From chaos to order: How ants optimize food search

May 26 2014

Temnothorax rugatulus. Credit: Arizona State University

Ants are capable of complex problem-solving strategies that could be widely applied as optimization techniques. An individual ant searching for food walks in random ways, biologists found. Yet the collective foraging behaviour of ants goes well beyond that, as a mathematical study to be published in the *Proceedings of the National Academy of Sciences* reveals: The animal movements at a certain point change from chaos to order. This happens in a surprisingly efficient self-organized way. Understanding the ants could help analyze similar phenomena - for instance how humans roam in the internet.

"Ants have a nest so they need something like a strategy to bring home the food they find," says lead-author Lixiang Li who is affiliated both to the Information Security Center, State Key Laboratory of Networking and Switching Technology, at the Beijing University of Posts and Communications, and to the Potsdam Institute for Climate Impact Research. "We argue that this is a factor, largely underestimated so far, that actually determines their behavior."

Leaving a trail of scent

The Chinese-German research team basically put almost everything that is known about the foraging of ants into equations and algorithms and fed this into their computers. They assume that there are three stages of the complex feed-search movements of an ant colony: Initially, scout ants indeed circle around in a seemingly chaotic way. When exhausted, they go back to the nest to eat and rest. However, when one of them finds some food in the vicinity of the colony, it takes a tiny piece of it to the nest, leaving a trail of a scent-emanating substance called pheromones.

Other ants will follow that trail to find the food and bring some of it home. Their orchestration is still weak because there is so little pheromone on the trail. Due to their large number, the ants go lots of different ways to the food source and back to the nest, leaving again trails of scent. This eventually leads to an optimization of the path: Since pheromones are evaporative, the scent is the stronger the shorter the trail is – so more ants follow the shortest trail, again leaving scent marks. This generates a self-reinforcing effect of efficiency – the ants waste a lot less time and energy than they would in continued chaotic foraging.

Importantly, the researchers found that the experience of individual ants contributes to their foraging success – something also neglected in previous research. Older ants have a better knowledge of the nests surroundings. The foraging of younger ants is a learning process rather than an effective contribution to scout food, according to the study.

"A highly efficient complex network"

"While the single ant is certainly not smart, the collective acts in a way that I'm tempted to call intelligent," says co-author Jürgen Kurths who leads PIK's research domain Transdisciplinary Concepts and Methods. "The principle of self-organisation is known from for instance fish swarms, but it is the homing which makes the ants so interesting." While the study of foraging behavior of ants is certainly of practical ecological importance, the study's authors are mainly interested in understanding the fundamental patterns of nonlinear phenomena. "The ants collectively form a highly efficient complex network," Kurths explains. "And this is something we find in many natural and social systems."

So the mathematical model developed in studying the ants is applicable not only to very different kinds of animals which share just the feature that they have a home to return to, such as Albatrosses. It also provides a new perspective on behavioral patterns of humans in areas as diverse as the evolution of web services and smart transportation systems.

More information: Li, L., Peng, H., Kurths, J., Yang, Y., Schellnhuber, H.J. (2014): Chaos-order transition in foraging behavior of ants. *Proceedings of the National Academy of Sciences*, Early Edition: DOI: 10.1073/pnas.1407083111

Provided by Potsdam Institute for Climate Impact Research