Fig. 2 A surgeon performs fenestration on a spine model using our system

system, and the cutting and motion states were recorded. The training dataset for the SVMs was obtained from the demonstration (Fig. 2).

To evaluate the performance of the SVMs, cross-validation was performed using the dataset obtained from the surgeon's demonstration. Next, the surgeon once again performed fenestration on a spine model using our system, and the bone penetration detection was evaluated.

Results

The result of the cross-validation shows that the SVMs recognized cutting and motion states with an accuracy of 99.7 and 100 %, respectively. In the fenestration experiment involving the surgeon, bone penetration detection accuracy was 75 %. This indicates that the proposed system enables reliable bone penetration detection. Furthermore, we learned from the experiment that bone penetration detection performance depends on the shape of the target bone.

Conclusion

In this study, we developed a hand-held bone cutting tool system with autonomous bone penetration. Our system detects bone penetration by monitoring the cutting and the motion states of the tool. The proposed bone-cutting tool system is based on a commercial scheme widely used in the industry. It learned bone penetration detection from demonstrations by a spinal surgery expert. Experimental results showed that our system successfully and accurately detects bone penetration.

Acknowledgements

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A modular CT/MRI-guided teleoperation platform for robot assisted punctures planning

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Keywords Teleoperation · CT/MRI · Modular platform

Purpose

Teleoperated robotics has the advantage of improving efficacy of percutaneous insertions while avoiding radiation to the clinician and promoting more comfort to the patient. However, CT/MRI-compatible teleoperated platforms are not commonly used for abdomino-pelvic percutaneous insertions. The teleoperation platform presented in this work is the only multimodal CT/MRI-guided that fully control needle translation, orientation and insertion during insertion. This work presents pilot feasibility proof of this modular teleoperation architecture and provides an option for a robotic platform that could teleoperate the full range of needle steering during abdomino-pelvic percutaneous insertions under scenarios such as CT/MRI.

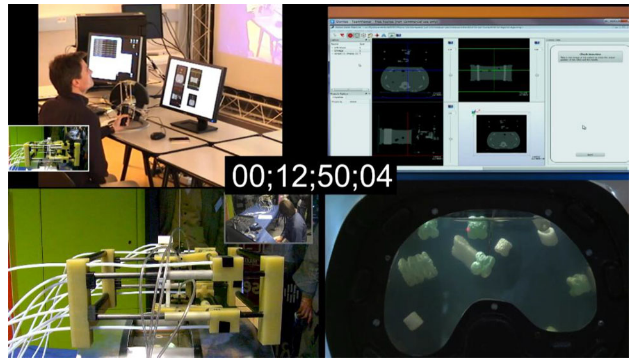

Fig. 1 Pilot feasibility experiment

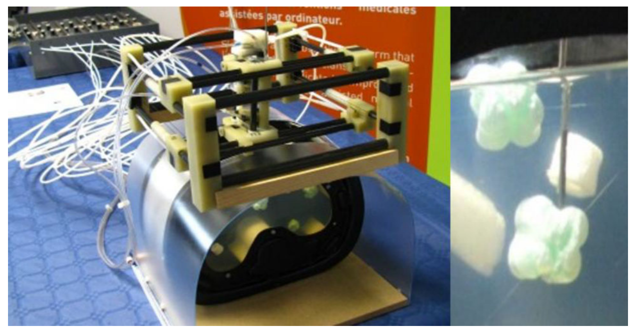

Fig. 2 *Left* robot setup in Grenoble. *Right* needle reaching the 15 mm Styrofoam target

Methods

LPR [1] is a 6-DoF, CT/MRI compatible patient-mounted robot that can translate, rotate and perform percutaneous needle insertions. Its parallelogram-type manipulator architecture was designed as a patient-mounted insertion module suspended by four adjustable straps to a bed-mounted frame. It has two strategically embedded fiducials allowing their visibility under CT and MR imaging. It also allows the registration of the needle position and inclination in the images.

The teleoperation architecture was defined following a master–slave model, in which two PC's use Ethernet communication under TCP protocol. Client (master-side) PC receives images coming from the scanner and runs GUI that allows user interacts with the system. Using a 7-DoF Omega master device, it can sends action requests to the slave robot. The slave-side PC acts as server and receives control requests from client PC. It translates these requests into robot control commands which are then sent to the slave robot. Client and server PCs had the following configurations. Server: Intel Core i7, 2.8 GHz, 8 GB RAM. Client: Intel Xeon, 2.4 GHz, 12 GB RAM.

Pilot experiment was done into a public demonstration (Fig. 1) for which we have no access to CT/MRI scanner. We therefore hypothesized a clinical scenario in which the clinician would plan an insertion in a first image, have to readjust the position in a second image and finally insert the needle to the chosen target in a third image. The three images were taken beforehand in CT scanner in the same setup as during the demonstration. Thus, all the re-planning and corrections were performed guided by the GUI and with user controlling the haptic device. We proposed a scenario composed of phases and states. In the initial phase the robot was mock registered to the first image. We say "mock" because the image was taken prior to the test. The registration allows the model of the robot to be displayed in the 3D image in the correct location. The planning phase consisted of an exploration state, in which the user manipulated the Omega master device in order to explore the image volume and verify that the image was correct and showed all the necessary elements. The position of the center of the Omega's coordinate frame was used to scroll through the transverse, sagittal and coronal slices of the 3D image.

The teleoperation platform was developed under a modular architecture, on top of the CamiTK [2] (Computer Assisted Medical Intervention Toolkit) core, as a set of its extensions. Thus, slave and master were controlled through their own respective extensions. A generic interface extension was created for each to which the specific master and slave control classes could be plugged. The communication protocols were also programmed as extensions that could be plugged into the CamiTK core. Although TCP communication was used in this experiment, it would be very simple to change to a different type of communication in the future.

Results

A feasibility demonstration was performed during the Academy of Surgery 2013 in Grenoble, France. A radiologist in Montpellier, France, was invited to perform a teleoperated insertion on a phantom located in Grenoble. Using Omega, he was asked to interact with the GUI's platform while choosing and reaching a 15 mm Styrofoam target embedded into a synthetic phantom. Guided by the system he executed a predefined workflow under a hypothesized clinical scenario with several tasks while positioning and inserting the needle. The radiologist, who was totally unfamiliar with the system, was successfully able to guide the needle and insert it to reach the chosen target (Fig. 2). The GUI was proposed in the form of a state machine and guided the clinician throughout the procedure by allowing him to progress back and forward through the protocol using next and back buttons. Thus, at each step, the system automatically loaded all the necessary components and updated 2D and 3D images with the appropriate elements necessary for the current step. This step-by-step procedure made it possible for any user, even if totally unfamiliar with the procedure, to use the system. The main demonstration was performed in nearly 13 min because the clinician was narrating to the public over video-conference. However, considering the several experiments performed, success insertion trials, performing the full predefined insertion planning tasks workflow, were observed to be performed in nearly 60 s.

Conclusion

This work aims to provide modular teleoperated architecture able to perform translation, orientation and insertion and compatible with the CT/MR image-guided scenario. Pilot proof of its feasibility was described here in which a clinician in Montpellier inserted a needle in a synthetic phantom in Grenoble oriented by the system's GUI. Future works committed to needle path planning, are being developed to explore accuracy of the system while steering the needle and reaching the target.

Acknowledgements

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Ultrasound probe scanning system for 3D volume reconstruction and needle guidance

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Keywords ultrasound guidance · Robotic system, Navigation system · Volume reconstruction

Purpose

US has been widely used as a popular image guidance modality, because it is low latency, convenient to use in a conventional operating room, and inexpensive compared to CT and MRI. Moreover, US is also safe for fetus assessment. However, one of technical issues of US is that a technician has to hold a US imaging probe and scan on surface of patients. That causes following issues: One is that US technicians are at risk for developing work-related musculoskeletal disorders, and the other is that three-dimensional positions of obtained images are not provided. To address the issues, we have developed a lightweight robotic probe scanner using pneumatic actuators in order to acquire 3D volume by a conventional 2D probe and automatic image plane positioning based on a surgical tool position [1]. In this paper, to clarify the system feasibility, dynamic accuracy of the robot, accuracy of needle guidance, and volume reconstruction was evaluated.

Methods

The probe scanning robot was designed as wire-driven parallel mechanism with six pneumatic actuators (Sik-t, SQUSE) and a DC motor (RE10 EB, MAXON Japan). The robot can control a probe by 6 degrees of freedom: 5 dof by parallel wire mechanism and 1 rotation by the DC motor. As for the wire actuator, Mckibben pneumatic muscle was selected because of its low impedance and safety. The robot consists of two parts: a frame mechanism and a probe holding mechanism. The pneumatic actuators are attached to the frame

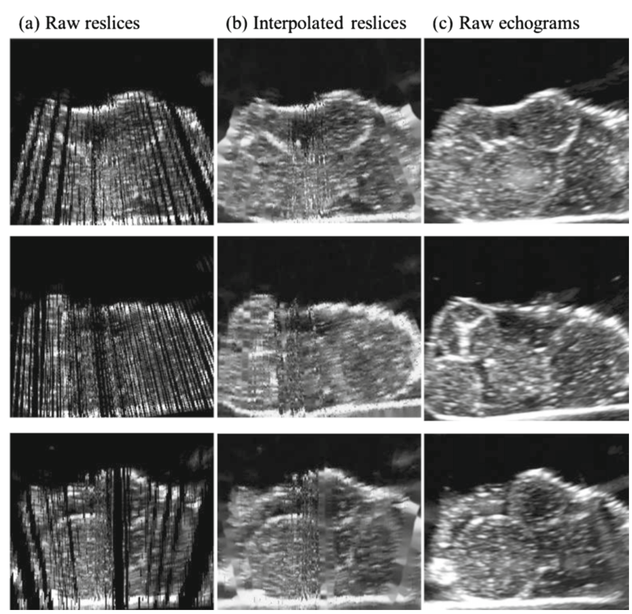

Fig. 1 Experiment setup for the needle guidance test