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Introduction

This Special Issue on Robotics has been organized to provide a broad perspective on the uses of modern robotic technology in the rehabilitation of human disability, as well as new and valuable information to those researchers, consumers, and manufacturers who are forwarding developments in this area. Although science fiction writers and Hollywood producers have created a glamorous public notion of robot capabilities, the use of robotics in rehabilitation has been less sensational and more pragmatic, and has advanced through basic research and entrepreneurial energy.

In lieu of the dry standard definition, a robot may be described simply as a programmable machine that physically manipulates objects. In successful industrial applications, robots perform a small number of repetitive tasks with high accuracy and have little interaction with humans. In contrast, robots used in rehabilitation applications require close human-robot interaction and must be capable of performing a wide range of tasks in the relatively cluttered human environment.

A rehabilitation robot can be considered to be part of the same family as an upper limb prosthesis or orthosis, and, for this reason, is sometimes referred to as a telethesis. A telethesis is generally suitable for someone whose disability results in a severe limitation of manipulation ability, and the dysfunctional anatomy is normally intact. A discussion of the disability populations that would most likely benefit from robotic aids is provided in the first article of this issue, 'Demographics of Rehabilitation Robotics Users.'

A primary issue in rehabilitation uses of robots is the method through which the user controls the device to perform tasks. Approaches to control may be described in terms of two general categories, 'robot as assistant' and 'robot as extension.' The 'robot as assistant' approach provides the user with a set of high-level commands that may be issued. Through a computer program, the robot is equipped with information about the task, as well as the algorithms that cause the robot to move in the correct manner. Once a command, such as *move the straw to the cup*, is issued, the robot carries out the task while the user supervises the activity.

Practical implementations of the 'robot as assistant' control approach are normally executed as part of a dedicated workstation. A number of the articles in this issue describe use of robot workstations in educational and vocational activities. 'Classroom Applications of Educational Robots for Inclusive Teams of Students with and without Disabilities' describes work being carried out as part of a collaboration between the Department of Education at Ohio State University and the Applied Science and Engineering Laboratories of the University of Delaware and the A.I. DuPont Institute, which is examining the potential role of a robot in supporting science education of students with physical disabilities in mainstream classrooms.

Two papers are presented that discuss the use of robots in vocational accommodations. 'An Assessment Methodology and Its Application to a Robotic Vocational Assistive Device' describes a study performed by the Neil Squire Foundation in Vancouver, Canada, in which they evaluate the differences in productivity and required assistance from an attendant in an office environment

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with and without a robotic workstation. 'Robotic Vocational Accommodations in Manufacturing Jobs' describes research performed at the University of Cambridge, the goal of which has been to identify job criteria for successful implementation of robotic vocational accommodations for a wide range of job types. A further example of a vocational robotic application will appear in the next issue of *Technology and Disability*. This article entitled 'Engineering Reasonable Accommodation: The Delivery and Use of Assistive Technology in a Vocational Training Program.' discusses the use of DeVar, the Desktop Vocational Assistant Robot, in a vocational training program. DeVar was developed at the Veterans Administration Rehabilitation Research Center in Palo Alto, in conduction with the Center for Design Research of Stanford University.

In the 'robot as extension' control approach, robot movements are directly linked to a physical input of the user. Although recent research has been investigating 'robot as extension' options similar to those employed in the control of body-powered prosthetics and industrial teleoperators, the primary approach has been the use of keypad inputs, where a key on the pad controls either a single motor on the robot or a prescribed axis of movement in space. Although such an interface is easy to access, it is quite difficult and time-consuming to plan tasks of even moderate complexity.

Other broad uses of robotic devices are being explored in the field of rehabilitation. 'Consumer Criteria for an Arm Orthosis' describes research which is attempting to create a powered brace to support the limbs of those with progressive muscular diseases. Many of the issues in the design and control of a powered orthosis are similar to those of the 'robot as extension.' 'Robotic Devices for Physical Rehabilitation of Stroke Patients: Fundamental Requirements, Target Therapeutic Techniques, and Preliminary Work' discusses the potential uses of robot devices in the rehabilitation of stroke patients. In this application, the robot becomes a rehabilitation tool and is able to provide information about and adapt to the status of the patient.

Much effort has been expended in exploring the potential of robots in rehabilitation, but only minimal success has been achieved in the rehabilitation marketplace. Approximately 200 robot devices, similar to those described in the articles above, have been sold for rehabilitation uses. It may be said, however, that thousands of robots have already been sold as products in the rehabilitation market. Successful 'robots' include devices such as powered mechanical feeders and page-turners, of which a number of commercial models exist. These electromechanical devices are robots in that they are controlled by the user to manipulate objects, albeit in a narrowly defined environment.

The final three articles of the issue have been prepared by developers and manufacturers of the existing range of rehabilitation robotic products. Two commercial wheelchair-mountable robotic devices are currently available, both of which rely on the 'robot as extension' control approach. 'Manus: The Evolution of an Assistive Technology' describes the history and status of Manus, which was developed in the Netherlands by the TNO Institute of Applied Physics and the IRV, and is now being sold commercially by Exact Dynamics. 'Preliminary Evaluation of the Helping Hand Electro-mechanical Arm' discusses evaluation results of the Helping Hand, which is being manufactured by Kinetic Rehabilitation Instruments, Inc. of Hanover, Massachusetts.

Also included is 'Handy 1, A Robotic Aid to Independence for Severely Disabled People,' which describes a British commercial robotic feeding aid that has sold over one hundred units in Europe. The Handy 1 demonstrates an advantage that robotics offers over dedicated machines in that it may also be programmed to perform other tasks, such as assisting with personal grooming, painting and drawing, and application of make-up. The flexibility of this and other robotic aids represents the potential for their eventual commercial success.

In order for commercial acceptance to be achieved, researchers must continue to compile statistics showing that robots reduce the need for an assistant and provide users with greater independence and self-esteem. Rehabilitation robot manufacturers must introduce their products into the traditional marketing and reimbursement channels that are utilized by the consumer populations. Will robots become commonplace? If so, will this be the result of a revolutionary new product, or simply through common sense evolutionary development? It is more likely that small successes will lead to greater awareness and acceptance, and eventually will meet the expectations of researchers through commonplace acceptance in mainstream rehabilitation channels.

By no means does this Special Issue address all of the developments of rehabilitation robots in the world. Further information may be obtained from the proceedings of the Annual RESNA Conferences, through the February, 1995 Issue of the *IEEE Transactions on Rehabilitation Engineering*, and the December, 1993, issue of the journal, *Robotica*. The Rehabilitation Engineering Research Center on Rehabilitation Robotics at the Applied Science and Engineering Laboratories distributes the bi-annual *Rehabilitation Robotics Newsletter*, which serves as an additional reference.

In conclusion, this Special Issue is dedicated to the memory of Robin Jackson, who passed away last year. Through his guidance and leadership in the Department of Engineering at the University of Cambridge, Robin was instrumental in advancing the field of rehabilitation robotics. It was because of his character and friendly nature that Robin also created a sense of community among those working in this area. Robin will be missed, both as a colleague and as a friend, but his mark will continue to be made through those he has influenced.

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