Helping a robot "find its wheels" means plenty of outdoor games


# Do the locomotion

A faltering advance in transportation is bringing stability to the wobbly world of robots. **Douglas Fox** climbs aboard

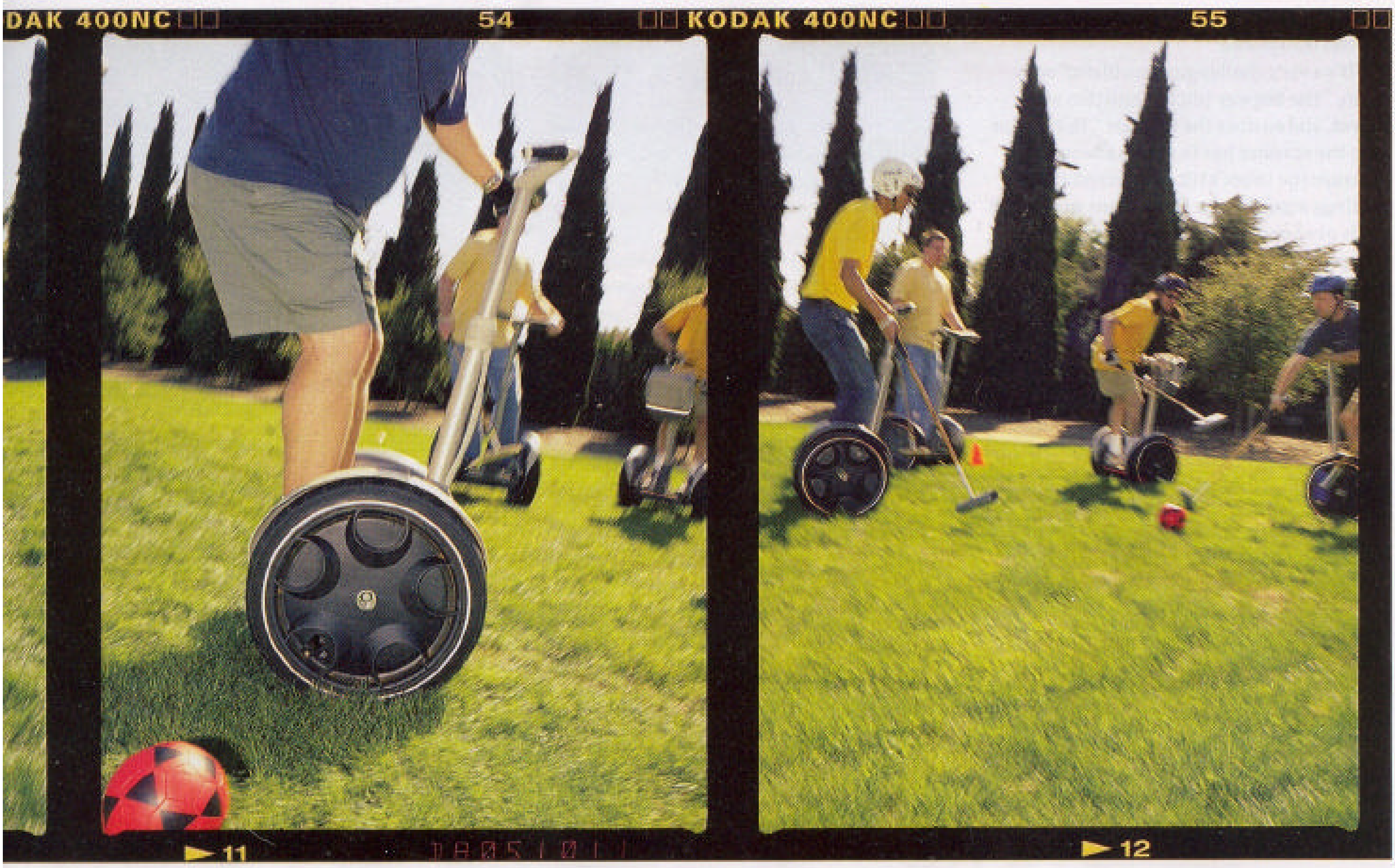
AS ONE, Segfrieda and I zoom past trash cans and dingy doughnut shops through the damp streets of Oakland, California. If I lean forwards, forwards we glide. If I lean backwards, backwards we glide. If I do neither, we simply balance on our own two wheels, as paradoxically stable as a hippopotamus on a beach ball.

As we roam the city, we catch the attention of passing college students and hip-hopsters in baggy pants. Common sense dictates that we should fall over, but we don't. Instead we can balance even in the most precarious of places, such as a slanted kerb, where alone I couldn't balance if I spent a week trying.

Segfrieda is the name of my Segway transporter, the two-wheeled scooter launched in 2002 to a marketing fanfare that declared it was about to revolutionise the way we get around in cities. So far, it hasn't (see "Segway culture"), but it is having a more serious impact in another area: robotics.

Just as learning to balance changes a toddler's world forever, getting a robot to balance is a crucial step towards making it autonomous. But this is remarkably tricky. Most robotics labs, whether they are building a robo-hand to collect golf balls, a cute robotic pet or a life-sized humanoid, spend months and tens of thousands of dollars fine-tuning their systems just so that they don't fall over.

When the Segway hit the streets, the Pentagon's research agency, DARPA, was one of its first customers, buying a fleet and handing them out to a select group of robotics labs. DARPA's aim was to develop robots that piggyback on Segway's cheap and ingenious gyroscope technology (see "Balancing on a dime", page 36). The result is a new breed of robot-Segway hybrids that, just like Segfrieda and I, exhibit an uncanny sense of balance, constantly rolling their wheels forwards or backwards to stay upright as their centre of gravity shifts.




Segway bases are already helping robots achieve a major milestone – leaving behind the wide-bottomed world of R2D2 for the tall, thin form of C3PO. For a big-bummed robot that looks like a trash can, the transformation should be a dream come true.

Suppose you want robots to clear tables in a bustling restaurant, for example. A fat R2D2-style bot would have to push people and chairs aside as it lumbered about. But a slender robot that can actively balance could turn and zip through the bottlenecks like a cyclist in heavy traffic. It could also perform other trademark human moves, such as leaning forward to snatch a plate off a corner table while sticking its bum out to balance, or even un-balancing to throw its weight into pushing a heavy trash bin out of the door.

"If you put a robot in a built-for-human environment, you have to deal with those challenges," says Rodney Brooks, director of the Computer Science and Artificial Intelligence Lab at the Massachusetts Institute of Technology. "You need something tall and skinny, and to be tall and skinny you need to balance."

Of course, robots long ago colonised environments that were designed especially for them, such as factory assembly lines. They were bolted to the floor or had wide bases that kept them from falling over without having to balance. But now many observers believe robots' next big foray will be onto human turf, helping to care for the elderly, for example. Japan, with its ageing population, is investing heavily in this area.

Andrew Howard, a roboticist at the University of Southern California in Los Angeles, is using his Segway robot to develop methods for mapping urban terrain – especially collapsed buildings. At the Los Angeles Fire Department training ground, Howard's machine trundles around a tangle of twisted steel and concrete, scanning it with a laser rangefinder that plots thousands of dots per second to create a three-dimensional landscape

For this task, tall, balancing robots beat their belly-crawling counterparts hands down. "It's very difficult to build maps of the world when you have an ant's-eye view," Howard says. "Human environments are built to be viewed from 1.2 to 1.8 metres up, and with Segway you can do that."

Another important challenge for balancing robots is detecting slip-and-fall hazards, such as gravel patches, and adjusting their speed accordingly. Ron Arkin, a roboticist at Georgia Institute of Technology in Atlanta, has equipped a Segway robot with a laser rangefinder that scans and measures the unevenness of the ground in front of it every quarter of a second. The robot then ▶

## Segway culture

**Segways certainly haven't brought about the huge innovation in transport that was promised by the company's marketing department prior to their launch in 2002. But they have found a use in some strange cultural niches.**

- Deer hunters are riding into the woods on camouflaged Segways, sometimes even treated with pheromones to attract prey.
- In Silicon Valley, Apple Computer founder Steve Wozniak and his venture capital buddies have been seen playing Segway polo, and the game is now catching on all over the United States.
- Gadget enthusiasts are building their own Segway knock-offs from scratch, using detailed instructions available on the web.
- Segways have won the heart of urban Los Angeles gangland, appearing adorned with shiny chrome fenders.
- A Segway was used for the first time in a "drive-by" shooting in February 2004 in Los Angeles. The victim died, but the perpetrator was caught, perhaps because the Segway's top speed is a modest 20 kilometres per hour.

speeds up or slows down depending on how uneven things look.

"It's a very challenging problem," says Arkin. "The Segway pitches and tilts as it moves, and so does the scanner." To counter that, the scanner has to simultaneously measure the robot's tilt and correct its readings accordingly. The system works well but is over-conservative, slowing down for bumpy surfaces like lawn grass that are actually safe. Arkin hopes to add a colour sensor that can help the robot tell the difference between grass and ice, say.

Meanwhile, Brooks and other researchers are using Segway's balancing skills to tackle a host of other challenges. Brooks is mounting a robot with two arms and hands onto the Segway, and hopes to teach it how to grasp objects, choosing the right grip for objects of different shapes and sizes. One medium-term goal is for it to be able to cope with door knobs. And Brooks's colleague Oliver Brock of the University of Massachusetts at Amherst is already testing a new approach to staying upright while carrying out a variety of other tasks. In one simple demonstration he persuaded a Segway robot to follow a person around an empty parking lot while avoiding obstacles put into its path.

One of the flashier personalities riding a Segway these days is Darwin, a robot with a neural network "brain" composed of 100,000 digital neurons – about the brainpower of a fruit fly – stuffed into a round black box the size of a toaster. What's unique about Darwin is how those artificial neurons are arranged: the 1.5 million connections between them mimic the anatomy of the visual and motor cortices of the human brain. Darwin's visual cortex, for example, is wired so that neurons early on in the circuitry's processing stream respond to any stimulus confined to very small, pixel-like areas of the visual field, whereas neurons further down the processing respond to more specific types of stimuli, but in progressively larger areas of the visual field.

If Darwin performs well, it could inspire a new generation of anatomically inspired robo-brains. But for the moment, Jeffrey Krichmar, a computational neuroscientist at the Neurosciences Institute in San Diego, is using Darwin to study how the brain untangles the cluttered world of shapes, lines and colours into individual objects. One theory is that a neuron positioned late on in the brain's vision-processing circuitry identifies a feature of interest, such as a characteristic squiggle on a tomato soup can. This tentative identification is then tested by neurons with connections looping back to the early visual cortex. They delve back into the earlier morass of fragments and fish out information about position, colour and other properties likely to reinforce the tomato soup can picture.

## Balancing on a dime

**The appeal of Segway for robotics labs is not that it makes balancing possible, but that it makes it cheap. Balancing depends on having a sensitive gyroscope to measure tilt, so that a computer can correct for it.**

Traditional gyros contain a wheel that spins almost frictionlessly. As its angular momentum does not change, it continues to spin at the same rate irrespective of what happens to its housing. This makes it possible to measure the rotation of an object by detecting small changes in the speed of a gyro wheel inside it relative to that of the housing.

These delicate devices have to be painstakingly assembled under a microscope by hooded and gloved workers in clean rooms. Contamination even by microscopic airborne dust will interfere with the wheel's near-frictionless spinning. As a result, most commercial gyros are worth their weight in gold, and are reserved for big-ticket items like F-15 fighter jets, Stinger missiles and space satellites.

Segway's gyros, developed over the past two decades by British company BAE Systems, are another matter altogether. They contain no spinning parts, just a silicon ring the diameter of a pea that is etched out of a solid silicon chip, and still attached to it by eight tiny "legs". When a current passes through the ring, it vibrates. Tilting the chip forwards or backwards distorts the pattern of vibrations, shifting it either clockwise or counterclockwise depending on the direction of rotation.

These gyros can be mass-produced much like computer chips. Up to 52 can be made from each silicon wafer. And since these gyros are solid devices, they are much more rugged than traditional ones. You could throw a silicon gyro as hard as you can against a wall with no ill effects, whereas a regular gyro becomes junk if you so much as drop it.

A laser rangefinder and kicker is all you need to score

Will sightseeing tourists on Segways soon be led by robot guides?

**"If our future is populated by robots doing household tasks, they won't look like trash cans on wheels"**

Darwin is currently cutting its object-finding teeth on soccer. It has been hard-wired to want to be near and kick a little orange ball – just as many children are hard-wired to like sweets. Mounted on his Segway wheels, Darwin can already recognise the ball by its colour, chase it down, and pass it to another player using a piston-like kicker. "It's not a trivial task," Krichmar points out. "Because Darwin had never chased a ball before, it had to learn the proper movements and how to recognise objects on the field."

A crucial element of Darwin's learning ability is a digital version of the human brain's network of dopamine-producing neurons. Dopamine is the neurotransmitter that provides pleasure in response to certain stimuli, whether from brilliant ball play, a piece of chocolate, or a drag from a hash pipe. Squirts of virtual dopamine made sure Darwin remembered sequences of moves as successful. It quickly learned to chase down the ball and position itself for a successful kick. "Anything that took it closer to the ball was rewarded," says Krichmar. "Anything that took it further away was punished. And it worked. Within 3 minutes it was making very fluid movements toward the ball."

Segway robot soccer will make its debut this May in Atlanta in RoboCup, an annual contest that was set up several years ago to inspire research in AI and robotics. The match will bring together two mixed teams, each consisting of some robot Segways and some humans on Segways, one team fielded by Krichmar's group and the other by a group led by Manuela Veloso, an artificial intelligence researcher at Carnegie Mellon University in Pittsburgh. "Sports trigger a lot of motivation to do research and be smart," says Veloso. "The same way that in the beginnings of artificial intelligence, playing chess and beating the world chess champion was set as a goal."

Hefty Segway robots will certainly be a change from the little chihuahua-like AIBO robots that have been a staple of RoboCup. And it's probably best that the two are not playing each other. After all, soccer between humans and ankle-high AIBOs would work about as well as a steamy love affair between King Kong and Fay Wray. It wouldn't be long before one of those cute little doggy-bots was accidentally punted through the goal posts.

This raises an important point: if robots move onto human turf, humans will need to interact with them, direct them, even tell them when they've done wrong. And since we are unlikely to see any English-speaking robo-boffins like C3PO any time soon, much of that interaction will be non-verbal.

"A lot of people, when their dog does something wrong, they kick their dog," says Jessica Banks, who is Brooks's PhD student at MIT. "It's wrong to kick your dog, but I don't think it's wrong to kick your robot."

Her point is that we should engineer robots so that interacting with them feels natural to humans who are already accustomed, for example, to dealing with pets. If a household vacuum-bot gets underfoot, you nudge it aside. If your vacuum-bot sucks up the family guinea pig, a whack with a slipper tells it to cough up the fur ball and return to its corner. And if you want it to clean another room, you grab its arm and lead it there.

But for Segfrieda and I, there's no need to resort to a shove, or even a kick in the hubcap. Instead, I am simply comforted to know that if our future is truly to be populated with robots doing our menial chores, they probably won't look like trash cans on wheels. ●

**Douglas Fox is a freelance science writer based in Oakland, California**

**www.newscientist.com/channel/mech-tech**