Foreword

Science is a swarm.

To the layperson, the stereotypical scientist is logical, clear-thinking, well-informed but perhaps socially awkward, carefully planning his or her experiments and then analyzing the resulting data deliberately, with precision. The scientist works alone, emotion-free, searching only for truth, having been well advised about the pitfalls and temptations that lie along the path to discovery and the expansion of human knowledge.

Those who work in science understand how inaccurate this stereotype is. In reality, researchers' daily routines follow a process better described as collective trial-and-error, nearly random at times. A most salient feature of scientific behavior is its collaborative nature. From applying for grants to seeking tenure, from literature reviews to peer review to conference presentations, every bit of the scientific enterprise is social, every step of the process is designed to make scientists aware of one another's work, to force researchers to compare, to communicate, to study the work that others are doing, in order to push the paradigm forward - not as independent, isolated seekers-of-truth, but more like a swarm.

If we plotted a group of scientists as points on a space of dimensions of theories and methods, and ran the plot so we could see changes over time, we would see individuals colliding and crossing, escaping the group's gravity field and returning, disintegrating but simultaneously cohering in some mysterious way and moving as a deliberate, purposeful bunch, across the space - constantly pushing toward a direction that improves the state of knowledge, sometimes stepping in the wrong direction, but relentlessly insisting toward an epistemological optimum.

The book you hold in your hand is a snapshot of the swarm that is the swarm paradigm, a flash photograph of work by researchers from all over the world, captured in mid-buzz as they search, using collective trial and error, for ways to take advantage of processes that are observed in nature and instantiated in computer programs.

In this volume you will read about a number of different kinds of computer programs that are called "swarms." It really wouldn't be right for something as messy as a swarm to have a crisp, precise definition. In general the word swarm is probably more connotative than denotative; there is more to the way swarms feel than to any actual properties that may characterize them. A swarm is going to have some randomness in it - it will not be perfectly choreographed like a flock or a school. A swarm is going to contain a good number of members. The members of the swarm will interact with one another in some way, that is, they will affect one another's behaviors. As they influence one another, there will be some order and some chaos in the population. This is what a swarm is.

The swarm intelligence literature has mostly arisen around two families of algorithms. One kind develops knowledge about a problem by the accumulation of artifacts, often metaphorically conceptualized as pheromones. Individuals respond to signs of their peers' behaviors, leaving signs themselves; those signs increase or decay depending, in the long run, on how successfully they indicate a good solution for a given problem. The movements of swarm population members are probabilistically chosen as a function of the accumulation of pheromone along a decision path.

In another kind of swarm algorithm each individual is a candidate problem solution; in the beginning the solutions are random and not very good, but they improve over time. Individuals interact directly with their peers, emulating their successes; each individual serves as both teacher and learner, and in the end the researcher can interrogate the most successful member of the population to find, usually, a good problem solution.

It is important that both of these kinds of algorithms, ant colony swarms and the particle swarms, are included together in one volume, along with other kinds of swarms. In the forward push of knowledge it is useful for researchers to look over and see what the others are doing; the swarm of science works through the integration of disparate points of view. Already we are seeing papers describing hybrids of these approaches, as well as other evolutionary and heuristic methods - this is an inevitable and healthy direction for the research to take. Add to this the emergence of new swarm methods, based for instance on honeybee behaviors, and you see in this volume the upward trajectory of a rich, blooming new field of research.

Science is a way of searching, and should not be mistaken for a list of answers - it is a fountain of questions, and the pursuit of answers. No chapter in this book or any other will give you the full, final explanation about how swarms learn, optimize, and solve problems; every chapter will give you insights into how the unpredictable and messy process of swarming can accomplish these things.

As the stereotype of the scientist as a lone intellect has been challenged, revising the stereotype should change the way we think about knowledge, as well. Knowledge is not a package of information stored in a brain, it is a process distributed across many brains. Knowing is something that only living beings can do, and knowing in the scientific sense only takes place when individuals participate in the game. Every paradigm has its leaders and its followers, its innovators and its drones, but no scientific paradigm can exist without communication and all the living behaviors that go with that - collaboration, competition, conflict, collision, coordination, caring.

These chapters are technical and challenging, and rewarding. Here our basic task is data-mining, where we have some information and want to make sense of it, however we have defined that. Swarm methods are generally good in high dimensions, with lots of variables; they tend to be robust in noisy spaces; swarms are unafraid of multimodal landscapes, with lots of good-but-not-best solutions. Researchers in this volume are pushing this new paradigm

into highly demanding data sets, reporting here what they are able to get it to do.

May 05, 2006 *James Kennedy, USA*