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Group 8: Force Feedback of Dual Force Sensing Instrument for Retinal Microsurgery

Due: March 26, 2013

**ARTICLE: FORCE FEEDBACK-BASED MICROINSTRUMENT FOR MEASURING TISSUE PROPERTIES AND PULSE IN MICROSURGERY**

**PAPER CITATION**

A. Menciassi, A. Eisinberg, G. Scalari, C. Anticoli, M. Carrozza, and P. Dario, “Force feedback-based microinstrument for measuring tissue properties and pulse in microsurgery,” *in IEEE International Conference on Robotics and Automation*, 2001, pp. 626–631.

**PURPOSE**

There is a demand to develop a set of robotic microinstruments to assist the surgeon during minimally invasive surgery (MIS). The paper delineates the main features and performance of a prototype miniature robotic instruments comprised of a microfabricated microgripper, instrumented with semiconductor strain-gauges as force sensors. For the experiments done in vitro, the microgribber is mounted on a workstation and operated remotely. A haptic interface provides force-feedback to the operator. The system was able to differentiate tiny skin samples based on their different elastic properties and feel microvessels based on the pulsating fluid flowing through them.

**SETUP**

The microrobotic system was modular and teleoperated. Its components are: a microfabricated instrumented probe which can exert controllable force-displacement cycles on soft tissues and measure force generated by pulsating flow in microvessels, a 3 DoF motorized manipulator which moves the microgripper, a fiber optic microscope with a monitor which allows the operator to see the sample and microgripper position, PC-based control unit, and a haptic interface that provides a force-feedback to the operator.

The microprobe has flexure joints to generate large displacement at the fingertips in a compact structure. When the actuator pushes the rear part of the microgripper, the flexure joint-based deformable structure amplifies the displacement. The result is a larger displacement at the tip.



The microprobe is instrumented with a semiconductor strain gauge. The symmetry of the microgripper structure corresponded to that of the strain gauge sensor for accurate measurements, thermal compensation, and better signal to noise ratio.



As the fingertips grasp a tissue sample, the strain gauges measures the deformation of the microprobe structure. With proper calibration, the output signal of the strain gauge bridge can be read as a force signal.

Calibration tests showed a linearity between the fingertip force and strain-gauge sensor output.

Superelastic alloy was chosen because it allowed to obtain a more robust and stiffer microprobe and to fabricate flexure joints which reached a large displacement amplificiation factor within the elastic range of the material

The system control is implemented by means of a PC, which shows the interface of the microgripper actuating and sensing circuits with the Phantom haptic interface. In normal operation, the operator drives the actuators by the haptic interface and simultaneously “feels” the grasping forces measured by the instrumented microprobe. By using this apparatus, different micro-samples of soft tissues have been tested and pulse in microvessels have been”felt”. For valuable quantitative measurements, a method was devised for signal processing.

**TESTING METHODS AND EXPERIMENTAL RESULTS**

No tests on animals were done. Instead, tiny samples of human skin freshly excised from areas around the fingernails of three volunteers were used.

To obtain information on the elastic properties of the microsamples, the microgripper grasped the sample (while doing so, a small signal step voltage was applied) resulting in a sudden closure of the gripper. Then, the small oscillations of the gripper fingertips at frequencies dependent on the resonant frequencies of the mechanical system will appear.

Since the step responses were not sufficient enough to discriminate the different skin samples, the microgripper system was identified by means of a small step impulse excitation, filtering, and Fast Fourier Transform (FFT) of the output signals.

Using Bode plots and diagrams, one was able to determine the three different skin samples that were grasped.

The same system was used to test pulse in microvessels. The microvessels were modeled by polymeric microtubes and the pulsating blood flow was simulated by a simple microfluidic circuit. The micropump was PC-controlled.

The pulse signal was measured by the strain gauge sensor and “felt” by the operator through the Phantom interface as well.

**CRITIQUE**

This paper provided a possible technique suitable to measure in vivo the mechanical properties of different tissues. Considering that this paper was written in written in over 10 years ago, there has been much time for it to have improved since.

First, it mentions that if the probe is much stiffer than the tested samples, the discrimination accuracy improves considerably. Newer alloys can give way to better probes.

Another is that, since the time the article was written, further developments in the haptic feedback system has been made.

Though the paper focuses on the importance of differentiating between skin tissues, I believe more research should be done in fine-tuning it to obtain quantitative numbers. Though their simulations were models, there may be more complicated case for real blood vessels. There may be more factors to consider and the blood vessel may not be uniformly elastic (e.g. an arterial clog).

The ethical issues have clearly been thought through with the cautiousness to use human subjects. However, eventually I believe if this technique were to be explored, a more realistic model is necessary—perhaps a pig.

In conclusion, the paper had a great start—groundbreaking even. Perhaps if this method was to be done again, better material and models should be used to produce more accurate results. Since a retinal microsurgery needs finer measurement (due to the delicate nature of the blood vessels and tissues in the eye), this technique needs to be much more refined before it can be implemented for the eye.