Image Guidance for Robot-Assisted Ankle Fracture Repair: Final Presentation

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Mentors: Dr. Jeffrey H. Siewerdsen and Dr. Wojtek Zbijewski

Overview

- Project Background and Importance
- Technical Approach
- Aims/Deliverables
- Team Management
- Status
- Next Milestones

Background: Ankle Fracture and Syndesmosis

Ankle fractures have incidence of up to 187 cases per 100,000 adults per year – over 5 million cases per year in the U.S. alone[1]

Most common affected groups are young, active people and elderly people[1]

The incidence of PTOA has been reported as high as 70%[2]

[1] Goost H, Wimmer MD, Barg A, Kabir K, Valderrabano V, Burger C. Fractures of the ankle joint: investigation and treatment options. *Dtsch Arztebl Int*. 2014;111(21):377–388.
[2] Mehta SS, Rees K, Cutler L, Mangwani J. Understanding risks and complications in the management of ankle fractures. *Indian J Orthop*. 2014;48(5):445–452.

Project Summary

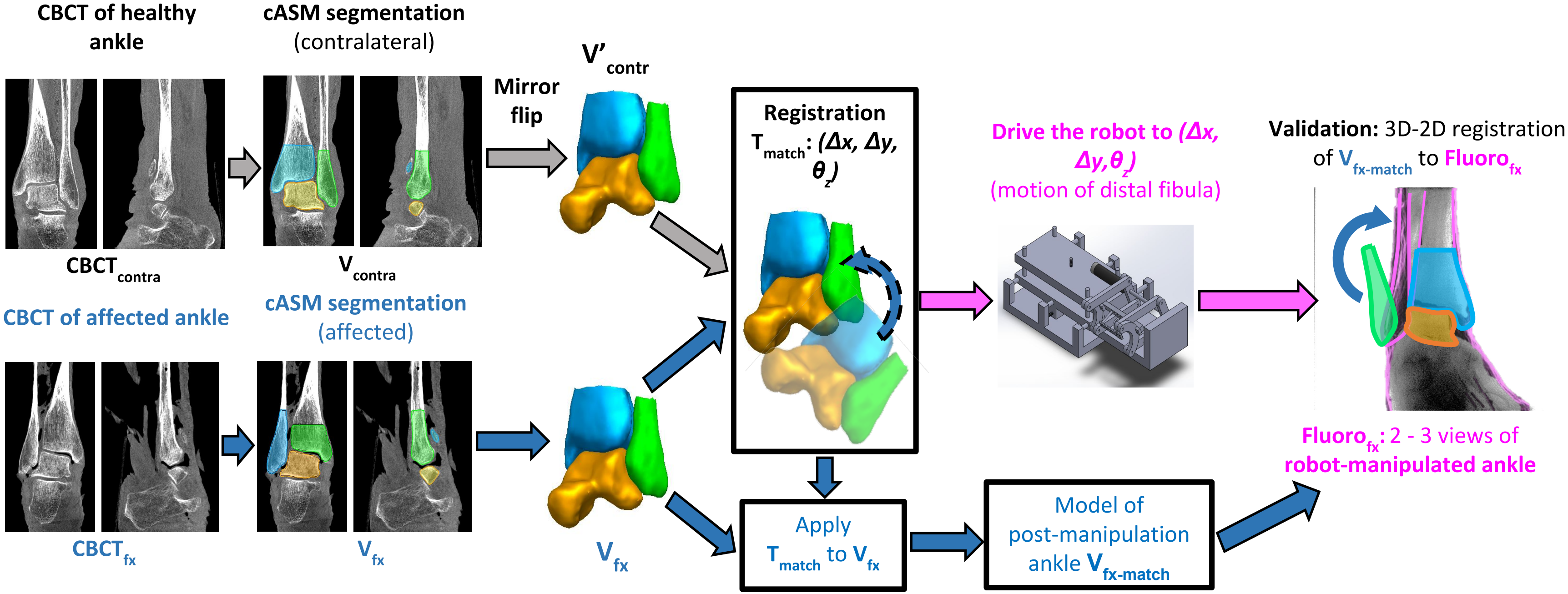


Figure by Wojtek Zbijewski

Aims/Deliverables

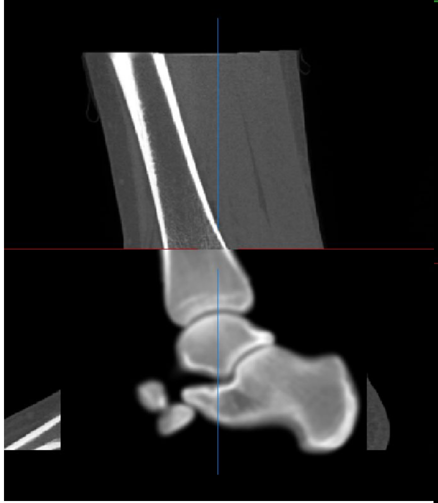
Minimum: Complete	Expected: Almost Complete	Maximum: Incomplete
○ Validate accuracy of Coupled Active Shape Model with average segmentation error of 5 mm for high quality cone beam images ○ Perform error analysis on failure modes on low quality CT images	○ Validate accuracy of joint deep learning - cASM model with mean segmentation error of 2mm for low quality CT images of healthy ankles without metal artifacts	○ Publish paper ○ Incorporate metal artifacts and unhealthy ankle data into deep learning - cASM model with mean segmentation error of 2mm

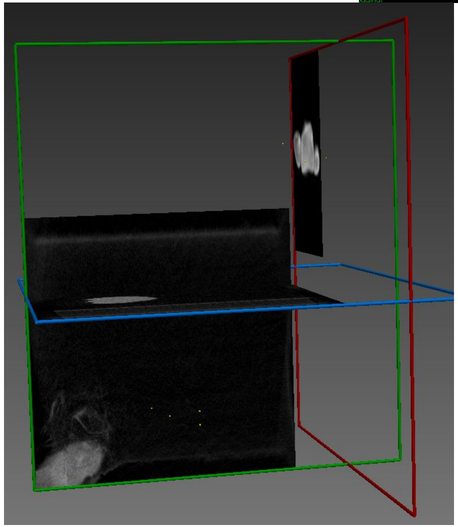
Team Management

Member	Responsibilities	Meeting Attendance
Asef Islam	• Create workflow for processing C-arm data • Adjust active shape model to first work for cone beam and then to work for c-arm data	• F 3:30-5pm • Sat 3-5pm • When needed
Jayaram Mandavilli	• Develop deep learning framework and multiple models for ankle segmentation • Develop U-net and simple CNN	• Fri 3:30-5pm • Sat 3-5pm • When needed
Anthony Wu	• Create training data • Develop deep learning model for ankle segmentation • Developed validation framework	• Fri 3:30-5pm • Sat 3-5pm • When needed
Mentors: Wojtek Zbijewski, Jeff Siewerdsen	• Provided feedback on presentations and project pathways • Provided many resources including access to C-arm (to collect data) and remote GPU access	• Fri 3:30-5pm

cASM Status

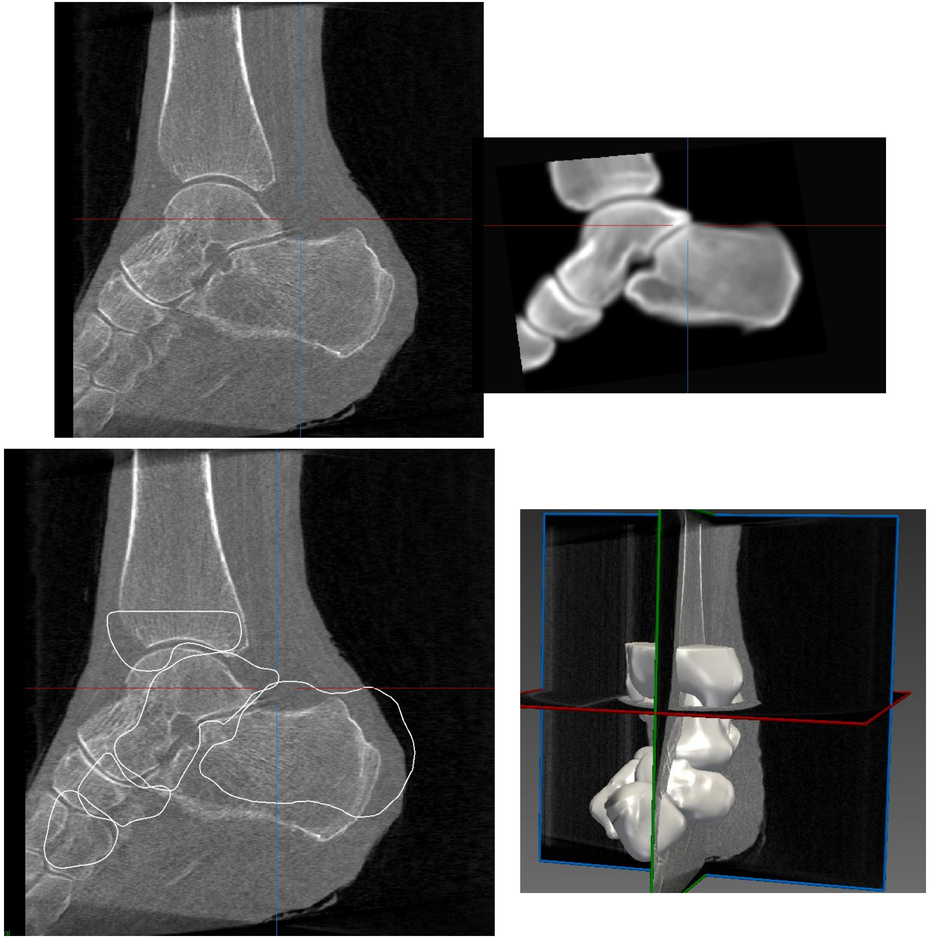
- cASM model works for CBCT data, begins with near perfect initial coarse registration of mean image
- Difficulty registering mean image to C-arm data due to different voxel sizes and different axes.





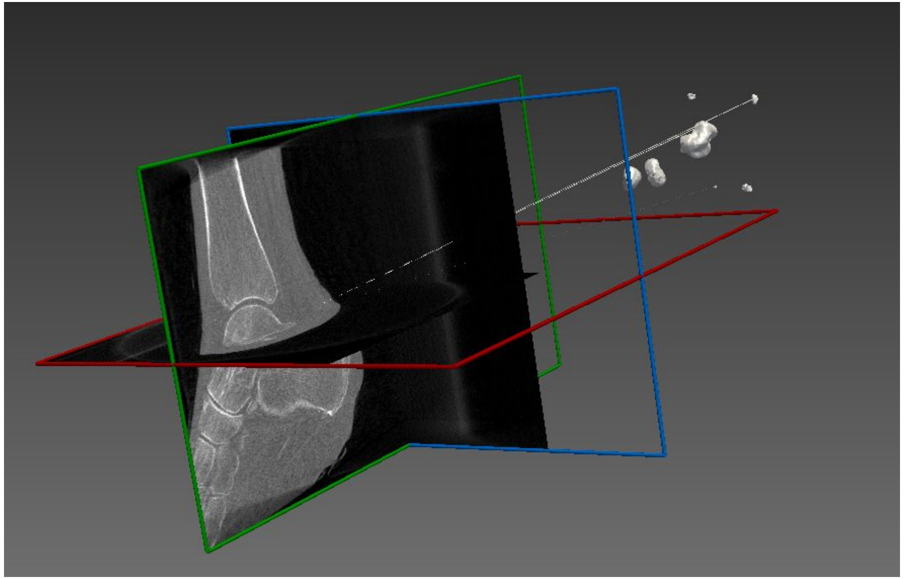
cASM Status

- Mean image has different coordinate frame and voxel size compared to C-arm images.
- Fixed: Improved initial alignment of mean image through CPD registration, manual tuning, adjusting scaling and origin
- Better initialization of mean shapes



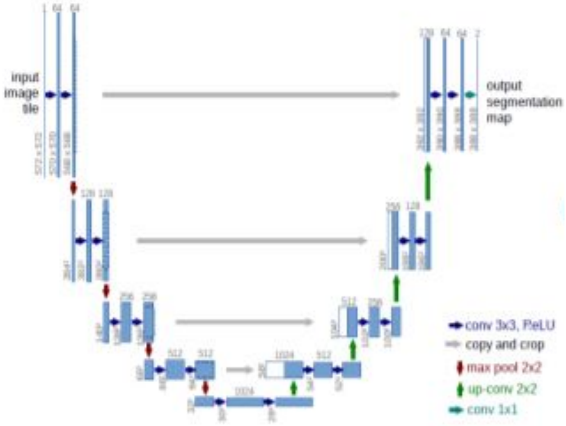
cASM Status

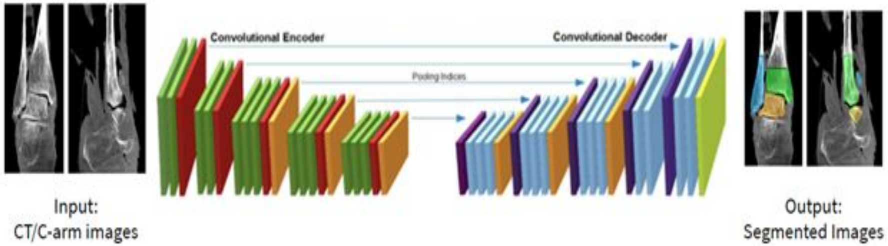
- Current problems
  - Re-meshed versions of mean shapes
  - Erroneous normals
  - Mean shapes once again become misaligned from image after surface deformation



Neural Net Status

- Data Pre-Processing
  - Splice 3D images: 2D inputs to neural nets
  - Zoom in data: reduces computational burden
  - Reduce bias: reduce the percentage of slices without the bone
  - Average slices: reduce noise for each input slice
- Approaches: fibula
  - Look at each slice from each plane (coronal, sagittal, and axial)
    - Identify if slice has fibula or not
    - Say ith axial slice, jth sagittal slice, and kth coronal slice all had fibulas, then can say pixel i, j, k is part of the fibula
  - Main approach: segment 2D slices with U-net
    - Used coronal slices

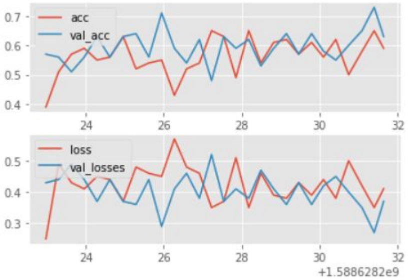




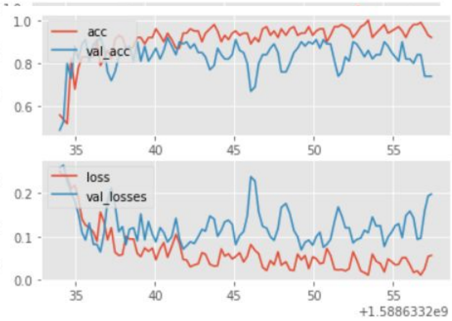
Neural Net Results

Convolutional Neural Network (CNN)

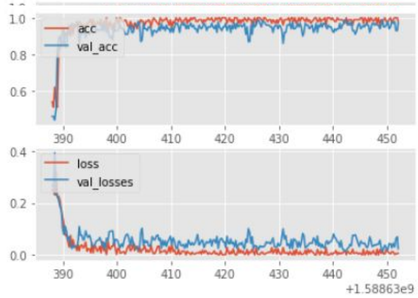
Coronal



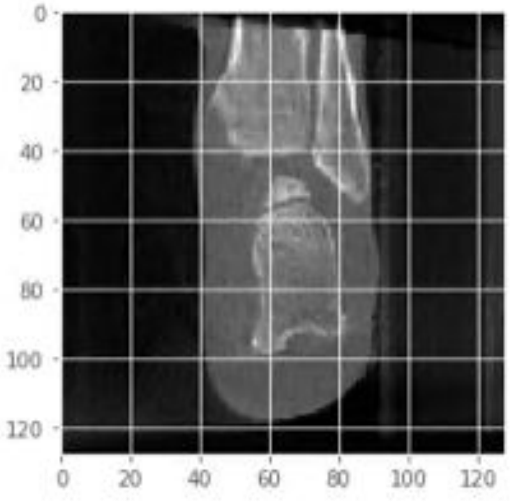
Sagittal



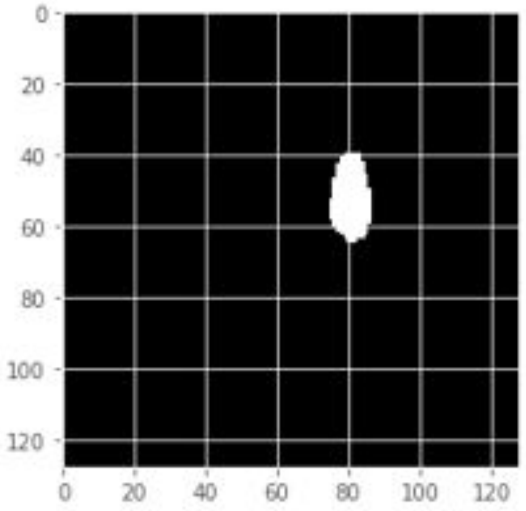
Axial



Neural Net Results Part 2



- Trained U-Net on 200 EPOCHS
- Accuracy: 99.3% on pixels of test data
  - Loss Function Value: 0.03
- However, must evaluate if neural net had bias
- Loss Function = $-\sum x * \log(y)$
  - x is the truth value (0 for no bone, 1 for bone)
  - y is the probability of x happening.



What We Learned

- cASM
  - Better understanding of code and its different steps through time spent debugging
  - Highly modular
  - Computationally intensive, often causes personal laptop to crash
  - Latest stable release is calibrated towards diagnostic CBCT scanner, so when trying to use code with new imaging modalities or scanners it has to be re-calibrated in terms of initial alignment
  - Sensitive to parameter choices
- Deep Learning
  - Trial and error
  - Neural networks require much more computational power than we anticipated
  - Pre-processing of data is very important
    - Helps increase accuracy
    - Can help reduce computational burden
  - Found a creative way to solve a semantic segmentation problem

Next Milestones (Summer)

- Achieve full functionality of cASM for C-arm images
  - Resolve problems noted with mean shapes, normals, misalignment
  - Quantify segmentation accuracy for images based on quality (high, low, artifacts, etc.)
  - Tune parameters (iterations, # PCs, kernel sigmas, etc.) to find what works best
- Develop deep learning approach for low quality C-arm images
  - Look into more model types
  - Develop networks for all 7 bones of interest in ankle
- Implement pre-processing steps to clean up data
  - Enhance contrast to strengthen gradient signals of bone edges
  - Incorporate metal artifact and noise reduction algorithms

Questions?