Synthetic Aperture Ultrasound Imaging with Robotic Tracking Technique

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Introduction

Background

- Resolution of ultrasound (US) image is determined by transmission frequency and aperture size of transducer.
- Synthetic aperture (SA) is a technique to improve resolution by synthetizing received signals and extend the aperture size for reconstruction.

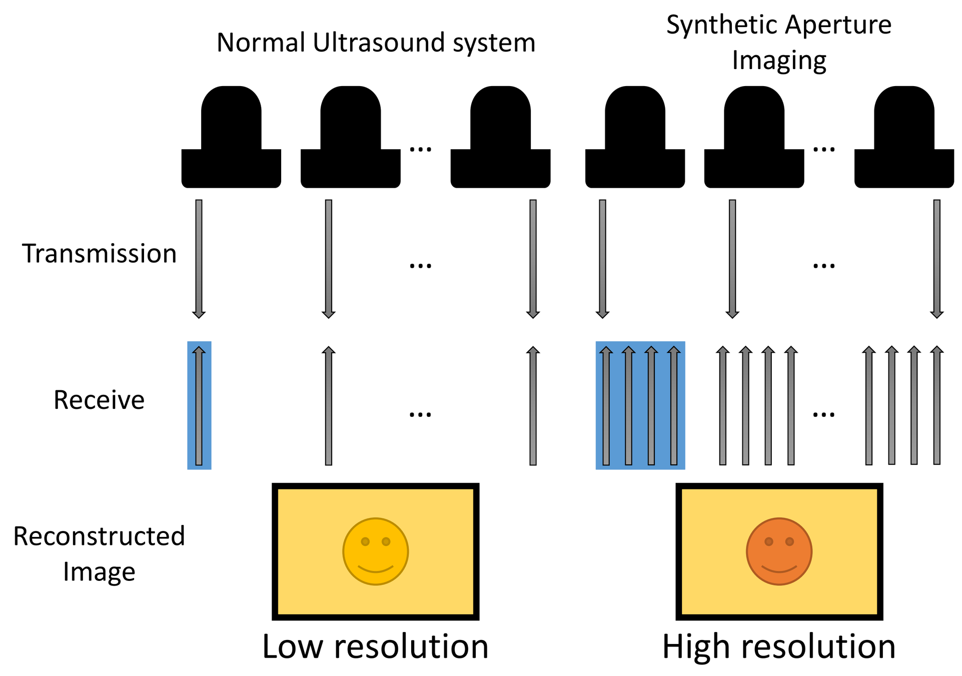


Figure 1: One synthetic aperture algorithm is shown compared to conventional ultrasound image acquisition.

Problem / Objective

- The performance of conventional SA is restricted by the physical size of US transducer.
- Robotic tracking technique can be used to generate imaginary elements, which extend the aperture size more.
- The goal is to achieve higher resolution through robotic SA imaging.

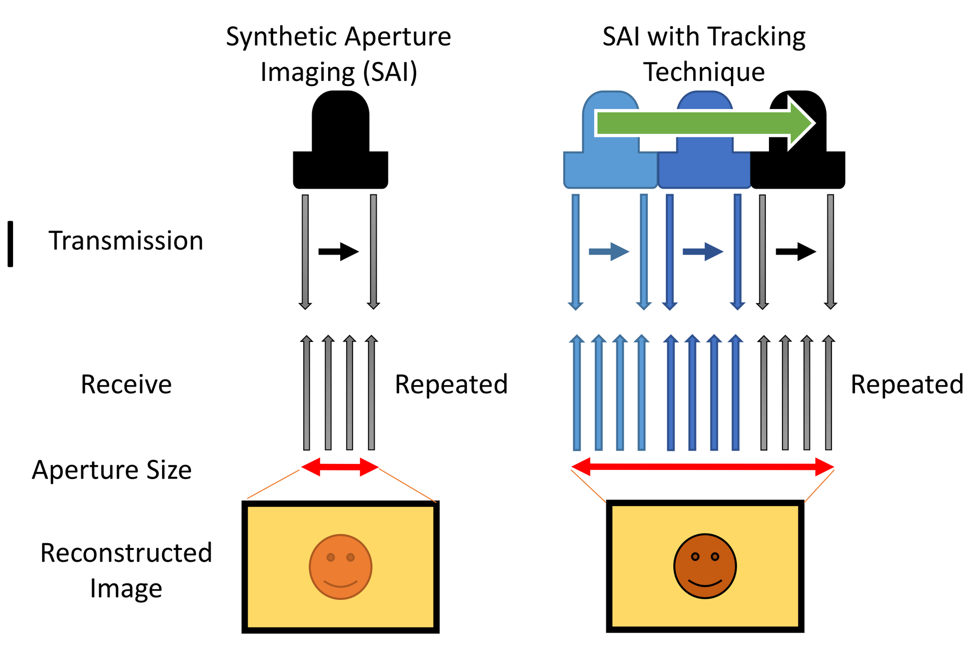


Figure 2: Synthetic aperture imaging with robotic tracking. Wider aperture size can be kept by combining multiple poses information.

Technical Approach (Solutions, Outcomes, and Results)

Ultrasound Calibration

- In order to register multiple poses information, unknown rigid-body transformation on the transducer from sensor to image is needed to be calibrated.

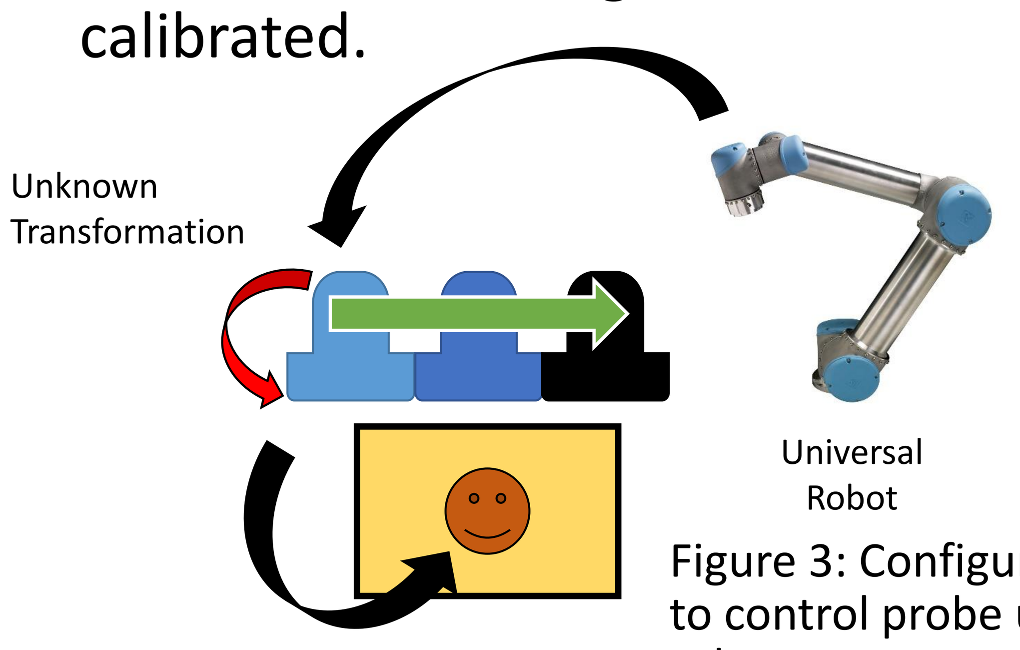


Figure 3: Configuration to control probe using robot.

Two US calibration methods are investigated to improve the accuracy

1.Utilizing trajectory of moved phantom

•Moved phantom displacement is tracked by cross-correlation to reduce the segmentation error.

•High accuracy is confirmed through simulation study.

Rotation (degree)	Error from GT	STD	Translation (mm)	Error from GT	STD
Yaw	0.092	0.058	X	0.372	0.261
Pitch	0.096	0.073	Y	0.210	0.12
Roll	0.071	0.04	Z	0.165	0.147
Norm	0.15	0.102	Norm	0.46	0.323

2.Active-echo based calibration

•Acoustic feedback helps US image mid-plain detection.

•High reconstruction precision is experimentally validated.

Type of Points	Reconstruction Precision
Active Echo	1.05 mm
Crosswire	2.36 mm

Synthetic Aperture Algorithm

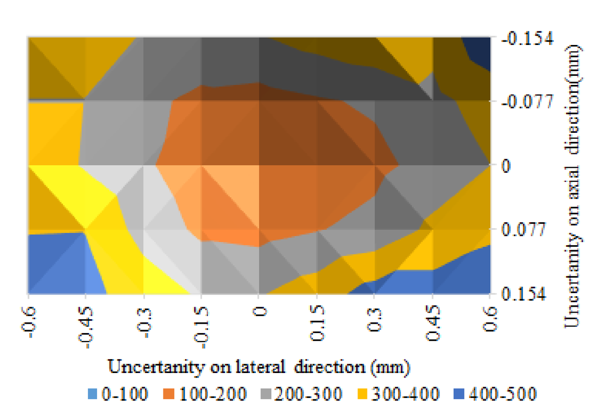
- Synthetic aperture focusing algorithm is built, and simulations for the robotic synthetic aperture system are conducted using Field II.

1. Single Pose vs 2 Poses Simulation

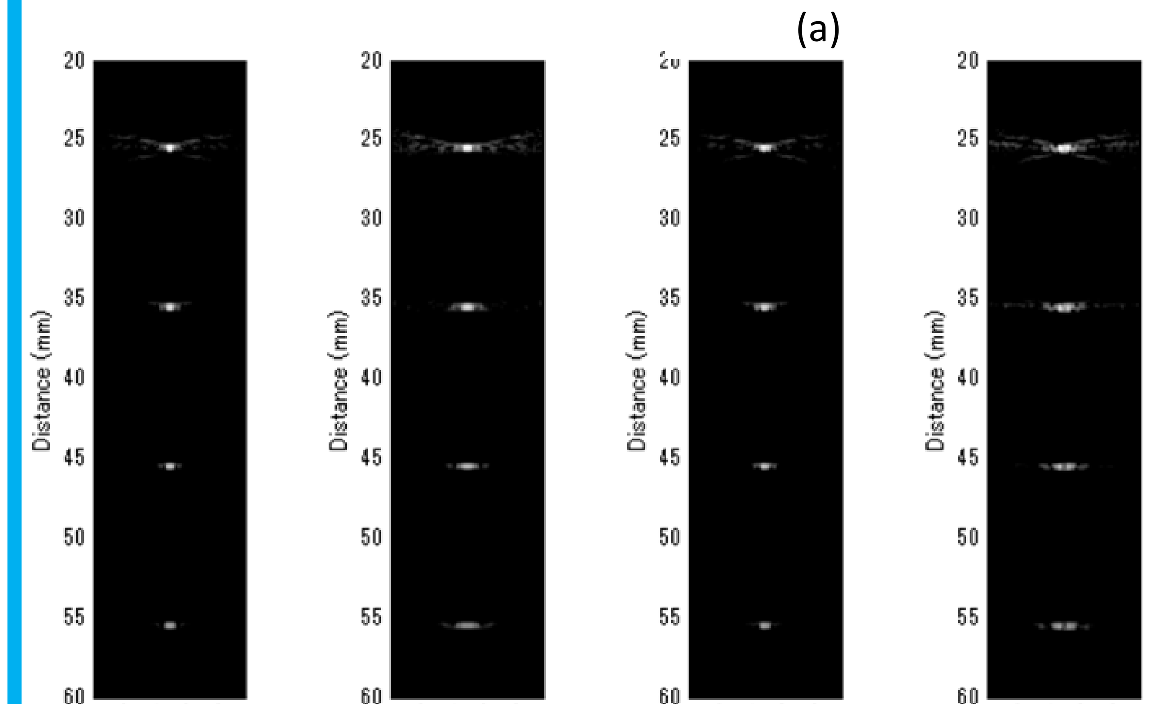
- Image quality has improved in the case of two-poses reconstruction because of wider aperture size. (Figure 4b and 4c)

2. Uncertainty Introduced

- Small displacements with a range of different magnitudes in axial and lateral directions are added to the second pose before reconstruction.
- Same amount of displacement (0.15 mm) in both lateral and axial directions. Axial displacement have more effect on the resolution. (Figure 4d and 4e)
- The effect of uncertainty is summarized. (Figure 4a)



(a)



(b) (c) (d) (e)

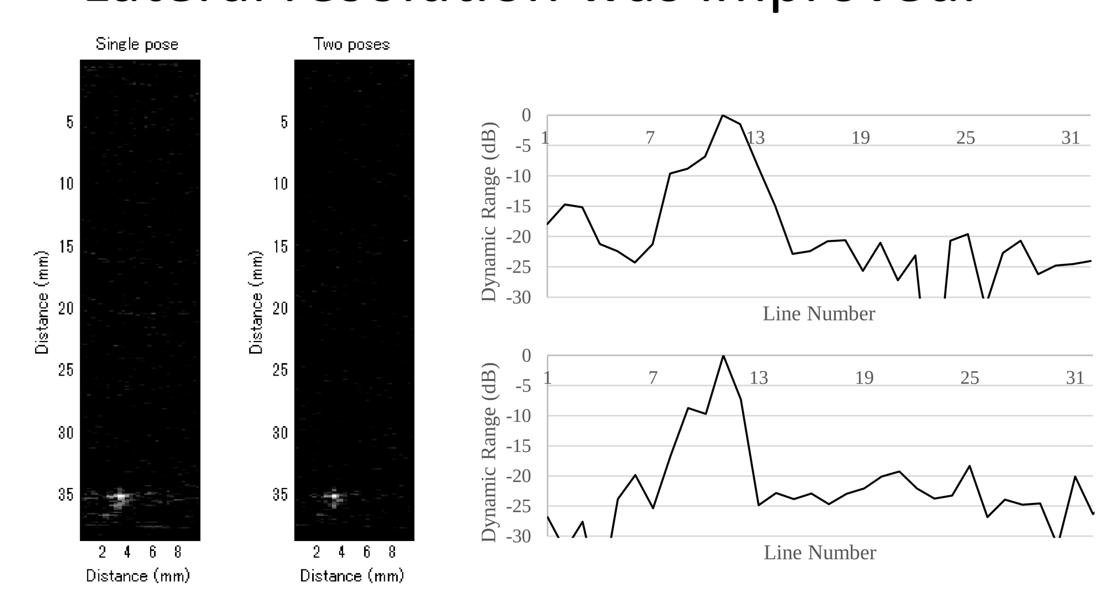
Figure 4

Final Implementation

- The feasibility of the proposed idea is experimentally validated.
- Universal robot (UR5) was used to move the transducer and pre-beamformed RF signals were collected from US machine (Sonix Touch, Ultrasonix Inc.) using DAQ.
- 1-D translation is applied, and SAF is used for reconstruction..

1. Iterative Alignment Result

- Lateral resolution was improved.



(a) (b)

Figure 5: a point source is placed at 3.5 cm, and single pose (32ele) and two poses (64ele) result is shown.

2. Result Using Tracked Transducer

- Reconstruction worked in multiple poses by applying compensation.
- Resolution improvement could be seen, but the contrast was unstable.

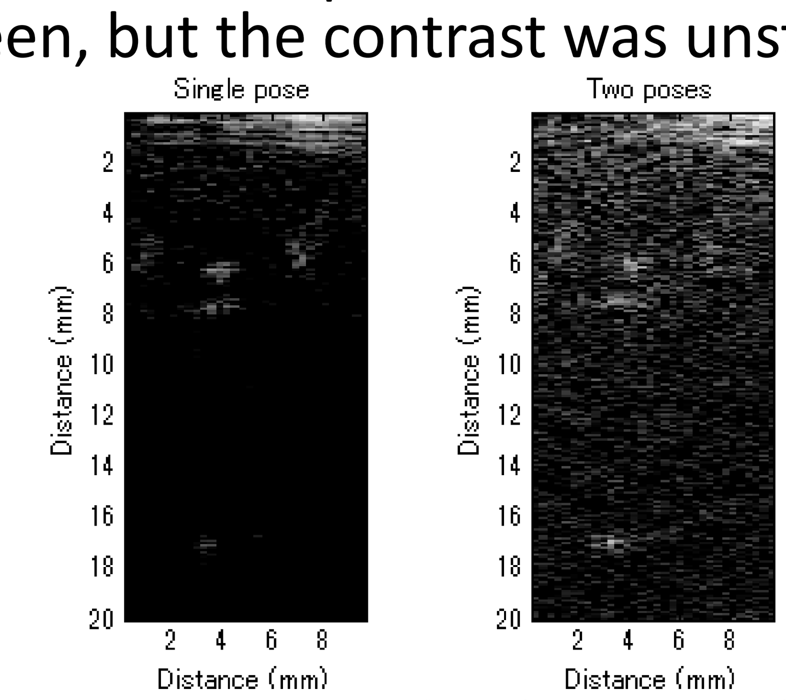


Figure 5: Two wires are placed at 6mm and 17 mm.

Future Work

- Introduce new geometry to apply into synthetic aperture imaging
- Improve the calibration accuracy by developing proposed methods more.
- Introduce reconstruction algorithm which compensates the uncertainty happen between multiple poses.

Credits

Haichong: Algorithm development and experimental design

Ezgi: Simulation implementation

Lessons Learned

- Learn calibration techniques, image registration, and robotic control
- Learn ultrasound simulation through Field II
- Learn ultrasound reconstruction algorithm such as DAS and synthetic aperture.

Publication

- Calibration approaches are submitted in UITC and MICCAI
- A journal article is in preparation

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