

Co-Robotic Ultrasound Imaging of Breast Assisting Mammography

Computer Integrated Surgery II
Spring, 2022

Julian Brown, Yuxin Chen, and Kevin Wang under the auspices of Professor Emad Boctor, Professor Russel Taylor, Professor Web Stayman, and Yixuan Wu

Introduction

Goal: To develop an algorithm for the autonomous acquisition of breast lesion ultrasound (US) images during a mammography screening.

Significance: Ultrasound data will augment the data collected by a mammogram, reducing the frequency of return visits.

The Problem

- After receiving a mammogram, around **6 million** patients are called back for US scans each year, despite only **350,000** patients actually being diagnosed. **94% False Positive Rate**

The Solution - Overview

- Ultrasound imaging in combination with X-Ray imaging has been shown to increase the accuracy of breast cancer screenings.
- A robotic system to acquire US images would make the mammography screening process more efficient without the need for additional US technicians.

The Solution - Calibration

- Camera Calibration**
 - Got rid of distortion on the image edges
- Hand Eye Calibration**
 - found T_{ES} by using Aruco Marker and solving an $AX=XB$ problem
- Ultrasound Calibration**
 - found T_{EU} by using a cross wire Phantom and solving a BXp problem

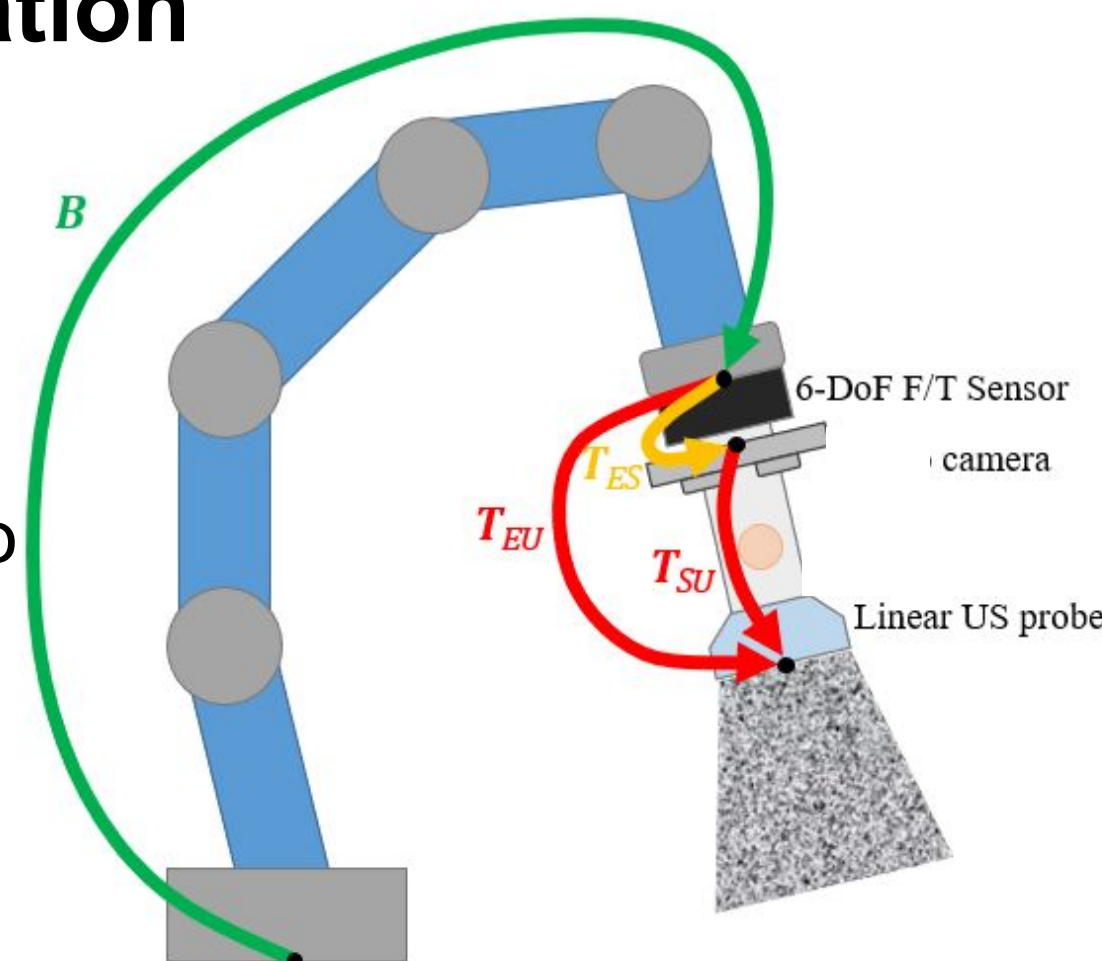


Figure 1: Transformations on setup

The Solution - Motion Planning

- Path Planning** to arrive at inputted lesion locations.
- Force based motion** applies appropriate pressure for ultrasound acquisition.
- Automated “wobble” motion** captures ultrasound images of a lesion at multiple angles.

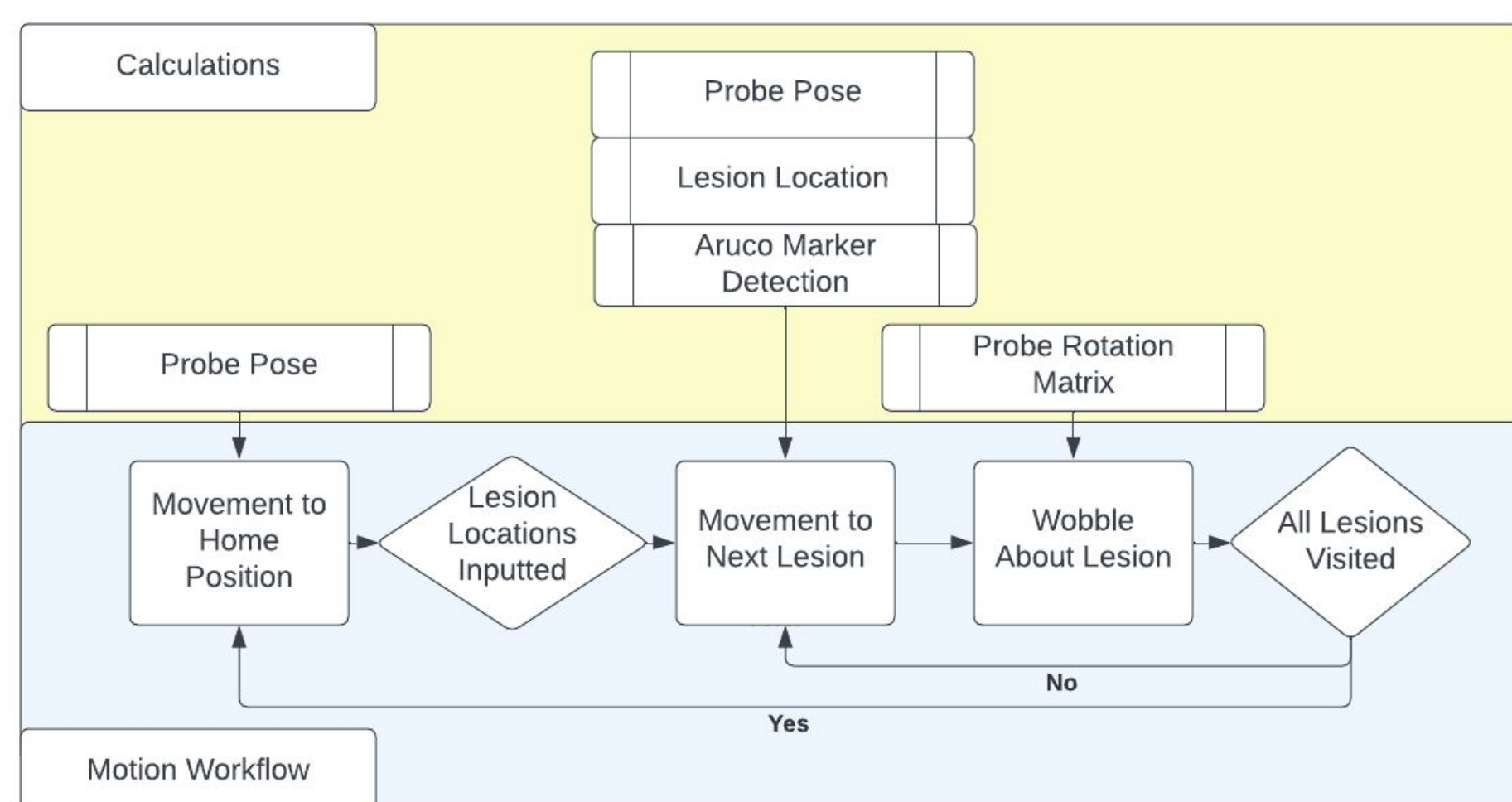


Figure 2: Co-Robotic Ultrasound Mammography Ultrasound Acquisition Workflow

Publications

- H. K. Zhang, A. Cheng, Y. Kim, Q. Ma, G. S. Chirikjian, and E. M. Boctor, “Phantom with multiple active points for ultrasound calibration,” Journal of Medical Imaging, vol. 5, no. 04, p. 1, 2018.
- F. Aalamifa, “Co-robotic Ultrasound Tomography: A New Paradigm for Quantitative Ultrasound Imaging”, Dept. of Electrical and Computer Engineering, Johns Hopkins University, Baltimore, US, 2016, [Online]. Available: <https://jscholarship.library.jhu.edu/handle/1774.2/40409>

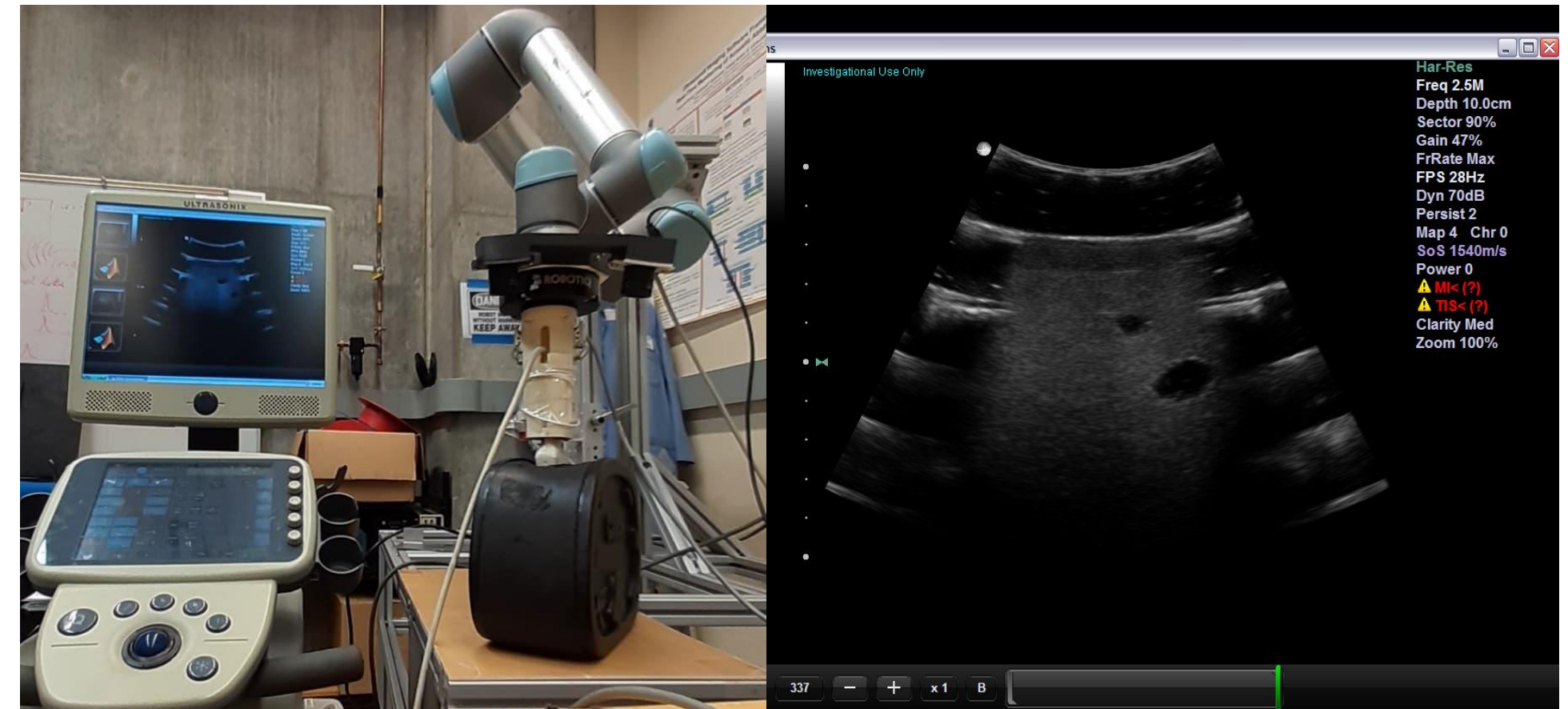


Figure 3: Ultrasound Data Collected by UR5 Robot

Outcomes and Results

- Calibrated camera and ultrasound probe to UR5 robot
 - Achieved accurate transformations from the frame of the end-effector of UR5 to the camera frame and to the ultrasound probe frame
- Designed workflow for robotic ultrasound acquisition
 - ROS, RViz, and MoveIt integrated with C++ to create workspace, constraints, and motion paths for UR5 robot
 - Robotiq 6-DoF FT-150 Sensor used to control force applied to US probe during testing
 - Movement to lesion and “wobble” motion paths

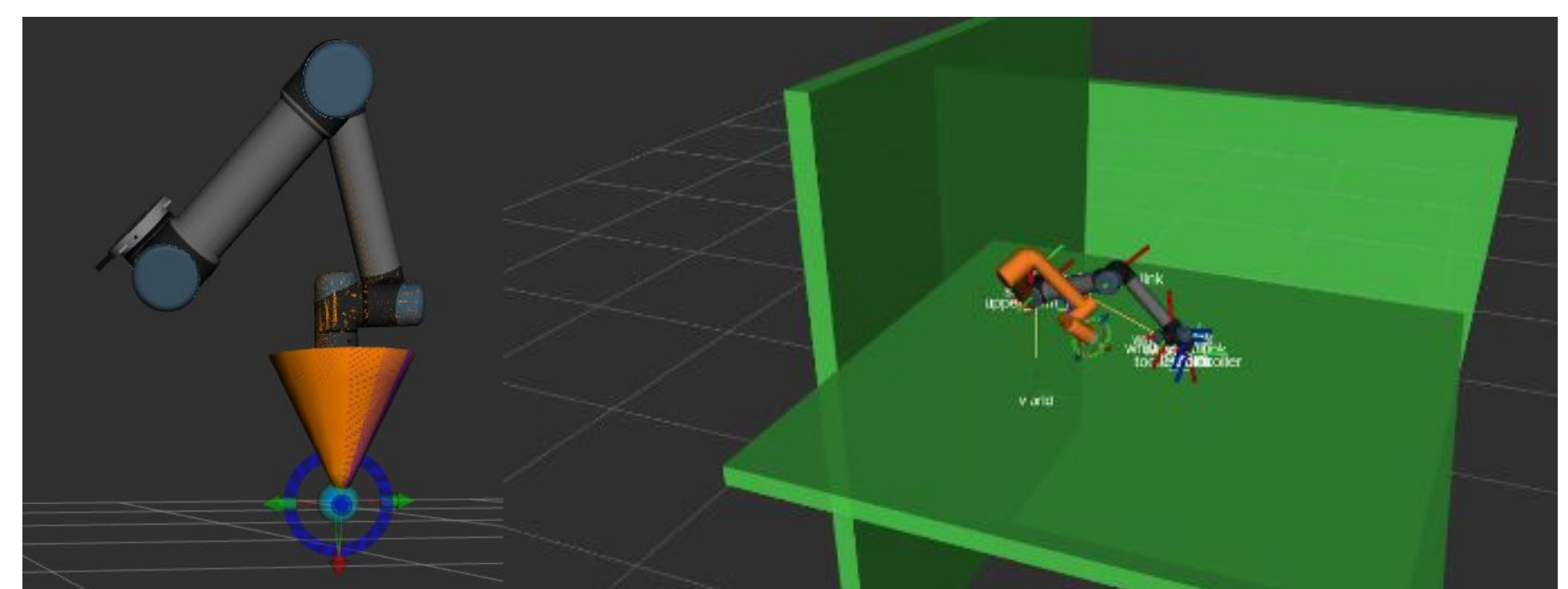


Figure 4: Virtual Robot Model and Workspace Used for Path Planning (Bounding Boxes Removed for Visualization)

Future Work

- Kevin and Yuxin will continue work over the summer.
- Improve consistency of motion planning algorithms.
- Automate control of Ultrasonix ultrasound imaging computer system.
- Modify camera location for real time motion planning.
- Deep learning based lesion detection.

Lessons Learned

- Applied the camera calibration, hand eye calibration and ultrasound calibration in realistic problem.
- Interface with UR5 using R-Viz and MoveIt to plan robot trajectories and control a UR5 in cartesian space.
- Teamwork skills and experience.

Credits

- Yuxin(Ethan) led the camera calibration, hand-eye calibration, and ultrasound calibration.
- Kevin led the development of the robot workspace and motion planning algorithms.
- Julian designed the user interface for the inputting of lesion site locations and augmented the motion planning with force sensing capabilities.

Support by and Acknowledgements

- Thank you to each of our mentors, Dr. Boctor, Dr. Taylor, Dr. Stayman, and Yixuan, for their support and guidance!

