Laparoscopic Surgery Simulation: *in vivo* Data Acquisition and an Advanced Haptic Interface

Ela Ben-Ur, Mark P. Ottensmeyer & J. Kenneth Salisbury

Artificial Intelligence Laboratory
Massachusetts Institue Of Technology
Cambridge, Massachusetts 02139

http://www.ai.mit.edu

The Problem: This project looks at two aspects of producing a highly realistic simulation of laparoscopic (abdominal minimally invasive) surgery. We are developing instruments which can measure the mechanical properties of tissues *in vivo*. These data are parameters that describe the tissue to simulation software, which will use a haptic (force and tactile) interface that we have designed and constructed to provide the proper feedback to the user.

Motivation: Laparoscopy training relies on models, animals or guidance from experienced surgeons in the operating room (O.R.). Models often poorly simulate organ tissue properties and aspects such as breathing and heartbeat motions and bleeding. Animal use is being reduced for ethical and cost reasons. Guidance in the O.R. presents danger to the patient and requires patients with specific maladies for practice.

Our work seeks to provide data acquisition tools to populate a computer simulation, and to provide an interface so that students can train for any procedure, practicing under ideal conditions or with complications, without danger to patients or animals, and with the proper visual and haptic feedback.

Previous Work: Most previous mechanical property measurements on biological tissues have been done *in vitro*[1], using tissue samples placed in stress-strain testing cells. Dead organ and muscle tissues typically stiffen with time, and do not have blood flowing through them under typical pressures. A few groups have begun in vivo measurements, but there is not yet a reasonable catalog of tissue properties to draw upon.

There are a number commercially available or research surgical simulators with haptics (e.g. [2]). Until now, none has covered all of the degrees of freedom or the ranges of motion used in real laparoscopy.

Approach: We have developed two tools to measure properties *in vivo*[3]. The first is a small displacement, one-axis indenter which will measure tissue compliance over a wide range of frequencies. The second device will be able to deflect tissues in 3-D over a larger range. This will allow us to provide data to and validate the performance of the simulation on small and large tissue deformations. Both devices will pass through standard 12mm laparoscopy trocars, and will be suitable for use during open or laparoscopic procedures. We will be acquiring data from pigs used by surgeons for training purposes, but the tools will be designed with eventual use on humans in mind.

Our surgical haptic interface supplements a PHANToM Haptic Interface with grasping and tool roll axis motions[3]. With the pitch, yaw and thrust motions supplied by the PHANToM, we can recreate all of the haptic sensations experienced by the surgeon during surgery. The interface integrates real laparoscopy toolhandles and a compliant torso model to complete the set of visual and tactile sensations.

Difficulty: The tissue property sensing instruments need to fit through 12 mm tubes, which provide access to the inside of the body, so many of the sensors and actuators need to be custom designed. Design for safety must be considered, as there are strict regulations on electro-surgical devices. Further, biological tissues exhibit time dependent and strain-rate stiffening behaviors, mean that choice of what data to sample, and the analysis of those data will be a non-trivial task.

The haptic interface hardware needs to cover the surgeon's likely range of motion. It must also be small, light and hidden from view to provide a visually realistic surgical environment, and one which does not distort the forces perceived by the surgeon. These constraints must be traded off against the fairly large forces that the surgeon may use, which would otherwise argue for larger, more powerful actuators.

Impact: A computer-based surgical simulator, with full visual and haptic feedback would be a valuable tool for medical students and surgeons. It would improve the learning experience over physical models, reduce or eliminate

Figure 1: Minimally invasive tissue property measurement tool and laparoscopic haptic interface

the need for animals, and provide the opportunity to practice at the convenience of the student, rather than on the misfortune of a human patient. It could also be used by experienced surgeons who would use pre-operative patient data to practice on a virtual version of the real patient before entering the O.R.

Future Work: The work to develop the tissue property sampling tools is ongoing; testing on silicon rubber models has begun and em in vivo measurements should also begin before the end of the year. Extraction of tissue property parameters is expected to be completed shortly thereafter. The prototype haptic interface has been completed, and is ready to be integrated with simulation software when it has been completed by our sponsors. A second copy of the device may be constructed to permit two-handed operation, as would be experienced in the O.R. A simplified version, including gripping action but with no roll feedback, has been provided to the Lab for Human and Machine Haptics for use with their simulation system.

Research Support: This research is being pursued in cooperation with the Center for Innovative Minimally Invasive Therapy at the Massachusetts General Hospital, as well as the Touch Lab at MIT and Draper Labs. The work was supported in part by the Department of the Army, under USAMRAA Cooperative Agreement No. DAMD17-99-2-9001. The statements made herein do not necessarily reflect the position or the policy of the government, and no official endorsement should be inferred.

References:

[1] E.J. Chen, J. Novakofski, W.K. Jenkins and W.D. O'Brien, Jr. "Young's Modulus Measurements of Soft Tissues with Application to Elasticity Imaging." *IEEE Trans. on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 43, no. 1, Jan 1996.

[2] Immersion Corp. Medical Products, webpage. Aug 11, 1999, updated Jul 1998. <http://www.immerse.com/webpages/medical.html>

[3] M.P. Ottensmeyer, E. Ben-Ur, J.K. Salisbury "Input and Output for Surgical Simulation: Devices to Measure Tissue properties *in vivo* and a Haptic Interface for Laparoscopy Simulators." *Proceedings of Medicine Meets Virtual Reality 2000*, Newport Beach, CA. IOS Press. pp235-242. Jan 2000.