Project 13: Real-time Photoacoustic Imaging Using Clinical Ultrasound Systems

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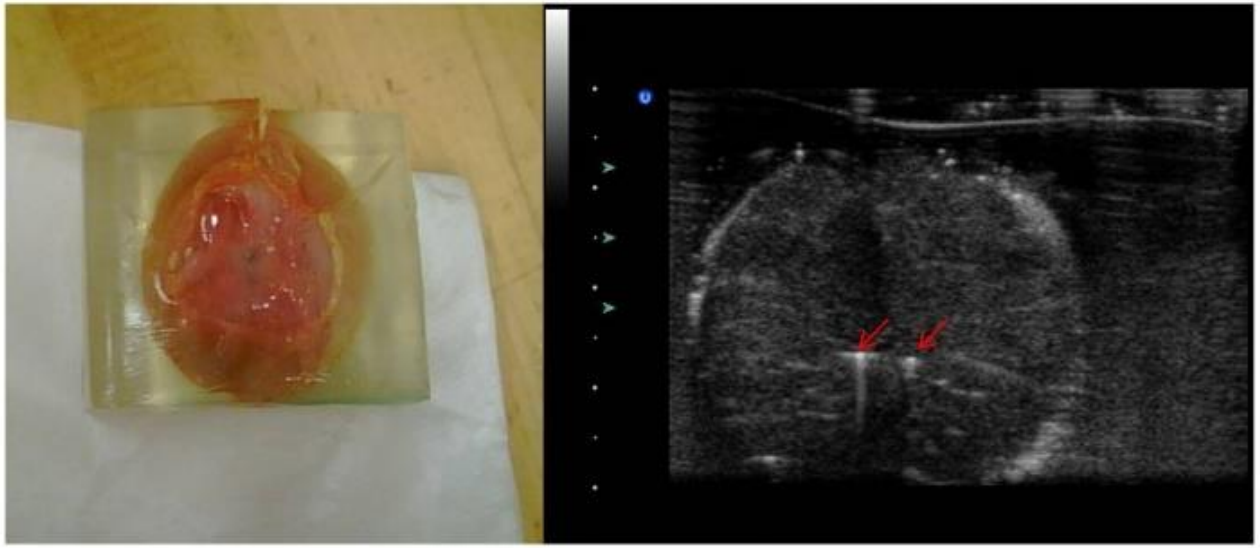
Overview of Photoacoustic Imaging

- Relies on emission of sound waves from materials absorbing light.
- Materials that demonstrate the photoacoustic effect include metallic objects and hemoglobin.
- Useful in cancer detection, blood vessel visualization, instrument tracking (Brachytherapy therapy seed tracking project) .



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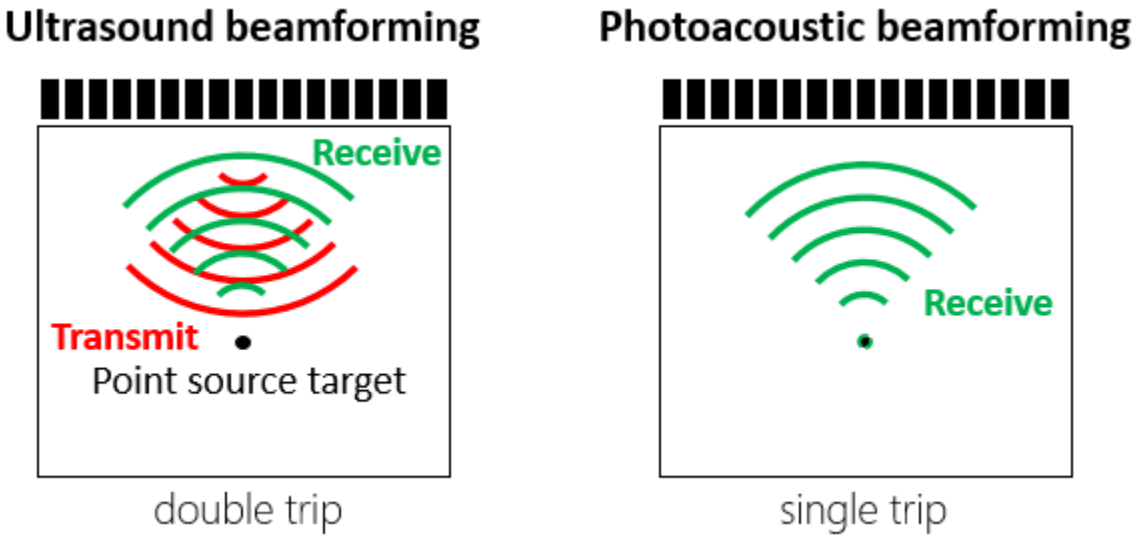
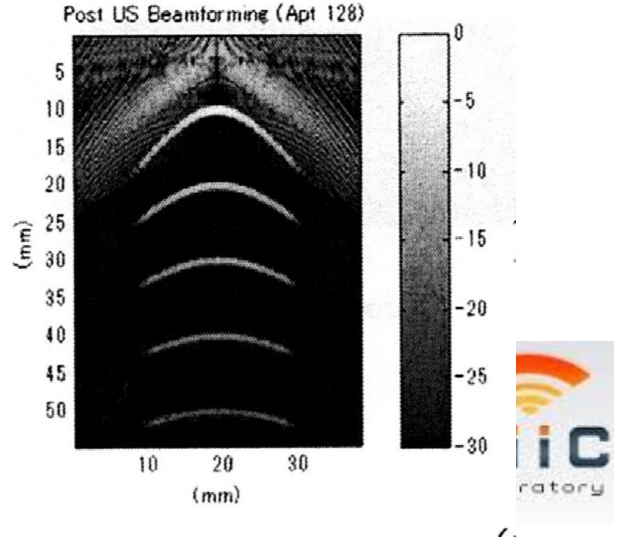
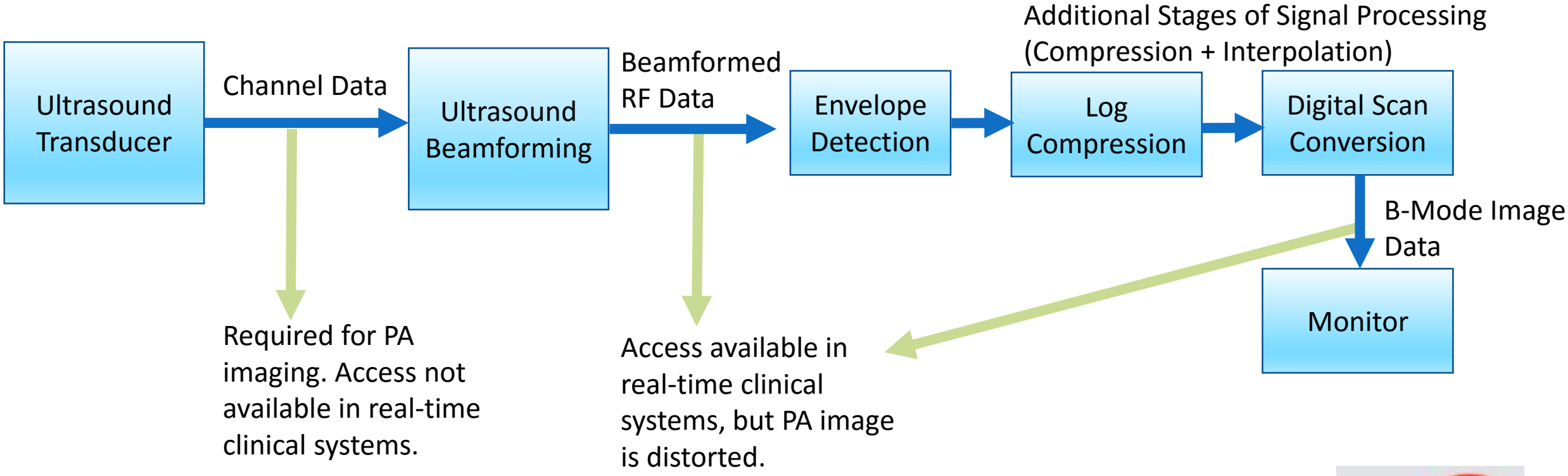
Limitations

- Oftentimes paired with ultrasound imaging.
- Need separate hardware to implement PA imaging (expensive).
- Current clinical US systems cannot process PA images (incorrect beamforming).



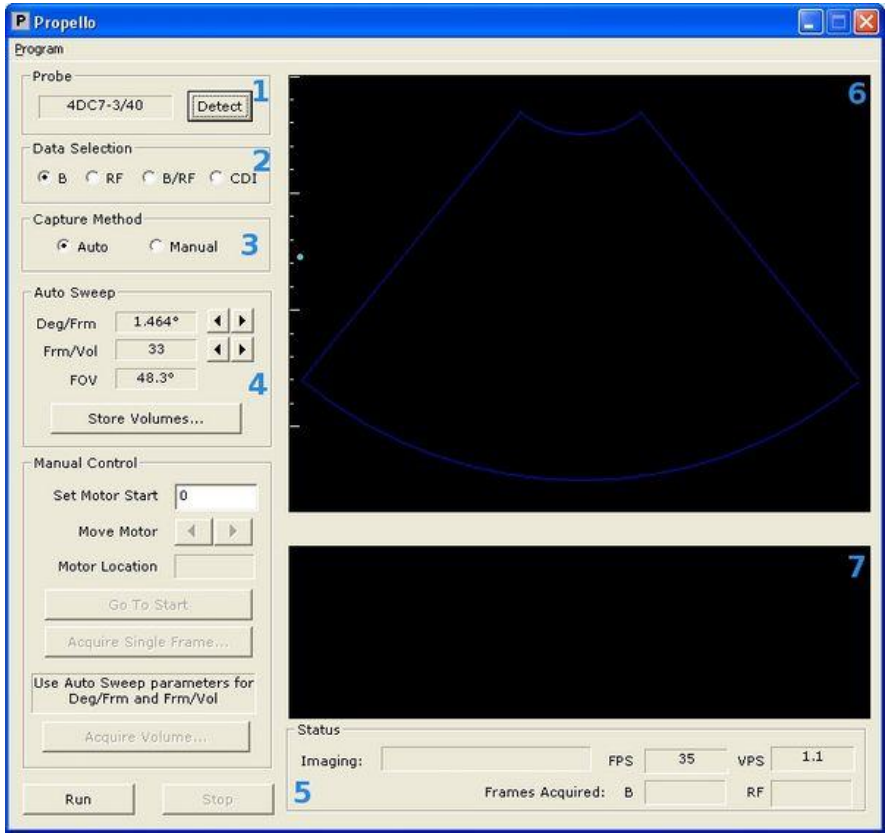


Ultrasound Image Processing



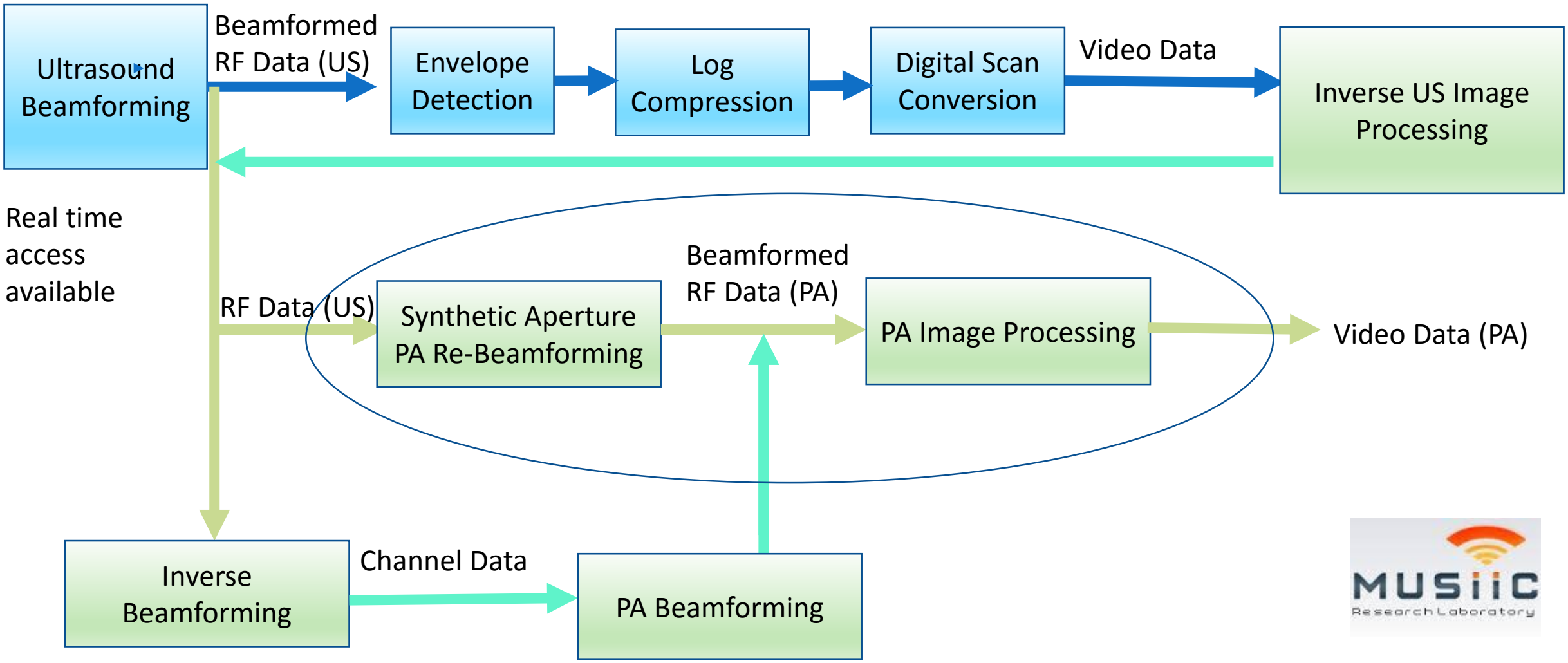
Project Goal

Design a real-time photoacoustic imaging system on a clinical ultrasound platform.

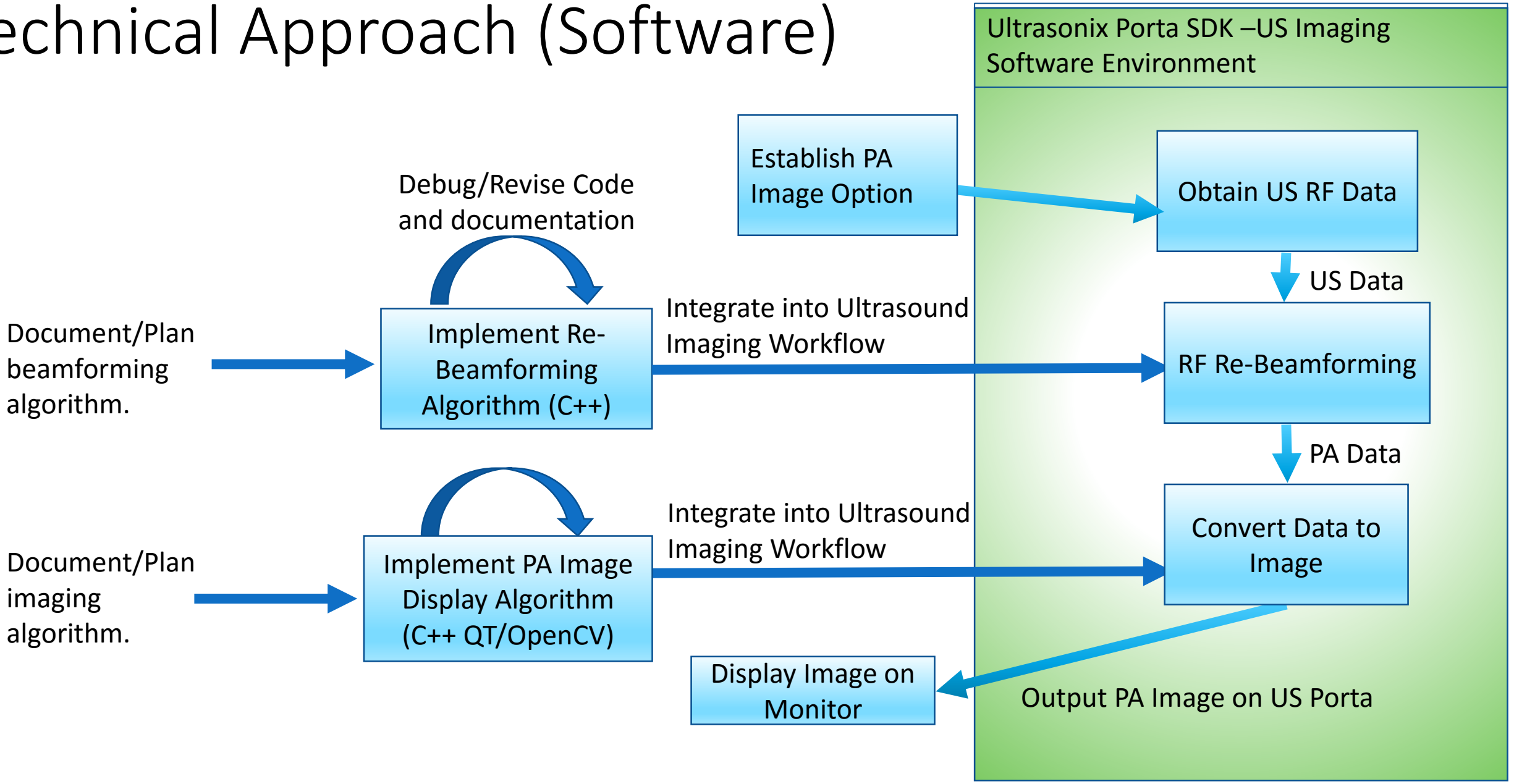


Derived from Ultrasonix Porta SDK

Technical Approach



Technical Approach (Software)



Deliverables

Minimum:

1. Documentation of PA re-beamforming algorithm and its integration into an US visualization platform.
2. Implementation of re-beamforming algorithm (C++ code).
3. Scripts to debug algorithm with simulation data sets (basic results + code).

Expected:

1. Adapt existing US platform to allow for PA imaging. Integrate our PA software into system (finished code).
2. Construct PA/US phantoms. Set up experiments to test PA imaging system.
3. Test PA imaging system using real RF US data (more detailed results).

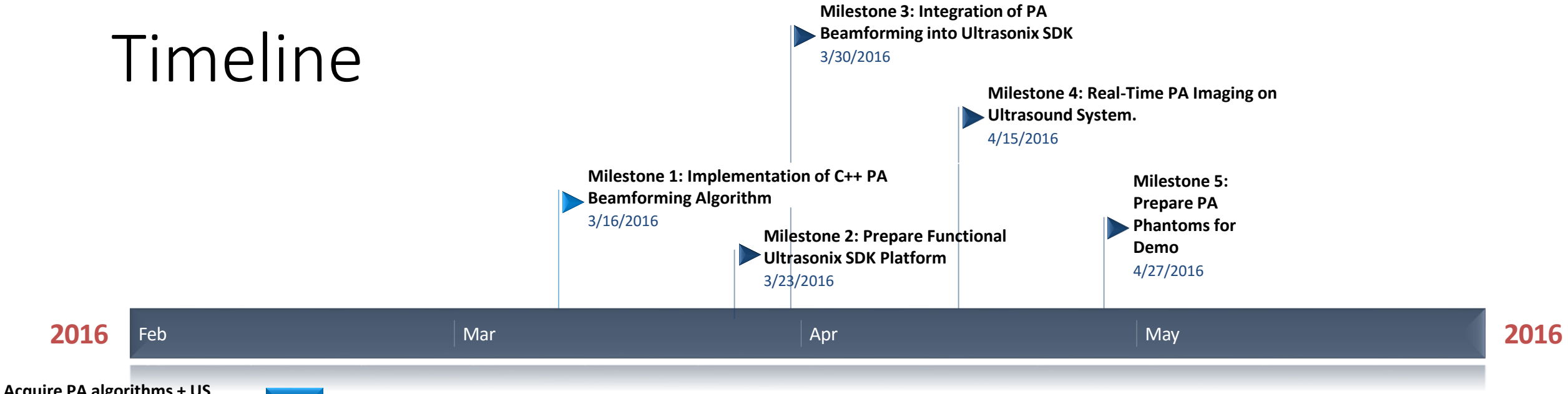
Maximum:

1. Implement additional PA image algorithms (inverse beamforming, US visual data conversion) in completed PA imaging system.
2. Summarize findings in a paper for submission.
3. An in-class live demo of real-time PA imaging system.

Dependencies

- Access to Robotorium and lab (Submitted Permission Form)
- PA re-beamforming algorithm (Acquired from Mentor)
- PA inverse beamforming and video processing algorithm (Available)
- US Ultrasonix Porta SDK Software (Acquired)
- PA Image Setup (Laser system, PZT element as source) (Available)
- US System and Probe (Present)
- US Phantom (Basic phantoms Available)

Timeline



Acquire PA algorithms + US imaging SDK	2/15/2016 - 2/19/2016
Read existing PA literature. Document PA algorithms.	2/22/2016 - 3/3/2016
Read Ultrasonix SDK, QT, OpenCV manuals. Document Ultrasonix implementation.	2/22/2016 - 3/16/2016
Implement PA Re-beamforming Algorithm in C++	3/3/2016 - 3/16/2016
Set up Ultrasonix SDK environment. Begin work on PA imaging.	3/3/2016 - 3/23/2016
Incorporate PA Beamforming into Ultrasonix SDK	3/16/2016 - 3/20/2016
Enable PA Image Processing on Ultrasonix SDK	3/20/2016 - 4/6/2016
Finish Implementing PA Imaging on Ultrasonix SDK. If possible, incorporate other US to PA algorithms	4/6/2016 - 4/20/2016
Collect RF test data on PA beamforming and imaging	4/6/2016 - 4/20/2016
Prepare demo and final report/paper on results	4/20/2016 - 5/5/2016

Contingency Plan: If delays are encountered in Milestones 2-3, change focus to developing and testing PA beamforming algorithms. Make research paper into an expected deliverable and shift milestones to PA algorithm tests/PA phantom preparation.

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Management Plan

- Established weekly meetings with Kai (Mentor).
- Regularly check code and project status.
- Keep frequent backups of code, on multiple storage systems (JHBox, personal Dropbox, etc.)
- Will contact mentors for assistance when stuck and switch to alternate timeline plan if delays are encountered.

Responsibilities

- Understand coding in C++, Ultrasonix SDK, and QT3/OpenCV environments.
- Understand PA beamforming and imaging algorithms.
- Work on documentation for PA imaging code.
- Once PA algorithms are implemented, will then need to plan and document integration of PA algorithms into existing US framework .
- Ask mentors about Ultrasonix SDK when stuck.

Reading List

- Zhang, Kai, et. al. “Synthetic Aperture Based Photoacoustic Image Re-beamforming From Ultrasound Post-beamformed RF Data”. Unpublished Manuscript (will be submitted for publication).
- Park, Suhyun, et al. "Adaptive beamforming for photoacoustic imaging using linear array transducer." *Ultrasonics Symposium, 2008. IUS 2008. IEEE*. IEEE, 2008.
- Kuo, Nathanael, et al. "Real-time photoacoustic imaging of prostate brachytherapy seeds using a clinical ultrasound system." *Journal of biomedical optics* 17.6 (2012): 0660051-0660057.
- Kang, Hyun-Jae, et al. "Software framework of a real-time pre-beamformed RF data acquisition of an ultrasound research scanner." *SPIE Medical Imaging*. International Society for Optics and Photonics, 2012.
- Harrison, Travis, and Roger J. Zemp. "The applicability of ultrasound dynamic receive beamformers to photoacoustic imaging." *Ultrasonics, Ferroelectrics, and Frequency Control, IEEE Transactions on* 58.10 (2011): 2259-2263.
- Frazier, Catherine H., and William Brien. "Synthetic aperture techniques with a virtual source element." *Ultrasonics, Ferroelectrics, and Frequency Control, IEEE Transactions on* 45.1 (1998): 196-207.
- J. Kortbek, J. A. Jensen, K. L. Gammelmark, “Synthetic Aperture Sequential Beamforming,” *Proc. in IEEE Int. Ultrasonics Symp*., 966-969 (2008).
- Wilson, Thaddeus, et al. "The ultrasonix 500RP: A commercial ultrasound research interface." *Ultrasonics, Ferroelectrics, and Frequency Control, IEEE Transactions on* 53.10 (2006): 1772-1782.

Questions.