

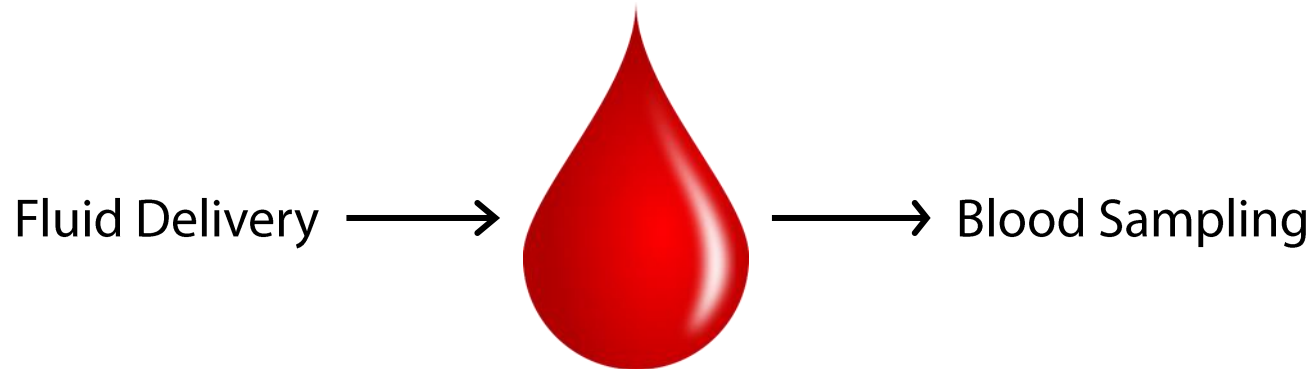
An Autonomous Robotic System for Rapid Blood Draws and Analysis

Max L. Balter, Alvin I. Chen, Timothy J. Maguire, and Martin L. Yarmush
Rutgers University, Piscataway, NJ, USA

Most common medical routine performed in the world

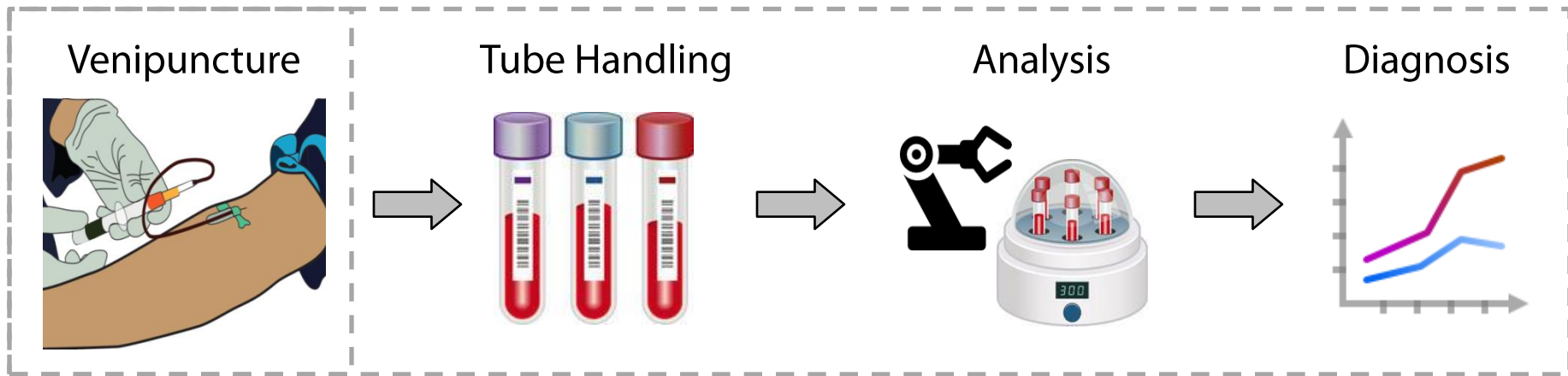
9/10 patients admitted to the hospital require venipuncture^[1]

1.2B venipunctures per year in the U.S.^[2]



Critical to the diagnosing, monitoring, and treatment of diseases

Medical Robots | Diagnostic Testing Integration



#1 Cause of Patient Injury^[3]
- 1B failed sticks per year



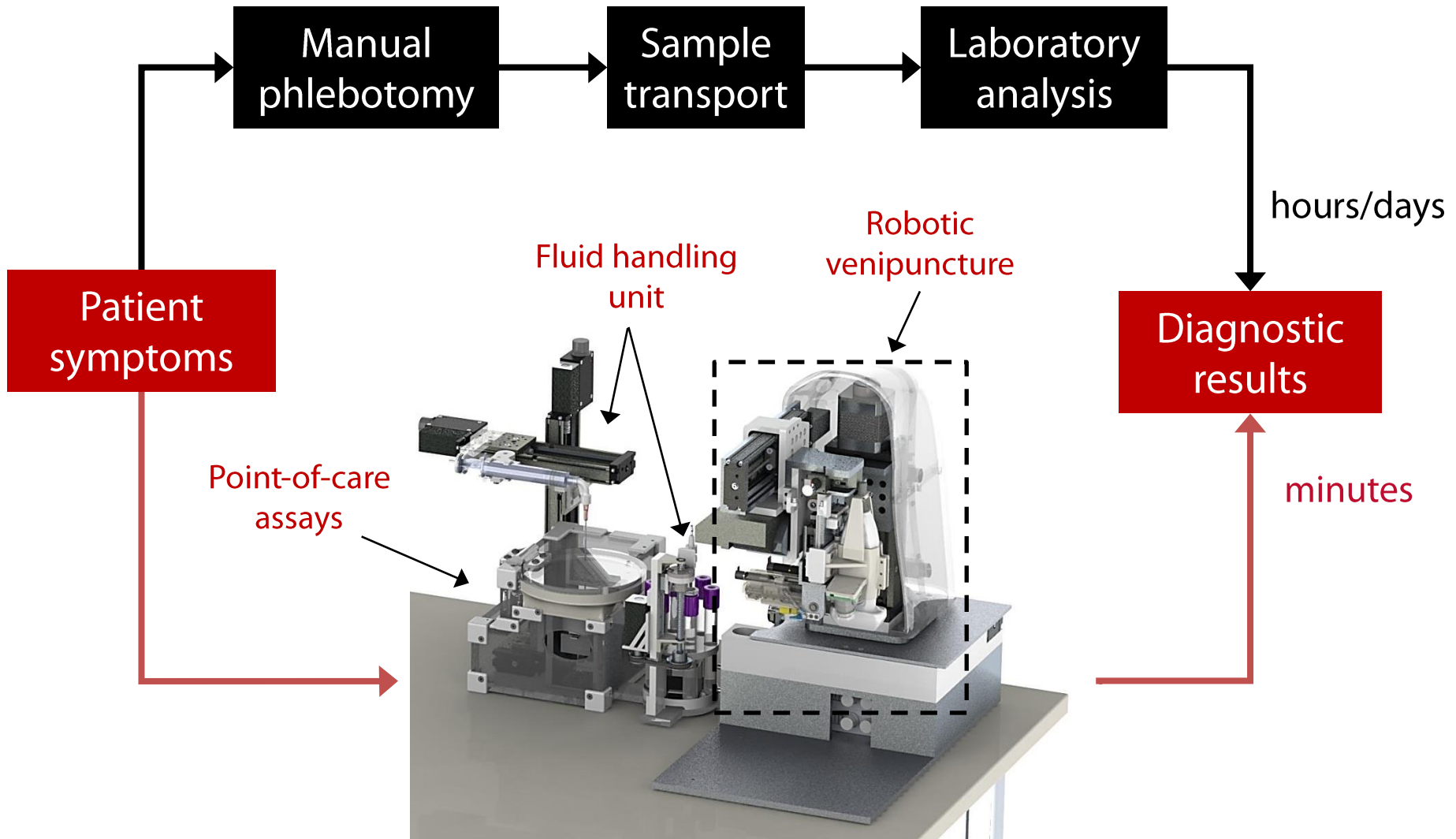
#1 Cause of Clinician Injury^[4]
- 1M sharps injuries per year



\$5B / Yr in Costs due to Difficult Venipuncture^[5]

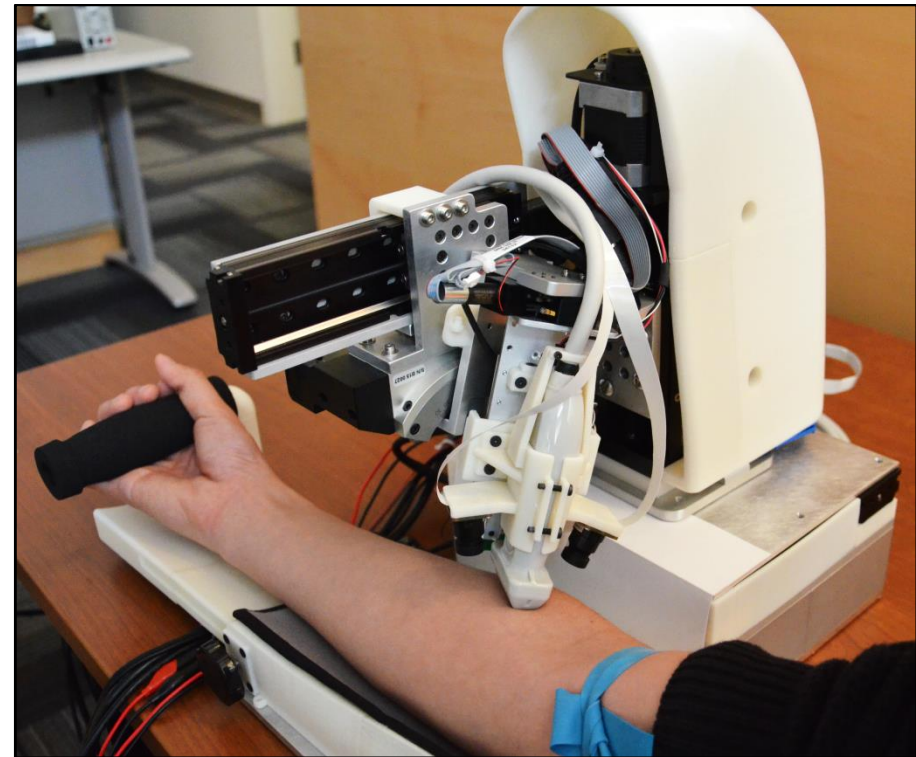
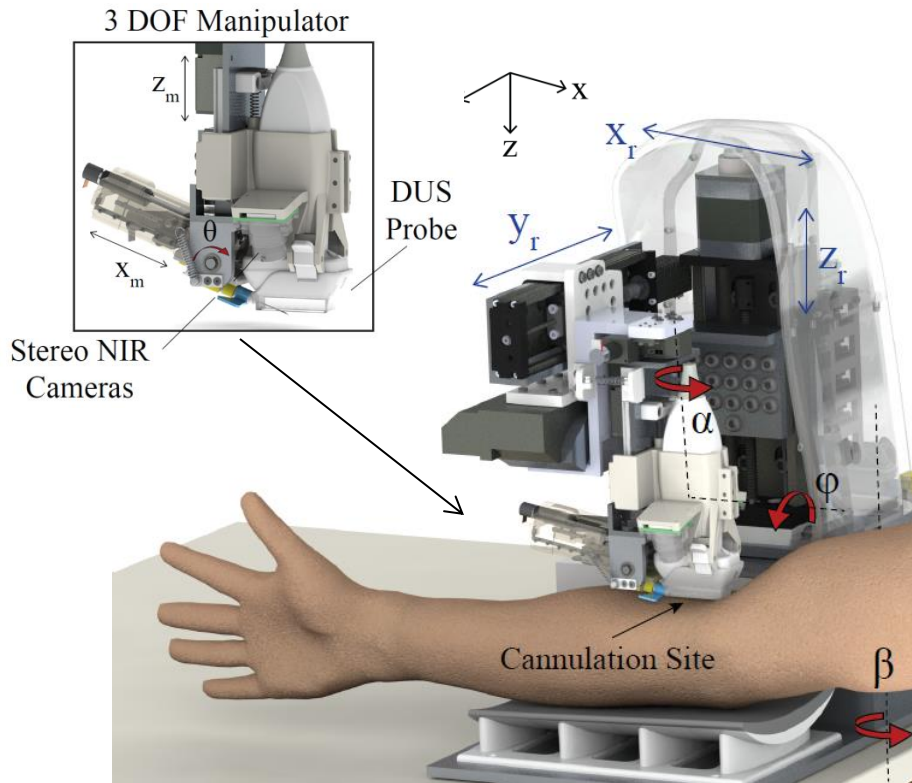


Blood Draw & Analysis Device | Rapid Diagnostic Testing



Venipuncture Robot | The VenousPro™

A portable, image-guided medical robot that improves the quality, safety, and cost-effectiveness of venous access in a fully automated fashion



Graphical User Interface | Clinical Protocol

This venipuncture is for
Sam's check-up.

Two samples will be drawn
for Hct and WBC.

Prep for procedure

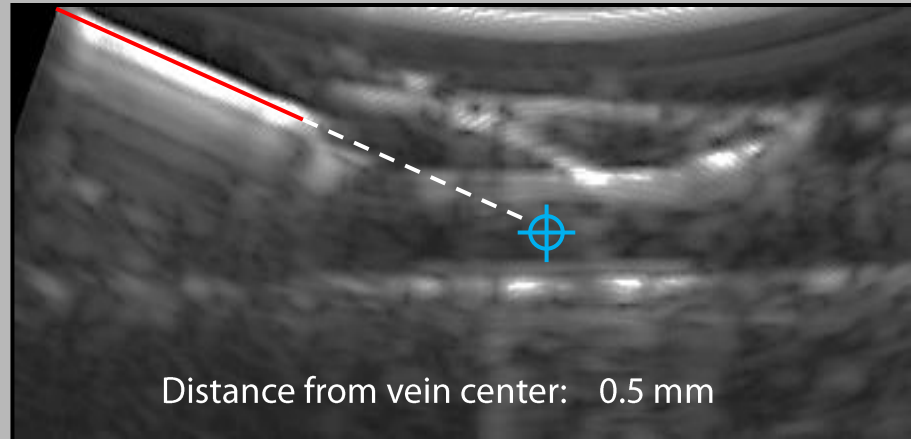
Scan and select vein

Confirm with Doppler

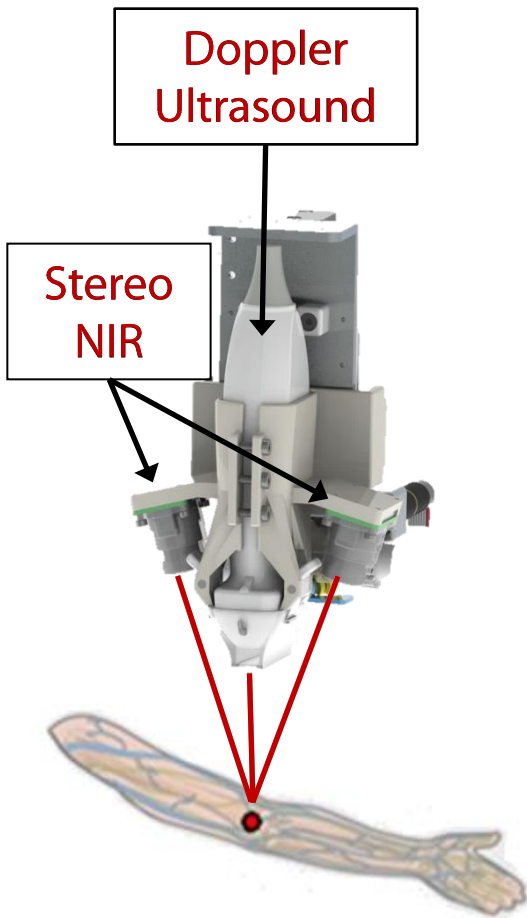
Place cannula

Collect samples

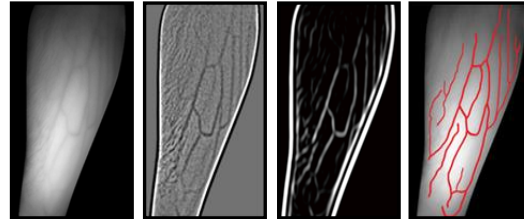
Track needle tip in ultrasound image:



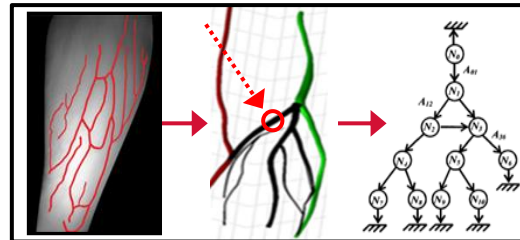
Bimodal Imaging | Near-infrared & Ultrasound



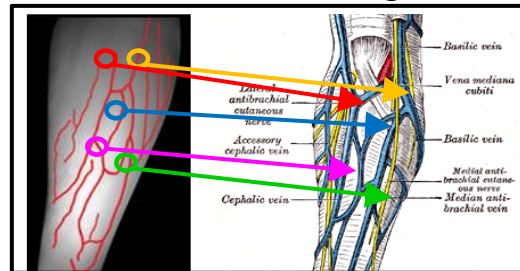
3D Near IR
(Coarse imaging)
Vein Segmentation



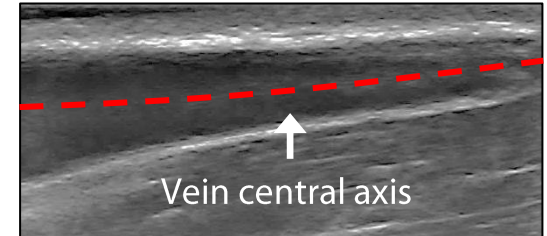
3D Stereo Reconstruction



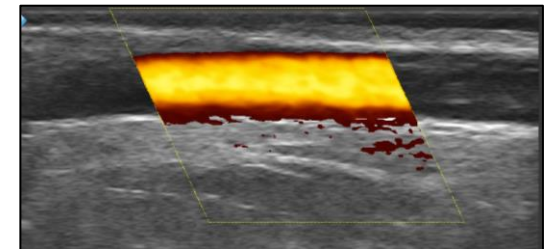
Vein Structure Recognition



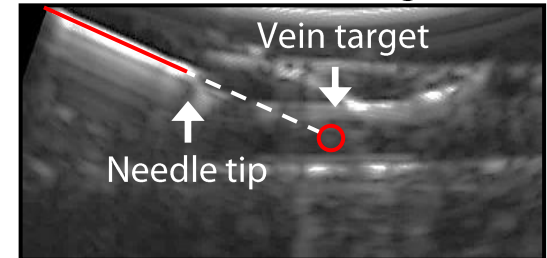
Ultrasound
(Localized imaging)
Vessel Wall Tracking



Blood Flow Detection

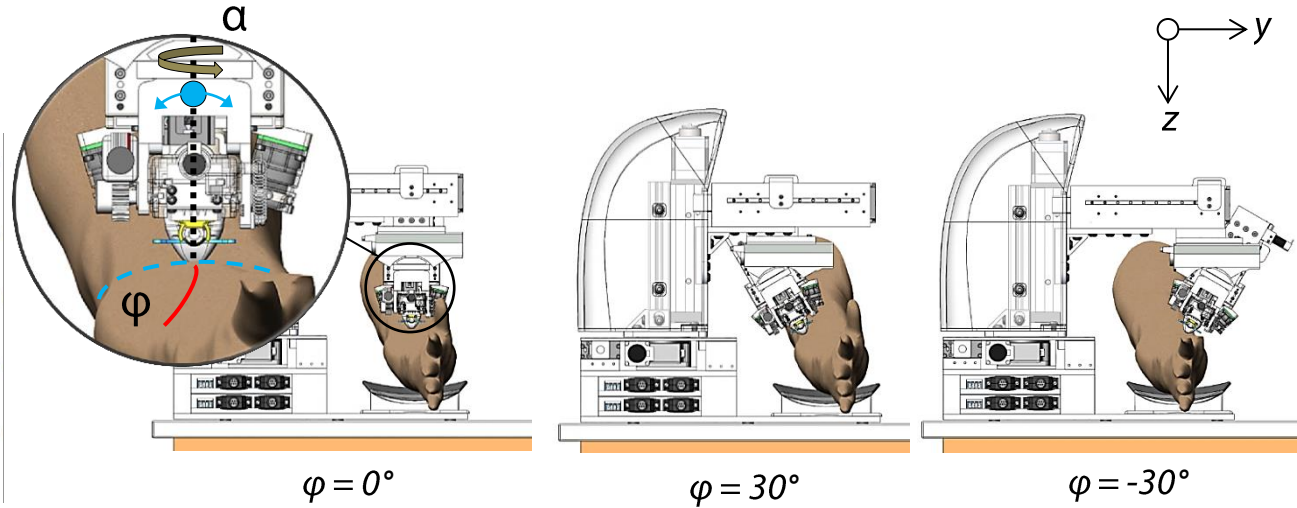
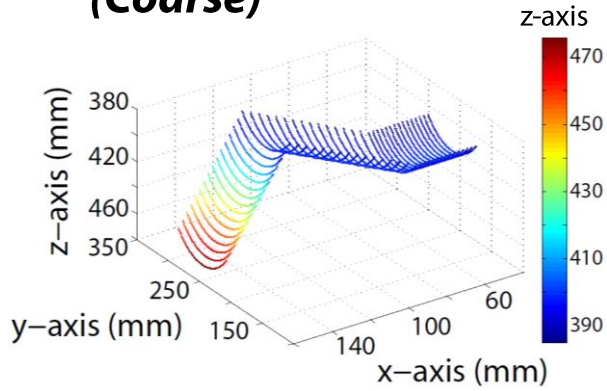


Needle Tracking

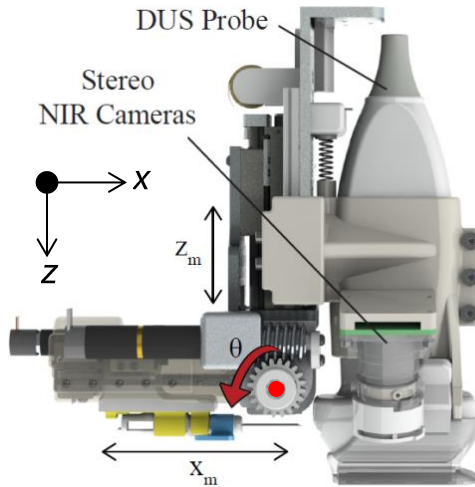
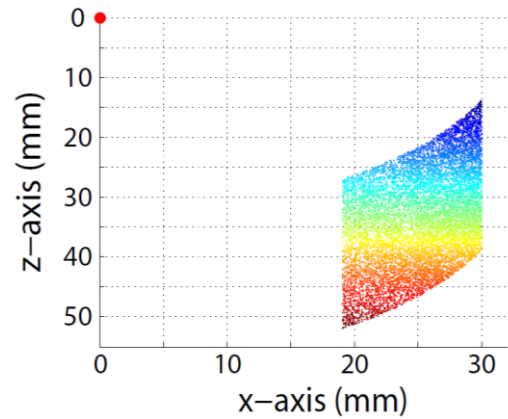


Robotic System | Gantry & Manipulator

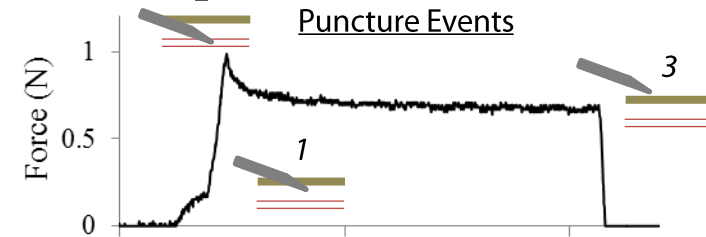
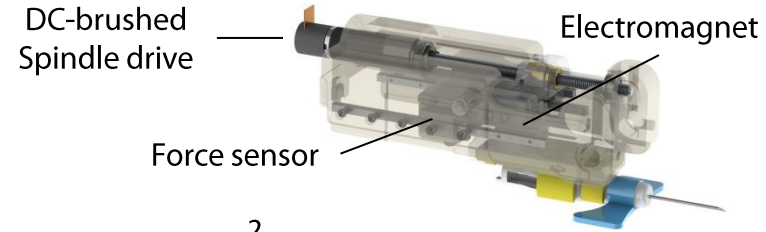
Base Positioner (Coarse)



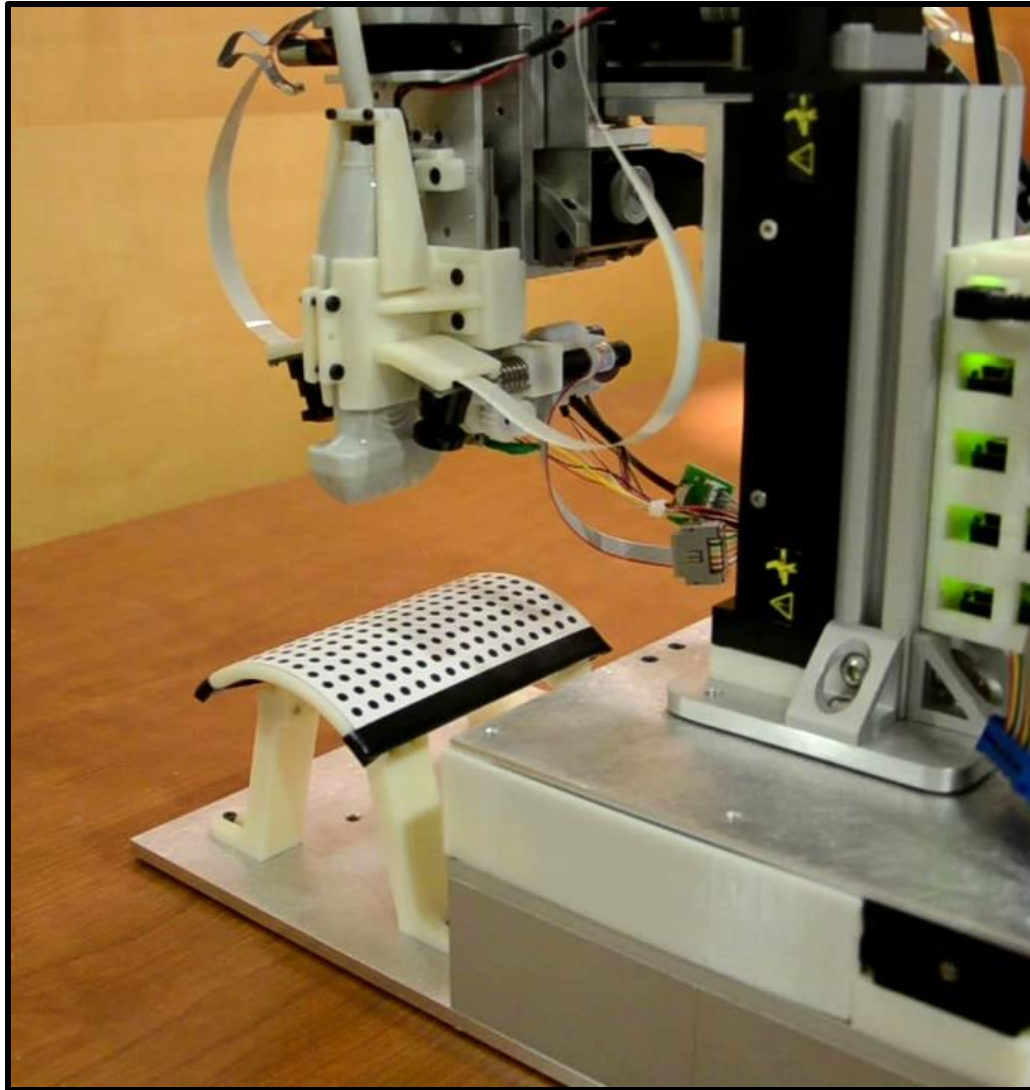
Manipulator (Localized)



Needle Insertion Mechanism



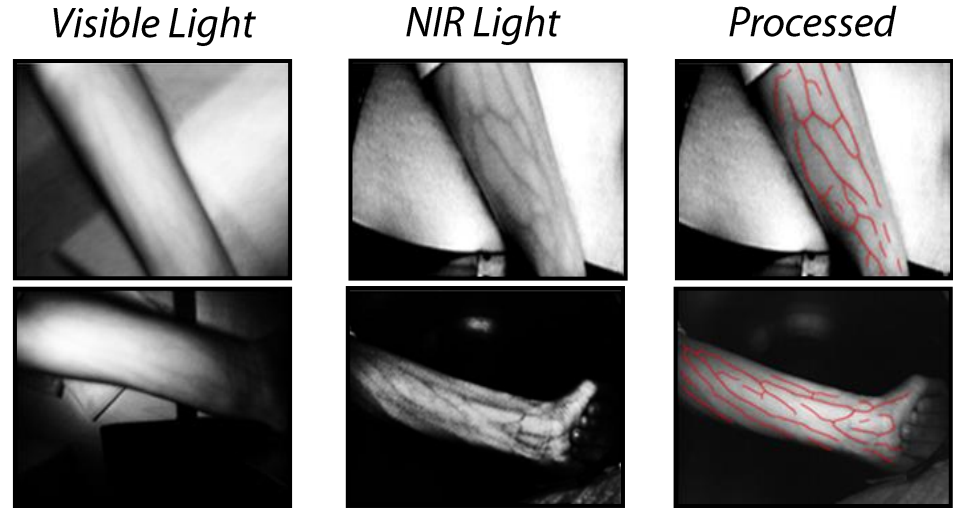
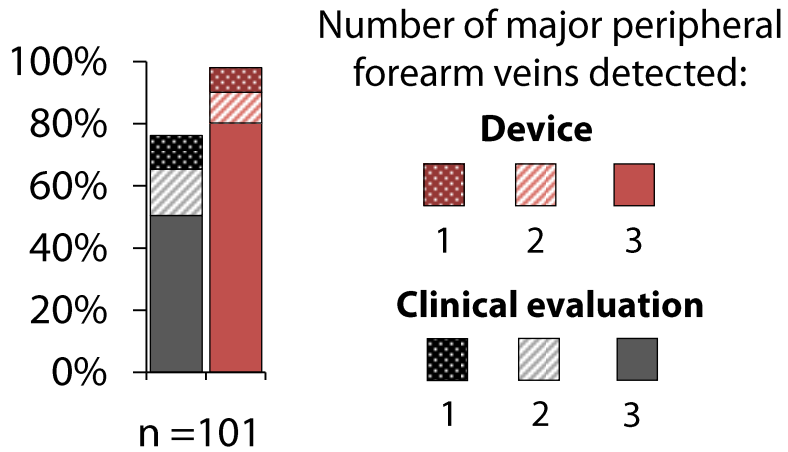
Robotic System | Motion Testing



4.5x Speed-up

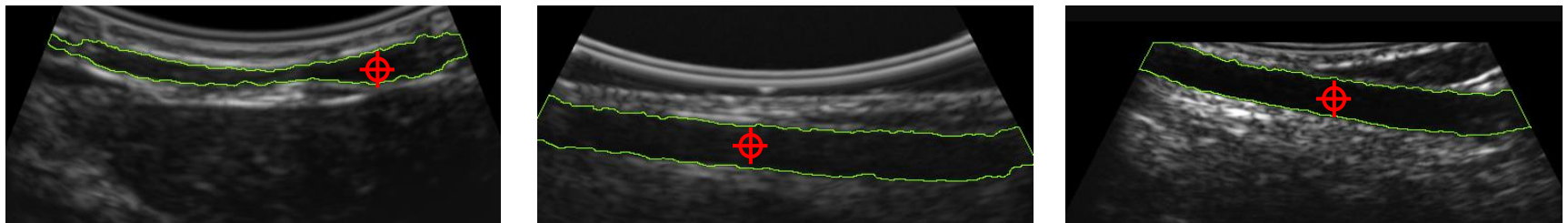
Venipuncture Device | Imaging Experiments

Human NIR-Imaging Study – compare NIR vs. visible light vein imaging



Chen et al, *Technology* 01(01), 2013

Human US-Imaging Study – evaluate the sensitivity/specificity of vein segmentation



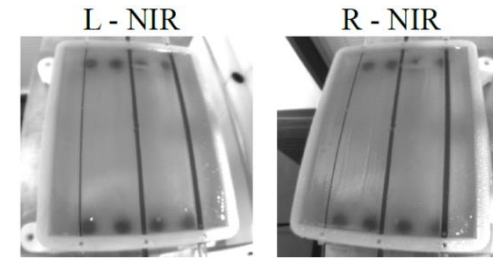
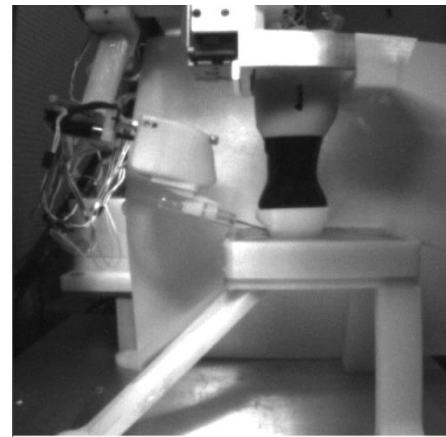
Balter et al, *Medical Image Analysis* (in prep)

Venipuncture Device | Cannulation Testing

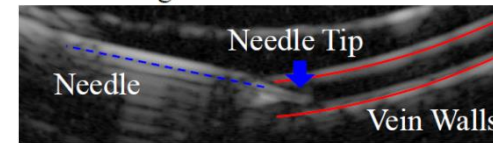
In vitro Studies – evaluate the cannulation accuracy and precision of the robot

Experimental Protocol:

- Scan surrogate veins under 3D NIR
- Select insertion site
- Lower US probe and track vein center
- Introduce cannula at 15° angle

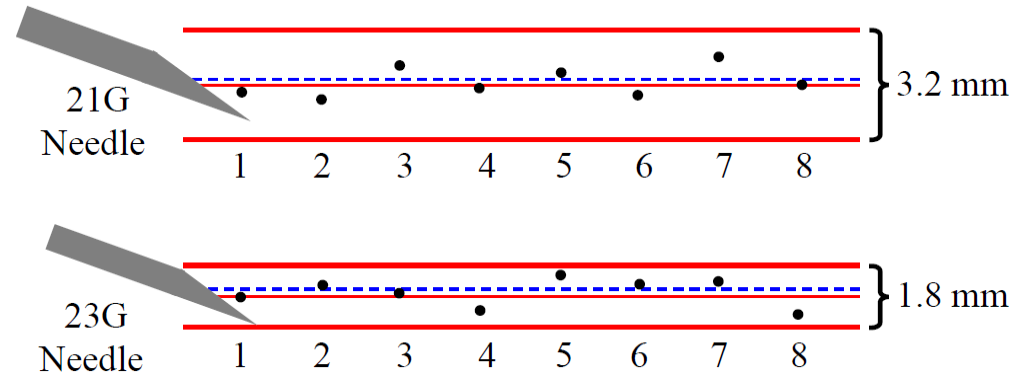


Longitudinal B-mode US



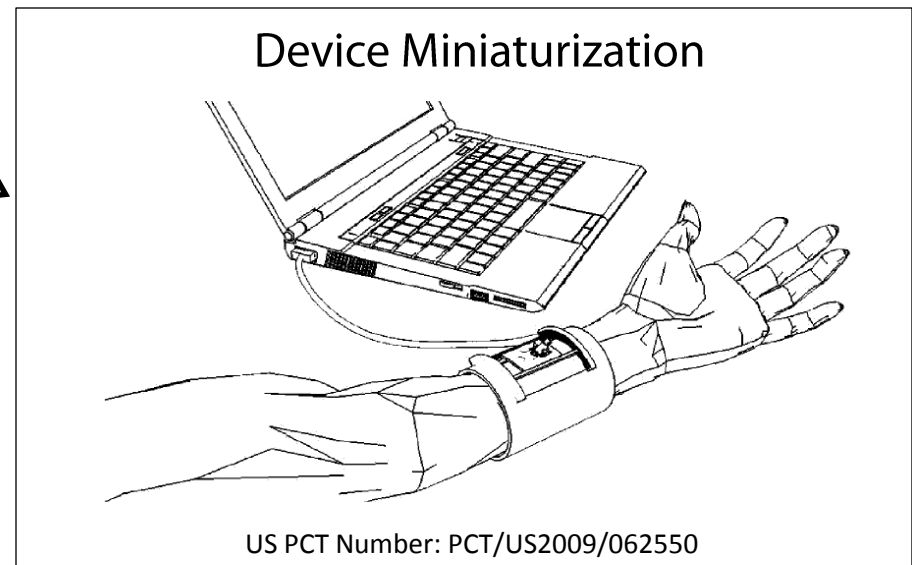
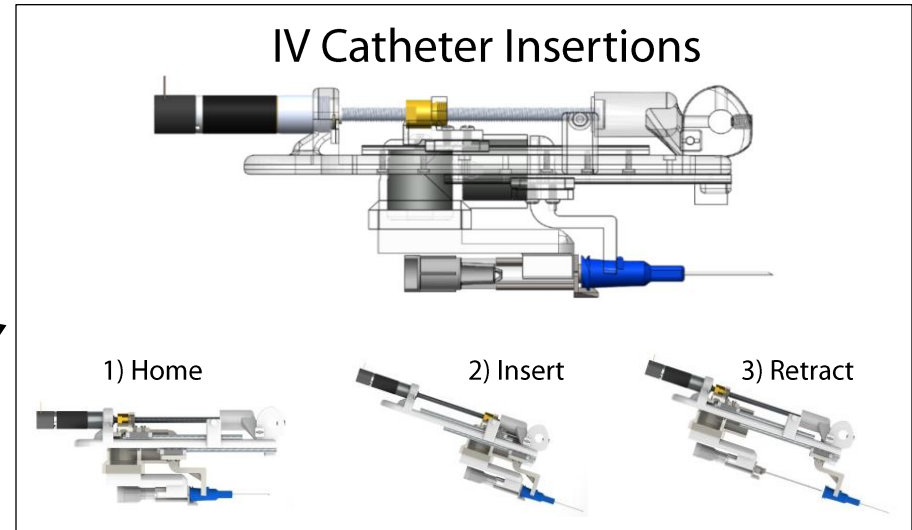
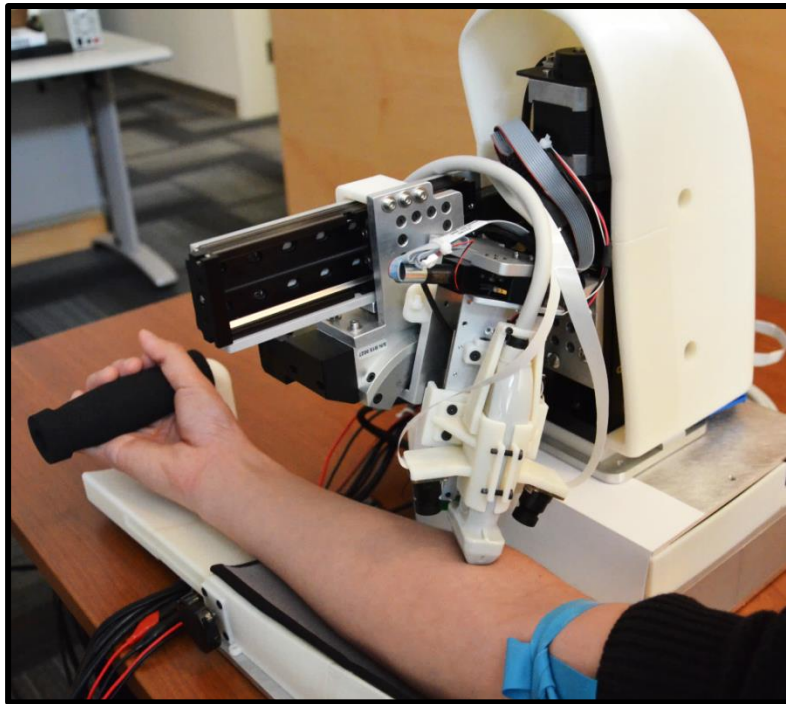
Results:

- 16 trials; 100% first-stick success
- RMS errors:
 - 0.3 ± 0.2 mm - $\varnothing 3.2$ mm vein
 - 0.4 ± 0.2 mm - $\varnothing 1.8$ mm veins



Balter et al, *IEEE Transactions on Robotics* 31(4), 2015

Future Directions | Extend Clinical Functionality



Acknowledgments

Alvin Chen



Dr. Tim Maguire



Dr. Martin Yarmush



NIH R01: Award: EB020036

NSF SBIR Ph I: Award: 1448550

NSF GRF: Award: DGE-0937373

NIH F31: Award: EB018191

NIH: Award: T32 GM008339

NI Med Device Grant

