WHAT'S NEXT

For Simpler Robots, a Step Forward

By ANNE EISENBERG
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WASHINGTON

THE moment of truth had come for the knee-high robot standing on its improvised runway at a hotel news conference.

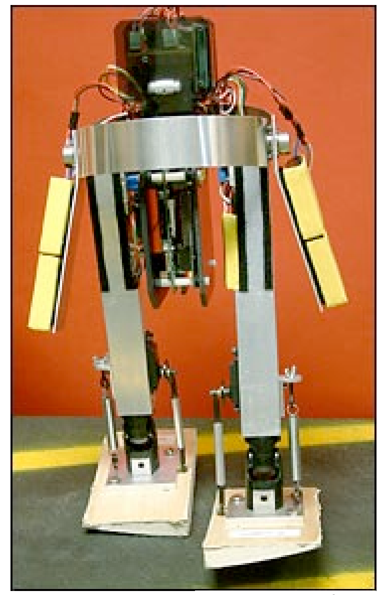
Reporters circled it, their microphones and cameras trained on the machine as it tried to start up. Then a curious 13-year-old boy who had joined the throng reached out, poked his fingers between the robot's metal legs and gave them an exploratory push.

With that, the robot, built at the Massachusetts Institute of Technology, lived up to its nickname, the Toddler. It rocked gently until the poking stopped, steadied itself and marched firmly across the level surface, a tabletop propped up on cinderblocks.

If two-legged robots are ever going to walk among people, they may look a lot like this sturdy machine and two others, introduced Feb. 17 on the makeshift catwalk at the annual meeting of the American Association for the Advancement of Science.

The robots - the others were built at Cornell and at Delft University of Technology in the Netherlands - are designed in a way that differs significantly from standard creations. One of the robots moves so efficiently that in the future it may be able to amble along for a day, not the 20 or 30 minutes most robots now manage without recharging or refueling.

"And our robots walk far more naturally," said Andy Ruina, a professor at Cornell who took one of the robots to the meeting and whose nephew Josh Bennett, of Chevy Chase, Md., did the unscripted poking.



Teresa Weirui Zhang
WALK THIS WAY - A knee-high robot designed at M.I.T. was one of three unveiled last week that walk far more naturally.

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The design may be important not only for future energy-saving robots, but also for intelligent prostheses - leg and foot replacements for amputees.

Dr. Ruina's robot and its companions from Delft and M.I.T. are descendants of some early ramp-walking machines, mechanical devices that have been around for a century. These contraptions - toys like waddling penguins and later two-legged robots - were not powered in any way. Instead, they relied on gravity and the mechanics of objects in motion to walk stably down sloping surfaces.

Modern versions of the machines, called passive-dynamic walkers, have been built for decades and have long been thought useful models of human locomotion, Dr. Ruina said. But in the past the machines were not able to walk on level ground.

Now the researchers from the three universities have shown that the classic passive-dynamic walking machines need not depend on gravitational power. Instead, they have put small motors on their robots and shown that they can walk on level ground. The robots' workings are described in detail in the journal Science.

"Our machines show that there is nothing special about gravity," said Russ Tedrake, a postdoctoral researcher at M.I.T.'s department of brain and cognitive sciences, and one of the Toddler's creators.

Unlike famous state-of-the-art walking robots like Honda's Asimo, which typically have complex control algorithms that demand extensive, real-time computation, the Cornell biped, as well as the Delft one, walk with simple control algorithms, Dr. Ruina said. "Our sensors detect ground contacts, and our only motor commands are on-off signals issued once per step," he said.

Perhaps to show how much the passive-dynamic robots depend on mechanics and not on electronic calculating power for their humanlike gait, the Delft robot has a blue bucket for a head, and the Cornell robot has an orange plastic bird attached to its head.

This less-is-more approach also applies to sensory feedback. The Cornell and Delft robots don't use sophisticated, real-time calculations or a lot of feedback as do other robots that continuously sense the angles of their joints, for example. "This suggests that human walking, too, might require only very simple controls," Dr. Ruina said. (The M.I.T. robot does incorporate sensory feedback as a means of learning how to walk.)

Michael J. Foster, director of the National Science Foundation division that supported some of the M.I.T. research, said the work demonstrated that complex objects could be controlled simply. The walking robot goes through complex motions, yet explicit computer control is not needed over every joint.

"Much of the control is given to us by the laws of physics rather than by our own efforts in programming," Dr. Foster said.

Marc Raibert, president of Boston Dynamics, a software engineering company that specializes in human simulation, said that the principles of passive-dynamic design would be important for future robot generations. "Every practical legged robot will incorporate these principles," he said. "If you make the mechanical structures right," for example, adjusting the mass and length of the upper and lower legs to mimic the natural dynamics of walking, "the legs do the right thing from physics."

In passive designs, he said, the mechanism has built into it the elements that let it move naturally. "This way we can avoid relying on the computer to have the knowledge of how something should move," he said.

Cornell's robot uses very little energy to walk forward, mainly because its passive-dynamic design emphasizes the natural interaction of gravity and inertia and minimizes the role of control and actuation. "Our robots use a 10th, a 20th or a 50th the energy of all other powered robots," Dr. Ruina said, depending on the robot and the way the energy is calculated. "We let mechanics take care of a lot of the motion, as opposed to

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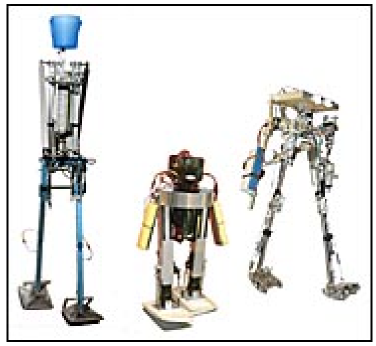

ON THE MOVE Robots, from left, from Delft University of Technology, M.I.T. and Cornell, were unveiled at the national meeting of the American Association for the Advancement of Science.

using motors to control all the joints in time."

The Cornell robot has a 12-volt battery on each arm to provide the energy the motor uses to power the ankles when they push off. Springs in the legs store the energy. Each arm is mechanically linked to the opposite leg.

Steve Collins, a doctoral student at the University of Michigan, designed the robot when he was an undergraduate working under the direction of Dr. Ruina. "As each leg swings forward," he said, "a small motor stretches a spring," which is released to provide a push. As the forward foot lands, a microchip tells the rear foot to push off.

It was important, Mr. Collins said, to bear in mind the way people move naturally. He said "the leg is analogous to a pendulum," which can either be let go to swing or driven exactly in a movement. He added, "We are letting the legs swing naturally."

Right now, the passive-dynamic robots move forward only, and they will need far more power, for example, to climb stairs.

In the future some of their principles may combine with those used in sophisticated robots in which every angle is controlled. "Perhaps we'll use natural dynamics for walking when there's no high energy requirement," Mr. Collins said. Even if the machines are not entirely built on passive-dynamic principles, the parts that are may lead to a reduction in cost.

Mr. Collins hopes to use the insights gained in building the Cornell robot in work he is doing on prostheses. With the National Science Foundation's support, he has started a company to develop a prosthetic foot. "The study of passive-dynamic models has given us insights into the way energy is used in walking," he said, in particular details of step-to-step transitions that have a large impact on the energy used in walking. "Based on these insights," he said, "we should be able to build prosthetic feet that require less energy, making it a lot easier to walk."

Dr. Tedrake of M.I.T. is not sure how passive-dynamic robots will play out in the future. "For now," he said, "we'd like to convince Japanese robotic makers to insert some of our ideas into their robots."

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