Bionic leg is controlled by brain power

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The act of walking may not seem like a feat of agility, balance, strength and brainpower. But lose a leg, as Zac Vawter did after a motorcycle accident in 2009, and you will appreciate the myriad calculations that go into putting one foot in front of the other.

Taking on the challenge, a team of software and biomedical engineers, neuroscientists, surgeons and prosthetists has designed a prosthetic limb that can reproduce a full repertoire of ambulatory tricks by communicating seamlessly with Vawter's brain.

A report published Wednesday in the *New England Journal of Medicine* describes how the team fit Vawter with a prosthetic leg that has learned - with the help of a computer and some electrodes - to read his intentions from a bundle of nerves that end above his missing knee.

For the roughly 1 million Americans who have lost a leg or part of one due to injury or disease, Vawter and his robotic leg offer the hope that future prosthetics might return the feel of a natural gait, kicking a soccer ball or climbing into a car without hoisting an inert artificial limb into the vehicle.

Vawter's prosthetic is a marvel of 21-st century engineering. But it is Vawter's ability to control the prosthetic with his thoughts that makes the latest case remarkable. If he wants his artificial toes to curl toward him, or his artificial ankle to shift so he can walk down a ramp, all he has to do is imagine such movements.

The work was done at the Rehabilitation Institute of Chicago under an $8 million grant from the Army. The armed forces hope to apply findings from such studies to the care of about 1,200 service personnel who have lost a lower limb in Iraq and Afghanistan.

"We want to restore full capabilities" to people who have lost a lower limb, said Levi J. Hargrove, lead author of the new report. "While we're focused and committed to developing this system for our wounded warriors, we're very much thinking of this other, much larger population that could benefit as well."

The report describes advances across a wide range of disciplines: in orthopedic and peripheral nerve surgery, neuroscience, and the application of pattern-recognition software to the field of prosthetics.

Weighing just over 10 pounds, the leg has two independent engines powering movement in the ankle and knee. And it bristles with sensors, including an accelerometer and gyroscope, each capable of detecting and measuring movement in three dimensions.

Most prosthetics in use today require the physical turn of a key to transition from one movement to another. But with the robotic leg, those transitions are effortless, Vawter said.

"With this leg, it just flows," said the 32-year-old software engineer, who spends most of his days using a typical prosthetic but travels to Chicago several times a year from his home in Yelm, Wash. "The control system is very intuitive. There isn't anything special I have to do to make it work right."

Before Vawter could strap on the bionic lower limb, engineers in Chicago had to "teach" the prosthetic how to read his motor intentions from tiny muscle contractions in his right thigh.

At the institute's Center for Bionic Medicine, Vawter spent countless hours with his thigh wired up with electrodes, imagining making certain movements on command with his missing knee, ankle and foot.

Using pattern-recognition software, engineers discerned, distilled and digitized those recorded electrical signals to catalog an entire repertoire of movements. The prosthetic could thus be programmed to recognize the subtlest contraction of a muscle in Vawter's thigh as a specific motor command.

Given surgical practices still in wide use, the prospects for such a connection between a patient's prosthetic and his or her peripheral nerves are generally dim. In most amputations, the nerves in the thigh are left to languish or die.

Dr. Todd Kuiken, a neurosurgeon at the rehabilitation institute, pioneered a practice called "reinervation" of nerves severed by amputation, and Vawter's orthopedic surgeon at the University of Washington Medical Center was trained to conduct the delicate operation. Dr. Douglas Smith rewired the severed nerves to control some of the muscles in Vawter's thigh that would be used less frequently in the absence of his lower leg.

Within a few months of the amputation, those nerves had recovered from the shock of the injury and begun to regenerate and carry electrical impulses. When Vawter thought about flexing his right foot in a particular way, the rerouted nerve endings would consistently cause a distinctive contraction in his hamstring. When he pondered how he would position his foot on a stair step and ready it for the weight of his body, the muscle contraction would be elsewhere - but equally consistent.

Compared with prosthetics that were not able to "read" the intent of their wearers, the robotic leg programmed to follow Vawter's commands reduced the kinds of errors that cause unnatural movements, discomfort and falls by as much as 44 percent, according to the New England Journal of Medicine report.

Vawter said he had "fallen down a whole bunch of times" while wearing his everyday prosthetic, but not once while moving around on his bionic leg.

He said he could move a lot faster too - which would be helpful for keeping up with his 5-year-old son and 3-year-old daughter. But first, Vawter added, he needs to persuade Hargrove's team to let him wear it home.