OP:Sense, a rapid prototyping research platform for surgical robotics

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Introduction

A number of commercial systems for robot assisted surgery are currently available [1]. According to the specific needs of different surgical disciplines these systems are specialized on a certain type or class of surgical treatments. The integration level is pretty low. Important information about the working surrounding of the robot, e.g. the surgical personnel and their actions, are not integrated into any of the actual systems.

Our approach, the research platform OP:Sense [2] as a future generation of modular surgical robotic systems is characterized as follows: (a) fast adaptation to different types of interventions due to its modularity, (b) enable the surgeon to choose the optimal control mode and (c) integrate sensing capabilities for the perception of actions and the surrounding of the robotic system.

System concept

The modular research platform OP:Sense consists of different types of components classes: actuators (e.g. KUKA light weight robots (LWR), Stäubli RX90, PI hexapod system), human machine interfacing capabilities (e.g. haptic input devices by Force Dimension, hands-on by force/torque-sensing) and an extensive sensing system (e.g. different camera systems for tracking and 2/3D vision, ultrasound, force/torque-sensing), see Figure 1.

For robot control, the OP:Sense system offers three different modes to the surgeon: telemanipulation, hands-on mode and automatic mode. The surgeon has the option to switch between the different modes. He can select the best fitting mode to perform the optimal action to the patient.

The system concept and architecture of the OP:Sense system support the adaptability to different surgical scenarios. For example, to evaluate the feasibility of using a KUKA LWR for osteotomy, two different studies have been performed using a single light-weight robot, a haptic input device [3] and the marker based tracking system. For performing the ablation different effector are being used: a milling tool and a CO_2 laser. A pre-planned trajectory was then executed, controlled either by telemanipulation mode or completely automatically.
For expanding the sensing capabilities, an ultrasound probe was mounted onto the robot and guided along the anatomic region of interest, i.e. a human arm. This configuration is taking advantage of the internal torque sensing of the LWR. A force-based adaptive guidance could be achieved along the complete trajectory. This sensing system would allow the surgeon in future to mark starting and end pose on the skin surface to be scanned automatically by the robot. An on-line image processing and an adaptive probe control will guarantee an optimized 3D image acquisition.

Figure 1. OP:Sense set up with two light-weight robots in hands-on mode and different camera systems
Figure 2.

In these different surgical scenarios, the camera based supervision is designated to guarantee a safe interaction [4] between the surgical personnel, the patient and the robot even by sharing the same workspace.

Currently we are working on a level-dependent interpretation of the different sensor data and a semantic integration for situation awareness. This will be part a workflow based master control of the complete operating room.

Conclusions

In summary, the OP:Sense system presents a modular approach for robotic surgery, allowing the surgeon to optimally configure the system to the specific application needs of individual patient treatment. Different surgical concepts have already been evaluated or are under current research, including further topics such as workflow detection and enhanced safety features. This research will help to organize a high-automated operating room by preventing mental overload of the surgical personnel. The goal is an optimal interlocking of human and machine capabilities.

References

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