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Review of Application of Robots in Health Care

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Abstract: Robotic systems have invaded health care from many different directions. The intent of this paper is to point out some of the areas in health care where robotic systems are currently being used. The paper classifies robotic systems into, surgical robotic systems, rehabilitation robotic systems and mobile robotic systems for hospitals. The paper reviews the most important past and ongoing research projects in these three areas.

Key Words: Surgical Robots: Rehabilitation Robots: Minimal Invasive Surgery (MIS)

Introduction

The application of robotic technology to medicine has moved rapidly in the last few years. Today robotics can be considered as a real opportunity available to operators in the medical field, as well as to investors who moved away from this field, because of its uncertainty in the past. The uncertainty comes from the fact that, robots did not gain immediate acceptance in the medical community for the following reasons:

1. Psychological reasons, since robots, may be perceived as competitors by physicians and as potentially dangerous exotic machines by patients.
2. Technical reasons, industrial robots are reliable, but no real expertise exists to deal with robots in contact with human.
3. Economical reasons, since most service robots are quite expensive.

The above reasons indicate that people in the past were afraid of robots used in medical field due to the lack of safety in medical robots. Of course safety is one of the key issues in designing a medical robot and traditional safety methods for industrial robots are not enough for medical robots. The importance of safety requirements comes from the fact that medical robots are used in medical settings for patients and concern human life, while industrial robots are operated in factories for products.

Many factors can cause safety problems for medical robots. Human error is one aspect, such as wrong instruction or manipulation. System error is another important aspect which can be divided into: pure software, pure hardware, hardware triggered by software and software triggered by hardware.

Nowadays medical robotics safety received more attention and becomes an interesting research area. For example Bao Wei and his group propose a systematic methodology named Hazard Identification and Safety Insurance Control (HISIC) to analyze, control and evaluate the safety of medical robots. The (HISIC) strategies were adopted for safety enhancement in mechanical, electrical and software design.

The early work on computer-assisted surgery was devoted to microsurgery. Today and with high safety insurance in medical robots, robot-assisted surgery extends over many other medical areas, such as:

- Orthopedic surgery.
- Eye surgery.
- Laparoscopy.
- Prostatectomy.
- Endoscopy (Holler *et al.*, 1993).
- Cardiac surgery.

In the last few years the literature in this area revealed that, the application of robotic systems in health care has been approached from many different directions .It is not our intent to describe every medical robotic system in existence. Rather our efforts will be focused on presenting robotic systems employed in surgery, in rehabilitation and mobile robotic systems for hospitals. The intent of this paper is to point out some of the areas in health care where robotic systems are currently being used.

The paper classifies robotic systems into surgical robotics, rehabilitation robotic systems and mobile robotic systems for hospitals.

Robotics for Surgery: In the last ten years, researchers have discovered the field of robotics for surgery as an interesting research area and many different projects have been carried out in this field .The outcomes of some of these projects are industrial systems that are currently under clinical evaluation and intensive checking inside hospitals (1). This class of industrial robots is defined in this paper as surgical robots. Surgical robots use a large variety of techniques, tools and apparatus and include a multiplicity of applications. The numerous applications of robotics to surgery can be classified into two main areas : those based on image-guidance and those aimed at obtaining minimal invasiveness.

Image-guided Surgery: The basic idea behind image-guided surgery is the use of a robot workstation integrated into the operating theatre where some parts of the patient's body are fixed by means of suitable fittings. The technique is easy to implement for orthopedic surgery, where fixators are commonly used to fix bones and also for neurosurgery where the required exact matching between pre-operative and intra-operative reference frames is accomplished by mounting on the patient head a stereotactic helmet.

The off-line planning of the intervention is performed on the basis of diagnostic images from CT, MRI and US tomography which are used to interpret the measurements that involve a large amount of data.

The robot is used in a CNC machine tool-like fashion for precise cutting, milling, drilling and other similar tasks. Experimental evidence shows a superiority of robot operations versus similar operations performed by surgeons in terms of accuracy and repeatability. Real-time images can also be employed during intervention in conjunction with diagnostic images and end-effector position / orientation data in order to provide the surgeon with feedback about the current state of the operation. It is important to point out that the surgeon supervises the robot system during operation, and in simple interventions, operation planning is performed mentally by the surgeon prior and during the operation. Nowadays image-guided surgery includes: orthopedic surgery, spine surgery, neuro-surgery, reconstructive / plastic surgery and ORL surgery. Although image-guided surgery spreads over a large area of surgical operations as mentioned above, but like other surgical techniques it has some drawbacks. The main drawback is due to the fact that, most interventions on parts of human body involves soft tissues, so large deformations may occur during the operation. This results in possible discrepancies between pre-operative and intra-operative images.

Virtual Reality (VR), teleportation and advanced man / machine interfaces will play a key role in the near future of image-guided surgery. VR methodologies have considerably enhanced the man-machine interface to locally or remotely controlled autonomous systems, and made possible to convey information in an intuitive way so as to combine supervision capabilities with new heuristic control methods. VR is a suitable technology for student/surgeon training through simulation of the intervention in a virtual environment possessing realistic 3-D representations of the human body organ. Teleoperation / telesurgery may be needed when a patient needs an urgent surgical intervention in a place where no specialized surgeon is available (for example, on a battlefield or an ambulance) or when it is not advisable for the surgeon to be in the patient place (eg when the patient possesses an infectious disease or long operations under X-ray). Teleoperation has the advantage of solving the problem of the increasing requirement for room for equipment in the neighborhood of the patient's bed, so that it might become necessary for the surgeon to move away and operate remotely.

Minimal Invasive Surgery : Minimal Invasive Surgery (MIS), also called endoscopic surgery is gaining increased acceptance as a powerful technique beneficial to the patient's integrity, cost and time of recovery (Georgeson *et al.*, 2000). At stage of development, MIS depends on three prerequisites, the availability of high quality video endoscopy, the availability of high quality precision surgical instruments and the manual skill of well-trained surgeons. The technique depends on accessing the organ to be operated through a small hole, and the surgeon, although directly responsible for the manipulation of the surgical tool, misses a large part of the information necessary to finely control the end effector (Hall-Craggs *et al.*, 2000). At its earlier stages MIS depends on a sort of craftsmanship where operating surgeons must compensate with their skills for the fact they can not touch and sense with their fingers for diagnostic purpose, they lack 3-D view of the work space, the access to the work space is restricted and they can not feel the force / torque and pressure they are exerting at the end effector tip.

Generally speaking, robotics technology can contribute to reduce the level of surgical invasiveness in three different areas, namely laparoscopic surgery, endoscopic surgery and the third area is not linked to any specific type of surgery and consists of an attempt of improving the performances of traditional macro surgical tools by applying mechatronic technologies aimed at decreasing the invasiveness of tool operation.

Rehabilitation Robots: The possibility to rely on the use of robots to aid a disabled to get certain independence, was considered in the eighties. Some advanced assistant robotic prototypes were already available by the mid-eighties. The goal of such robots is to replace the lack of motion capability of an impaired person to be able to approach and to manipulate objects in his/her environment, with the need to continuously rely on an assistant. And even to be able to perform a certain numbers of daily life activities, such as eating, grooming or toileting. Presently, the area in health care with greatest use of robots is rehabilitation.

One of the key factors for the success of robotic aids for the disabled is certainly the potentiality to make these peculiar users still able to exert a complete control on their environment by using a robotic interface (Wagner *et al.*, 2000). In rehabilitation robotics, the term "environmental control" refers to a disabled user's capacity to actively interact with his/her external environment. For a disabled to have complete environmental control all of his/her sensory and motor functions are needed and for this reason disabilities based on partial or total loss of upper limb function are particularly serious, due to the consequent reduction in , or complete loss of the manipulative function. This kind of disability hinders the disabled from carrying out common every- day activities, because the user receives the external stimuli but he/she is unable to respond to , or act on them

Rehab-Manipulators: The primary objective of a rehabilitative robotic manipulator termed a rehab-manipulator, has always been to fully or partly restore the disabled user's manipulative function by placing a robot arm between the user and environment. The manipulator is not designed to perform repetitive tasks like its industrial counterpart; instead, it must be able to perform various tasks in minimally structured environment.

To perform these tasks satisfactorily there are some important factors in the design consideration of these peculiar manipulators: degree of disability (a system must be flexible enough to be adapted to each user's capabilities), modularity (system inputs and outputs must be easy to add or remove according to each user's need), reliability (a system must not let the user down) and finally cost (the system must be affordable). Many configurations of robot systems reflecting the above mentioned factors have been built, tested and evaluated and considered as feasible for the assistance of severely and moderately disabled users.

From the above solutions we consider three different configurations. The first configuration that will be considered is the bench or table mounted manipulator included in a completely structured desktop workstation. Many systems based on this approach were positively evaluated by users and commercially are available on the markets, such as DEVAR system by Tolfa Corporation, USA and the RAID system by Oxford Intelligent

Machines Ltd, England. The drawback of this system is that, the system is mainly suitable for disabled users for executing vocational tasks at their workspace.

The second configuration is the wheel chair-mounted arm. This system is the most suitable one for users with upper limb disabilities and who are able to move or control the movements of the wheel chair, so that the robot can be taken to the areas of activity. This solution is becoming more popular among disabled and elderly users because they can use the robot arm everywhere and not restricted by fixed structured locations. A good example in this group is the KARES (Song *et al.*, 1999), which is the intelligent rehabilitation system with a 6-DOF robotic arm mounted on a powered wheelchair. The system was developed to assist the disabled and the elderly for the independent activities. To perceive environment one color vision sensor and one force / torque sensor are mounted on the end-effector of the robotic arm of KARES. The system can perform different tasks such as, picking up a cup on a table, picking up a pen on the floor, moving an object to the user's face and operating a switch on the wall.

Although this system is widely experimented, but it has some technical problems. The technical problems mainly to deal with the accuracy which can be obtained in grasping operations and the possibility of equipping the wheel chair with complex arm controller.

The third solution is the use of an autonomous or semi-autonomous mobile vehicle equipped with a manipulator and additional sensor systems for autonomous or semi-autonomous operation. The system is suitable for severely disabled or bed-ridden users as long as the interface between the user and robot is easy to use. A real rehabilitative mobile robot of this kind was developed by S. Tachi at MITI Japanese laboratories. The system has a name of MELDOG and was designed to act as robotic dog for blind users. Various prototypes of autonomous or teleoperated mobile robots to assist the disabled in different activities have been implemented and others are currently under development like the American MOVAR system and the Italian URMAD system.

Mobile Robotics Systems for Hospitals: The use of mobile robots in hospital has increased recently due to the current shortage of help in hospitals, or as a solution to the problem of the diseases (lumbago, low back pain) which affect the personnel involved in heavy physical tasks such as lifting a patient and carrying him/her to the toilet or as a release from unpleasant tasks such as changing sheets in the bed of an incontinent patient.

Recently some of the above hospital transport mobile robots have been presented by some research centers such as Transition Research Corporation (now Helpmate Robotics, Danbury, CR, USA). The robot is mainly designed to assist in such tasks as point-to-point delivery. An example of a point to point delivery task which can be carried out by 'Help Mate ' is the delivery of off schedule meal trays, or a lab and pharmacy supplies or a patient records. Help Mate navigation system relies on sensor-based motion planning algorithms that specifically structured environment.

Several hospitals have make use of Help Mate. In some hospitals Help Mate is in operation 24 hours per day and the hospitals are reporting an increase in productivity and efficiency. As well as being used in hospitals, the system can also be used in industry, as a valuable solution to some basic needs requiring the transportation of lightweight objects. Rossetti *et al.,* 2001) examine clinical laboratory and pharmacy deliveries in middle to large size hospitals, in order to evaluate whether or not a fleet of mobile robots can replace a traditional human-based delivery system. The methodology was applied to the University of Virginia Health Centre. It was shown with a high confidence that a fleet of mobile robots can achieve better final results than a human-based transportation system according to a representative preference structure formulated by a hospital manager.

In the medical field heavy robots could be used to help nurses to execute tasks requiring hard muscular work. The Japanese were the first to invest a substantial effort in the development of fetch and carry robots for hospitals. The best example of such robot is the patient care robot named " MELKONG " developed by the Mechanical Engineering Laboratory in Japan (Nakano *et al.*, 1981) . The robot was designed to lift, hold and carry an adult patient or disabled child. To perform this task the robot will come to the bed in the hospital room, lift the patient in its arms from the bed, move back still holding him/her in its arms and transfer him/her to the toilet or bathroom or dining room. Usually a nurse controlled the robot, but it was expected that at night the patient could also call the robot and control it by means of simple commands given through a joystick.

Conclusion

Medical robots have been widely used in different areas in health care. The paper points out some of the areas in health care where robotic systems are currently being used. The paper classifies robotic systems into surgical robotic systems, rehabilitation robotic systems, mobile robotic systems for hospitals and reviews the most important past and ongoing research projects in these areas.

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