Entwicklung eines aktuierten und sensorintegrierten Zangeninstruments für die minimal invasive, robotergestützte Chirurgie.

Development of actuated and sensor integrated forceps for minimally invasive robotic surgery.

Bernhard Kübler[1], Ulrich Seibold[1]

[1]DLR - Deutsches Zentrum für Luft- und Raumfahrt e.V., Institut für Robotik und Mechatronik

Purpose

In minimally invasive surgery (MIS) the patient.s skin forms an effective barrier between the operation area and the surgeon. This prevents direct access to the operation site and limits the sensation of tissue manipulation forces, therefore complicating MIS procedures significantly. A telepresence approach can overcome these limitations. Additional degrees of freedom (DoF) inside the patient provide full manipulability and force torque sensors at the distal end of the instrument allow precise measurement of interaction forces. Using a suitable man machine interface free Cartesian motion and kinaesthetic feedback can be achieved, thus providing a virtual open surgery environment to the surgeon.
At the same time it is possible to improve the motion characteristics of the additional degrees of freedom e.g. by closing additional subsidiary control loops or by plausibility checks.
The presented system (Fig.1) allows the implementation in a telepresence working environment as well as semi-autonomous functions e.g. motion compensation.

Material and Methods

Actuated forceps were developed (10 mm in diameter) using a cardanic joint to achieve additional degrees of freedom and a Stewart platform based force torque sensor (FTS) to detect manipulation reactions (Fig.2). Gripping forces are measured independently. The cardanic joint provides linear motion characteristics and allows for twisting of the forceps around its longitudinal axis without large lateral movements of the outer suspension.

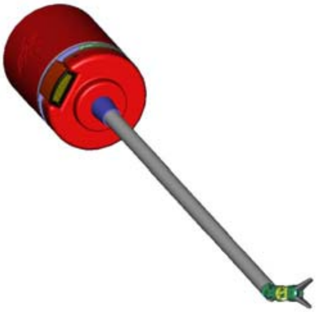
Actuation of joint and forceps is achieved by a propulsion unit and cable transmission (Fig.3). In the propulsion unit cable forces and positions are measured. The position of the actuator is detected by sliding variable resistors (absolute, coarse position) in combination with commutation signals (incremental, fine position) and push-button switches as a fail-safe.
The measurement of both cable and manipulation forces supports a plausibility check and error detection as well as an improvement of position control assuming known cable compliance. Closed loop control and a possible actuation frequency of up to 5 Hz permits e.g. motion compensation on the beating heart.
Issues arising due to autoclaving (thermal stability of electronic components) were solved by dividing the propulsion unit into two parts. The part without patient contact including electric motors and electronics is mist sterilisable. The part with patient contact is steam sterilisable and contains the cable drives.
Essential for satisfactory motor control is a backlash free connection between actuators and cable drive which is achieved by pre-stressing the connections. Reassembly after sterilisation however can be easily performed by technically untrained staff in a surgical environment. As cable material liquid-crystalline, high-modules thermoplastic polymer (trade name: Vectran() is used since this material offers inherently negligible inclination to creep. The necessary pre-stressing of the cables is therefore not lost over time and consequently position accuracy and force transmission are unaffected.

Results

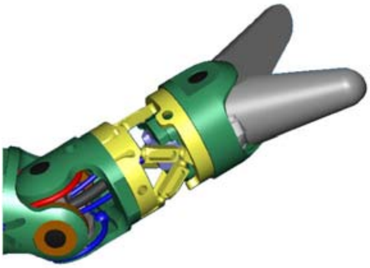
The mechanical and electrical components have been fabricated, presently the system is in the assembly stage and will be evaluated with software being currently developed. The functionality of the joint and sensor design has been shown in previous prototypes.
Preliminary tests show promising results and that the system meets the expectations.

Conclusion

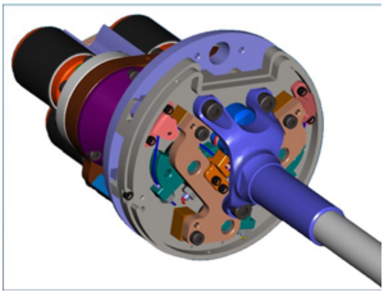
It was shown that the necessary components of a surgical instrument including force sensing and advanced control can be integrated in a volume suitable for minimally invasive robotic surgery. Furthermore autoclaving of sensors, motors and other thermo sensitive components can be largely avoided by dividing the propulsion unit into two parts.
The geometry of the forceps branches can easily be varied. Propulsion unit and basic components of the forceps are also designed for the application e.g. with needle holders, clip applicators or clamps. The system therefore is very adaptable also providing pure telemanipulation as well as semi-autonomous functionality.



curac2004/ Entwicklung eines aktuierten und sensorintegrierten Zangeninstruments für die minimal invasive, robotergestützte Chirurgie.



curac2004/ Entwicklung eines aktuierten und sensorintegrierten Zangeninstruments für die minimal invasive, robotergestützte Chirurgie.



curac2004/ Entwicklung eines aktuierten und sensorintegrierten Zangeninstruments für die minimal invasive, robotergestützte Chirurgie.