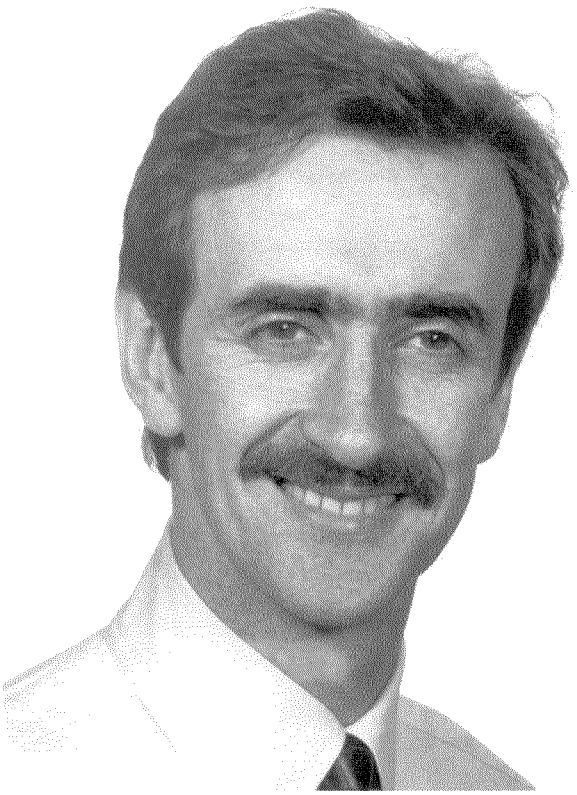
GUEST EDITORIAL

Rehabilitation Applications of Robotic Technology

Since Karel Capek's 1921 play *R.U.R.* (*Rossum's Universal Robots*) originated the name, robots have become a firmly entrenched icon of modern culture. The image of the robot as a "tin man" remains deeply rooted in the popular perception of these machines and may account for the preconceptions (and perhaps some anxiety) of patients and clinicians when first introduced to the concept of using robots to assist in rehabilitation. Of course, the present reality of rehabilitation robotics is very far from the capabilities implied by the "tin man" image (often to the relief of both patients and clinicians). One challenge of this rehabilitation technology is to find the right vision, an accurate picture of what can reasonably be expected of rehabilitation robotics. The papers collected in this single-topic issue may provide some indication of what is to come.

A perspective on the future of rehabilitation robotics may be gained by considering the several decades of research and development of industrial robotic applications. The 1980's opened with an almost boundless optimism about the future of industrial robotics. The high-flown hyperbole was matched by volumes of venture capital investment, as the potential value of this technology was seen to be high. That early enthusiasm has been somewhat tempered by experiences of the intervening decades. The potential value of industrial robotics remains high, but much of the potential is as yet unrealized. It turned out (perhaps predictably) that the particular application was a key factor in determining success. The application determined the market that in turn drove the technology innovation created to meet the specific needs of that application. By analogy, the future of rehabilitation robotics is likely to be determined by success in specific applications. The critical question is: What value is added? A practical way to answer this question is to try a technology and pay close attention to how it is used. One common theme of the papers in this single-topic issue is experience with people going through the rehabilitation process.



Neville Hogan, PhD
Professor of Mechanical Engineering
Professor of Brain and Cognitive Sciences
Director, Newman Laboratory for Biomechanics and Human Rehabilitation
Massachusetts Institute of Technology
Cambridge, MA 02139 USA

The idea of applying robotic technology to rehabilitation has a long and venerable history. Earlier research emphasized applications to assist persons with disabilities. Some of that work has resulted in devices that are now beginning the transition to commercially available products. As yet, the size and sustainability of the market for these products remains to be seen, but whatever the outcome, further refinement of these applications is arguably beyond the realm of research and for that reason, this

Journal of Rehabilitation Research and Development Vol. 37 No. 6 2000

class of applications is not emphasized here. (An excellent survey is available in the March 1995 issue of the *IEEE Transactions on Rehabilitation Engineering*.) The papers in this single-topic issue describe newer applications of robotic technology. The emphasis of the research has turned to supporting the process of rehabilitation and minimizing the impact of neuromotor dysfunction on quality of life.

As with industrial robotics, two different philosophies are evident in the work reported here. Early industrial robot applications emphasized controlling robot motion. For some applications (e.g., automobile spray-painting) that is the best approach, but more recent applications have recognized the importance of controlling forces and the dynamics of robot interaction with the objects it manipulates. The latter approach appears to be emerging as the method of choice for applications involving human interaction (e.g., minimally invasive surgery). Similarly, several of the approaches to robotic rehabilitation reported here attempt to control the motion of limb segments as a means of providing treatment; others attempt a more interactive approach. It is as yet unclear whether either approach is superior. Extrapolating from industrial experience suggests that both approaches may find successful application.

Cost effectiveness of robotic technologies is an important but thorny problem. A point sometimes overlooked is that the cost of technology used in research may have little bearing on the cost of the corresponding market product; a "low-technology" product may require "high-technology" research. Design, research, development, and evaluation should use the best tools available—the most sophisticated technology appropriate for the application. The cost of a product depends sensitively on the size of its market, but for the technologies described in these papers, the market has not yet been established, rendering cost predictions unreliable. There is ample historical precedent for this state of affairs: Many successful technologies were considered unpromising "orphans" at the outset. For example, airplanes were considered a rich man's hobby until World War I demonstrated their military potential. From a researcher's viewpoint it is clear that effectiveness must come before cost. A technology that works but is expensive is intrinsically more promising than one that's cheap but doesn't work. (Airplanes had to fly before their potential importance could be realized.) More important, cost effectiveness cannot be assessed until effectiveness has been demonstrated. The papers in this single-topic issue address effectiveness to varying degrees, but clearly much remains to be done.

Examining the results reported in these papers, it is clear that even the most successful technologies have, as yet, shown only modest impact on functional recovery. However, it would be unwise to underestimate the value of robot-aided rehabilitation based on these results because so much remains to be done. The papers here address several key functions of the arms and legs, but there remains ample room to create new technologies to treat a wider range of limb segments and functional activities. Even if no new devices are forthcoming, the software to take full advantage of the capabilities of what presently exists remains vastly underdeveloped.

Nevertheless, the greatest impact of the application of robotics to rehabilitation will probably not be the devices themselves, but their effect on the infrastructure supporting rehabilitation. Using robots to assist the rehabilitation process will inevitably provide more precise, objective, and detailed data on what actually happens during recovery. That will in turn lead to a better understanding of the key biomechanical and neurological (and perhaps even psychological) factors required for successful rehabilitation. A better understanding of the biology of recovery will lead to better ideas of how technology can help rehabilitation. It promises to be an exciting future.

Neville Hogan, PhD