An Intelligent Catheter System Robotic Controlled Catheter System

M. NEGORO, M. TANIMOTO*, F. ARAI*, T. FUKUDA*, K. FUKASAKU, I. TAKAHASHI, S. MIYACHI

Department of Neurosurgery, Nagoya University School of Medicine

*Department of Micro System Engineering, School of Engineering, Nagoya University

Key words: Robotic control, angiography, catheterization

Summary

We have developed a novel catheter system, an intelligent catheter system, which is able to control a catheter by an externally-placed controller. This system has made from master-slave mechanism and has following three components; 1) a joy stick as a master (for operators) 2) a catheter controller as a slave (for a patient), 3) a micro force sensor as a sensing device.

This catheter tele-guiding system has abilities to perform intravascular procedures from the distant places. It may help to reduce the radiation exposures to the operators and also to help train young doctors.

Introduction

Recent robotic technology has been applied to surgical operations and several surgical robots are available for clinical usage. Remote tele-manipulation of surgical instruments is now possible in the operating theaters¹.

On the other hand, robotic control of catheterization is not developed yet because of technological complexity. At recent intravascular procedures by catheterization are getting great attention as minimum invasive treatment.

This procedure is performed under x-ray control away from lesions. One drawback is the radiation exposure to operators. Another diffi-

culty is the lacking of direct visualization of lesions and it requires for operators to manipulate catheters by tactile information with the help of x-ray monitoring.

These difficulties stimulate to develop tele-control system for a catheter manipulation. We have been working in ten years for developing the catheter control system with cooperation of Department of Engineering, Nagoya University². In this report we are going to report a novel catheter system, an intelligent catheter system, which is able to control a catheter by an externally-placed controller. It will be applied for telemedicine to mentor intravascular procedures to less-experienced doctors.

Method

In this intelligent catheter system, a master slave system is chosen for moving the catheter forward, backward & rotate³. The joystick as a master has very small mechanical impedance and conveys the exact orders from the operator. The controller as a slave device has 2-axis force sensor, which measures the contact force between blood vessels and the catheter. There is a micro force sensor in the "tip" of the catheter, which measures the contact force between the catheter tip and the blood vessel wall. It will give the sensation of the catheter tip to the operator.

Figure 1 A) General view of intelligent catheter system and simulator B) Joy Stick as a master with force display mechanism.

Structure of a Master Joystick

The master joystick has two joints. The first joint is a master joint and this joint is connected to the forward and backward motion of a catheter. The second joint is a revolute joint and this joint corresponds to rotating motion of a catheter. Each joint is connected to a motor with a wire mechanism. There is no gear between the motor and the joint to reduce the influence of the friction and backlash. Each joint has an optical rotary encoder, and the resolution of the position measurement is 1.6 micro meter per pulse, 0.023 degree per pulse, respectively.

Structure of a Slave Device

The slave device has an inner unit in an outer shell. The catheter is put between a pair of rollers. A motor is connected to the rollers, and a catheter is driven forward and backward by the rollers. The outer shell rounds to generate the rotating motion of the catheter. The inner unit is hung from the outer shell with thin pillars.

There is a strain gauge on the thin pillars. This is a force sensor, which measures the pushing component of the contact force between a catheter and a blood vessel. The two rollers are connected by thin pillar. There is also a strain gauge on the thin pillar. This force sensor measures the rotating component of the contact force.

Microforce Sensor

A micro force sensor is installed in the tip of a catheter. The diameter and the length is 1.2 mm, 5 mm, respectively. We can measure the contact force between the catheter tip and the blood vessel wall. The resolution is less than 0.5mN, and frequency response is fine up to 2kHz.

Actual Movement of Master Joystick & Slave Device

The master joystick is placed in the x-ray control room. A catheter or a guide wire can be controlled with slave device on the angiography table.

Under the fluoroscopic control the catheter can be navigated with manipulating the master joystick from the control room(distant place). Force information, which is measured by two force sensors (micro force sensor in the tip of a catheter and the strain gauge force sensor at the slave device), is displayed on the master joystick. By this method the operator can get tactile information from the catheter tip. When the catheter makes contact with the blood vessel wall, it will feed back to operators as the sense of resistance.

Discussion

This intelligent catheter system is the first step for future robotic control of neurointer-

Figure 2 Controller as a slave & Microsensor-tipped catheter. Controller consists of force-sensor equipped servomotor and driving rotor.

vention. There are several issues to be solved before clinical application.

The part, which contacts with the catheters & wires, should be sterilized by the method of disposable appliance.

For safety reason automatic emergency stop mechanism should be added.

Once these problems are solved, it will contribute to reduce radiation exposure to interventionalists. Furthermore, this system will be applied for teaching of neurointervention by telemedicine. If it will be connected to telecommunication system, experienced doctors can instruct less-experienced doctors from re-

mote sites (telementoring)⁴. Although its infancy, this intelligent catheter system will be a major breakthrough for robotic neurointervention.

Conclusion

In this report we have described an intelligent catheter system, which composed by a master-slave mechanism. This system will contribute to control the catheterization by external placed controller. And also help to mentor neurointervention by the method of telemedicine.

References

- 1 Chitwood WR Jr, Nifong LW et Al: Robotic surgical training in an academic institution. *Ann Surg* 234: 475-484, 2001.
- 2 Negoro M, Fukuda T et Al: The application of micromachine technology for intravascular neurosurgery. *Proceedings of 8th Meetings of Japanese Society for Intravascular Neurosurgery*: 283-285, 1993 (Japanese).
- 3 Tanimoto M, Arai F et Al: Augmentation of safety in teleoperation system for intravascular neurosurgery. *IEEE Int'l Conf on Robotics and automation*: 2890-2895, 1998.
- 4 Moore RG, Adams JB et Al: Telementoring of laparoscopic procedures: initial clinical experience. *Surg Endosc* 10:107-110, 1996.

M. Negoro, M.D.
Department of Neurosurgery
Nagoya University School of Medicine