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

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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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| | | |
|---|---|---|
| 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 | - | Vissible 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 | - | Society of American Gastrointestinal and Endoscopic Surgeons |
| 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