Microrobots dance on something smaller than a pin's head

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Microscopic robots crafted to maneuver separately without any obvious guidance are now assembling into self-organized structures after years of continuing research led by a Duke University computer scientist.

"It's marvelous to be able to do assembly and control at this fine a resolution with such very, very tiny things," said Bruce Donald, a Duke professor of computer science and biochemistry.

Each microrobot is shaped something like a spatula but with dimensions measuring just microns, or millionths of a meter. They are almost 100 times smaller than any previous robotic designs of their kind and weigh even less, Donald added.

Formally known as microelectromechanical system (MEMS) microrobots, the devices are of suitable scale for Lilliputian tasks such as moving around the interiors of laboratories-on-a-chip.

In videos produced by the team, two microrobots can be seen pirouetting to the music of a Strauss waltz on a dance floor just 1 millimeter across. In another sequence, the devices pivot in a precise fashion whenever their boom-like steering arms are drawn down to the surface by an electric charge. This response resembles the way dirt bikers turn by extending a boot heel.

New research summaries describe the group's latest accomplishment: getting five of the devices to group-maneuver in cooperation under the same control system.

"Our work constitutes the first implementation of an untethered, multi-microrobotic system," Donald's team writes in a report to be presented on June 1-2, 2008 during the Hilton Head Workshop on Solid State Sensors, Actuators and Microsystems in South Carolina.

More comprehensive details on how the scientists achieve this "microassembly" will be published later in their report for the Journal of Microelectromechanical Systems.

The research was funded by the National Institutes of Health and the Department of Homeland Security, and also included Donald's graduate student Igor Paprotny and Dartmouth College physicist Christopher Levey.

Donald has been working on various versions of the MEMS microrobots since 1992, initially at Cornell and then at Stanford and Dartmouth before coming to Duke. The first versions were arrays of microorganism-mimicking ciliary arms that could "move objects such as microchips on top of them in the same way that a singer in a rock band will crowd surf," he said. "We made 15,000 silicon cilia in a square inch."

A February 2006 report in the *Journal of Microelectromechanical Systems* by Donald, Paprotny, Levey and others detailed the basics of the current design: devices about 60 microns wide, 250 microns long and 10 microns high that each run off power scavenged from an electrified surface.

Propelling themselves across such surfaces in an inchworm-like fashion impelled by a "scratch-drive" motion actuator, the microrobots advance in steps only 10 to 20 billionths of a meter each, but repeated as often as 20,000 times a second.

The microrobots can be so small because they are not encumbered by leash-like tethers attached to an external control system. Built with microchip fabrication techniques, they are each designed to respond differently to the same single "global control signal" as voltages charge and discharge on their working parts.

This global control is akin to ways proteins in cells respond to chemical signals, said Donald, who also uses computer algorithms to study processes in biochemistry and biology.

In their new reports, the team shows that five of the microrobots can be made to advance, turn and circle together in pre-planned ways when each is built with slightly different dimensions and stiffness.

Following a choreography mapped out with the aid of mathematics, the microdevices ultimately assemble into group micro-huddles that could set the stage for something more elaborate.

"Initially, we wanted to build something like a car that could drive around at the microscopic scale," Donald said. "Now what we've been able to do is create the first microscopic traffic jam."

He said it took him and various colleagues from 1997 to 2002 to create a microrobot that can operate without a tether, three more years to make the devices steer under global control, and another three to independently maneuver more than one at a time.

"The hard thing was designing how multiple microrobots can all work independently, even while they receive the same power and control," he said.

Source: Duke University