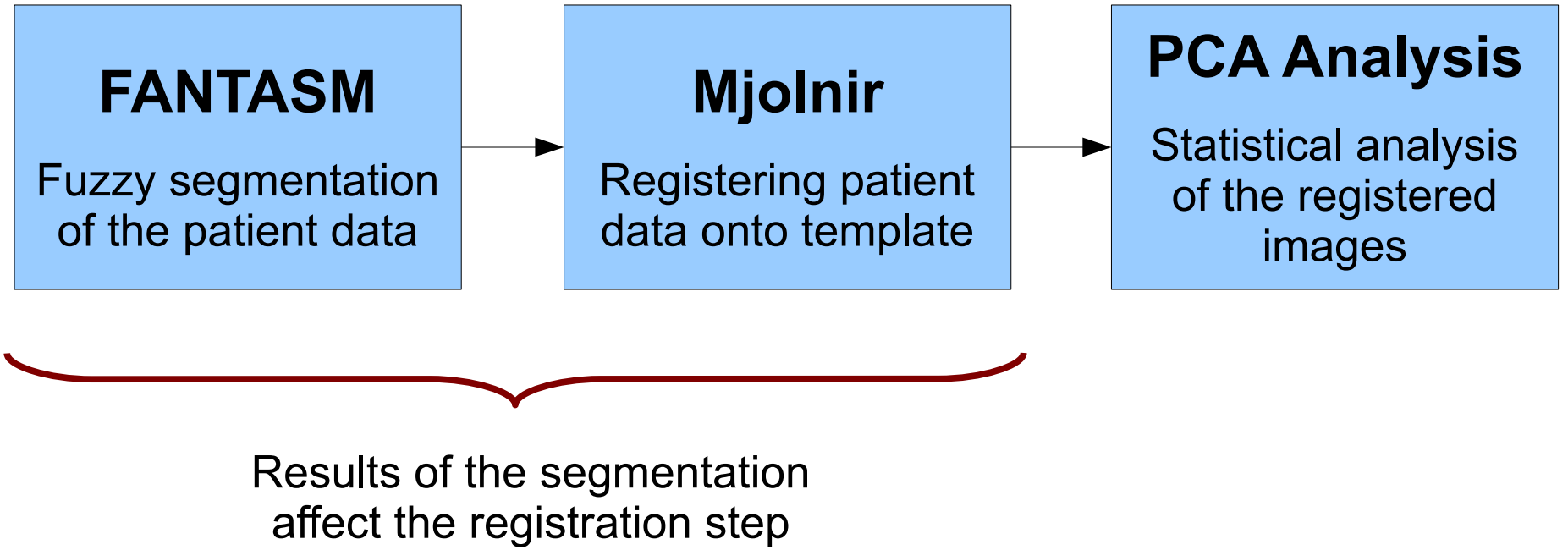
Estimating bone tunnel locations after ACL surgery

- Input:
  - 2D X-ray image of the patient
  - 3D knee atlas
- Method:
  - 2D-3D registration algorithm (done)
  - Edge detection to extract tunnel location in 2D image
- Output:
  - Estimated tunnel location



http://goortho.net/images2/acl-knee-surgery.jpg

Final Steps of the Pipeline



Segmentation / Registration

Current Pipeline

- Uses FANTASM for fuzzy segmentation of patient images
- Uses Mjolnir to register the segmented patient images onto the tetrahedral mesh

Proposed Pipeline

- Use a simultaneous segmentation / registration algorithm to combine the two separate steps

Difficulties encountered so far...

- File formats can complicate things.
  - We used intermediate MATLAB functions for format conversion
- ITK-SNAP uses intensity range to aid segmentation – mid-bone is difficult to segment in the cadaver data
  - Manual segmentation

Documentation

- The MATLAB scripts are well documented.
- Video demonstration to guide the users through the process
- For weekly meeting minutes, you can visit our project page.

Thank you!

Questions?