Institute for Pure and Applied Mathematics University of California, Los Angeles presents

Swarming by Nature and by Design

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Organizing Committee: **Andrea Bertozzi** (UCLA, Mathematics), **Daniel Grunbaum** (University of Washington, Oceanography) **P. S. Krishnaprasad** (University of Maryland, Electrical and Computer Engineering), **Ira B. Schwartz** (Naval Research Laboratory, Nonlinear Dynamical Systems)

Scientific Overview

The cohesive movement of a biological population is a commonly observed natural phenomenon. With the advent of platforms of unmanned vehicles, this occurrence is attracting renewed interest from the engineering community. The purpose of this workshop is to foster advances in the modeling and analysis of biological swarms and to explore design ideas for efficient algorithms to control groups of autonomous agents. This interdisciplinary program draws from ideas in biology (experimental and theoretical), mathematics (including PDEs, dynamical systems, and numerical analysis), physics (statistical mechanics and non-equilibrium thermodynamics), computer science (distributed AI), and engineering (control theory).

Biological perspectives on formation and dissolution of groups are motivated by the fact that nearly all organisms are aggregated relative to environmental variables and to other members of their own species. Swarms, schools, flocks and herds successfully perform tasks that individual members cannot. Aggregated populations fulfill different objectives from those met by dispersed populations. The relationships between individual behaviors and resulting group characteristics are of ecological and evolutionary importance.

Biological studies of collective motion are developing rapidly, spurred by technological improvements in the observation of behavioral interactions among individuals within groups, by advances in behavioral theory and computer simulations, and by insights such as those gathered from studies of how kinship within a group affects group characteristics. In biomechanics, among other fields, collaboration between biologists and engineers has advanced biological understanding and inspired engineering concepts. The topic of biological aggregation, particularly active social aggregation behaviors such as swarming and schooling, is now ripe for this kind of cross-disciplinary collaboration.

In many areas of science and engineering, it is important to quantify the location of coherent structures, whether large scale -- internal waves in the ocean -- or microscopic, such as space-time chaos in CO platinum reactions. In two dimensional problems, the structures may be viewed by remote sensing and imaging. However, in many cases, direct measurement may be the only way to locate coherent structures. Direct measurements require multiple coordinated mobile sensors. The problem of coordination of collective sensing naturally leads to new mathematical explorations of pattern-forming systems. Sensors could be put on mobile vehicles, and in the future, micro- or nano-particles might be used for exploration and control-- an idea that was once proposed by Richard Feynman. As machines get smaller, it is evident that new possibilities for direct sensing may be found in fluid control, materials science, and bio-engineering, among other fields. By forming systems which are not only coupled but interact with their environment we will encounter problems that require new mathematical tools to make reasonable predictions. Such tools will require areas as diverse as nonlinear analysis of PDE-ODE systems, stochastic nonlinear equations, communication theory, game theory and voting theory. The areas the conference will cover represent just a few of the new ideas for swarming dynamics. They will include areas such as:

- **Controlling unmanned autonomous vehicles**
- **Building swarming targeting and acquisition systems**
- **Embedding swarming sensors in advection-reaction systems**
- **Swarming Levy distribution search processes**
- **Search algorithms and their implementation on platforms**
- **Pattern formation in biological swarms**
- **Control of biological swarms, such as locusts**

Participation:

We have funding to support the attendance of recent PhD's, graduate students and researchers in the early stages of their career. Mathematicians and scientists at all levels who would like to learn more about this area are encouraged to apply for funding. Encouraging the careers of women and minority mathematicians and scientists is an important component of IPAM's mission and we welcome their applications.

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