Abstract. This paper describes a laparoscopic cholecystectomy surgical training software system we have developed using the Immersion Laparoscopic Surgical Workstation™ and the Verefi Technologies Inc USB 30 degree Endoscopic Ecamera™ system hardware. The trainer is designed to train and test for many laparoscopic skills such as: manipulation of the laparoscope, grasping and stretching the gallbladder to expose the cystic duct, clip application to the cystic duct, cutting the cystic duct, and removing the gallbladder from the abdomen. Simulated patient breathing is accomplished by using a texture motion algorithm. The gallbladder, cystic duct and bile ducts are stretched and compressed using Hooke's law of \( F = -kx \) within a mass-springs model. The intent is to provide an effective method to learn the laparoscopic cholecystectomy procedure using a haptic surgical simulator.

1. Introduction.

Laparoscopic cholecystectomy (LC) is a common surgical procedure that is often the first laparoscopic operation learned by surgeons. While LC may be considered an “entry level” laparoscopic operation, there is the potential for disastrous complications, including bile duct leak or injury. A need exists for training in skills pertinent for LC prior to a surgeon’s first case in the operating room. Some researchers have developed subtasks or modules in the simulation of the laparoscopic cholecystectomy procedure [1-5]. Our current system is designed with the intent of practice for the majority of the LC operation.

2. Tools: Hardware and Software.

The laparoscopic simulator hardware is the commercially available Laparoscopic Surgical Workstation™ (LSW) by Immersion, Inc. The LSW is a human-computer interface tool designed for VR simulations of laparoscopic and endoscopic surgical
procedures. We have developed a low-cost 30 degree prototype camera hardware unit which attaches easily onto the Immersion VLI handle tube and plugs into the computer via the USB port. The VLI tracks the motion of a pair of laparoscopic surgical instruments, each moving in 5 degrees of freedom. The VLI system provides an effective, low cost, means of tracking laparoscopic and endoscopic surgical procedures. The training software runs on a conventional Windows XP™ workstation with a 1.0 GHz Pentium™ processor (or higher) and an OpenGL graphics accelerator such as the Nvidia GeForce™ board. The training software will run under the Windows 2000/NT, or XP™ operating systems.

Figure 1. The Immersion VLI device is used in conjunction with the Verefi Technologies Inc USB 30 Degree Endoscopic Ecamera™ system

Figure 2. The Immersion Laparoscopic Surgical Workstation is used as the haptics device.
Figure 3. Screen shot of laparoscopic cholecystectomy surgical simulator showing the user exposing the cystic duct.

Figure 4. Screen shot showing cystic duct clipped with staples.
3. Modeling and Software.

The storyboard for the laparoscopic cholecystectomy surgical training session entails navigating the virtual surgical field with the 30-degree endoscopic camera, locating the gallbladder, then grasping and stretching the gallbladder to expose, staple, and sever the cystic duct. After the user has correctly located the desired camera orientation and position to show the proper workspace, the user then grasps and stretches the gallbladder to expose the cystic duct. A mass-springs model is used to model duct and gallbladder stretching. The lesson includes placing two staples around the cystic duct near the bile duct, and one staple close to the gallbladder. The cystic duct should then be severed in between the staples. The three dimensional (3D) models of the virtual laparoscopic tool and all organs in the abdomen were built in 3D Studio Max™ and are stored as 3ds files.

These models are loaded into the graphics simulation. The application software makes calls to our virtual haptic medical toolkit (VHMT) API that calls OpenGL graphics routines. The training system has a data collection module that collects various metrics such as: time spent on each sub-procedure and time spent on the whole procedure, tissue tears (over stretching), stapling errors and cutting errors. Another software module records the motions of the user. This is accomplished by recording the positions and orientations of all 3D graphics objects. Thus, the 3D graphics are used to replay the technique, showing the medical student or mentor what the user did during the training session.

4. Conclusions and Future Work.

The goal of this software training module is to provide an effective method to learn key elements of laparoscopic cholecystectomy using a haptic surgical simulator. The simulator is designed to train and test many laparoscopic skills such as: navigation with a rigid laparoscope, locating the gallbladder in the abdomen, grasping and exposing the gallbladder properly for safe dissection of cystic duct, application of clips to the cystic duct, cutting the cystic duct, and removing the gallbladder from the abdomen. This software runs on the Immersion haptic Laparoscopic Surgical Workstation™ utilizing our virtual haptic medical toolkit (VHMT) API for graphics and haptics. The system also uses the Verefi Technologies Inc USB 30 degree Endoscopic Ecamera™ system hardware. System validation is currently underway.

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