Photoacoustic Registration and Visualization: Paper Seminar Presentation

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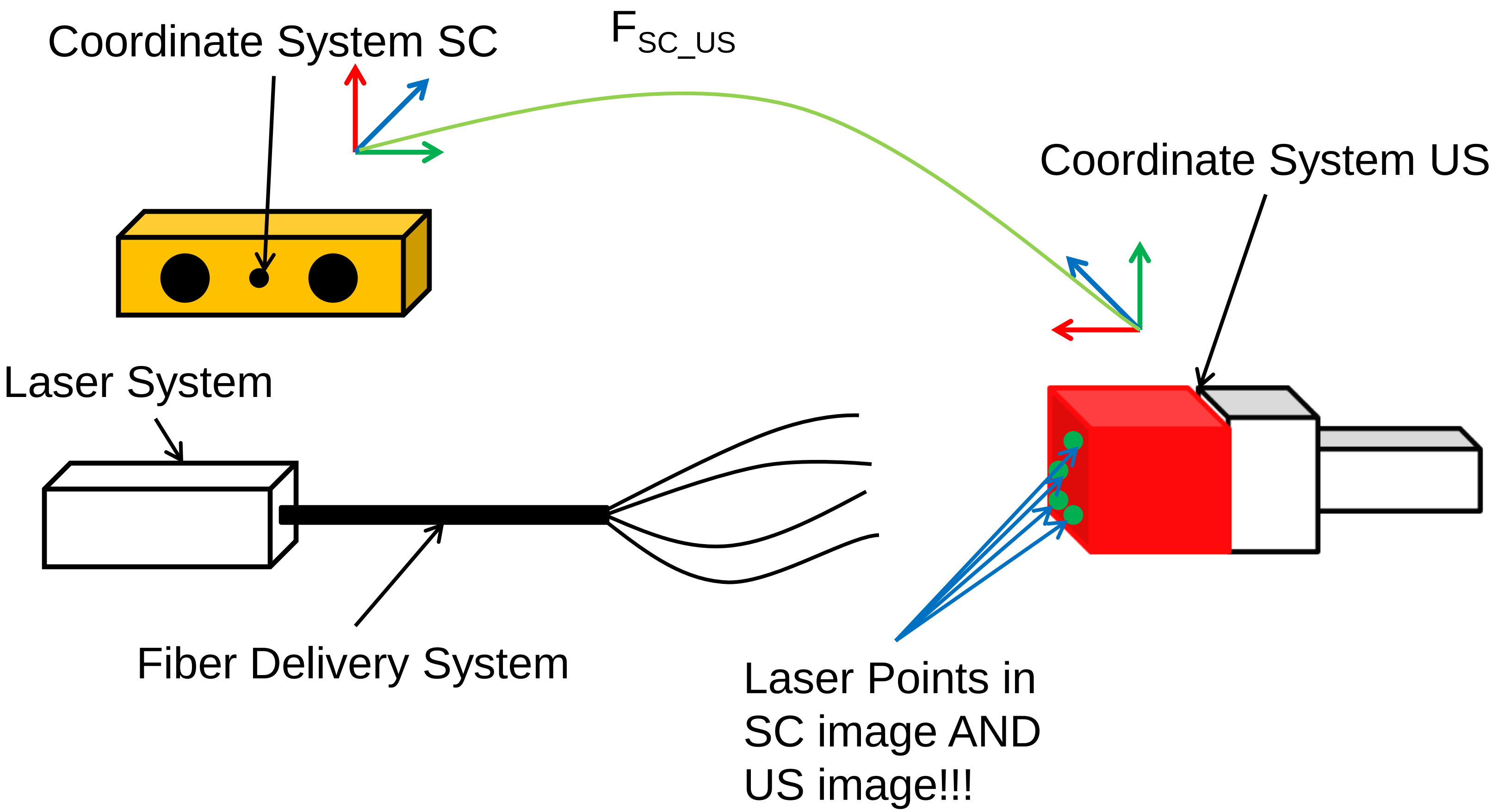
Overview

- Background
- Paper Summary
- Paper Analysis
- References

Background

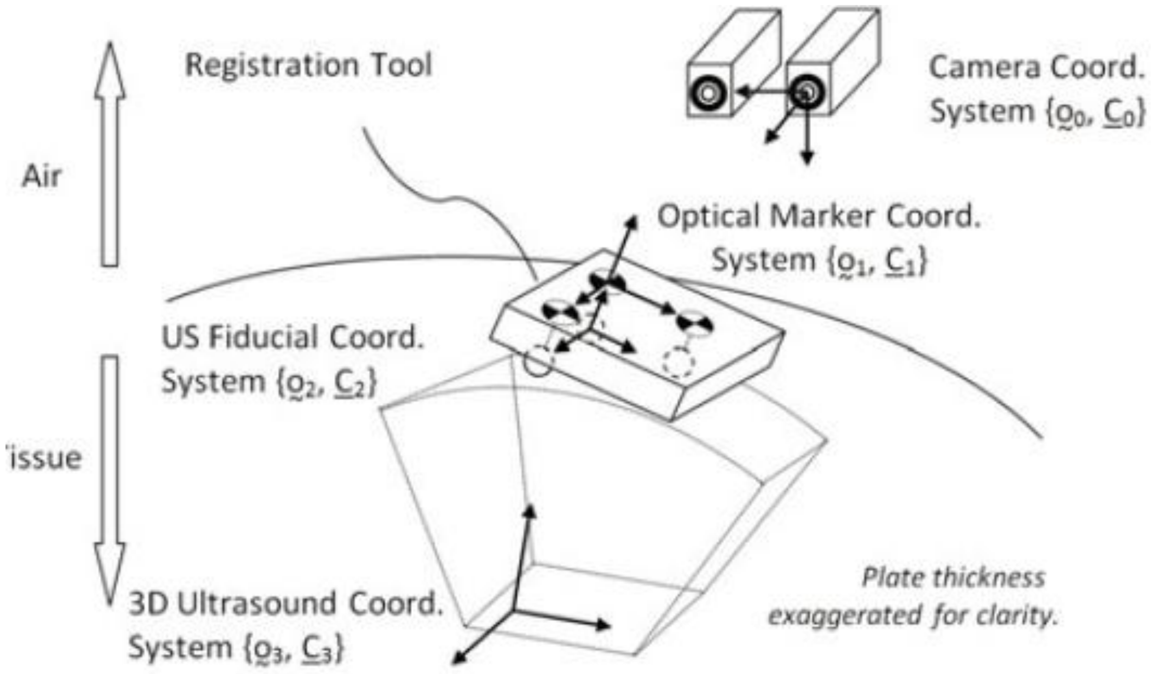

Coordinate System SC
F_{SC_US}
Coordinate System US
Laser System
Fiber Delivery System
Laser Points in
SC image AND
US image!!!

Paper Summary

- Yip M. C., Adebar T. K., Rohling R. N., Salcudean S. E., Nguan C. Y., "**3D Ultrasound to Stereoscopic Camera Registration through an Air-Tissue Boundary**". MICCAI 2010, Part II, LNCS, vol. 6362, pp.626-634. Springer, Heidelberg (2010)

- State-of-the-art solution for the same problem as my project
- Their statistical analysis is applicable to my project
- Their experimental considerations are applicable to my project

Paper Summary



- Goals:
  - Accuracy of localizing fiducials on an air-tissue boundary in Ultrasound
  - Accuracy of registration from 3D Ultrasound to Stereoscopic Camera

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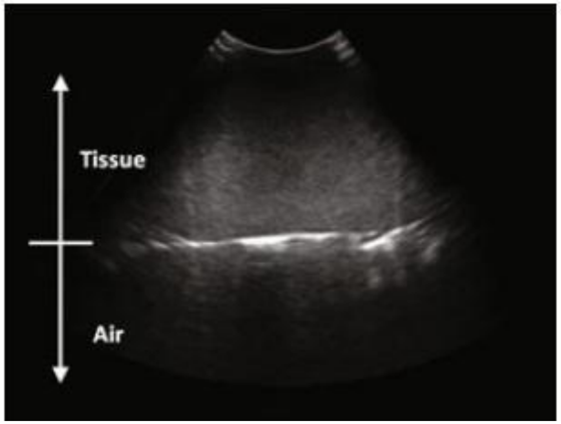
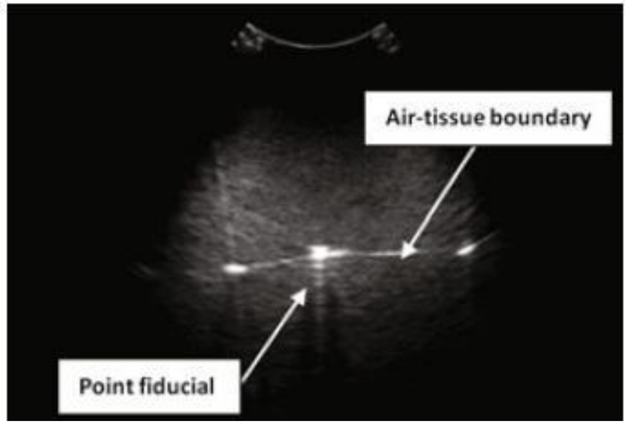
Paper Summary - Localization





Case	Fiducial Size	Lateral Position in US Image	Angle of Air-Tissue Boundary	Boundary Depth	Stiffness of Tissue
1	2mm	Offset (10cm)	0 degree	3cm	12 kPa
2	3mm	Central	20 degree	6cm	21 kPa
3	4mm	N/A	40 degree	9cm	56 kPa
Control	3mm	Central	0 degree	6cm	21 kPa

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Paper Summary - Localization

- One-way Analysis of Variance (ANOVA) testing for statistical significance in the variables
- 80 measurements for each variable combination

Variable	Value	Mean ± Std Dev. (mm)	Median (mm)	RMS Error
Fiducial Size	2 mm	0.94 ± 0.34*	0.89	1.00
	3 mm	0.82 ± 0.28	0.78	0.87
	4 mm	0.70 ± 0.20	0.67	0.73
Boundary Depth	Long (9 cm)	0.54 ± 0.18*	0.55	0.57
	Med. (6 cm)	0.82 ± 0.28	0.78	0.87
	Short (3 cm)	0.66 ± 0.20*	0.64	0.69
Tissue Stiffness	High (12kPa)	0.81 ± 0.30	0.78	0.86
	Med. (21kPa)	0.82 ± 0.28	0.78	0.87
	Low (56kPa)	0.80 ± 0.19	0.80	0.82
Boundary Angle	0°	0.82 ± 0.28	0.78	0.87
	20°	0.78 ± 0.28	0.75	0.83
	40°	1.04 ± 0.35*	0.97	1.10
Lateral Position On Boundary	Center	0.82 ± 0.28*	0.78	0.87
	Offset (10 cm)	0.60 ± 0.28*	0.59	0.66

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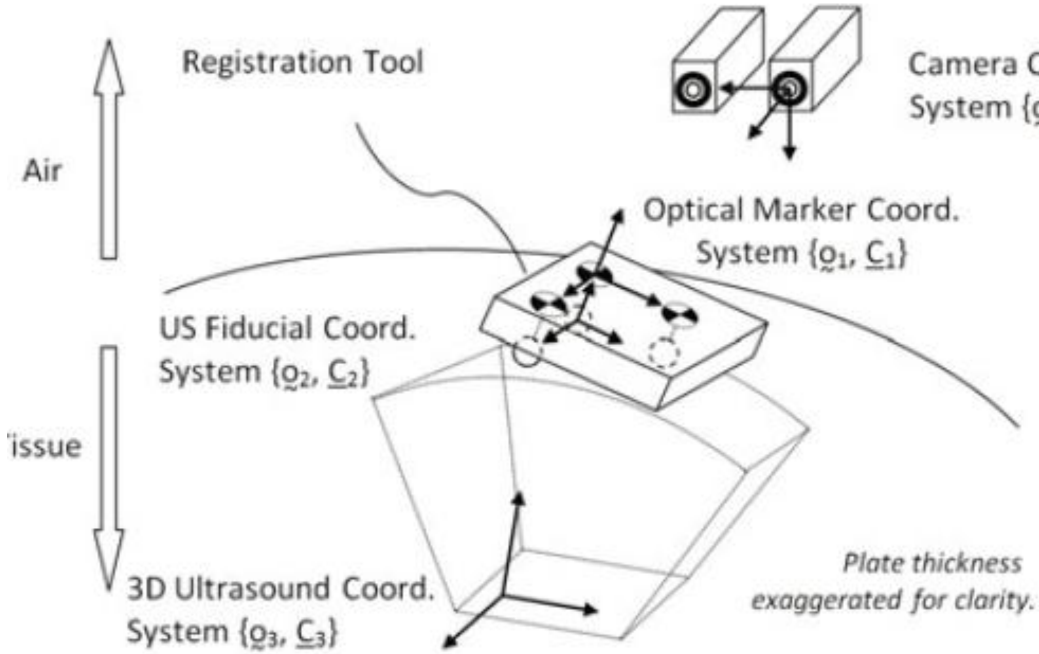
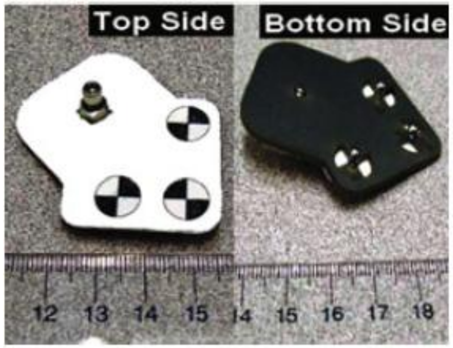
Paper Summary - Registration



$$^3v_1 = {}^3x_1 - {}^3x_0$$
$$^3v_2 = {}^3x_2 - {}^3x_0$$
$$^3i_2 = \frac{^3v_1}{||^3v_1||}$$
$$^3k_2 = \frac{^3v_1 \times {}^3v_2}{||^3v_1 \times {}^3v_2||}$$
$$^3j_2 = {}^3k_2 \times {}^3i_2$$
$$^3T_2 = \begin{bmatrix} ^3i_2 & ^3j_2 & ^3k_2 & ^3x_0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



$^0T_1$ is given by the stereo camera's triangulation of the optical markers

$^1T_2$ is given by the registration tool geometry

$^0T_3 = {}^0T_1{}^1T_2{}^2T_3$

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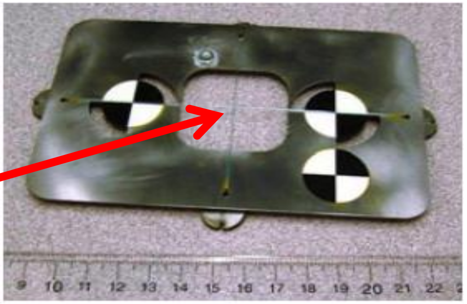
Paper Summary - Registration

1. Get registration by placing registration tool on phantom surface in water bath
2. Remove phantom and place test tool inside
3. Acquire US volume
4. Segment center of crosswire
5. Drain water
6. Obtain SC images that track the optical markers on the test tool
7. Resolve crosswire center in stereo camera space based on tool geometry
8. Use registration to transform SC point to US space
9. Error is Euclidean norm between US point and transformed SC point

crosswire



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Paper Summary - Registration

12 test points
ElectroMagnetic: 3.07 +- 0.75 mm [1]
Optical: 2.83 +- 0.83 mm [2]

	$e_{Lateral}$ (mm)	$e_{Elevational}$ (mm)	e_{Axial} (mm)	e_{Total} (mm)
Registration 1	0.90 ± 0.44	0.77 ± 0.33	1.08 ± 0.75	1.75 ± 0.56
Registration 2	1.02 ± 0.45	0.60 ± 0.32	1.14 ± 0.99	1.83 ± 0.74
Registration 3	0.65 ± 0.43	0.76 ± 0.33	1.01 ± 0.63	1.55 ± 0.53
Registration 4	0.57 ± 0.40	0.82 ± 0.30	1.03 ± 0.79	1.60 ± 0.58
Average	0.78 ± 0.45 mm	0.74 ± 0.32 mm	1.07 ± 0.78 mm	1.69 ± 0.60 mm

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Paper Summary - Discussion

- Fiducial Tail Artifact
  - Model tail artifact to reduce axial error
- Ultrasound and stereo camera ideally fixed
  - Reacquire registration
  - Use robot kinematics to get new registration
- Laparoscopic camera have smaller disparity
  - Larger foldable registration tool
- Minimum required fiducials used
  - More registration fiducials to average errors

Paper Analysis

Pros

•Good overview of the field

•Excellent choice of variables in fiducial localization

•Excellent statistical analysis to show significance

•Leads reader through frame transformations in detail

•Specific tools for testing purposes

•Subsurface error as opposed to surface

Cons

•Other variables directly affecting image quality such as level of scattering

•Localization is manual and difficult to reproduce

•A figure would have helped registration accuracy experiment

•Foldable registration tool sounds terrible

References

- [1] Cheung, C.L., et al.: Fusion of stereoscopic video and laparoscopic ultrasound for minimally invasive partial nephrectomy. In: Medical Imaging 2009: Visualization, Image-Guided Procedures, and Modeling. Proc. SPIE, vol. 7261, pp. 726109–726110 (2009)
- [2] Leven, J., et al.: DaVinci canvas: a telerobotic surgical system with integrated, robot-assisted, laparoscopic ultrasound capability. In: Duncan, J.S., Gerig, G. (eds.) MICCAI 2005. LNCS, vol. 3749, pp. 811–818. Springer, Heidelberg (2005)

Questions?