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HIGHLIGHTING RAYTHEON'S TECHNOLOGY

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Raytheon's Culture of Innovation

Providing Leading-Edge Customer Solutions

Raytheon

Customer Success Is Our Mission

Swarm Intelligence for Automatic Knowledge Extraction

Raytheon's 2007 IDEA program of the year enables competitive awards

Raytheon internal research in ant colony systems (ACS) and artificial immune systems (AIS) was recognized with Raytheon's 2007 IDEA Program Innovator of the Year award. (For more about the IDEA program, see "Innovation at Raytheon.") The IDEA Program seed funding led to the award of a highly competitive contract research and development project from the National Reconnaissance Office's Director's Innovation Initiative Program. It also led to another recently awarded highly competitive contract with the Air Force Research Laboratory on dynamic defensive counter-space indications and warning.

Most complex problems in mission management and sensor data exploitation are related to optimization, search, learning or control. Traditional mathematical techniques in operations research require rigorous problem formulation, and an optimal solution is not always achievable. Furthermore, a real-time solution is frequently needed by the decision-maker in the battlefield and often must be drawn from a set of incomplete and uncertain observations.

New techniques that are more robust, fast and effective in solving these problems are required. Raytheon has been exploring bio-inspired techniques, in particular swarm intelligence, for automatic knowledge extraction, target recognition and tracking, and anomalous event detection. Two specific techniques under investigation within Raytheon include ACS and AIS, due to their robustness, great flexibility, and efficiency in automatic complex optimization problem-solving.

ACS and AIS provide better tools for solving complex problems in mission management and data exploitation. They are particularly suitable for designing multi-agent systems for solving difficult combinatorial optimization problems. There is currently a lot of ongoing activity in the scientific community to extend/apply these algorithms to many different problems like task scheduling, vehicle routing, sequential ordering, graph coloring, routing in communications networks, etc.

Recognizing the utility of swarm intelligence, a team of European researchers is currently developing tiny autonomous robots that can cooperate to perform different tasks — much like termites, ants or bees forage collaboratively for food, build nests and work together for the greater good of the colony. Under the European Union-funded I-SWARM project, a team created a 100-strong centimeter-scale robots to be used for future exploration of the planet Mars.

Applying Swarm Intelligence

Swarm intelligence, when combined with knowledge representation techniques such as cognitive graphs, will become a very powerful means for solving many complex problems in data exploitation; system analysis; intent identification; and intelligence, surveillance and reconnaissance mission management.

Current research and development efforts are in the use of swarm intelligence for automatic knowledge extraction for

situational awareness, robust intrusion detection, mobile target detection and tracking, abnormal behavior recognition, cancer detection and screening, etc. The use of ACS and AIS as a new and better way of solving old problems in Raytheon traditional markets will support our effort to maintain our customer base and provide a means to expand our business into adjacent markets.

Ant Colony Systems

Ant algorithms were inspired by the observation of real ant colonies. Ants are social insects; insects that live in colonies are directed more to the survival of the colony as a whole than to that of a single individual component of the colony. An important and interesting behavior of ant colonies is their foraging behavior, in particular how they can find the shortest paths between food sources and their nest.

While walking from food sources to the nest and vice versa, ants deposit pheromones, forming a pheromone trail. Ants can smell the pheromones, and when choosing their way, they tend to choose, in probability, paths marked by strong pheromone concentrations. It has been shown experimentally that this pheromone trail-following behavior can give rise, once employed by a colony of ants, to the emergence of the shortest paths.

Artificial ants (e.g., robotic ants or software agents) have a double nature. On one hand, they are an abstraction of those behavioral traits of real ants that seem to be at the heart of the shortest-path-finding behavior observed in real ant colonies. On the other hand, they have been enriched with some capabilities that do not have a natural counterpart, making them more effective and efficient.

Artificial Immune Systems

Parallels have been drawn between the human immune system (HIS) and anomaly detection problem domains, particularly with regard to intrusion detection systems. The HIS, for the most part, successfully protects the body from harmful pathogens that come in many forms. Each type of pathogen has a different cellular structure, method of replication and mechanism for entering the body. The immune system has evolved complex structures and methods for identifying these pathogens and removing or responding to the threat that they possess.

The widely held view in immunology is that the main function of the immune system is to distinguish between "self" (cells belonging to the individual) and "non-self" (pathogens). However, immunologists are increasingly finding fault with traditional "self–nonself" thinking and a new "danger theory" is emerging. This new theory suggests that the immune system reacts to threats based on the correlation of various (danger) signals, and it provides a method of "grounding" the immune response, i.e., linking it directly to the attacker.

In AIS, a variety of contextual clues may be essential for a meaningful danger signal, and immunological studies provide a framework of ideas as to how danger is assessed in the HIS. Once the danger signal has been transmitted, the AIS can react to those artificial antigens (e.g., anomalous events/targets in the input data set) that are "near" the emitter of the danger signal. This allows the AIS to pay special attention to dangerous components and would have the advantage of detecting rapidly spreading viruses or scanning intrusions at an early stage, preventing serious damage.

Swarm intelligence belongs to the relatively new wave of stochastic meta-heuristics like evolutionary computation, simulated annealing, tabu search and neural computation, which are built around some basic principles taken by the observation of a particular natural phenomenon. Within the artificial-life field, ACS and AIS represent the two most successful applications of swarm intelligence. ●

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ENGINEERING PROFILE

Duong Nguyen
Senior Principal Multi-Disciplined Engineer, IIS

During his seven years with Raytheon, Duong Nguyen has been a member of the Intelligence and Information Systems (IIS) Rocky Mountain Engineering/Advanced Planning and Technology Development program. He is also responsible for contract funded research and development (CRAD) and University Directed Research Programs at IIS' Aurora, Colo. site.

Before joining Raytheon, Nguyen was in academia for many years. He also worked in research and development at Centre National d'Etudes Spatiales in France, as chief scientist at Geodynamics, and as a technical advisor at Northrop Grumman.

According to Nguyen, innovation is creating a new and useful idea that provides a solution to a problem of interest to our customer, or helps improve Raytheon in-house capability and allows it to operate more effectively. He has applied this definition throughout his career.

He was the first to propose the use of "Real Options Theory" in the financial investment domain for dynamic satellite tasking and secured a highly competitive CRAD project for the idea. Later, while exploring bio-inspired techniques for better space mission planning and management, he proposed the use of "swarm intelligence" for automatic knowledge extraction. This innovative idea led him to receive an in-house IDEA award and another CRAD project. In all, Nguyen has been awarded two in-house IDEA projects and three highly competitive CRAD projects, with two patents pending, in four years.

One of the biggest challenges that Nguyen encounters is motivating engineers to come up with innovative ideas. He believes that it's imperative for Raytheon engineers to realize that innovation generates CRAD, and CRAD sustains and supports business growth.

"It's relatively easy to motivate young engineers to realize that innovation and CRAD have a causal relationship. Without innovation, it's hard to get CRAD projects," he explained. "Also, without CRAD requirements we don't know what innovative ideas customers need."

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