CIS II: Project No. 2
Synthetic Aperture Ultrasound Imaging with Robotic Tracking Technique

Team: Haichong “Kai” Zhang, Ezgi Ergun

Mentors: Dr. Emad M. Boctor, Xiaoyu Guo, Alexis Cheng

LABORATORY FOR Computational Sensing + Robotics
THE JOHNS HOPKINS UNIVERSITY

MUSiiC Research Laboratory

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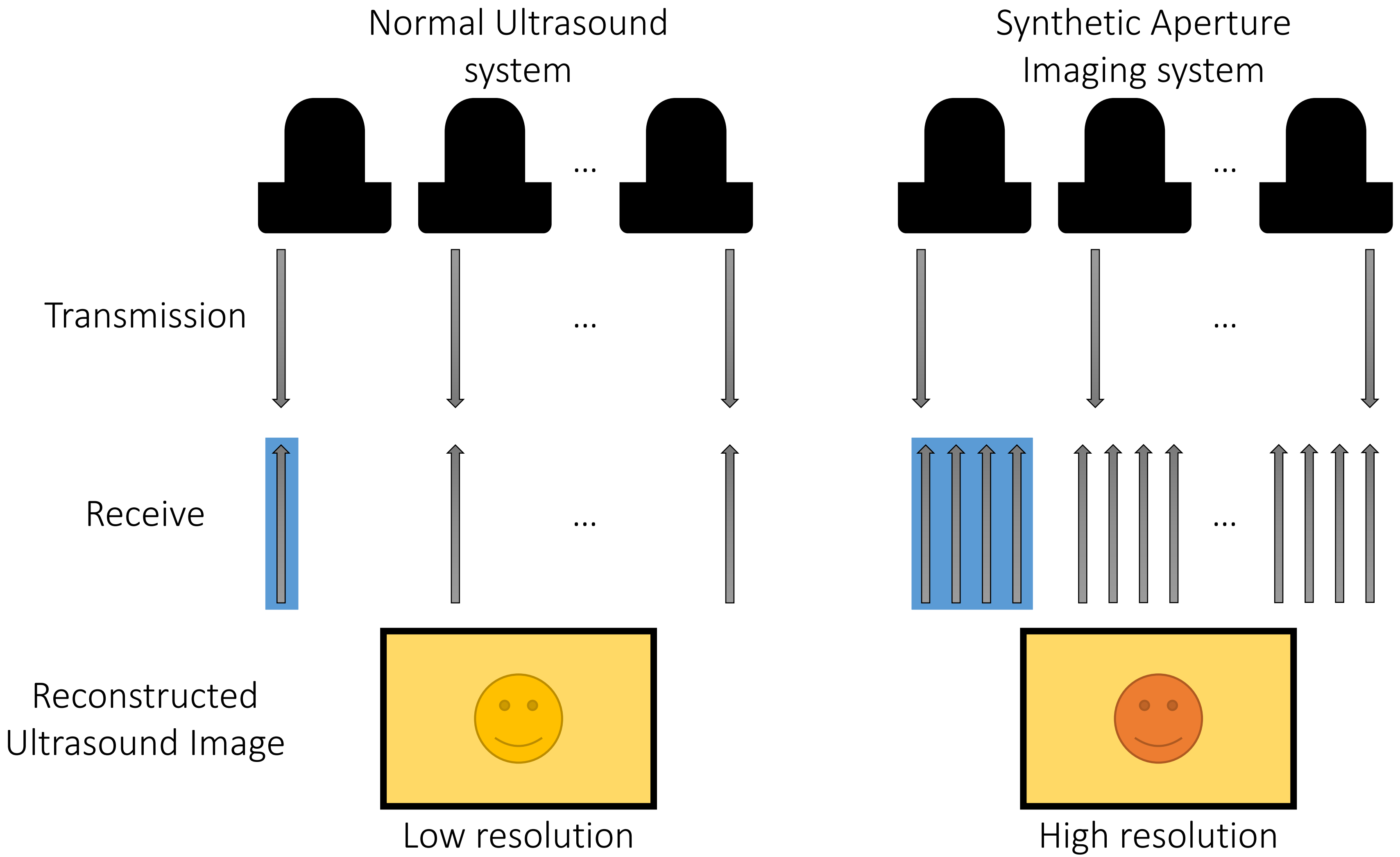
Stated Topic and Goal:
Ultrasound Imaging

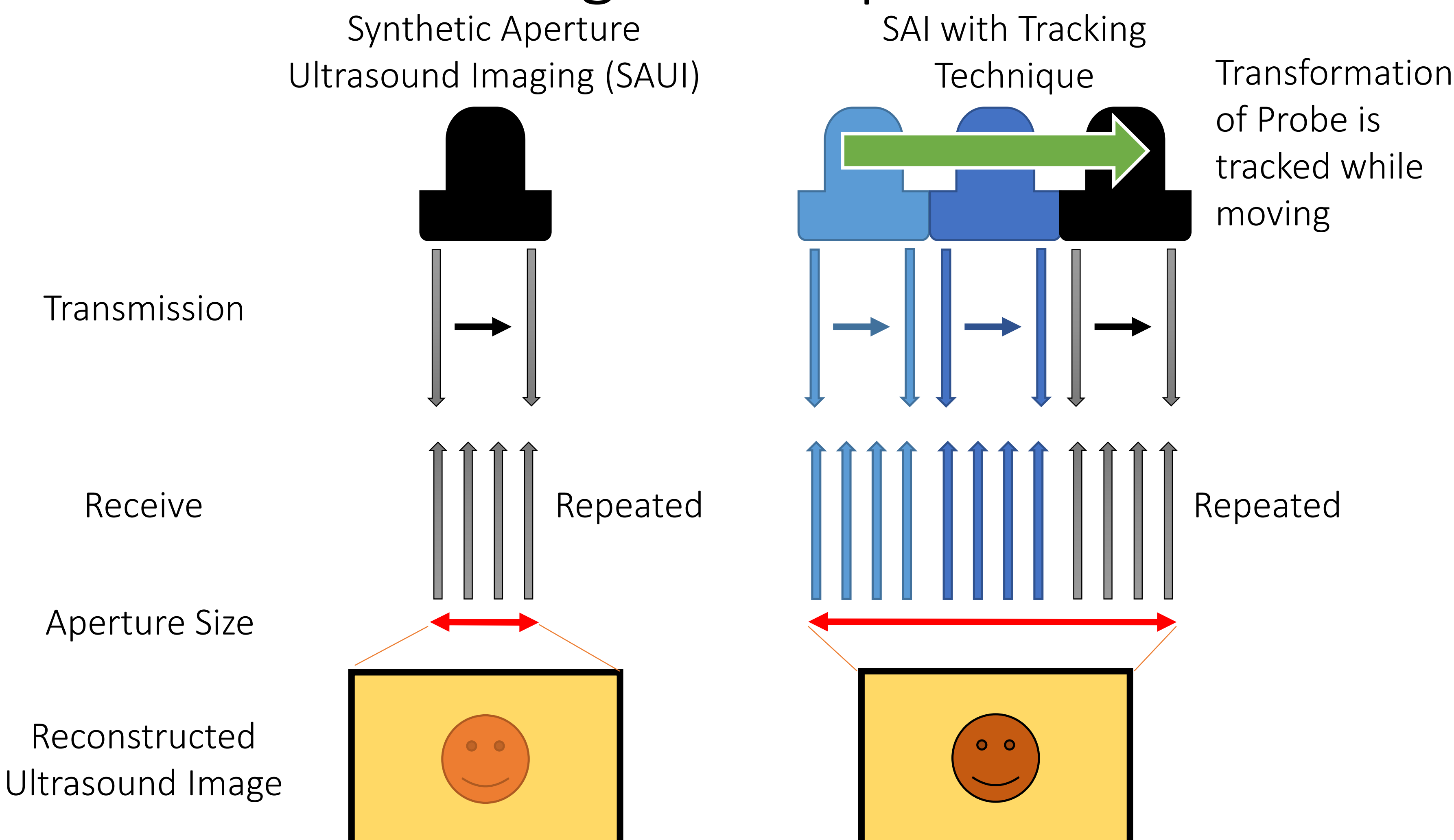
12 week fetus
http://www.qlife.jp/dictionary/item/i_030840000/

- Ultrasound imaging is used in general medical diagnosis and diagnosis of pregnancy.
- Axial resolution is determined by frequency of ultrasound system.
- Lateral resolution is restricted by aperture size of ultrasound transducer.

Stated Topic and Goal:
Synthetic Aperture Ultrasound Imaging

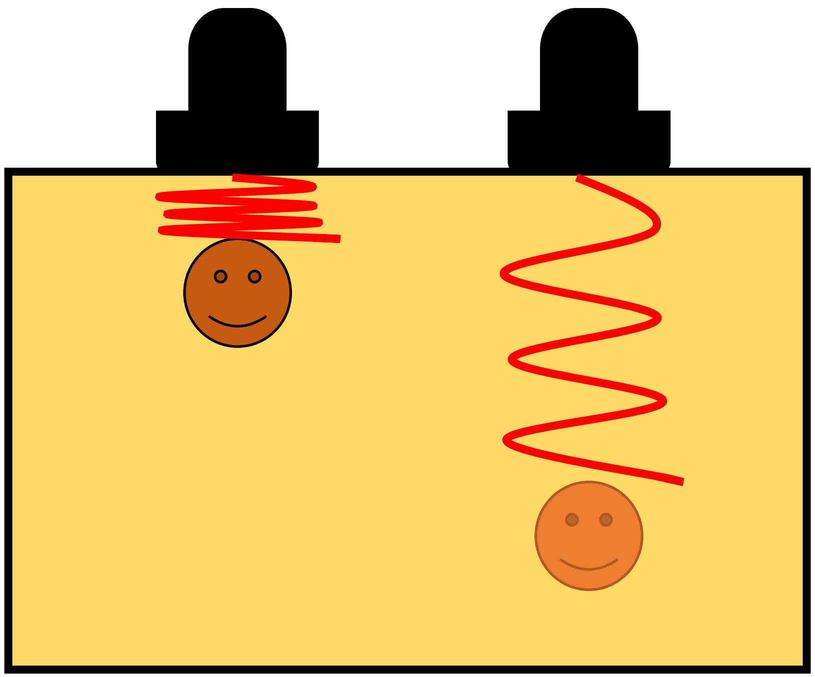


Stated Topic and Goal:
SAUI with Tracking Technique



Higher resolution can be achieved by expanding the aperture size.

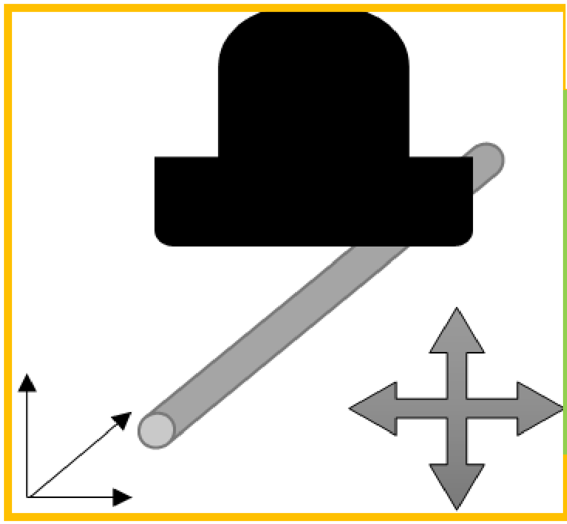
Statement of Relevance/Importance



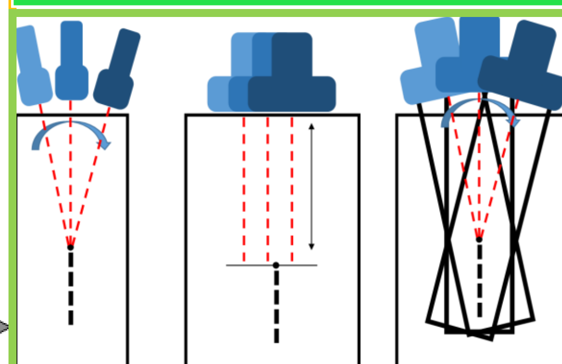
- To see deep site of tissue, only low frequency around 2MHz is available, so that the image resolution is limited.
- Goal of SAUI with tracking system is the improvement of ultrasound image resolution.
- Visualizing precise structure of fetus in early stage helps early disease detection as well as correct diagnosis.

Technical Summary of Approach

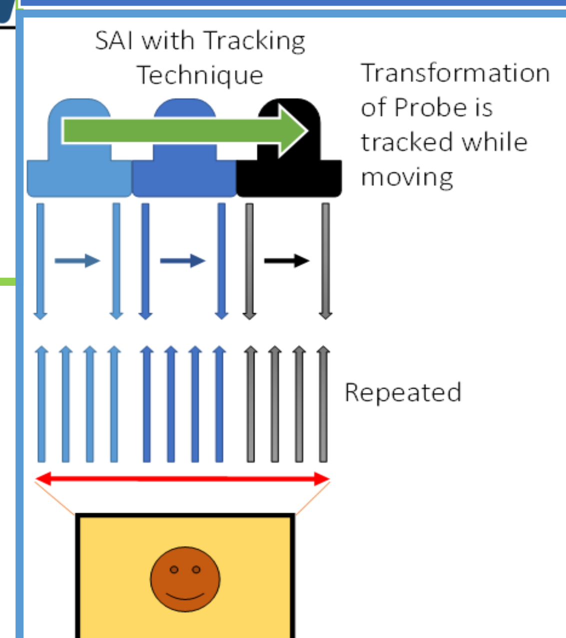
Invent a decent ultrasound calibration method



Primitive Investigation



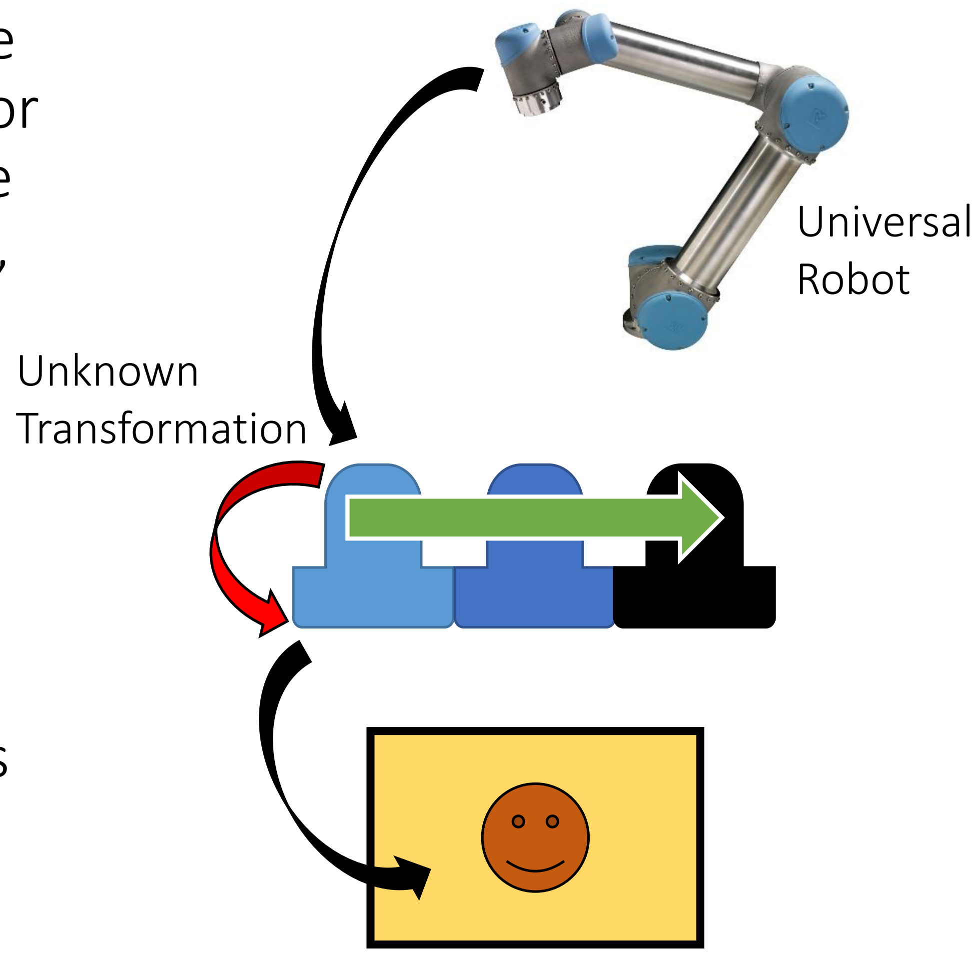
Final Implementation



Technical Summary of Approach:

Invent a decent ultrasound calibration method

- In order to move the probe for a designated position, or to know the location of the origin of ultrasound image, unknown rigid-body transformation on the transducer from sensor to image is needed to be calibrated.
- Process to identify this unknown transformation is called ultrasound (US) calibration.



Technical Summary of Approach:
Invent a decent ultrasound calibration method

- A major ultrasound calibration (hand-eye calibration) is based on segmentation method.
- The problem is very difficult to find out a representative from a cloud.
- Accuracy is limited (1.5 mm~) although compensation method is applied.

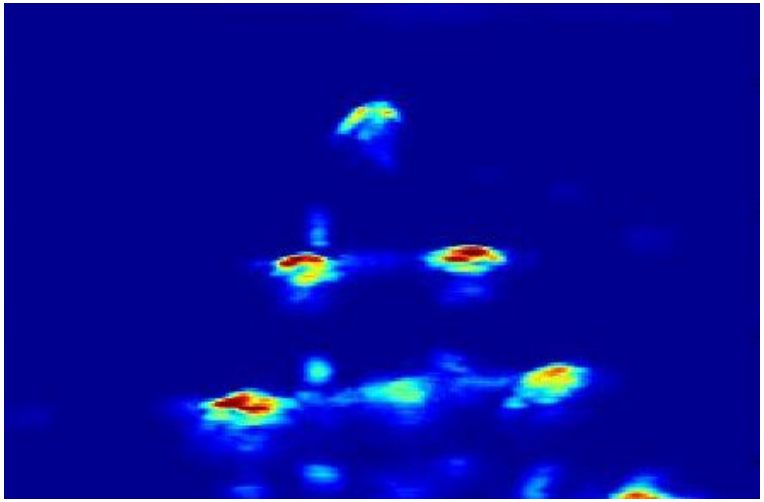


Figure:
AX=XB-phantom is used to reconstruct 3D information.
Rotation and transformation can be obtained through one image.
It is very difficult to identify the center of the point.

Technical Summary of Approach:

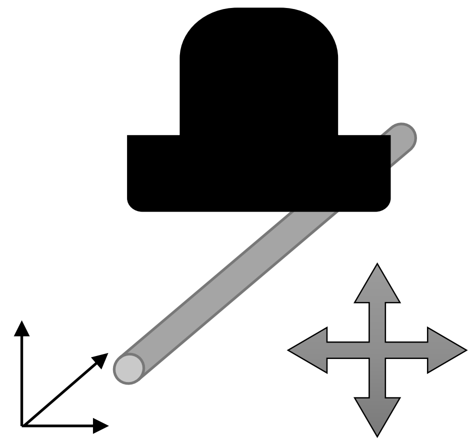
Invent a decent ultrasound calibration method

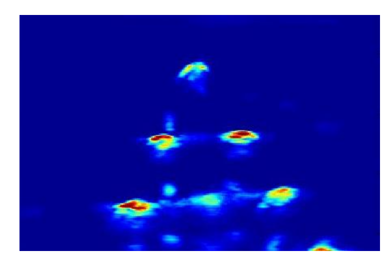
Goal: accuracy of 500 µm (wavelength of 2.5MHz transducer)

Idea to improve the accuracy:

US Calibration Using Moving Phantom

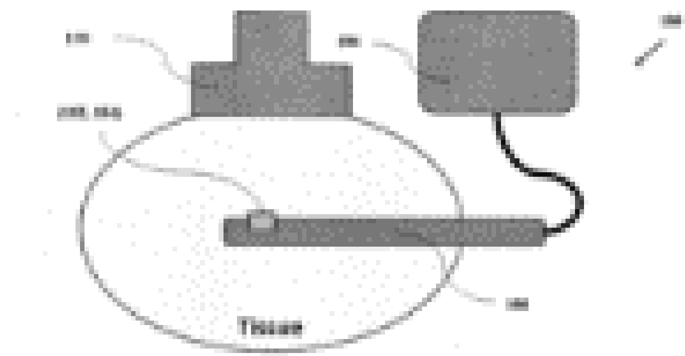
- Moving the phantom toward x and y axis, from the coordinate of phantom.
- Normalized cross correlation (NCC) is used to identify the displacement of phantom in image.
- The goal of this project is to reconstruct X only using moving information.
- 0.3 µm accuracy is confirmed in simulation





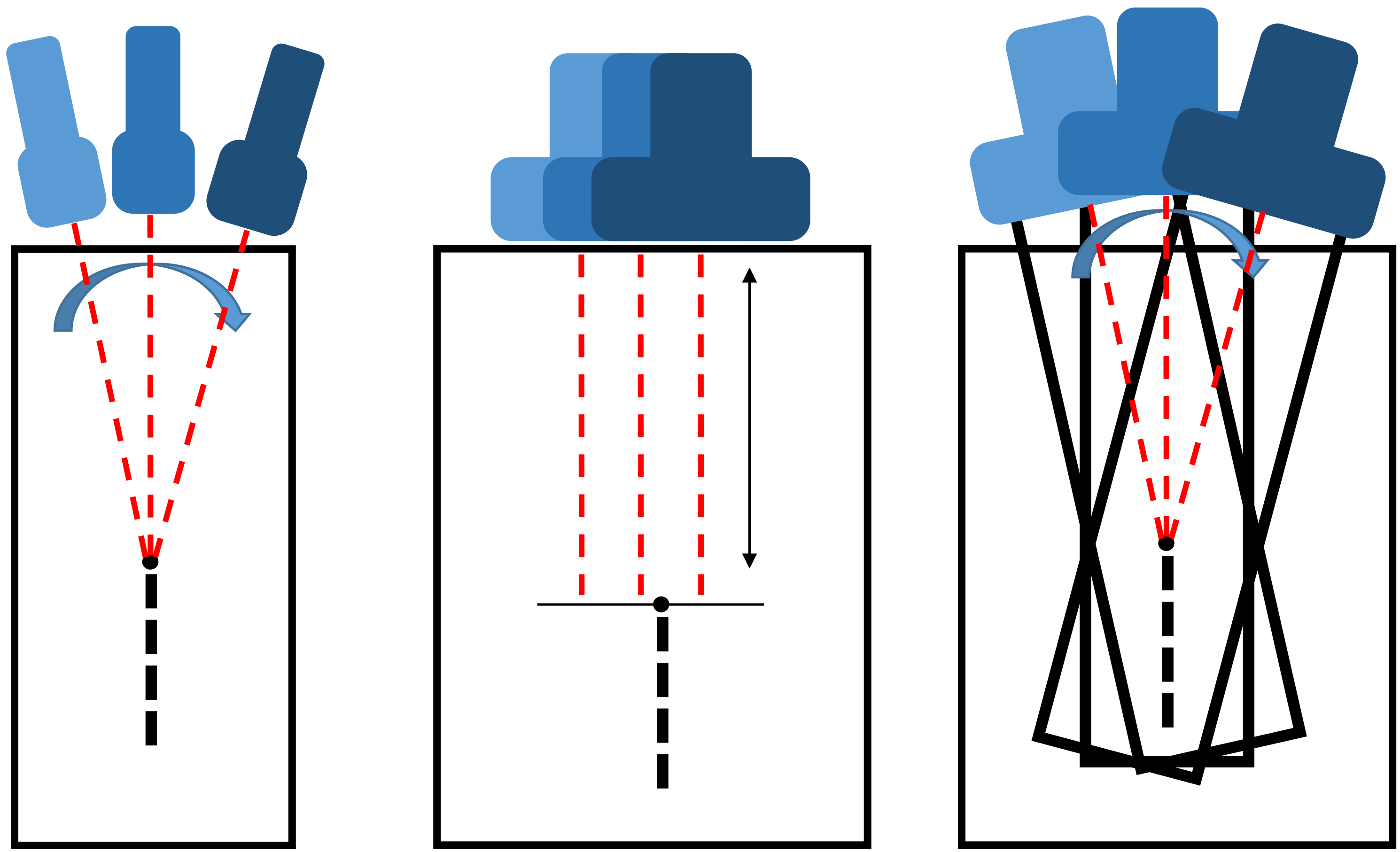
Technical Summary of Approach:
Primitive investigation

- Without US calibration, primitive confirmation of the potential of the technique is available using precise tracking system and accurate location indicator.
- Active echo element is a strong candidate for the test due to its accurate sensitivity for ultrasound transducer center detection (50 um).
- Learn SAUI algorithm and optimize it for this approach.



High quality closed-loop ultrasound imaging system
US 20140024928 A1

Technical Summary of Approach:
Primitive investigation



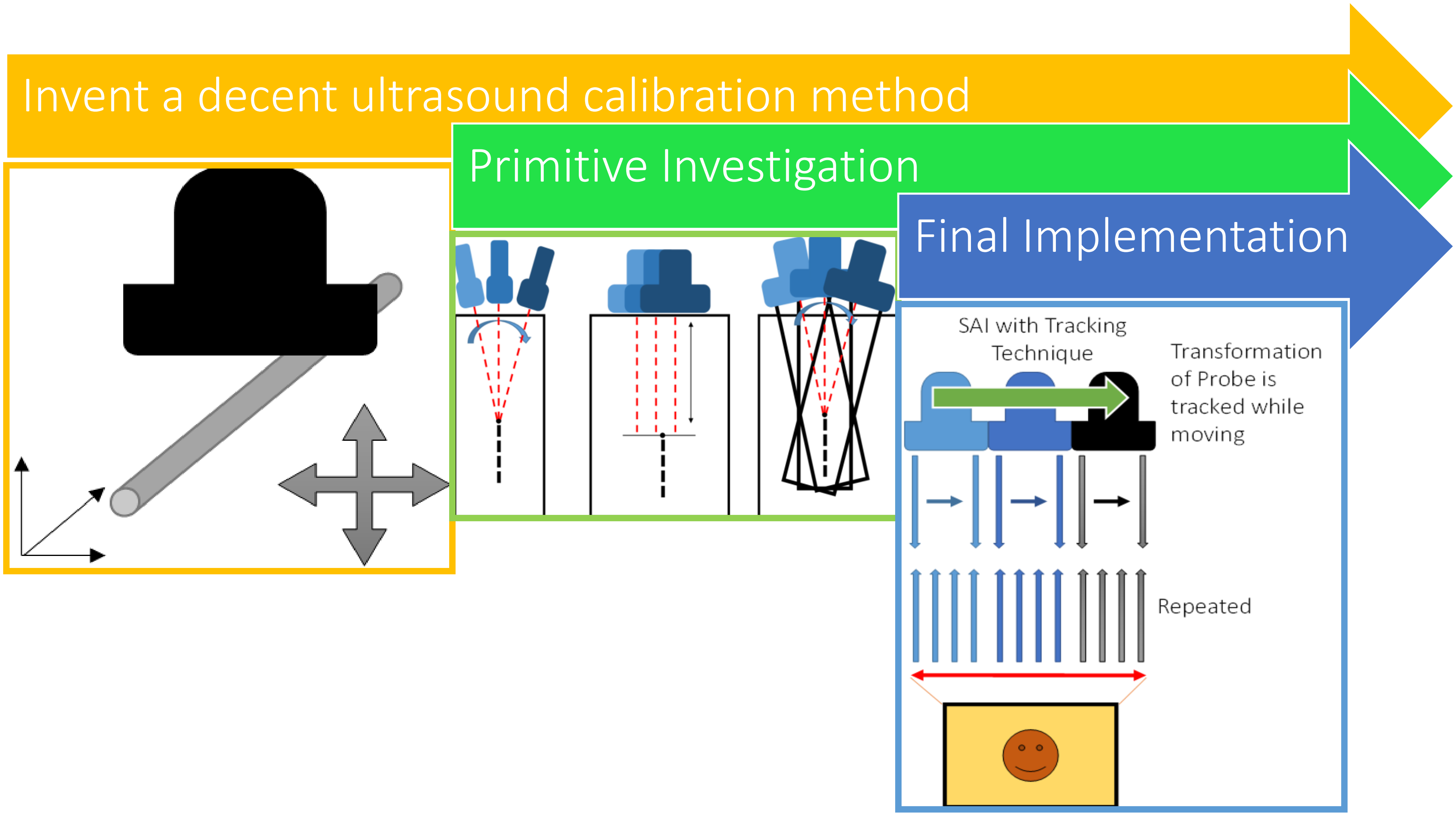
Rotate probe while keeping the length of red line same

Scan a probe by keeping the length of red line same

Rotate probe while keeping the length of red line same

Figure: Three scenarios for the synthetic aperture test

Technical Summary of Approach



Deliverables

Minimum

- Experimentally confirm the new calibration method is superior to segmentation based calibration.
- Construct the design for SAUI w/ robotic tracking using active-echo system.

Expected

- Confirm SAUI w/ robotic tracking using active-echo system.

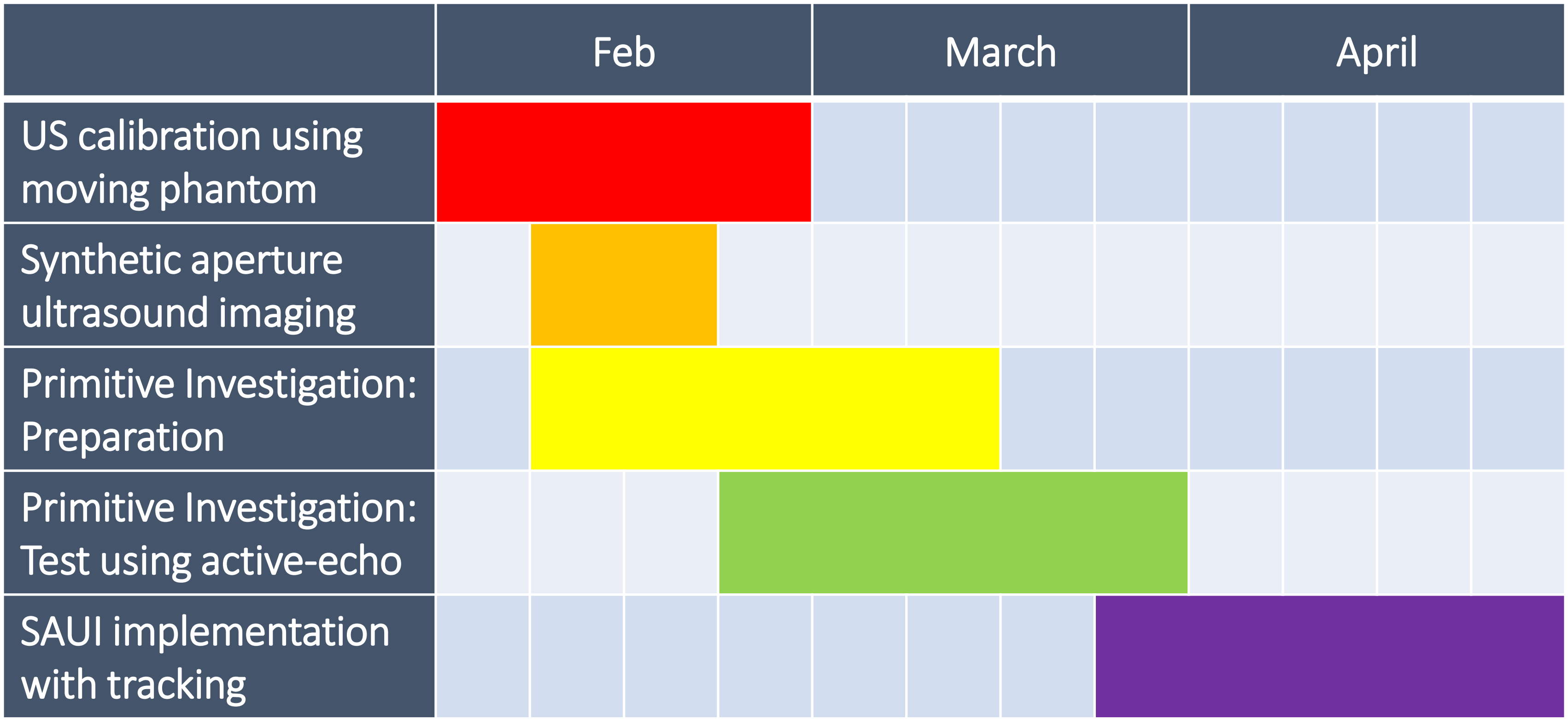
Maximum

- Implement SAUI w/ robotic tracking using calibrated transducer
- Confirm the resolution improvement through phantom experiment

List of Dependencies and Plan for Resolving

- Ultrasound imaging system
  - ✓ MUSiiC Lab
- Low frequency ultrasound probe
  - ✓ Got a 2.5MHz phased array transducer
  - ■ Need to make a connector to available US machine
    Discuss with Xiaoyu
  - ■ Need to make a attachment to robot
    Print in 3D or using silicon labber
- Tracking system: Robot
  - ✓ Universal Robot is available
  - ■ Need to figure out control system
    Learn from Rishabh and Fereshteh
- Access to mentors
  - ✓ Meeting with Dr. Boctor
  - ■ Take appointments to other mentors when needed

Key Dates and Assigned Responsibilities



Management plan

Kai: US calibration and robotic control system

Ezgi: Synthetic aperture imaging algorithm

Reading List

- Nock, L.P. , Trahey, G.E.

"Synthetic receive aperture imaging with phase correction for motion and for tissue inhomogeneities. I. Basic principles", IEEE TUFFC, 1992

- Trahey, G.E., Nock, L.P.

"Synthetic receive aperture imaging with phase correction for motion and for tissue inhomogeneities. II. Effects of and correction for motion", IEEE TUFFC, 1992

- Jørgen Arendt Jensen, Svetoslav Ivanov Nikolov, Kim Løkke Gammelmark, Morten Høgholm Pedersen

"Synthetic aperture ultrasound imaging", Ultrasonics, 2006

- Karaman, Mustafa,Pai-Chi Li, O'Donnell, M.

"Synthetic aperture imaging for small scale systems", IEEE TUFFC, 1995

Thank you for your attention.

Question?