Current trend of robotics application in medical

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Abstract. The applications of robotics in recent years has emerged beyond the field of manufacturing or industrial robots itself. Robotics applications are now widely used in medical, transport, underwater, entertainment and military sector. In medical field, these applications should be emphasized in view of the increasing challenges due to the variety of findings in the field of medicine which requires new inventions to ease work process. The objective of this review paper is to study and presents the past and on-going research in medical robotics with emphasis on rehabilitation (assistive care) and surgery robotics which are certainly the two main practical fields where robots application are commonly used presently. The study found that, rehabilitation and surgery robotics applications grow extensively with the finding of new invention, as well as research that is being undertaken and to be undertaken. The importance of medical robot in medical industry is intended to offer positive outcomes to assist human business through a complicated task that involves a long period, accuracy, focus and other routines that cannot be accomplished by human ability alone.

1. Introduction

There has been a lot of research carried out in the field of robotics in this day and age because of the growing demand in the usage of robots, the application of robotics can be seen in almost all sector of the economy e.g. Transport, Manufacturing, Medical, Defence, Entertainment. However the word ‘Robot’ originated from the Czech word ‘Robota’ meaning ‘Slave Labourer’. In the early 20’s Karel Capek a Czechoslovakian dramatist first used the word robot in his play titled ‘Rossum’s Universil Robots’ where he illustrated a robot as a timeless worker, till date there has not been a clear definition of robots. A robot is a mechanically controlled, reprogrammable, multi-use automatic system with several degrees of freedom. This may be either fixed in place or mobile [1].

Robots can be classified using several criteria such as the application area, control techniques, actuators, geometrical configuration, intelligent robots and others. The merits of classifying robots are very huge because it makes it easier in identifying robots to be used for a particular task. In this review we will be discussing the current trends in medical application of robotics.

Medical and healthcare robots are designed for different terrain and tasks. Those that involve the development of wheel chairs, rehabilitation manipulators for assisting disabled and elderly persons can be categorized as Macro-robotics while those that involve the development of tools for surgery such as minimally invasive surgery, image-guided surgery, computer-integrated advanced orthopaedics, stereotactic guidance can be categorized as Micro-robotics. The last category is the Bio-robotics which involves the development of modelling and simulating biological systems for providing a better knowledge of human body and system [2]. Figure 1 shows the classification of robotics according to their application in the medical field.
2. Rehabilitation robotics

Rehabilitation robotics involves the use of assistive devices for disabled and aged people. Examples of such devices are smart wheelchairs, artificial limbs, exoskeletons and dedicated interfaces which involve the replacement of impaired functions by means of advanced prostheses and orthoses to help them go about their day to day activities at home, office, and hospitals. The main motive of robotics in residential care which is also known as rehabilitation robotics is to completely or partially substitute the disabled or elderly user’s manipulative function by placing a robot arm between the user and the environment [2].

There have been so many developments in recent years from neurorehabilitation for patients with neuromuscular injuries or diseases to sensory therapy which enables patient relearn how to move in case of chronic or cerebral stroke patients. An example of such robots is the Massachusetts Institute of Technology (MIT) - Manus rehabilitation robot which is now commercially available. It provides so many functions which include assisting, resisting and stretching which are all based on real time response. One of the main features of this robot is that it can acquire data to quantify the recovery of the patients [4]. Figure 2 shows the InMotion 2.0 Shoulder Robot developed by MIT for intensive rehabilitation of patients with stroke or brain injuries; and with limited strength or movement in the upper extremities.

Figure 1. Shows the classification of robotics according to their application in medicine [2].
Personal care for disabled population is another area in which rehabilitation robotics application can be seen. The growth rate of disabled populations which includes those with physical and social disorders which may be developed from birth or age related, demands a growing need for personal care to provide mobile aids ranging from simple self-stabilizing canes for the visually impaired to intelligent/smart wheelchairs for physically disabled to increase mobility and accessibility for them to go about their normal daily activities independently in their homes. A sophisticated device that enables severely disabled to perform tasks like personal toiletry and getting in/out of bed are still in their early development stages. To fulfill the various requirements of the disabled population the Politecnico di Milano designed an autonomous wheelchair control system called (LURCH) which means Let Unleashed Robots Crawl the House.

The LURCH provides options for the user to choose from different autonomous and interfaces ranging from a touch screen, a joystick, an electromyography (EMG) interface and a brain-computer interface (BCI) which transmits the user’s intention by analyzing the user’s brain signals. Thus the LURCH system is not integrated with the wheelchair at the digital control bus stage but only relies on the simulation signals from the joystick in analogue domain [5]. In Prosthetics the National Health Interview Survey indicated that the people using Prosthetics are well over 3.5 million in the U.S.A and the amount is expected to double up to 7.3 million by 2020. Prosthetics are devices used in assisting, supporting a weak or non-functional joint, muscle, limb or substituting for a missing human body part. The use of Prosthetics dates back as early as ancient Egyptians time where a mummy's big toe had been amputated during his life time and replaced with a well-crafted wooden toe. From then till now massive development has taken place from the development of the Belgrade hand [16] and the UTAH arm [17] in the early 60's and 70's to the C-leg and I-limb which is microprocessor controlled. A good illustration and summary of rehabilitation robotics from the late 60's to early part of 21st century can be found in the commentary by Hillman [15].

3. Surgical robotics
Surgical Robotics can be classified in two main areas; those based on "Image-guidance and minimally invasive". Most surgical robots today are being controlled directly by a surgeon mostly in a teleoperation mode in which human controls the input device and on the patient end robot follows the input. One of the main goal of that partnership between surgeons and robots exploit the capabilities of both performing the task better than either can perform alone [5]. Image-guided surgery includes orthopaedic surgery, spine surgery, neuro-surgery, reconstructive/plastic surgery and ORL surgery. The mode of operation behind image-guided surgery is the use of a robot workstation integrated into the surgical suite where some of the parts of the patient's body are fixed by means of suitable fittings. A very representative example of image guided surgery is the RoboDoc in knee and hip surgery developed by da Vinci systems.
Da Vinci is a teleoperated system in which the surgeon controls the surgical robot at a console and the robot arms follow those motions. Da Vinci consists of three arms to hold two tools and an endoscope which is mounted to a single bedside cart. The grasper tool has 2 DOF inside the patient to be operated on while the EndoWrist shown in figure 3 below enhances the articulation and makes it go about complex manipulations with ease. The console incorporates separate video screen for each eye to display 3D video from the 3D endoscope. The operational end of the tools is mapped to the surgeon's hands to provide more detailed control [14].

![Da Vinci Surgical System](image)

**Figure 3.** Shows the da Vinci Surgical System [22].

4. Current research and development in surgical robots
This section of the review paper focuses on the current research in surgical robots with the view that such research will lead to new capabilities of future commercial systems.

4.1. Neuro Arm and MrBot
One of such is NeuroArm and MrBot which are researching on improved MR-compactible robots. The MrBot developed by Johns Hopkins University is designed for (Magnetic Resonance Imagers) MRI-guided access of the prostate gland, it consists of a parallel linkage arm with a novel pneumatic stepper motor actuator to reduce the MR interference. While the NeuroArm robot which is being developed by University of Calgary in collaboration with MacDonald Dettwiler and Associates and IMRIS is an MRI-guided two- arm with 3 DoF neuro-surgical robot with a piezoelectric motor actuator [10, 11]. Figure 4 and figure 5 show the pictures of NeuroArm and MrBot.

![NeuroArm](image)

**Figure 4.** NeuroArm [23].

![MrBot](image)

**Figure 5.** MrBot [23].
4.2. HeartLander
HeartLander is a heart surgical robot; it is basically a minimally invasive robot which uses suction to move around the surface of the heart. It provides a better alternative to closed-chest, beating heart endoscopic surgery and endocardial approaches. It is used for intrapericardial drug delivery, cell transplants etc. [12]. Table 1 shows how the robot works under the physician control and figure 6 shows the design of HeartLander.

Table 1. Robot working activity under physician control [24].

|   |   |
|---|---|
| 1 | Enters the chest through an incision below the sternum |
| 2 | Adheres to the surface of the heart |
| 3 | Travels to the desired location |
| 4 | Administers the therapy |

Figure 6. The design of HeartLander [24]

4.3. Amadeus
Titan Medical Inc. is currently developing Amadeus. Amadeus is a four-armed laparoscopic surgical robot system which uses a snakelike multiarticulating arm for improved manoeuvrability, and the system is being designed to accommodate teleoperation for long-distance surgery. The first human trial operation using Amadeus is planned for late 2013 [25]. The elements that make up the Amadeus Robotic Surgical System is shown in Table 2, while figure 7 shows the Amadeus Robotic Surgical System by Titan Medical Inc.

Table 2. Other elements that make up the Amadeus Robotic Surgical System [25].

| Multi articulating arms                  | To enable obstacle avoidance in the body. Give multiple approach paths to a surgical target. Free the arms from fulcrum constraint at the body port site. |
|-----------------------------------------|------------------------------------------------------------------------------------------------|
| Communications                         | To allow the world’s expert surgeons to be in the room with the patient. Increase access to specialized care. Save transportation cost. |
| Enhanced vision systems                | Allow surgeons to see anatomy with better resolution and more viewing angle. |
| Force feedback                         | To let surgeons know how hard they are pulling on tissues, sutures or other structures for the first time. |
4.4. Raven II
Raven II developed by the University Of Washington and University of California Santa Cruz is an academic surgical robot which is used to research into endoscopic telesurgery. It was designed to maximize surgical performance based clinical measurements [13]. The surgical robot consists of 7 degree of freedom each cable driven with two patient side arms. The arms are smaller, lighter and less expensive compared to the current robots for laparoscopy. Teleoperation experiments have been carried out with Raven II using data transmission through an unmanned aircraft. In early 2012, five surgical robotics where provided to different research labs to spur collaboration and further developmental efforts [13]. Figure 8 shows the picture of Raven II Surgical Robots.

5. Conclusion
From the introduction of this paper, it is obvious that there is a huge demand and advantages of using medical robots. The use of robots in medical, agricultural and construction field combined are still not on par when compared to the use of robots in manufacturing industries. In medical community for example, the reasons why robots did not gain immediate acceptance is both psychological in the sense that robots may be perceived as "competitors" by physicians and as potentially dangerous exotic machines by patients but presently the surgical robots are now rarely designed to replace a member of...
the surgical team but to augment the medical teams by imparting superhuman capabilities such as accuracy that will otherwise be physically impossible with humans alone. Although there has been so much development from rehabilitation robotics to surgical robotics; where telemonitoring and telepresence surgery is employed which provides global access to medical/health care but there is still much to be done in terms of advancement and improvement for example in telepresence which allows a surgeon at one location to operate on a patient at a different location by employing an integrated surgical robotic system, the issue of speed of transfer of information from operator to robot and the lag time from operator to execution time is a major issue. In addition economic issues such as cost-effectiveness of medical robotics and ethical issues such as patient privacy have to be addressed in the future.

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