SEND IN THE SWARM

On the frontier of artificial intelligence, mobs of cheap robots collaborate like ants in a colony or bees in a hive. *By Stuart F. Brown*

THIS JUST IN

"IMAGINE IF YOU COULD convince a bunch of robots to act like ants, and further convince them that they really like land mines," observes James McLurkin. "That would be a boon to society."

McLurkin commands a "swarm" of more than 100 little autonomous wheeled robots that look sort of like clock radios topped with bright flashing lights. He is a senior lead research scientist at iRobot in Burlington, Mass. Founded by a trio of scientists from the MIT Artificial Intelligence Lab, the company is best known for making the Roomba floor-vacuuming robots. But iRobot also does contract research and development like McLurkin's Software for Distributed Robots project, which is funded by the Defense Advanced Research Projects Agency.

Military brainstormers think that scores or hundreds or even a few thousand cheap robots working in concert may play an important role in future operations such as land-mine disposal or taking over buildings held by bad guys. Hence the financial support for figuring out the software for coordinating and controlling such swarms. As befits a man who looks to the insect world for inspiration, McLurkin has on his bookshelf such volumes as *Journey to the Ants*, by Harvard naturalist Edward O. Wilson, and *The Wisdom of the Hive*, by Cornell honeybee expert Thomas Seeley.

Insects make great conceptual models for cheap robots because they have simple local interactions with one another that nonetheless add up to very complicated group behaviors, such as building a hive or foraging for nectar. The whole, in other words, is greater than the sum of its parts. iRobot's SwarmBots are cubes measuring five inches on each side. They have rechargeable nicad batteries and a pair of electric motors inside, along with a microprocessor and some associated circuitry. A "bump skirt" helps the robots sense and avoid crashing into obstacles. Each has a small color camera for simple object recognition, as well as sensors that detect light. Communications between robots are handled by an array of infrared transmitters and receivers similar to the ones used in TV remote controls.

The iRobot researchers conduct a charming SwarmBot demo in foam-board corrals arranged on a carpeted office floor. It simulates exploring an unfamiliar interior environment, much as commandos would when storming a building. These little dev-

SwarmBots were developed for the Defense Department by the people who invented the Roomba floor vacuum. In the image at top, SwarmBots orbit a stationary robot in a maneuver that could be used for, say, perimeter surveillance. When the robots sense that their batteries are low, they automatically pull into a charging dock (bottom).

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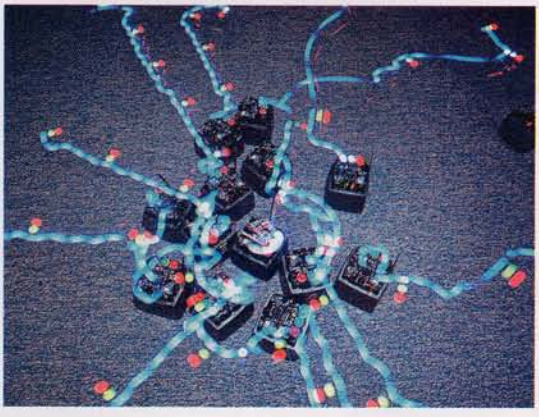
ils are efficient, in the computational sense; the software that's needed to run the robots through the exploration routine occupies just 60 kilobytes of memory, the equivalent of a medium-sized Microsoft Word file. Musical tones and flashing red, blue, and green LEDs that look like plump, luminous gumdrops atop the robots keep the humans clued in to what the members of the swarm are doing. A red light means a robot is seeking to maintain uniform spacing from its neighbors. Blue signals that a robot is moving into unexplored territory. Green indicates that a robot is heading back to the charging dock to top off its batteries. Robots showing all three colors at once have detected an object and are "guarding" it. Watching all that helps the observers identify bugs (pardon the expression) in the evolving software and devise fixes. The computer code is designed to work with as few as ten robots and as many as 10,000.



The SwarmBot team (from left): James Frankel, James McLurkin, and Jennifer Smith. At bottom, robots cluster.

Unleashed on the exploration mission, the little robots do their best to get to every area of the corral. Robots on the leading edge of the swarm flash blue. They're pioneers, pushing the frontier outward. The robots filling in the space behind them continually relocate to keep themselves equidistant, chiming and blinking as they go. "If you have a whole lot of robots and they spread out evenly across an area, you no longer need to map the area," says McLurkin. "You can simply map the robots." When it's time to return home, some robots nominate themselves to be landmarks, or "bread crumbs," that wait at corners until the followers catch up. Without such landmarks to maintain line-of-sight communications, some bots would lose contact with the swarm. Once the last moving robot passes a landmark robot, the stationary one abandons its post and follows the gang home for a bracing charge of electricity.

"This research is really about answering the question 'If you could make small robots cheaply, what would you use them for? How would they do what you want, with the minimum of resources onboard?' " says Douglas Gage, DARPA's manager for the swarm program. He envisions some swarming robots being totally disposable machines with one-use batteries. Like insects, they would have the minimum of features needed to do their jobs. "We want to have this technology ready when good applications for swarming come along." Some strategists think such an application might be legions of robots on the ground, coordinating their actions with aerial combat drones that are being developed. Now that would be an awesome swarm. F

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