Ein neues Robotiksystem für die minimal invasive Chirurgie
A New Robot for Minimally Invasive Surgery

Holger Weiss[1], Tobias Ortmaier[2], Gerd Hirzinger[1]

[1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Robotik und Mechatronik
[2]Laboratoire de Robotique de Paris, Universite Paris 6

Purpose

Minimally invasive surgery (MIS) is an operation technique established in the 1980s. In contrast to open surgery only three small incisions are necessary. This reduces pain and trauma, leads to shorter hospital stays and shorter rehabilitation time and provides also cosmetic advantages. However, MIS also challenges the surgeon.s skills due to his separation from the operation area: Direct access to the operation area is lost. Palpation of tissue is not possible. Sensation of manipulation forces is reduced due to friction in the trocar. Hand eye coordination is reversed. Manipulability at instrument tip is decreased. Because of this MIS did not prevail as desired by patients and surgeons.

Material and Methods

Key technologies to overcome the drawbacks of manual MIS are robotic and mechatronic systems, which help the surgeon to regain virtually direct access to the operating field. With appropriate control algorithms the undesired reverse hand motion can be avoided. The downscaling of the surgeon.s hand motion before it is transmitted to the robot is another benefit. Additionally, the surgeon.s tremor can be reduced using low-pass filters. Actuated instruments with two additional DoFs give back full dexterity inside the human body to the surgeon. Small force/torque sensors adjusted near the instrument tip allow for the measurement of manipulation forces/torques which can be displayed to the surgeon, thus providing kinesthetic feedback.

Today.s commercial robotic MIS systems like daVinci from Intuitive Surgical provide already a lot of these features. But some other ones like kinesthetic feedback are still missing. Therefore surgical robotics remains an active field of research. The Institute of Robotics and Mechatronics of the German Aerospace Center (DLR) contributes to this research field by developing an advanced robotic surgery system (see figure 1). The robotic arm provides 7 torque controlled DoFs and therewith kinematic redundancy (see figure 2).

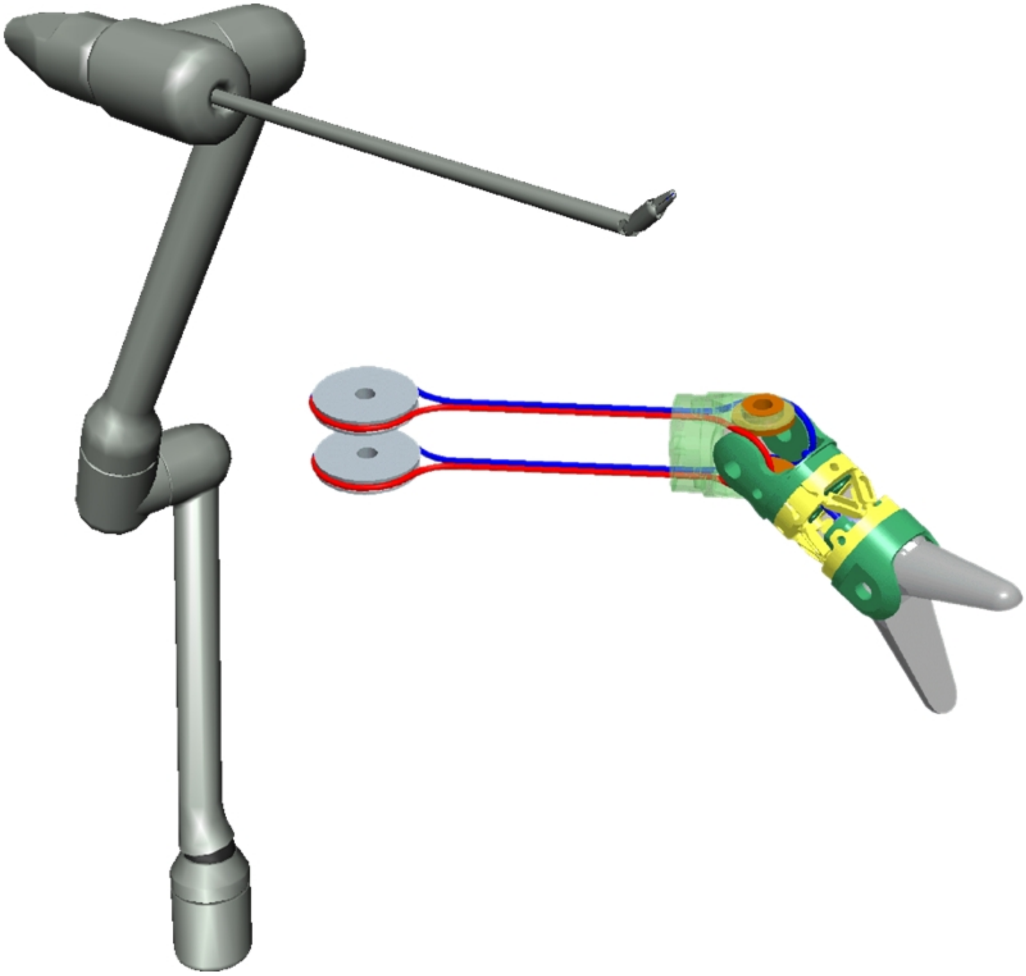
The kinematic dimensions are determined such that the robotic arm performs optimally with respect to dexterity and accuracy in typical MIS application scenarios like heart and abdominal surgery but has a compact and light-weight design, too. The robot carries an actuated and sensorized instrument.
By these additional two DoFs full dexterity is regained inside the patient. The integrated miniaturized force/torque sensor allows for measurement of manipulation forces and torques. Moreover, the instrument enables also the decoupled measurement of grasping forces. The robot will be controlled from an operator console which consists of a stereo video screen and a kinesthetic feedback device for the grasping and manipulation forces.

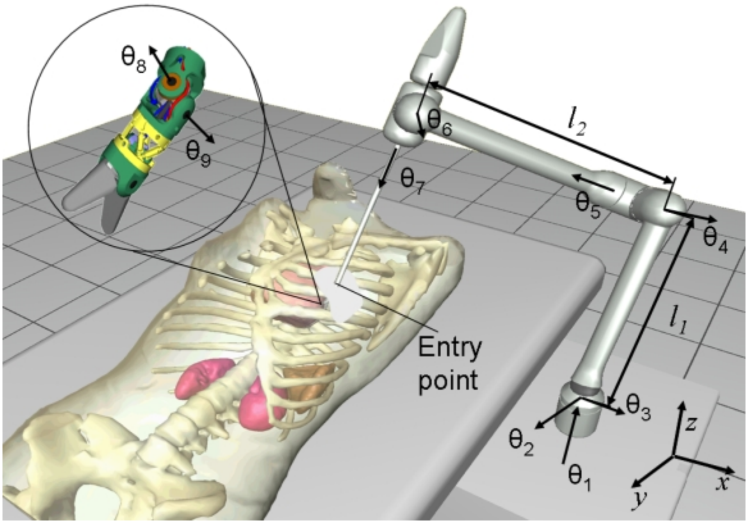
Results

The joint units of the robotic arm are currently assembled and tested. First experiences with the complete prototype are expected for fall 2004. The miniaturized force/torque sensor was already included into a rigid instrument (see figure 3) and has been evaluated in force feedback test series.

Conclusion

Tele-surgical MIRS systems are set out to broaden the application fields of MIS and to improve the quality of surgical interventions. The new DLR robot for MIS tries to meet this challenging and demanding goals by exploiting the possibilities of current robotics and mechatronics.




θ8
θ6
l_2
θ9
θ7
θ5
θ4
l_1
Entry
point
θ3
z
θ2
θ1
x
y