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No Iron Man suits yet, but CMU is making progress with exoskeleton technology

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By David Templeton / Pittsburgh Post-Gazette

Science can draw inspiration from science fiction, with exoskeletons long succeeding in cinema to make villains more threatening and superheroes better at saving worlds.

Returning to reality, exoskeleton technology — devices outside the body that may improve physical activity and energy efficiency — is not yet able to turn humans into Iron Man but continues progressing step by exoskeleton-assisted step.

Now, Carnegie Mellon University's latest study shows that a computer-controlled system it developed — essentially an ankle brace with a motor that helps flex the ankle to push off the ground more easily during walking — brings notable energy savings for those with normal walking ability.

Steven H. Collins, associate professor in CMU's Department of Mechanical Engineering, led the study, published last month in the journal Science.

The personalized means of walking support showed energy savings of 24 percent, as compared with walking when the system is worn but not operable. Energy savings of 14 percent were realized when compared with the energy expenditure of walking naturally.

"In this case the system alters its support of ankle movements in four areas — peak torque [rotation], timing of peak torque, and rise and fall times," according to a statement explaining the research. "Over the course of about one hour of walking, the system identifies which patterns of assistance help the person expend the least amount of energy."

A person may rotate his or her ankle more than others while walking. To develop a more personalized exoskeleton Juanjuan Zhang, the study's lead author, was the first person to apply an existing matrix (algorithm) to an assistive device, with "subtle changes to its pattern of assistance."

In the study, 11 volunteers on average experienced the 24 percent reduction in energy expenditure while walking. One volunteer wearing a more optimized exoskeleton on both ankles experienced a 33 percent reduction in energy expenditure. That suggests that users who continue using the device may adapt to it in time and realize additional energy savings.

"Exoskeletons can help enhance human abilities, for example, by allowing people to lift greater weight or expend less energy during rehabilitation," according to a statement about the study. "Yet, because each person exhibits unique natural movements, a one-size-fits-all exoskeleton approach will not work, research shows."

Walking on a treadmill with the device on the right calf and foot feels as though one's toe is pushing off much more dramatically. The computer-controlled apparatus, in fact, is pulling up on the heel of the foot, replacing the action of the calf muscle and Achilles tendon.

The system shows promise to assist able-bodied people such as soldiers and others who are on their feet all day long, said Rachel Jackson, a CMU post-doctoral fellow who participated in the study.

Prior to this study, the best method of selecting settings for exoskeleton control was hand-tuning — turning knobs until something works, said Kirby Witte, a Ph.D. student who served on the research team.

"Now we have a new method of systematically turning the controller to find the optimal settings for each user," she said. "By making the users walk in a wide range of settings, they are forced to interact with the device in new ways, which helps facilitate learning. This way both the person and the device adapt to each other."

Key exoskeletal advances include putting the person in the loop with computer-controlled robotics, allowing the system to adapt and improve any person's walking efficiency. The team used the existing algorithm to monitor a person's walking method and make adjustments to minimize energy expenditures, based on metabolic rates including carbon-dioxide levels in respiration.

A Simon Fraser University professor of biomedical physiology and kinesiology said the study, in which he wasn't involved, represents "an important advance in exoskeleton research for two main reasons."

"First, they convincingly demonstrate that for exoskeletons to be effective, they will have to be tuned for each user," Max Donelan said. "But this tuning is tricky because there are a huge number of possible parameter combinations, and one has to try to find combinations that work well.

"The second reason that this work is important is that the Collins team demonstrated efficient ways to search this parameter space and deliver customized exoskeleton controllers that differed substantially between users but worked exceptionally well for each."

Future systems will use sensory feedback to adapt the technology to each user

"If this were shoes instead of exoskeletons, the shoes would be able to change the thickness of the mid-sole, how stiff they are, how much energy they store, etc., while the person is wearing them and in response to how much it is helping the person," Mr. Donelan said.

In a final analysis, he added, "a big part of future exoskeleton research will be less about optimizing the exoskeleton and more about helping people learn to symbiotically partner with the technology," which is an important early accomplishment in the CMU study.

The current technology, weighing about 1½ pounds per foot, also holds promise in providing specialized support for those with walking disabilities due to strokes, paralysis, amputations or leg injuries, CMU researchers say.

The team, also including CMU Ph.D. student Katherine Poggensee, said it next will use the same algorithm to control more sophisticated exoskeleton devices being designed to assist ankles and knees of both legs.

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