

Force-controlled Surface Exploration of Ultrasound Probe

Haoran Cheng, Nicolas Mateo Zevallos-Roberts

Motivation

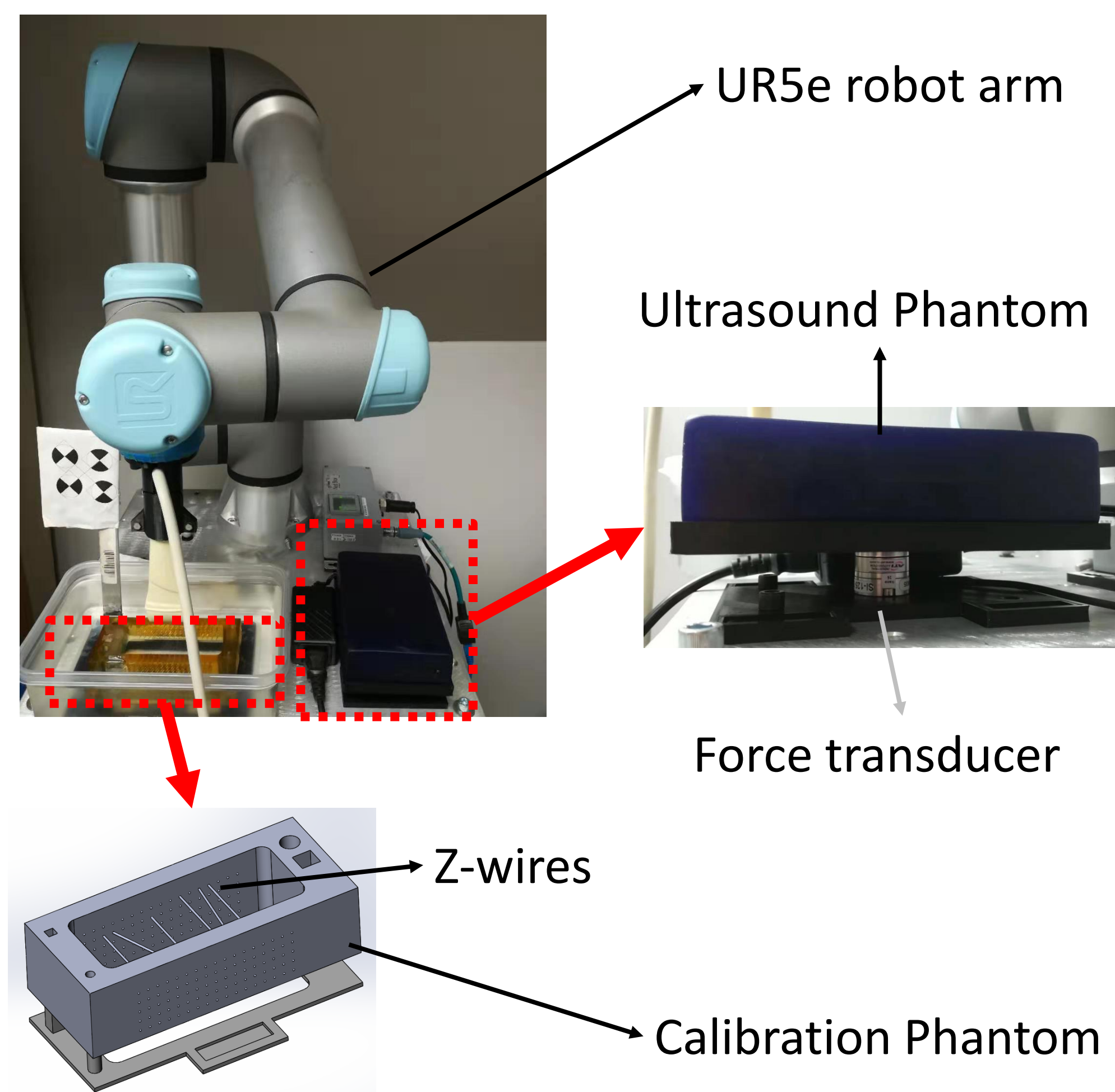
The physician exerts significant force in uncomfortable positions during examination

Probe force and orientation need to be fine-tuned to obtain good image qualities.

Previous works have been focused on uni-direction orientation adjustment on flat phantom[1][2] and surface exploration of spherical probe[3].

Materials and Methods

System setup



Zero-force mode

$$\mathcal{V}_f[i] = \alpha \mathbf{K} \mathcal{F}_f[i] + (1 - \alpha) \mathcal{V}_f[i - 1]$$

- $\mathcal{V}_f = [v_f, \omega_f]^T$: 6x1 desired twist in force sensor frame
- α : constant of low-pass filter
- \mathbf{K} : diagonal matrix of scaling factors
- $\mathcal{F}_f = [F_f, M_f]^T$: wrench reading from the UR5 force sensor.

$$\mathcal{V}_s = \begin{bmatrix} R & 0 \\ 0 & R \end{bmatrix} \mathcal{V}_f$$

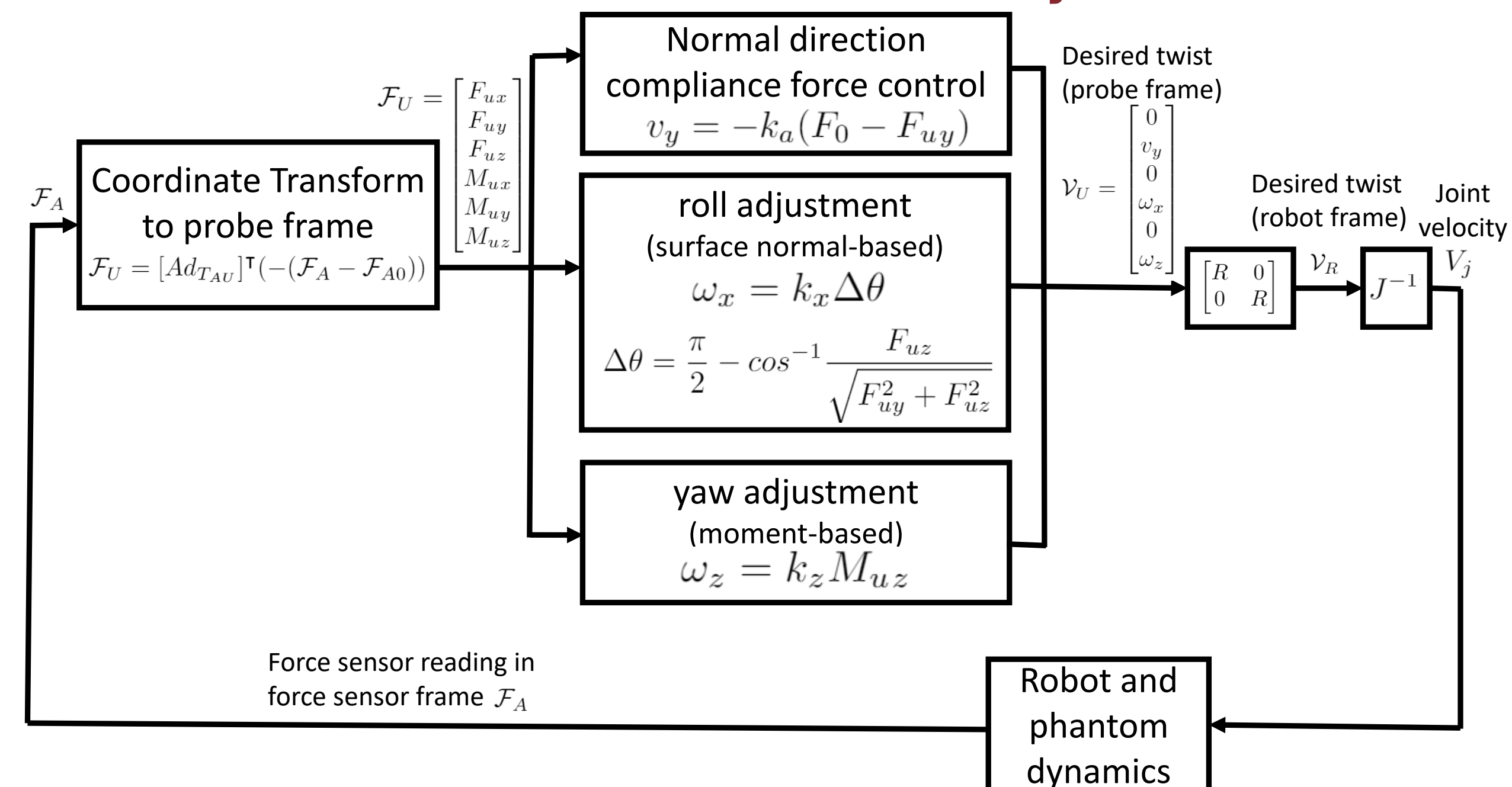
\mathcal{V}_s : desired twist in space frame

$$V_j = J^{-1} \mathcal{V}_s$$

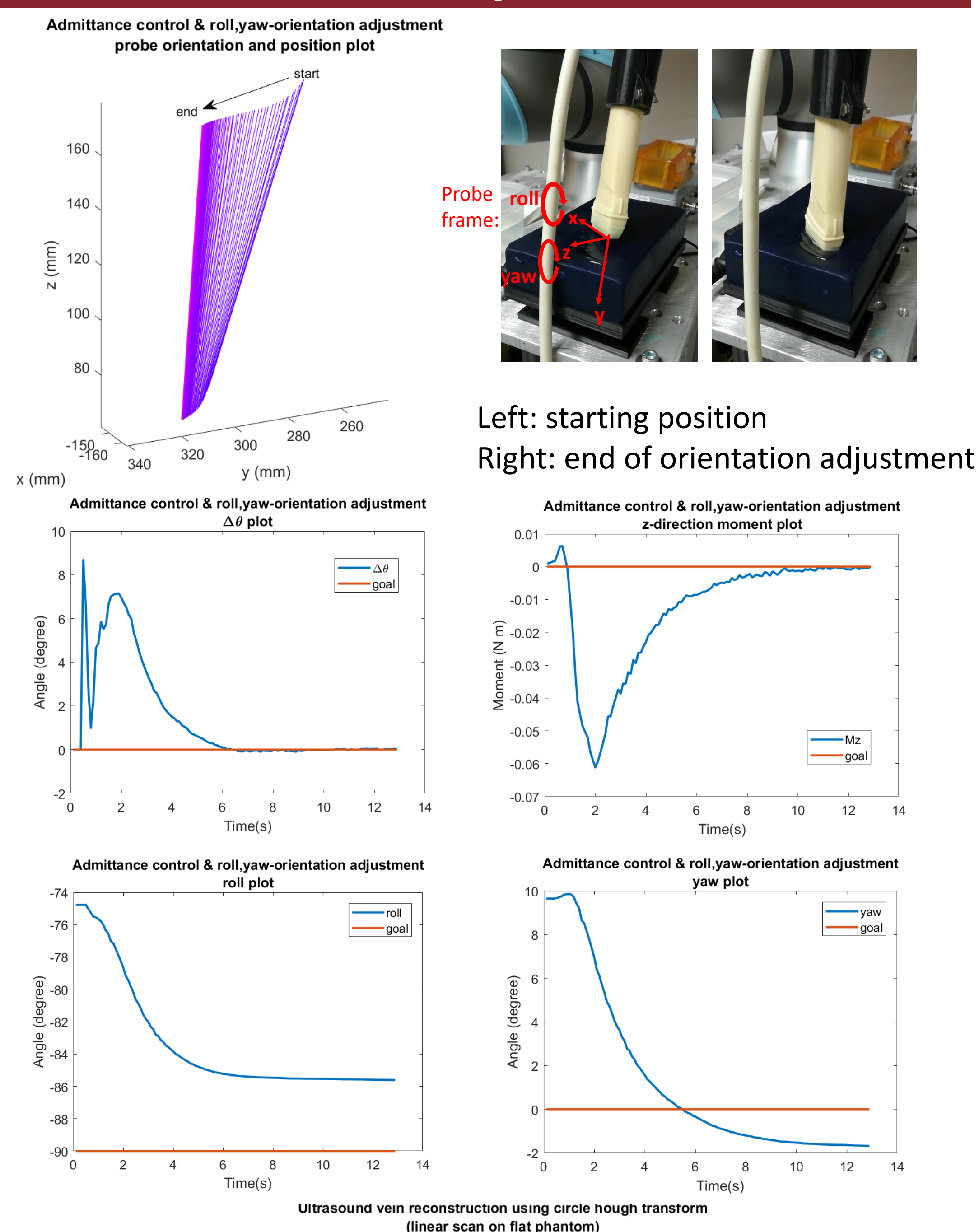
- V_j : joint velocity
- J : instantaneous Jacobian matrix from MoveIt.

Materials and Methods

Force-controlled orientation adjustment



Preliminary Results

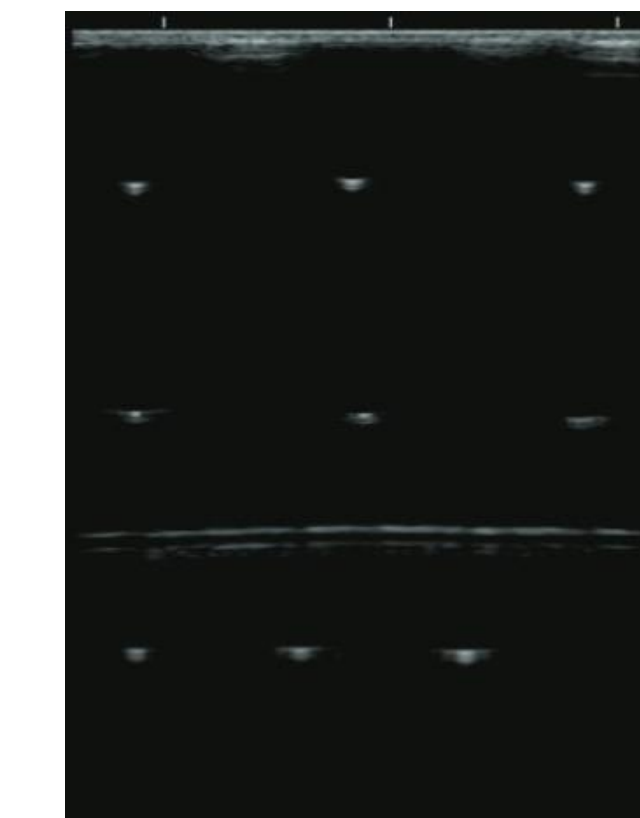


Materials and Methods

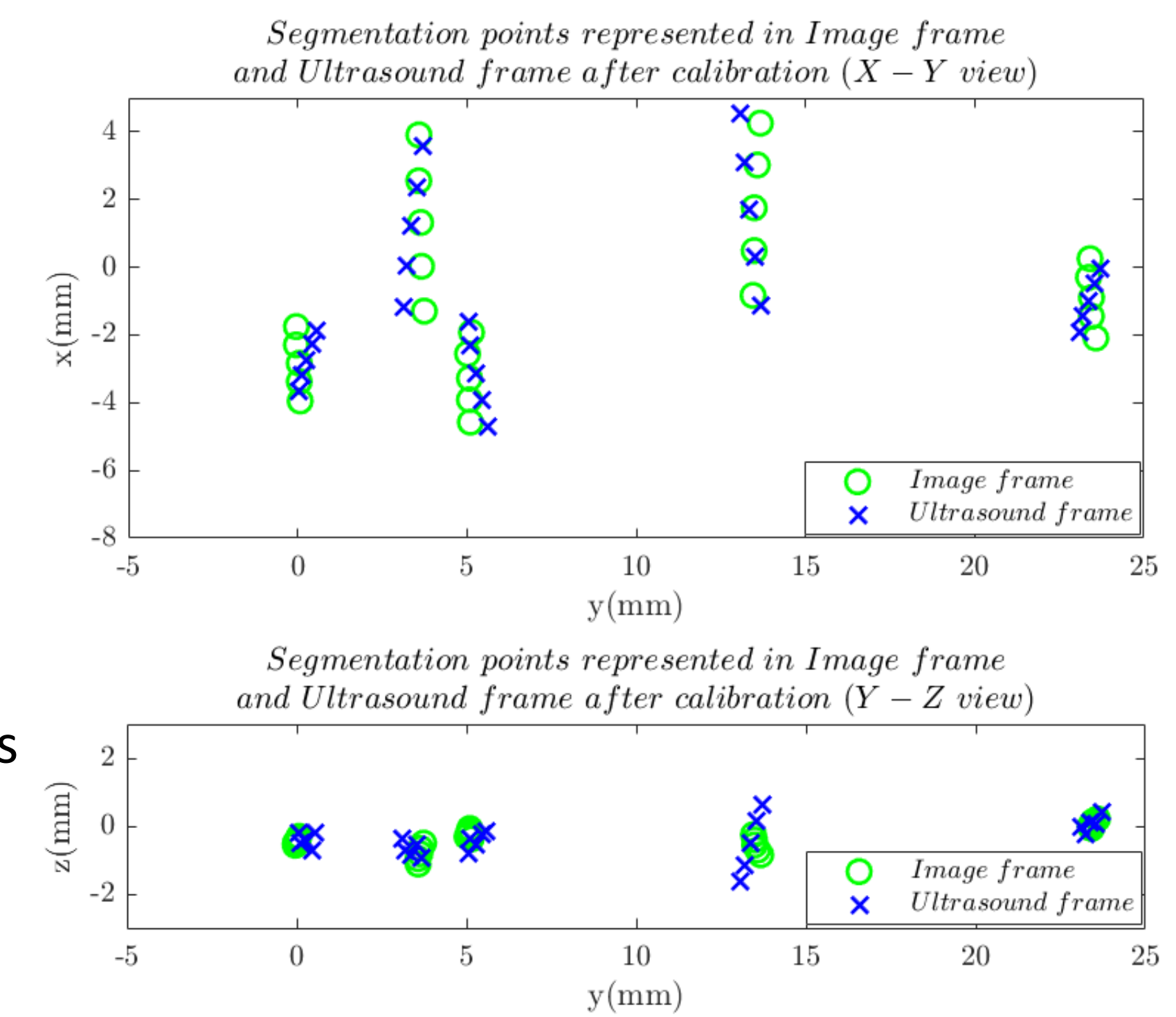
Ultrasound Calibration

Goal: to find the transform from image frame to probe frame.

Method: registration with known correspondence (by SVD)



Wire cross-sections shown in ultrasound image



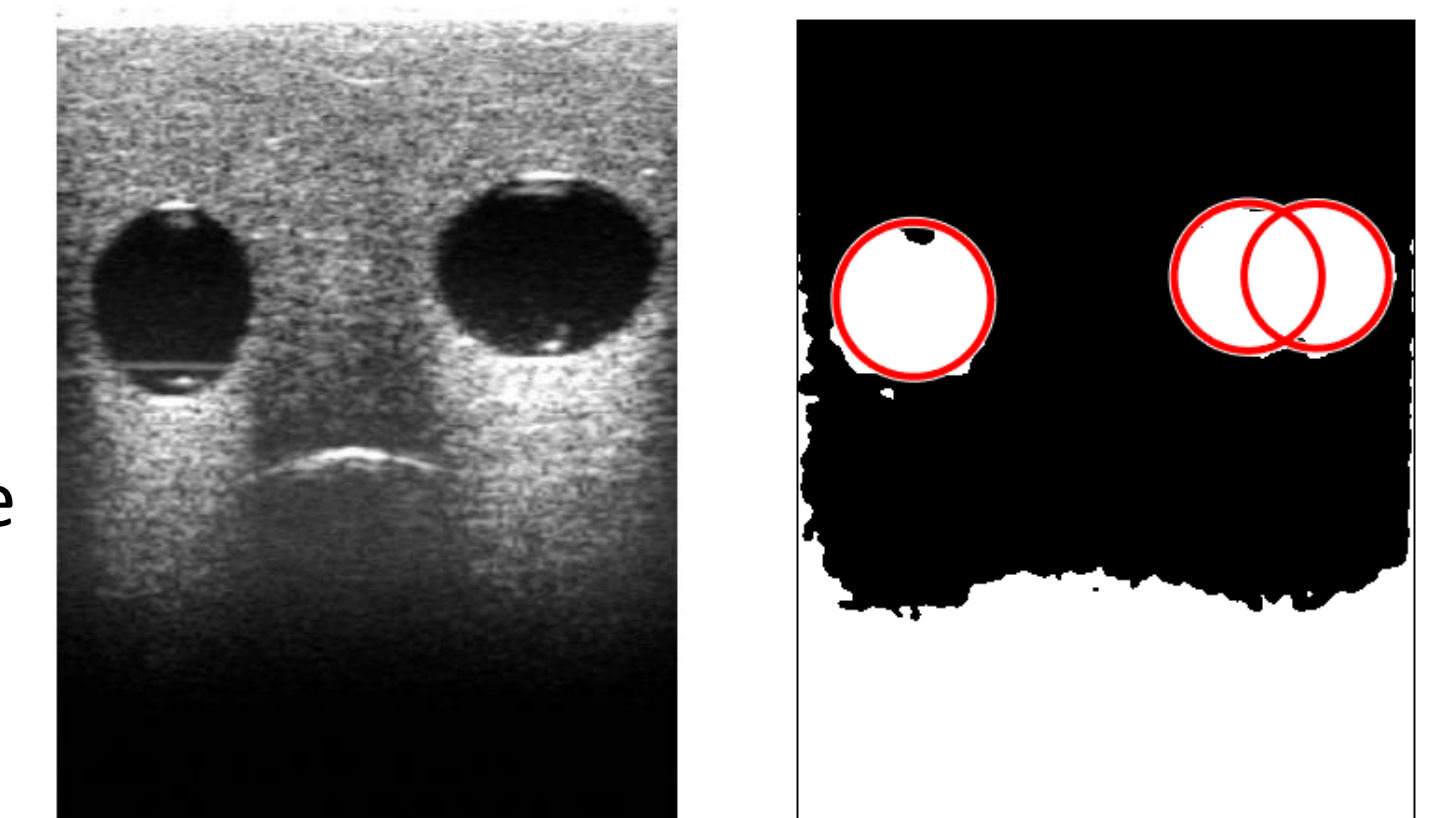
Calibration result

Image segmentation

- (1) Gaussian filtering
- (2) Thresholding
- (3) Hough transform

Left: raw ultrasound image

Right: after segmentation



Acknowledgement

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References

- [1] K. Mathiassen, J. E. Fjellin, K. Glette, P. K. Hol, and O. J. Elle, "An ultrasound robotic system using the commercial robot ur5," *Frontiers in Robotics and AI*, vol. 3, p. 1, 2016. [Online]. Available: <https://www.frontiersin.org/article/10.3389/frobt.2016.00001>
- [2] S. Merouche, L. Allard, E. Montagnon, G. Soulez, P. Bigras, and G. Cloutier, "A robotic ultrasound scanner for automatic vessel tracking and three-dimensional reconstruction of b-mode images," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 63, no. 1, pp. 35–46, Jan 2016.
- [3] L. Wang, Z. Chen, P. Chalasani, R. Yasin, P. Kazanzides, R. Taylor, and N. Simaan, "Force-controlled exploration for updating virtual fixture geometry in model-mediated telemanipulation," *Journal of Mechanisms and Robotics*, vol. 9, no. 2, 2017.

