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Swarm-Bots:
Swarm of Mobile Robots able to Self-assemble and Self-organize

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Abstract

Swarm-bots consist of a collection of mobile robots able to self-assemble and to self-organize so to solve problems that could not be solved by a single robot. They combines the power of swarm intelligence and the flexibility of self-reconfiguration as aggregate swarm-bots have the ability to dynamically change their structure to match environmental variability.

SWARM-BOTS, a project funded by the Future and Emerging Technologies program of the European Community (project IST-2000-31010), focuses on the design and the implementation of self-organising and self-assembling biologically-inspired robots. The project benefits from the joint activity of four European research institutes: the Artificial Intelligence Laboratory of the Université Libre de Bruxelles (IRIDIA); Dalle Molle Institute of Artificial Intelligence Studies of Lugano (IDSIA); the Autonomous Systems Laboratory of the Swiss Federal Institute of Technology (ASL-EPFL), and the Institute of Cognitive Sciences and Technology of the Italian National Research Council (ISTC-CNR).

A *swarm-bot* is an aggregate of *s-bots* (mobile robots able to self-assemble by connecting/disconnecting from each other) capable of performing exploration, navigation and transportation of heavy objects on rough terrains in situations in which a single *s-bot* has major problems at achieving the task alone (see Figure 1 and 2). Each *s-bot* has simple sensors and motors, limited computational capabilities, and physical links that allow it to connect to other *s-bots*. The *swarm-bot* should move as a whole and reconfigure along the way when needed. For example, it might have to adopt a different shape in order to go through a narrow passage or overcome an obstacle. Finally, the aggregate should form as a result of self-organizing rules followed by each individual *s-bot* rather than via a global template. Thus *swarm-bots* combine the power of swarm intelligence, as they are based on the emergent collective intelligence of groups of robots, and the flexibility of self-reconfiguration as aggregate swarm-bots might have the ability to dynamically change their structure to match environmental variability.

At the present stage, we developed the hardware design (the first hardware prototypes will be ready in the next few weeks). As shown in the Figure, each *s-bot* has a cylindrical body with a diameter of 116 mm and consists of a mobile base provided with two differential drive mechanisms controlling tracks and wheels, and a main body provided with two grippers that allow an *s-bot* to assemble with other *s-bots* or to grasp objects. The first gripper is supported by a mobile structure that can rotate around an horizontal axis and the second gripper is supported by a motorized arm that allows large movements through the vertical and horizontal axis. The main body rotates with respect to the base supporting the tracks. From the sensory point of view, each *s-bot* is provided with proximity sensors, light sensors, accelerometers, humidity sensors, sound sensors, an omni-directional color camera, light barrier sensors (on the grippers), force sensors etc.

To develop the control systems of a *swarm-bot* we are following two different but complementary research directions. The former consists in building control systems by mimicking the characteristics of biological systems such as social insects. The latter consists in building control systems that are only loosely inspired by what we know about real organisms and develop their ability through a self-organization process based on artificial evolution. At the present stage, by following the first approach, we were able to develop, for example, the control systems of a group of simple LEGO™ robots that are able to aggregate into chain formations. By following the latter approach, we were able to develop simulated *s-bots* able to display coordinated movements, collective obstacle avoidance, and object pushing/pulling (see Figure 3 and 4).

Potential application of this novel type of robot are, for instance, semi-automatic space exploration, search for rescue or underwater exploration.

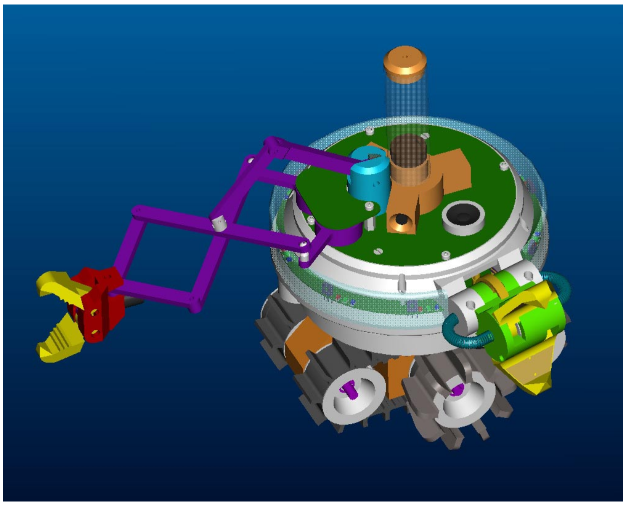

Figure 1. The design of a single *s-bot*.

Figure 2. A *swarm-bot* made of several assembled *s-bots* passing a fosse.

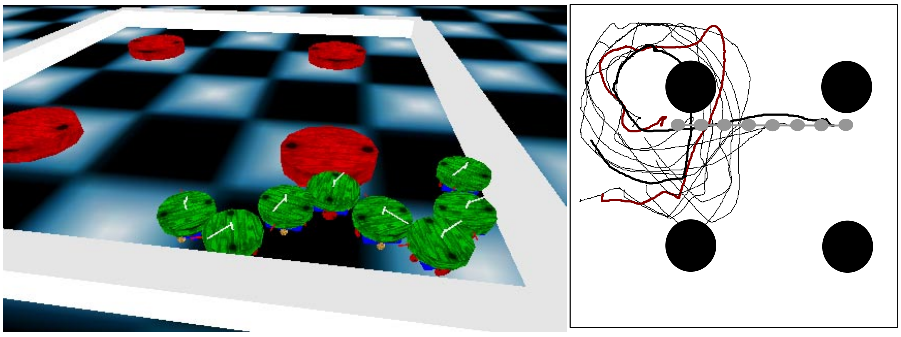

Figure 3. A *swarm-bot* displaying collective obstacle avoidance. **Left**: Eight simulated s-bots assembled into a snake-like formation placed in an arena surrounded by walls with four cylindrical obstacles. **Right**: Trajectory produced by the *swarm-bot* that move in the arena. The small gray circles represent the initial position and shape of the *swarm-bots*. The square and the large full circles represent the walls and the obstacles. The lines show the trajectory of the *s-bots*. As can be seen, the swarm-bot is able to avoid obstacles and pass narrow passages eventually deforming its shape according to the configuration of the obstacles.

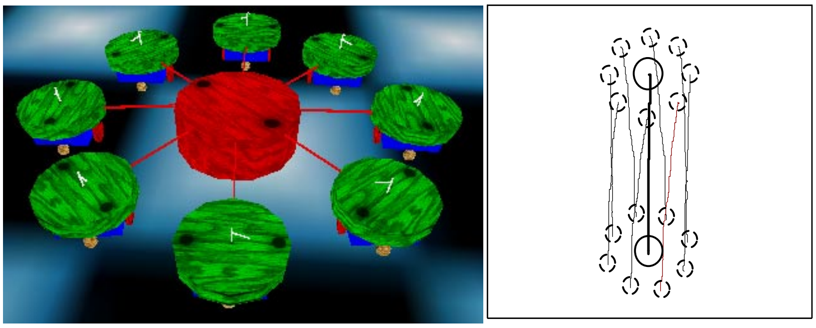

Figure 4. A *swarm-bot* displaying object pushing/pulling. **Left**: the swarm-bot consists of 8 *s-bots* connected to an object. **Right**: traces left by the *s-bots* (thin lines) and the object (bold line) during few seconds. Large and small dotted circles represent the initial (bottom) and final (top) positions of the object and of the *s-bot*, respectively.

Links:
http://www.swarm-bots.org/

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