instruments. The opposition of the end-effectors was essential for an intuitive working. The gallbladder could be hold with a grasper through the left effector and dissected by using a TT knife introduced through the right. The gallbladder was recovered through the main incision after a last check up for bleeding and complication. The end-effectors were steered to a straight position so that the complete system could be pull out of the abdomen and finally both incisions were sutured. The complete surgical intervention, without technical set-up, could be accomplished in 110 minutes. Compared to the conventional laparoscopic cholecystectomy, however, the operation took considerably longer. This extended time can be deduced from the cumbersome handling of the interface and experience of the physicians. Coordination of three physicians was essential for the performance and quality of the intervention. The previous interdisciplinary training was indispensable for that reason. It is expected that the integration of the simulation interface can significantly accelerate the planning and coordination of interventions.

Conclusion

Laparoscopic cholecystectomy using the HVSP support system is feasible. The intervention time can be reduced by optimizing the fully automated HVSPS and introducing an intuitive man machine interface and a simulation and planning environment. For the first time, it is also possible to use the HVSPS for retroflective interventions which were not possible yet. However, a new control design should be developed, since it was impossible to work in a head over position.

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Electromagnetic tracking of a new laparoscopic camera control system

Fiolka A.[1], Polski M.[1], Can S.[1], Schneider A.[1], Feussner H.[2]

[1] Klinikum rechts der Isar, TU-Muenchen, Workgroup MITI, Munich, GERMANY

[2] Klinikum rechts der Isar, TU-Muenchen, Department of Surgery, Munich, GERMANY

Keywords solo surgery, electromagnetic tracking, camera control

Introduction

In minor access surgery (MAS) an assistant guides the camera and makes the field of surgery visible. This task is stressful and needs full concentration especially during long interventions.

Over the past years, different systems were presented, offering positioning assistance and control of the laparoscope [1]. Typically, voice control systems or joysticks were used. To improve the handling, research groups automated some of these camera control systems. Colour-tracking seemed promising, however for this method, stereo-optics was necessary. Here, the position of the camera is semi autonomously corrected by the position of the instrument in the dominating hand of the surgeon [2–3]. However these systems did not succeed, because they were often huge, expensive and prone to error.

We built a new clinically suitable semi-autonomous camera control system based on an electromagnetic tracking system. The new system should be less expensive and avoid the disadvantages of the former systems. The new system achieves the position and orientation of the tip of the instrument and uses this information to focus continuously the telescope.

Material and methods

For measurement of orientation and position, the DC magnetic tracker miniBIRD (Ascension, Burlington, VT, USA) was used. Camera control was provided by the new manipulator device SOLOASSIST (Figure 1, AKTORmed, Barbing, Germany). This mechatronic device is driven by fluid actuators and has no electric drives, solenoids or sensors in the arm.

Figure 2 presents the test set-up for automated camera guidance. The intraoperative situs was simulated with a wooden rack with the field generator positioned at the distance of about 200 mm. First, disturbance of the generated magnetic field by the SOLOASSIST was assessed. For these measurements a sensor was fixed in defined positions in the work space. During the manual actuator movement through the field the position and orientation was captured. Measurement errors were analyzed in several test setups. To minimize these errors, mathematical algorithms were used, as well as varying the number of sensors.

First, the accuracy of the magnetic tracking device in the working range of the manipulator was assessed. Therefore, one sensor was fixed to the handhold of the instrument. With the tip of the instrument twelve defined points were aimed at. Subsequently, the position and orientation was captured during 10 sec/point and afterwards the position of the tip was calculated. Second, the experiment was repeated with two sensors per object (Figure 2). With the results of these experiments, the camera control was designed and put into practice.

Fig. 1 SOLOASSIST is a mechatronic system that aid camera guidance during a minimally invasive surgical intervention. This system allows a 360° circle range in conjunction with an 80° inclination of the endoscope.

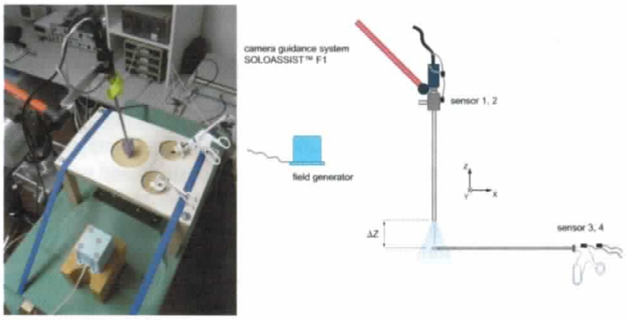

Fig. 2 The test setup for the laparoscopic camera control based on electromagnetic tracking

The functions were implemented directly into the IConnect software (Micro-Epsilon, Ortenburg, Germany) of the SOLOASSIST control unit, running on a standard industrial-PC.

Finally, the automated camera control was compared to manual camera control in an experimental study. A needle had to be entered into an eye with an inner diameter of 2 mm, mounted on a plate with overall 10 eyes. The time used was recorded and compared. Finally the users had to rate both systems.

Results

The autonomous camera control system could be successfully realized with an electromagnetic tracking system.The size of the generated magnetic field was sufficient for this application.

In the first experiments with one sensor we recognized that during actuator movement the position of the sensor changed irregularly up to +/−12 mm. This inaccuracy of position falsifies strongly the calculated results, which then deviated up to 60 mm on the tip, because of the transformations. The accuracy was increased significantly by using two sensors per object. With both sensors the position of the tip could be calculated with an accuracy of +/−10 mm. This precision was found sufficient enough for camera control.

In the current software version only simple safety functions were implemented. For example, the user had to define manually the work space and the distance between instrument and camera tip. If the instrument tip leaves the working space, the actuator always stops. Camera speed was made proportional to the distance between the instrument and camera tip.

Finally, the semi-autonomous camera control was evaluated with five test persons. Significant differences could be determined. The exercise could be finished twice as fast with the semi autonomous system as compared to the manual controll. Each person confirmed that the task could be completed more simply with the automated camera control. Three persons could imagine that the electromagnetically guided system could be used under clinical conditions. However, one person found the sensor cables distracting and the continuous readjustment was found inconvenient by four persons. They would prefer an on-demand solution.

Conclusion

The experiments showed that an electromagnetic tracking system is a potential alternative to other positioning techniques concerning precision, handling and dependability. With this technology it is possible to control mechatronic camera control systems precisely and confidently. The sensors are small enough for unproblematic integration into the instruments; however the used instruments should be amagnetically.

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Atlas-based deformation compensation using salient anatomical features for image-guided liver surgery

Clements L.[1], Dumpuri P.[1], Chapman W.[2], Galloway R.[1], Miga M.[1]
[1] Vanderbilt University, Biomedical Engineering, Nashville, UNITED STATES
[2] Washington University School of Medicine, Dept. of Surgery and Cell Biology, St. Louis, UNITED STATES

Keywords image-guided surgery, liver surgery, deformation atlas, feature registration

Introduction

Salient anatomical features, identifiable in both preoperative image sets and intraoperative liver surface data, have been utilized to provide more robust surface alignments for use in image-guided liver surgery (IGLS). Similar to the well documented brain shift experienced during neurosurgical procedures, intraoperative soft tissue deformation in open hepatic resections is the primary source of error in current IGLS systems. The use of biomechanical models has shown promise in providing the link between the deformed intraoperative patient anatomy and the preoperative image data. More specifically, the current protocol for deformation compensation in IGLS involves the determination of displacements via registration of intraoperatively acquired sparse data, via a laser range scanner, and subsequent use of the displacements to drive the finite element method (FEM) solution of the linear elastic model. However, direct solution of the model during the surgical procedure has several logistical limitations including the ability to accurately prescribe boundary conditions and material properties. Recently, approaches utilizing an atlas of preoperatively computed model solutions based on *a priori* information concerning the surgical loading conditions and resection plan have been proposed as a more realistic avenue for intraoperative deformation compensation.

Methods

In order to improve the applicability of an atlas-based technique for deformation compensation in IGLS, we propose the use of reliably identifiable anatomical features, such as the liver inferior ridge of segments IV, V, and VI, within the proposed iterative closest atlas (ICAt) algorithm. Similar to the atlas-based technique proposed for model-updating in neurosurgical procedures, we utilized a linear inverse model to match the intraoperatively acquired data to the preoperatively computed deformation atlas. Additionally, an iterative approach was implemented whereby point correspondence was updated during the matching process, being that the correspondence between intraoperative data and the preoperatively computed atlas is not explicitly known in IGLS. Salient features were incorporated into the ICAt algorithm via the biasing of point correspondence determination and point weighting in the solution of the linear inverse model. Validation experiments of the proposed algorithm were performed using a set of simulation and phantom data sets.

Results

The results of the simulation studies suggest that the incorporation of salient feature information into the proposed ICAt algorithm increases the robustness and performance of the method. Further, the phantom studies revealed that the ICAt algorithm yields similar results to the