



Simulation System for Training in Laparoscopic Surgery

Simulations are more realistic than are those of prior systems.

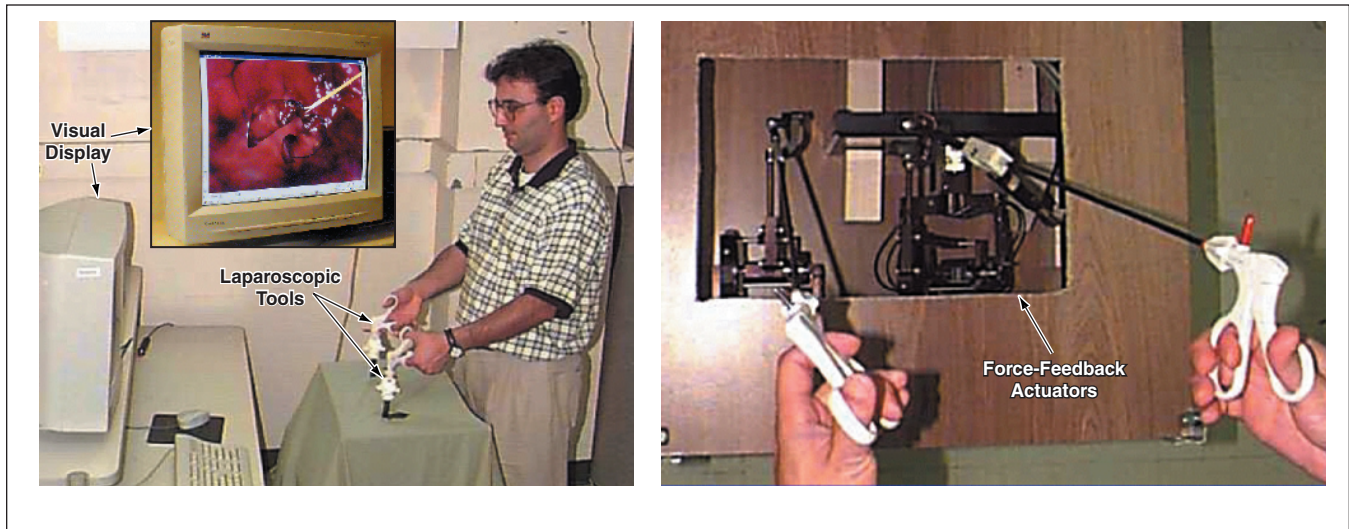
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A computer-based simulation system creates a visual and haptic virtual environment for training a medical practitioner in laparoscopic surgery. Heretofore, it has been common practice to perform training in partial laparoscopic surgical procedures by use of a laparoscopic training box that encloses a pair of laparoscopic tools, objects to be manipulated by the tools, and an endoscopic video camera. However, the surgical procedures simulated by use of a training box are usually poor imitations of the actual ones. The present computer-based system improves training by presenting a more realistic simulated environment to the trainee.

orientation sensors that provide input data for the simulation and (2) actuators that provide force feedback to simulate the contact forces between the tools and tissues.

The simulation software includes components that model the geometries of surgical tools, components that model the geometries and physical behaviors of soft tissues, and components that detect collisions between them. Using the measured positions and orientations of the tools, the software detects whether they are in contact with tissues. In the event of contact, the deformations of the tissues and contact forces are computed by use of the geometric and physical models. The image

software for real-time simulation of the visual and haptic interactions (1) between forceps and the catheter, (2) between the forceps and the duct, and (3) between the catheter and the duct. The deformations of the duct are simulated by finite-element and modal-analysis procedures, using only the most significant vibration modes of the duct for computing deformations and interaction forces. The catheter is modeled as a set of virtual particles uniformly distributed along the center line of the catheter and connected to each other via linear and torsional springs and damping elements. The interactions between the forceps and the duct as well as the catheter are simu-



A User Manipulates Laparoscopic Tools while viewing an image of the distal ends of the tools in simulated interaction with a patient's tissues. The tools provide force feedback, which is an essential part of the simulation.

The system includes a computer monitor that displays a real-time image of the affected interior region of the patient, showing laparoscopic instruments interacting with organs and tissues, as would be viewed by use of an endoscopic video camera and displayed to a surgeon during a laparoscopic operation. The system also includes laparoscopic tools that the trainee manipulates while observing the image on the computer monitor (see figure). The instrumentation on the tools consists of (1) position and

on the computer screen shows tissues deformed accordingly, while the actuators apply the corresponding forces to the distal ends of the tools.

For the purpose of demonstration, the system has been set up to simulate the insertion of a flexible catheter in a bile duct. [As thus configured, the system can also be used to simulate other endoscopic procedures (e.g., bronchoscopy and colonoscopy) that include the insertion of flexible tubes into flexible ducts.] A hybrid approach has been followed in developing the

lated by use of a ray-based haptic-interaction-simulating technique in which the forceps are modeled as connected line segments.

This work was done by Cagatay Basdogan of Caltech and Chih-Hao Ho of Cambridge Research Associates for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21192.