

**DEVELOPMENT OF ORGAN STIFFNESS MODELS  
FOR HAPTIC FEEDBACK IN LAPAROSCOPIC  
SURGERY SIMULATION**

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## **DECLARATION OF THE CANDIDATE & SUPERVISOR**

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## ABSTRACT

Laparoscopic surgery is the most common Minimally Invasive Surgery (MIS) performed routinely for certain procedures such as appendectomy and Cholecystectomy. Laparoscopic surgical procedures are very complex compared to open surgeries and require a higher level of experience and expertise. A comprehensive training session on surgical simulator handling for trainee surgeons is highly recommended before the hands-on training in a real surgery. Comprehensive surgery simulators such as physical phantoms which are available for training are expensive and not readily available in many health care centers around the world. VR simulators have a great potential to revalorize the training paradigm of surgical interns. The haptic feedback plays as equally as visual feedback to provide a realistic environment to trainees. Realistic organ-force model is a key requirement of a VR simulator to experience real-time tool-tissue interaction forces. However, modeling real tissue properties has not been achieved due to several limitations such as the inaccessibility to *in-vivo* tissue properties, the complex behavior of biological tissues and anatomical variability.

We have adopted an alternative approach to incorporate force feedback to VR simulators. The abdomen organ models (liver, gallbladder, stomach, bone, and vessel) were generated using the color Cryosection dataset of the Visible Human Project. A novel method was applied to render forces by fine-tuning the stiffness of organ model and integrating the three force ranges: soft, mild/firm and hard into organ models using feedback received from expert surgeons. The proposed system provides the interaction forces through a haptic device with six Degrees of Freedom (DoF) position sensing and three DOF force feedback.

The simulated organ models were evaluated by two experienced surgeons. The proposed haptic models were mostly in harmony with their experience in real-world tool-tissue interaction and the overall accuracy of identifying the correct organ property was more than 68%. The organ models were also tested with senior registrars. The results showed a considerable improvement amounting to more than 34% chances of selecting the correct organ property after training.

**Keywords:** Laparoscopic surgery, minimally invasive surgery, Virtual Reality simulators, Haptic feedback, force feedback

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## LIST OF ABBREVIATIONS

MIS	-	Minimally Invasive Surgery
LC	-	Laparoscopic Surgery
RAS	-	Robot - Assisted Surgery
VR	-	Virtual Reality
DoF	-	Degrees of Freedom
DC	-	Direct Current
DoFF	-	Degrees of Force Feedback
VRT	-	Virtual Reality Training
GL	-	Graphic Libraries
HIP	-	Haptic Interface Point
API	-	Application Programming Interface
HLAPI	-	Haptic Library Application Programming Interface
HDAPI	-	Haptic Device Application Programming Interface
PDD	-	Phantom Device Drivers
QH	-	Quick Haptic
VHP	-	Visible Human Project
NLM	-	National Library of Medicine
CT	-	Computerized Tomography
MRI	-	Magnetic Resonance Imaging
USB	-	Universal Serial Bus

CELTS	-	Computer Enhanced Laparoscopic Training System
SAGES Surgeons	-	Society of American Gastrointestinal and Endoscopic
FLS	-	Fundamental of Laparoscopy
FEM	-	Finite Element Methods
VTK	-	Visualization Toolkit
ITK	-	Insight Toolkit
SBB	-	Skill Based Behavior
RBB	-	Rule Based Behavior
KBB	-	Knowledge Based Behavior
FGE	-	Flexible Gastrointestinal Endoscopy
EVS	-	Endovascular Surgery
LEM	-	Long Element Method
MIRS	-	Minimally Invasive Robotic Surgery
HPDM	-	Hybrid Physically Based Deformation Modeling
SDM	-	Synthetic Deformation Modeling
VHTM	-	Virtual Haptic Medical ToolKit
GUI	-	Graphical User Interface
SR	-	Senior Registrar

## **LIST OF APPENDICES**

### **Appendix A:**

Features of the augmented reality simulators provided by their manufactures

### **Appendix B:**

C++ codes for the simulator with embedded haptic models