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Robotics for Telesurgery

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Abstract: We as human beings have always been dissatisfied with our skills especially with our vision, hearing and use of other sensory organs as each of them have their limits. This has led us to develop robots to tend to our domestic as well as human social needs. The application of robotics to medicine and surgery has assured humanity with new and highly developed techniques. However, developing robots requires many resources and hence has remained a privilege of the rich countries.

Keywords: Minimally Invasive Surgery, Robotics, Robots, Robotic Telementoring, Telepresence Surgery, Telesurgery

I. Introduction

Robots are defined by Encyclopedia Britannica like " any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a human like manner. By extension, Robotics is the engineering discipline dealing with the design, construction and the operation of robots".

The aim of Robotics is to design a robot which could match or exceed human intelligence and performance in unknown, rapidly changing and unpredictable situations. The creation of new needs outside the traditional market which includes cleaning, construction, shipbuilding and agriculture has led to increase in demand for service robots in these new areas especially for human social needs. The evolution of robotics research is mainly in three different areas: robot manipulator, mobile robots and biologically inspired robots.

The craft of surgery has always relied on the use of instruments and tools. The innovations in surgery has enabled in achieving outcomes not possible in the days of yore. The interface between the surgeon and the patient has now changed with the use of computers and its related technology which has poised to improve a patient‟s health by enhancing a surgeon‟s skills and training. Medical robotics is an active area of research on the application of computers and robotic technology to surgery in planning and execution of operations and also in training of surgeons.

The goal of robotic telesurgery is to develop tools to replace or enhance the performance of hand instruments used in surgery. However, these robotic tools are not robots but teleoperated systems which are under the direct control of the surgeon, hence the name Telesurgery.

II. Ethics in Robotics Used in Surgery

To ensure high performance of robots in an ethical way, a medical doctor must be involved in the development. Now, ethics in robotics can answer the following questions:

a. Should robots have consciousness or sense of emotions?
b. Is there a need for a special code to ensure the dignity or rights of robots?

The robot is considered to be a mechanical device that performs preprogrammed repetitive tasks. These attributes has helped the industry to mass produce these devices. However, each surgery has different demands. Surgical robots today are a form of computer assisted surgery. Thus, they have a master- slave relationship wherein the surgeon is the master who can control the actions of the robot thereby improving his precision and overall performance.

III. Application of Robotics in Medicine

The role of medical robots is not to replace doctors but to assist them. However, there are many challenges in the implementation of robotics in the medical field mainly due to safety, precision, cost and reluctance to accept the new technology. Medical robots may be classified in many ways: by manipulator design (e.g., kinematics, actuation); by level of autonomy (e.g., preprogrammed versus teleoperation versus constrained cooperative control); by targeted anatomy or technique (e.g., cardiac, intravascular, percutaneous, laparoscopic, micro-surgical); by intended operating environment [e.g., in-scanner, conventional operating room (OR)], etc.

A robot surgical system generally consists of one or more arms (controlled by surgeons), a master controller (console) and a sensory eye giving feedback to the user. Different Artificial Intelligence (AI) techniques belonging to three different areas of AI: learning, reasoning and problem solving are provided to the robot so that it can operate in uncertain dynamic environments.

Surgeons rely on vision as their source of feedback; however, due to the limited resolution of current generation video cameras, there is interest in optical overlay methods, in which graphic information is superimposed on the surgeon‟s field of view to improve the information provided. As surgeons frequently have their hands busy, there has been also interest in using voice as an interface.

Much of the past and present work on telesurgery involves the use of master-slave manipulator systems. These systems have the ability to feed forces back to the surgeon through the master manipulator, although slaves‟ limitations in sensing tool-to-tissue forces can somewhat reduce this ability.

A. Minimally Invasive Surgery

Minimally Invasive Surgery (MIS) is a technique wherein a surgery is performed with instruments and viewing equipment is inserted into small incisions rather than large incision to reach the site to be operated. Minimally invasive operations include laparoscopy (abdominal cavity), thoracoscopy (chest cavity), arthroscopy (joints), pelviscopy (pelvis), and angioscopy (blood vessels).

MIS has a number of advantages like reduced trauma to healthy tissues thereby reducing post-operative pain and long hospital stay. Thus, there is reduced blood loss, reduced intake of medicines, faster recovery and hence leading to reduced procedure costs. However, MIS procedure can be more demanding on the surgeon as the advantages of natural 3D image, depth perception are lost. Magnification of small structures was difficult and instruments are rigid without joints.

B. Robotic Telesurgery Concept

Robotic Telesurgery is an extension of the capabilities in MIS. The surgical tools are replaced with robotic instruments which are under the direct control of the surgeon. This restores the manipulation and sensation capabilities of the surgeon which are lost due to MIS. Some of the limitations are relieved by providing fine motor control, magnified 3D imaging and articulated instruments.

Zues Robot

In the early 1990s Computer Motion (Goleta, CA, USA) developed the Zeus robot which is a master–slave system. It was specifically designed for cardiac operations; however, it was diversified for several surgical specialties, for example general surgery, urology, and gynecology.

The system consists of control unit, a robotic arm for a camera and two robotic arms which are directly mounted on the operating table. It has 4 degree of freedom. The Zeus system has two subsystems „the surgeon side‟ and „the patient side‟. The surgeon‟s subsystem consists of a console that can be positioned anywhere in the operating room. The console consists of a video monitor and two handles that control the robotic arms holding the surgical instruments. The patient-side subsystem consists of three robotic arms attached to the table. The disadvantages of the initial Zeus system included instruments lacking intra-abdominal articulation and the console containing a 2D viewing monitor. This system is currently no longer commercially available.

da Vinci Robot

In 2000, the da Vinci Robot, a type of master-slave system was built by Intuitive Surgical has become the most commonly used instrument for telesurgery.

Fig 1. da Vinci Surgical Robot Image from http://www.davincisurgery.com, ©2009 Inuitive Surgical, Inc.

The da Vinci system is based on three components:

a. a master–slave, software-driven system that enables intuitive control of laparoscopic instruments with six degrees of freedom;
b. a stereoscopic vision system displayed in an immersive format; and
c. a system composed of redundant sensors to provide maximum safety in operation.

The system consists of three separate units:

a. Console – The console is positioned remotely from the patient and connected by a cable to the video cart and the surgical cart. The console houses a stereo viewer, which has an infrared beam to deactivate the robotic arms whenever the surgeon moves his head out of the console. The surgeon‟s hands are inserted into free-moving „„„masters‟‟ or finger controls, which convert the movements of the surgeon‟s wrist and fingertips into electric signals. These are then converted to computer commands to direct the robotic instruments to perform the same movements in the operative field. The console has controls for 3D viewing, the height of the console, the ability to choose a 0_ or 30_ laparoscope, motion scaling (5–1 means that five units of motion of the surgeons hands are reduced to one unit of motion for the instruments), and tremor filtration. There is an ability to control the camera, energy devices, and the „„„masters‟‟ with foot pedals
b. Video Cart - The video cart has two video camera control boxes and two light sources, in addition to asynchronizer.
c. Surgical Cart - The surgical cart supports either three or four robotic arms. Surgical instruments are attached to the robotic arms through an adapter, which uses an 8-mm da Vinci-specific port. The central robotic arm houses a 12 mm telescope, which contains two separate 5-mm telescopes for 3D vision. The robotic surgical instruments are capable of intra-abdominal articulations with seven degrees of freedom. The robotic instruments can be used for up to ten cases after which they must be replaced

Disadvantages include bulky robotic arms with large excursion arcs that can lead to collisions, limited instrumentation, and the inability to move the surgical table when the robot arms are attached to the ports. The large size of the robot also limits the ability of surgical assistants to move around the patient.

Fig 2. The da Vinci surgical robot in use with assistant surgeons alongside operative table

Image from Kevin M. Reavis, David R. Renton and W. Scott Melvin, “Robotic telesurgery for achalasia” London; Springer Accepted: 13 November 2006 / Published online: 20 January 2007, pp. 27

Fig. 3 The da Vinci surgical robot in use with head surgeon operating from the console

Image from Kevin M. Reavis, David R. Renton and W. Scott Melvin, “Robotic telesurgery for achalasia” London; Springer Accepted: 13 November 2006 / Published online: 20 January 2007, pp. 27

C. Telepresence Surgery

Remote telesurgery is the same as normal telesurgery, except that the surgeon and the patient are separated by significant distances. Telepresence surgery and robotic telementoring are two revolutionary applications achieved by linking a robot to a telecommunication system.

The speed of remote surgery is made possible through Asynchronous Transfer Mode (ATM) which is designed for the high-speed transfer of voice, video, and data through public and private networks using cell relay technology. Cell relay technology is the method of using small fixed length packets or cells to transfer data between computers or network equipment and determines the speed at which information is transferred. ATM technology has a maximum speed of 10 Gbit/s.

Telepresence surgical devices enable surgeons from remote sites to tele-mentor amateur surgeons still developing skills. However, telepresence surgery raises a host of ethical issues such as patient privacy, speed of transmission, and responsibility for the care of the patient are critical issues when dealing with a surgeon at the bedside and a surgeon operating from a remote location and will need to be addressed before incorporation of this technology into mainstream.

Fig 4 Dr. Jacques Marescaux performing a gall bladder surgery while he was in New York and the patient was in France.

Image from J. Marescaux, et al.,"Transatlantic robot-assisted telesurgery," Nature, vol. 413,pp. 379-380, 2001.

IV. Scope of Robotic Telesurgery in India

Robotic TeleSurgery holds great promise for the surgeons as well as the patients across the world. Robotic Surgery is a young field but one which has grown relatively faster. India too is not left far behind with at least three centers in India acquiring robots in their surgical departments.

However, the scope of Robotic Telesurgery in India is limited due to cost considerations. The cost of the Da Vinci system is around $1.4million (Rs.7crores) and an annual maintenance cost of $100,000 with a lifespan of five years. So as a matter of fact, the surgical costs for the patient increases even more when Robotic Telesurgery is used than with the conventional methods. Compared to procurement and maintenance costs, the number of persons actually using the service is miniscule.

Also, one of the major reasons for using Robotics in surgery is the reduced surgery time. However, this reduced time is compensated by the time required for the „set up" process for the robot. Another reason, for the use of Robotics is minimal fatigue for the surgeons. However, is any surgeon ready to spend $1.4 million to experience comfort in a robot that would be used in less than 10% of his surgeries?

India is known for its mortality statistics and abysmal access to healthcare facilities. Diseases like tuberculosis, malaria, chikungunya, dengue kills thousands. More than thousand women die of pregnancy related complications every year. So, is this technology affordable in a country where 26% of the population lives below the poverty line? The government cannot afford any new and costly technologies in government hospitals which leaves these services at the discretion of the private health sector. This in turn would make medical treatment more expensive. As the patents expire, manufacturers around the world are expected to join the market thereby increasing the competition. It is difficult to obtain a robotic revolution if the costs remain as it is today. However, it can be hoped that increasing use will help the lowering of the costs.

As of now, in India only Telementoring service is feasible provided there is good exchange of audio and video signals. However, more bandwidth is required. Telementoring involves real time teaching of surgical techniques by an expert surgeon to a student with both being at different sites

V. Conclusion

Robotic technology has undoubtedly revolutionized the way many surgical procedures are performed today and will be performed in the future. Additional technical modifications of robotic systems may increase the effectiveness of robotic surgery.

As the techniques of expert surgeons are studied and stored in special computer systems, robots might one day be able to perform surgeries with little or no human intervention. Carlo Pappone, an Italian surgeon, has developed a software program that uses data collected from several surgeons and thousands of operations to perform surgery without human intervention. This could one day make expensive, complicated surgeries much more widely available, even to patients in regions which have limited access to healthcare facilities.

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