Co-Robotic Ultrasound Imaging of Breast Assisting Mammography

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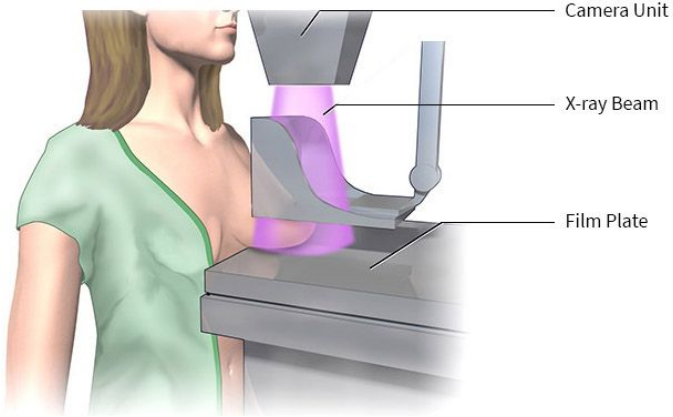
Mentors: Dr. Emad Boctor, Dr. Web Stayman, Dr. Russell Taylor, Yixuan Wu

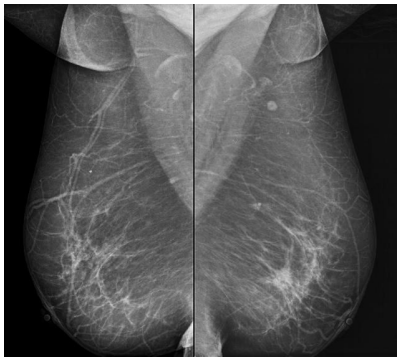
Outline

1. Background
    - Significance
    - Combined X-ray and Ultrasound
    - Vision/Gap
2. Technical Approach
    - Current Status
    - Calibration
    - Robot Motion
    - Deliverables
3. Logistics
    - Dependencies
    - Timeline/Milestones
    - Project Management
    - Reading List

Issues with Mammography

- Mammography is a screening for breast cancer using X-Ray imaging.
- Over 40 million examinations performed in the US per year.
- Around 6 million patients (15%) are called back to the office.
- Around 350,000 patients (0.008%) are actually diagnosed with breast cancer per year

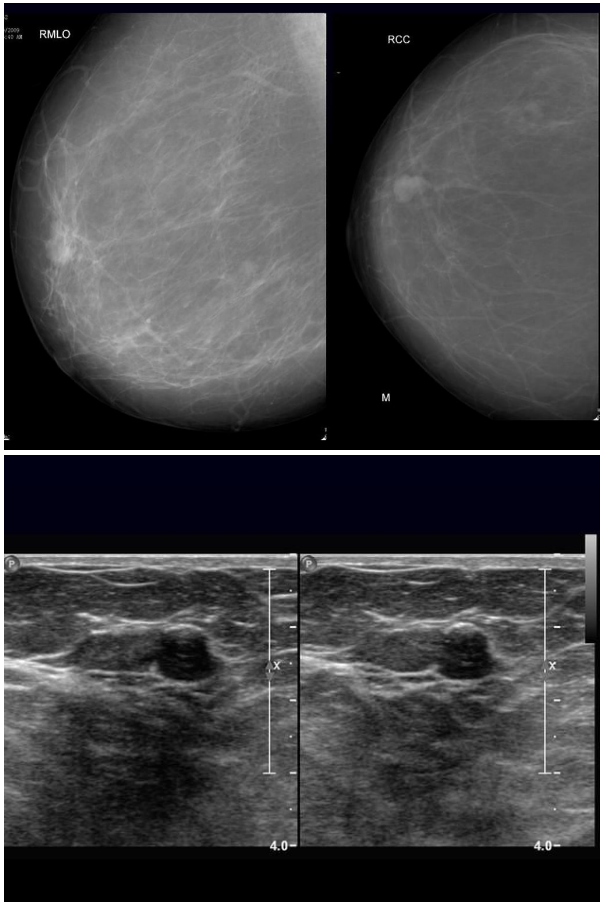




https://gangabreastcare.com/mammography.php
https://www.cdc.gov/cancer/breast/basic_info/screening.htm
https://www.cancer.net/cancer-types/breast-cancer/statistics#:~:text=More%20women%20are%20diagnosed%20with,(in%20situ)%20breast%20cancer.
https://radiopaedia.org/articles/breast-imaging-reporting-and-data-system-bi-rads?lang=us

X-Ray + Ultrasound Imaging

- Mammography is highly specific, but lacks sensitivity
- Ultrasound is highly sensitive, but lacks specificity
- Diagnostic accuracy in screenings increases from 0.78 to 0.91 when both Mammogram and Ultrasound are performed (Berg et al.)



M

US

https://radiopaedia.org/cases/birads-iv?lang=us

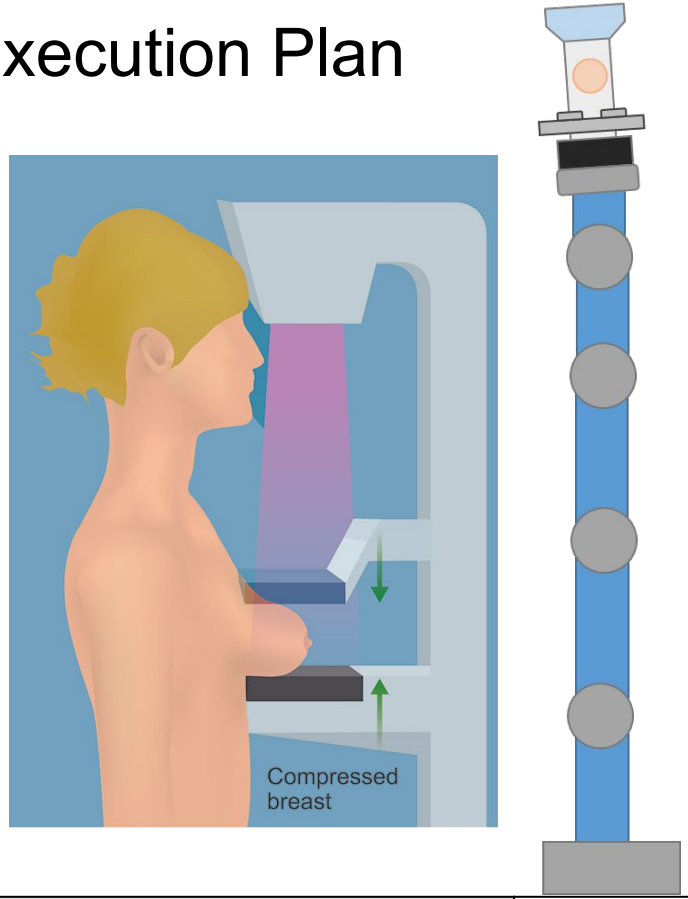
Why Robotics?

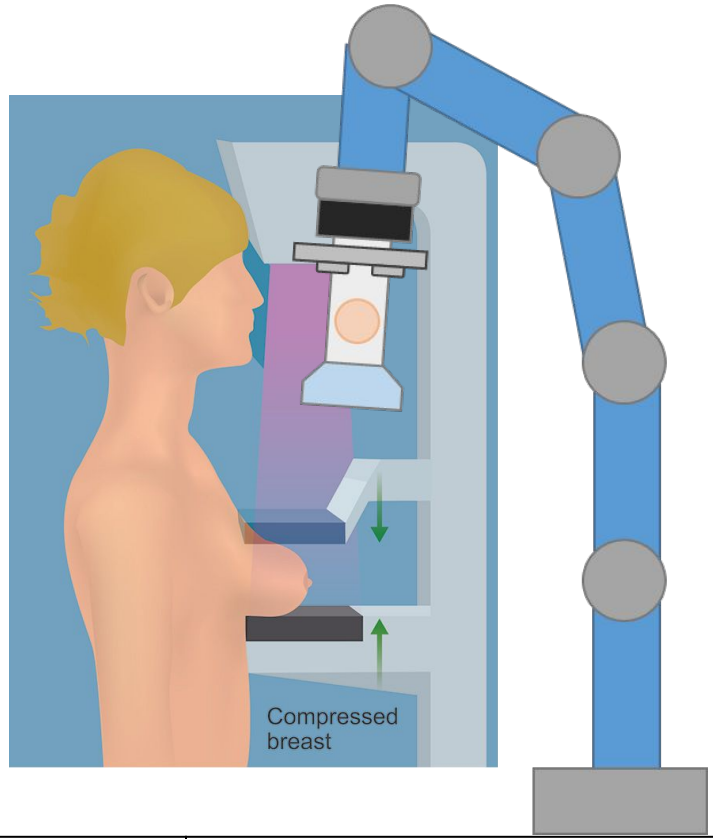
- Logistics
  - 46 million mammograms conducted per year
  - US requires dedicated ultrasound technician to conduct US
- Procedure Replication
  - Registration
- Privacy

Problem Statement

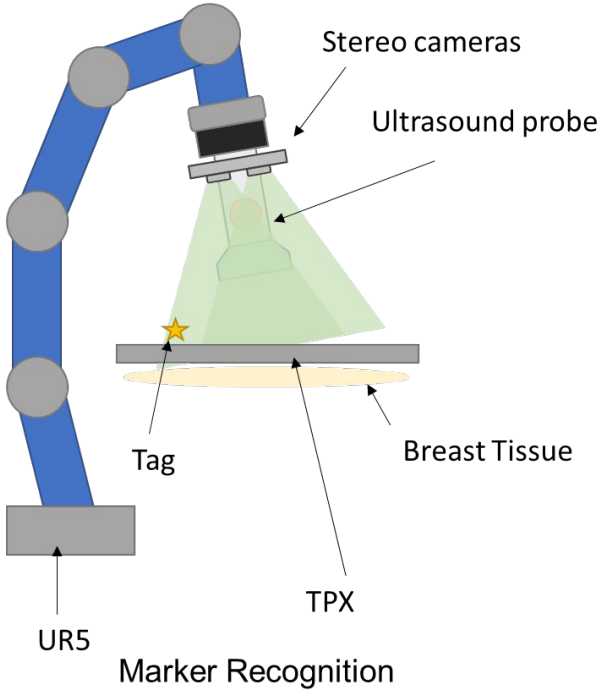
- A way to sensitively and specifically collect breast tissue scans robotically, in routine breast disease checkups, in order to minimize false positive flags.

Execution Plan

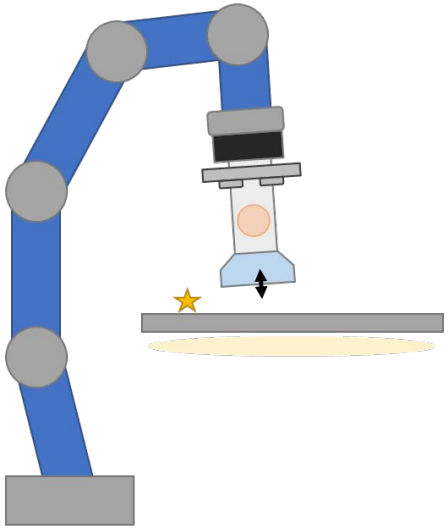




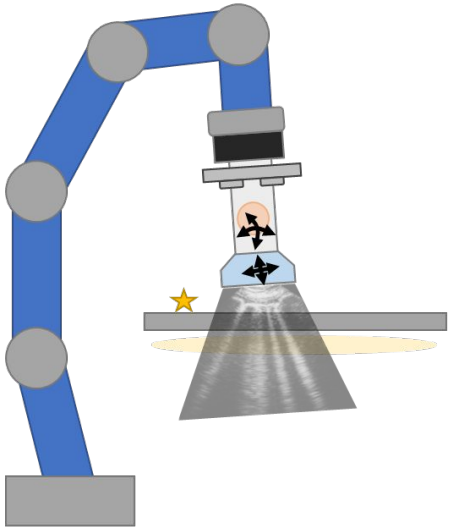
Execution plan



Marker Recognition



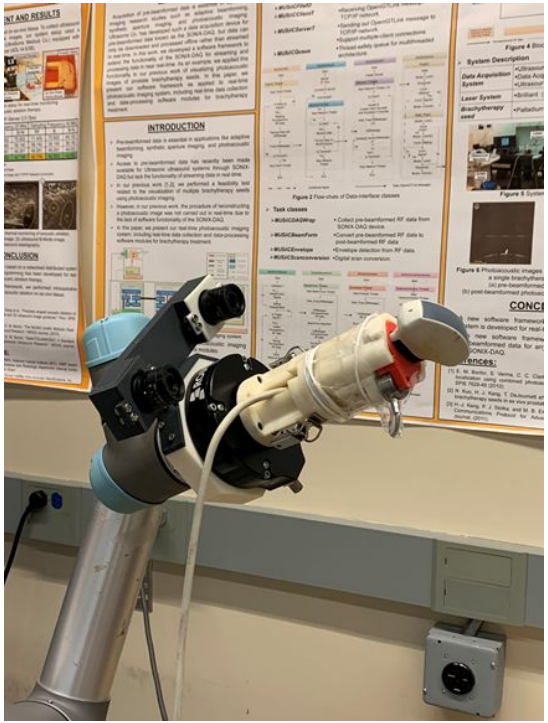
Motion to Region of Concern



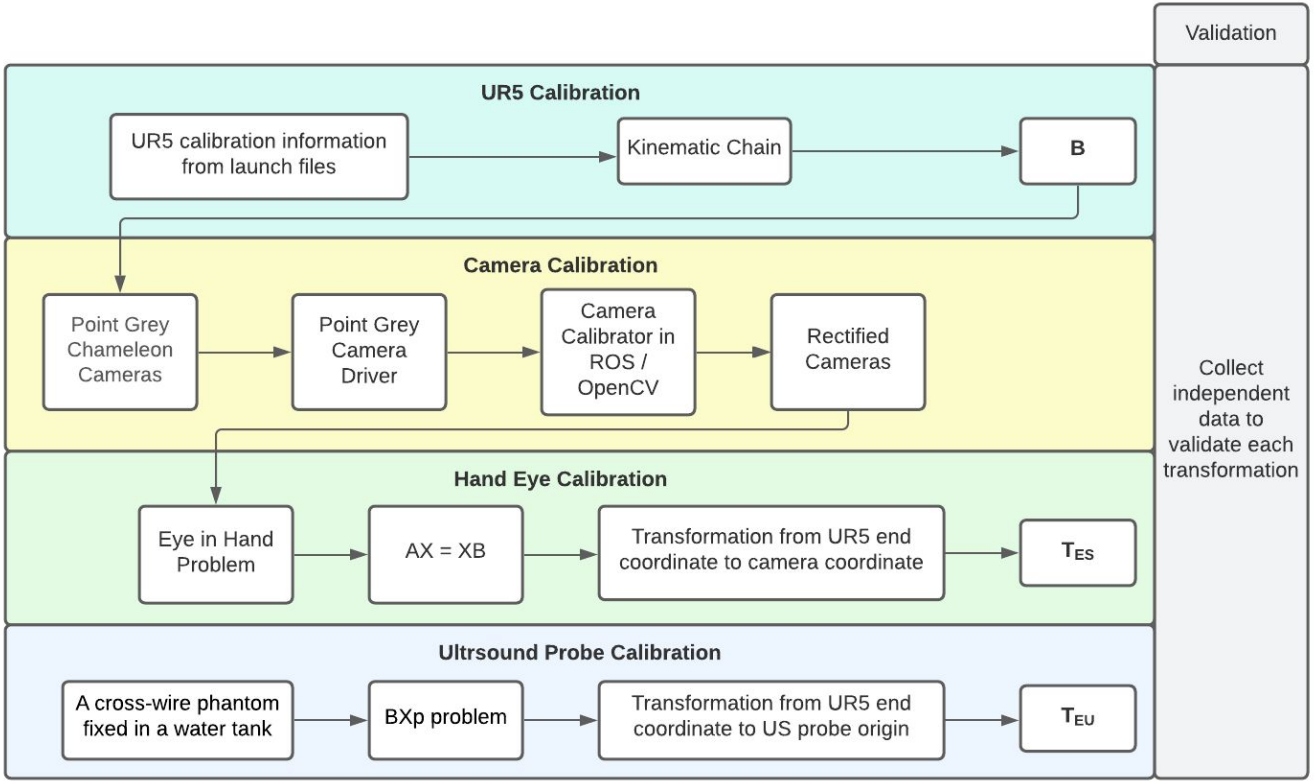
Ultrasound Image Acquisition

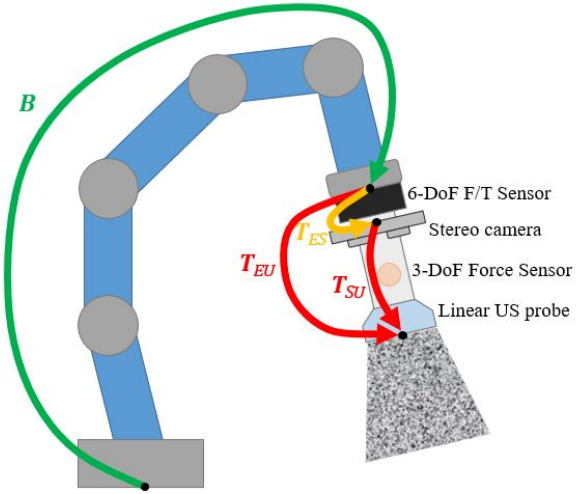
Technical Approach - Current Status

- End-Effector has been completed
  - Two Point Grey Chameleon Cameras
  - 6-DOF Robotiq Force Sensor
  - Ultrasound Probe
- Hand-Over-Hand control completed from another project



Calibration





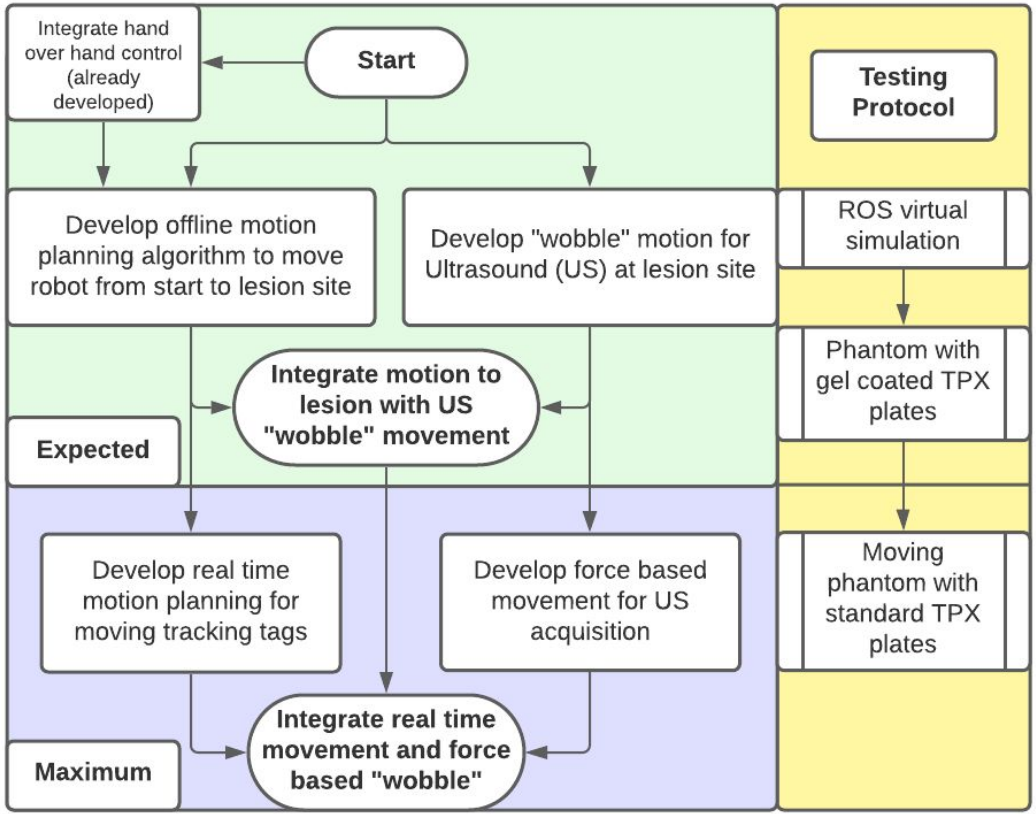
Technical Approach
Robot Motion

Required Movement

1. Hand over hand control to start position
2. Movement from start to lesion site
3. Movement about lesion for Ultrasound volume

Approaches

1. Offline approach
2. Real time planning
3. Motion with force sensing



Deliverables

Minimum:

- Calibration of the robotic arm.
- Setup of the imaging validation and tests.
- Hand-over hand control of the robot (already developed but needs to be integrated)
- Simple motion planning to land the ultrasound probe on a specific location on the compression plate. Offline (open loop) control, directing ultrasound probe to lesion from target.

Expected:

- A real-time interface to acquire stereo camera and ultrasound images.
- With the developed real-time interface, demonstrate automatic ultrasound acquisition of a region of interest (whole lesion) with a known location with respect to the tracking tag on the compression plate.
- Documentation

Maximum:

- Demonstrate dynamic and real-time adaptation as the tracking tags move.
- Force control of the robot arm to ensure safety.
- Integration and registration with a second modality (Mammography, CT, or preoperative 3D ultrasound).

Dependencies

Dependency	Domain	Status	Backup
Linux System	Motion Planning	Acquired	Wyman computer lab
ROS	Motion Planning & Computer Vision	Acquired	Wyman computer lab
OpenCV	Computer Vision	Acquired	ROS package
Hand over hand code integration	Software environment	Acquired	Rewrite the code
Mentor Availability	All	Acquired but subject to change	Communication and planning

Dependency	Domain	Status	Backup
UR5 Robot	Motion Planning	Acquired	ROS Simulation
Two Point Grey Chameleon Cameras	Motion Planning	Acquired	ROS Simulation
6 DoF Force Sensor	Force Sensing	Acquired	ROS Simulation
Ultrasound Probe	Ultrasound Imaging	Acquired	Path planning without US acquisition
TPX plates	Ultrasound Imaging	Acquired	Purchase and construct
Acoustic Gel	Ultrasound Imaging	Acquired	Purchase
Cross Wire Phantom	Ultrasound probe calibration	Required	Build by ourselves

Timeline

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dates	1/24 - 1/29	1/31 - 2/4	2/7 - 2/11	2/14 - 2/18	2/21 - 2/25	2/28 - 3/4	3/7 - 3/11	3/14 - 3/18	3/21 - 3/25	3/28 - 4/1	4/4 - 4/8	4/11 - 4/15	4/18 - 4/22	4/25 - 4/29	5/2 - 5/6	5/9 - 5/13
Intro	Intro															
Plan Presentation		Plan Presentation														
Project Proposal		Project Proposal														
Checkpoint										CP						
Hand-Eye Calibration		Hand-Eye Calibration														
Hand-Over-Hand Integration						H-o-H										
Motion Planning						Motion Planning										
Testing												Testing				
Demo														Demo		
Final Report															Final Report	
Final Presentation															Final Presentation	
CIS II Coursework																
Lab work																

Milestones:
Calibration and H-o-H Integration (3/4), Motion Planning and Testing (4/22), Demonstration Complete (4/29)

Management Plan

- Setting up weekly project meeting with mentors: Yixuan, Dr. Boctor, Dr. Taylor, Dr. Stayman
- Weekly team meeting for progress updates
- Code Management by Github
- Other documentation uploaded to google drive

Yuxin(Ethan)	**Julian**	**Kevin**
Camera set-up & Camera Calibration	UR5 Calibration	
Hand Eye Calibration		Imaging (US integration, potential other modalities)
Ultrasound Probe Calibration	Hand-Over-Hand Integration	
Robot Motion Planning		

Reading List

- Wendie, A., Berg, M. D., & Jeffrey, D. (2008). Combined Screening with Ultrasound and mammography compared to mammography alone in women at elevated risk of breast cancer: results of the first-year screen in ACRIN 6666. *JAMA*, *299*(18), 2151-2163.
- Buist, D. S., Porter, P. L., Lehman, C., Taplin, S. H., & White, E. (2004). Factors contributing to mammography failure in women aged 40–49 years. *Journal of the National Cancer Institute*, *96*(19), 1432-1440.
- LaValle, S. M. (2006). *Planning algorithms*. Cambridge university press.
- Gilboy, K. M., Wu, Y., Wood, B. J., Boctor, E. M., & Taylor, R. H. (2020). Dual-Robotic Ultrasound System for In Vivo Prostate Tomography. In Medical Ultrasound, and Preterm, Perinatal and Paediatric Image Analysis (pp. 161-170). Springer, Cham.
- Aalamifar, F. (2016). Co-robotic ultrasound tomography: a new paradigm for quantitative ultrasound imaging (Doctoral dissertation, Johns Hopkins University).
- Zhang, H. K., Cheng, A., Kim, Y., Ma, Q., Chirikjian, G. S., & Boctor, E. M. (2018). Phantom with multiple active points for ultrasound calibration. Journal of Medical Imaging, 5(4), 045001.

Questions?

Reading List

- Combined Screening with Ultrasound and Mammography Compared to Mammography Alone in Women at Elevated Risk of Breast Cancer: Results of the First-Year Screen in ACRIN 6666 (Berg et al.)
- Factors Contributing to Mammography Failure in Women Aged 40–49 Years (Buist et al.)
- Steven M. LaValle, Planning Algorithms. Cambridge University Press, 2006

Notes from class

- Impacts if dependencies arent hit
- Backup plan
- Emphasize milestones and timeline
- Show info flow and architecture
- **System block diagram**
- Number slides
- Running outline on bottom of slide
- Provide outline at start of presentation
-

Around 12(10) min
Upload copy of slides to wiki (to professor)

Team 1:
Actual goal
Deliverable are measurable
Have documentation in deliverable
Details about technical approach
Plan for picking approach
Files uploaded to onedrive
Timeline and milestone

Team 2:
Backup
Dependencies
Font size not too small
Details on plan

Team 3:
Image reference?
Dependencies/alternative
Assessment metric
Technical approach
Just white background
Compare(comparison) words
Documents in deliverables