Ultrasound Needle Point Guidance using Active Echo and iPhone Camera

Project Group:

Team members: Phillip Oh, Bofeng Zhang
Mentors: Alexis Cheng, Dr. Emad Boctor

Summary:

Combining the active echo ultrasound calibration technique with the active out-of-plane ultrasound calibration is the main topic of this project. In addition, there will be some computer vision topics including image segmentation and optical tracking. The goal of this project is to provide a more accurate ultrasound calibration using active echo and to calculate the 3D position of a needle point in a separate frame of an iPhone camera.

Background and Relevance:

Image guidance is useful in surgery to help surgeons track the location of their tools in potentially very sensitive parts of the body in order to increase surgery accuracy and to decrease risk of harm to the patient. There are many ways to do this, but the advantage of ultrasound is the fact that it can be done easily intraoperatively without exposure to radiation. In order for ultrasound to be used, a calibration must be done between ultrasound coordinates and the tracker of the tool. Many methods are performed to do this; however, the precision of these methods can be improved, as EM tracking for registration results in a 3 mm error. Current methods are also unable to track the needle point if it is outside the ultrasound plane, knowing only the point where the needle crosses the plane.

The advantage of using the active echo technique combined with the active point out-of-plane is an accurate calibration which can track the needle point outside of the ultrasound plane, using only an ultrasound probe, and active source on the needle point, and camera, which reduces equipment needed for calibration and increases precision.

Technical summary of approach:

1. Capture images of needle using camera (possibly webcam)
2. Process images: Image segmentation of needle to give the plane of the needle with respects to the camera's frame
3. Ultrasound Calibration using active echo from the tip of the needle and with the Active out-of-plane ultrasound calibration method
4. Design CAD model of camera holder for attachment onto the ultrasound probe along with a physical prototype

5. Recovery of the needle tip positioning with the ultrasound calibration which gives an arc with relative distance and the plane of the needle given by the image segmentation of the needle from the camera images.

Deliverables:

Minimum: 3D position of probe-tip offline, more specifically

1. Segmentation of needle in images taken from webcam/iPhone
2. iPhone mount to ultrasound probe
3. Ultrasound calibration
4. Recover needle-point position using US and iPhone images

Expected: Analysis and validation of technique

Maximum: Real-time 3D position of probe-tip using live-feed from iPhone camera and US machine.

Dependencies:

Dependency	Plan for Resolving
Access to ultrasound machine, needle, webcam, active point	Provided by MUSiiC lab (Permission given)
Wyman 3D printer access	Contact Neil Leon (by 3/1)
Access to labs: Robotorium, MUSiiC lab in Robotorium	Contact LCSR admin office (Lab access granted)
URS robot arms	Contacting Dr. Armand's Bigss Lab (by 3/1; need arms by 3/7)
Meetings with Alexis	Scheduled weekly Wed 2:30 PM
Meetings with Dr. Boctor	In process of scheduling

Key dates & assigned responsibilities:

Dates:	Important Dates / Responsibilities / Milestones
1/27 – 2/5	Presentations of possible project ideas
2/5 – 2/12	Determining project to pursue
2/15 – 2/21	2/20 Project Proposal 2/21 Paper read of Image segmentation using edge detection
2/22 – 2/28	2/24 Project Proposal Presentation 2/28 Paper read of Active point out-of-plane ultrasound calibration 2/28 Written outline of design for the overall project
3/1 – 3/7	3/7 CAD model of camera holder 3/7 Segmentation of needle image from camera
3/8 – 3/14	3/14 3-D printed camera holder 3/14 Recover needle tip positioning by combining Segmentation and Calibration – Min.
3/15 – 3/21	3/16 – 3/22 Spring Break

3/22 – 3/28	3/28 Test needle location accuracy in water via experiments
3/29 – 4/4	4/4 Analysis of the accuracy and precision of the location - Expected
4/5 – 4/11	4/11 Build test phantom
4/12 – 4/18	4/18 Test needle location accuracy in phantom via experiments
4/19 – 4/25	4/25 Implement real-time system to locate needle tip - Max
4/26 – 5/2	5/2 Explore mobile implementation of camera
5/3 – 5/9	5/8 Final Report and Poster Session Presentation

Management Plan:

Semiweekly meetings between team members Phillip and Bofeng (Tuesday, Thursday 2:45pm-4:00pm)
Weekly meetings with mentor Alexis Cheng (Wednesday 2:30pm-3:30pm)
Biweekly meetings with mentor Dr. Emad Boctor (Time TBD)

Phillip Oh will serve as the Project Lead. As the Project Lead, Phillip will review the project plan at each meeting and make plan adjustments accordingly. Phillip will also be in charge of communications between the group members as well as with the mentors.
Bofeng Zhang will serve as the Project Engineer. Bofeng will be in charge of designing the camera holder as well as manufacturing it.
Both team members will share the responsibilities of paper reading, algorithm implementation, and system integration.

Reading List:

Guo, Xiaoyu, et al. "Active Echo: A New Paradigm for Ultrasound Calibration." *Medical Image Computing and Computer-Assisted Intervention–MICCAI 2014*. Springer International Publishing, 2014. 397-404.

Cheng, Alexis, et al. "Active point out-of-plane ultrasound calibration." SPIE Medical Imaging Conference, Orlando, 21-26 February 2015. 9415-30.

Bouguet, Jean-Yves. "First Calibration Example - Corner Extraction, Calibration, Additional Tools." *Camera Calibration Toolbox for Matlab*. California Institute of Technology, 2 Dec. 2013. Web. 18 Feb. 2015.