Vendor-Independent PA Imaging System Enabled with Asynchronous Laser Source

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Motivation

Implement photoacoustic (PA) imaging on conventional ultrasound (US) systems, by software methods.

- Make PA systems vendor-independent.
- Popularize PA imaging and lower the cost.

Goal & Strategy

1. **Correct frequency:** synchronize laser pulse and ultrasound line acquisition (algorithm 1)
2. **Correct phase delay:** synchronize image frames (algorithm 2)
3. Use synchronized signals to implement real-time PA imaging.

Methods

1. Correct frequency error

- When pulse repetition frequency/ line frequency < 1: detect peak in symmetric lines
- When pulse repetition frequency/ line frequency > 1: detect peak in one line

2. Correct phase error

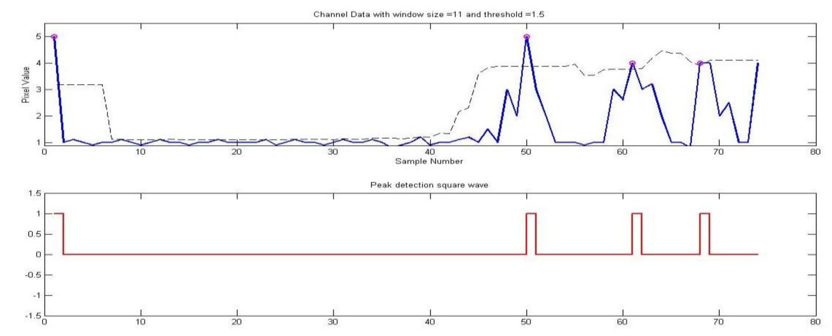
- Binary search, compare maximum intensity

3. Errors combined

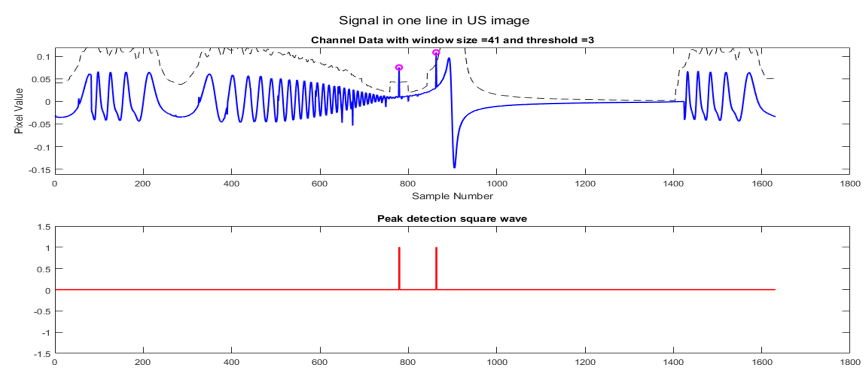
- Coarse to fine: first use 1 and 2 to estimate the sample number, then linear search

4. Image processing techniques

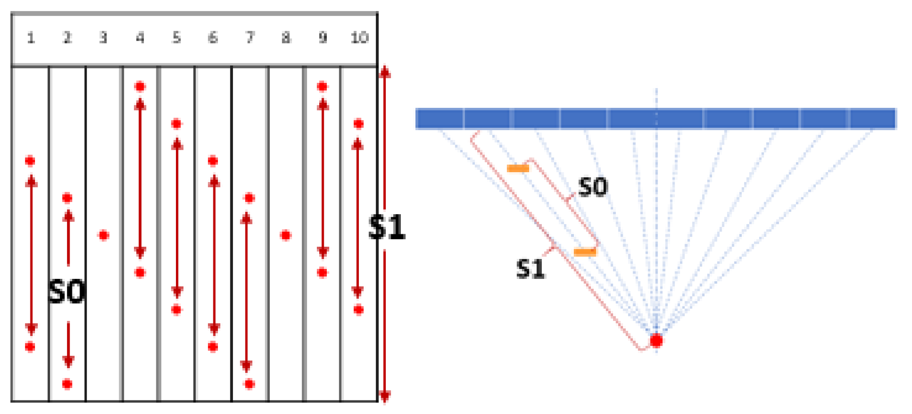
- Z-window peak detection, Savitzky–Golay filtering, Band pass filtering



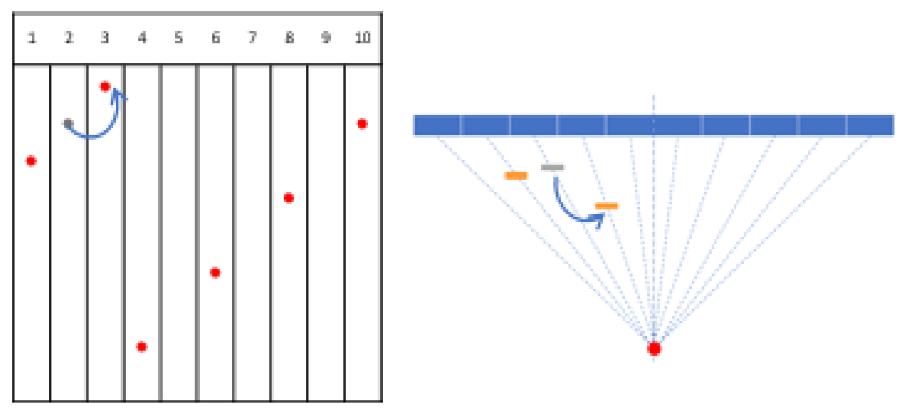
Z-window peak detection



Savitzky–Golay filtering



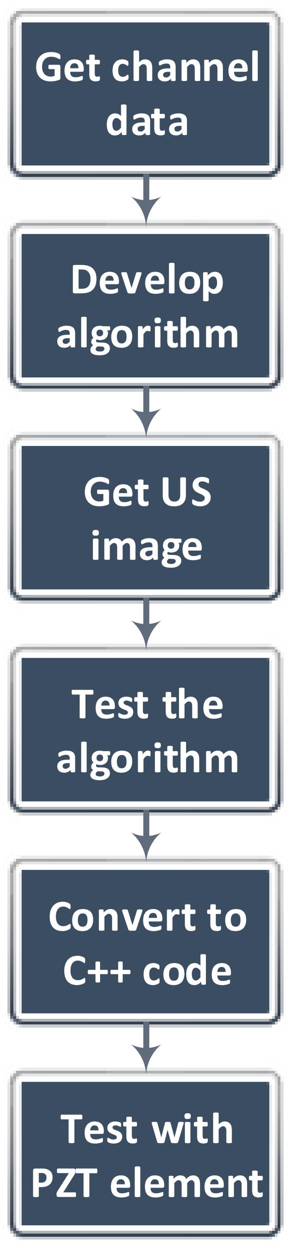
PRF/LF > 1



PRF/LF < 1

workflow

1. K-wave: obtain channel data
2. Develop algorithm in simulation
   - Add frequency/phase error to channel data, and correct them separately.
   - Combine both errors, correct them altogether.
   - Apply US beamforming to get US image, add both errors and correct them
3. Convert Matlab code to C++ code
   - Compare property of C++ code and Matlab code
   - Run on US machine
4. Integrate the method with SPARE beamforming method. Test with PZT element on real US machine.



Simulation setup:

- Matlab, k-wave toolbox
- Visual Studio 2010

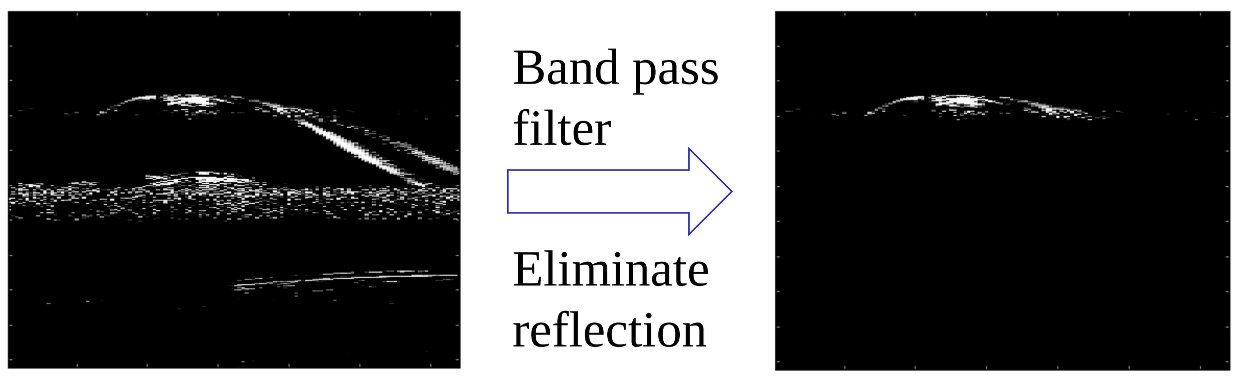
Experiment setup:

- Ultrasonix machine, HP 33120A function generator, oscilloscope, Tektronix TDX 2010 oscilloscope, PZT element, custom made circuit board

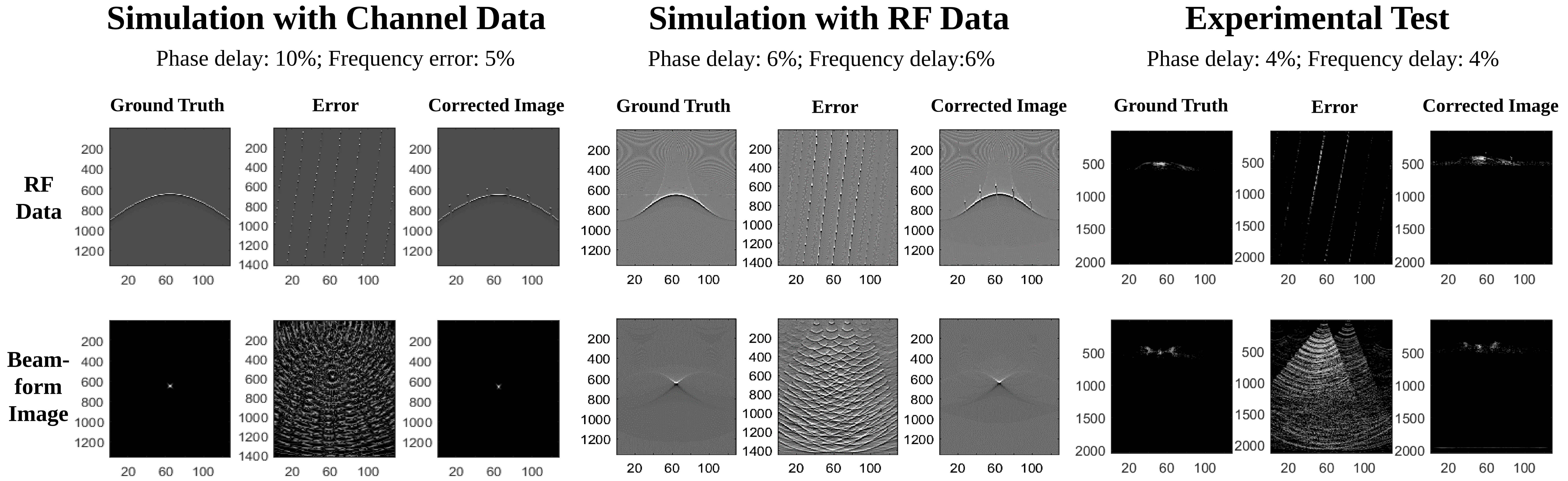
Ultrosonix machine

PZT, circuit board, function generator, scope

Get region of interest



Results



Conclusion

- To implement photoacoustic imaging on conventional ultrasound machines, synchronization problem between the line trigger in the ultrasound probe, and the laser pulse from the laser source is investigated. To correct frequency and phase errors, binary search for phase delay and peak detection for frequency correction are developed. SPARE beamforming method is also integrated and applied in beamforming RF data.
- Results indicates feasibility of offline US image to PA image correction. With only US image given, PA image can be achieved by first correct frequency error, then correct phase error.

Future work

- Develop algorithm for better frequency correction
- Improve the algorithm to get higher accuracy and reduce time complexity

Acknowledgement

Thank Kai and Dr. Boctor for guidance. In addition, Thank Howard for software instructions and Younsu for help with experiments.