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Reading 1: Foraging, Stigmergy, Network Routing and Optimization

Paper 1: Self-organized shortcuts in the Argentine Ant, Naturwisenchaften, 76, 579-581, 1989

Paragraph or two on any/some of the following points:
What do you feel the main contribution of this paper is? What's the essential principle that the paper exploits? What did you find most interesting about this work?

Finding the shortest path between home and food sources serves apparent advantages for an individual social insect as well as its community. We as humans have long been interested in this problem from a mathematical and a practical perspective. Some would argue that the ability to find the shortest path requires a certain level of cognitive abilities such as learning and memory. But as Goss et al., 1989 discovered, the Argentine ants have (elegantly) solved this problem even with limited cognition and limited navigational information. The authors presented what I've long admired in social insects, the power of stimergy, and how collective exploration and pheromone communication give the colony of the Argentine ants the ability to find the shortest route between their nest and the food source.

This paper contributes (to behavioral ecology and to science in general) a fairly simple but illuminating model of the ants' solution to the problem of finding the shortest route between 2 points. The model offers the predictions of the probability that the ant colony finds the shorter branch given the difference between the lengths of the 2 branches. The model also gives insights into scenarios in which the ants may not come to prefer the shorter branch: if the short branch is presented later than the long branch and if the foragers only lay their pheromones when returning to the nest rather than both when they're leaving and returning. The model relies on the assumption that the ants choose and affect their sisters' choice of branch based on quantities of pheromones on the competing branches. I find that there's an interesting implication: that these animals operate like memoryless agents in a stochastic world. If a forager repeatedly chooses a certain branch, do we conclude that, based on this model, her choice is based on the pheromone dynamics her colony has collectively created? Or can we also be open to the possibility that she can learn and remember that this is the most optimal path to the food source?

Short answers to the questions below

One major strength of the paper

I appreciate the authors' considerations of details in the experiment to ensure the ants' spatial behaviors in the lab were as close to their behaviors in their natural habitat. For example, care was taken to make each of the 2 branches 30º to the axis of the central bridge and to include 2 opposite models of the branches in the path, to minimize potential experimental biases that could affect the foragers' preference of routes to food.

Unrelated to the science itself, I like the very clear and legible writing style of this paper. Since papers are the primary way scientists communicate, I am always looking for good writing style to emulate. I wonder if writing style is also field-related. I just read molecular biology papers that have endless acronyms and are as dense as possible. This was a refreshing read!

One weakness of this paper

I'd like to know if the authors used a method to measure the pheromones present in the branches (if that's feasible), to further support their proposal that the ants individually and collectively choose the branches based on quantity of pheromones in the 2 branches, S_j and L_j. I'd also like to know the distribution of the lifetime of the volatile pheromone. The authors gave the mean lifetime of 30 min. But if there's a lot of variation, this model should take that into consideration, as high variation may make the assumption that ants choose a branch based on quantity of pheromone (assumably proportional to lifetime) less likely to hold.

Short discussion of

One question or future work direction you think should be followed. Or some insight/connection you think is interesting to pursue.

The authors stated that they deliberately did not include effects of individual memory and other cognitive functions in the model to keep it simple and they described a few experiments where they test the ants' memory. But since there is much literature showing ants' learning abilities and in the interest of invertebrate behaviors, it is worth it to explore such abilities of the ants and perhaps add this parameter to the model to enhance its depiction and prediction of true natural behaviors of these animals.

I imagine people might have already done this since this is a 1989 paper, but it must also be interesting to complicate the paths to the food source and observe how long and how well the ants can collectively choose the shortest route. Are they, as a community, sensitive enough to choose between 2 branches/paths with very similar lengths?

Paper 2: AntNet: Mobile Agent for Adaptive Routing, Intl Conf on Systems Science, 1998

Paragraph or two on any/some of the following points:
What do you feel the main contribution of this paper is? What's the essential principle that the paper exploits? What did you find most interesting about this work?

A neurobiology professor who I deeply cherished in undergrad taught me that the anthropocentric and erroneous view that insect brains are too simple to be academically worthwhile is slowly shifting, as we increasingly realize their elaborate neural circuits and complex behavioral functions. This paper by Di Caro and Dorigo is so gratifying to me, because it demonstrates how humans can learn a lot from the seemingly insignificant ants. And we can learn not only academic knowledge, but we can use that knowledge for practical and efficient applications, which in this case is adaptive routing.

This paper introduces AntNet, a packet routing algorithm inspired by the way real ants use stimergy to find the shortest route between locations of interest, as described by paper 1 above. In the AntNet algorithm, some mobile agents individually build paths between the source and the destination, while also exploring the network as other agents stimergically exchange info to modify the routing tables. The authors define an optimal routing algorithm as a "multi-objective optimization problem in a non-stationary stochastic environment." Performance of the algorithm is measured by throughput (number of packets routed per sec) and average packet delay (sec). AntNet is characterized as an adaptive routing algorithm, with the ability to adapt the routing to traffic conditions, though at the drawback of fluctuations in certain paths. As the authors demonstrated through comparing to other shortest path finding algorithms in existence, AntNet offers an effective and superior routing algorithm.

Short answers to the questions below

One major strength of the paper

The overall description of the algorithm is clear and concise, even for someone largely ignorant of algorithms and programming like me. The authors make it clear that the algorithm uses 2 types of agents: the forward ant gathers info about the network while moving from the source node to the destination node, while the backward ant uses the info to update the routing tables of the nodes moving in the opposite direction. It's also clear that the ants/agents communicate in the form of reading and writing info to the data structures at each node of the network. I also appreciate the comparison between AntNet and other contemporary routing algorithms. This introduces a new reader to the current state of this class of algorithms while showing what AntNet has to offer.

One weakness of this paper

I'd like to know how the routing tables were initialized. It seems to me that the authors did not mention this, only the method of updating the table. Is it reasonable, without knowledge of the initialization, to assume uniform distribution of probabilities?

Short discussion of

One question or future work direction you think should be followed. Or some insight/connection you think is interesting to pursue.

I'm curious about what happens when a link or a node fails. For a backward ant, $B_{d>s}$, if it cannot return to the source node, does the data in its stack still represent the network? I also wonder if the network requires a maximum number of ants/agents so the congestion does not hit a threshold.

Also, the authors mentioned that AntNet performance is affected mainly by frequency of agent launching and the agents' spatial distribution. Does performance of the algorithm also depend on network size?

Has AntNet been only applied to data communications? Can it be applied to real road traffic routing, to find the best/shortest routes for vehicles while avoiding congestion?