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Cockroaches Inspire Robot Antenna Design

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To most of us, cockroaches are a nasty nuisance. But to a team of engineers at Johns Hopkins University in Baltimore, Maryland, the pesky critters are excellent role models.

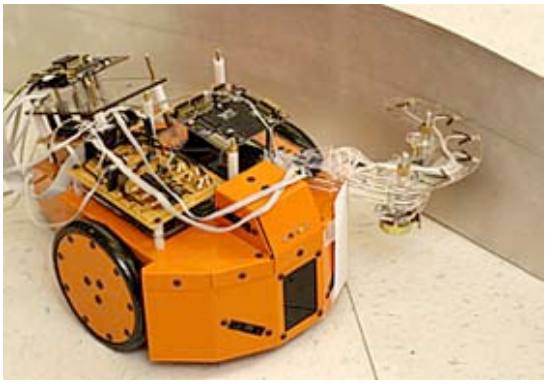
So when the scientists set out to build an antenna for a robot, they turned to cockroach biology.

The sensor-laden antenna they built resembles a cockroach's navigational appendage. The antenna sends signals to the robot's electronic brain, enabling the machine to scurry along walls, turn corners, and avoid obstacles, just like a cockroach.

The technology could provide an important navigational alternative for robots that are dispatched into dangerous locations, such as collapsed buildings.

Most robotic vehicles rely on artificial vision or sonar systems for their navigation. However, robotic eyes don't operate well in low light, and sonar systems can be confused by polished surfaces.

When a robot navigates with a sense of touch, on the other hand, "there is nothing that has to travel through the air that can be interfered with by particulate matter [like dust or smoke]," said the team leader, Noah Cowan, an assistant professor of mechanical engineering at Johns Hopkins.



Inspired by cockroach biology, engineers build an antenna for a robot that enables it to scurry along walls, turn corners, and avoid obstacles—just like the insect.

Photograph by Will Kirk

Secret Admirer

As a postdoctoral fellow at the University of California, Berkeley, Cowan and colleagues from Stanford University in Palo Alto, California, built a crude antenna prototype based on the navigational techniques of a cockroach.

After moving to Johns Hopkins, Cowan began refining the prototype design. His team studied cockroach locomotion to see how cockroaches use their antennae to track along walls in the dark.

To do that, the engineers built an oval-shaped "obstacle course" for the cockroaches, and then filmed

the insects as they maneuvered inside it.

"Every time I looked at the images of the runs, I was in awe of the cockroaches' agility and speed," said Jusuk Lee, a Ph.D. student who collected the data.

His observations provided crucial clues as to how cockroach antennae work, guiding many of the ideas about how to build a robotic antenna.

At the same time, Lee became a true admirer of the insect. When he moved into his Baltimore apartment near campus, he found a cockroach. Most people's first instinct probably would have been to kill it, but Lee gently nudged the pest into a cup and threw it down the trash chute into cockroach nirvana.

The robotic cockroach antenna has several functions. But the researchers are focusing on its mechanical sensors, which include receptive "hairs" and sensors that measure strain along the antenna.

Live cockroaches have control mechanisms at the bases of their antennae that allow them to sweep their antennae back and forth and up and down. This helps the insects gather rich sensory images of what's happening around them.

However, when cockroaches run rapidly (say when you flick on your kitchen light), they keep their antennae at a fixed angle. In this case, their antennae interact with objects, allowing the insects to make corrections in their locomotion patterns to avoid obstacles and follow along surfaces.

"Our first approach was to study that behavior in cockroaches as a possible model for rapid locomotion control in robotics," Cowan said.

Dark Locations

The most recent version of the robot antenna is made of cast urethane, a flexible rubberlike substance, encased in a clear plastic sheath. Embedded in the urethane are six strain gages, sensors that change electrical resistance as they are bent.

Cowan says he's not trying to exactly duplicate any specific function of the cockroach.

"It wouldn't be wise to copy exactly what nature is doing," he said. "[Instead] we're trying to understand the principles involved … and apply them in an engineeringly sound way."

The scientists attached their mechanical antenna to a commercially available wheeled robot. Data is fed from the antenna to the robot controller, enabling it to sense its position. When the antenna signals that the robot is veering too close to a wall, for example, the controller steers the robot away.

Mitra Hartmann, a mechanical and biomedical engineering professor at Northwestern University in Evanston, Illinois, said Cowan's design imaginatively applies the multisensor, multisegment aspects of real cockroach antennae.

"That it worked on a real robot, instead of just in computer simulation, is particularly important, because noise and system dynamics are often difficult or impossible to model in simulation," Hartmann said.

Cowan believes the cockroach antennae could eventually provide a new generation of robots with an enhanced ability to move safely through dark and hazardous locations.

"I can imagine, for example, a collapsed building with lots of debris and dust and not much light, where you have to get a robot into a very small space," Cowan said.

The researchers will present their project this month at the International Conference on Robotics and Automation in Barcelona, Spain.

Reverse Engineering

Other robotics engineers are also drawing inspiration from nature in their work. Mitra Hartmann, the Northwestern professor, is building sensors modeled after rat whiskers.

"Just as cockroaches use their antennae for wall-following and obstacle-avoidance, rats use their whiskers to navigate through the environment," Hartmann said.

The two systems differ in several important ways, Hartmann noted. "An antenna generally consists of multiple rigid segments and is covered all along its length with sensory receptors," she said. "In contrast, a whisker consists of a single, flexible, tapered hair and has tactile sensors located only at its base."

Still, bio-inspired robotics is just in its infancy.

"There's a lot of interesting and useful low-hanging fruit here, in that a myriad of animals use this kind of sensing to get around," Cowan said. "And so far it has found extraordinarily limited applications to robotics."

But scientists are increasingly looking at some of nature's solutions to help them overcome several of the problems that hamper progress using traditional engineering methods.

The U.S. military is particularly interested in bio-inspired robotics, as scientists are reverse-engineering the mechanics of insects and designing miniature robots to scout battlefields or to search for victims trapped in rubble.

"There hasn't been that much success on the perceptual side as there has been on the locomotion side," Cowan said. "I predict that in 10 to 15 years, the perceptual side will begin to catch up with the locomotion side, with people taking more ideas from nature."