iPASS: Photoacoustic Catheter Tracking: Project Plan

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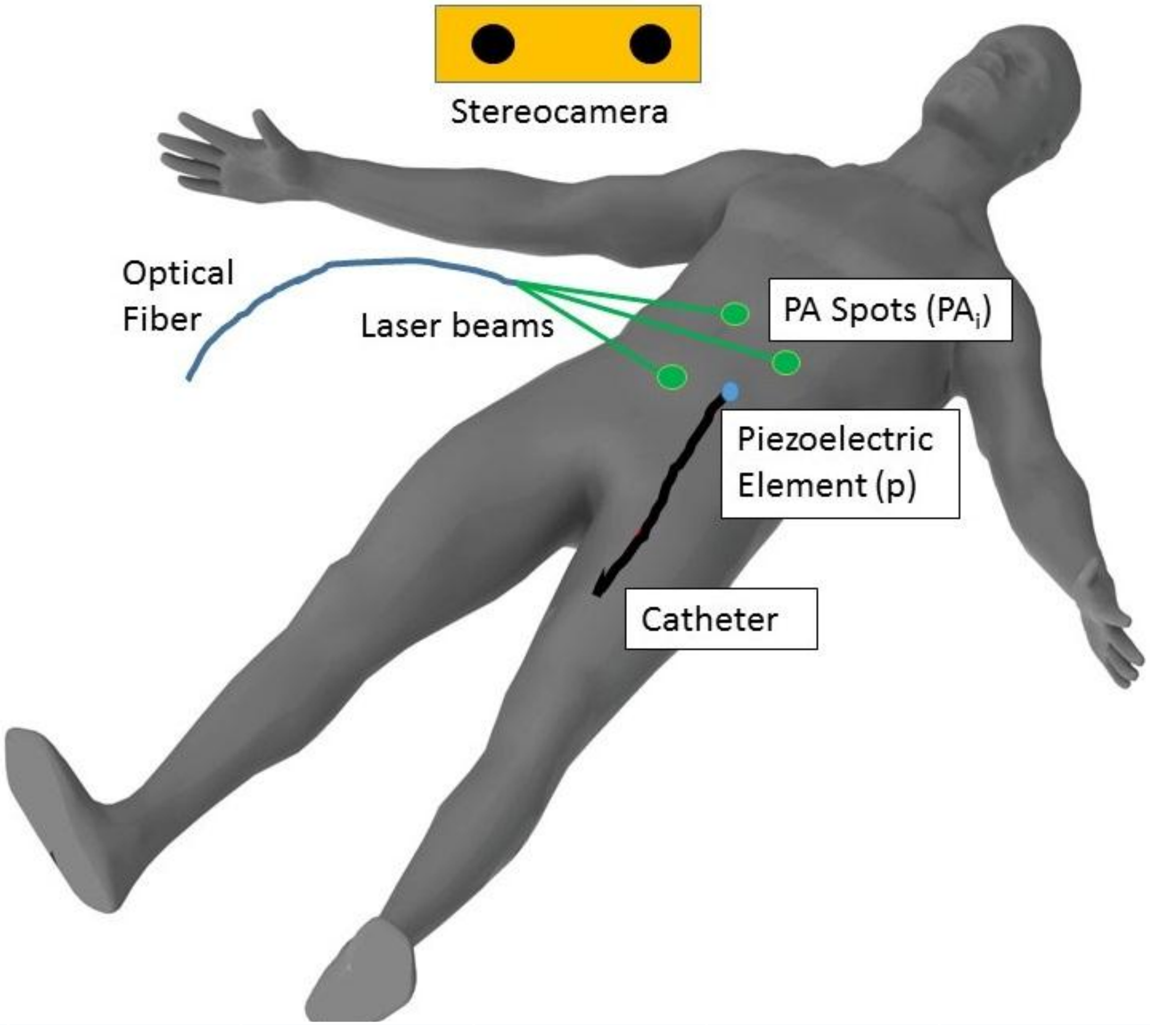
Overview

- Summary
- Background
- Motivation
- Workflow
- Technical Approach
- Deliverables
- Dependencies
- Milestones
- Management Plan
- Reading List

Summary

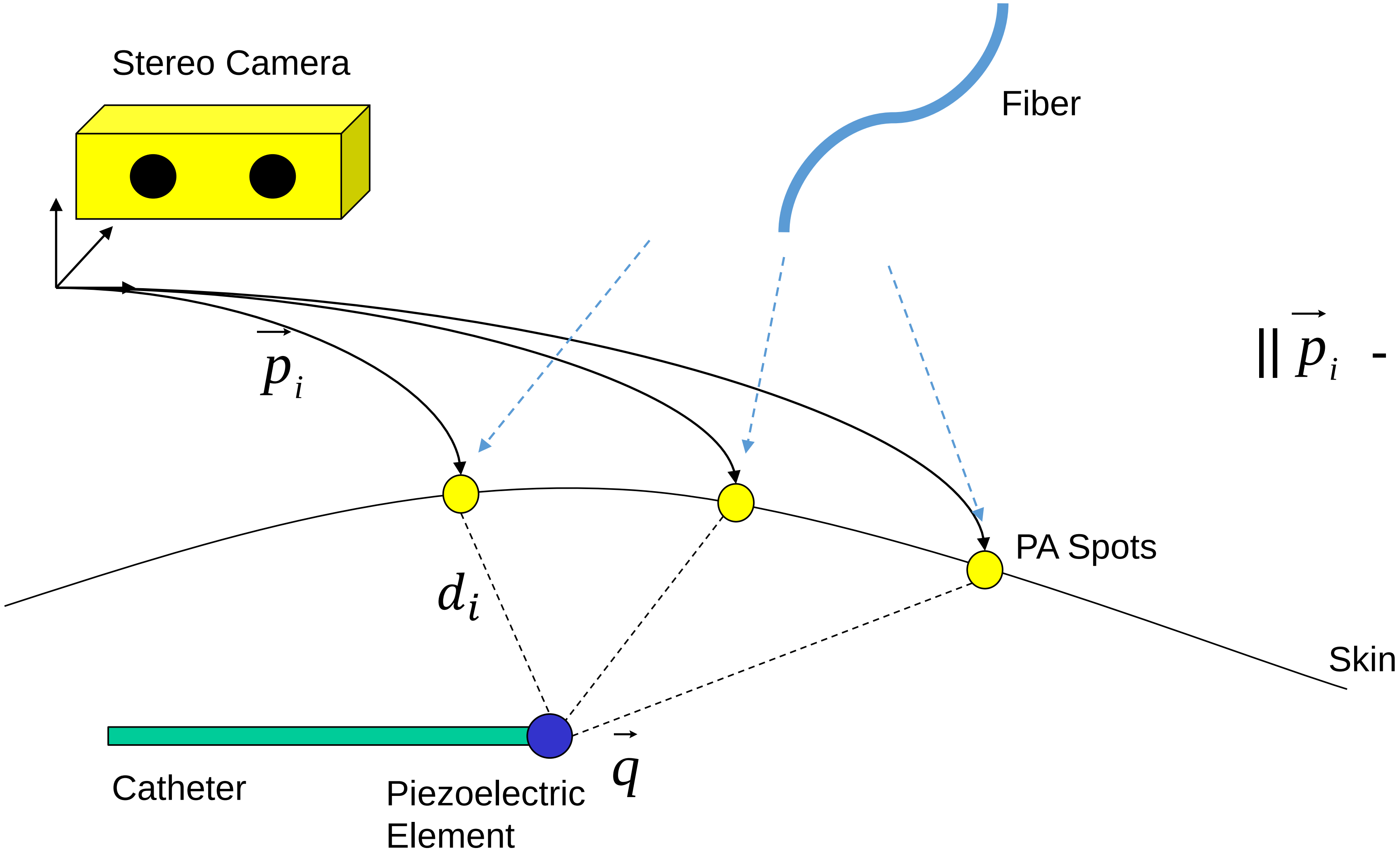
- Goal: To track a catheter using a stereocamera without direct line of sight by bridging the gap with a line of sound by applying laser spots on the patient surface, which can be seen by the stereocamera and generate a photoacoustic signal observed by the piezoelectric element
- Team Member: Yuttana (Big) Itsarachaiyot
- Mentors: Alexis Cheng, Younsu Kim, Dr. Emad Boctor

Summary



Stereocamera
Optical Fiber
Laser beams
PA Spots (PA_i)
Piezoelectric Element (p)
Catheter

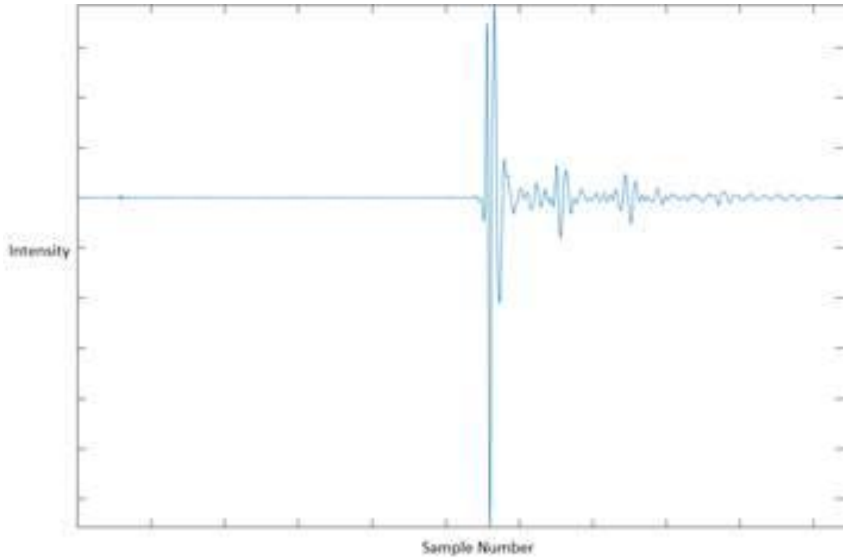
Summary



$$\|\vec{p}_i - \vec{q}\|_2 = d_i$$

Background

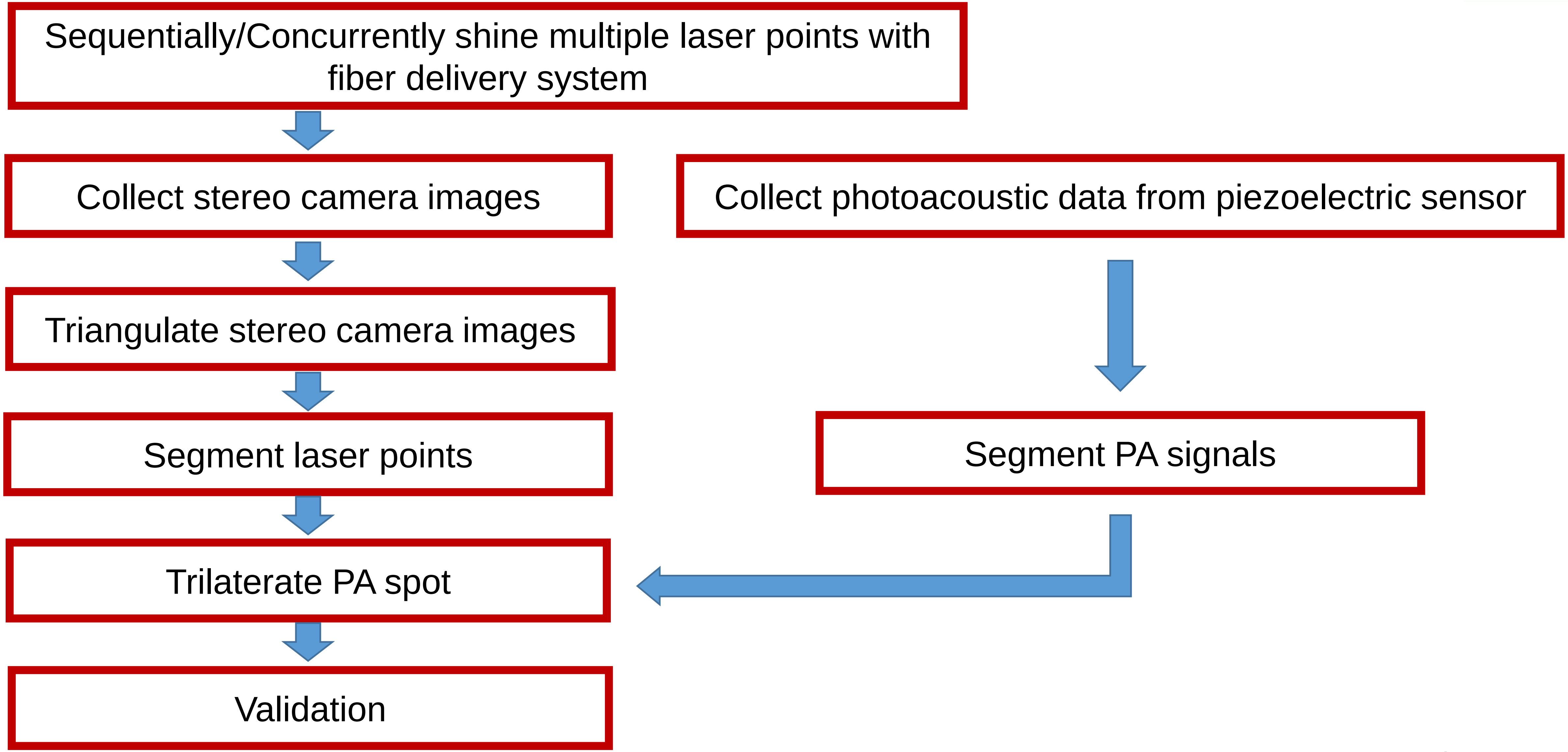
- Photoacoustic Imaging
  - Discovered in 1880 by Alexander Graham Bell
  - Light waves will generate acoustic waves when absorbed by the material causing thermal excitation
  - A photoacoustic signal can be detected by the piezoelectric element



Motivation

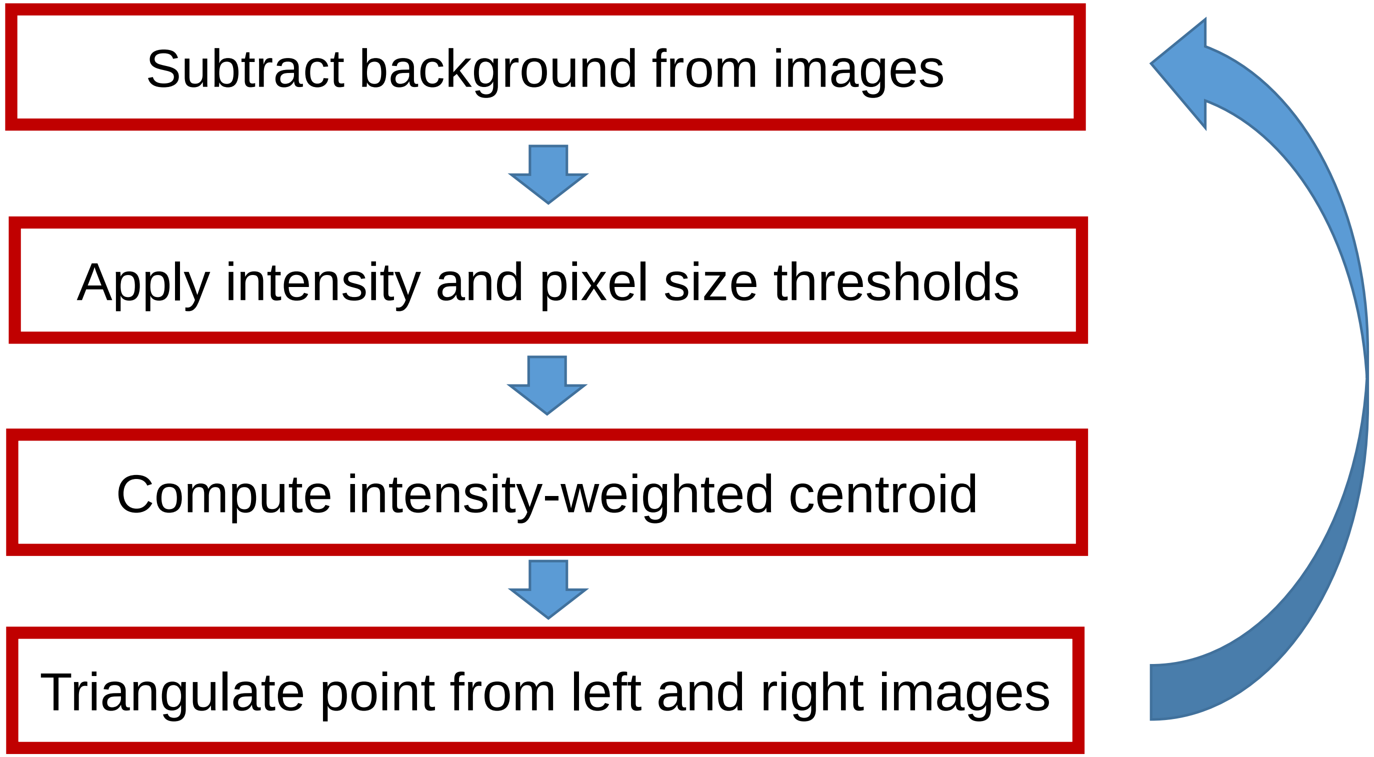
- Surgical tracking systems are widely used in computer assisted surgery
- So far, photoacoustics has been limited as an imaging solution
- Provide a tracking solution and integrate it into surgical tracking system

Workflow


Sequentially/Concurrently shine multiple laser points with fiber delivery system
Collect stereo camera images
Collect photoacoustic data from piezoelectric sensor
Triangulate stereo camera images
Segment laser points
Segment PA signals
Trilaterate PA spot
Validation

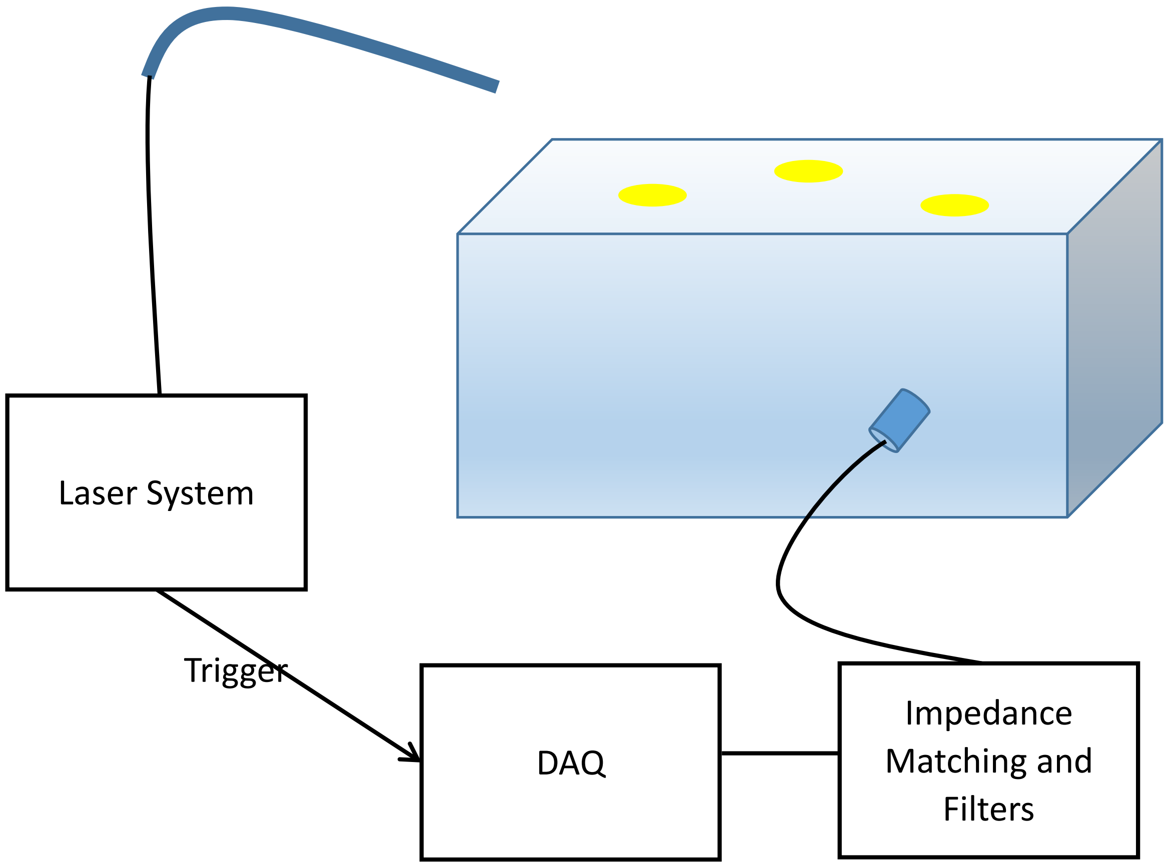
Technical Approach (1)

- Stereo camera point segmentation



Technical Approach (2)

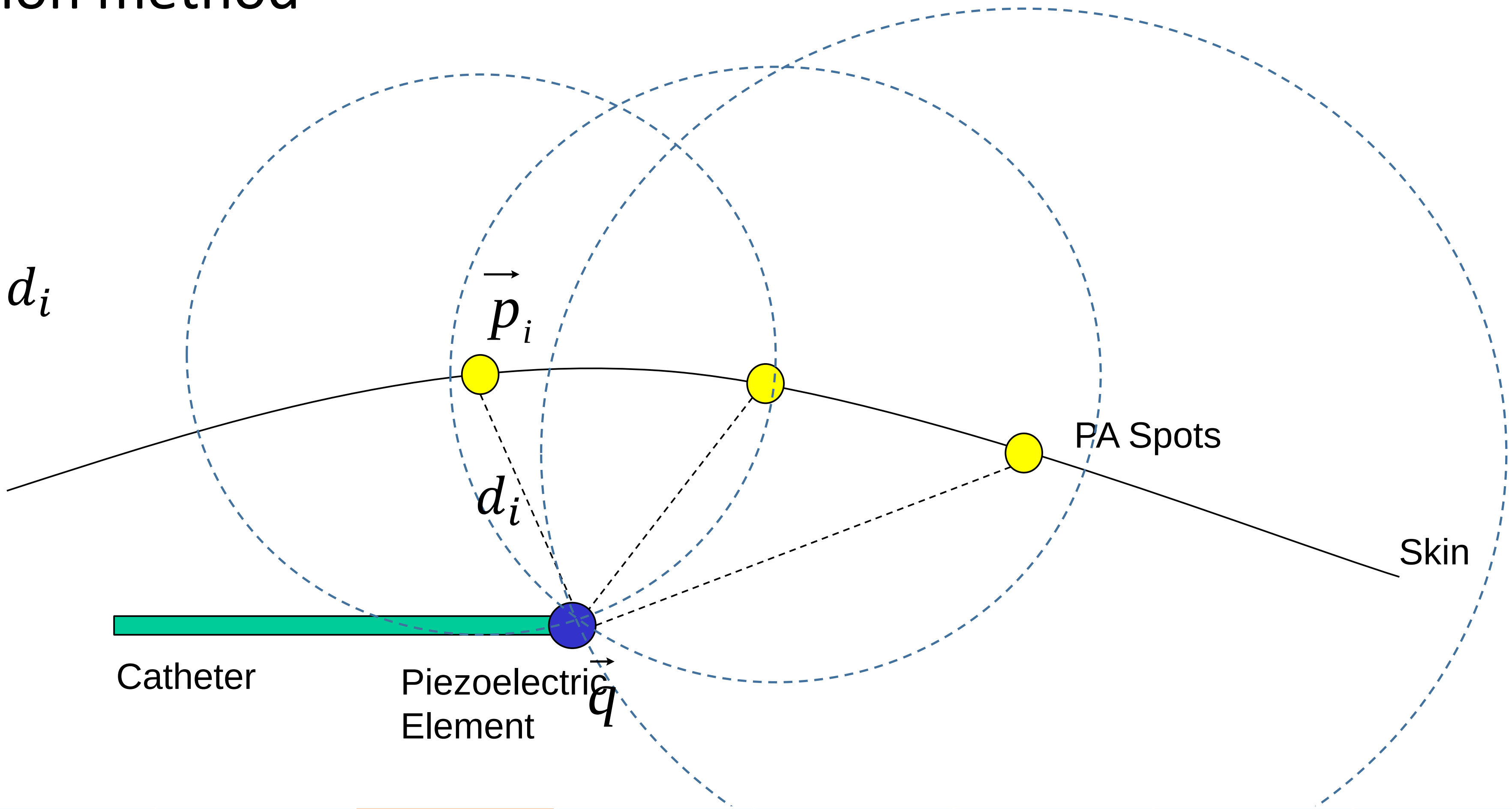
- System overview for PA signal acquisition



Technical Approach (3)

- Trilateration method

$$\| \vec{p}_i - \vec{q} \|_2 = d_i$$



Technical Approach (4)

- Validation
  - Repeatability
    - Shine the different spots, then choose a subset of those spots, compute the result
    - Compare the results from the different subsets of those spots
  - Relative Distance
    - Move the PZT element to the certain point
    - Compare the results from the system with known distance

Deliverables

- Minimum
  - Refined circuit board for collecting data
  - System configuration setup
  - Phantom and *Ex vivo* data for sequential projection
  - *In vivo* experimental protocol
  - Analysis and validation of accuracy and precision measures of experimental data

Deliverables

- Expected
  - Minimal Deliverables
  - Optimization of the number and pattern of spots
  - Concurrent projection of multiple laser points
  - Repeat the experiment with multiple points

Deliverables

- Maximum
  - Expected Deliverables
  - Real-time tracking system
  - *In vivo* experiment feasibility study

Dependencies

- Access to Laboratories
  - Dr. Boctor's Lab
  - Photo Lab in Barton Hall
- Access to Equipment
  - Laser system
  - Piezoelectric system
  - Data acquisition module and PC
- Functional Equipment

Milestones

- Phantom Acquisition
  - Date: February 27
  - Criteria: Find or create suitable phantom
- Circuit Board Refinement
  - Date: February 27
  - Criteria: Refine hardware filter and match impedance of PZT element for photoacoustic data acquisition
- *In vivo* Experimental Protocol
  - Date: February 27
  - Criteria: Set protocol for *In vivo* experiment

Milestones

- Synthetic/*Ex vivo* Experiment
  - Date: March 12
  - Criteria: Design and perform experiment to assess the efficacy of photoacoustic catheter tracking
- Analysis and Validation of Experimental Data
  - Date: March 19
  - Criteria: Analyze and validate the experiment data
- Concurrent Projection Method Development
  - Date: April 2
  - Criteria: Develop the concurrent projection method

Milestones

- Synthetic/*Ex vivo* Experiment for Concurrent Projection Method
  - Date: April 16
  - Criteria: Design and perform experiment to assess the efficacy of photoacoustic catheter tracking for concurrent projection method
- Real-time Tracking System
  - Date: April 23
  - Criteria: Develop a real-time tracking system
- *In vivo* experiment feasibility study
  - Date: April 30
  - Criteria: Study a feasibility of in-vivo experiment

Milestones

Minimum Expected Maximum

Task	14 Feb	21 Feb	28 Feb	6 Mar	13 Mar	20 Mar	27 Mar	3 Apr	10 Apr	17 Apr	24 Apr
Phantom Acquisition											
Circuit Board Refinement											
In vivo Experimental Protocol											
Synthetic/*Ex vivo* Experiment											
Analysis and Validation of Experimental Data											
Concurrent Projection Method Development											
Synthetic/*Ex vivo* Experiment for Concurrent Projection Method											
Real-time Tracking System											
In vivo Experiment Feasibility Study											
Analysis and Validation of Experimental Data											

Management Plan

- Schedule weekly meetings with mentors: Mondays at 3pm
- Review timeline and milestones weekly
- Adjust timeline accordingly weekly

Reading List

- Xiaoyu Guo et al. “Active Ultrasound Pattern Injection System (AUSPIS) for Interventional Tool Guidance”. PLoS ONE 9(10) 2014
- Alexis Cheng et al. “Catheter Tracking in an Interventional Photoacoustic Surgical System”. Submitted to CLEO 2016
- A.Wiles, D. Thompson, and D. Frantz, “Accuracy assessment and interpretation for optical tracking systems,” Proc. SPIE 5367, 421–432 (2004)
- Alexis Cheng et al. “Direct three-dimensional ultrasound-to-video registration using photoacoustic markers”. Journal of Biomedical Optics 18(6), 066013 (June 2013)
- M. Xu and L. Wang, “Photoacoustic imaging in biomedicine,” Rev. Sci. Instrum. 77, 041101 (2006)
- Alexis Cheng et al. “Direct ultrasound to video registration using photoacoustic markers from a single image pose”. SPIE 2015

Questions?