Telesurgery Via Unmanned Aerial Vehicle (UAV) with a Field Deployable Surgical Robot

Mitchell J.H. Lum[*], Jacob Rosen[*], Hawkeye King[*], Diana C.W. Friedman[*], Gina Donlin[*], Ganesh Sankaranarayanan[*], Brett Harnett[+], Lynn Huffman[+], Charles Doarn[+], Timothy Broderick[+], Blake Hannaford[*]

[*]*University of Washington, Seattle, WA, USA*
[+]*University of Cincinnati, Cincinnati, OH, USA*

Abstract: Robotically assisted surgery stands to further revolutionize the medical field and provide patients with more effective healthcare. Most robotically assisted surgeries are teleoperated from the surgeon console to the patient where both ends of the system are located in the operating room. The challenge of surgical teleoperation across a long distance was already demonstrated through a wired communication network in 2001. New development has shifted towards deploying a surgical robot system in mobile settings and/or extreme environments such as the battlefield or natural disaster areas with surgeons operating wirelessly. As a collaborator in the HAPs/MRT (High Altitude Platform/Mobile Robotic Telesurgery) project, The University of Washington surgical robot was deployed in the desert of Simi Valley, CA for telesurgery experiments on an inanimate model via wireless communication through an Unmanned Aerial Vehicle (UAV). The surgical tasks were performed telerobotically with a maximum time delay between the surgeon's console (master) and the surgical robot (slave) of 20 ms for the robotic control signals and 200 ms for the video stream. This was our first experiment in the area of Mobile Robotic Telesurgery (MRT). The creation and initial testing of a deployable surgical robot system will facilitate growth in this area eventually leading to future systems saving human lives in disaster areas, on the battlefield or in other remote environments.

1. Introduction

Just as minimally invasive techniques revolutionized the way many surgical interventions are performed, robot-assisted surgery stands to further revolutionize the medical field and provide patients with more effective healthcare. In most robot-assisted cases the surgeon is present in the operating room with the patient. However, surgical robotic systems teleoperate from the surgeon console to the patient; this can occur in either the same room or across the world. The challenge of surgical teleoperation across long distances was most prominently solved using standard means of telecommunication in a transatlantic experiment [1]. The challenge is now to deploy a surgical robotic system in a mobile setting or extreme environment and to control it through an unconventional data link such as an Unmanned Aerial Vehicle (UAV). This has implications for battlefield trauma, disaster response and rural or remote telesurgery.

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2. Methods

Research systems rarely leave the operating room or lab environment in which they were conceived. Deployment introduced problems rarely faced by researchers, including environmental concerns such as dust and high temperatures, and durability concerns such as shock absorption and packing. As a collaborator in the HAPs/MRT (High Altitude Platforms/Mobile Robotic Telesurgery) project, The University of Washington surgical robot system [2] was deployed in the desert of Simi Valley, CA for telesurgery experiments on an inanimate model.

Deploying the surgical robot system into an outdoor desert environment exposed the mechanisms, electronics and computer hardware to dusty winds and hot temperatures. To protect the surgical manipulators' motor packs (actuators, brakes, encoders and electrical wiring), 3-piece covers were designed and produced. The covers featured ventilation holes and a mounting point for a PC fan to cool the actuators in the desert heat. Clean power is not a primary concern in a hospital or lab, but in the field this was an important consideration. In order to prevent damage due to generators spikes two 1200W line regulators from APC were used. The ability to safely transport all the equipment to the remote site was also very important. Custom foam lined cases were designed to hold the surgical manipulators, surgical tools and master console devices (Phantom Omnis). The majority of the electronic components, including the control computer, power supplies, Maxon brushless motor amplifiers and USB2.0 interface device, were mounted inside two SKB Industrial Roto-Shock Rack cases. These cases have shock isolation between the plastic hard-shell exterior an internal frame.

In order to transport the system a Chevy Express cargo van was filled with approximately 700 kg of equipment. This included cases containing the two surgical manipulators, the SKB shock isolated cases, a custom made portable OR table, the surgeon console, tools, and back-up equipment.

(a) (b)

Figure 1. The surgical robotic system deployment in Simi Valley, CA. (a) The surgical Console (Master) (b) The surgical robot (slave)

The surgical manipulators were set up in one tent and the surgical console was set up in a second tent 100m away. Because of the UAV's range, the surgeons site and operation site could have been separated by a distance of up to 2km, but a closer distance was chosen for convenience in testing and debugging. Two surgeons

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interacted with inanimate objects that simulated internal organs; a modality commonly used to train surgeons. The surgeons performed gross manipulation tasks via a wireless communication link through Aerovironment's PUMA UAV. The radio link onboard the PUMA provided a TCP/IP Internet-style link between the two sites. The video signal was encoded using MPEG-2 transmitted at 800 kbps by a Hai560 hardware codec provided by HaiVision Inc. of Montreal, Canada.

3. Results

The experiment demonstrated telesurgery via wireless communication with limited bandwidth and variable time delays. A maximum time delay of 20 ms for robot control signals and 200 ms for video stream were observed. During the three days of field deployment, both kinematic data from the surgeons' commands and data characterizing the network traffic were collected. The two surgeons were able to perform the telemanipulation protocol through the wireless link. This experiment demonstrates the feasibility of performing telesurgery through wireless communication in remote environments.

Kinematic control signals were going to be sent to the manipulators at a 1kHz rate, and video signals sent to the surgeon using 2MB/s bandwidth. However, packet loss became a major problem (80% loss) during the initial testing at full bandwidth. When the overall bandwidth was scaled back packet loss was reduced to between 3%-15%. For the majority of the task experiments robot control signals were sent at 100 Hz and video bandwidth was 800kB/s. The surgeons noted increased pixilation in the video stream but did not feel it affected their task performance.

4. Conclusions

This was our first experiment in the emerging area of Mobile Robotic Telesurgery (MRT). Beyond the obvious environmental concerns, the experiments highlighted the need for minimal bandwidth, bandwidth scaling, a stable network and the support personnel to maintain a reliable communication link. It also demonstrated that under minimal or low visual feedback and network time delay, surgeons are still able to perform surgical tasks. When deploying in the field it is necessary to plan for all contingencies by bringing spare parts and tools; something the military has known for years. The creation and initial testing of a deployable surgical robot system will facilitate growth in this area and eventually lead to future systems which will save human lives in isolated or extreme environments.

References

1. J. Marescaux. "Transatlantic robot-assisted telesurgery." *Nature*, 413, Sept. 27. 2001
2. M.J.H. Lum, et al. "Multidisciplinary approach for developing a new minimally invasive surgical robot system." *In Proc. of the 2006 BioRob Conference*, Pisa, Italy, February 2006.

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