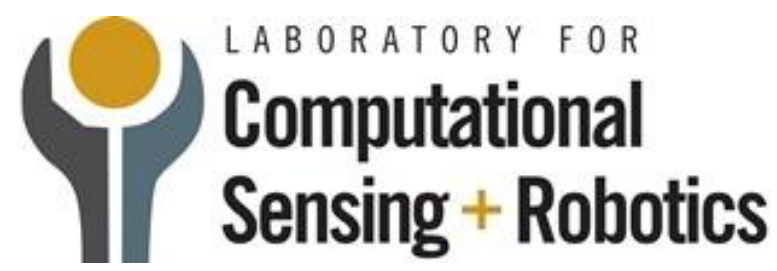# Co-robotic Ultrasound Imaging System

Computer Integrated Surgery II, Spring, 2017
Ting-Yun Fang, Weiqi Wang,
Haichong K. Zhang, Dr. Emad M. Boctor and Dr. Russ H. Taylor

Introduction

- Integrate UR5 robot arm with ultrasound imaging system
- Implement admittance robot control and virtual fixtures to assist user's motion
- Combine Synthetic Tracked Aperture algorithm to increase the US resolution and imaging field
- Improve the existing system to higher dexterity by replacing the 1 DOF load cell to 3-axis force sensor.
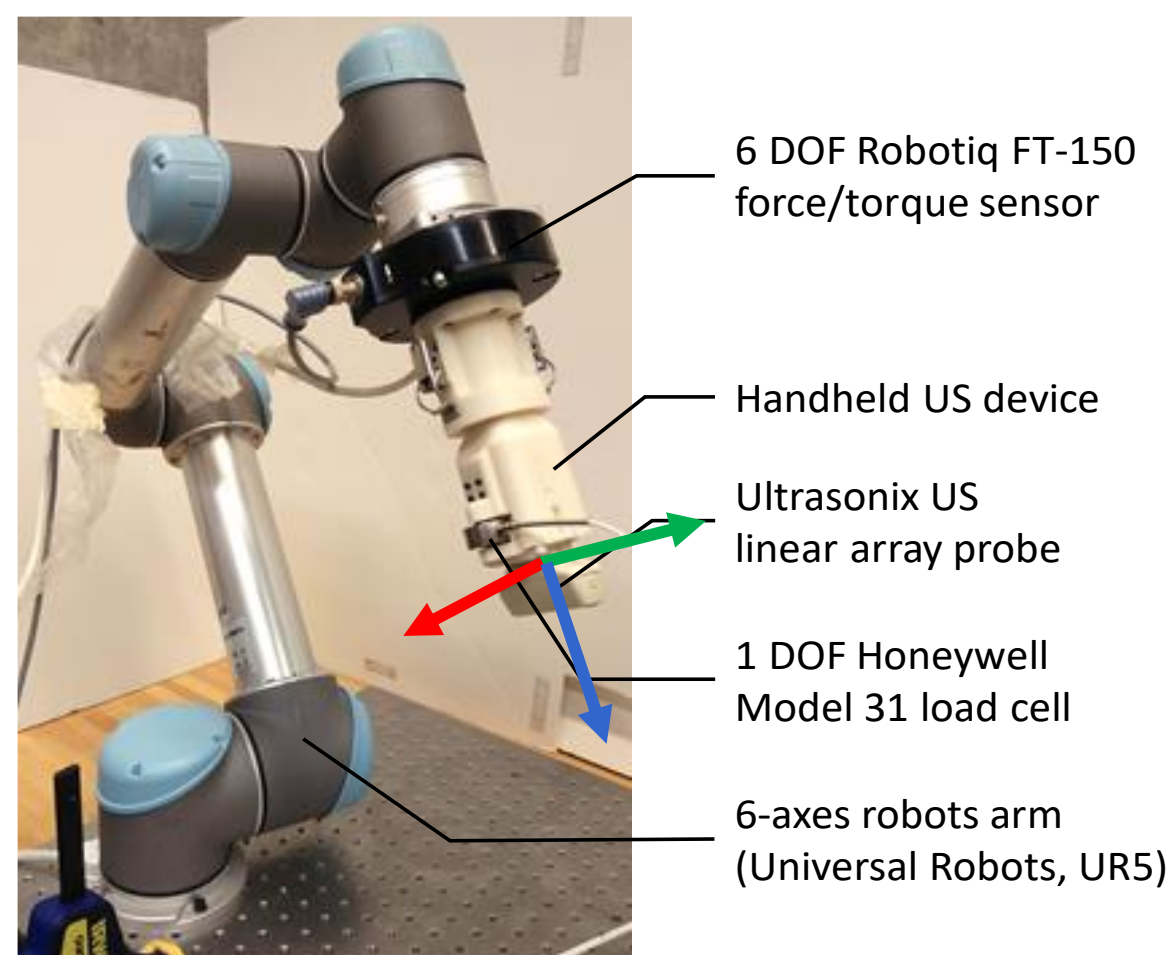

Figure 1. Dual force sensing co-robotic ultrasound system

The Problem

- Ultrasound image quality is limited to the aperture size of the transducer, especially for deep tissue and it highly depends on operator's skill
- STRATUS algorithm aims to solve this problem but it takes time to process before getting the result
- Virtual fixture stay on line is not enough
- The US attachment only has 1-DOF sensing feature which is not enough for general clinical use.
- The system lacks of in-vivo studies

The Solution

- Combine UR5 and dual force sensors with US system
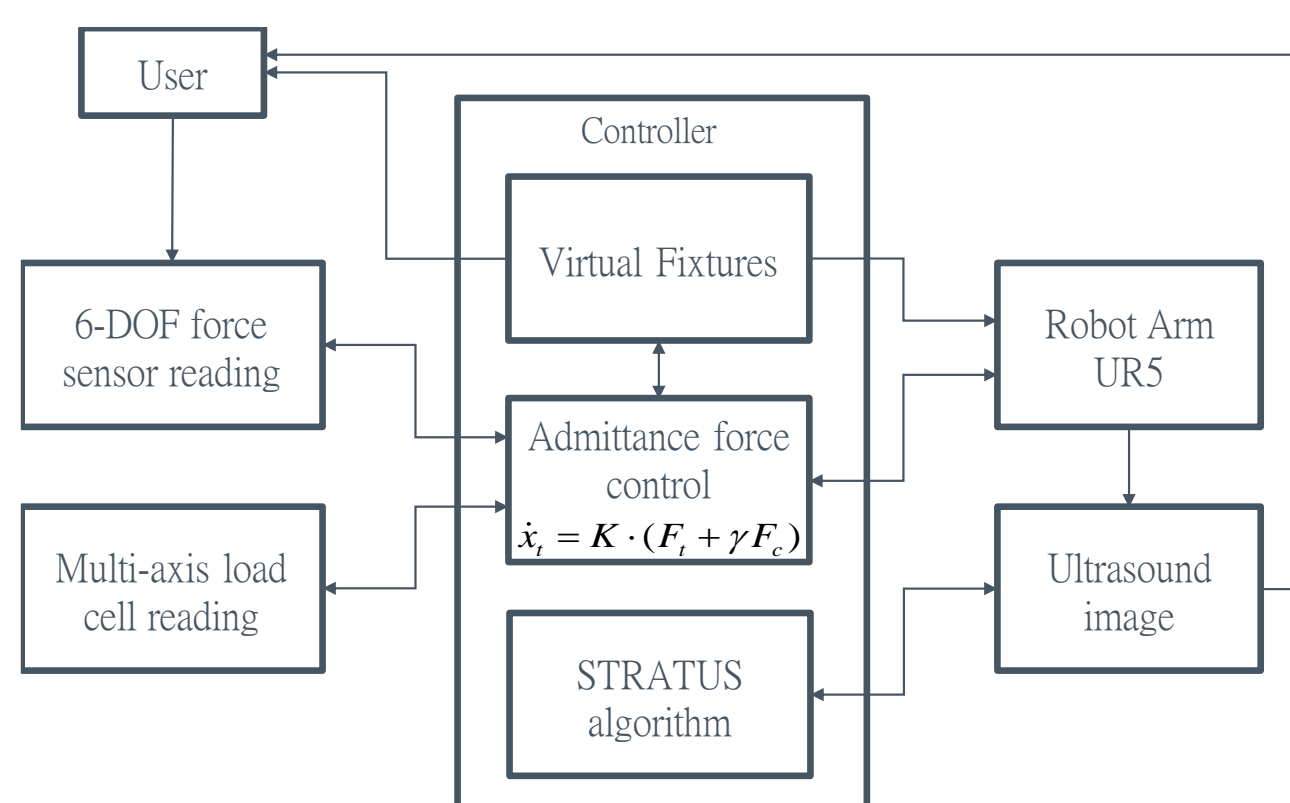- Implement admittance control and virtual fixtures which enable real-time STRATUS

Figure 3. The algorithm control loop of the proposed robotic US system

Figure 4. Virtual spring method for haptic guidance

- Improve the algorithm time efficiency for real-time visualization
- Develop virtual spring method for VF: follow trajectory
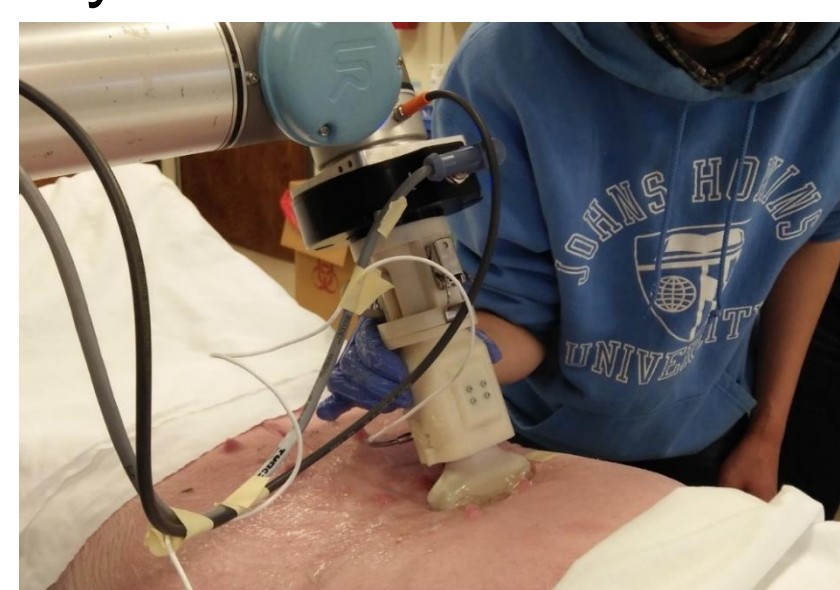- Performed phantom studies, animal and human experiments
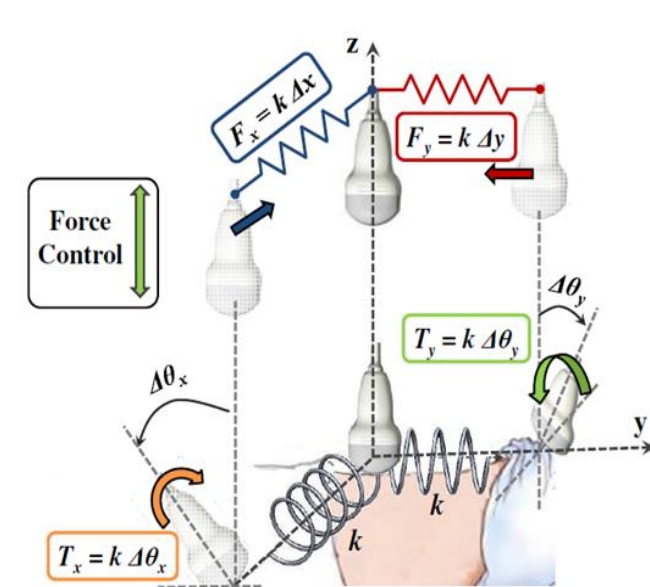

Figure 5. In-vivo study: animal experiment

Outcomes and Results

- Developed several virtual fixtures to constraint the user's motion and provide haptic guidance
- Improved the efficiency of 2D and 3D STRATUS algorithm
- Built real-time STRATUS GUI visualization
- Designed new US attachment for higher dexterity
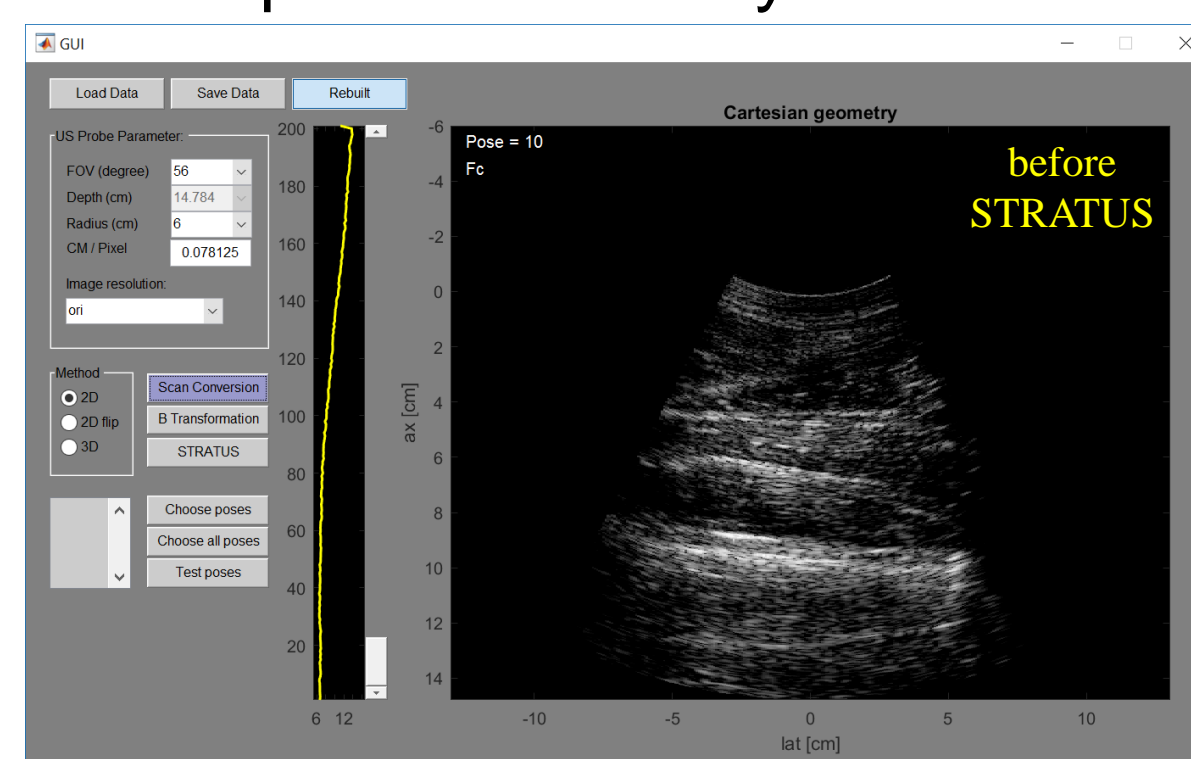- Conducted phantom study, animal and human experiments for system validation

Figure 6. STRATUS visualization GUI and human tight US image before STRATUS
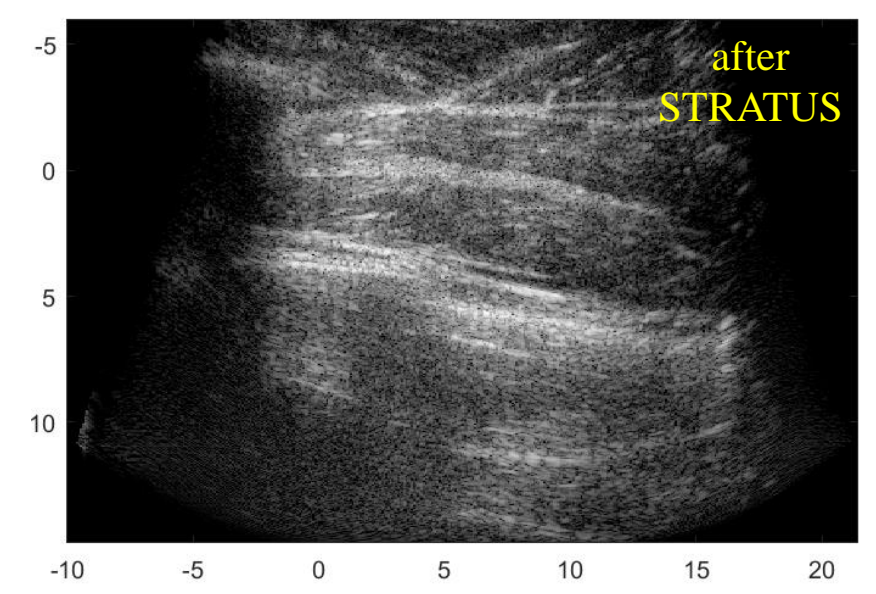

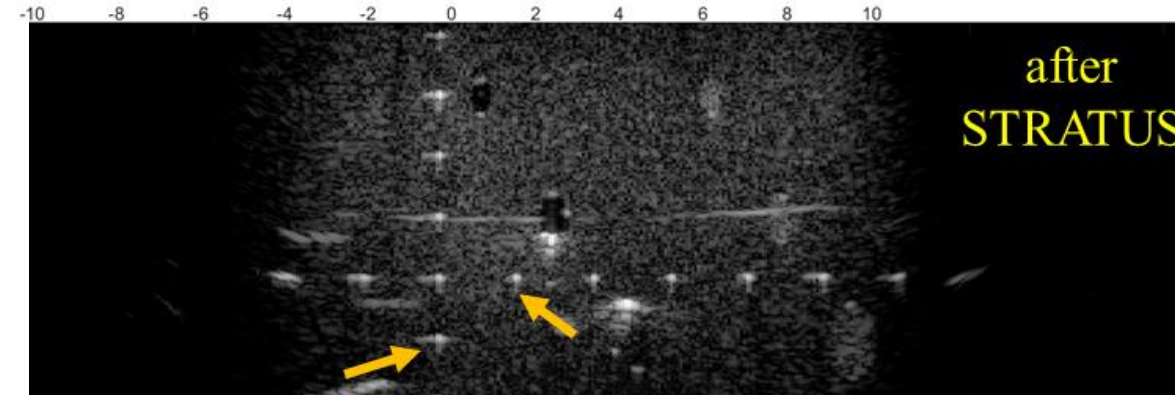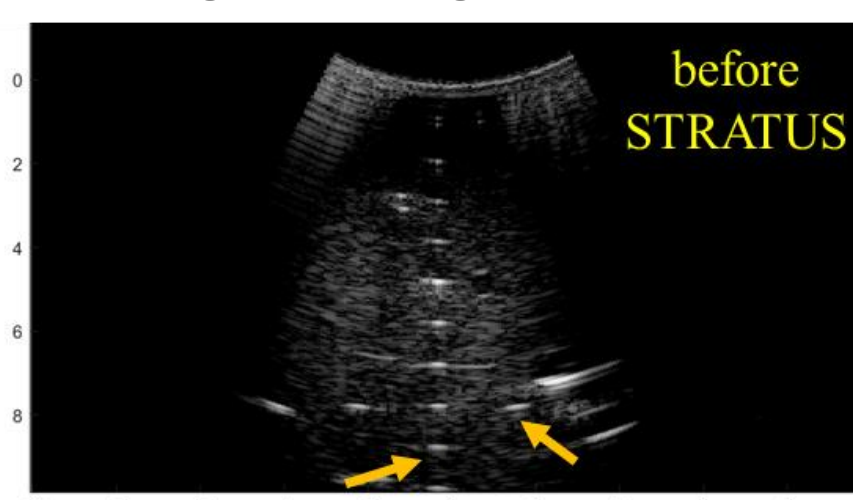Figure 7. STRATUS result of human tight US image

Figure 8. The result of phantom study

Figure 9. US attachment with 3-axis load cell

Future Work

- Upgrade the system with 3-DOF US attachment
- Validation of the system with more human experiments
- Include tissue motion compensation into the algorithm

Lessons Learned

- We acquired experience in CAD design, prototyping, Matlab GUI design, TCP/IP connection, and algorithm implementation
- It is really important and beneficial to continuously write laboratory reports

Credits

- Ting-Yun Fang – Design US attachments, real time STRATUS implementation, system validation
- Weiqi Wang – Virtual fixtures development, error compensation, system validation

Support by and Acknowledgements

- Thanks to our mentors for giving us advises and helping us identified problems
- Thanks to Rodolfo Finocchi and Haichong K. Zhang allowing us to use their initial work on this project