TECHNOLOGY

Indoor Robots Start Flying Blind

For the best of today's indoor industrial robots, the contest at the American Association of Artificial Intelligence meeting, held recently in Washington, D.C., should have been a breeze. All they had to do was find their way through a 3-foot-high maze outlining an imaginary office, as if they were, say, delivering coffee from the kitchen to the conference room. But most of the robots weren't up to serving the office coffee: Half the contestants dropped out, and the other half took up to 30 minutes to wend their way through the maze. Not Isaac, though. Isaac, a robot designed by Edward MacLeod of MacLeod Technologies in Chelmsford, Massachusetts, finished in 5 minutes. And unlike its competitors, Isaac was navigating blind.

Thumbing his nose at the majority of robot designers, who believe robots for use in factories or offices need mechanical vision for navigation, MacLeod designed Isaac (named after Isaac Asimov) to rely on an indoor, miniaturized version of the Global Positioning System (GPS), the satellite beacons that orient travelers and sailors. A longtime sailor, MacLeod knew how effective GPS could be as a weapon against disorientation. So he set out to create a scaled-down system, which he calls Computerized Opto-electronic Navigation and Control (CONAC).

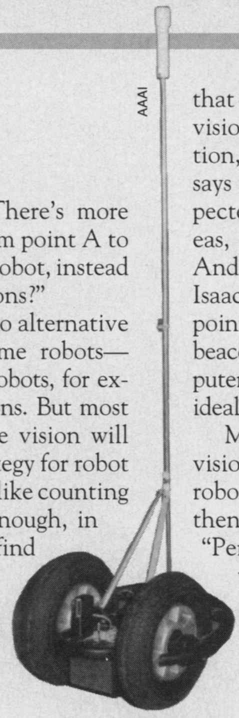
An infrared beacon atop Isaac's robot head whirls around at 3000 rpm like a frenzied lighthouse. With each revolution the beacon swings past three sensors, positioned around each room, that are connected to a central computer. By comparing when the infrared signal arrives at each sensor, the computer can pinpoint the robot's whereabouts on a prememorized map and direct its movements via radio signals.

As a result, Isaac always knows its position to within a few millimeters. It moved through the competition office quickly and assuredly, only slowing down to make tight curves. Some of its sighted competitors, meanwhile, repeatedly dead-ended into walls and corners like blockaded toy cars. To MacLeod, Isaac's smooth performance implies that a robot equipped with his system can negotiate an office or factory floor as quickly and as accurately as a human. MacLeod has begun putting CONAC to use in robots doing routine carrying, shifting heavy equipment, and even operating wheelchairs for the blind.

For some researchers, Isaac's 5-minute finish was an eye-opener. Says Frank Koss, a contestant from the University of Michigan, "As an engineer, I know that if something like GPS makes a task much easier for a robot, then that's the best way to do it." Others, however, found MacLeod's strategy less than elegant. Says computer engineer Avi Kak of Purdue University, "There's more than just making a robot go from point A to point B. Why not have a smart robot, instead of a dumb one that needs beacons?"

Robot designers have seen no alternative to relying on beacons for some robots—untethered underwater survey robots, for example, often use acoustic beacons. But most designers believe that machine vision will ultimately be a far superior strategy for robot navigation indoors, where cues like counting doorways or turns should be enough, in theory, to help a sighted robot find its way. After all, says computer scientist Steven Shafer of Carnegie-Mellon University, "There's no question that machine vision will eventually exceed human capabilities."

Most robot designers have opted for exploiting that potential, hoping that they will be able to design machines that do far more than just navigate. Even if vision is still an inefficient tool for navigation, it gives a robot other valuable skills, says Kak: detecting and avoiding unexpected obstacles, mapping unexplored areas, or cataloguing warehouse inventory. And though critics like Kak concede that Isaac's navigation skills are superb, they point out that the necessary equipment—beacons in every room and a central computer—flies in the face of robot designers' ideal of a truly autonomous robot.



AAAI

Isaac the navigator. The robot is crowned with an infrared beacon that reveals its position to sensors.

MacLeod, though, thinks that for now, vision just isn't the answer. "Most indoor robots typically know where they start and then they count their footsteps," he says. "Periodically they look around to find out where they are. They invariably move very slowly and often get disoriented." Watching the contest, he shook his head as another robot bumbled into the wall. "It's pretty bizarre what people are trying to make work." For the moment, anyway, it would seem that his sightless machine is a vision of loveliness.

–Karen Fox

OPTICS

Flat Twist on Holographic Displays

Three-dimensional images have been jumping up from postage stamps, magazine covers, and credit cards now that holography has taken its place in our technological landscape. But holography has wider and more serious applications. Now a team of researchers from the Weizmann Institute of Science in Israel claims to have demonstrated a new holographic display strategy that could be compact, simple and presumably cheap enough to allow viewers wearing head-mounted displays, for example, to monitor instrument readings while keeping their eyes on something else. That something else could be the sky, the road, or a prone patient—making the devices ideal for commercial pilots, drivers, and surgeons.

This holographic innovation, which has yet to be developed into a commercial version, could make such "heads-up" displays commonplace. Present heads-up systems are costly and require bulky arrangements of lenses and mirrors to compensate for chromatic aberration, which results when various wavelengths of light bend at different angles as they pass through a lens, blurring images and distorting colors. The biggest user of these complex displays is the defense industry, which puts them in fighter planes.

Getting them into more cost-conscious sectors of society will take a new approach. The one described by Yaacov Amitai and Asher Friesem and their team in the 1 August *Optics Letters* involves a pair of holograms recorded photographically on the same glass plate, which can be as small as a microscope slide. Both holograms, rather than harboring images, act like lenses and bend light. One of the holograms deflects incoming light—perhaps from an instrument monitor—at an angle so that the light bounces back and forth between the plate's internal surfaces until it hits the second hologram, which projects the image onto a convenient spot in the viewer's field of vision. The whole system can be very small, says Friesem. And the lenses and the optical pathways within the plate can be designed to cancel chromatic aberration.

"It is an interesting technique," concedes holography researcher Nicholas George of the University of Rochester. But it will have tough competition from other holographic display strategies, such as a system under development by Nicholas' colleague at Rochester, G. Michael Morris. In Morris' system panels of liquid crystal, rather than lines etched on glass or photographic emulsion, serve as the holographic medium. The image projected from the liquid crystal can be rapidly changed with computers that control the crystals' orientation, leading to a holographic movie. To beat that, it seems, an optics researcher would have to come up with something truly amazing, like edible, holographic popcorn.

–Ivan Amato