Photoacoustic Image Based Intro-Operative Surgical Guidance System in a da Vinci Surgical Robot Platform

Zijian Wu and Shuojue Yang, under the auspices of Hyunwoo Song, Dr. Hamid Moradi, and Professor Emad M. Boctor

EN.601.656 Computer Integrated Surgery II, Spring 2022

Introduction

Prostatectomy is one of the most common treatment for surgery by completely removing prostate gland. Robot-assisted laparoscopic prostatectomy (RALP), in which the surgeon moves the robotic arm through a computerized control system (e.g., da Vinci surgical robot), counts for over 80% of the entire radical prostatectomy procedures performed in the United States, as its minimally invasive surgical approach shortens the recovery time and reduce the risk of post-operative complications[1]. In this project, an intropeative surgical guidance system exploits the endoscopic camera and Transrectal Ultrasound (TRUS) probe to monitor this surgery, where a key component is the registration between the TRUS and endoscopic camera. By leveraging photoacoustic effect (active source points can be detected by TRUS), we perform the registration between the fluorescence (FL) image of the da Vinci endoscopic camera and the TRUS image.

The Problem

- The degree of automation of the surgical guidance system is low, which seriously affects its availability and efficiency in clinical practice.
- Manually aligning the ultrasound imaging plane with the photoacoustics virtual markers is cumbersome and time-consuming.
- Registration algorithm and surgical tool tracking are not implemented and verified.

The Solution

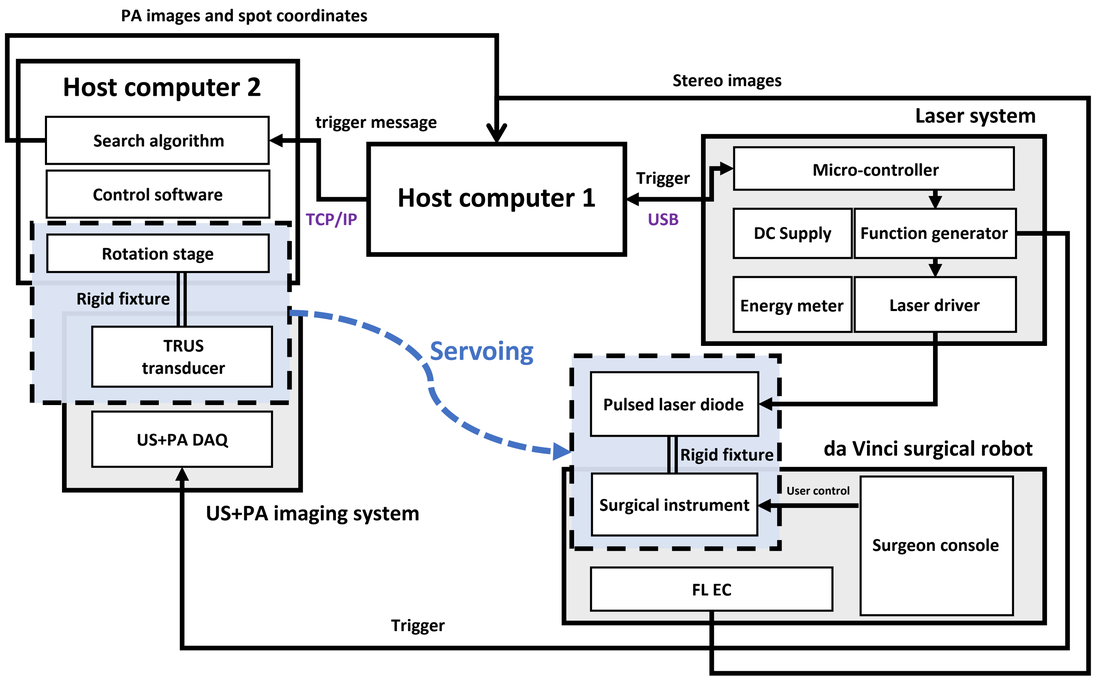

Figure 1: The overall system architecture of TRUS+PA image-guided surgical guidance system. DAQ: Data acquisition system; FL EC: Fluorescence endoscopic camera. The proposed surgical guidance system is composed of several modules including the host computer, da Vinci surgical robot, a pulsed-laser system, an actuator control module, and a US+PA imaging system. The black arrows indicate the signaling direction between the connected modules[2].

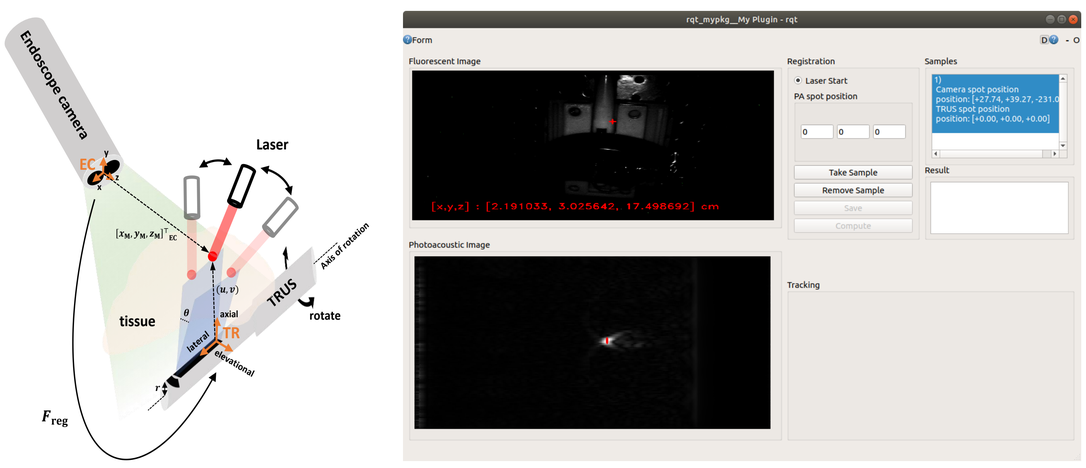

Figure 2: Left Figure: Conceptual illustration of registration and tracking using photoacoustic markers (PM)[2]; Right Figure: GUI screen shot

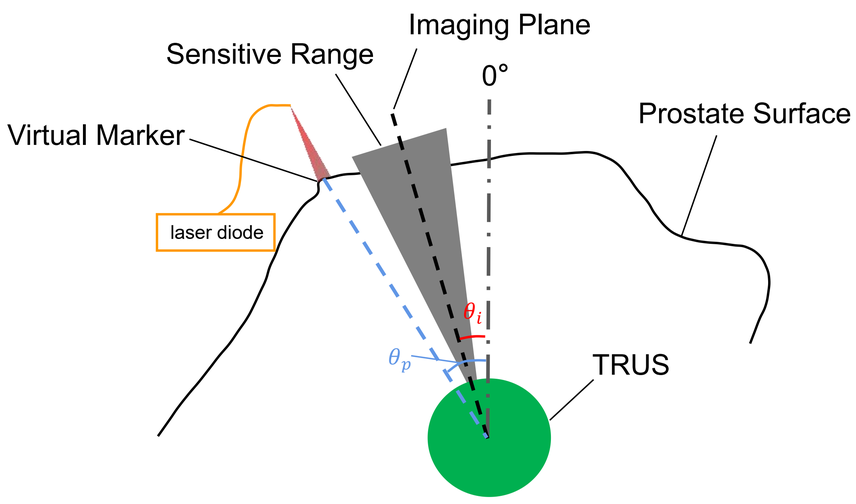

Figure 3: The diagram of search algorithm. θ_i is the rotation angle of imaging plane, and θ_p is the angle of PA virtual marker that we are trying to find.

Outcomes and Results

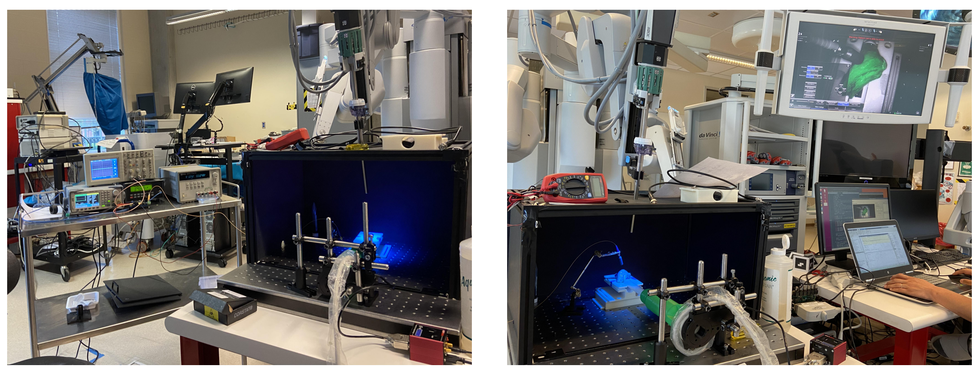

Figure 4: Experimental Setup

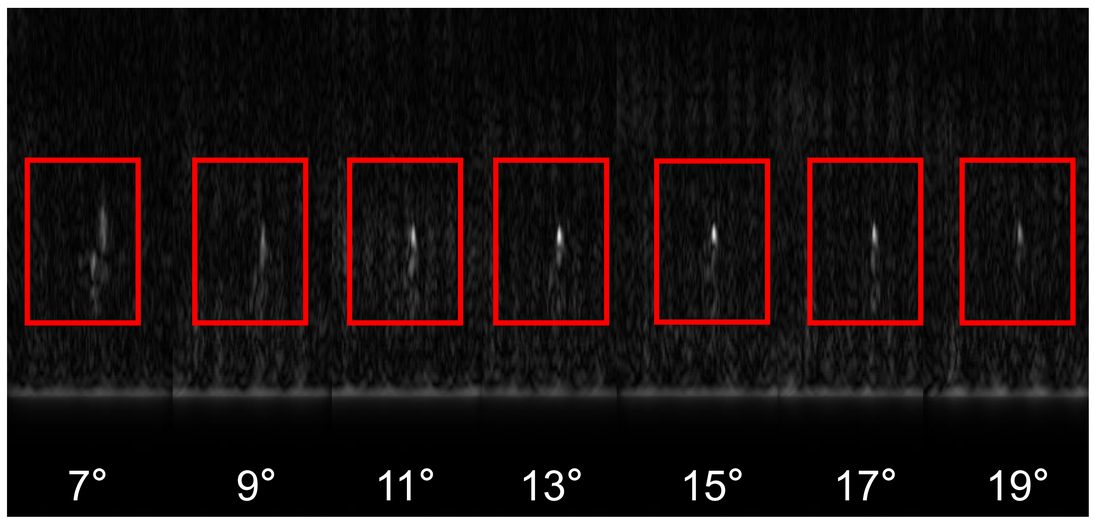

Figure 5: Visualization of how laser spot intensity changes (in PA image) with different rotating angles

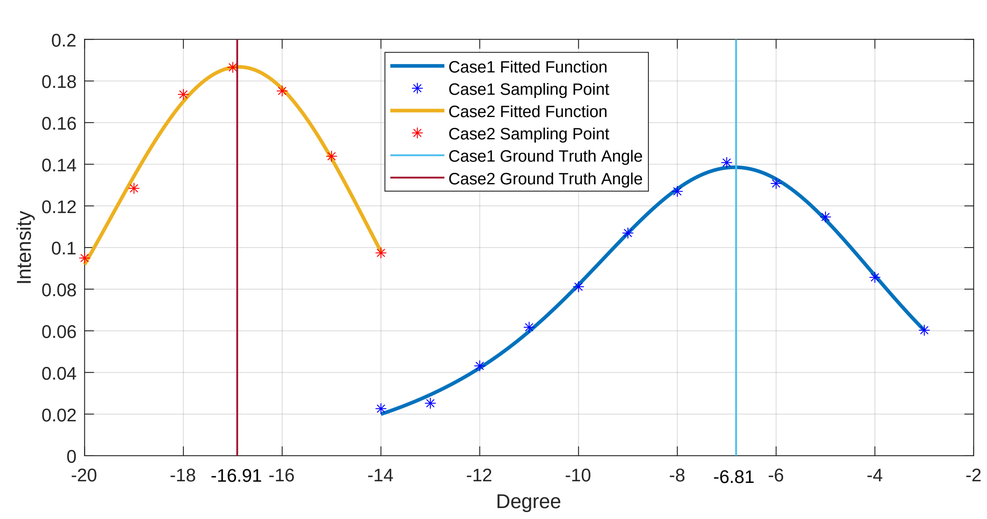

Figure 6: Examples of searching results. In case 1, the error is 0.03° ; in case 2, the error is 0.08°.

Future Work & Lessons Learned

- We planed to explore new registration methods independent on the TRUS rotation angle, which can lead to a simple yet efficient workflow.
- The experiment of registration error should be conducted to verify the effectiveness of our workflow.
- When planning the project, the availability of dependencies and their alternatives should be well investigated ahead of schedule.
- The experiments take much longer time than we expected due to the complex setup, therefore an appropriate timeline should take possible delay into consideration.

Credits

Zijian: search algorithm and experiment; Shuojue: system integration and experiment.

References

[1] Herbert Lepor. “A review of surgical techniques for radical prostatectomy”. In: *Reviews in urology* 7 Suppl 2 (2005), S11–7. ISSN: 1523-6161. URL: https://europepmc.org/articles/PMC1477597.

[2] Hyunwoo Song et al. “Real-time intraoperative surgical guidance system in the da Vinci surgical robot based on transrectal ultrasound/photoacoustic imaging with photoacoustic markers: an ex vivo demonstration”. In: (2022).

Support by and Acknowledgement

This research was supported in part by NSF Career Award 1653322,NIH R01-CA134675, the Johns Hopkins University internal funds, Canadian Institutes of Health Research (CIHR), CA Laszlo Chair in Biomedical Engineering held by Professor Salcudean, and an equipment loan from Intuitive Surgical, Inc. Sincere thanks to everyone of MUSiiC Lab for their help.