Enabling Technologies for Robot Assisted Ultrasound Tomography

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Group 11

CIS2 Project Goal

Goal:

- Design a prototype that uses a robot controlled ultrasound probe to follow the motion of the free hand probe that can be used for Ultrasound Tomography.

- Note: All images are from the papers thet I am presenting today

Paper(s) Selected

- **Paper 1**

Hippocrate: a safe robot arm for medical applications with force feedback

- **Authors:**Francois Pierrot, Etienne Dombre, Eric D´egoulange, Loıc Urbain, Pierre Caron, Sylvie Boudet, J´erome Gari´epy and Jean-Louis Megnien
- **Published:**Medical Image Analysis (1999) volume 3, number 3, pp 285–300
- **Purpose:** To develop a robotic system to help doctors to reconstruct the three-dimensional profile of arteries using Ultrasound

- **Paper 2**

3D Femur reconstruction using a robotized Ultrasound Probe

- **Authors:** Pedro M.B. Torres, J. Miguel Sanches, Paulo J.S. Gonclaves, Jorge M.M. Martins
- **Published:** IEEE RAS/EMBS on Biomedical Robotics and Biomechatronics, Rome(June 2012)
- **Purpose:** To develop a robotized ultrasound probe to perform 3D Femur reconstruction

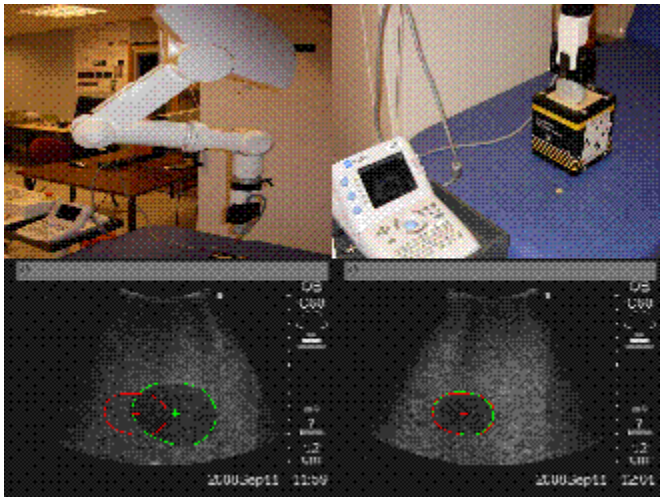
Motivation Behind Papers Selected / Importance to our Project

Gain Understanding of:

- Robots for performing ultrasound
- Ultrasound Tomography using 2D probes
- Previous work done
- Different control loops to get better accuracy and thus, images.

Why is it needed

- Helps combat injuries to sonographers
- Constant force applied
- Data can be stored for future use
- 3D reconstruction from 2D images
- Better accuracy



Ultrasound image-based visual servoing on a phantom. Objective: reach the target cross-section image (red) from an initial one (green)

Key Result

- Help get better accuracy and better quality of images.
- Exert symmetric force throughout the process of collecting data
- Get 3D images from 2D data
- Get bone data in Ultrasound Images using filters

Technical Approach Adopted (Paper 1)

- Aim:

Reconstruct 3D profile of carotid artery and to quantify the volume of atheromatous plaques(fatty deposit along the lining of artery) obstructing it.

- Can be done using free hand or robotic probe but need higher accuracy, reproducibility, force control.

- This is why robot controlled ultrasound is better approach.

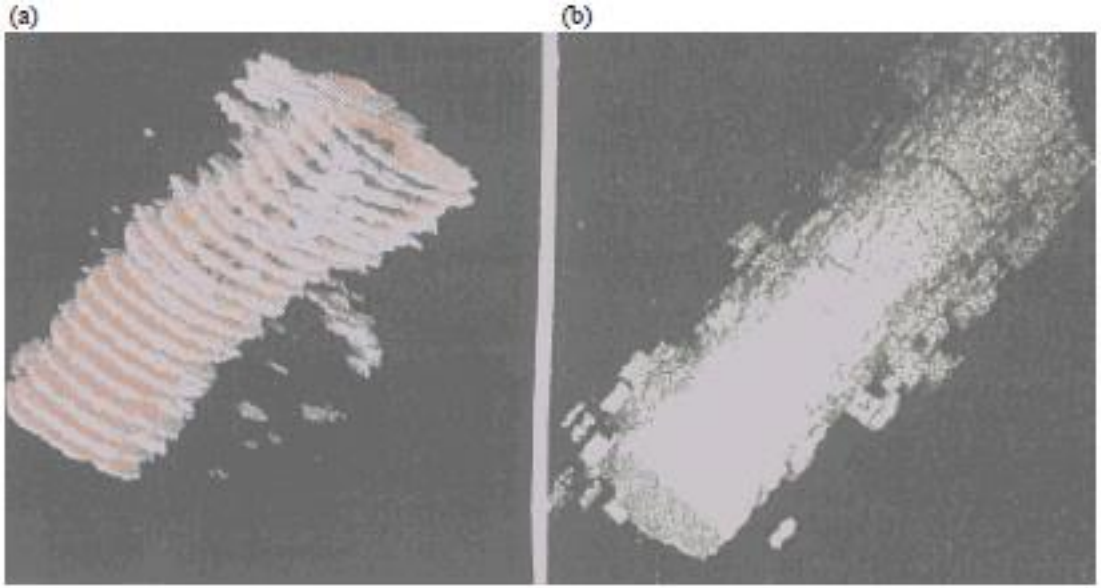


Figure 11. (a) Manual measurements; (b) robotized measurements.

Safety Constraints for using Robot

- When failure occurs, uncontrolled motion must be prevented.
- Only slow motions allowed
- Any automatic motion to be run under a Dead man switch.
- Force applied on patient's skin must be controlled.
- Working area of robot must be restricted.

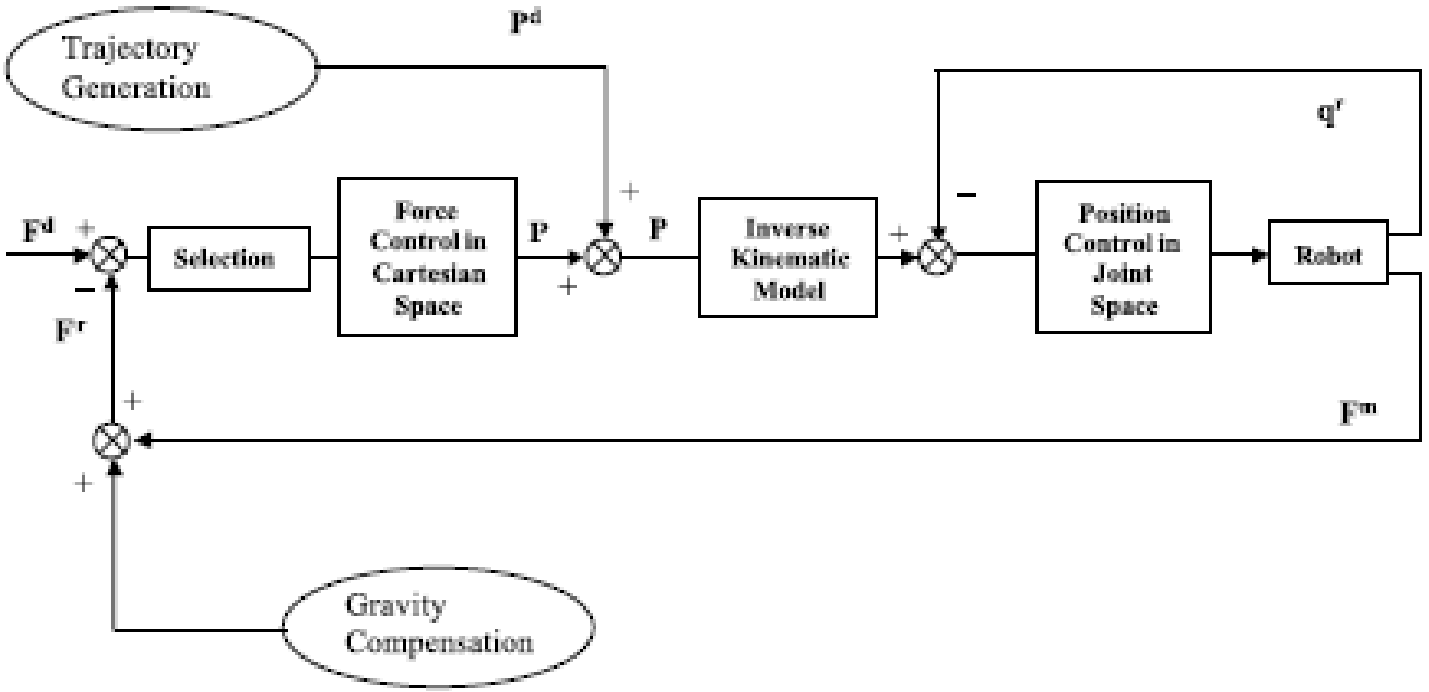
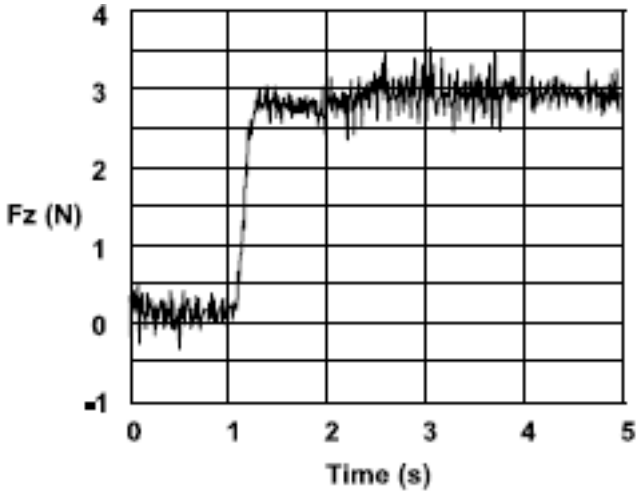


Figure 2. Block diagram of the external force control.

Figure 4. Testbed for force control.



Procedure

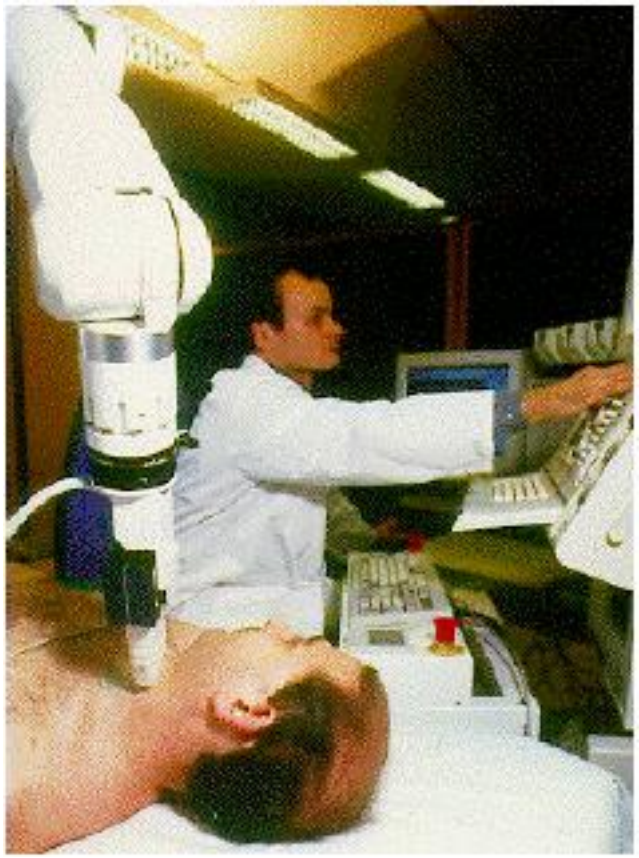


Figure 9. Hippocrate and its environment.

Teaching Phase

Automatic Phase

Hippocrate Safety and Security

- 3 emergency buttons to switch off power
- Watchdog board, if anything goes wrong in the software part, the cyclic signal sent to the watchdog is stopped.
- If any process stops at a time, entire process is stopped
- If force exerted by US probe exceeds a limit, system is shut down
- Joints have limits, to limit workspace
- When difference between current and desired position is high, power is switched off
- Action of DMS(foot pedal) necessary to authorize any motion
- If robot reaches singularity, any and all motion stopped until it is moved away from it.

Technical Approach Adopted (Paper 2)

- System Calibration

Calculate Sx and Sy, scale factors for u,v using a cube Phantom with a small and Large egg of known dimensions

$$P(u,v) = \begin{bmatrix} S_x u \\ S_y v \\ 0 \\ 1 \end{bmatrix}$$

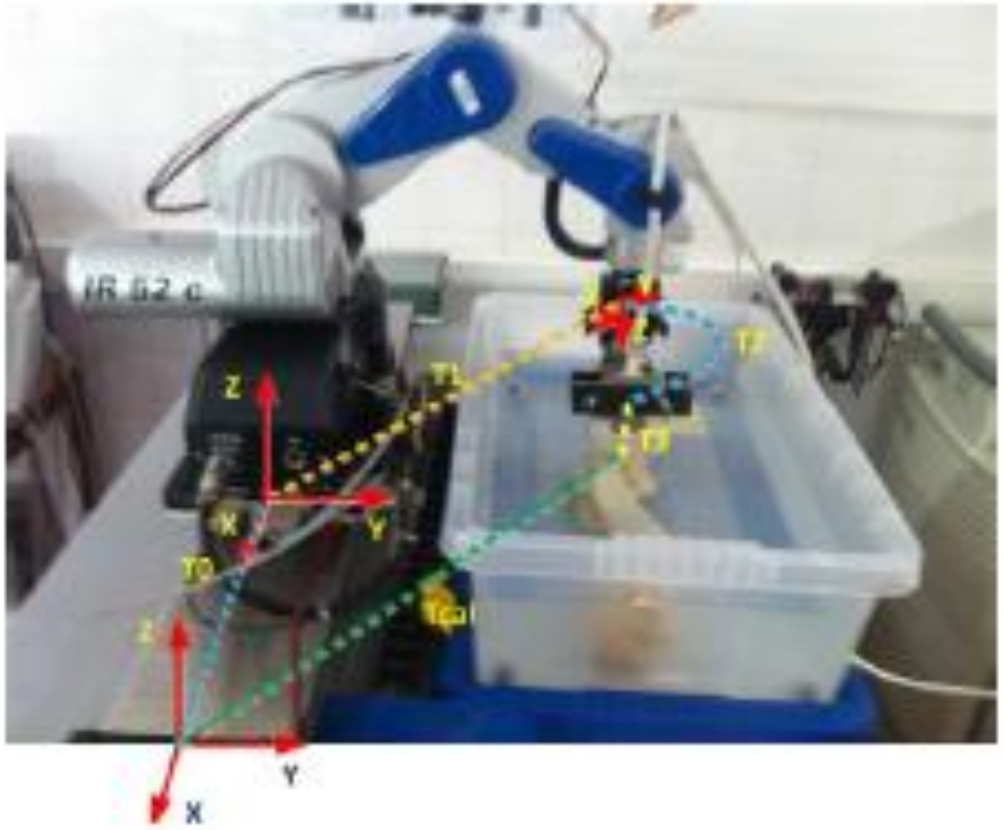


Fig. 1. Robot with frames used in calibration.

$$T_{cal} = T_0 \times T_1 \times T_2 \times T_3 \times P(u,v)$$

- Ultrasound Image Processing

Fig. 3. Example of Images Alignment. a) Image 1, b) Image 2, c) Image 2 aligned with 1.

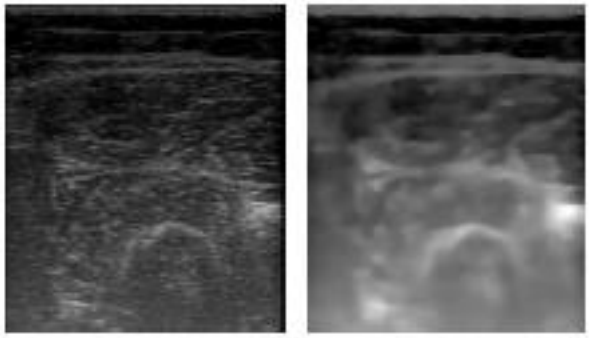


Fig. 2. a) Bone Ultrasound Image b) Denoised Image.

Normalized Cross Correlation

$$\gamma(u,v) = \frac{\sum_{x,y}[f(x,y) - \bar{f}_{u,v}][t(x-u,y-v) - \bar{t}]}{\left\{\sum_{x,y}[f(x,y) - \bar{f}_{u,v}]^2[t(x-u,y-v) - \bar{t}]^2\right\}^{0.5}}$$

where $\bar{t}$ is the mean is the mean of the template and $\bar{f}_{u,v}$ is the mean of $f(x,y)$ in the region under the template.

- Image Segmentation

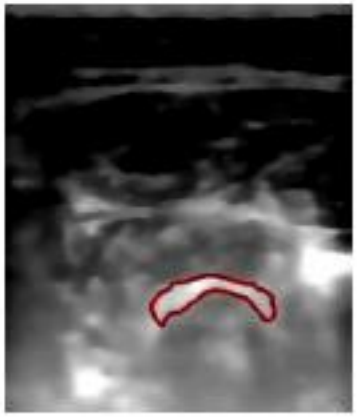


Fig. 4. Bone surface segmentation.

Bone surface reconstruction done using Marching Cube's Algorithm, using the segmented images.

Fig. 5. Bone surface Reconstruction.

My Assessment

Paper 1

Novel Idea for using Robots to perform Ultrasound
Has a good control loop, multiple in order to make it safe for use next to humans
Good Safety features
Applying Constant force to get better output images

Lack of provision of explained application
Lack of information/ placement of details at required places

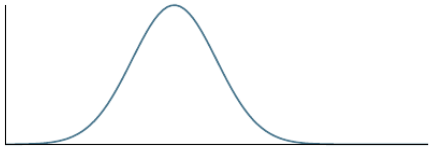
Paper 2

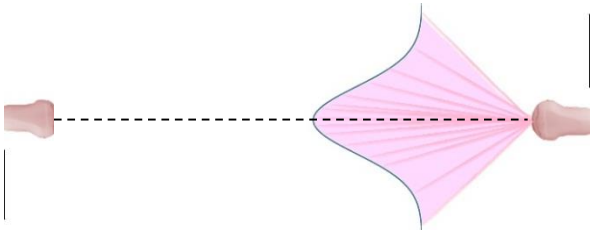
An idea to use Ultrasound to detect bone surface in 3D
Using Image Processing Techniques to get better output
Image segmentation

Lack of explanation of concrete complete examples
Lacks better explanation of ultrasound images

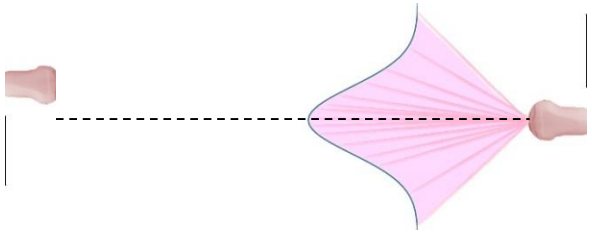
Possible Future Work

- Energy Profile Tracking (EPT)





Aligned



Not Aligned

- B-Mode Tracking

Conclusion

- A system required to help provide better Ultrasound quality images
- Hippocrate and Hiprob can help in solving the problem.
- Implementing robust and more control loops to guarantee even better Ultrasound imaging in 3D using 2D linear US probes

Thank You!

QUESTIONS?