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).
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

Ultrasound Transducer → Channel Data

Ultrasound Beamforming

- Beamformed RF Data
- Required for PA imaging. Access not available in real-time clinical systems.

Envelope Detection

- Access available in real-time clinical systems, but PA image is distorted.

Log Compression → Digital Scan Conversion

Additional Stages of Signal Processing (Compression + Interpolation)

B-Mode Image Data → Monitor

Access available in real-time clinical systems, but PA image is distorted.
Project Goal

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

Derived from Ultrasonix Porta SDK
Technical Approach

Ultrasound Beamforming

Beamformed RF Data (US) -> Envelope Detection

Log Compression -> Digital Scan Conversion

Video Data -> Inverse US Image Processing

Real time access available

RF Data (US) -> Synthetic Aperture PA Re-Beamforming

PA Image Processing

Video Data (PA)

Channel Data -> PA Beamforming

PA Re-Beamforming

MUSIC Research Laboratory
Technical Approach (Software)

Document/Plan beamforming algorithm.

Document/Plan imaging algorithm.

Implement Re-Beamforming Algorithm (C++)

Integrate into Ultrasound Imaging Workflow

Obtain US RF Data

US Data

RF Re-Beamforming

Integrate into Ultrasound Imaging Workflow

Convert Data to Image

PA Data

Output PA Image on US Porta

Display Image on Monitor

Establish PA Image Option

Debug/Revise Code and documentation

Ultrasonix Porta SDK – US Imaging Software Environment

Implement PA Image Display Algorithm (C++ QT/OpenCV)
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)
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.
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


Questions.