Section: **Mechatronik**

ID: 23

Abstract-Title:
PROTOTYPIC SETUP OF A SURGICAL FORCE FEEDBACK INSTRUMENT FOR MINIMALLY INVASIVE ROBOTIC SURGERY PROTOTYPISCHER AUFBAU EINES KRAFTRÜCKKOPPELNDEN CHIRURGISCHEN INSTRUMENTS FÜR DIE MINIMAL INVASIVE, ROBOTERGESTÜTZTE CHIRURGIE

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Abstract-Text:
Purpose
Restricted access to the operation site in minimally invasive surgery (MIS) causes a lack of dexterity 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 (FTS) 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 an environment to the surgeon which is similar to open surgery. The development of actuated and sensor integrated instruments suitable for minimally invasive robotic surgery (MIRS) is presented here, as well as a prototypic closed-loop force feedback system using these components.
Method
The instrument combines a 7 DoF FTS with a 2 DoF cable driven wrist and all necessary mechatronic components in one self-contained unit. An FTS based on a Stewart platform was chosen to measure tissue manipulation forces. Gripping forces are measured independently of the manipulation forces. The two DoF in the instrument wrist required to achieve full dexterity inside the patient are provided by a cardanic joint. Due to direct patient contact the instrument must be autoclavable (a steam sterilization process). However, various components do not tolerate the respective process conditions. Thus, the instrument can be separated into an autoclavable part (with direct patient contact) and a spray sterilisable part (without patient contact) containing sensors, motors, and other thermally sensitive components. The instrument is designed to be used in conjunction with the DLR lightweight surgery robot “Kinemedic”. For evaluation purposes the instrument is tested as a stand alone system together with a commercially available haptic man machine interface (Omega by Force Dimension Inc.). Since the performance of a haptic telepresence system depends strongly on the round trip delay in the loop, it is controlled by the real time operating system QNX. The model runs at 1kHz sample time and is responsible for communication, scaling of signals and calibration. An embedded controller directly on a digital signal processor runs the motor control (1kHz), and the sampling of the force sensor (235Hz). The round trip delay of the whole system therefore adds up only to about 50ms. To ease software development a model-based rapid prototyping approach based on MATLAB/Simulink and Rt-Lab (Opal-RT) is used. Results
The miniature hexapod sensor shows high linearity, high sensitivity and only little crosstalk

(see fig. 3). The instrument allows fast (up to 200°/s) and accurate positioning. The system shows an adequate force feedback behaviour when manipulating test objects with different compliance. Thanks to the low communication latency the system performs well even with hard contacts (see fig. 4). On rigid surfaces, structures of sizes down to 0.1mm can be perceived during haptic exploration. All in all the system promises very good performance once it will be mounted on our surgical robot. Conclusion
The functionality of sensor and wrist design has been shown previously. It also has been demonstrated that the necessary components for additional DoF, force sensing and advanced control in a surgical instrument can be accommodated in a design space suitable for MIRS. The evaluation presented here shows functionality on the system level including instrument sensors and actuators, propulsion unit and haptic input device using appropriate control algorithms. Therewith, it could be confirmed that an intuitive commandment with force feedback is possible as well for haptic purposes as even for easy tactile purposes. Still the entire system is applicable in MIRS concerning size, sterilization and operation. Images
1) MIRS-instrument with propulsion unit; functional instrument end with FTS and joint depicted enlarged. 2) Operating sketch of the stand alone system including the Omega by Force Dimension, Inc. Due to the lack of appropriate drivers for the Omega it can temporarily not be connected directly to the realtime target.
3) Calibration diagram of the 6 DoF force torque sensors (FTS); response to externally applied loads, loading and unloading behaviour shown for force components only. 4) Touching a rigid object: The user moves freely, the instrument tip touches a hard surface, after a short communication delay, the user feels the contact and reacts until an equilibrium depending on the users stiffness is reached. The user backs off, the force falls to zero.

Bild 1/JPG

Bild 2/JPG

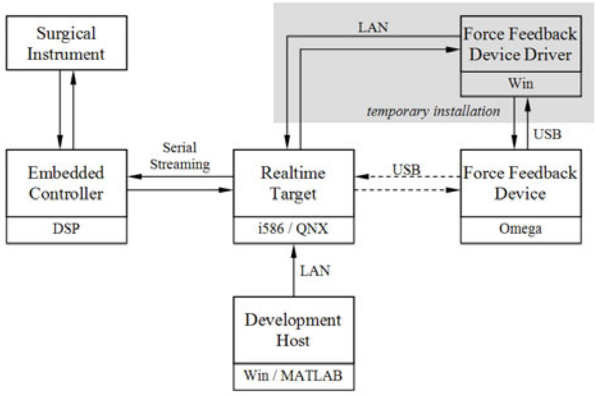

Bild 3/JPG

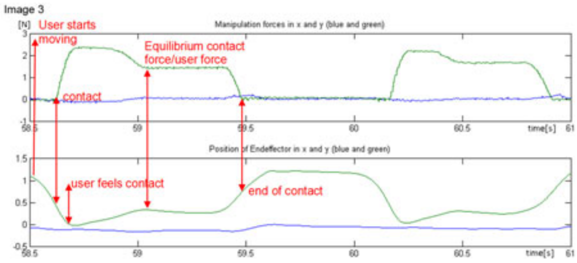
Image 3
[N]
User starts
moving
Manipulation forces in x and y (blue and green)
Equilibrium contact
force/user force
contact
time[s]
Position of Endeffector in x and y (blue and green)
user feels contact
end of contact
time[s]

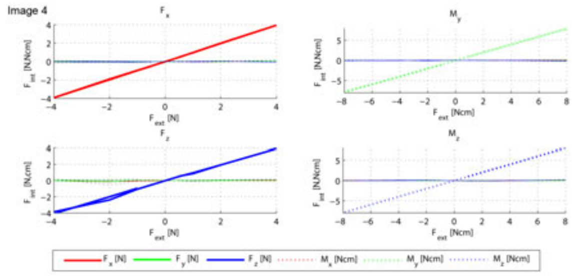
Image 4
F_x
M_y
F_int [N,Ncm]
F_ext [N]
F_ext [Ncm]
F_z
M_z
F_int [N,cm]
F_x [N]
F_y [N]
F_z [N]
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