Orbital Research Inc.

SWARM ALGORITHMS

Advanced Techniques for Multi-Agent Coordination

Orbital Research has leveraged the work of biologists and computer scientists to develop biologically-inspired swarm algorithms for the control of swarms of autonomous agents ranging from unmanned air vehicles (UAVs) to data packets on a communications network. Using algorithms honed by evolution, Orbital Research combines these algorithms with its background in advanced controls to produce efficient algorithms for multi-agent coordination that are robust to changing situations and can operate under highly restrictive communications bandwidth requirements.

Swarm Intelligence

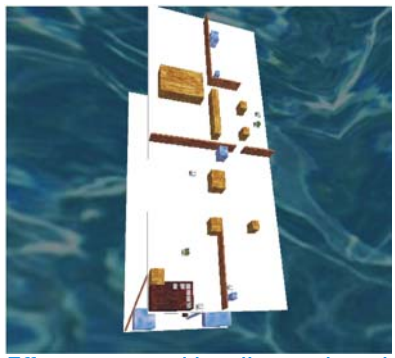
Imagine an ant colony overrun with activity. Hundreds of thousands of ants, each following only the simple rules encoded in their DNA, will eventually build an elaborate structure that rivals in complexity many of today's modern marvels. This is just one of the many examples of swarm algorithms that can be found in nature. Using nature as a guide, Orbital Research can leverage millions of years of evolution to produce algorithms that can coordinate large heterogeneous swarms of autonomous agents.

Ants, as well as many other creatures, communicate through stigmergy, which is a form of indirect communication through modification of the local environment. For example, ants leave chemical pheromone trails, which when encountered by another ant will help dictate the next action taken.

A swarm of UAV's track a chemical weapon cloud

Applications

Orbital Research has successfully applied its extensive background in biologically-inspired swarm algorithm development in many areas of research. Unmanned air vehicles (UAVs) provide a safe and cost-effective way of performing many of the tasks still performed today by soldiers, such as reconnaissance and battle damage assessment (BDA). In order to fully realize the capabilities of UAVs, multiple UAVs need to be deployed simultaneously and they must have the ability to realize the presence of the other UAVs. Orbital Research has developed several UAV coordination algorithms that allow a single controller to command large groups of UAVs to perform such tasks as formation flying, dynamic task assignment, reconnaissance, and chemical cloud tracking. In addition many of these algorithms have been shown to be directly applicable to similar systems such as unmanned underwater vehicles (UUVs), unmanned ground vehicles (UGVs), and submunitions autonomous.



Efficient material handling on board aircraft carriers is enabled with swarm algorithms.

Underway replenishment of a naval carrier is a time-consuming task where the largest cost comes from the need to constantly train new sailors. In order to reduce cost, a reduction in manpower is needed, which in turn requires an increase in efficiency. Orbital Research is currently developing swarm-based algorithms for the

Swarm algorithms can be used to coordinate large numbers of vehicles such as the XUV

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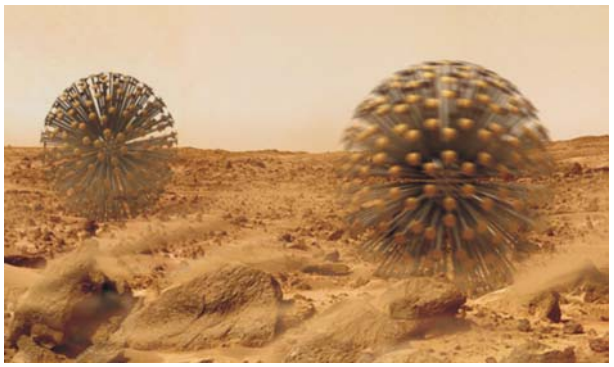
Rev F: RMK-12-09-2003

efficient routing of packages through a carrier. These algorithms combine the efficiency of graph theory with the power of swarm algorithms to produce a package that can provide efficient paths while considering important factors such as package type and priority, carrier status level, current bottlenecks, and broken conveyors/elevators.

Swarm algorithms are also being used to enable the low cost exploration of space. A new concept for the exploration of Mars calls for the use of large groups of lightweight, wind driven rovers based upon the Russian Thistle or tumbleweed. These groups of Martian rovers use swarm algorithms to coordinate their behaviors while using nothing more than wind as their motive power. In addition, this concept and the technologies developed for it have relevance to the exploration, surveillance and reconnaissance of any dangerous or inaccessible environment.

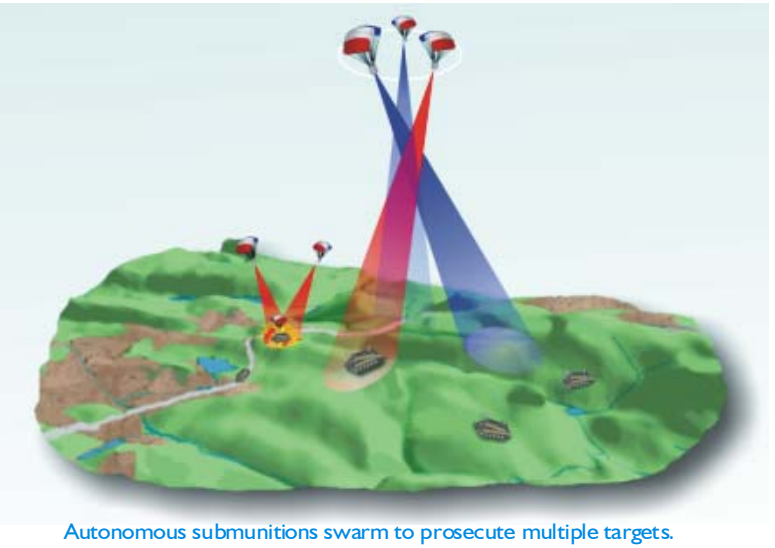


Autonomous Martian Rovers, based upon tumbleweeds, use swarm algorithms for cooperative control.

Swarm Algorithm Development

SWEEP-Re (Swarm Experimentation and Evaluation Platform, Recursive) is Orbital Research's autonomous agent simulation and modeling tool suite. The SWEEP-Re model consists of four modules: ACT, ICE, HIVE, and EPIC. The Agent Control Toolbox (ACT) is the main controller for the agent. The Hybrid Integrated Virtual Environment (HIVE) is a model of the environment in which the agents reside. The Evaluatory Probes and Interactive Control (EPIC) module enables users to gather data from all parts of the simulation and also to change run-time parameters on-the-fly. Finally, all of the previous components are tied together through the Independent Communications Layer (ICE), which is an XML enabled protocol that provides methods of translating communiqués between two independent sources. The current state of the art in swarm algorithm development is relegated to a tedious trial-and-error methodology due to the complex behaviors that arise from the large numbers of agent interactions. Orbital Research has leveraged evolutionary programming to automate and streamline the process of swarm algorithm development. Evolutionary programming is another biologically-inspired technique that uses concepts borrowed from the theories of Darwinian and Lamarckian evolution that allow computer programs to compete for survival. Orbital Research has developed a component-based evolutionary programming package that is fully interoperable with the SWEEP-Re simulation system and has been successfully used to evolve many standard swarm algorithms.

This algorithm development suite enables rapid formulation of control systems for complex systems, including human-in-the-loop (HIL) systems



Autonomous submunitions swarm to prosecute multiple targets.

Future Directions and Ongoing Research

Orbital Research is maintaining its competitive advantage in this field by conducting substantial research and development into new types of swarm algorithms, new tools for their development and application. New approaches based upon complex systems theory are being used for rigorous examination of the properties of swarm algorithms and to provide new methods for algorithm generation. Applications such as information fusion, data mining, and data routing in computer networks are being developed using swarm algorithms. The versatility and robustness of the swarm intelligence-based algorithms developed at Orbital Research coupled with new theoretical results being produced by Orbital Research researchers ensures that Orbital Research will continue to be a leader in the field of swarm intelligence algorithms.

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