A VIRTUAL SYSTEM FOR LAPAROSCOPIC SURGERY TRAINING

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Abstract: Laparoscopic surgery requires that the surgeon develops the capacity to manipulate instruments in a 3D real environment based on images transmitted by video to a 2D monitor. Moreover, the size of the instruments and limitations on video imaging reduces the perception of the surgeon during the surgery. Laparoscopic training is usually performed in animals, cadavers or real patients. However, this technique of training presents some problems. LAPAROS is a new laparoscopic surgery training system that allows the surgeon to develop and acquire the skills demanded for this surgical procedure. This system provides the user with virtual exercises based in our own experience at medical school. LAPAROS is based on virtual reality technology and 3D computer graphics. The hardware component is based in our own state-of-the-art mechanical simulator and a tracking subsystem. The system provides a metric evaluation in each exercise and also keeps track of all training sessions for every user.

1 INTRODUCTION

Laparoscopic surgery, or Minimally Invasive Surgery (MIS) of the abdomen has shown a rapid growth in the last years, because the risk of complications is reduced and the patient recovery is faster than with traditional surgery. In this procedure, a laparoscope is inserted through a 10 mm incision in the abdominal wall. A camera mounted on the laparoscope transmits the image to a monitor. The surgeons handle the camera and the instruments inside the abdominal cavity, based on the visual feedback of the image displayed on the monitor.

Some factors exist that reduce the perception of the surgeon during surgery, for example: the instruments reduce dexterity, eliminate tactile sensation, and reduce kinesthetic force feedback [1]. The lack of a stereoscopic image, geometric viewing distortions and limitation on resolution, contrast, and color inherent in video imaging increase the difficulty of the procedure [1]. Additionally, the surgeon should develop the ability to interpret two-dimensional images out of a three-dimensional real environment, corresponding to the abdominal cavity of the patient.

Laparoscopic training is usually performed in animals, cadavers or real patients. However, animals do not have the same anatomy as a human being, cadavers have incorrect physiology and training on real patients involves risk to patient safety. Therefore, an alternative is simulation. It allows the surgeon to develop and acquire the skills demanded for this surgery through practice, increasing surgeon’s experience and patient safety. The simulation systems can be classified according to their technology as mechanical simulators [2] or virtual reality simulators [3, 4].
In this paper we present LAPAROS, a virtual reality laparoscopic surgery simulator that includes a brand new educational component, to assist the surgeons in improving their skills on laparoscopy surgery. LAPAROS is setup with both hardware and software components. For the hardware component, we present our own state-of-the-art mechanical simulator [2]. For the software component, we exploit current technology in 3D computer graphics and virtual reality. In addition, we have included a brand new educational component that provides the user with a record of his training sessions and an evaluation [4] of his skills.

2 THE LAPAROS SYSTEM
LAPAROS is a virtual reality system for laparoscopic surgery simulation. The hardware component is mainly conformed of a mechanical simulator and a tracking subsystem. The mechanical simulator was developed at the Bioengineering Center, UCV. The tracking subsystem no is completed. Nevertheless, we are using the commercial hardware Isotrack II. This device is connected to the laparoscopic instruments and gives the rotation and displacement position of the instrument with respect to the tracker location. The software component is conformed of an information subsystem and a 3D graphics subsystem and it was developed at the Computer Graphics Lab, UCV. The system is already being tested at the Experimental Surgery Institute of our university.

3 THE MECHANICAL SIMULATOR
We propose for LAPAROS a mechanical simulator (figure 1) that resembles the size and shape of a male abdomen. SIMULAP V-1 [2] accommodates the tracking subsystem when working as part of the virtual reality system, or a real camera when working as isolated mechanical simulator. In addition, the trainee can incorporate different laparoscopic instrument.

![Figure 1: Two views of the SIMULAP V-1 mechanical simulator, showing the top frame, the base, the openings and the removable camera holder.](image)

The top frame can be inclined or removed. It has several openings strategically located to simulate several surgery procedures. Trocars can be inserted through the holes on the top frame as well as laparoscopic instruments. The openings have special rubber gums that simulate resistance of the body tissue to the insertion of the instruments. When SIMULAP V-1 is used as an isolated mechanical simulator, a camera or a standard laparoscope can be easily accommodated. The scope is connected to a light source and camera monitor system as it would be in the operating room.
4 TRAINING SESSIONS

Training sessions for medical students in laparoscopy surgery conducted at the Experimental Surgery Institute (UCV), were systematically observed and analyzed by our developing team. This experience allowed us to design exercises corresponds to three levels: basic, intermediate and advanced. Table 1 summarizes the abilities of each level.

<table>
<thead>
<tr>
<th>Basic</th>
<th>Intermediate</th>
<th>Advanced</th>
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<tbody>
<tr>
<td>Spatial orientation and perception.</td>
<td>Camera navigation</td>
<td>Dissecting</td>
</tr>
<tr>
<td>Hand-eye coordination including</td>
<td>Instruments handling</td>
<td>Suturing</td>
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<tr>
<td>dominant and non-dominant hand.</td>
<td>Grasping</td>
<td></td>
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<tr>
<td>Hand-inverse eye coordination.</td>
<td>Cutting</td>
<td></td>
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Table 1: Summary of abilities associated with each exercise level.

Some exercises are developed using deformable models [5] to simulate the deformation produced on a tissue by a specific action. Collision detection is used to provide a realistic visual feedback when, for instance, a virtual instrument touches an object simulating an organ. Surface models of the liver and gallbladder are generated by a fast segmentation procedure [6] from the visible male dataset [7], as shown in figure 2. The exercises corresponds to advanced level is already being implemented by our developers.

![Figure 2: (a) Virtual Model of the liver. (b) Virtual Model of the gallbladder.](image)

The exercises proposed in our virtual environment have their own metric and their complexity can be increased. The main metrics used are time performance and precision. Figures 3, 4 and 5 show the LAPAROS’s workstation displaying some of the exercises included by the system. Together each figure, we have included a review of the exercise.

Across the rings

**Description:** The user must go through different color rings using a needle, dominant and non-dominant hand can be used.

**Evaluation:** Starting from a maximum score, points are subtracted when the user touches the border of a ring. The user obtains a perfect score only when no borders are touched.

**Figure 3:** Exercise corresponds to basic level designed to increase the precision of the trainee during the movement of the instruments.
Putting the figures

Description: The user must take each figure and put it on the rectangle of the same color in the predetermined time, using his dominant and non-dominant hand.

Evaluation: The final score depends on the number of spheres placed correctly in the predetermined time and the times that the user touches other rectangles or exceeds the board.

Figure 4: Exercise of intermediate level designed to train the ability of grasping.

Cutting the threads

Description: The user must cut the section coloured of the thread in the predetermined time, using his dominant and non-dominant hand.

Evaluation: The final score depends on the number of sections cut correctly in the predetermined time and the times that the user touches or cuts outside this.

Figure 5: Exercise of intermediate level, designed to train the ability of cutting.

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6 REFERENCES