Ein handgehaltener Operationsroboter: proof of concept und erste Ergebnisse

A handheld surgical robot: proof of concept and first results

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Purpose

A robot system for computer aided surgery is presented. The device is a hand-held six-degree-of-freedom surgical manipulator (Intelligent Tool Drive - ITD) intended to perform a mechanical process such as drilling or milling while stabilizing tremor of the surgeon's hand. Being completely handheld, it provides for force-feedback and permanent eye-contact to the situs. Position data of the device and the patient for navigation and stabilization is delivered by a specially developed optical tracking system (MOSCOT).

Task Definition

The System is being developed for orthopaedic surgery. Holes have to be drilled in a moving bone (breathing) while the device is handheld (tremor and other unintended movements). The placement of pedicle screws is planned to be the first clinical application. For the first system evaluation holes were milled in polystyrene foam.

System Design

The manipulator has to stabilize a surgical tool against the bone while performing a milling task. It is handheld and no additional articulated arm, balancer or other devices are used. The experimental setup provides three cameras for the tracking of the robot and the workpiece. The user holds the robot freely in his hands.
The robot can be moved in MOSCOT's workspace (approx. 20x20x20 cm^3) which tracks its position and orientation. To achieve this a rigid body with 3 coloured marker points is attached to the device. The test specimen is also optically tracked but due to technical restrictions in the current hardware only using one marker point. The tracking system runs on a Linux machine and uses a serial connection to the control computer.
The robot is designed in a hexapod configuration and provides an active workspace of approx. 40x40x40 mm^3 for the drilling tool. The six struts are actuated by linear motors (Linmot, Zurich, CH) thus providing a bandwidth of about 10 Hz. This first prototype weighs 6,5 kg and measures 320mm in diameter and 360mm in length. The milling tool is actuated by a standard DC-motor. For safety the milling tool is attached using a magnetic clutch.
The device is controlled using the real-time operating system QNX Neutrino (QNX Software Systems, Ottawa, Canada). The kinematical computations and the controller implementation are performed using Matlab/Simulink©. For the control of the ITD a cascade controller is used with a velocity and a position loop of the strut length and an outer loop for the absolute position control of the tool in the world reference frame.

Conclusion

The system design of a handheld robotic device for orthopaedic surgery is presented.
The concept using an optical tracking system, internal position sensors and a cascade controller enables the position control of the tool and the compensation of disturbances provoked by a human operator. The control loop was closed via the tracking system and the basic functionality of the system has been shown by milling holes in a tracked workpiece made of polystyrene foam. Compared to a standard round column drilling machine, the holes were considerably larger.
Although the static and dynamic properties of the device and its size and weight must be improved for clinical applications, the basic system functionality is feasible.