

# **Image Guidance for Robot-Assisted Ankle Fracture Repair**

Team Members: Asef Islam, Anthony Wu, Jayaram Mandavilli

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

# Background: Ankle Fracture and Syndesmosis



Source of Graphic: Mercy Medical Center

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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<sup>[1]</sup>



Most common affected groups are young, active people and elderly people<sup>[1]</sup>

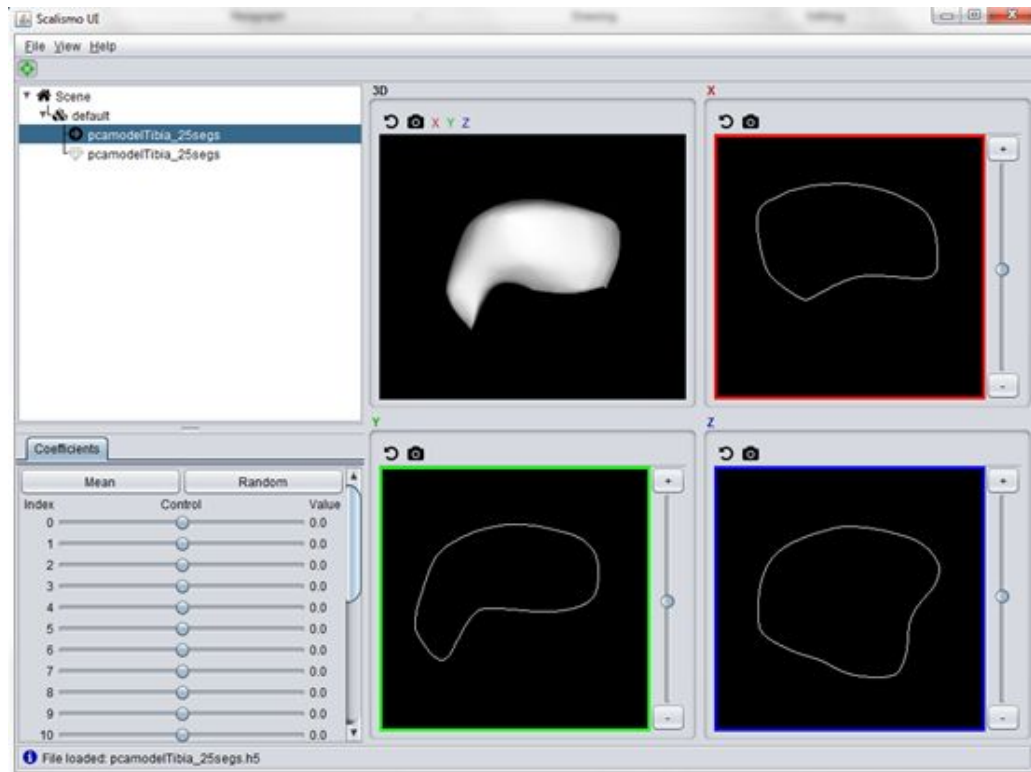
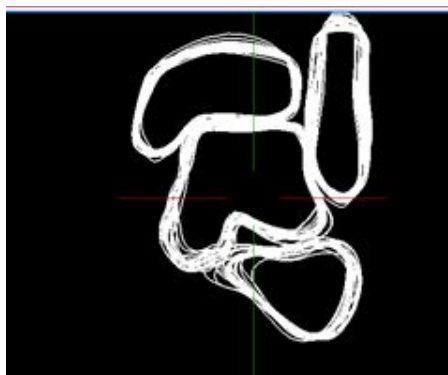
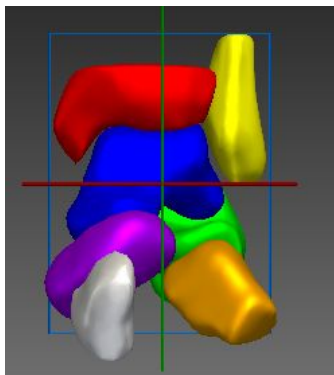
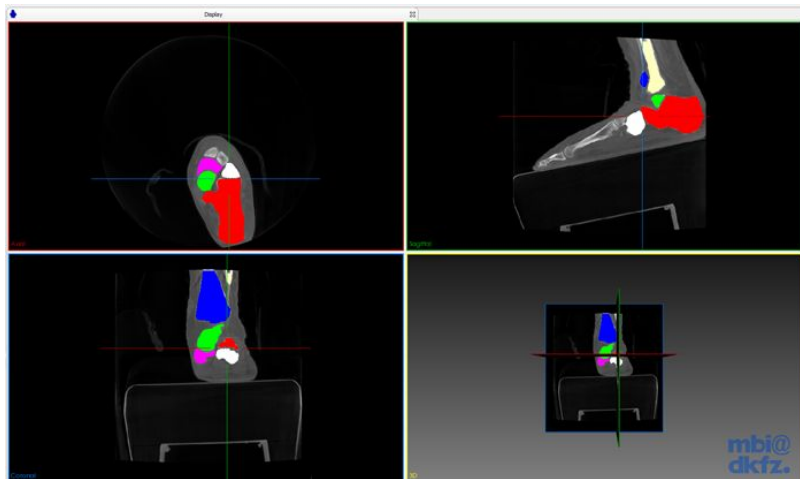


The incidence of PTOA has been reported as high as 70%<sup>[2]</sup>

[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.

# Past Work: Active Shape Models



# Past Work: Coupled Active Shape Models

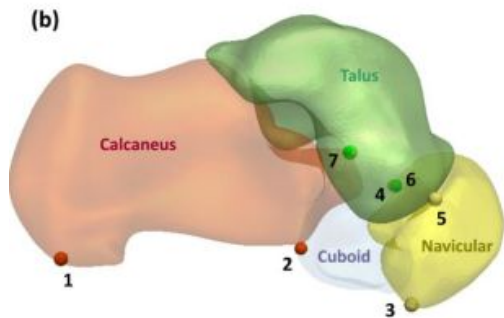
## Coupled Active Shape Models for Automated Segmentation and Landmark Localization in High-Resolution CT of the Foot and Ankle

M. Brehler,<sup>a</sup> A. Islam,<sup>a</sup> L. Vogelsang,<sup>c</sup> D. Yang,<sup>c</sup> W. Sehnert,<sup>c</sup> D. Shakoov,<sup>b</sup> S. Demehri,<sup>b</sup> J. H. Siewerdsen,<sup>a,b</sup> W. Zbijewski<sup>a</sup>

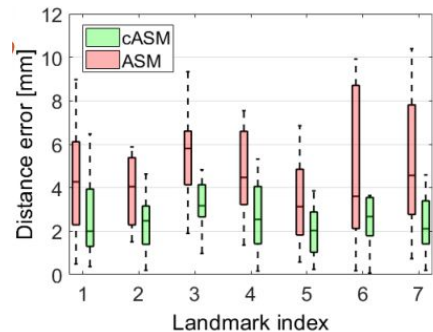
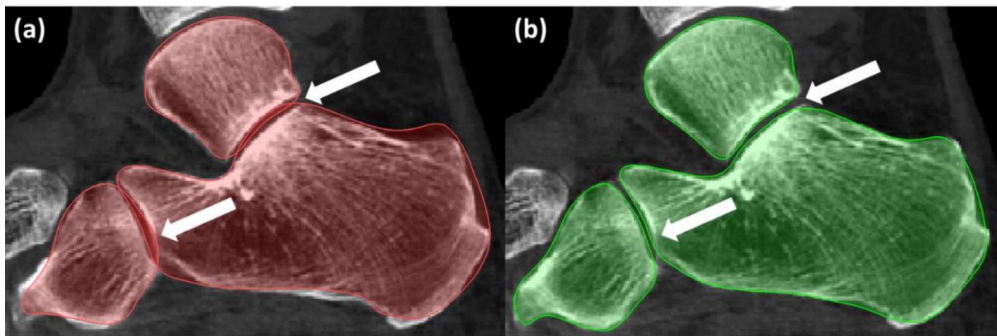
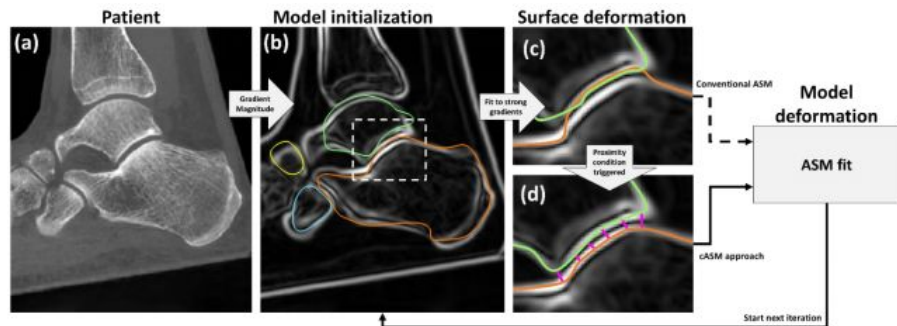
<sup>a</sup>Department of Biomedical Engineering, Johns Hopkins University, Baltimore, MD USA

<sup>b</sup>Department of Radiology, Johns Hopkins University, Baltimore, MD USA

<sup>c</sup>Carestream Health, Rochester, NY USA



Articular Surface Distances	Min [mm]	Max [mm]	Mean [mm]
Calcaneus to Cuboid	0.64	1.49	1.00
Calcaneus to Talus	0.92	2.64	1.57
Cuboid to Calcaneus	0.69	1.58	1.03
Navicular to Talus	0.70	2.27	1.40
Talus to Navicular	0.85	2.61	1.54
Talus to Calcaneus	0.81	2.02	1.26



# Technical Approach: Robot Guidance

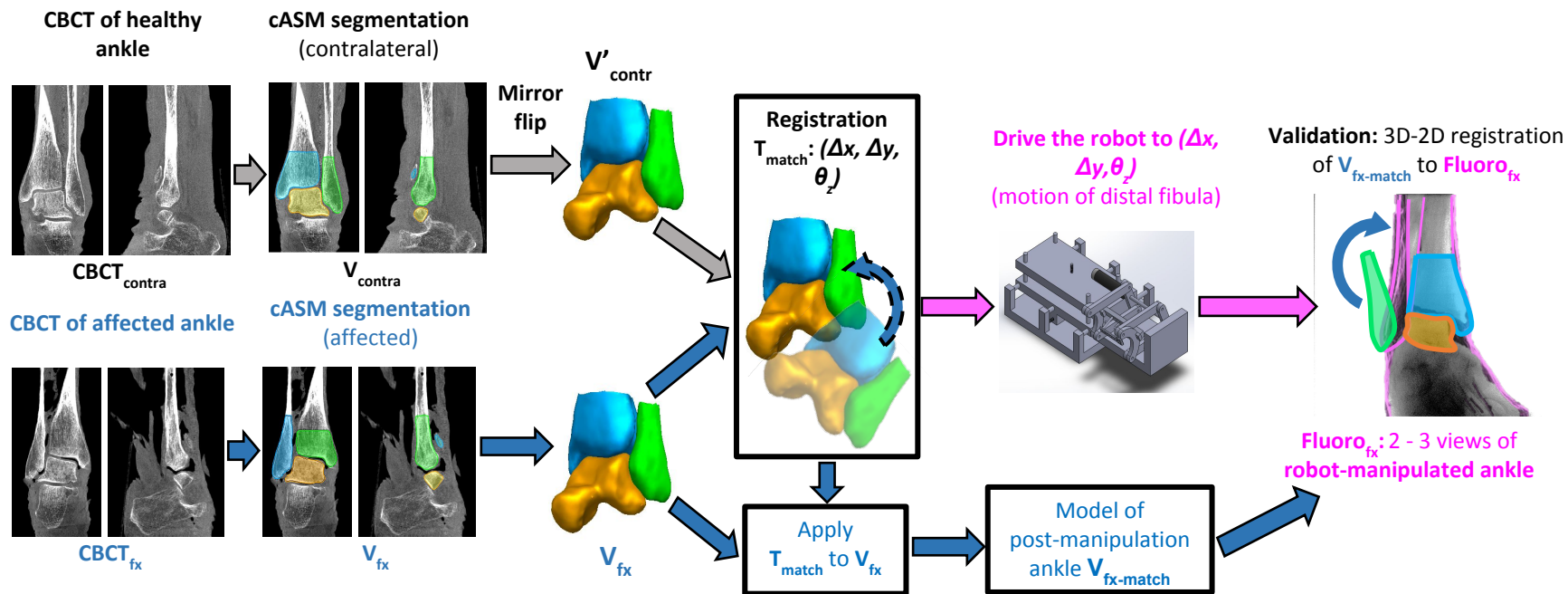
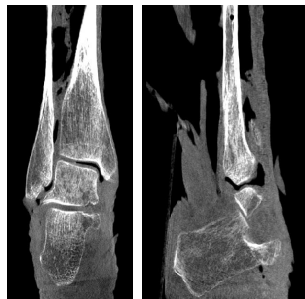
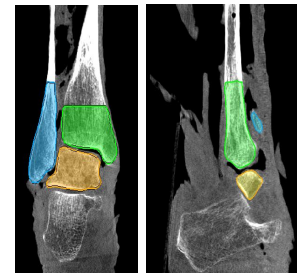
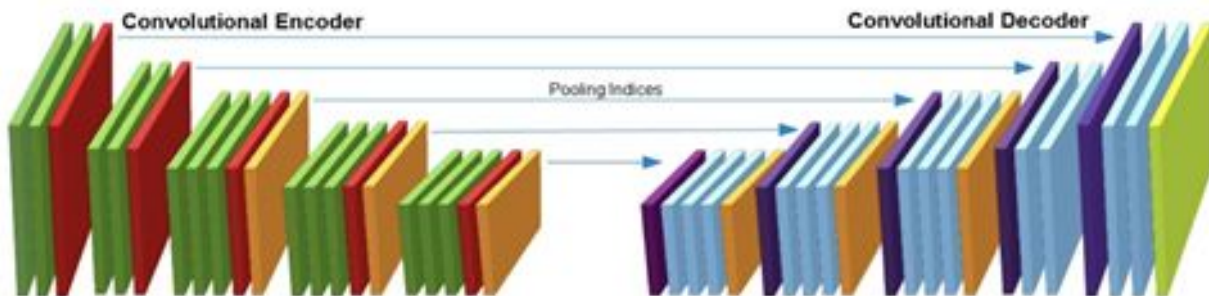


Figure by Wojtek Zbijewski

# Technical Approach: Deep Learning



Input:  
CT/C-arm images



Output:  
Segmented Images

# Aims

- Aim 1
  - Adjust active shape model (ASM) for noise to apply transformation for C-Arm data. Ensure accuracy within 5 mm to improve accuracy compared to human eye ( $\geq 95\%$  of the time)
- Aim 2
  - Create a deep learning model for ankle segmentation with an accuracy within 5 mm ( $\geq 95\%$  of the time)
- Aim 3
  - Combine deep learning and ASM model with an accuracy within 1 mm ( $\geq 95\%$  of the time)

# Deliverables

<b>Minimum</b>	<b>Expected</b>	<b>Maximum</b>
<ul style="list-style-type: none"><li>○ Create a script to validate accuracy of any model</li><li>○ To validate, we will compare the transformation of unhealthy ankle to images of patient's healthy ankle</li><li>○ Validate accuracy of Active Shape Model within 5 mm (<math>\geq 95\%</math> of cases)</li></ul>	<ul style="list-style-type: none"><li>○ Develop deep neural network to “memorize” position of a good joint</li><li>○ Validate accuracy of deep learning model within 5 mm (<math>\geq 95\%</math> of cases)</li></ul>	<ul style="list-style-type: none"><li>○ Publish paper</li><li>○ Combine with multi-body 3D-2D registration to guide reduction within 1 mm (<math>\geq 95\%</math> of cases)</li></ul>

# Team Management

Member	Responsibilities	Meeting Attendance
Asef Islam	<ul style="list-style-type: none"><li>• Create workflow for processing C-arm data</li><li>• Adjust active shape model to account for artifacts and noise</li></ul>	<ul style="list-style-type: none"><li>• F 3-5pm (JHMI)</li><li>• Sat 2-7pm (Homewood)</li></ul>
Jayaram Mandavilli	<ul style="list-style-type: none"><li>• Create testing framework to calculate accuracy of an arbitrary model</li><li>• Develop deep learning model for ankle segmentation</li></ul>	<ul style="list-style-type: none"><li>• Fri 3-5pm (JHMI)</li><li>• Sat 2-7pm (Homewood)</li></ul>
Anthony Wu	<ul style="list-style-type: none"><li>• Create and plan workflow for developing deep learning model</li><li>• Develop deep learning model for ankle segmentation</li></ul>	<ul style="list-style-type: none"><li>• Fri 3-5pm (JHMI)</li><li>• Sat 2-7pm (Homewood)</li></ul>
Mentors: Wojtek Zbijewski, Jeff Siewerdsen	<ul style="list-style-type: none"><li>• Provide feedback and resources for project</li></ul>	<ul style="list-style-type: none"><li>• Fri 3-5pm (JHMI)</li></ul>

# Dependencies

Dependency	Plan	Backup	Person to Contact
C-Arm Data	Use C-arm data already generated	Use C-arm provided by the lab to get data	Dr. Qian Cao, Solved
Computers (GPU array)	Connect to lab computers and GPU cluster from personal laptops or work entirely locally on personal laptops with GPUs	Go to medical campus to work directly on lab computers	Dr. Siewerdsen
Validation Data	Use cadaver ankles at Carnegie as test	Use phantom model ankles	Dr. Siewerdsen
Feedback from Mentors	Meet with mentors at lab, every friday between 3 - 5 pm	Communicate via email and schedule meeting times outside of standing meeting times	Dr. Siewerdsen and Dr. Zbijewski
Imaging Libraries	Utilize already established MATLAB packages (Image Processing Toolbox, Computer Vision Toolbox, Robotics System Toolbox)	N/A	Solved
DL Libraries	Utilize already established Python packages (Tensorflow, PyTorch)	N/A	Solved
Version Control	Utilize GitHub to backup code and data	Store data and code in a backup hard drive	Solved

# Schedule of Activities

 Asef  Jay  Tony



# Reading List

1. Coupled Active Shape Models for Automated Segmentation and Landmark Localization in High-Resolution CT of the Foot and Ankle (Brehler)
2. Coupled Multi-Bone Active Shape Model of the Foot and Ankle (Brehler)
3. Risk factors for post-traumatic osteoarthritis of the ankle: an eighteen year follow-up study (Lubbeke)