Workshop on Algorithmic Equivalences Between Biological and Robotic Swarms

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I. Introduction: Workshop Goals

This workshop brought together researchers in biology and robotics who study distributed computational systems: insect colonies and multi-robot teams. The main goal was to enable rigorous discussion of the common algorithms employed by natural and artificial swarms.

The premise is that similarities in our respective high-level models of sensing, communication, processing, and mobility constrain the distributed algorithms that can be used. We set out to discuss many open questions: What fundamental mathematical theories underpin both biological and artificial systems? What analytical tools are commonly used in one field, which may be of benefit to the other? What specific common constraints apply to the solutions found by nature and robot engineers? When do roboticists wish they knew more biology? When do biologists wish they knew more computer science or control theory? What tasks and applications for swarm technology are most like those of their natural counterparts? What is the most productive way to use "natural algorithms" in distributed robotics?

II. Presentations

The workshop consisted of two invited talks, four research presentations, and a series of discussions. The workshop program and abstracts can be found at *http://projects.csail.mit.edu/rss2007workshop/program.html*.

1) Invited talk: *Collective decision-making by ant colonies: Linking group and individual behavior* Stephen Pratt School of Life Sciences, Arizona State University
2) Invited talk: *Cooperative Control of Multi-Agent Systems* Sonia Martinez Diaz Mechanical and Aerospace Engineering (MAE), University of California at San Diego
3) *Rational swarms for distributed on-line bayesian search* Alfredo Garcia, Chenyang Li and Fernan Pedraza
4) *Macroscopic information processing in natural systems as an insight for swarm robotics* Dylan Shell and Maja Mataric
5) *Genetic structure and cohesion of insect societies* Michael Goodisman
6) *Energy-efficient multi-robot rendezvous: Parallel solutions by embodied approximation* Yaroslav Litus, Pawel Zebrowski and Richard T. Vaughan
7) *Roadmap-based group behaviors* S. Rodriguez, R. Salazar, N.M. Amato, O.B. Bayazit, and J.-M. Lien

III. Discussion

The afternoon discussions identified broad categories of commonality between our two fields: 1) the assumptions and constraints underlying physical distributed systems, 2) the models we use in researching these systems, and 3) the algorithms and mechanisms used by biological and robotic swarms. In addition, we have discussed experiments and applications that are relevant to our respective communities.

A computational model of many insect societies shares several key components with a model of distributed computation on teams of robots: short-range, local communications, limited processing, and constraints on information gathering and algorithm execution. For example, the physical speed of an insect (or robot) affects how much territory it can survey in a given amount of time. The general theme is that the similarities in physical hardware should forces the theory underlying these two systems to be similar.

Our discussions highlighted many differences as well. In many insect societies, physical polymorphism is used to produce workers in many different sizes for different jobs. Large-scale heterogeneous systems are currently the exception in multi-robot teams. The scale of natural systems can be very large, with some global behaviors only evident above certain population thresholds, but there is no coherent view of how colony size affects algorithms in general. Individual variation seems to be important in natural systems and may help smooth community responses to external stimulus and prevent global oscillations.

Artificial distributed systems sometimes break the common assumptions for the sake of elegant proofs, which can limit the applicability of these results to biological systems.

The applications of natural and artificial systems differ fundamentally. Artificial systems are designed to perform a desired task, natural systems are selected by their ability to reproduce.

The final discussion topic constructed a bibliography for for a graduate student wishing to study this problem. A next step would be to develop an interdisciplinary curriculum for a course. The references can be found at *http://projects.csail.mit.edu/rss2007workshop/bibliography.html*.