Review Article

Understanding robotics in rehabilitation

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Robotics is penetrating into the realm of rehabilitation very slowly and is seen to be a "future technology." The main reason is its emergence as a viable alternative solution to ease functional difficulties of persons with disabilities. Current rehabilitation approaches like cost containment and shorter hospital stay have truly deviated from our earlier rehabilitation attempts to restore lost motor abilities in the paretic limb and teaching of compensatory techniques to improve functional skills. However, potential users as well as most rehabilitation experts do not know the actual capabilities of robots or are unaware of the existence of rehabilitation robots.

The term "robot", a Czech word for a slave was first used in Capek's "Rossums Universal Robots" in the 1920's[1]. Since then, there has been lots of progress made in robotics. Presently there are more than 750000 robots in industrial use. The Robot Institute of America defined a robot as "a re-programmable, multifunctional manipulator designed to move material, parts, tools or specialised devices through variable programmed motions for the performance of a variety of tasks". Rehabilitation robotics has been defined as a special branch of robotics which focuses on machines that can be used to help people recover from severe physical trauma or assist them in the activities of daily living.

The progress in surgical and medical robotics has been very dramatic with the invention of robots for high profile neurosurgery, cardiac surgery, orthopaedic surgery and endoscopic surgeries.

The first application of robotic technology to rehabilitation at CASE Institute of Technology was recorded in the early 1960's when the integrated circuit had just been invented[2]. The first International Conference on Rehabilitation Robotics was held in 1990 at AI DuPont Institute, Delaware. The use of robots in rehabilitation has been studied in major areas of assistive devices, mobility, prosthetics and orthotics, education, communication and robot mediated therapy. Therefore, rehabilitation robots fall into two main classes: robots designed to compensate for lost skills, including manipulation, self-feeding, or mobility; and those developed to remediate or retrain lost motor function after a disabling event such as stroke. Most of the recent studies are on uses of robotics in the management of stroke patients.

For convenience, the use of robotics in rehabilitation can be discussed under the following headings:

Assistive :

The potential uses of assistive robots in rehabilitation may be identified as follows[3];

(i) Eating and drinking
(ii) Personal hygiene – washing, shaving and applying make up
(iii) Work and leisure – computer use, equipment such as hi-fi and video systems, games
(iv) Mobility – opening doors and windows
(v) Reaching – up to shelves, down to the floor

Robots may be grouped into three based on the mobility of the device.

(i) Devices that operate in a fixed site (e.g, Handy I, DeVAR IV)
(ii) Devices that can be moved around from one location to another (e.g, Wessex robot, KARES II robot system)
(iii) Devices that are attached to a wheelchair (eg, Manus, Raptor)

A mobile assistive robot can be instructed to fetch an item or to place a book on the shelf. Different media (human machine interface device) can be used to

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communicate such command to the controlling computer. The chosen solution may be a combination of different media like natural language speech recognition, joystick, some form of scanned system etc and will also depend on the abilities of the user.

Mobility

Automatic guided vehicle (AGV), also referred to as smart wheelchair, is a power wheelchair whose mobility is controlled by the sensors which can detect objects in the environment. This technology has a great potential in addressing the mobility needs of the persons with wide range of disabilities. DX wheelchair bus system, omni-directional wheelchair and iBOT wheelchair are few examples of AGV.

iBOT wheelchair may be driven in a conventional way with the gyroscopic sensors and processors allowing the chair to balance on two wheels or to climb stairs giving the much needed stability and security. MELDOG developed a mobility aid which would function the same way as a guide dog for a blind person by guiding them around the streets, downloading a basic map and using landmark sensors[4]. However, with the increasing miniaturisation of electronics and GPS positioning, it is very possible to develop a body worn device to minimise the mobility difficulties for disabled persons.

Prosthetics and orthotics has been closely associated with rehabilitation robotics[1]. There have been lots of work done on prosthetic arm and hand with minimal use of robotic technology. Utah artificial arm and dextrous hand developed by Jacobsen, Leverhulme hand and Southampton hands are important milestones in the development of functional hand. Robotic prostheses or orthoses may be powered or non-powered. Two main issues which are critical in powered prosthetics and orthotics are miniaturisation and adequacy of the power supply. Both issues are critical for a hand prosthesis, where the complete system has to fit within the outline of a human hand and the energy requirement is far greater. Presently, compressed CO_2 has also been used as a power supply besides electrical batteries.

Among non-powered prosthesis, Blatchford's intelligent knee prosthesis uses sensors to regulate the swing of the knee depending on the speed of walking.

Movement Therapy :

Robots can be used to replicate the exercise regime used by the physiotherapist. The use of robotics to provide movement therapy for the rehabilitation of patients following stroke has been an area of major growth within the rehabilitation robotics.

The following are the three main areas where robots are used for stroke rehabilitation[5];

(i) Passive mobilisation to maintain range of motion at the joints
(ii) Active assisted where robot assist the movement initiated by the patient
(iii) Active resisted where robot resist the movement generated by the patient

MIME system[6] used either active or passive mode or a bilateral mode where patient attempts to move both the affected and unaffected limbs. A similar MIT-Manus system[7] is available as commercial product. The robot seems to be as effective as conventional therapy though faster and earlier improvement was noted in the robotic group. Beyond stroke, robot arms are used in the rehabilitation of joints following surgery[8].

Education :

Robots can be used in the education of persons with physical and learning difficulties. The Cambridge University Educational (CUED) robot[9] with a vision recognition system allowed the child to interact with their environment in various ways ranging from dropping a toy brick onto a drum, to painting or playing board games. AnthroTronix developed telerehabilitation tools to motivate and integrate therapy, learning and play.

Communications :

Many of the physically disabled persons encounter difficulty to read a book, magazine or newspaper. Assistive robot makes difficult task like page turning possible.

Dexter hand[10], a finger spelling hand designed for hearing and vision impairments enables to input text, for example at a keyboard which is then converted to finger spelling by Dexter to communicate with another person who uses finger spelling.

Conclusion :

Though integration of robotic technology into rehabilitation practice is presumed to be a possible "future technology" to ease functional difficulties of persons with disabilities, its ultimate role is still controversial. However, it is believed that robotic systems provide some measurable benefits, but the magnitude of these benefits is still rather modest. Again, to holistically address limitations in the functions, activities and participation, the integration of novel technologies with conventional rehabilitation methods seems prudent.

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