Nature meets Machinery: Swarm Robotics

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Abstract

Swarm robotics escapes complexity, precision, and cost of current robotics technology enough to “be easily reproduced … at home” (12). It combines the concepts of swarms and robotics to allow more socialistic freedom, shape reconfiguring, and scattered togetherness for automatons. Tiny robots are individually useless and separated, yet they function as a whole robot for tasks. Although, the risk to this is a diminished precision within larger groups. Fortunately, larger swarms can accomplish more, multi-task, and scatter for discovering and solving a problem than a single robot. The benefits of swarm robotics illustrate the capabilities to support future Mars Rover missions.

Introduction

Swarm Concept

Swarms are groups of individuals who don't have specific purposes individually, but can be useful as a whole. An individual has limitations that swarms surpass, like being in multiple places at once. They also decrease personal consumption (3), a characteristic seen in teamwork. Swarms are seen almost everywhere socialistically (5), from insects and animals to humans. Algorithms can be created based off of boid rule patterns (2) created by swarms.

Robotic Concept

Robots are created to free-up time for more critical thinking. Some of the uses are "monotonous … dangerous … superhuman speed and accuracy … inaccessible … entertainment, research, and education" (11). There are unlimited specializations for robots, since they help people in every aspect of their lives. Individuals advance technology more quickly with robots. In addition, the automatons become more complex with these increases. Like swarms, they also have limitations and rules to follow.

Swarm Robotics Concept

Merging the two concepts together, swarm robotics involves the biomimicry of swarms added to the applications of robotics. The mechanical swarm idea gives greater freedom to robotics while overriding the technological progressions of them. Robots are becoming expensive, larger, and more specialized. The complexities are "hard to define and program" (3), which is counter-intuitive to having robots.

The simplicity of swarm robots removes this worry. They could "display features like versatility, robustness, or capacity to perform complex tasks in unknown environments" (4) just by being a group. Individual robots need rigorous development to match these capabilities. Essentially, the benefits allow robots to populate Mars and replace the current Mars Rovers.

Summary of Swarm Robotics

Flock Behavior

Unlike the colony, a flock is a true swarm. It acts as a whole instead of separating into designated tasks. This is when everyone abides by the same rules. Boids rules, where each robot is a “boid” in the flock (3), limits individuals for the group’s overall coordination. The three restricting rules are “collision avoidance”, “velocity matching”, and “[staying] near neighboring boids” (3).

A flock is useful, because many robots working on the same project is more powerful than individuals focusing on the same task. Even though flocks require more communication and time to work together, the benefit is worthwhile for large-scale achievements.

Lattice Creation

This concept is a combination of individualized robots and swarms. Like ants creating a bridge, lattice robots connect together to form any object. The purpose is to create a larger robot from many smaller robot modules “that can potentially navigate through steep concave regions or bridge large troughs” (4). It allows swarms to have the capabilities of a specialized single robot while maintaining the characteristics of swarms and boids.

The lattice-bot has a centralized control center or objective that coordinates each individual’s task. Claytronics, an example of shape-shifting behavior, exemplifies the process that atom-like robots, or catoms (10), connect and collaborate to form a larger structure. Essentially, the robots will interact to mold into an object a person commands (10).

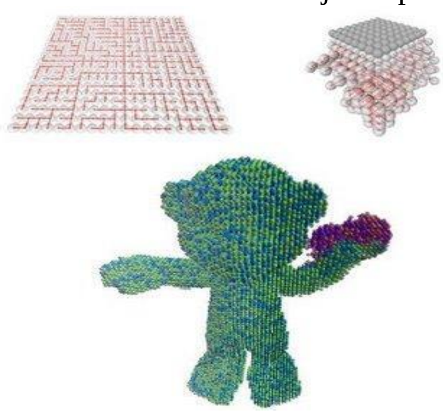

Figure 2. Miniature robots configuring/shape-shifting into different objects, such as this bear.

Evaluation/Recommendation

Both the flock and lattice swarm behaviors have advantages and disadvantages for exploring Mars.

The following provides a description of the behaviors separately as well as the advantages and disadvantages they share.

Flock Examples

A group type of robots is called “collective robots” (4). These can identify tasks, explicate to others about it, and compare results” (1). This integrated social thinking is unachievable with an individual robot. The uses for “collective foraging” (4) surfaces when entering uncharted territory. They can warn each other about dangers, as well as attract many to a problematic site. Expensive projects, like the Mars rover, wouldn’t end in disaster, have there been a few apprentices by its side. There are disadvantages though, because production decreases with larger groups (4).

Flocks scatter easily and can map out uncharted territory quickly on Mars. Their

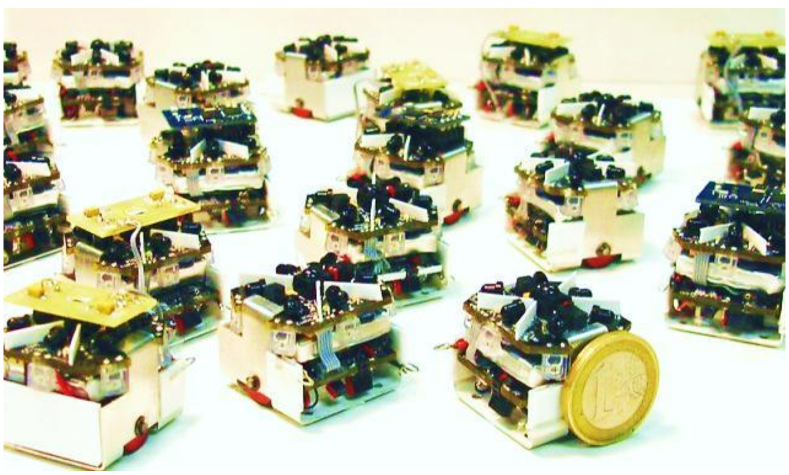

Figure 3. Largest robot swarm created by similar-looking modules.

Lattice Examples

The next type of robots is “second-order robots” (4), in which miniature robots connect to form a larger one. Examples are lattice robots. These lattices can form structures, as well as disassemble for a different configuration. It takes from nature’s example of ants work together to create bridge structures.

Some difficulties are the limitations for how many robots there are. Also, stability in creating larger robots diminishes. The more connections there are, the easier the structure can disintegrate before completion. Think of building a card house. The more massive it becomes, the greater the chance of it crumbling.

A lattice has enough strength to go over rough landscapes. The connections keeping each robot together create a joint, which propels them over any surface (5). This advantage helps chart a landscape for Mars and can pull the Mars Rover over unleveled surfaces by creating bridges (9).

Simplicity

Flocks obey the three boids rules (3). They follow as: 1) avoid bumping, 2) maintain same speed for all individuals, and 3) stay close to each other (3). When applying these to robot hoards, complex simulations whittle down to simple algorithms. For coordination on extraterrestrial projects, simplification produces more objective focus.

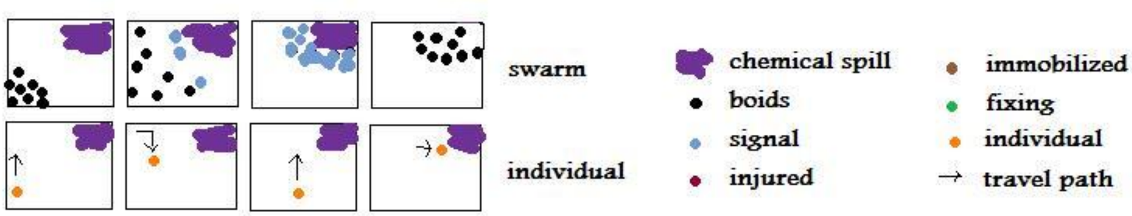

Figure 4. Swarms signaling to attract attention to a chemical spill. The individual robot traces most of the landscape before reaching the spill.

Allows for Error

Swarm robots are small and populated. If a robot breaks down, many more modules carry on without it. An individual robot rarely mends itself together. This dilemma foreshadowed the Mars Rover Spirit's decline of use (9). In the future, Mars Rovers should be guarded with swarms for their feedback, speed, and cost efficiency.

Prevention and caution requires consideration for expensive projects. An optimal solution allows swarms to chart the unknown Mars landscape and assist the Rover when necessary. With each module connecting each other, rough terrain becomes less challenging. The mapping feedback illustrates the optimal path to trek. Plus, swarms carrying equipment can fix any difficulty with the Rover and other swarm robots. This saves time and money.

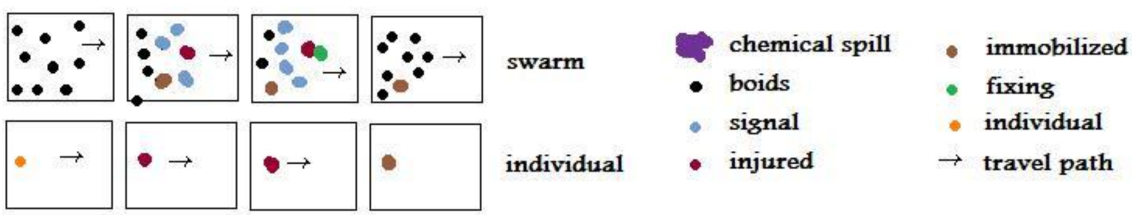

Figure 5. A robot in a swarm is mending a damaged module. Another robot in the swarm becomes immobilized, but does not affect the swarm as a whole. However, the individual robot decreases in mobility due to neglect.

Unproductivity

As a swarm increases in size, the productivity towards the objective decreases. Algorithms that applied to small groups resist adherence to every individual in larger groups (2). Like societies, various problems emerge. Examples are breaking in to smaller groups, getting off track, and counteracting another robot’s work. To solve the problem, swarms require limitations to a hundred individual groups. For the Mars Rover’s mission, no more than ten robots necessitate support.

Conclusion

Already, scientists created lattice and swarm robots for the Mars Rover missions. Still, their implementation awaits the future rovers. Lattice robots chart territory and coordinate tasks. With a few simple communication algorithms, multiple robots are controlled. Flocks help also with their simplicity and low cost. However method, lattice or flock, optimally-sized swarms supply a benefit to the Rovers traveling alone.

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