



# Real Time Needle Integrated Ultrasound Imaging

**Mentor:** Emad Boctor, PhD

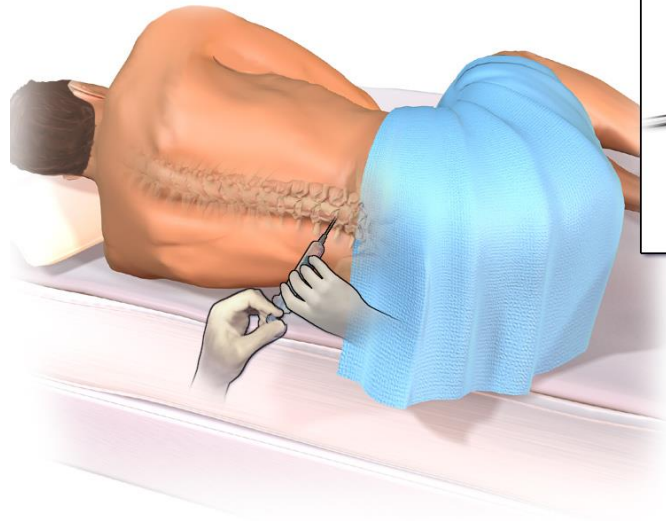
**Graduate Student Mentors:** Haichong Zhang, Younsu Kim

**Undergraduate Student:** Ernest Scalabrin

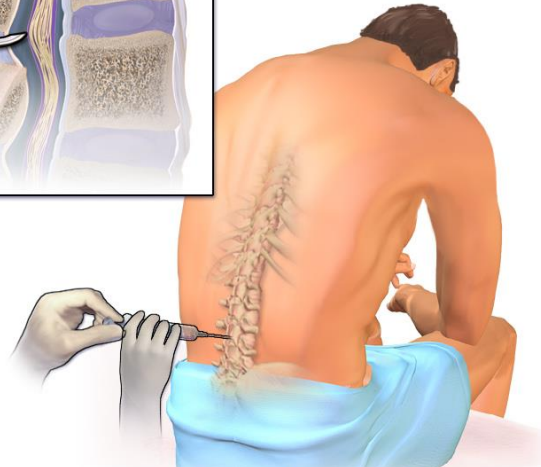


# LUMBAR PUNCTURES

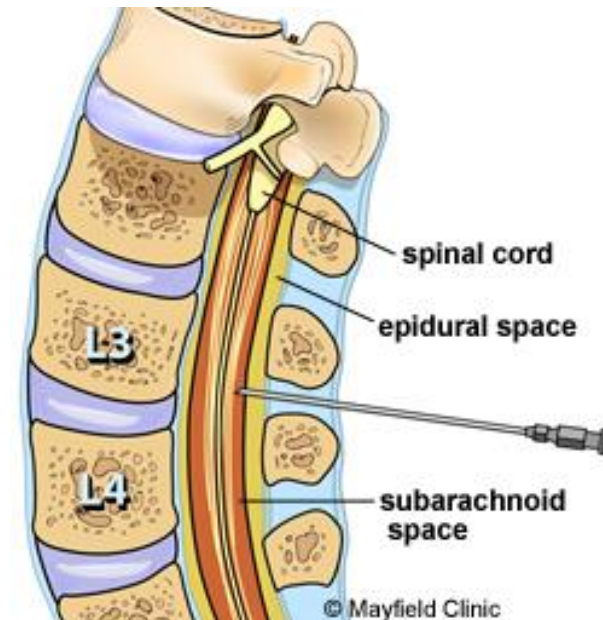
## Lumbar Puncture



Lying Position



Sitting Position



- CSF is located in the subarachnoid space of the spine
- Collected via Lumbar Puncture, navigation of a collection needle to subarachnoid space
  - Physicians must avoid blood vessels, nerves, and bone without visibility

CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

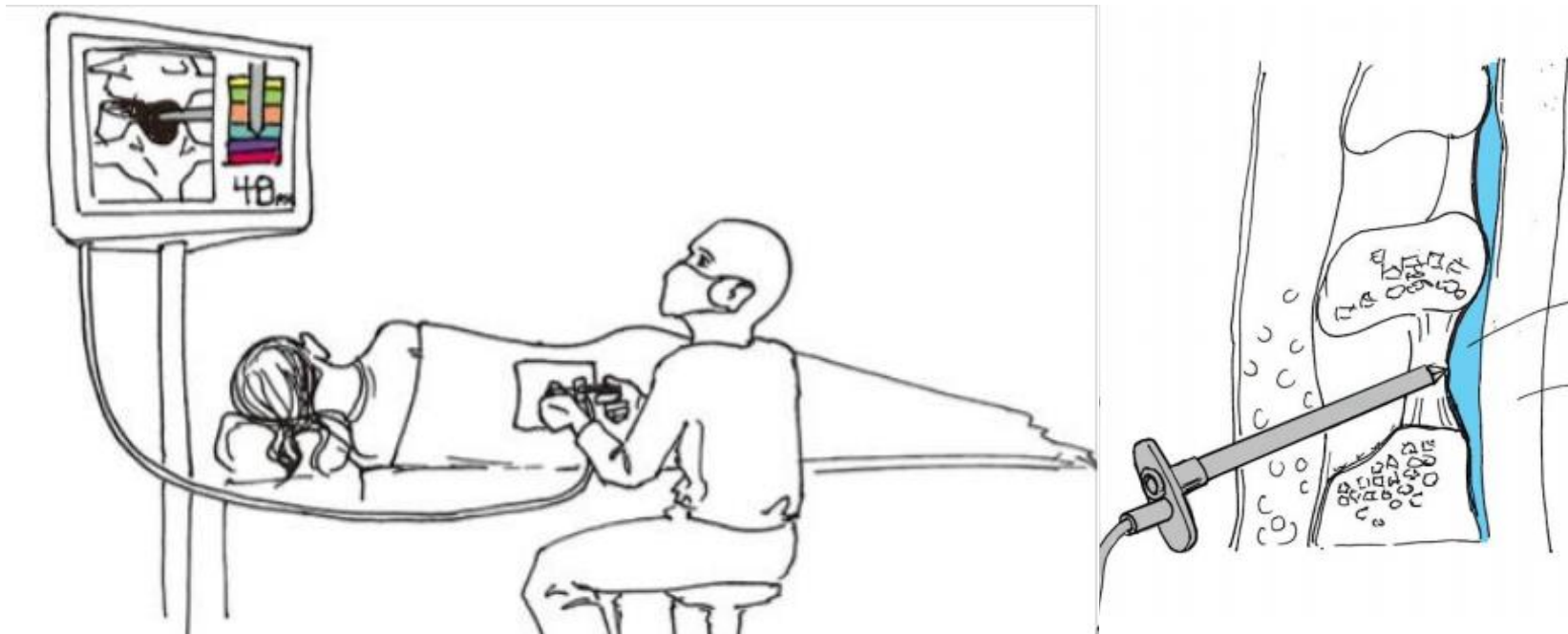
NEW  
APPROACH

SETBACKS

PROGRESS

NEW PLAN

# SOLUTION



Device will provide:

- Improved image quality through sub-dermal imaging
- Dynamic guidance to allow the correct placement of the needle on the first attempt
- Reduced rate of iatrogenic complications

CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

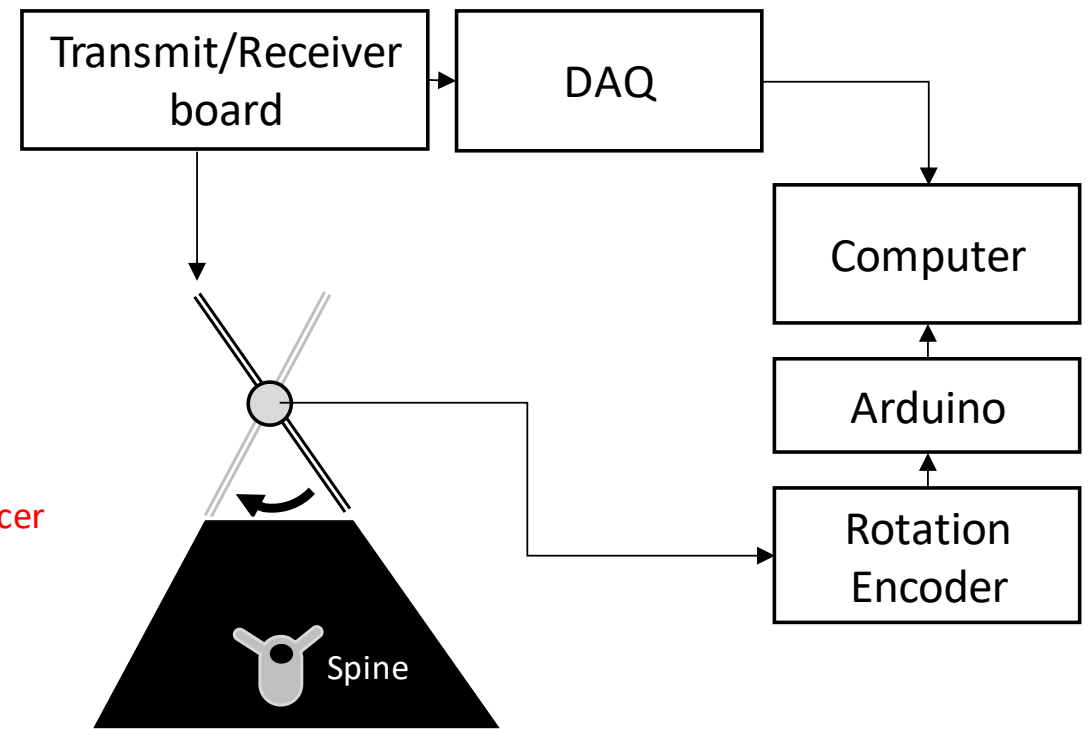
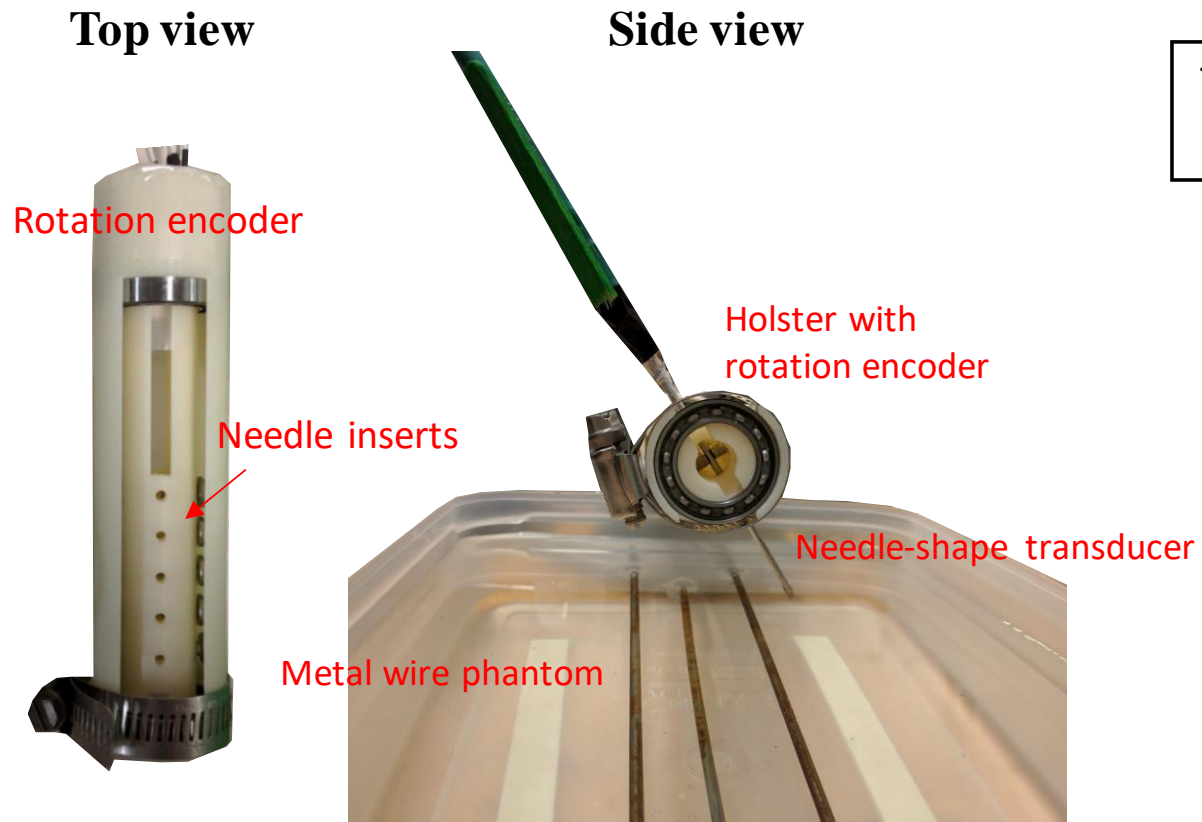
SETBACKS

PROGRESS

NEW PLAN



# CURRENT PROTOTYPE



CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

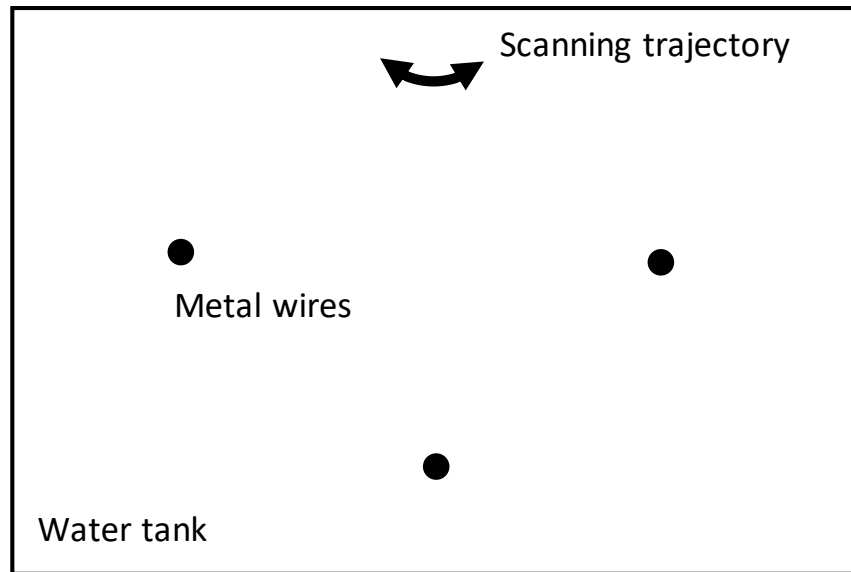
SETBACKS

PROGRESS

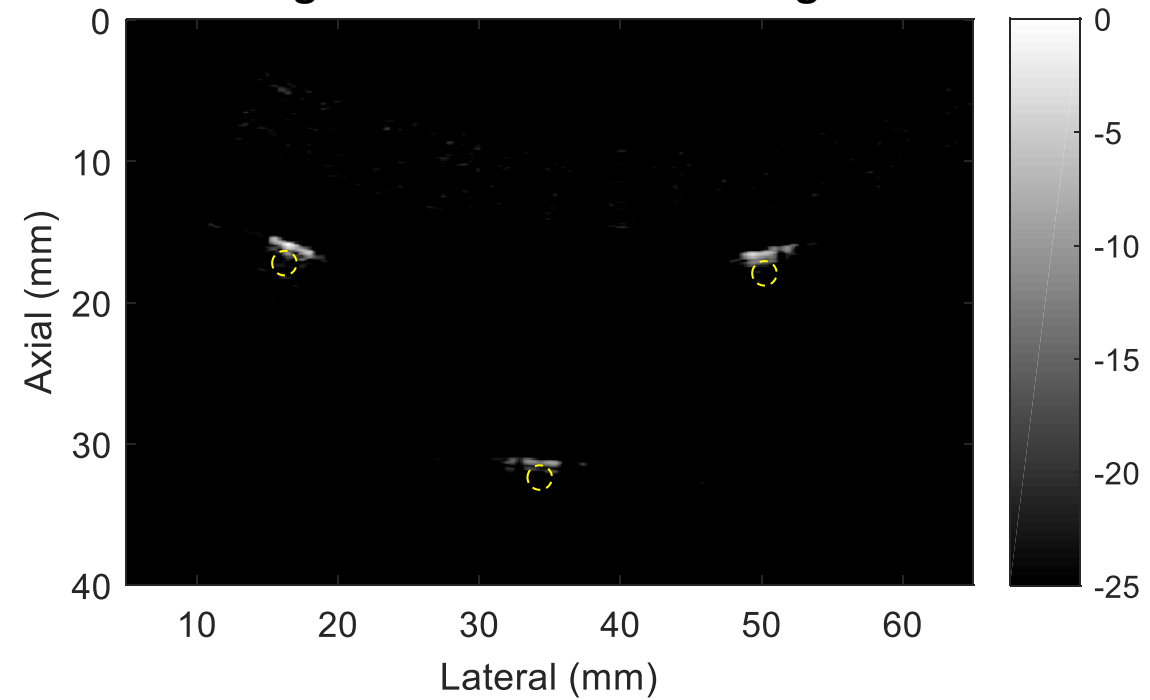
NEW PLAN

# CURRENT PROTOTYPE

## Phantom design



## Single element STRATUS image



## Synthetic Tracked Aperture Ultrasound (STRATUS)

Figure Credit: Kai Zhang

CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

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# ORIGINAL GOALS VS NEW GOALS

## Original

Task	Priority
<del>C++ Translation and Speed Optimization</del>	Minimum Deliverable
Beamform & Scan Conversion Integration in Realtime	Expected Deliverable
<del>Needle Depth Tracking</del>	Maximum Deliverable

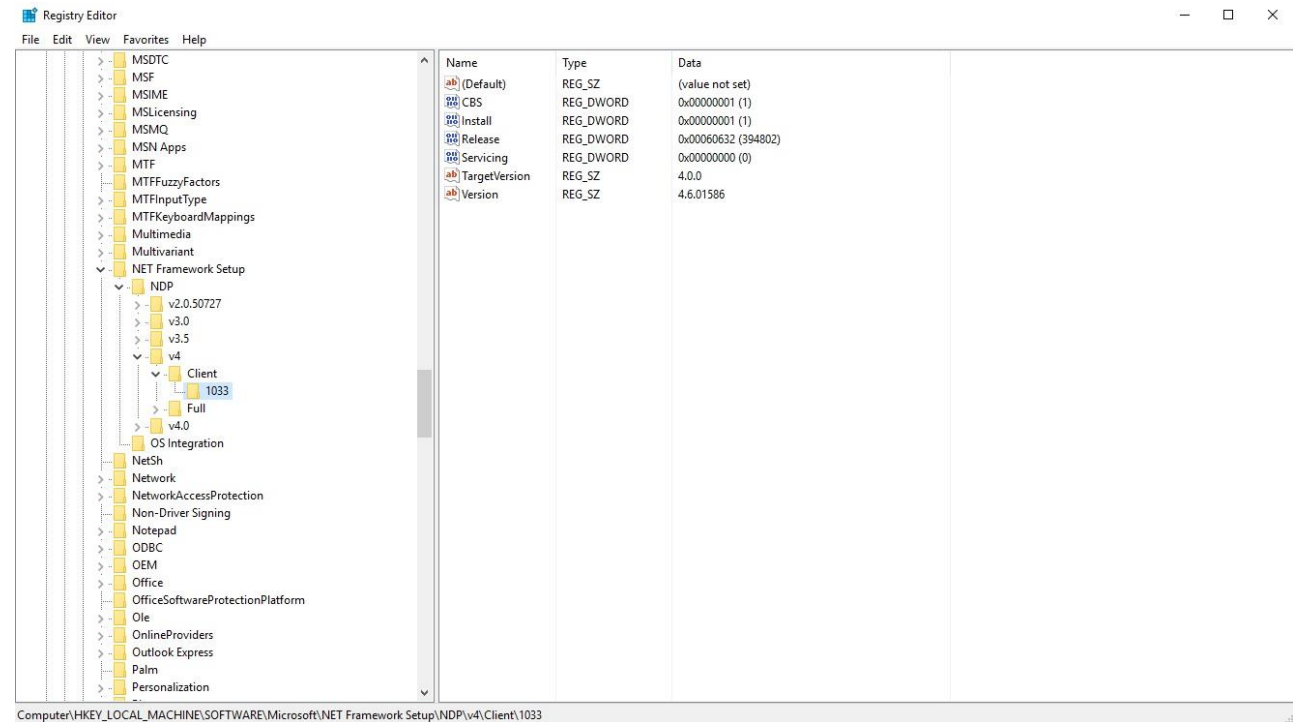
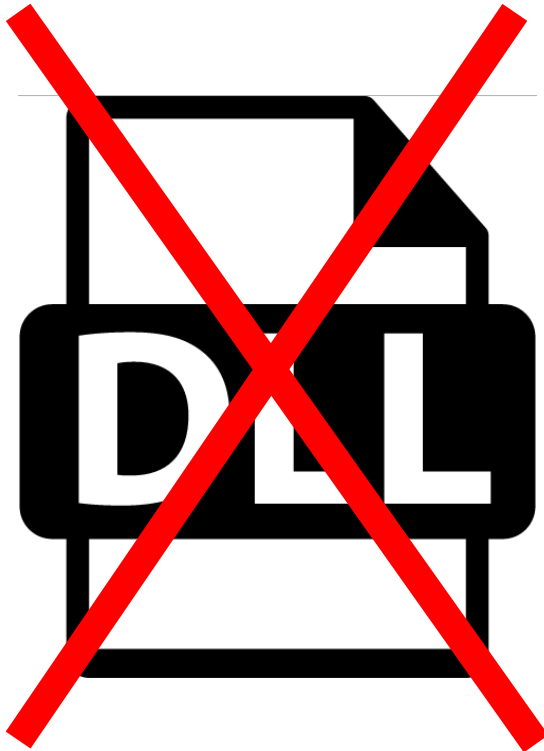
## New

Task	Priority
<b>Pseudo Realtime Scan Conversion Algorithm</b>	Minimum Deliverable
Pseudo Realtime Beamforming Algorithm	Expected Deliverable
<b>Integrate into Realtime Code</b>	Maximum Deliverable



# SETBACKS

- Unforeseen Dependency: Getting US KEY dynamic link libraries (DLLs) to work on Windows 10.
  - Of 4 machines (1 mac and 3 PCs, 1 worked)
  - Then that one crashed...



CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

SETBACKS

PROGRESS

NEW PLAN



# SETBACKS

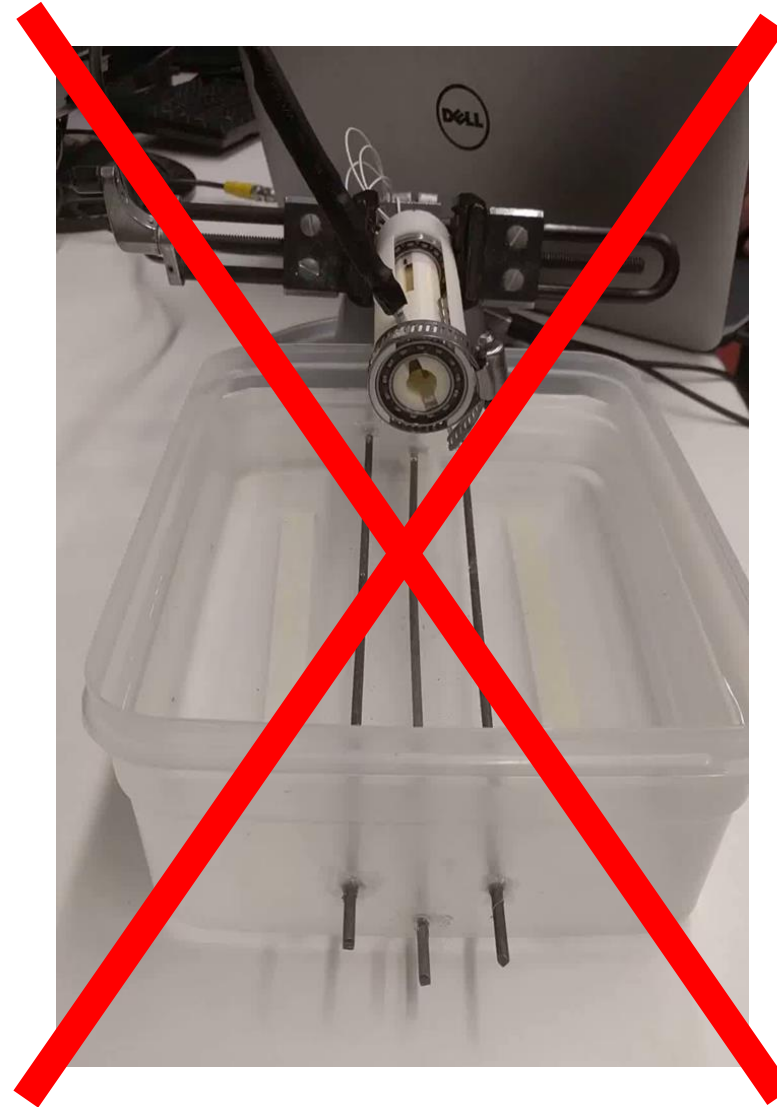
Too focused on real-time data acquisition





## Simulated real time data acquisition

- Uses raw A-line data array from previous experiments.
- Passes A-line data 1 by 1 into algorithm to simulate acquiring A-line data in real time.
- Much more flexible
  - Testing and Analysis
  - Time



CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

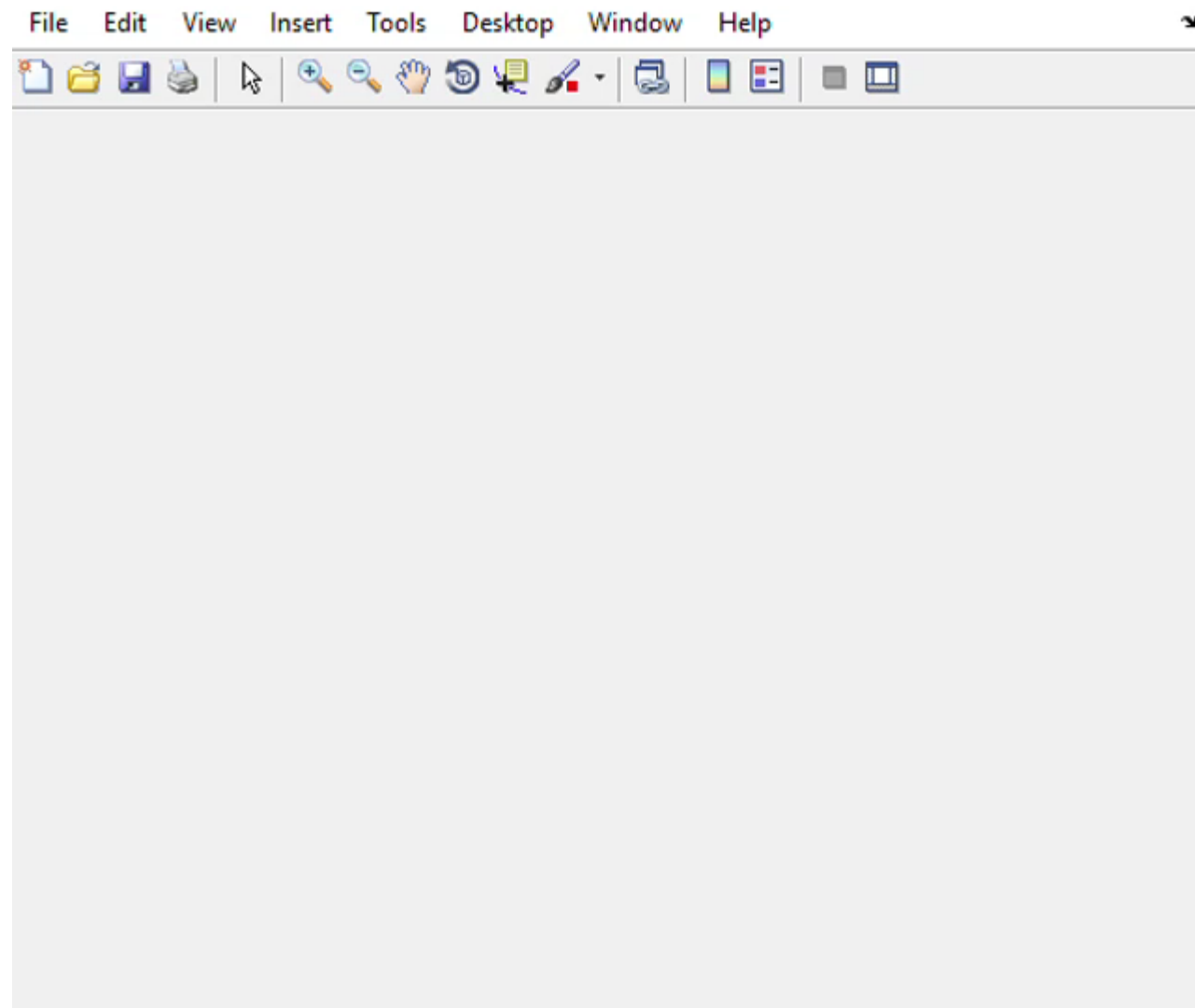
NEW  
APPROACH

SETBACKS

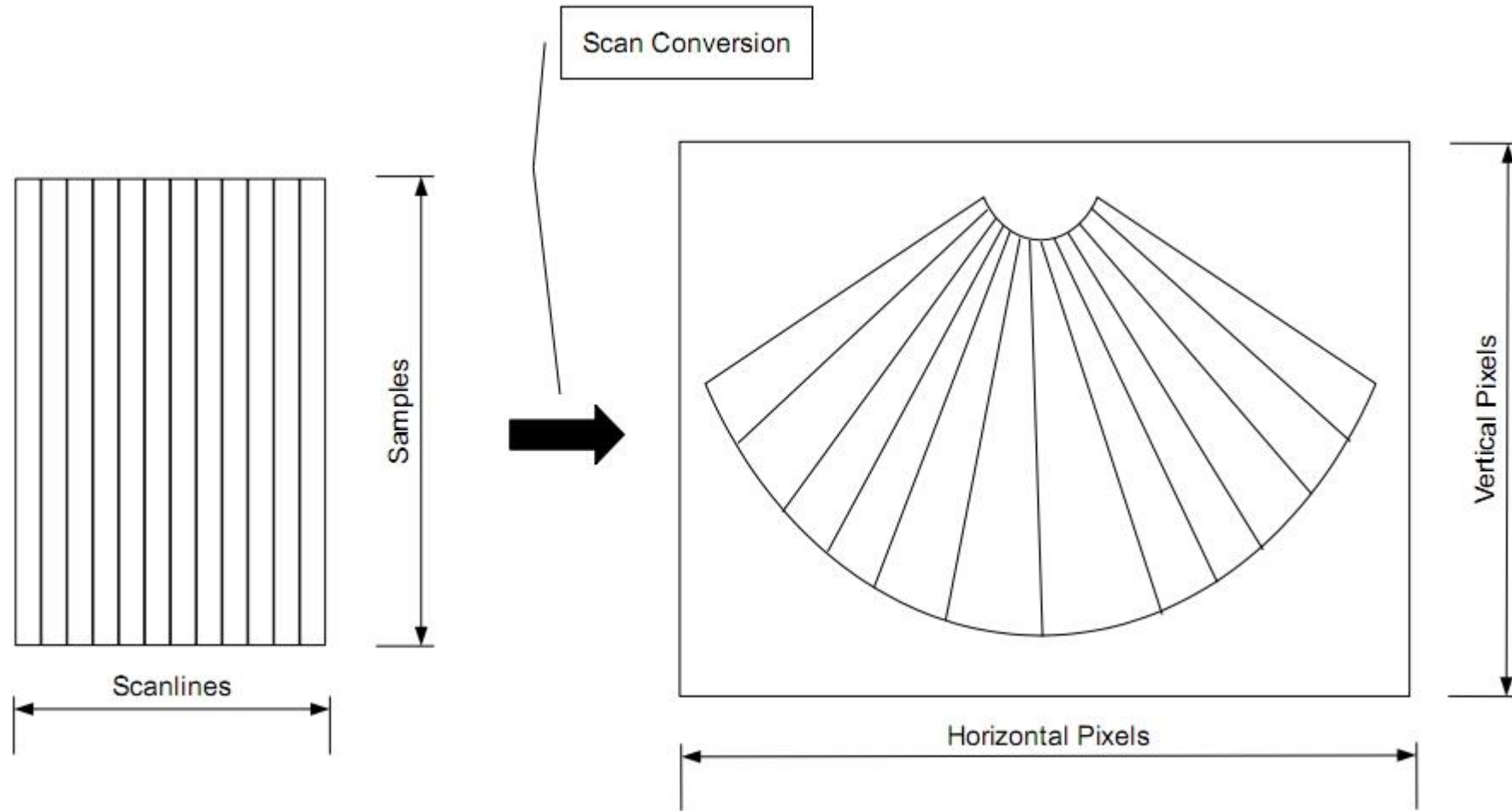
PROGRESS

NEW PLAN

# SIMULATION



# SIMULATED REAL-TIME SCAN CONVERSION



CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

SETBACKS

PROGRESS

NEW PLAN

# SCAN CONVERSION TECHNICAL APPROACH

Read in Raw Data

Create cartesian Matrix

**for (number of A-lines)**

    apply bandpass filter

**for (number of samples)**

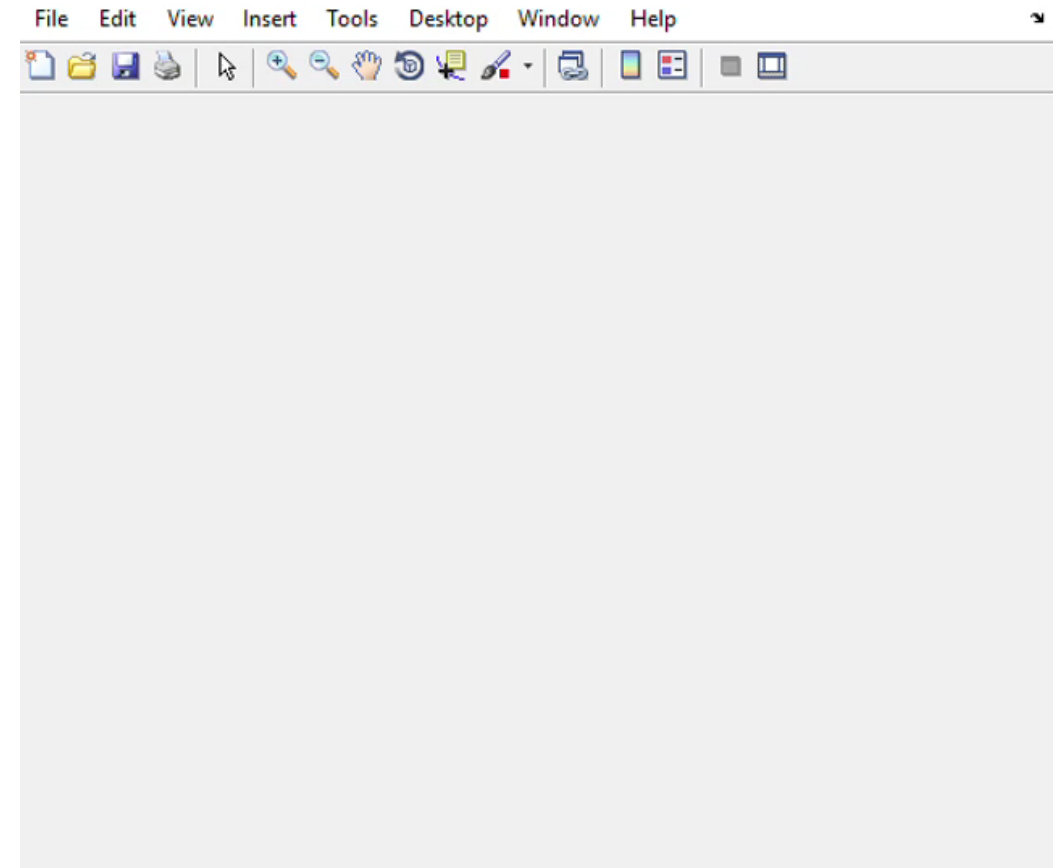
        calculate and assign X coordinate

        calculate and assign Y coordinate

**end**

Display cartesian matrix

**end**



CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

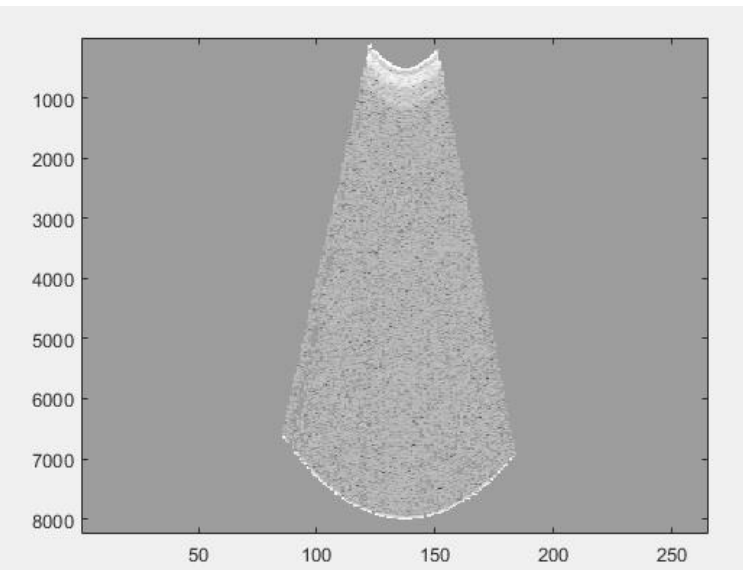
SETBACKS

PROGRESS

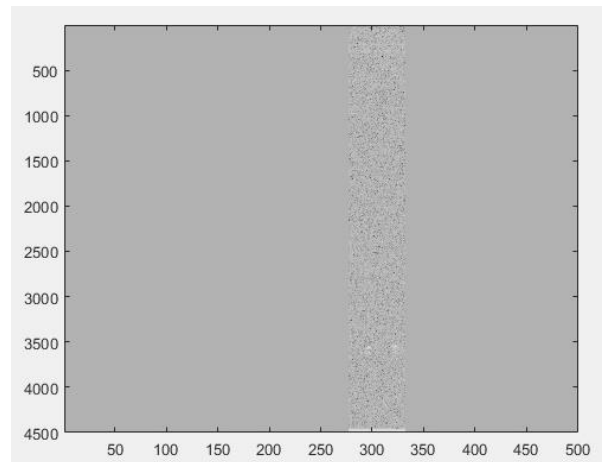
NEW PLAN



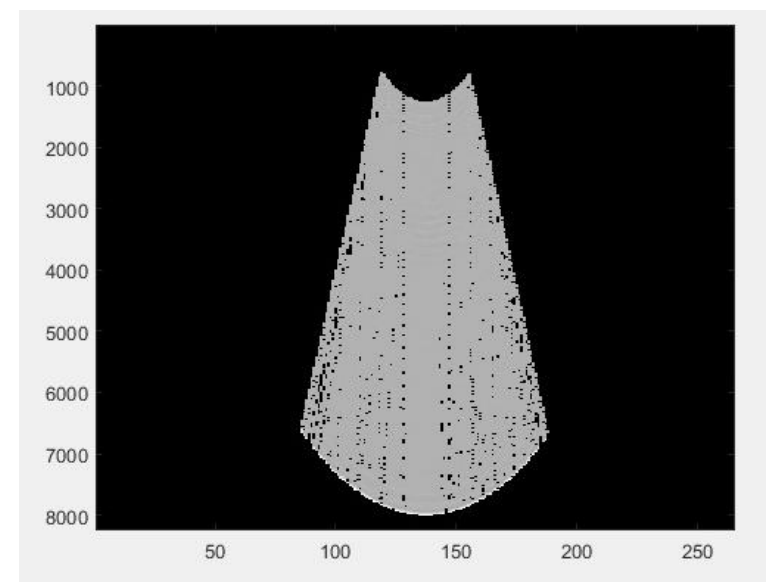
# SIMULATION



↑ SC raw data



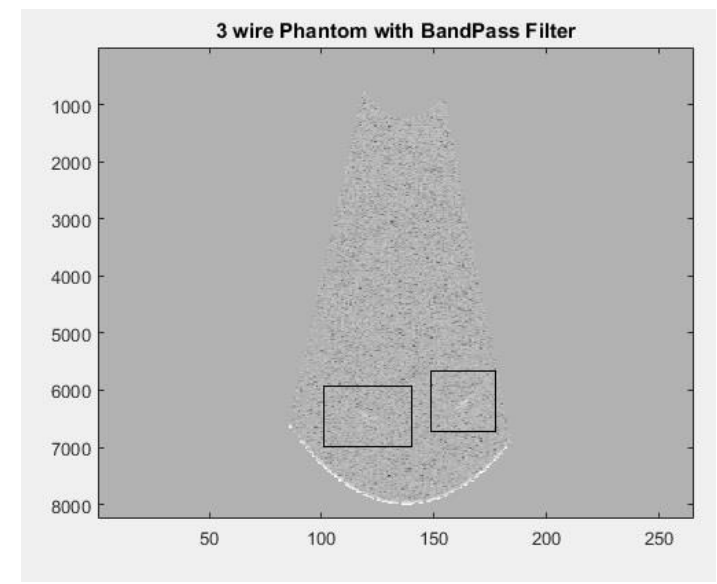
Raw Data in PC



Remove interface noise



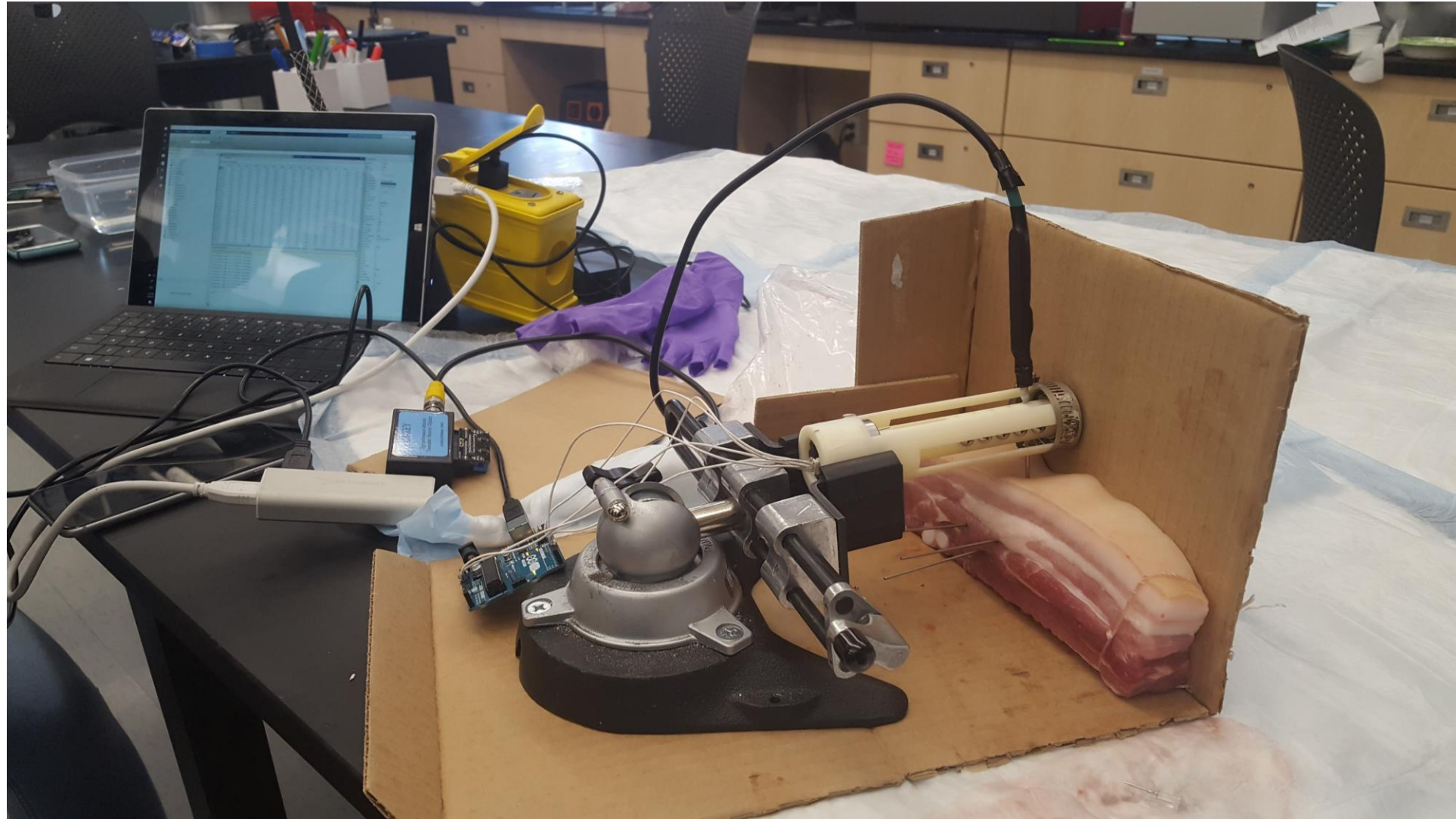
AND WE DIDN'T EVEN BEAMFORM YET!



Hamming Bandpass filter



# EX-VIVO EXPERIMENT



CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

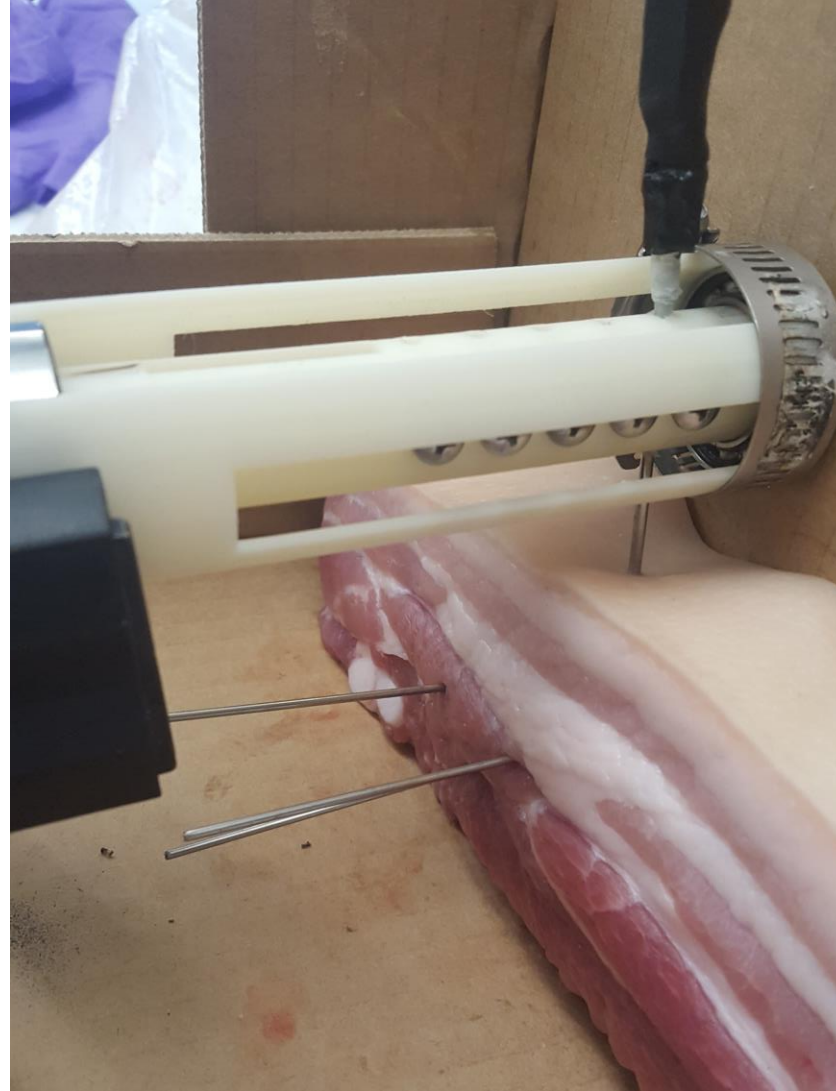
NEW  
APPROACH

SETBACKS

PROGRESS

NEW PLAN

# EX-VIVO EXPERIMENT



CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

SETBACKS

PROGRESS

NEW PLAN

## Develop Technical Approach for Beamforming Algorithm

- How to overcome excessive iterations as image updates.
- How to modify or calibrate for different data.
- Will discuss with Kai and Younsu on Monday

## Performance Analysis of Scan Conversion and Beamforming

- Quantify Image Quality
  - Spatial Resolution and Accuracy
- Identify factors which affect image quality
- Will discuss with Kai and Younsu on Monday

CLINICAL  
BACKGROUND

TECHNICAL  
BACKGROUND

NEW  
APPROACH

SETBACKS

PROGRESS

NEW PLAN



# DEPENDENCIES

Dependency	Method to Resolve	Progress
Availability of working PC for real-time integration	Conduct experiments at weekly Saturday meeting with working PC.	Resolved
Access to previous experimental data.	N/A	Resolved
Availability of wire phantom.	N/A	Resolved
Need access to porcine tissue.	Purchase from butcher or grocer.	Resolved



# ORIGINAL GOALS VS NEW GOALS

## Original

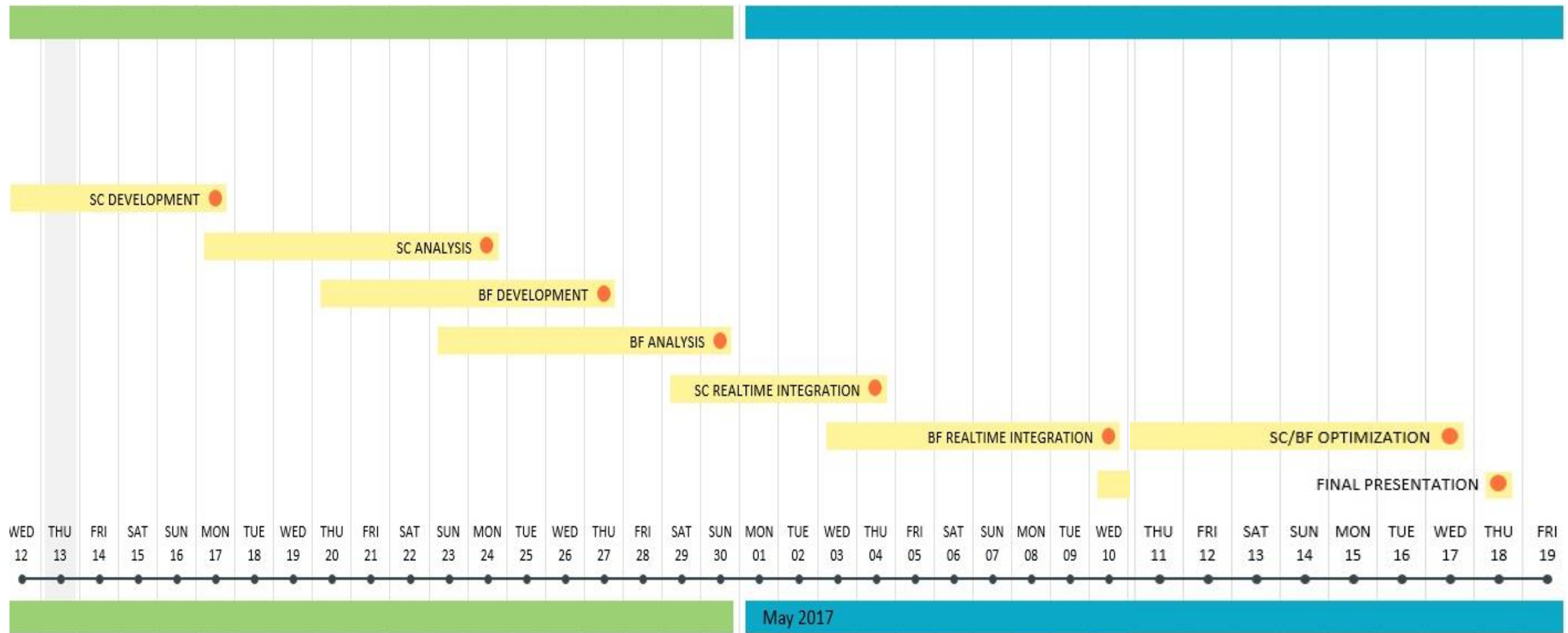
Task	Priority
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## New

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<b>Pseudo Realtime Scan Conversion Algorithm</b>	Minimum Deliverable
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# NEW GOAL TIMELINE



CLINICAL BACKGROUND

TECHNICAL BACKGROUND

NEW APPROACH

SETBACKS

PROGRESS

NEW PLAN





## Appendix

# REFERENCES

1. Armon C, Evans RW. Addendum to assessment: prevention of post-lumbar puncture headaches. *Neurology* 2005; 65: 510– 512
2. American Society for Healthcare Risk Management (n.d.). *Risk Management Handbook for Health Care Organizations* (Vol. 1).
3. Edwards, Cory, MD, Enrique C. Leira, MD, MS, and Pedro Gonzalez-Alegre, MD, PhD. "Residency Training: A Failed Lumbar Puncture Is More about Obesity than Lack of Ability." *American Academy of Neurology* (2015): n. pag. Print.
4. Shah KH, Richard KM, et al. Incidence of traumatic lumbar puncture. *Academic Emergency Medicine*
5. Ahmed, S. V., Jayawarna, C., & Jude, E. (2006, November). Post lumbar puncture headache: Diagnosis and management. *Postgraduate Medical Journal*, 82(273), 713-716.
6. Ultrasound imaging for lumbar punctures and epidural catheterisations: systematic review and meta-analysis
7. Brook, A. D., J. Burns, E. Dauer, A. H. Schoendfeld, and T. S. Miller. "Comparison of CT and Fluoroscopic Guidance for Lumbar Puncture in an Obese Population with Prior Failed Unguided Attempt." *Journal of NeuroInterventional Surgery*, 2013, 323-27.
8. Changing the needle for lumbar punctures: Results from a prospective study
9. Ungi, Tamas, Purang Abolmaesumi, Rayhan Jalal, Mattea Welch, Irene Ayukawa, Simrin Nagpal, Andras Lasso, Melanie Jaeger, Daniel Borschneck, Gabor Fichtinger, and Parvin Mousavi. Spinal Needle Navigation by Tracked Ultrasound Snapshots. *IEEE Transactions on Biomedical Engineering*, Oct. 2012. Web.
10. Moore, John, Colin Clarke, Daniel Bainbridge, Chris Wedlake, Andrew Wiles, Danielle Pace, and Terry Peters. Image Guidance for Spinal Facet Injections Using Tracked Ultrasound. *Medical Image Computing and Computer-Assisted Intervention*, 2009. Web.
11. Chen, Elvis C. S.; Mousavi, Parvin; Gill, Sean; Fichtinger, Gabor; Abolmaesumi, Purang. Ultrasound guided spine needle insertion. *Medical Imaging 2010: Visualization, Image-Guided Procedures, and Modeling*, edited by Kenneth H. Wong, Michael I. Miga, *Proceedings of SPIE*, Volume 7625, 762538, 2010.
12. Single-Camera Closed-Form Real-Time Needle Tracking for Ultrasound-Guided Needle Insertion. Najafi, Mohammad et al. *Ultrasound in Medicine and Biology*, Volume 41, Issue 10, 2663 - 2676
13. Xiang L. Wang ; Philipp J. Stolka ; Emad Boctor ; Gregory Hager ; Michael Choti; The Kinect as an interventional tracking system. *Proc. SPIE* 8316, *Medical Imaging 2012: Image-Guided Procedures, Robotic Interventions, and Modeling*, 83160U (February 23, 2012); doi:10.1117/12.912444.
14. Nagpal, S., Abolmaesumi, P., Rasouljan, A. et al. *Int J CARS* (2015) 10: 1371. doi:10.1007/s11548-015-1247-5
15. Jørgen Arendt Jensen, Svetoslav Ivanov Nikolov, Kim Løkke Gammelmark, Morten Høgholm Pedersen, Synthetic aperture ultrasound imaging, *Ultrasonics*, Volume 44, Supplement, 22 December 2006, Pages e5-e15, ISSN 0041-624X.

NEED

CONSTRAINTS

SOLUTION

# MILESTONES

Task	Priority	Completion Date
<b>Beamform &amp; Scan Conversion Integration</b>	<b>Expected Deliverable</b>	<b>3/24/17</b>
Study Literature		2/25/17
Understanding the Code		3/1/17
Beamforming		2/27/17
Scan Conversion		3/1/17
Able to Implement Existing Algorithm		3/6/17
Add real time scan conversion visualization in Matlab		3/17/17
Backprojection Reconstruction		3/24/17

NEED

CONSTRAINTS

SOLUTION

# MILESTONES

Task	Priority	Completion Date
<b>Needle Depth Tracking</b>	<b>Maximum Deliverable</b>	<b>4/30/17</b>
Acquire images of wire phantom		3/31/17
Attempt to use cross correlation to measure depth		4/6/17
Fabricate needle with side shooting element (or mechanical or optical tracking)		4/13/17
Integrate side shooting signal into algorithm		4/30/17

NEED

CONSTRAINTS

SOLUTION

# DEPENDENCIES

Unknown	Estimated Likelihood	Resolution Plan
Cross Correlation	Moderate (depending on anatomical effects)	Resort to mechanical or optical depth tracking. Implement side shooting element.

NEED

CONSTRAINTS

SOLUTION



# READING LIST

- [1] Armon C., Evans R. W., "Addendum to assessment: prevention of post-lumbar puncture headaches," *Neurology* 65, 510-512 (2005).
- [2] American Society for Healthcare Risk Management, "Risk Management Handbook for Health Care Organizations", Jossey-Bass, 5 (2009).
- [3] Edwards C., Leira E. C., and Gonzalez-Alegre P., "Residency Training: A Failed Lumbar Puncture Is More about Obesity than Lack of Ability," *Neurology* 84(10), e69-72 (2015).
- [4] Shah K. H., Richard K. M., et al., "Incidence of traumatic lumbar puncture," *Academic Emergency Medicine* 10(2), 151-4 (2003).
- [5] Ahmed S. V., Jayawarna C., and Jude E., "Post lumbar puncture headache: Diagnosis and management," *Postgraduate Medical Journal* 82(273), 713-716 (2006).
- [6] Shaikh F., Brzezinski J., Alexander S., Arzola C., Carvalho J. C., Beyene J., and Sung L., "Ultrasound imaging for lumbar punctures and epidural catheterisations: systematic review and meta-analysis," *BMJ* 346 (2013).
- [7] Brook A. D., Burns J., Dauer E., Schoendfeld A. H., and Miller T. S., "Comparison of CT and Fluoroscopic Guidance for Lumbar Puncture in an Obese Population with Prior Failed Unguided Attempt," *Journal of NeuroInterventional Surgery* 323-27 (2013).
- [8] Engedal T. S., Ørding H., Vilholm O. J., "Changing the needle for lumbar punctures," *Clinical Neurology and Neurosurgery* 130, 74-79 (2015).
- [9] Tamas U., Abolmaesumi P., Jalal R., Welch M., Ayukawa I., Nagpal S., Lasso A., Jaeger M., Borschneck D., Fichtinger G., and Mousavi P., "Spinal Needle Navigation by Tracked Ultrasound Snapshots," *IEEE Transactions on Biomedical Engineering* 59(10), 2766-72 (2012).
- [10] Moore J., Clarke C., Bainbridge D., Wedlake C., Wiles A., Pace D., and Peters T., "Image Guidance for Spinal Facet Injections Using Tracked Ultrasound," *Medical Image Computing and Computer-Assisted Intervention*, (2009).
- [11] Chen E. C. S., Mousavi P., Gill S., Fichtinger G., Abolmaesumi P., "Ultrasound guided spine needle insertion," *Proc. SPIE* 7625, 762538 (2010).
- [12] Najafi M., Abolmaesumi P., Rohling R., "Single-Camera Closed-Form Real-Time Needle Tracking for Ultrasound Guided Needle Insertion," *Ultrasound in Medicine and Biology*, 41(10), 2663-2676 (2015).
- [13] Wang X. L., Stolka P. J., Boctor E., Hager G., Choti M., "The Kinect as an interventional tracking system," *Proc. SPIE* 8316, 83160U (2012).
- [14] Nagpal S., Abolmaesumi P., Rasouljan A., et al., "A multi-vertebrae CT to US registration of the lumbar spine in clinical data," *Int. J. CARS* 10(9), 1371-81 (2015).
- [15] Jensen J. A., Nikolov S. I., Gammelmark K. L., Pedersen M. H., "Synthetic aperture ultrasound imaging," *Ultrasonics* 44(22), e5-e15 (2006).
- [16] Zhang H. K., Cheng A., Bottenus N., Guo X., Trahey G. E., Boctor E. M., "Synthetic Tracked Aperture Ultrasound (STRATUS) Imaging: Design, Simulation, and Experimental Evaluation," *Journal of Medical Imaging* 3(2), 027001 (2016).
- [17] Bottenus N., Long W., Zhang H. K., Jakovljevic M., Bradway D. P., Boctor E. M., Trahey G. E., "Feasibility of Swept Synthetic Aperture Ultrasound Imaging," *IEEE Transactions on Medical Imaging* 35(7), 1676-1685 (2016).

NEED

CONSTRAINTS

SOLUTION