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ART AND MEDIA

When Art Blows the Fuse

GESCHÄFTSPARTNER Russland

THEMA Gastgeschenke weltweit

BASICS Risk Assessment

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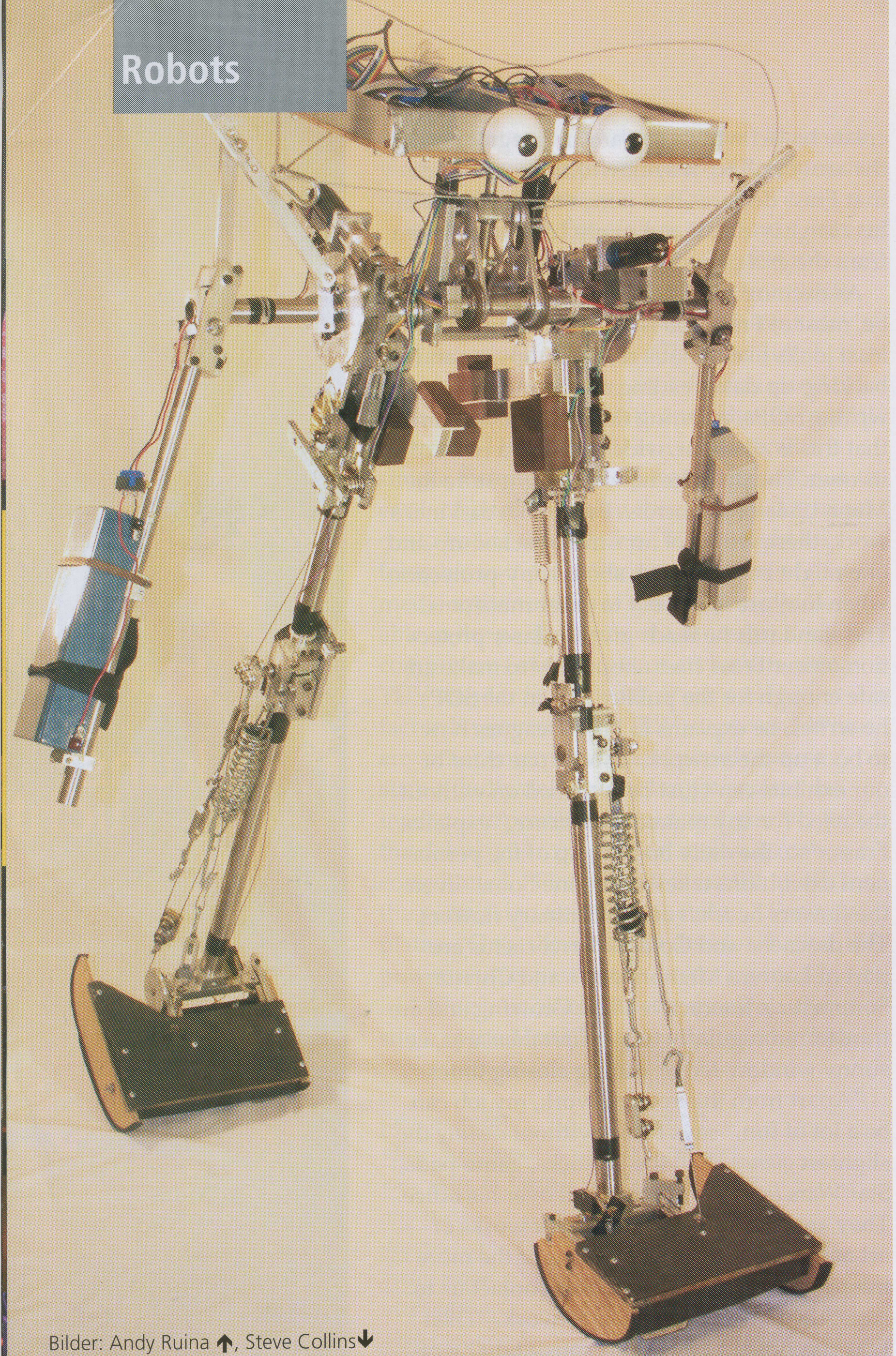
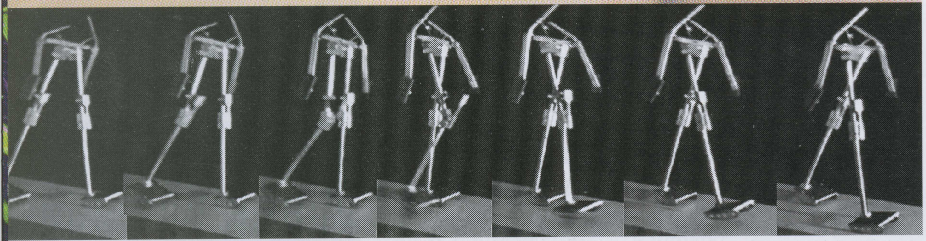


Bilder: Andy Ruina ↑, Steve Collins↓



The Cornell powered walker built by Steve Collins in Andy Ruina's lab has the greatest energyeconomy of any powered biped robot ever made. Obviously it doesn't take a lot of brain to walk.
Insert: Its predecessor, the passive-dynamic Robota, in motion.

Der Gang aufrecht gehender Roboter wirkt meist eckig und steif. Die Technik, mit der Forscher den Blechkameraden nun mehr Eleganz verleihen wollen, ist erstaunlich simpel – und spart zudem Energie.

Easy **Striders**

Traditional two-legged robots usually walk in a stiff and unnatural manner. New, surprisingly simple mechanics now give the humanoids a more elegant and also more efficient gait.

Before it moves, the robot doesn't look like much. A *rickety* bundle of metal plates and rods standing on two thin legs, it *resembles* a science fair project more than it does a major *advance* in technology. Only two small motors, some simple wiring at its *hip*, and two batteries weigh it down. Then, with a slight push off one *heel*, the robot steps forward and *ambles* along with a remarkably human gait.

This graceful stride differs radically from the stiff, unnatural motion of traditional two-legged robots. Not only that, says its co-creator Andy Ruina of Cornell University, but the walker uses a small *fraction* of the energy required by other two-legged machines, and it runs on a control system no more complex than that of a coffee machine. In fact, Ruina says, this *slender*, one-metre-tall robot, simple as it looks, introduces a new class of robotics based on the theory known as passive dynamics.

The principles of passive-dynamic walking emerged in the late 1980s, pioneered by *roboticist* Tad McGeer. While at Simon Fraser University in Burnaby, British Columbia, McGeer showed that a humanlike frame can walk itself down a *slope* without requiring muscles or motors. Unlike traditional robots, which *guzzle* energy by using motors to control every motion, McGeer's early passive-dynamic robots *relied* only *on* gravity and the natural swinging of their *limbs* to move forward.

"It's taken 10 to 15 years for McGeer's impact to really sink in," says *prosthetics* researcher Art Kuo of the University of Michigan in Ann Arbor. "It was such a novel thing." Now, he says a 'movement' has begun. Although McGeer's entirely passive robot could walk only downhill, a new generation of related, mostly passive, machines uses small motors to navigate flat ground. Some roboticists still see these robots as toys that can't handle complex tasks. Others see them as a step toward more sophisticated machines.

An increasing number of researchers say that the energy-efficient walkers are providing insight into human *locomotion*. Such devices may inspire new prosthetic-limb designs and eventually move robotics closer to science fiction's popular vision of *ambulatory* humanoids.

McGeer learned how to build robots by thinking about how planes fly. Trained as an aerospace engineer, he moved into robotics because he felt he'd missed taking part in the major advances that had transformed flight technology in the 1950s and 1960s. "For me, walking machines were an unexpected *diversion*," he says.

McGeer became interested in robot locomotion after some of his colleagues at Simon Fraser University had developed a concept for a crawling robot "with all sorts of muscles," he says. "It struck me as all rather complicated." Because of his aerospace background, McGeer then thought of how the Wright brothers pioneered flight. They had explored how an *airborne* plane might *maintain* stability and control by experimenting with a series of unpowered gliders, which eventually stayed *aloft* while travelling over 1,000 feet off the ground. McGeer realized that such an approach, focused on *equilibrium* and mechanics, might work equally well for *bipedal* robots.

Searching the Perfect Gait

McGeer also knew of a concept called ballistic walking, developed by Harvard roboticist Thomas McMahon in 1980. Inspired by a simple walking toy called a Wilson Walkee, a penguin-shaped, unpowered *gadget* that could *toddle* down a slope on two legs, McMahon and his student Simon Mochan calculated that a walker could take a single step using no energy after an initial activation. In their model, a leg behaves like a *pendulum* that swings passively until the body leans forward and the foot strikes the ground.

In a series of seminar papers, McGeer extended McMahon's concept. He calculated that a walker could not only take one step without energy beyond the initial *nudge* but could also execute the entire walking cycle powered only by gravity. The downhill-walking cycle, he found, was passive and repeatable - even, remarkably, if the walker bent its knees. "I could write down these formulae that said you could build a machine that looks like this and it will walk by itself," he says. "Intuition said that seems pretty *far-fetched*." Intuition proved wrong. McGeer succeeded in building a passive walker that could march downhill while bending and straightening its knees. However, the simple robot *cheated* slightly by relying on four, rather than two, legs to maintain side-to-side stability.

Striding Sticks and *Hinges*

When McGeer left *academia* for industry, another outsider to robotics picked up where he'd left off. Ruina had started his career as a geophysicist but became interested in mechanical engineering when someone in his lab *insisted* on studying bicycle mechanics. Ruina took a *sabbatical* to learn more about biomechanics, *encountered* McGeer's work, and was *hooked*. ➔

*Vokabelownload unter www.engine-magazin.de/**extras***

stride, to	schreiten
gait • gäit	Gang
rickety	klapprig, wackelig
resemble, to	ähneln
advance	Fortschritt
hip	Hüfte
heel	Ferse
amble, to	schlendern, trotten
fraction	Bruchteil
slender	schlank
roboticist • robotißißt	Robotingenieur
slope	Gefälle, Hang
guzzle, to • gasl	fressen, schlucken
rely on, to	sich verlassen auf
limb	Glied
prosthetics • proßθetik	Prothesetechnik
locomotion	Bewegung
ambulatory • ämbjələtəri	gehfähig
humanoid	menschenähnlich
diversion	Ablenkung
airborne	fliegend
aloft	in der Höhe, hoch oben
equilibrium • ihkwilibriəm	Gleichgewicht
bipedal • beipihdl	zweifüßig
gadget	Vorrichtung, Apparat
toddle, to	watscheln, schwanken
pendulum • pendjələm	Pendel
nudge • nadsch	Stoß
far-fetched	weit hergeholt
cheat, to	mogeln
maintain, to	bewahren
hinge • hindsch	Gelenk, Scharnier
academia	die akademische Welt
insist, to	beharren, bestehen auf
sabbatical • ßəbätikl	Sabbatjahr
encounter, to	auf etwas stoßen
hooked	total begeistert

engine Lautschrift

Unsere vereinfachte Lautschrift orientiert sich an der deutschen Aussprache und wird gesprochen, wie sie geschrieben wird. Betonten Silben sind **fett** gedruckt. Leider geht es nicht ganz ohne Sonderzeichen:

θ = stimmloses th wie in „thank you"
ð = stimmhaftes th wie in „the"
ə = kurzes, unbetontes e wie in „danke"
ɔ = langes, offenes o wie in „hoffen"

The Wilson Walkie ramp-walking toy patented by John Wilson in 1938 inspired Thomas Mc Mahon to develop one of the first ballistic walkers in 1980.

Bild: Any Ruina

http://ruina.tam.cornell.edu/research
Andy Ruinas Aktivitäten am Biorobotics and Locomotion Lab der Cornell University

http://mms.tudelft.nl/dbl/research/biped
Das Biorobotics Lab der TU Delft mit vielen Informationen, Bildern und Videos von Denise und ihren Vorgängern

www.personal.engin.umich.edu/~artkuo
Webseite von Art Kuo zum Thema mechanisches Gehen

http://world.honda.com/ASIMO
Hondas kleiner Asimo ist derzeit wohl der menschenähnlichste aller Roboter

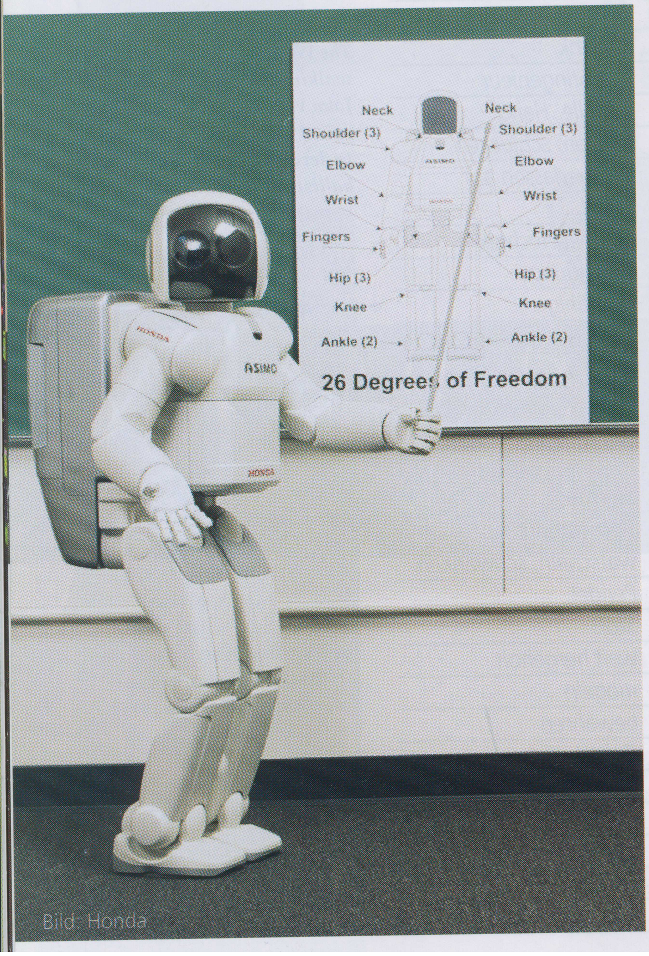
www.theworld.org/technology/robots
Beitrag der BBC zum Thema mit Audiolink zu einer Radioreportage

www.bea.hi-ho.ne.jp/meeco/biped/bipede.html
Bauanleitung für einen Walker aus Lego

Ruina and his students soon began developing passive-dynamic walkers that could navigate a slope on two legs instead of four. In 2001, undergraduates Martijn Wisse and Steve Collins put together "some sticks and hinges," Ruina says, to build a more advanced version that he still describes as "the nicest, best passive-dynamic walker that's out there." The walker ambled downhill with a comfortable, humanlike stride. "People were sort of confused because lots of people have made robots and no one has made one walk so nicely," Ruina says.

Still, the robot could only walk down a slope. So, Ruina and several colleagues at the Massachusetts Institute of Technology and Delft University in the Netherlands decided to prove that robots developed from passive-dynamic principles could, with the strategic addition of some motors, walk on flat ground.

The new robots rely on carefully designed mechanical tricks to walk while using extremely little energy. For instance, in the Cornell model, which was built first and is more energy efficient than the MIT and Delft robots, a single motor at the hip winds up a *spring* at the *ankle* of the robot's *planted leg*. When the robot's other leg strikes the ground ahead, an electrical signal back to the motor *releases* the spring, which pushes the ankle of the planted leg upward to start the next step. This *mimics* a person, who steps by pushing up from the ball of the foot, Ruina says.



Honda's Asimo robot is probably the most advanced humanoid robot to date. It walks, runs, climbs stairs and dances. But in contrast to the passive walkers, it uses brute force and a multitude of electric motors consuming a lot of power.

Motor-Intensive Movement

Compare this with the movement of Honda's Asimo robot, perhaps the most capable bipedal robot ever created. A computer-controlled motor sits at each of Asimo's 26 joints, directing the full *trajectory* of joint motion. This complete control enables the robot to walk, shake hands, climb stairs, kick a ball, and even run.

But Asimo pays a price for its virtuosity. The motors make the robot stiff and *unwieldy*. When the motors are turned off, each joint freezes in place, so even joints that don't need power in a given motion must be activated. Asimo must also *lug* around its full collection of heavy motors, gears, and electronics. The robot's large battery needs recharging every 45 minutes.

In contrast to the motor-intensive robots, the new walkers based on the passive-dynamic theory achieve an energy efficiency similar to that of a human being. Mathematically, a person's or a robot's energetic cost of transport equals the energy *expended* to move the walker's body weight a certain distance.

When walking, both an average person and the Cornell robot have a cost of transport of about 0.05, a unitless quantity based on work performed over a distance. The Delft robot, nicknamed Denise, uses pneumatic devices at the hip to power its walking and has a higher cost of 0.08. The person and these robots all achieve 10 to 20 times the energy efficiency of Asimo, however. Collins has estimated Asimo's cost of transport while walking at 1.6.

Wisse, now at Delft University, admits that passive-dynamic robots can't match Asimo's *capabilities*. But he says that Asimo consumes extra energy because, for example, the robot is controlled by algorithms that require it to walk flat-footed, without rolling up on its *toes* as a person might when walking. Wisse plans to continue research to make Denise less likely to *topple* over. He's also working on making the robot start, stop, and turn, since it currently needs a push to get moving, keeps going until it runs into something, and walks only in a straight line.

Meanwhile, Ruina says that he's still working on energy efficiency. "I'm a flower child, it's a hippie thing," he says. "During my *formative* years, I got the idea that the world was wasting energy." Aside from the moral high ground, energy efficiency has *crucial* practical importance, Ruina and others *assert*. "Once a robot is unplugged from the wall, once an animal is free to *roam*, either way, it's got to carry its energy supply with it," Kuo says. People typically engage in activity for half a day before stopping to power up with a meal. Robotics researchers hope to emulate this *stamina*. Moreover, since people naturally minimize their energy usage, it makes sense that principles driving passive-dynamic motion could explain human walking, says Collins. The most *immediate* practical application of passive-dynamic robotics, he says, lies in understanding how people move.

Easy Walking is Hard

Strolling along might feel easy, but researchers have long *struggled* to understand walking. That's partly because human locomotion depends on so many joints, including the knee, ankle, and hip, says roboticist Jerry Pratt of the Institute for Human and Machine Cognition in Pensacola, Fla. Each joint behaves differently, and a roboticist must decide how

ankle	*Fußgelenk, Knöchel*
appealing	*reizend*
assert, to	*beteuern, versichern, behaupten, bestätigen*
capability	*Fähigkeit*
cop-out	*Ausrede*
crucial • kruhschl	*entscheidend, wichtig*
determinant • ditöminənt	*Bestimmungsgröße*
emit, to	*ausstrahlen*
expend, to	*aufwenden, ausgeben*
formative	*prägend, formend*
immediate	*unmittelbar, direkt*
implication	*Auswirkung, Folge*
intriguing • intrihging	*faszinierend*
lug, to • lag	*schleppen*
mimic, to	*nachahmen*
notion	*Auffassung, Ansicht*
planted leg	*Standbein*
release, to	*lösen*
roam, to	*streunen, herumwandern*
spring	*Feder*
stamina • ßtäminə	*Durchhaltevermögen*
stroll, to	*schlendern, spazieren gehen*
struggle, to	*kämpfen, ringen*
toe	*Zeh*
topple, to	*fallen, kippen*
trajectory	*Bewegungsablauf*
unwieldy • anwihldi	*schwerfällig*

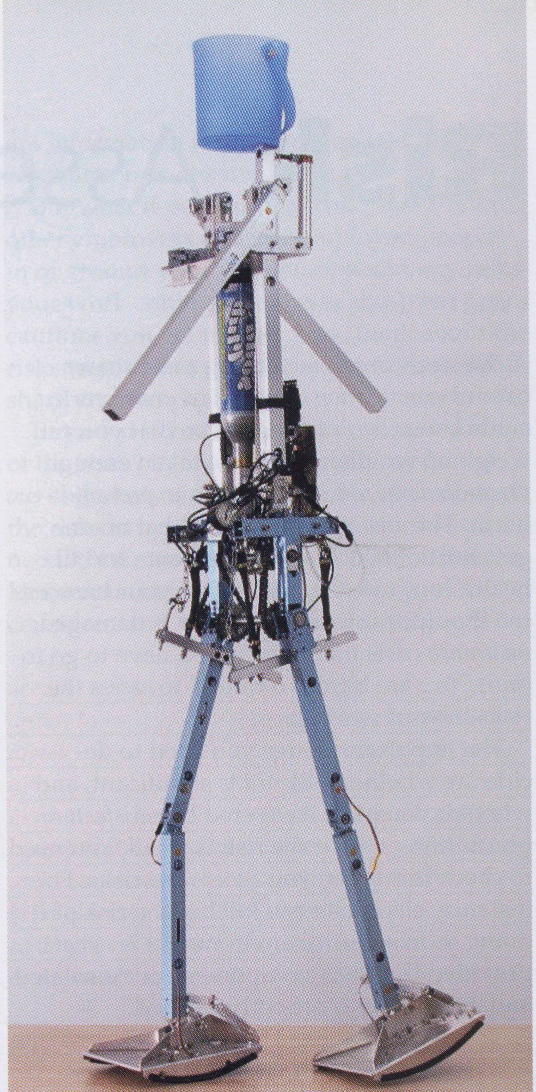


Bild: Herman Kempers/TU Delft

A lady's elegance: Passive-dynamic walker Denise uses pneumatic devices at the hip to stroll along the corridors of Delft University.

to control the movement at each one. "There are a lot of things that make walking hard, but instead of using that as a *cop-out*, most guys involved in the field of passive-dynamic walkers try to look more at what makes it easy," says Pratt. Permitting the leg to swing like a pendulum, for example, simplifies the task.

Kuo says that passive-dynamic walking has challenged a commonly held *notion* of how people walk called the "six *determinants* of gait." This theory, developed in the 1950s, asserts that a person minimizes energy by using six ambulatory tactics to keep his or her centre of gravity as level as possible. But Kuo says that both people walking normally and the new-style robotic walkers move their centres of gravity up and down. More information on human walking, he says, will lead to new prosthetic devices for people who have lost lower limbs.

Besides their *implications* for prostheses and improved robotics, the walkers built by Ruina and his colleagues have another *intriguing* aspect. In their gaits, which are so strikingly similar to human walking, the robots *emit* an *appealing* charm. ■

Naila Moreira

Dieser Artikel erschien ursprünglich in Science News, Vol. 168, No. 6, 2005, und wird hier mit freundlicher Genehmigung von Science Service veröffentlicht. Der vollständige Beitrag findet sich unter **www.sciencenews.org**