Critical Review

Paper: Methods for haptic feedback in teleoperated robotic surgery, A. M. Okamura, 2004

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In the paper "Methods for haptic feedback in teleoperated robotic surgery," Allison Okamura outlines the problems facing teleoperation and proposes solutions using haptic, or force and touch, feedback. The challenges concerned with current methods of teleoperative robotic surgery are two-fold. First, the loss of haptic information is a severe roadblock to using bilateral teleoperation systems such as the da Vinci Surgical System for procedures involving fine dexterous tasks such as cardiac suturing. This often contributes to operations that are longer and more technically challenging. Second, the steep learning curve, even for experienced surgeons, suggest that other modalities, perhaps haptic feedback, may be incorporated to shorten learning times and increase ease of use.

Okamura compares the efficacy of using the hand, and instrument with force feedback, and fully robotic graspers with no force feedback by measuring the magnitudes of force generated in the suture thread. The suturing of cardiac tissue is a highly dexterous task in which force generation at the instrument is crucial; enough tension must be applied to properly knot and tighten the suture, but not enough to break the delicate thread or damage sensitive tissue. Using the task of suturing to compare the effects of force feedback was both a timely and effective method: previous research had focused on haptic feedback in teleoperation for non-medical systems and this allowed for easily measurable and repeatable functional outcomes.

Hand ties, which generated the ideal force magnitudes, were compared to instrument ties (with or without force feedback) using a modified stylus with embedded strain gauges and robotic ties performed by the da Vinci console, which provided no feedback. The data was analyzed using paired student's t-tests to test the hypotheses that 1. Accuracy may be improved to the level of hand ties when force feedback is used and 2. Precision, or the repeatability of the task, is improved with force feedback. Although the experiment showed that instrument ties demonstrated 10% higher accuracy than robotic ties, Okamura rightfully concludes that this margin is not statistically significant to conclude that force feedback increases accuracy. The second experiment revealed that coefficient of variance for the instrument ties proved to be lowest out of all three methodologies evaluated, which supports her hypothesis that suturing precision could be improved with the incorporation of force feedback into the surgical robotic system.

Okamura's conclusion that force feedback is the factor which contributes to correctly and consistently generated forces is based on the assumption that viewing a stereo image through da Vinci console for the robotic ties, as opposed to viewing the workspace directly for the hand and instrument ties, does not affect performance. She mentions that since the stereo display system is of sufficient speed and resolution, this result is minor. A study citing the minimal effects of this indirect vision, or inclusion of this factor into her experiments, would strengthen her argument.

Okamura addresses the limitations of current control laws, in particular impedance control, in allowing for truly realistic haptic feedback. By distinguishing between different uses of haptics in minimally-invasive surgery and their effects, she identifies applications where haptic feedback are not required and may even convey to users the wrong information. For example, she addresses the issue of sensor-actuator asymmetry, which occurs when the degree of freedom of the master controller does not match the degree of freedom of the sensors on the remote manipulator. However, after performing experiments with these “missing” degrees of freedom, she concluded that certain forces do not significantly improve performance. This conclusion is important in order to correctly and practically implement haptic feedback in a real clinical setting; considering that the da Vinci tools are designed to be disposable, the addition of unnecessary or misplaced sensors would increase the prices of each tool, which may make the incorporation of force feedback cost-prohibitive.

After assessing different modes of suturing control and sensory substitution, Okamuara concluded that haptics does in improve performance, but is careful to qualify the statement by adding that it is applicable to highly dexterous, complicated procedures and not general minimally-invasive procedures. She also limits her findings to the area of force feedback, where forces are resolved to a single point, rather than full haptic feedback, which includes the sense of touch. Tactile displays, she says, are not likely to meet the size and weight constraints for multi-degree-of-freedom systems in the near future, which neatly allow her to exclude them from her current investigation.

It would have been useful to see her revisit the second main problem of teleoperated surgical systems that she mentioned in the introduction, the steep learning curve, to bring the discussion full circle. By expanding the discussion a little on why the system is so difficult to master initially, she could have perhaps suggested that the lack of force feedback is what contributes primarily to the learning curve. She discusses the potential of haptics to provide data for more realistic surgical simulations. Perhaps making the connection between better training software and decreased learning times would further justify the use of haptics in minimally-invasive surgery.

Reference:

Methods for haptic feedback in teleoperated robotic surgery. Okamura, A. M., 2004, Industrial Robot: An International Journal, Volume 31, Number 6, pp. 499-508