

Preface

It is thought that ants in an ant colony do not know exactly how the ant colony where they live should be built. Each ant has certain things that it does in coordinated association with other ants, but no ant designs the colony. How the colony of ants works collectively in the manner it does remains a mystery. However, an important clue to the answer to this question may be found by looking at interactions among ants.

Many organisms form collectives that strongly affect the behavior of individuals. Familiar examples include the schooling behavior of fish and the flocking behavior of birds. Collective behavior emerges from traits of individuals. Collectives emerge from relatively simple traits of individuals, and these traits give rise to individual behaviors that form the collective. Collectives can be treated as an additional level of organization between the individual and the population.

For the last decade, attempts have been made to develop some general understanding, and ultimately a theory of systems that consist of interacting agents. It is common to call these systems *collective systems* because it is difficult to reduce aggregate behavior to a set of properties characterizing the individual components. Interactions produce properties at the aggregate level that are simply not present when the components are considered individually.

In his book, titled *The Wisdom of Crowds*, Surowiecki (2004) explores an idea that has profound implications. A large collection of people are smarter than an elite few, no matter how brilliant they are and or how much better they are at solving problems, fostering innovation, coming to wise decisions, even predicting the future. His counterintuitive notion, rather than crowd psychology as traditionally understood, suggests new

insights regarding how complex social and economic activities are organized. He explains the *wisdom* of crowds emerges only under the right conditions, which are (1) diversity, (2) independence, (3) decentralization, and (4) aggregation.

On the other hand, the fact that selfish behavior may not achieve full efficiency has been well reported in the literature. Recent research efforts have focused on quantifying the loss of system performance due to selfish and uncoordinated behavior. The degree of efficiency loss is known as the *price of anarchy*. We need to design systems so that selfish individual behaviors need not degrade the system performance.

In this book, a collective system, or simply a *collective*, is modeled as a collection of autonomous decision-making entities, called *agents*. A collective refers to any complex system of interacting agents, together with performance measures by which we can rank the behavior of the entire system. Collective systems include a collection of diverse and mutually adaptive agents pursuing varied and often conflicting interests. The collective systems are situated between a few agents in game theoretic systems, a few hundred agents in multi-agents systems, and a larger scale of agents in typical economic and social systems.

The mission of collective evolution is to harness the collective systems of selfish agents and to serve to secure a sustainable relationship in an attainable manner so that desirable properties can emerge as *collective intelligence*. Of particular interest is the question as to how social interactions can be restructured so that agents are free to choose their own actions while avoiding outcomes that none would have chosen.

Darwinian dynamics based on mutation and selection form the core of models for evolution in nature. Evolution through natural selection is understood to imply improvement and progress. If multiple populations of species adapt to each other, the result is a co-evolutionary process. The problem to contend with in co-evolution based on the Darwinian paradigm, however, is the possibility of an escalating arms race with no end. Competing species might continually adapt to each other in more and more specialized ways, never stabilizing at a desirable outcome.

In biology, the gene is a better unit of selection by which to represent individuals. However, the collective evolutionary process is expected to compel agents towards ever more refined adaptation and evolution,

resulting in sophisticated behavioral rules. The persistence and sustainability of the collective system in turn depends on its persistent collective evolution.

Hardware developments will soon make possible the construction of very-large-scale models, for instance, models that contain one million to 100 million agents. It has been argued that the main impediment to creating empirically relevant agents on this scale is our current lack of understanding of the realistic behavior of agents. This bottleneck, i.e., what rules to write for agents, is the primary challenge facing the agent research community. The approach of collective evolution is very much at the forefront of this issue.

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Akira Namatame