

A Robotic Indenter for Minimally Invasive Characterization of Soft Tissues

Evren Samur September, 2005

Outline

Problem Our Approach Literature Review Design of the Robotic Indenter Controller Design & GUI Animal Experiments Experimental Results

Problem

The lack of data in current literature on *in-vivo* material properties of soft tissues has been a significant impediment in the development of virtual reality based laparoscopic simulators that can provide the user with realistic visual and haptic feedback for training medical personnel.

Goal

In-vivo characterization of soft tissue properties for integration into tissue models to be used in VR based surgical simulators.

Challenge

Soft organ tissues exhibit nonlinear <u>anisotropic</u>, nonhomogeneous, time, and rate dependent behavior, which are extremely challenging to measure, especially in vivo.

Our Approach

 Development of a robotic indenter
 Design of measurement experiments
 Extraction of tissue properties from measured data

Our Approach



Robotic Indenter

Tissue Properties



Experiments

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Literature Review Measurement site ■ in a living body (*in-vivo*) within a body (*in-situ*) • outside the living body (*in-vitro*, ex-vivo) Measurement methods *invasive*: a part of the body is entered, as by puncture or incision non-invasive: the body is not cut open, e.g. ultrasound *minimally invasive*: e.g. laparoscopy

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Literature Review

Hand-held

Invasive
 Carter et al.

*Minimally Invasive*Kauer et al.

Robotic
 Invasive Tay et al.

Minimally Invasive
Ottensmeyer
Brown et al.

 Ref: Brown, J.D. et al., (2003). "In-vivo and In-Situ Compressive

 Properties of Porcine Abdominal

 Soft Tissues", MMVR, Vol. 94, pp.

 26-32, Newport Beach, CA

Ref: Ottensmeyer, M. P., (2001), "Minimally Invasive Instrument for In vivo Measurement of Solid Organ Mechanical Impedance", Ph.D. Thesis, MIT

Our Contribution

<u>Robotic Probes</u> vs Hand-Held Probes
 <u>Minimally Invasive</u> vs Invasive
 <u>Large indentations</u> vs small indentations
 <u>Static</u> vs <u>Dynamic</u> indentations

Components of the Robotic Indenter

- Phantom haptic device (encoders for 3D position sensing)
- Laparoscopic Probe
- Nano 17 force sensor (3D force/torque sensing)
- Cover



Controller Design

PID control and tunning



Graphical User Interface

Automates the generation and execution of indentation profiles and data collection.

Koç University Robotics and Mechatronics Laboratory					
e Tools Help					
Sensor Related					
GO 0.0451	Bias Display • Voltages		and the second		
G1 0.0056	Unbias O F/T U	nits		A CARLES AND A CARLES	
G2 -0.5052					
G3 -4.4206	Thermistor: -1.5454 ∨			and the	
G4 12.6308			101		
G5 0.0332				A COM	
Phantom Related _ Indentation Configuration		Control Board]	
Indentation Profile:	Ramp & Hold Indentation 🔻			1	
Preindentation Depth (mm):	0	Start Phantom	Start Indentation	Kill Phantom	
Preindentation Velocity (mm/s):	0				
Rest Duration (s):	0	Phantom Information Screen		1	
Ramp Depth (mm):	6	Hit 'Start Phantom' button. Place robot on tissue surface. Load a calibration file. Choose F/T units and hit 'Bias' button Hit 'Start Indentation' button to start indentation. Hit 'Kill Phantom' button anytime during indentation to stop servos.			
Ramp Velocity (mm/s):	6 Clear Configuration				
Hold Duration (s):	30	Hit 'Emergency Exit' button	n case of an emergency.		
Amplitude (mm):	0	Servos started successfully. Indentation started success			
Frequency (Hz):	0	I am writing output files			
Sinusoidal Indentation Duration (s):	0	<u></u>			
Load Configurat	Load Configuration From File		Clear Information Screen		

Preliminary Experiments



Observation in Operating Room



Animal Experiments

In collaboration with Department of Surgery and Faculty of Veterinary Medicine of Istanbul University.



Animal Experiments



Indentation types
Static indentation
Stress relaxation
Dynamic indentation



Experimental Results



Effective elastic modulus for small indentation of an elastic half-space by a rigid hemispherical indenter

Indentation	Effective Young's
Depth	Modulus
δ (mm)	E (kPa)
2	16.9 ± 4.9
4	12.4 ± 4.1
б	10.8 ± 4.7
8	10.0 ± 4.7

Experimental Results



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