

MEDICAL ROBOTS

To integrate and to empower: Robots for rehabilitation and assistance

When Oscar Pistorius (often known as “Blade Runner”) became the first amputee sprinter to compete with able-bodied athletes for the men’s 400 m at the 2012 Olympics in London, the achievement raised the question of whether disabled athletes would ever out-compete their able-bodied counterparts. Now the German long jumper Markus Rehm, who uses a carbon-fibre bladed prosthesis for his amputated right leg and is outperforming more and more able-bodied athletes, is the notion of “cyborg,” coined over 50 years ago to describe part machine and part human, becoming a reality?

Those of us working in the field of robotics and prosthesis are more cautious, because what has been demonstrated represents years of incremental advances in biomechanics and prosthesis design. Human biomechanics is only one aspect that the research community is trying to address—extending human sensory experience, physicality, and cognition are fundamental advances that

we strive to achieve. One big hurdle is whether research findings can be translated into safe, effective, and—more importantly—accessible technologies that benefit the population at large. Between disabilities arising from health conditions and those caused by trauma, there is a growing need for devices to restore functionality.

The robotics community has played a key role in developing rehabilitation robots, wearable devices, and artificial limbs that restore and further extend the capabilities of humans. Last year, 66 teams and around 400 contestants from different countries participated in a rather different strength and endurance competition in Zurich, Switzerland: the Cybathlon (*1*). This is a new kind of contest to promote the development of assistive technologies. It allows powered assistance with bionic and cybernetic enhancements, beyond what is permitted by Paralympic Games. At the Cybathlon, people with physical disabilities compete against each other at tasks of daily life with the aid of advanced assistive devices, including robotic technologies. This contrasts with the Paralympics, where



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parathletes aim to achieve maximum performance, and is an important step in ensuring that physical disability does not affect normal ways of living and become a barrier to social integration, independence, and productivity.

Exoskeletons are wearable mechatronic systems incorporating physical interfaces for direct transfer of mechanical power, control, and exchange of perceptual information. They are used for recovering musculoskeletal function or as prosthetics for daily assistance, providing dexterity, natural mobility, and sensation to missing or paralyzed limbs. Upper and lower limb robotic exoskeletons are particularly helpful for people with disabilities and/or limb weakness or injury.

Current rehabilitation technologies include therapy robots for both physical and cognitive development and assistive robots for augmenting physical and social interaction. Some of the milestones in rehabilitation robotics can be applied to physical and occupational therapy, including the design of assist-as-needed controllers, also known as patient-cooperative strategies, as well as new Virtual Reality (VR) techniques for increasing patient mental participation and promoting the effect of neuroplasticity.

For many, physical independence is closely coupled with dignity and social inclusion, and the potential for supportive new technologies is limitless. Given the demographic shift associated with the aging population and increasing numbers of elderly living alone, assistive technologies need to consider not only physical but also perceptual and cognitive augmentation. More importantly, technologies need to be embodied in a way that carries no stigma. In this regard, collaborative work among engineering, clinical, therapeutic, and medical device manufacturing communities is key to enhancing the understanding of musculoskeletal morphology, perception, and neural control that will lead to analogous improvements in the design of smart, economical, stable, low-mass, as well as biologically or perceptually integrated assistive and rehabilitation devices. Other issues include quantitative assessment of motor performance and home-based programs.

This issue of *Science Robotics* includes studies of selective motor adaptation with robot-induced perturbations of human walking (2) and myoneural interface for prosthetic control (3). We also include a follow-on study of the soft exosuit (4) by Walsh and team on a different embodiment for assessing its effect on the metabolic cost of running (5). There is a large community behind the development of rehabilitation and assistive robots, and we are making big strides in technical achievements. Key challenges being addressed include mechatronic design with lightweight materials and low-power, miniaturized driving electronics combined with new actuation schemes such as artificial muscle [e.g., electroactive polymers (EAP) and ion-

ic EAP], Series Elastic Actuators (SEAs), and Variable Stiffness Actuators (VSAs); neural control signal interfacing and extraction of intent; redundant safety mechanisms and backdrivable system to reduce reflected motor inertia; and device design, cosmesis, comfort, and user acceptance. The study by Srinivasan *et al.* (3) is an example of tissue interfaces that connect the biological body to the machine, leveraging the advances in tissue implants and neuroprostheses, with information exchange not only at the mechanical level but also via chemical, electrical, and optical channels. Soft robotic technologies are also emerging as an attractive option for future applications in rehabilitation.

There needs to be a debate on the future evolution of technologies as the pace of robotics and AI is accelerating. It seems certain that future assistive technologies will not only compensate for human disability but also drive human capacities beyond our innate physiological levels. The associated transformative influence will bring on broad social, political, and economic issues. In a recent article in *National Geographic* (6), Max analyzed the evolution of human traits and technology versus natural selection, as well as the impact of technology such as embryo selection on our future generations. The conclusion expresses mixed feelings: “Our lives now are only partly biological, with no clear split between the organic and the technological, the carbon and the silicon. We may not know yet where we’re going, but we’ve already left where we’ve been.”

– Guang-Zhong Yang, Robert Riener, Paolo Dario

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