Photoacoustic Registration and Visualization: Checkpoint

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Overview

- Summary
- Motivation
- Milestones
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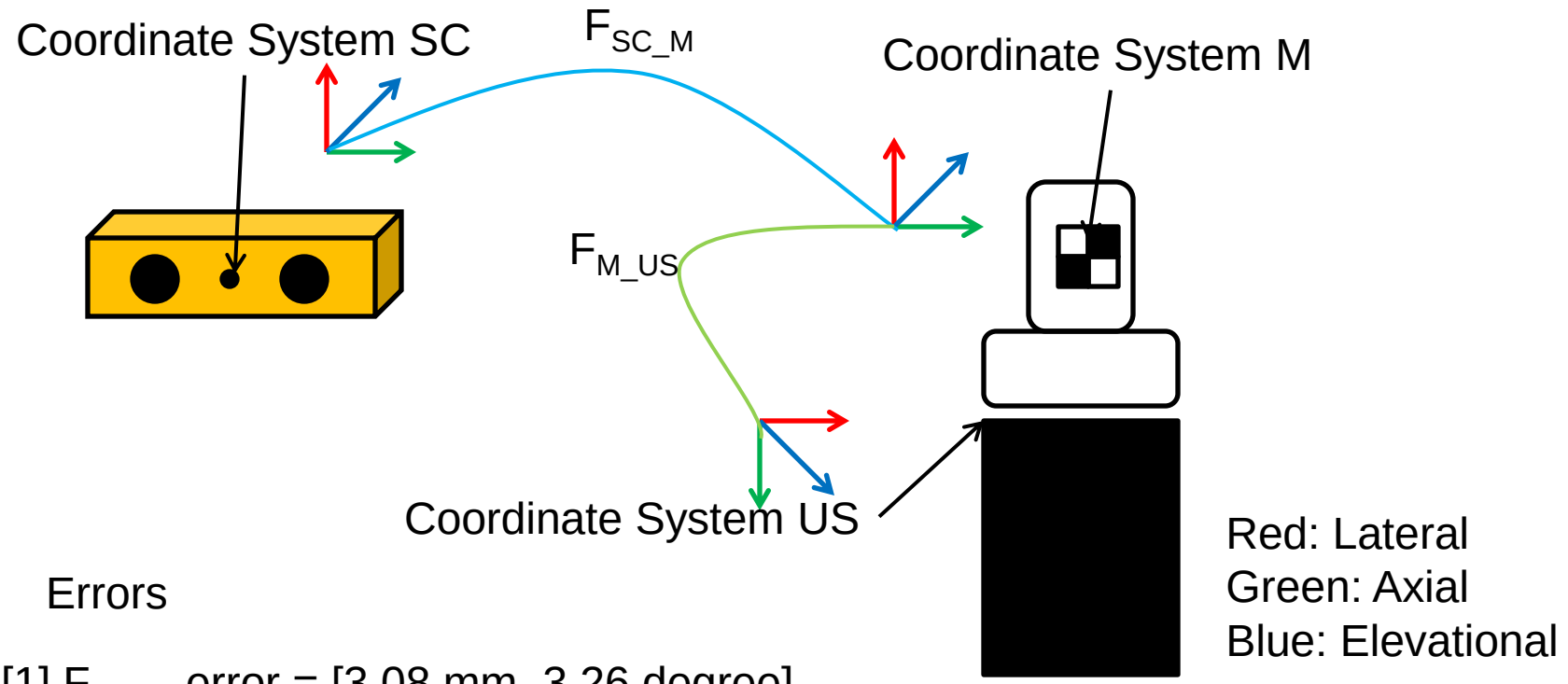
Summary

- Goal:
  - Direct Registration between 3D Stereocamera space and 3D Ultrasound space using Photoacoustic Imaging
- Aims:
  - Develop a multi-spot fiber delivery system
  - Collect Ultrasound data using a 3D probe
  - Segment laser points from Stereocamera images and photoacoustic signals from Ultrasound volumes automatically
  - Register 3D Stereocamera points with 3D Ultrasound points
  - Visualize points within the same space
  - Obtain experimental results on phantom and ex-vivo tissue
  - Demonstrate a sub-millimeter target registration error

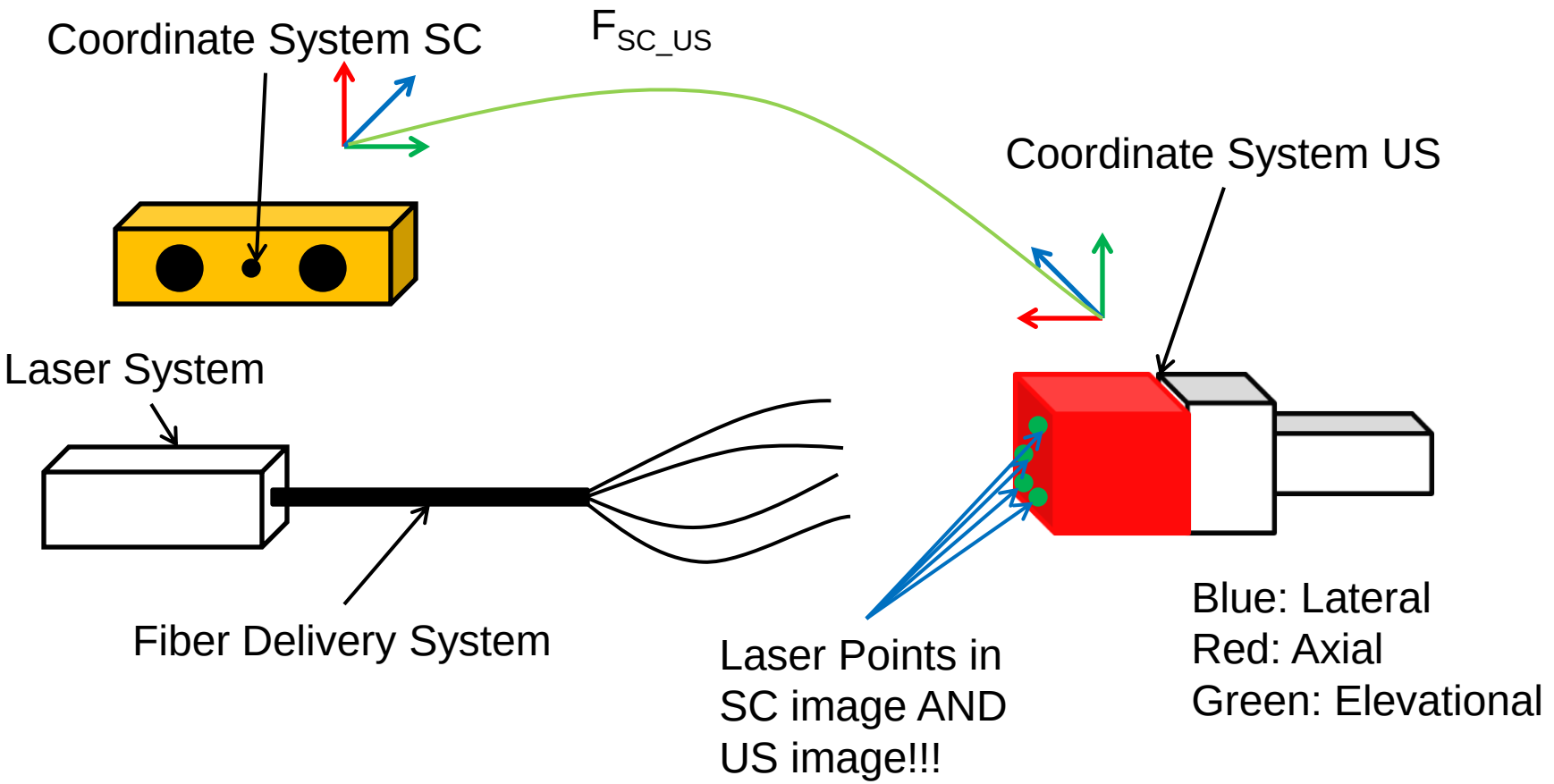
Motivation



Errors

[1] F_{M_US} error = [3.08 mm, 3.26 degree]
[2, 3] F_{SC_M} error = [0.5 mm, 0.11 degree]
F_{SC_US} error = [3.58 mm, 3.37 degree]

Motivation



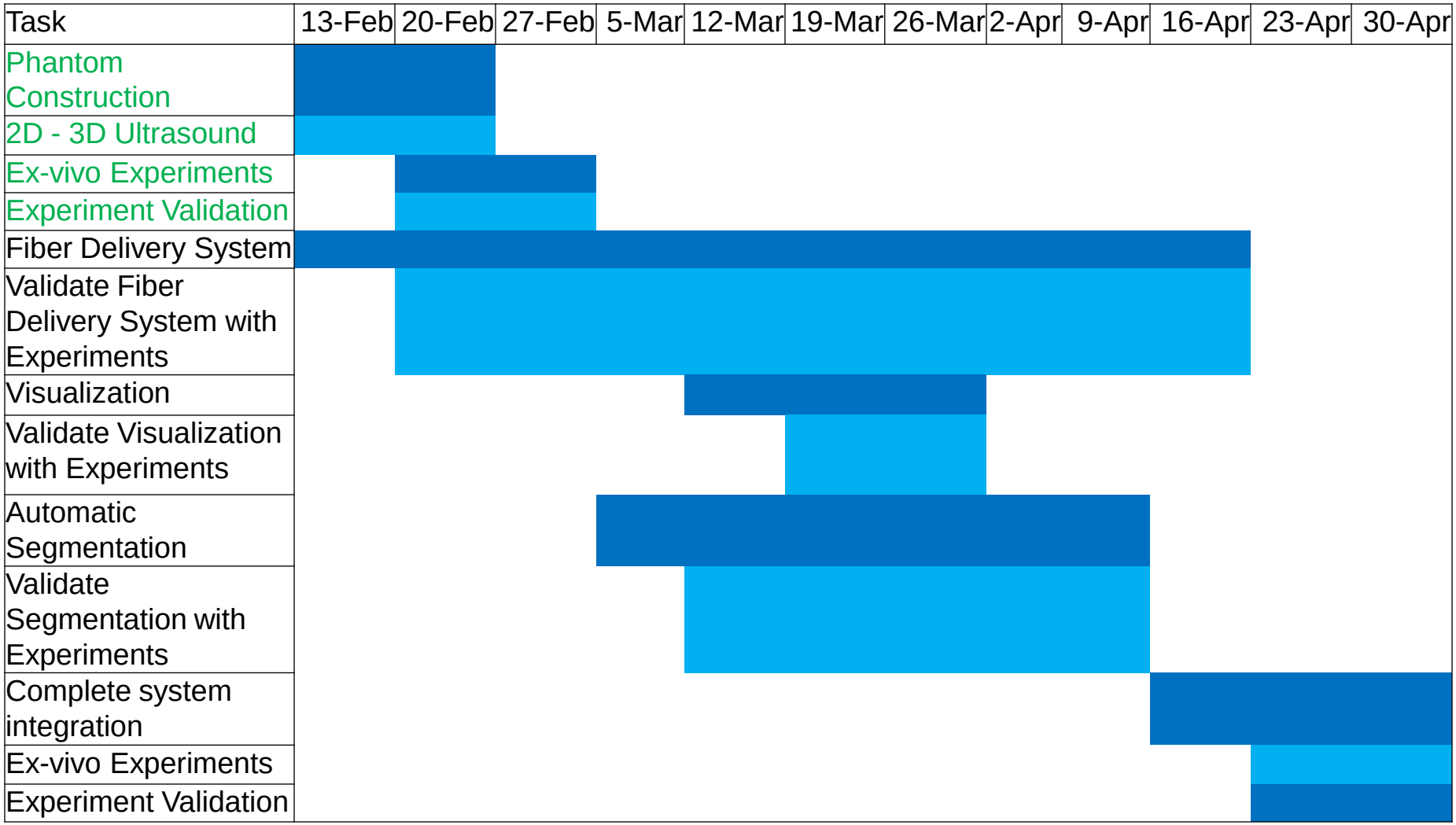
Milestones

- Phantom Construction (2/27)
  - Criteria: Create phantom suitable for 3D PA imaging
  - Status: Achieved. Made several ex-vivo tissue phantoms that have perished.
- 3D Ultrasound (2/27)
  - Criteria: Be able to manually segment the PA signal from a 3D volume
  - Criteria: Be able to collect a 3D Volume
  - Status: Achieved. Shown in Results later.
- Fiber Delivery System (3/5) (4/23)
  - Criteria: Develop a fiber that can shine multiple laser spots at once
  - Status: Delayed. Able to couple laser with fiber. Able to generate PA signal if fiber is very close to phantom. Shown in Results later.
  - Unresolved: Need to collimate laser coming out of fiber

Milestones

- Visualization (3/26) (4/2)
  - Criteria: Be able to display SC and US points in the same space
  - Status: Minimum Achieved. Shown in Results later.
  - Unresolved: Visualization of representation of US volume in SC space
- Automatic Segmentation (4/16)
  - Criteria: Able to segment desired PA signal from a set of images
  - Status: Ongoing. Preliminary results shown later.
  - Unresolved: Need to automatically determine threshold values
- System Integration (5/7)
  - Criteria: Pieces fit together
  - Status: Ongoing. Code is now modular and reusable.

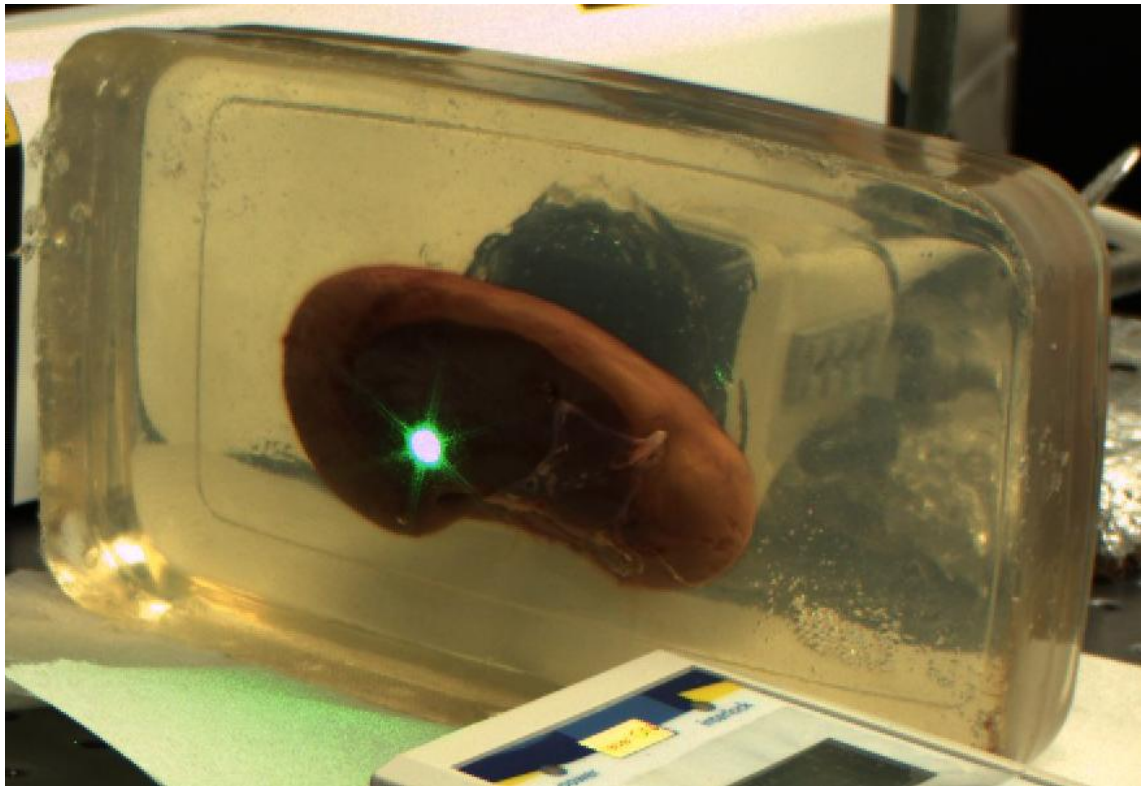
Milestones



Deliverables

- Minimum
  - Phantom and Ex-vivo Experimental Results with 3D Ultrasound
  - Ability to project multiple laser points concurrently
  - Visualization only shows points overlaid together
  - Automatic Segmentation working on 2D Ultrasound images or each individual 3D Ultrasound slice
- Expected
  - Visualization overlays points and representation of 3D Ultrasound volume
  - Automatic Segmentation working on 3D Ultrasound volume
- Maximum
  - Ability to collect 3D RF data without manually actuating motor
  - Complete system integrated together

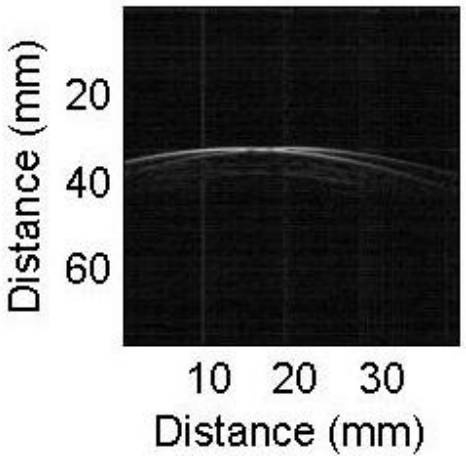
Results (Phantom)



- Porcine Kidney embedded in Gelatin Phantom
- Surface of Kidney is exposed

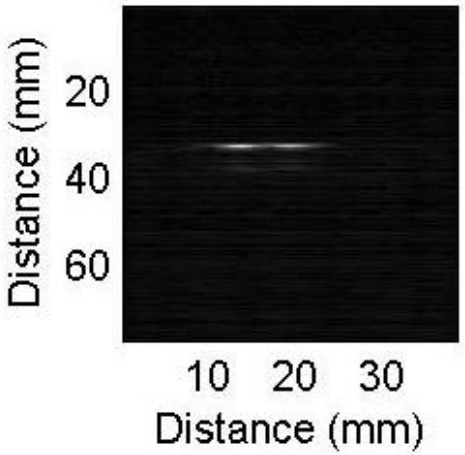
Results (Fiber Delivery)

Prebeamformed image 16 frame 3

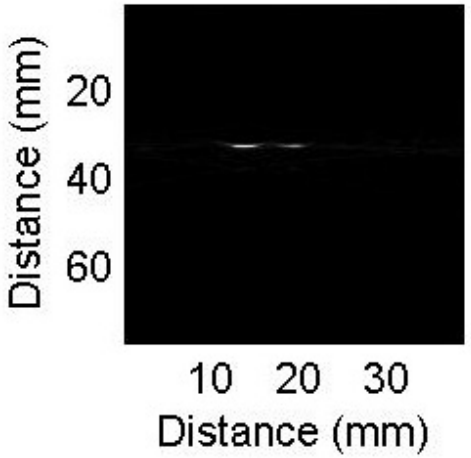


- Multiple laser spots projected at the same time
- Resulting beam size is ~ 1 mm diameter
- Fiber end is VERY close to the phantom

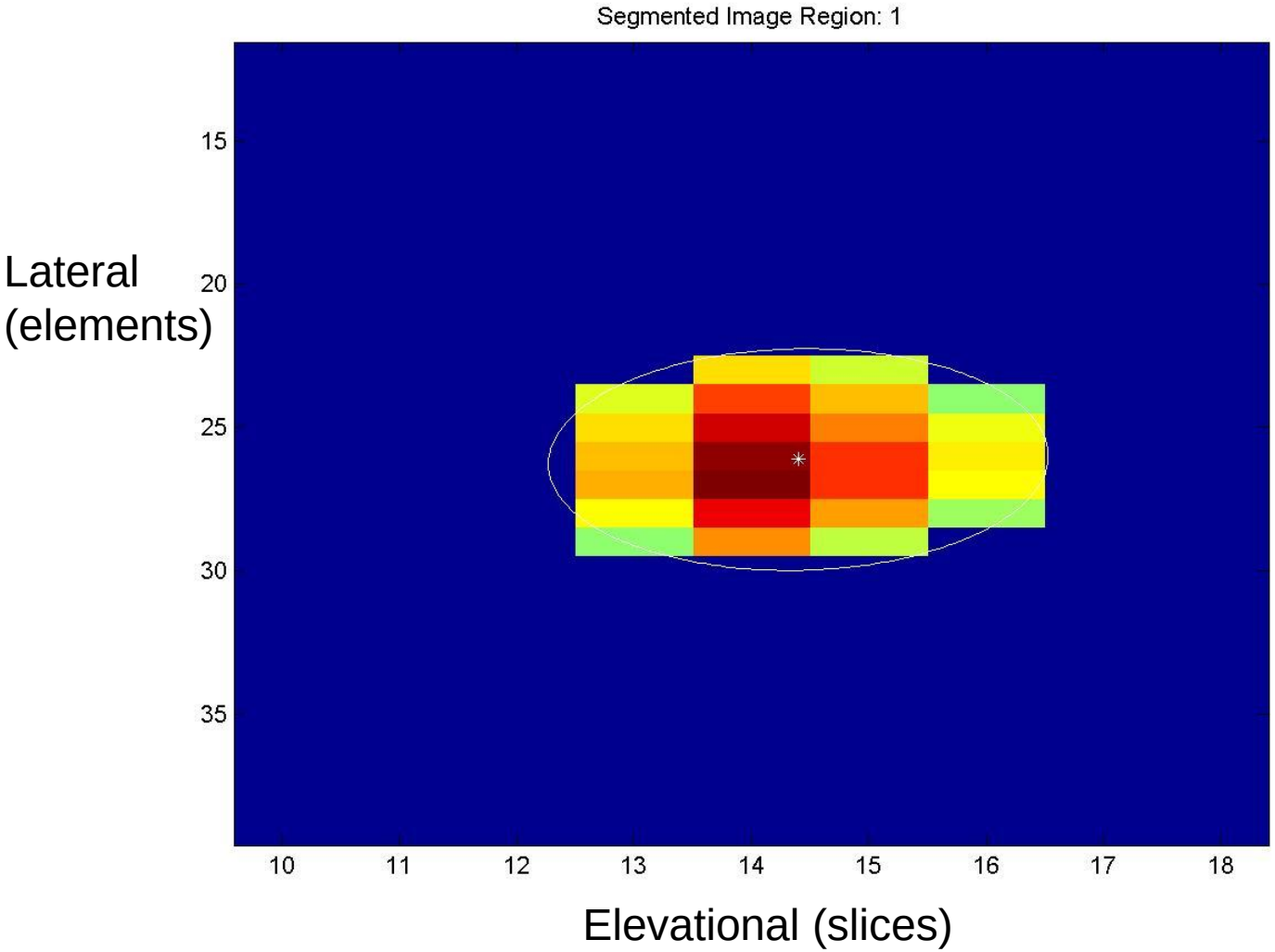
Beamformed image Delay-Sum 16 frame 3



Beamformed image K-Wave 16 frame 3

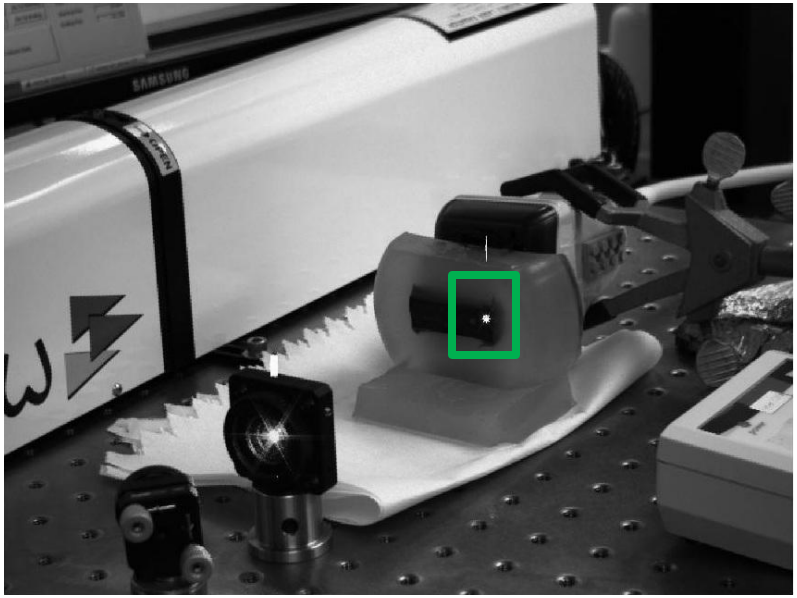


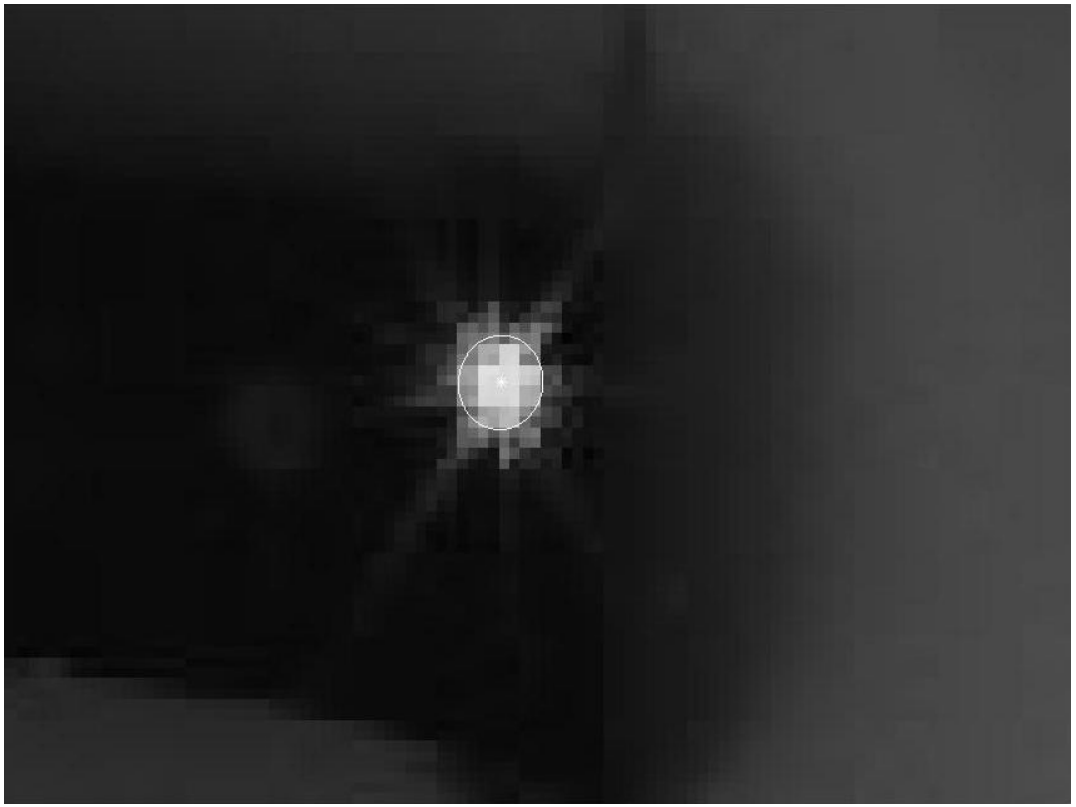
Results (US Segmentation)



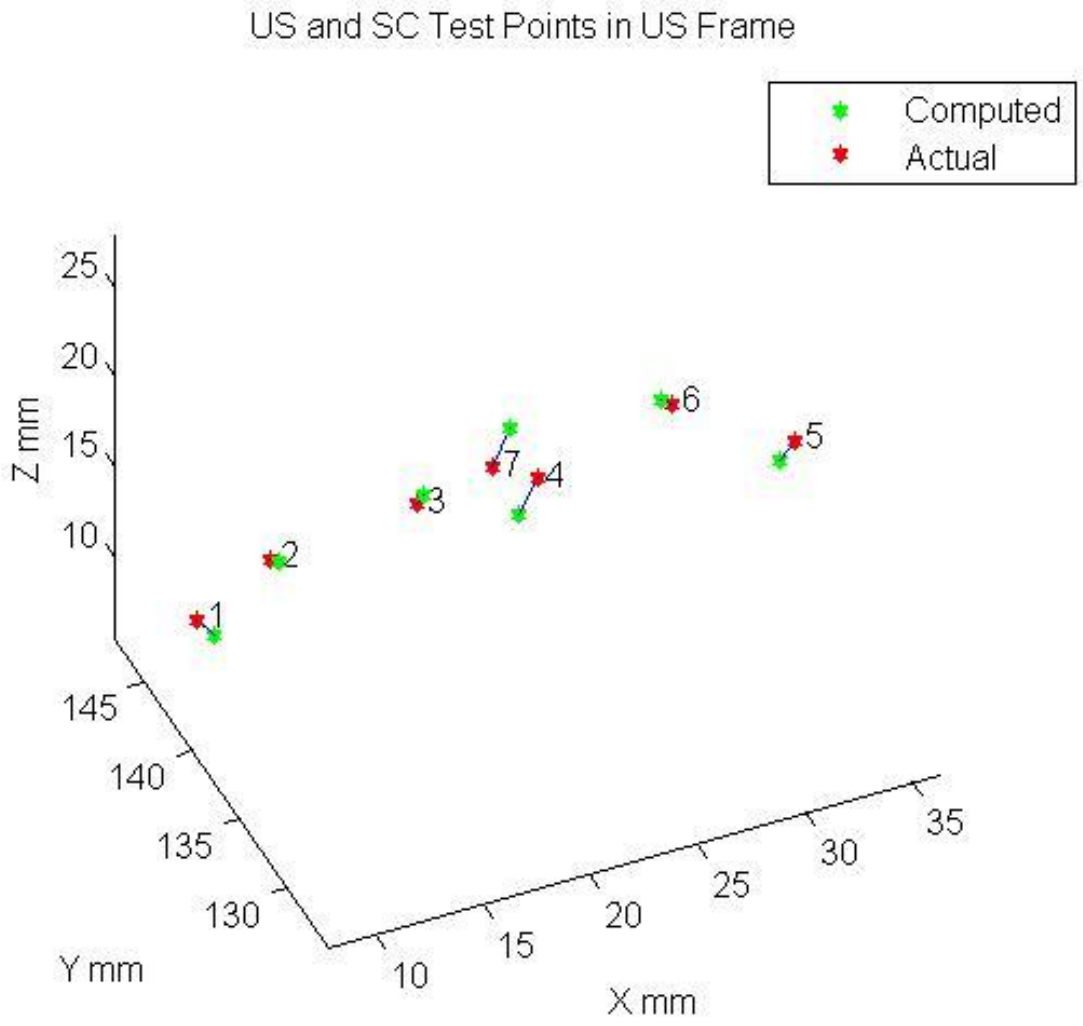
- Projected onto Lateral - Elevational plane
- Intensity is mean of pixel intensities in each axial ray

Results (SC Segmentation)





Results (Visualization)



Results (Ex-Vivo TRE)

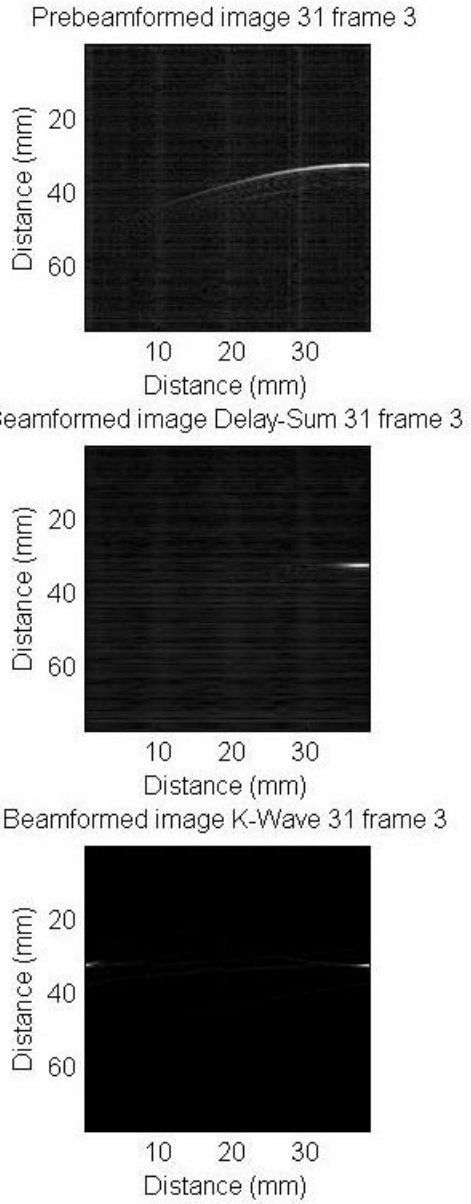
Test Point	Lateral (mm)	Axial (mm)	Elevational (mm)	Euclidean (mm)
7	0.38	0.91	2.68	2.86
6	0.5	0.07	0.5	0.71
5	0.76	0.04	0.85	1.14
4	0.43	0.92	2.62	2.81
3	0.08	0.53	0.88	1.03
2	0.22	0.4	0.04	0.46
1	1.09	0.62	1.67	2.09
Average	0.5	0.5	1.32	1.59

- Ex-Vivo Tissue Data
- [4] K-wave Beamformed
- 6 mm laser beam diameter

Results (Phantom TRE)

Test Point	Lateral (mm)	Axial (mm)	Elevational (mm)	Euclidean (mm)
6	1.08	0.84	1.55	2.07
5	0.92	0.67	0.02	1.13
4	1.2	1.73	1.77	2.76
3	0.49	0	1.35	1.44
2	2.58	0.01	0.15	2.58
1	0.34	0.07	1.02	1.08
Average	1.1	0.55	0.98	1.84

- Phantom Data
- Delay and Sum Beamformed
- ~ 1 mm laser beam diameter



Problems

- [4] K-wave beamforming vs Delay-Sum beamforming
  - K-wave produces a smaller spot laterally
  - BUT It doesn't work if the signal is near the edge!
- Correct Point in Region
  - How to determine a point from a region?
  - Centroid? Weighted Centroid? Centroid of Best fit Ellipse? Weighted Centroid of Best fit Ellipse?
- Automatic Segmentation
  - Difficult to determine threshold online because intensities vary between images
  - Correlation with a template PA signal?

References

- [1] Boctor E. et al., “A Novel Closed Form Solution for Ultrasound”. ISBI 2004
- [2] Navab N. et al., “Camera-Augmented Mobile C-Arm (CAMC) Application: 3D Reconstruction using Low Cost Mobile C-Arm”. MICCAI 1999, 688-697
- [3] Wiles A. et al., “Accuracy assessment and interpretation for optical tracking systems”. Medical Imaging 2004, vol. 5367: 421-432
- [4] Treeby B., and Cox B., “k-Wave: MATLAB toolbox for the simulation and reconstruction of photoacoustic wave-fields”. *Journal of Biomedical Optics.,* vol. 15, no. 2, p. 021314, 2010

Questions?