Robots Help Stroke Patients Regain Mobility

For stroke and spinal-cord injury patients, regaining the ability to walk can seem like an unreachable goal. But robotic devices being developed in the UD-ME Mechanical Systems Laboratory may bring this dream closer to reality for some patients.

A research group led by Professor Sunil K. Agrawal is developing a variety of exoskeletons for gait assistance and training of the movement impaired. The current group includes ME doctoral students Sai K. Banala and Vivek Sangwan, as well as Prof. John Scholz and members of his group from UD's Department of Physical Therapy (PT).

The research is funded primarily by the National Institutes of Health through a Bioengineering Partnership Grant and by the National Institute on Disability and Rehabilitation Research through a grant to a team led by the Rehabilitation Institute of Chicago.

Over the past five years, the work has resulted in the development of three lower-extremity exoskeletons for neuro-motor training. The first is known as a gravity balancing orthosis, or GBO, while the other two are referred to by the nicknames ALEX (actively driven leg exoskeleton) and SUE (swing-assist un-motorized exoskeleton).

"Each device has a unique design principle targeted for a specific population group, while addressing the issue of providing a flexible motor-learning environment," Agrawal says. "All three of them are designed for use on a treadmill equipped with a video monitor to provide the user with visual feedback on his or her gait motion through sensors on the exoskeletons."

GBO is an un-motorized exoskeleton that can alter the level of gravity at the knee and hip joints during motion. Agrawal explains that gravity plays an important role in human movement by assisting, or resisting, the motion of a joint such as the hip or knee over different parts of the leg swing. With an orthosis that alters gravity at the joints, the joints can swing through a larger range of motion for the same human-applied joint forces.

"As a result," says Agrawal, "this device enables a person with a weak musculature or poor motor control to gradually improve his or her gait and strength as the percentage of gravity assistance is reduced during training. And the GBO is tunable to the geometry and inertia of a specific human subject to achieve the desired level of gravity balancing."

So far, the device has been tested on healthy control subjects as well as on stroke patients with hemiparesis—partial paralysis affecting one side of the body, which is a typical result of stroke. The data show improved range of motion for the stroke patients with the use of GBO, but the most striking results were obtained with a chronic stroke patient who volunteered for training to determine the long-term training effects of the device. Agrawal explains that the term chronic as applied to stroke patients generally refers to those who are past the critical window of time when the brain can be retrained to restore lost functionality.

Surprisingly, it was found that this patient not only improved during training but actually continued to improve after the training regimen was over. "The improvement was reflected in all aspects of his performance," Agrawal says, including gait symmetry, speed, weight bearing, and range of motion."

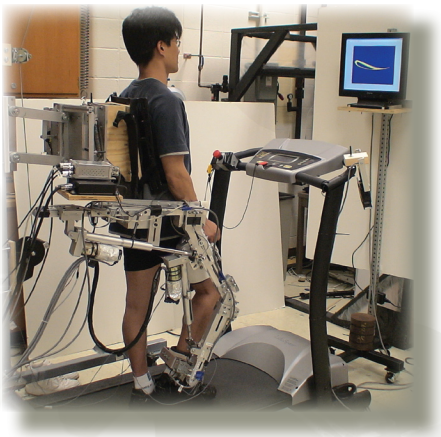
"This suggests that his brain had been triggered and that the effects of the training were still ongoing even though he was no longer using the machine. Although these results were obtained with just one subject, we are very encouraged by this outcome."

In contrast to GBO, which is passive, ALEX features motors at the hip and knee to supplement what the human subject can't do to execute a certain gait pattern. With this device, the desired trajectory of the foot during walking is defined by a tube. The controller guides the foot back into the tube if it deviates outside. So far, ALEX has been tested only on healthy subjects, but it has demonstrated success in training them to walk differently from their natural gait through selective control. One remarkable result found was that in about 45 minutes of training with ALEX, a healthy person can be taught to walk in a significantly altered gait.

ALEX is now being tested with a larger sample of subjects. "What we're learning," says Agrawal, "is that there is a fair amount of plasticity in the human brain that enables it to be trained with a force-field environment. We believe that there is great potential for gait retraining using these robotic tools, but what we've learned so far is on healthy subjects. We won't know about the effects of these exoskeletons on stroke victims until we try these."

The third device, SUE, is designed for use with victims of spinal cord injuries, where the problem is weak musculature that prevents the legs from swinging correctly. In contrast to GBO and ALEX, SUE is not attached to a walker. The device, which is un-motorized, lightweight, and portable, exploits the propulsive force of springs at the hip and knee to aid the patient.

"The idea here is to harness the energy from the treadmill to help swing the legs," Agrawal says. "The movement charges the springs, and the energy is then released to propel the patient forward." SUE has been tested on a single healthy subject to show how the springs can be tuned to the needs of the individual patient.

"We believe that devices like GBO and ALEX can make a substantial difference in future gait training of patients suffering from stroke, while exoskeletons such as SUE and ALEX can impact training of spinal cord injury patients," Agrawal says. "Rehabilitation using such devices reduces the number of rehab personnel needed, and repetitive and task-specific gait training can be provided more easily than with conventional therapies. The visual feedback provided by the monitor also engages the patient more actively in his or her recovery."

For Agrawal, there is almost no limit to the potential of robotic assistance for disabilities. His research group has built novel designs for ankle orthoses and neutrally balanced "sit-to-stand devices" that can be used to assist and train the elderly in getting up from a chair. He is currently investigating new designs for upper-arm exoskeletons. "Biomedical robotics is evolving to be a major theme for our lab," he says.