COLLECTIVE INTELLIGENCE IN ANIMAL GROUPS

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ABSTRACT

The regulation of foraging activity in harvester ant colonies exemplifies a complex biological system that operates as a large distributed, multi-agent network. There is no centralized control. The queen does not direct other ants; she merely lays the eggs. Colonies perform a range of tasks such as nest construction, caring for larvae, and foraging, in a coordinated way. An ant can change tasks. Each ant responds only to local information, including its its recent experience of its rate of interaction with other ants.

A long-term study of a population of colonies in the Arizona desert shows that harvester ant colonies adjust foraging activity to food availability, so as not to send out more ants than are justified by the current food supply. The ants collect seeds that are widely scattered, each retrieved by a single ant without the use of pheromone trails. Colonies must minimize water loss: ants spend water foraging in the desert sun and obtain water by metabolizing the fats from seeds.

Foraging is regulated using a simple positive-feedback process that operates without any spatial information. An outgoing forager leaves the nest on its next trip in response to the rate at which it interacts with foragers returning to the nest with food. Interactions consist of brief antennal contacts, during which one ant can assess the task of the other using odor cues. The rate at which foragers return is related to food availability, because the duration of a foraging trip depends mostly on how long the forager had to search to find a seed. When food is more plentiful, foragers return more quickly.

A recent model describes the algorithm colonies use to regulate foraging. Fitting the model to data shows how colonies vary in foraging behavior. Small differences among colonies, in the way the ants use this algorithm to respond to interactions, lead to differences among colonies in reproductive success. This makes it possible to show the ecological and evolutionary consequences of collective behavior in this system.

There are interesting analogies between the regulation of foraging by ant colonies and algorithms used in other systems; for example other work (in collaboration with B. Prabhakar) explores the resemblance to algorithms such as TCP that regulate the flow of data in the internet, and (in collaboration with M. Goldman) the resemblance to leaky integrator models of neural networks. Examining these analogies elucidates how the diverse processes that generate collective behavior are related to the diverse conditions in which they operate.