Haptic Guidance for Laparoscopic Surgery Immersive Training and Mentoring

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Background / Problem

This project is focused on developing of a haptic guidance system to facilitate minimally invasive surgical training and telementoring. While minimally invasive surgery (MIS) techniques have been shown to provide tremendous advantages for patients [1], novice laparoscopic surgeons developing their skills face challenging learning curves [2]. In addition, expert mentors are concentrated in relatively few centers and are often not readily available [3].

Our training and telementoring system combines the functionality of real time, intraoperative videoconferencing with haptic guidance that together allow a novice operator to perform an endoscopic procedure with the assistance of a remote expert. Using a console, the mentor defines the appropriate pathways for the novice surgeon to manipulate his instruments. Via this haptic guidance system, a distant mentor can effectively guide the hands of the trainee as the novice surgeon executes fairly complex procedures.

In addition to the telementoring application, an immersive training simulation is being generated by recording an expert surgeon perform a real operation while using this system. Intraoperative data is stored and later accessed at one or multiple training stations that are designed to reproduce an operating surgeon's ergonomic experience.

Tools and methods

Our system is based on tracking the spatial position and orientation of the instruments on the console for both the expert surgeon and the trainee. The technology is the result of recent developments in miniaturized position sensors that can be integrated seamlessly into the MIS instruments without compromising functionality. In order to continuously monitor the positions of laparoscopic tool tips, DC magnetic tracking sensors are used. Hierarchical software architecture translates the two-way position inputs of mentor and mentee into appropriate resistances generated by a high fidelity haptic interface. In order for our users to communicate with each other effectively, an intuitive graphic user interface displays the instruments spatial position and orientation for the mentor/trainee, patient vital signs, and endoscopic video information. These data are recorded and saved in a database for subsequent training and behavior analysis.

Results

Our instrument tracking system uses two 6 DOF DC magnetic trackers with a sensor diameter of just 1.3 mm - small enough for insertion into 4 French catheters. Both sensors are embedded in the shaft of a 5 mm Babcock grasper form Ethicon Endo-Surgery. One sensor is located at the distal end of the shaft while the second sensor is located at the proximal end of the shaft. The placement of these sensors does not impede the functionally of the instrument. Since the sensors are located inside the shaft there are no sealing issues between the valve of the trocar and the instrument. A signal processing unit is designed on PCI-bus card inserted in the desktop PC that is the master control unit. The DC magnetic field transmitter and the two sensors are attached directly to this signal processing unit.

The software component of the project is being implemented in the .NET framework using C# and the OGRE real-time rendering engine. During recording, the system both tracks and virtually reconstructs the stage and the tools on screen offering high-fidelity, real-time visual feedback. During playback the system displays the recorded tool motion as a translucent "ghost", which the operator tries to follow with his own tool, rendered as opaque, and visual feedback is given as to the operator's success in following the recorded motion.

Conclusion / Discussion

DC magnetic trackers transmit position and orientation data are provided over a full range of a surgeons hand movement. The sensors do not suffer from occlusion or line of sight restrictions, an important characteristic since we will track the tip of the instruments while inserted inside the human body. Also this system provides real-time guidance of instruments and delivery devices without radiation exposure or reliance on 2D X-ray imaging especially important when used in conjunction with radio-frequency ablation instruments. Due to sensor design and signal processing capabilities this system also offers conductive metal immunity such as the such as 300-series stainless steel and titanium - common metals present in surgical tools and equipment.

references

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