iPASS: Photoacoustic Catheter Tracking

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1 Introduction

1.1 Summary

This project proposes new way of tracking technology by integration of the laser technology with the computer vision, and also piezoelectric effect. The goal of this project is to track a catheter using a stereo camera and applying laser spots on the patient surface, which can be seen by the stereo camera and generate a photoacoustic (PA) signal observed by the piezoelectric element. Preliminary results show reasonable repeatability of element localization.

1.2 Background and Significance

Photoacoustics is an acoustic wave generation by an absorption of light. The history of photoacoustic effect discovery starts from 1880 when Alexander Graham Bell observed it. The photoacoustic effect is broadly applied for using in various fields, especially medical field for spectroscopy. While the piezoelectric element is a device using the piezoelectric effect to measure changes in pressure, temperature or force by converting them to the electrical charge. Piezoelectric effect is used in many applications, such as detection of sound and generation of electronic frequency.

When comparing to other guidance systems, the benefit of this project is that this method does not require any physical markers in order to create a coordinate transformation, also it does not need to have calibration processes because we can directly compute the coordinate transformation from the collected data. The significance of this project is to enable an innovation to track the tool in interventional photoacoustic system with no additional trackable markers and/or calibration processes.

2 Technical Approach

2.1 Stereo camera point segmentation

The goal of this approach is to locate the laser points in stereo camera images. Since we are dealing with multiple image frames, composed of either images with or without the laser point, the efficient segmentation method for those points is needed. Some characteristics of images are determined to be used as parameters of this segmentation method, such as intensity thresholds based on histogram of intensities, pixel size threshold, and shape filter.

2.2 System overview for PA signal acquisition

The reason for this approach is to acquire the PA signal. We use the DAQ system to collect the signal. We not only use a filter to remove some unwanted feature noises from a signal before being sampled in the DAQ, but also apply the impedance matching design to improve the signal-to-noise ratio.

2.3 Trilateration method

The reason for this approach is to acquire the location of piezoelectric element point or the location of catheter tip in this project. Trilateration is the method of calculating locations of points by measurement of distances, and applying the theory of geometry of circles and spheres.

2.4 Validation

The reason for validation is to show that this system succeeds the project goals. We will use two methods to validate the system. One of them is "repeatability": the result of calculation with different subsets of PA spots data should give the same location of catheter tip. Another method is "relative distance": the results of calculation of at least two different set-up tip locations will be compared with known distance of those points.

3 Project Plan

This section describes what will be achieved by this project which includes three levels of deliverables, and what is planned to reach the goals, including dependencies and a projected timeline of milestones.

3.1 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

Expected

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

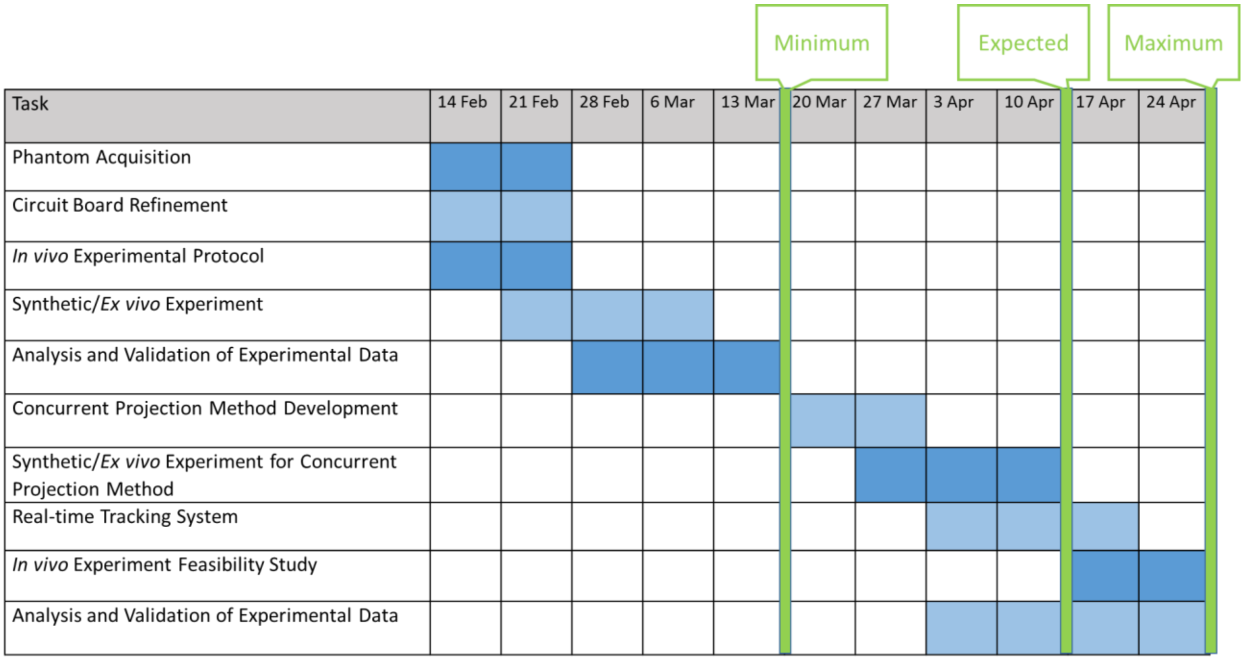
Maximum

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

3.2 Dependencies

Dependency	Resolution
Access to laboratories • Dr. Boctor's laboratory • Photo laboratory	Schedule time with Alexis and/or Younsu in advance, at least ten hours per week
Access to equipment • Laser system • Piezoelectric system • Data acquisition module and PC	Schedule time to work with these equipment with Alexis and/or Younsu in advance
Functional equipment	Coordinate with Alexis and/or Younsu to figure it out how to fix them in case of their malfunction case by case

3.3 Project Timeline and Milestones



Milestone	**Criteria**	**Expected Completion**
Phantom Acquisition	Find or create suitable phantom	February 27
Circuit Board Refinement	Refine hardware filter and match impedance of PZT element for photoacoustic data acquisition	February 27
In vivo Experimental Protocol	Set protocol for *In vivo* experiment	February 27
Synthetic/*Ex vivo* Experiment	Design and perform experiment to assess the efficacy of photoacoustic catheter tracking	March 12
Analysis and Validation of Experimental Data	Analyze and validate the experiment data	March 19
Concurrent Projection Method Development	Develop the concurrent projection method	April 2
Synthetic/*Ex vivo* Experiment for Concurrent Projection Method	Design and perform experiment to assess the efficacy of photoacoustic catheter tracking for concurrent projection method	April 16
Real-time Tracking System	Develop a real-time tracking system	April 23
In vivo experiment feasibility study	Study a feasibility of in-vivo experiment	April 30
Analysis and Validation of Experimental Data	Analyze and validate the experiment data	April 30

3.4 Management Plan

Weekly meeting with mentors is planned as follows.

Meetings: Mentors: Alexis Cheng and Younsu Kim
Location: Robotorium
Time: Monday 3:00 pm

These meetings are for guidance, work verification, and brainstorming. The project plan will be revised weekly. All materials, including any modifications will be posted on the class website.

Reading List

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