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Research Article

Study of Neuroarm and Force Sensing Grippers in Robo-Assisted Neurosurgery

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Abstract

Today ,the complexity and high technical requirements of neurosurgical operations are so demanding that modern robotic achievement and advances of accomplished technologies appears as the immanent means which can significantly improves Neurosurgical practices. The main objective of the present work is to study the modern technology in Neuroarms and Force sensing Grippers in roboassisted neuro surgery including Technological developments in Neuroarm, imaging guided surgery, microscopy, accuracy in motions of Neuro grippers which pushed the neurosurgeons to the limits of their dexterity and stamina.The future of robot-assisted neurosurgery, including the use of surgical simulation tools and methods to evaluate surgeon performance, is discussed.

Keywords: *Neurosurgery; robotics; neuroarms; imaging guided surgery; force detecting grippers.*

1. Introduction

The field of neurosurgery has made a concerted effort in adapting and incorporating advancing technologies into the operative field, adapting new techniques and devices successfully in an effort to increase the safety and efficacy of brain and spine surgery. Diligent efforts are made to minimize normal tissue trauma during surgical intervention while maximizing clinical outcomes. Among these adaptations are emphasis on surgical robotics. Those surgical robots have not found widespread clinical utilization in neurosurgical procedures is debatable, because the term “robot” itself has several definitions. For our purpose, we will focus our discussion to mechanical devices used in the operating field of neurosurgery that ultimately give the operator, i.e. surgeon, ability to control the device through automation or remote control. Technological advances in the field of robotics had clearly been incorporating into the operating room through the use of microscopy, navigation, instrumentation, optics, and imaging. However, the use of a mechanical device, whether through automation or remote control, to ultimately manipulate the instruments directly in contact with a patient is relatively new to brain and spine surgery.

The robotic arm attached to the operative microscope through a force reacting sensor that activates the motor of the arm to follow passively the direction of the surgical approach. Because the head of the patient is rigidly connected through the stereotactic frame to the surgical bed, it is possible, through an initial calibration of the system, to find a unique coordinate transformation between the stereotactic reference frame (the same used for image acquisition) and the reference frame connected to the microscope. In this way it is possible to know the direction of the line of sight of the microscope. Should the head position be modified during the procedure, are calibration procedure must be performed. Such recalibration is almost never necessary, however, when using a Mayfield-type head fixation .Computer graphic techniques have been developed to allow the tracking of the current position of the microscope within the volumetric reconstruction of the brain(Cesare Giorgi (1995)). The robotic arm has been designed to be compatible with the operation of microsurgical instruments, with particular care taken to achieve both safety and precision. Position sensor redundancy, fail-safe brakes, and backlash compensation have been used with a special cable routing embedded within the arm structure.

The dead end of neuroarm is with force sensing grippers ,Gripping force applied on the gripper is detected by strain gauges attached to the gripper clip. The signal is transmitted to the amplifier by wires running through the inner tube of the manipulator. Proportional force is applied on the finger lever of the operating unit by the surgeon using a bilateral control program. A pulling force experienced by the gripper is also detected at the gripper clip (Takeshi Yoneyama · Tetsuyou Watanabe (2011). The signal for the pulling

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*Corresponding author: **Mahajan Vivek** force is transmitted in a manner identical to that mentioned previously, and the proportional torque is applied on the touching roller of the finger lever of the operating unit. The surgeon can feel the gripping force as the resistance of the operating force of the finger and can feel the pulling force as the friction at the finger surface.

2. The Neuro- Robot

The results of robo-assisted neurosurgery depends mainly on design of Neuro robot,It consist of Neuroarm, IGS system, biovascular displays etc. A robot arm used within a surgical suite must meet some specific requirements, usually not applicable to industrial environments. For this reason, Telerobot, an Italian industrial company operating in the field of advanced robotics, has designed, manufactured, and tested an arm and its control system expressly for this application. (Cesare Giorgi (1995))

The presence of the robotic arm in the surgical suite must not, in so far as this is possible, interfere with the standard instrumentation setup. To find the best solution for the arm configuration, a passive mockup with adjustable links was installed within the operating room to simulate the presence of the robot. As a result of these tests, the following arm configuration has been developed: classical 7 DOF anthropomorphic kinematics: 3 DOF at shoulder level, 1 at elbow level, and 3 DOF (roll, pitch, roll with coincident axis) at wrist level with following table(1) dimensions.

Table 1 Standard Dimensions

S.No	Parameters	Dimensions
1	maximal width at wrist pitch axis	130mm
2	maximal diameter of the wrist/microscope interface flange	50 mm
3	turret (shoulder roll) maximal length	400 mm
4	Wrist length (from pitch axis to interface flange)	120mm
5	forearm length	500mm

The goal was to design a very "smooth" robot, not a fast one. The robot and effectors, in fact, must follow the movements imposed on the microscope by the surgeon, which are necessarily very slow(50 mm/sec). The low velocity allows the use of motors smaller than those normally used in industrial robots, with higher reduction ratios, contributing to the overall dimension reduction.

3. The Robot Control System

The robot control system allows the motion of the robot arms, whose end effectors is rigidly connected to the microscope, to follow the motion of the microscope itself without requiring the surgeon to modify the standard surgical routine. In other words, the forces and torques applied by the surgeon to the microscope must be "interpreted" by the robot control system as an in-tension of the surgeon to move or rotate it accordingly. Fig (1) explains each functional block according to the information flow between the different modules. To achieve this behavior, a commercial force , torque sensor, capable of measuring three force and three torque components, is interposed between the arm, the effectors, and the microscope body. When the surgeon moves the microscope, a reaction force and torque arises between microscope and arm. The 3 components of this force, Torque are measured by the sensor and transmitted, through a parallel line, to the robot control system. At the same time, the control system acquires the signals of the robot axis position sensors. It is thus possible to compute the Transpose Jacobean, obtaining the torques that should be exerted by the robot joints to balance the force, Torque applied to the end-effectors. Because the desired motion of the arm is according to the "intention'' of the surgeon, and not from the static balance of the arm, the values for joint torque as calculated above are transformed, through suitable coefficients experimentally determined, into increments of joint velocity to be realized by the PID axis controllers, whose output is connected to the motor drivers.

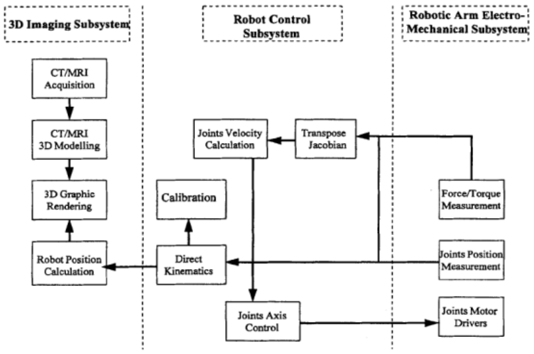

Fig. 1 Chart showing the functional blocks of the Telerobot system

Other parameters are introduced to simulate an effect of "viscous dumping" in the joint motion to avoid vibration and obtain a more continuous and smooth motion of the arm. The time requested by the control system for the execution of this loop is approximately 5mm/sec.From the acquisition of the joint position sensors and from the direct kinematic algorithm, the position and orientation in the arm reference frame of the arm end-effector are computed. By means of a transformation matrix, the parameters of which have been computed during the calibration phase, position and orientation are computed for the patient reference frame. These values are supplied, through a serial line connection, to the 3-D graphic station for the superimposition of the microscope optical axis on the reconstructed 3-D image of the patient's brain.

4. NeuroArm

NeuroArm consists of a robot, a controller, and a workstation. The system is based on master-slave control in which commanded hand-controller movements are replicated by the robot arms. The workstation provides visual, audio, and tactile feedback, creating an immersive environment for the surgeon. Recreating the usual surgical environment in this way will aid adaptation to this new technology. A binocular display provides stereoscopic views of the surgical worksite, and desk-mounted displays provide MR images, robot parameter updates, and various views of the surgical worksite. Tools will be superposed on the MR images, providing real-time visual feedback for intracranial procedures [Garnette R. Sutherland, Paul B. McBeth,(2003).

NeuroArm will perform standard techniques such as biopsy, microdissection, thermocoagulation, and fine suturing. Procedures such as lesionectomy and aneurysm clipping will be possible. The robot was designed to replicate the way that surgeons position themselves and their tools during surgery (a process known as biomimicry). It consists of 2 arms, each with 7 degrees of freedom for precise tool positioning, and a 1-degree-of-freedom tool actuation mechanism for each end-effector. Both arms are secured on a vertically adjustable mobile base. The mobile base is positioned adjacent to the operating room table and is mechanically secured using wheel brakes. For microsurgical procedures, standard tools such as bipolar forceps, needle drivers, suction, microscissors, and microdissectors were designed to fit the end-effector. For stereotactic procedures, a linear drive mechanism was designed to provide accurate targeting via a cannula and introducer. The robot end-effector is equipped with a unique tool-actuation mechanism, as well as a multiaxis force sensor system to provide haptic force feedback to the surgeon.

NeuroArm is designed for deployment within an MR magnet bore for stereotactic procedures. During stereotaxy, real-time MR images provide image guidance and improve tool positioning, ensuring that significant samples are extracted during biopsies. The feasibility of using neuroArm to perform microsurgery inside the magnet bore will be examined. If it proves reliable and safe, this configuration will allow the surgeon to view continuously updated MR images to ensure that the entire lesion has been removed. The current design of neuroArm permits image-guided microsurgery, which requires registration of preoperative MRI data to skin-mounted fiducial markers. This is accomplished using a mechanical digitizing arm attached to the robot base. The systems-controller computers will therefore always know the position of the tool tips in relation to the surgical target, which is outlined with a computer mouse–based cursor on the MRI during presurgical planning. This permits the ability to program "no-fly" or "no-go" zones before the procedure commences, protecting normal brain tissue from injury in the event of unskilled or accidental movement of the hand controllers.(Garnette R. Sutherland*, Paul B. McBeth,(2003))

5. Image guided system

An efficient interface tool to read and store image data collected from different neurodiagnostic units is also necessary. Graphic routines such as scaling, rotation, reformatting of images along arbitrary planes, and transparent representation of tridimensional volumes are very effectively employed to visualize the interaction of surgical strategies with the cerebral parenchyma. The patient anatomy is volumetrically displayed from stereotactically acquired CT, MRI, and DSA images. Images can contain morphological as well as functional data, e.g., from PET, SPECT, and anatomical atlases. The head frame is the common reference system for image reconstruction,. Modeling routines allow the surgeon to check the orientation of the arm, which is displayed on the graphic monitor with respect to the volumetric reconstruction of cerebral lesions and surrounding healthy tissue. Intraoperative images, acquired witha high-resolution charge coupled device (CCD)camera mounted on the microscope, can be fused with preoperative anatomical images. The robotic arm, detached from the microscope, can be employed to support other imaging sources such as an endoscope or an echographic probe whose images can be stereotactically integrated with preoperative data to monitor intraoperative tissue distortion and ablation.according to location shown by Image guided system the neuroarm get operated with accurate movement of grippers.

6. Force Sensing Grippers

The traditional operation for removing the deep-seated brain tumor is a piece-by-piece removal using manually handled forceps. Force sensation at the gripping finger is important for the surgeon to feel the force when touching the tumor and to sense the pulling force when removing the tumor. During the operation to remove deep -seated tumors by the micromanipulator using the master–slave control system, force feedback to the surgeon is one of the most important functions to feel the gripping force and pulling force during removal of the tumor. The force detection at the manipulator and force feedback at the surgeon's finger Because feeling the forces that occur during tumor removal is vital to the surgeon, (Takeshi Yoneyama · Tetsuyou Watanabe ,(2011)) The force-detecting gripper can detect both gripping force and pulling force during the gripping and removal of tissue of tumour. These detected signal transmitted to the operating system. Force sensor also installed at the finger lever and finger holder. During the operation, the micromanipulator moves according to the operated motion and the surgeon can feel the gripping force as the force resistance for closing the finger and can feel the pulling force as the friction at the finger surface by the control software in the operating system. The design and fabrication of a force detecting gripper with flexible manipulator and the force feedback system to the operating unit are described. The force feedback capability is also investigated by a basic operation test. For eg.The design specification of the detection of the gripping force is 1N for both the gripping and pulling forces. The force feedback on the surgeon's finger is estimated to be 3N for the gripping force resistance and 1N for the friction, indicating the feeling of the pulling force resistance. Force reflecting servo control is adopted as a control system for precise positioning and force feedback. The diameter of the manipulator shaft to be passed through the hole in the endoscope is 3mm, and its length is approximately 200mm. The flexion angle at the end of the manipulator is expected to be more than 20◦ which gives accurated gripping of tumour tissue.

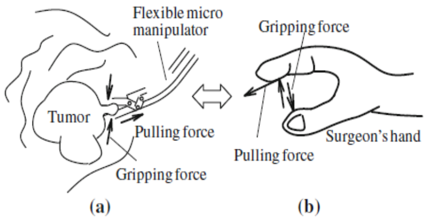

Fig.2 Gripping of tumour tissue

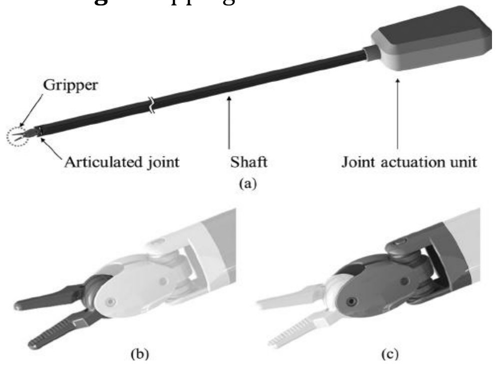

Fig.3 Grippers (https://www.researchgate.net/profile/Jong_Y)

7.Operating system

The operation of the grasping a target on the soft material using the master-slave control system has been carried out. Slave driving unit is shown in Fig.4 All the micro manipulator motions are driven by stepping motors. There are motors for closing the gripper, rotation of the gripper at the flexed manipulator end, flexion of the end part of the manipulator, rotation of the manipulator at the backside and forward-backward motion.. All the operating motions are assisted by stepping motors. Grasping force, rotation torque of the joystick and feed force are detected to operator, the other is bilateral mode where the master motion is transmitted to the slave manipulator while the force exerted on the slave manipulator is fed back and the operator can feel feedback the forces to the surgeons.((Takeshi Yoneyama · Tetsuyou Watanabe (2013.))There are two control modes for the proposed system; one is unilateral mode where the motion of the master manipulator is transmitted to the slave manipulator but the force exerted on the slave manipulator are not fed back to the forces such as gripping force and contact force. In the following experiment, unilateral mode is used only to know the motion performance and force detecting performance of the micromanipulator.

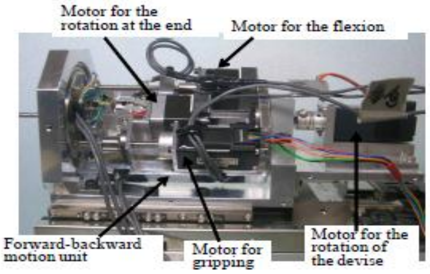

Fig.4 Slave manipulator driving device

Discussions

[1]A systematic approach has been applied to the development of a unique and dexterous neurosurgical robot.

[2]The system promises to enhance surgical performance, reduce fatigue and improve surgical outcomes due to microscope neurosurgery chances of completely removal of tumour tissues increases with Sophisticated controlling and positioning of grippers and neuroarm.

[3]By including these all setup with automatic control brain and spinal tumour get easily removed within stipulated period of time that's also increases accuracy of surgical operation with very minimum errors.

[4]To enhance the robotic implementation in surgery the controller should be properly programmed with sequence of operation.

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