The Superbot Robotic System

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Introduction

The Superbot is a modular, multifunctional, robotic system developed at the University of Souther California Information Sciences Institute (ISI). As shown in Figure 1, each superbot module consists of two linked cubes which are actuated to rotate relative to each other in three degrees of freedom. Each superbot module is capable of independent action, and may also link with other Suberbot modules to engage in complex collaborative behaviors. Collections of Superbots can self-assemble into a wide range of configurations, and in practice could reconfigure themselves into whatever shape best suits the task at hand. Collections of Superbots are intended to accomplish tasks in rough environments, and could be used in a broad range of capacities, including search-and-rescue, space, military, and even home use.

Technical Description

Each Superbot module consists of two linked cubes with two end effectors, allowing three degrees of rotational freedom (270º of roll, and 180º each of pitch and yaw), making them extremely flexible. Each module weighs 500 grams, and is 16.8cm long when fully extended. Each module has its own ATMegal128 microcontroller, a 3D accelerometer/inclinometer, power source, and actuators, making it fully capable of independent action. Six genderless universal connectors (found on each side of the end effectors) allow connection and communication between modules, enabling a collection of Superbots to act as a single robot. In this case, the collection is governed by ID-free distributed software loaded on each of the modules, and there is no central executive [1]. When they are not linked, Superbot modules may communicate via IR transmitters and receivers on their docking surfaces, which allow them to execute autonomous docking maneuvers.

Capabilities

Superbots may assume a wide range of locomotive configurations, as shown in Figure 2. A single Superbot may use its end effectors to move in a "caterpillar"

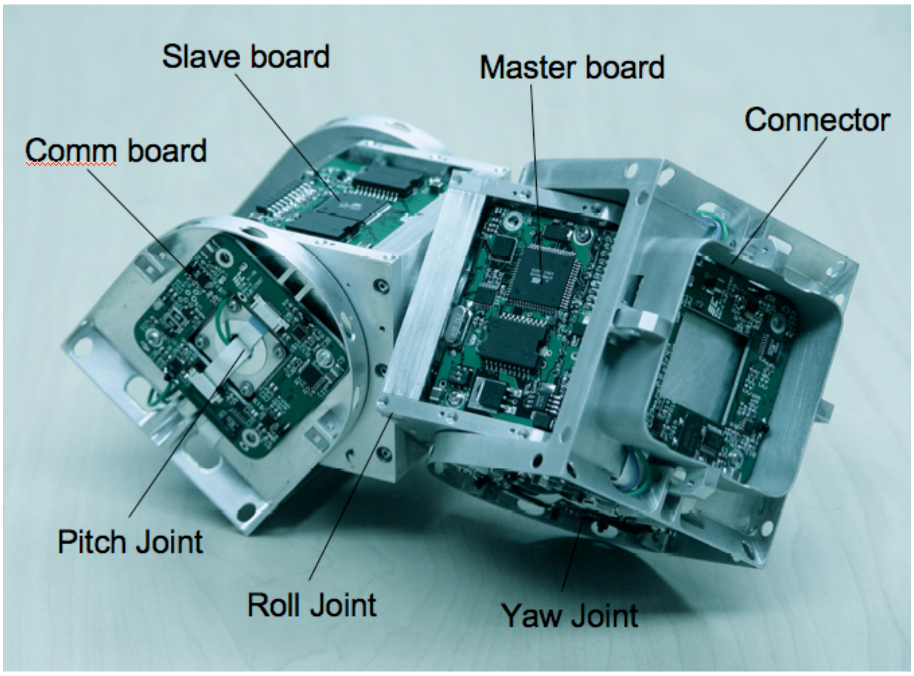

Figure 1: The Superbot[1]

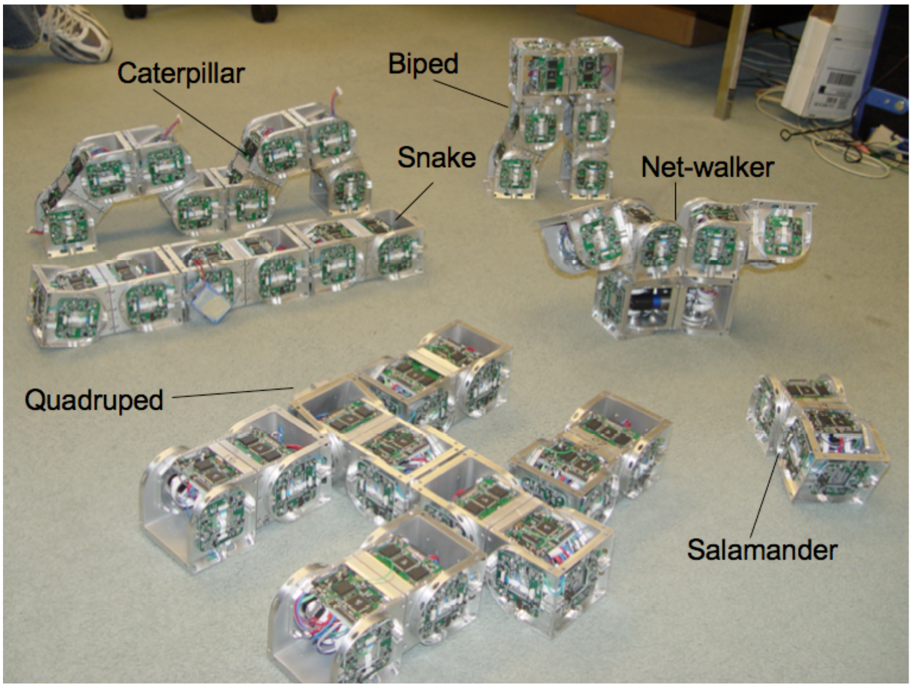

Figure 2: Locomotive Configurations of the Superbot [1]

gait, and a single chain of Superbots may use a wave-like motion to move sideways in a snake-like “sidewinder” fashion. Branched chains of Superbots may exhibit many different types of walking gaits, including bipedal, quadrupedal, and hexapedal motion. In addition to locomotion, collections of Superbots are capable of other complex activities, such as digging in soil and object manipulation [2].

Applications

The Superbot system developed at ISI is a research project, not an immediate solution to a real-world problem. The underlying technology, however, could be broadly applied. Modular reconfigurable robots are extremely versatile, as they can adapt their form on the fly to accomplish a task. This makes them ideal for search-and-rescue missions – imagine a robot capable of caterpillar crawling through a small hole in a collapsed mineshaft and then splitting up into many smaller modules to efficiently search for injured miners. When one is found, they could reconvene to configure themselves into a quadrupedal medical transport and move the victim to a safe location. In a military operation, they could be tightly packed for an airdrop into enemy territory, and then assemble themselves into an all-terrain scout robot. If this scout took enemy fire, it could quickly shed the broken modules, reconfigure itself, and continue its mission. For space missions, where weight is paramount, a group of reconfigurable modules could take on roles which would otherwise require many different robots, making room for other important equipment. A Superbot-like system could even make our day-to-day lives easier as household cleaning and maintenance robots. A set of general-purpose modules could connect to specialized cleaning modules, like a vacuum module to clean the living room carpet, or a scrubber module to clean the bathtub. To clean the second floor, the robot could easily change from crawling to legged locomotion in order to climb the stairs.

Impacts and Implications of This Technology

Aside from the practical utility of modular robotic systems, the development of distributed algorithms such as those used to control the Superbot could help us understand processes in economics, ecology, and sociology. These fields all study systems that are composed of independent intelligent agents that interact without a central executive – analogous to the distributed operation of the Superbot system.

While its potential for practical use is very great, there are some important ethical implications of distributed robotics that should be considered. A distributed robotic system such as the Superbot is designed so that the whole is greater than the sum of its parts: the combination of several modules gives rise to emergent behaviors which an individual unit could never achieve. If equipped with a genetic algorithm or artificial intelligence, a distributed robotic system could generate entirely new, potentially unsafe emergent behaviors. Without a central executive, a 'rogue' distributed robotic system could be difficult to control or shut down. Science fiction writer Michael Crichton explores a scenario much like this in his novel Prey, in which a swarm of nanobots with a genetic algorithm develop predatory behavior and begin to hunt humans and animals. To avoid such a catastrophic (or even just problematic) situation, designers of distributed robotic systems must be careful to build fail-safe mechanisms into their robots that allow remote shut-down if problematic behaviors develop.

The Future of the Superbot

The Superbot is an exciting robotic technology with great promise for practical applications in the future. To make these ideas a reality, a great deal of work must still be done. First and foremost, the technology is very expensive, and commercial viability would require that modules be mass-produced quickly and cheaply. The second most important challenge lies in actuation – at this point, Superbot movement is quite slow, so the development of lighter-weight, higher-power actuators would help to speed them up. Finally, the continued development of distributed control algorithms and software will allow the Superbot and other robotic systems to behave in new, interesting, and useful ways.

References

[1] Shen, Wei Min. "Rolling and Climbing by the Multifunctional SuperBot Reconfigurable Robotic System." (2008): n. page. Print. <http://www.isi.edu/robots/prl/shen2008multifunctional-superbot-reconfigurable-system.pdf>.

[2] "Superbot Videos." Graphic. ISI Superbot Media. 2009-2011. Web. 22 Sep 2011. <http://www.isi.edu/robots/media-superbot.html>.