CORVUS Full-Body Surgical Robotics Research Platform

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Background

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Despite medical advances, surgery remains dangerous. Surgical errors have been estimated to account for at least 32,000 deaths per year in the United States, placing it among the top 15 causes of death in the US [1]. Specifically, vascular injury accounts for one third of complications in laparoscopy[2] and is the second highest cause of death within laparoscopic surgery, second only to anesthesia, with a mortality rate estimated at 15%[3]. Surgery is also extremely common: currently surgeries are performed at a rate of 50 million per year, giving the average American an expected 7 surgeries in their lifetime[4].

With a full-body six-axis robotic platform, additional research can be performed with the goal of making surgery safer through end-effector sensors and smart robotics.

Figure 1: Overview of workspace

CORVUS

- Originally designed for the Traumapod project sponsored by the Department of Defense through DARPA.
- Software written in C/C++ using the CanFestival and Qt open-source libraries.
- The end effector may be located anywhere on the exterior of a human body (5%-95% weight) with six degrees of freedom, as well as at an external location for tool storage.

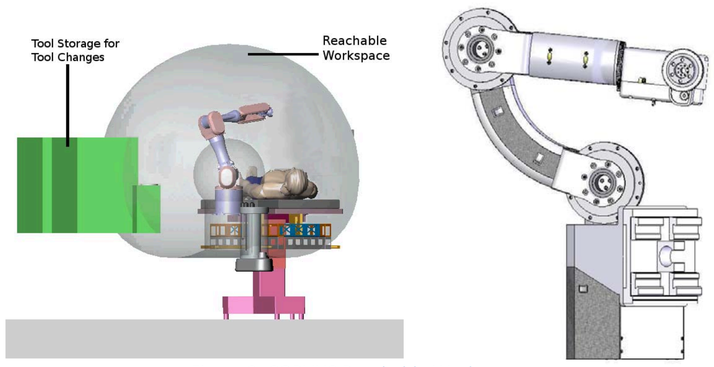

Figure 2: CORVUS Reachable Workspace

Completed Projects

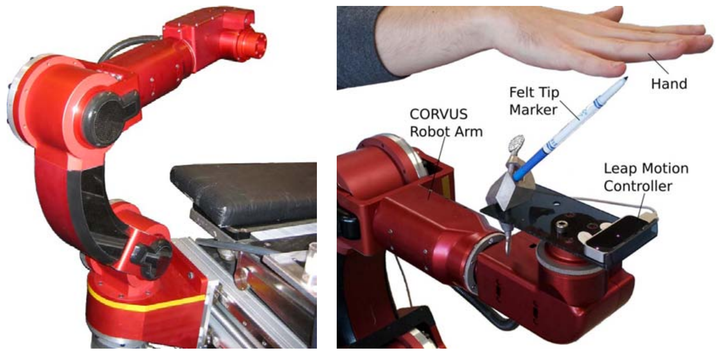

Figure 3: Overview of Experiment Setup

Online Free Anatomy Registration via Non-Contact Skeletal Tracking for Collaborative Human/Robot Interaction

For this experiment[5], the end effector was fitted with a tool (marker), and a 3-D scanning skeletal tracker (Leap Motion), as shown in Fig.3.

- A hand shape was used as the target object.
- The end effector stays stationary with respect to the hand, then draws a line on the hand.
- The trajectory is projected onto a horizontal plane, allowing the human to lower their hand onto the tool. This controls the Z axis, which controls the force of the interaction as seen in Fig.4.
- The robot then measures the X, Y, and orientation of the hand, and computes the appropriate point for the trajectory.
- The user can disengage at any time by pulling their hand up and away. If the hand is returned, the robot will resume the trajectory.
- Drawings of the felt tip marker path were then used to quantify the performance in terms of pixels occupied.

The skeletal tracker allows visual servoing to compensate for the drifting and shaking of a human hand being held in the air, and allows an intuitive human/robot interaction with the human in the control loop. This allows the robot to provide the precision, while the human provides the intuition.

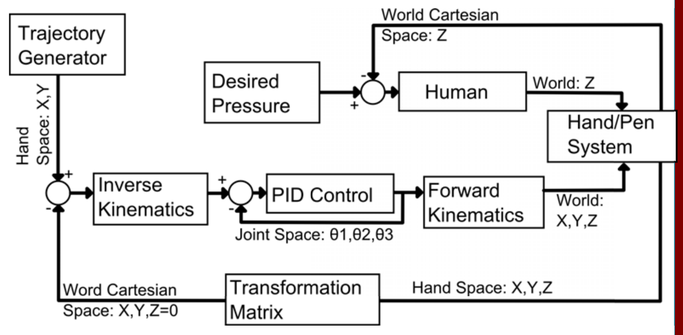

Figure 4: Control Loop for Human Robot Interaction

Active Projects

Soft Tissue Registration

- Currently testing with a DepthSense time of flight camera, Leap Motion and Xbox Kinect for feasibility of soft tissue registration.
- The time of flight data will be gathered through an endoscope to allow for real-time identification and avoidance of dangerous areas.
- For the time of flight camera, a local rigid transformation will be used, with the prior data segmented into nested segments for increasingly fine alignment. The alignment will be performed by an iterated closest point algorithm or a particle filter.

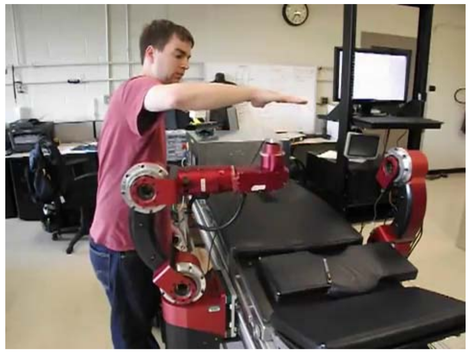

Figure 5: Visual servoing with Leap Motion

Six-Axis 3-D Printing

The platform will be used to 3-D print organs from the actual patient MRI for surgical practice prior to surgery, or to print directly onto the patient. The printing will be performed with silicone to allow realistic durometer for the organs, and sensors will be embedded into the organs.

Sensor System for Safe Collision Detection

Testing multiple systems for flexible collision detection, including tactile, pneumatic, and pressure dependent conductive sensors.

References

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[2] Anna Mases, Antonio Montes, Rocio Ramos, Lourdes Trillo, and Margarita M Puig. Injury to the abdominal aorta during laparoscopic surgery: an unusual presentation. Anesthesia & Analgesia, 91 (3):561{562, 2000.
[3] Philip A Philips and Joseph F Amaral. Abdominal access complications in laparoscopic surgery. Journal of the American College of Surgeons, 192(4):525{536, 2001.
[4] Atul Gawande. Two hundred years of surgery. New England Journal ofMedicine, 366(18):1716-1723, 2012.
[5] O'Neill, John, and Timothy Kowalewski. "Online Free Anatomy Registration via Non-Contact Skeletal Tracking for Collaborative Human/Robot Interaction in Surgical Robotics." Journal of Medical Devices 2014.

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