ROBOT ASSISTED ULTRASOUND TOMOGRAPHY

Computer Integrated Surgery II ***Spring, 2013***

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INTRODUCTION

Ultrasound Tomography is the process of getting a 3D view of soft tissue in the human body. In order to get this, one can take ultrasound images using linear array 2D probes and combine those 2D images to give a 3D view of the patient's tissue. In this study a new approach is developed that incorporates the use of an ultrasound probe attached to a robotic arm and a freehand probe operated by the surgeon/doctor. The motion of the free hand probe is followed by the robotic arm as a mirror image so that they are always aligned along a line at opposite sides of the soft tissue that needs to be viewed in ultrasound. We can use the probes in different modes: transmitter-receiver, receiver-transmitter, or transmitter/receiver. Combine them to get a better ultrasound image of different sections of the tissue in 2D, followed by their incorporation into a 3D model.

THE PROBLEM

- High dependency on surgeon/doctors visual expertise.
- Lack of precise motion of the probes to align along the same axis.
- Building a tomography out of a group of images without information about the physical body part under consideration.
- Ability to perform ultrasound on obese patients.
- Constant force application on the patient so that the images obtained are always with same deformation of the soft tissue.

THE SOLUTION

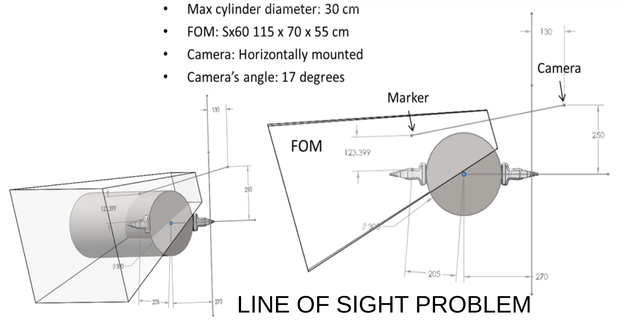
- Build a new end effector for the robot through rapid prototyping which has a micron tracker and an ultrasound probe attached to it.
- Design the system such that the marker attached to the free hand probe can be viewed by the micron tracker (mobile) at all times to get the precise location of the free hand probe.
- Perform Ultrasound calibrations and Hand eye calibration so that the system is defined and algorithm is implemented such that the robot probe follows the motion of free hand probe as a mirror image to be placed on the opposite side of the tissue to get ultrasound images.

OUTCOMES AND RESULTS

•In this study, a prototype system was developed to perform ultrasound tomography using a robot for higher precision. In this system, a micron tracker to track the position of the free hand probe is used; and then the algorithm calculates the precise position where the robot controlled probe is supposed to be thus aligning the two probes along an axis at opposite ends of the tissue that is to be scanned.

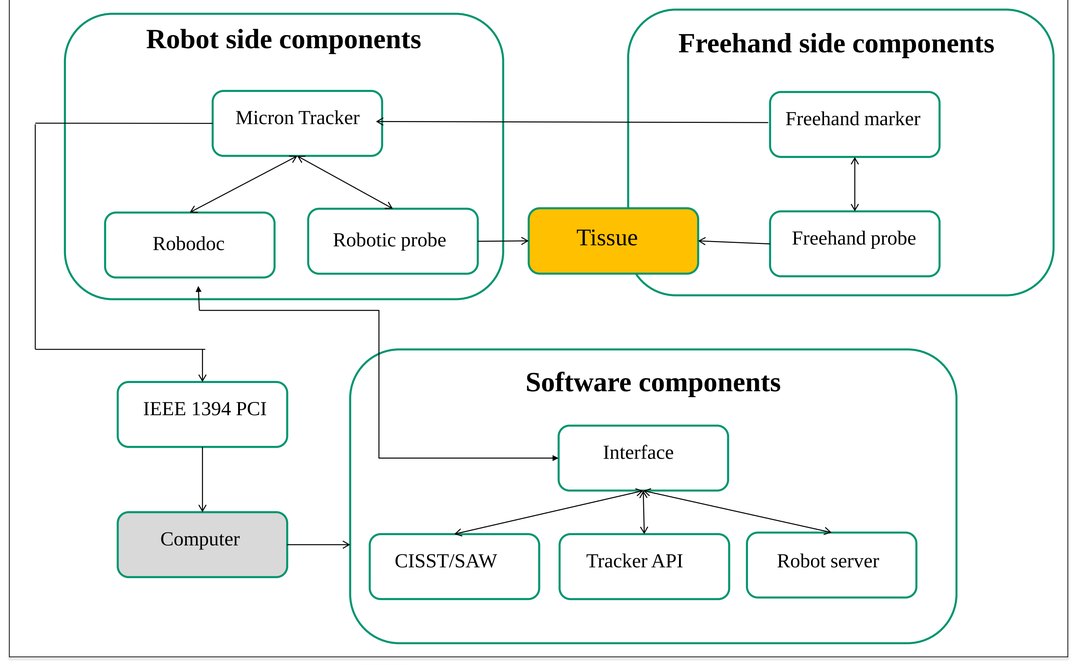
•The accuracy of the system is calculated through physical experiments.

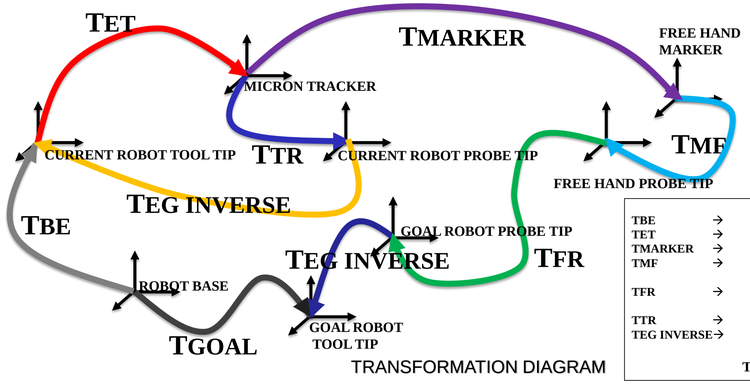
- Max cylinder diameter: 30 cm
- FOM: Sx60 115 x 70 x 55 cm
- Camera: Horizontally mounted
- Camera's angle: 17 degrees



LINE OF SIGHT PROBLEM

SYSTEM COMPONENTS AND SCHEMATICS





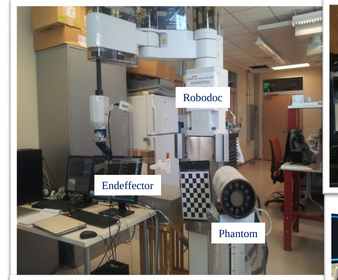
TRANSFORMATION DIAGRAM

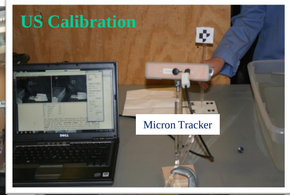
TBE	→	Current Tool Tip Transformation with respect to Robot Base
TET	→	Transformation Between Tool Tip and the Micron Tracker
TMARKER	→	Transformation Between Micron Tracker and Free Hand Probe Marker
TMF	→	Transformation Between Free Hand Probe Marker and Free Hand Probe Tip
TFR	→	Transformation Between Free Hand Probe Tip and Goal Robot Probe Tip
TTR	→	Transformation Between Micron Tracker and Robot Probe Tip
TEG INVERSE	→	Transformation Between Robot Probe Tip and Robot Tool Tip

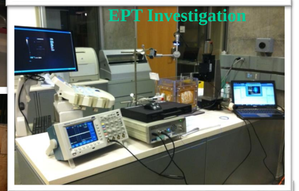
$$T_{EG\ INVERSE} = T_{TR}^{-1} * T_{ET}^{-1}$$

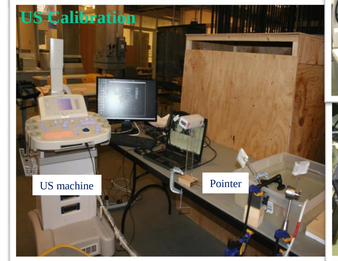
$$T_{GOAL} = T_{BE} * T_{ET} * T_{MARKER} * T_{MF} * T_{FR} * T_{EG\ INVERSE}$$

VARIOUS EXPERIMENTAL SETUPS









LESSONS LEARNT

- Computer integrated surgery in a real application
- Team work and project management skills
- Academic presentation and writing skills

FUTURE WORK

- Improvement in accuracy of the system is required, which can be done by implementing another control algorithm for energy profile tracking alignment.
- Use force sensor to apply a constant force throughout the procedure and keep a record so that if procedure is done again, the same force is applied to get identical tissue compression.
- Testing and validation of the overall system on different irregular shaped phantoms.

ACKNOWLEDGEMENTS

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CREDITS

- Fereshteh Aalamifar – End Effector Design, Ultrasound Calibration, Tracking System
- Rishabh Khurana – Mock US probe Design, Hand Eye Calibration, Robot Control, System Code Implementation