Robots for spine surgery

WISA RoMed

In the project "Robots and Manipulators for Medical Applications – RoMed" four Fraunhofer institutes are developing a robot system for use in spinal column surgery, as well as a system for use in motor rehabilitation. The Fraunhofer Institutes for Manufacturing Engineering and Automation IPA, Production Systems and Design Technology IPK, Biomedical Engineering IBMT and Computer Graphics Research IGD have teamed up in the WISA RoMed business-oriented strategic alliance.

WISA RoMed
ar.ipk.fhg.de/ProjekteundProdukte/WISA-ROMED/ROMED-index-e.html

More and more often, surgeons are being helped to perform operations by robots. The metallic assistants have already been deployed in several hundred hospitals. Up to now, however, no robot has been able to help in operations on the spinal column. Fraunhofer research engineers have now presented the prototype of a spinal column robot.

The surgeon studies the monitor in deep concentration. The screen shows a small opened section of a brain. The patient is lying on the operating table, his head fixed motionless in a clamp. Then the surgeon carefully moves the joystick. There is a slight whirring noise and the robot moves the endoscope a few tenths of a millimeter to the left. The neurosurgeon checks the movement on screen, and again uses the joystick to move the surgical robot further.

The innovative robot system URS Evolution 1 has been in use at the University Clinic of Neurosurgery in Erlangen for a few months now. It is used for brain operations. Dr Volker Urban explains a key medical benefit of the robot system: "The robot is an aid which helps surgeons to operate more precisely. For instance, the great accuracy of the surgical robot enables the neurosurgeon to reach his operational target with as little disruption as possible to the sensitive brain tissue." The robot is extremely steady and can even work precisely to hundredths of a millimeter. "That is essential. Our brain is a highly complex system of nerve pathways and important structures. Almost every millimeter of tissue has a functional significance," the medical expert emphasizes.

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Dr Urban knows what he is talking about. He is not just scientific head of the company Universal Robot System, which produces the URS Evolution 1, but is also a neurosurgeon at the Emma Clinic for Operative Medicine. With his expert knowledge he is helping to spin off the company from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. The young enterprise developed the prototype of a surgical robot designed by IPA scientists into a marketable product. The first devices have already been sold. The robot systems are already in service in Erlangen and Frankfurt am Main.

Robots for spinal column surgery

While Universal Robot System markets the surgical robot, the IPA scientists are already working on the next generation. They are developing a robot system for performing operations on the spinal column. In Germany alone more than 20 million people suffer from back trouble. When the pain is severe as a result of a serious disk herniation or vertebral damage, patients can only be helped by a special operation – posterior lumbar interbody fusion (PLIF). In this operation two or more vertebrae are linked together using two rigid rods. For this purpose the surgeon screws bolts through the fine vertebral arch pedicels into the vertebrae. This difficult operation requires great surgical skill. The bolts have to be exactly placed in order to avoid damaging the spinal cord, nerves and major blood vessels. Robot systems to help the surgeon perform this delicate work would be a tremendous breakthrough.

In the business-oriented strategic alliance "Robots and Manipulators for Medical Applications – RoMed" the IPA has therefore been working together with three other Fraunhofer institutes for two years on the development of a robot for use in spinal column surgery. A few weeks ago the research scientists were able to present the first prototype. "We have developed a robot system which assists the surgeon precisely and reliably in drilling and inserting the bolts in the spinal column," explains Jan Stallkamp of the IPA, describing what the prototype can do. Recent scientific results show how useful the robot's steady and precise hand will be in operations on the spinal column. They reveal that in operations performed manually the bolts are incorrectly placed in 20 to 25 per cent of cases, which can lead to complications or permanent damage to the nerve roots. The innovative surgical robot will help to avoid these problems.

Steadier and more precise than a surgeon's hand

The robot incorporates a special kinematic concept. This is referred to as a 'hexapod' after its six telescopic legs and is also used, for example, in flight simulators. The hexapod is free-moving and possesses six degrees of freedom. "In view of its high accuracy and rigidity the parallel kinematics of the hexapod can be applied particularly well to the difficult area of spinal column surgery," explains project head Andrea Hiller. The robot is steadier and more precise than a surgeon's hand and can place the pedicel bolts to accuracies of one tenth of a millimeter. A pre-positioning system makes up for the relatively small operational area of the hexapod, aligning it roughly over the location of the operation. It is in the actual operative procedure that the precision kinematics of the robot comes into its own.

The Fraunhofer research scientists have developed a special instrument for spinal column operations which can drill and insert bolts. It incorporates a force and torque sensor in order to precisely monitor the drilling and bolting process. Sensors record the forces that are active in drilling and bolting and check whether they are within the specified limits.

To enable the robot to work with absolute precision, however, the operation has to be planned and controlled very carefully. For this purpose pictures are taken of the affected region of the spinal column in a computer tomograph before the operation – in line with the established practice. A system developed by the Fraunhofer Institute for Computer Graphics Research IGD then uses this data to make a three-dimensional model which the surgeon can use to plan the operation. These planning data provides the basis for controlling the robot system. During the operation an ultrasound-based navigation system provides pictures of the spinal column. As a result the robot always knows exactly where it is located relative to the spinal column and how it must position the bolts. At the same time the surgeon is also provided with all the information he requires on a special monitor and can intervene in the operation at any time.

The surgeon controls all the processes and operative procedures on the monitor.
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Innovative input device for medical equipment

The design engineering of this input device was a special challenge. Because the device is used directly in the operating room it must be able to withstand a sterilization process lasting five minutes in steam at a temperature of 135 °C. Sensitive electronic equipment cannot withstand such treatment. The IPA scientists therefore removed the sensitive electronic components from the actual input device. A special projection disc on a metal arm serves as the computer screen and input device. This robust construction comes through the sterilization process unharmed. A projector outside the sterile area projects the graphical user interface of the medical systems and the operation data onto the projection disc. The surgeon operates the input device using a metallic optical pointer, the size of a ballpoint pen, to touch the command fields on the screen and control all the processes and operative procedures on the monitor.

The company U.R.S.
medicalrobots.com/

Experienced surgeons are impressed by the prototype of the surgical robot: "Up to now only navigation systems have been used in the region of the spinal column. The development work at the Fraunhofer Institute is producing the first robot system for use in spinal column surgery which will enable bolts to be inserted in the spinal column with the greatest precision," emphasizes the Medical Director of the Employees' Cooperative Accident Clinic in Frankfurt, Prof Dr Martin Börner. But it will still be a few years before the robot can be deployed in the operating room.
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