INTELLIGENT ARTIFICIAL LIMBS

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Alberta-based machine learning research is paving the way for more intelligent prostheses and better quality of life for Canadian amputees.

Today it is now possible to acquire and store massive amounts of information through new microdevices that promise to capture real-time information from our muscles, our blood, and even our brain. Similarly, biomedical technology has developed an impressive capacity including ultra-dexterous surgical robots and microelectrodes that could someday stimulate thousands of dormant neurons in the spines of paraplegic patients. We are witnessing a revolution in both large-scale systems and personalized medical devices.

However, it will be impossible to access the full potential of next-generation biomedical innovations without corresponding developments in information processing. Now, more than ever, we are in need of new information technologies to integrate sensory data with computational systems. This is the realm of machine intelligence.

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A USER CAN QUICKLY TEACH A MACHINE LEARNING SYSTEM TO CONTROL THE MULTIPLE JOINTS OF A ROBOTIC ARM—ALL WITHOUT NEEDING PRIOR TECHNICAL KNOWLEDGE ABOUT THE USER OR THE ROBOT LIMB.

LIMBS THAT LEARN

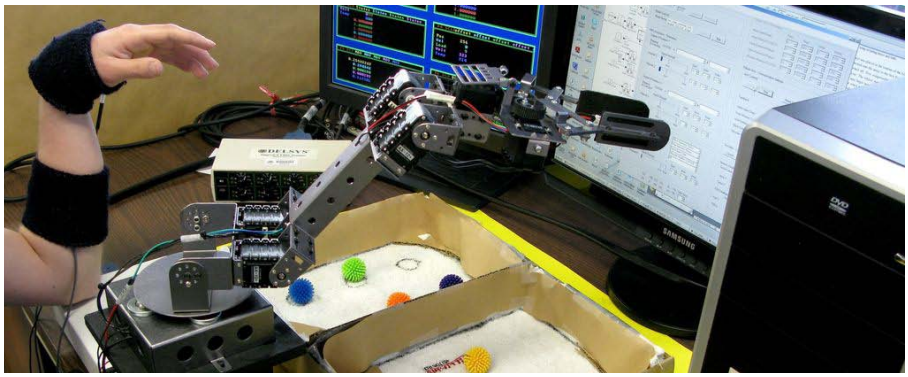
Artificial limbs are getting smarter. They need to. Recent surveys of prosthesis users highlight the need for improved limb capabilities, better sensory feedback, and more intuitive control over prosthetic devices. These issues are not unique to artificial limbs. As devices become more advanced, natural control by a human user becomes increasingly more difficult. For artificial limbs, the principal challenge is connecting a large and diverse set of signals recorded from a unique human body to a large set of control commands for a robotic limb. What's more, this complex mapping must be done in real time—tens, hundreds, or thousands of times a second.

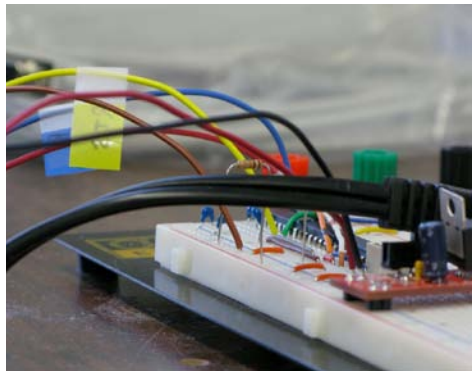
Work to address these challenges is underway at the Alberta Innovates Centre for Machine Learning (AICML). AICML's Adaptive Prosthetics Project is pursuing methods that let artificial limbs adapt to individual amputees. The project has evolved in close partnership with collaborators from the University of Alberta's Faculty of Rehabilitation Medicine, the Faculty of Engineering, the Centre for Neuroscience, and Edmonton's Glenrose Rehabilitation Hospital. The interdisciplinary nature of researchers, engineers, and clinicians working together has been critically successful in moving the project forward. The collaboration addresses the mechanics of learning and translating this knowledge to clinical applications.

The goal is to develop artificial limbs that learn and adapt to the needs of their users. Enhanced functions will be based on shared effort where the robot appendage uses learned data to extend an amputee's abilities. Our approach is unique by the way the system learns; improvements occur during real-time interactions between a user and the artificial limb. Numerous predictions are made in parallel with each individual prediction or control decision being updated hundreds of times a second. This provides the ability to adapt – the limb builds up knowledge about the user's needs and modifies this knowledge over time through use.

A recent study by our group showed that a prediction-based control system, as learned and updated online, was able to dramatically simplify a complex limb control interface. These benefits extend beyond natural intuitive control. Anticipating future events has the added potential to improve safety; for example, if a limb controller can predict when a cup of hot coffee will slip into an amputee's lap, it can adapt its grip to prevent the spill.

Machine learning can also enable patients to improve how their limbs function in their natural environment. It may be possible for an amputee to someday train their artificial limb much like they would a canine companion. Our group has found that, by providing a signal of approval or disapproval, a user can quickly teach a machine learning system to control the multiple joints of a robotic arm – with minimal training and no prior technical knowledge.





While it will be a few years before these innovations see routine clinical use, it is clear that machine intelligence holds great promise for improving the lives of amputees. Tests with amputees are ongoing, paving the way for artificial limbs that replicate – and someday perhaps even exceed – the functioning and feedback from a patient's biological limb.

LOOKING FORWARD: SMART REHABILITATION AND HEALTHCARE

Machine learning makes it possible for assistive medical devices to adapt and change in significant ways during real-time use. This enables devices that are more robust, less likely to fail, and can adapt to the lives and needs of individual patients.

While current research promises to benefit future amputees, the idea of patient-specific adaptation has far-reaching implications for healthcare systems in Alberta and beyond. Within the realm of patient care and rehabilitation, adaptive forms of machine intelligence play an important role in the development of advanced wheelchairs, surgical robots, and smart homes for the elderly. Other areas of near-term impact include rapid disease testing and better support for remote or at-home treatment.

Alberta has internationally recognized expertise in machine learning; a technology that is becoming increasingly accessible for commercial and social benefit. As a province, we are well positioned to make this a reality; it's time to put our machine intelligence to the test. Artificial intelligence and machine learning may be the magic bullet that helps lower healthcare costs and wait times while improving outcomes. Our research brings machine learning technology into routine use by Canadian amputees.

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