Dieu My Nguyen
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Reading 2: Collective Transport by Ants and Robots

Paper 1: Collective strategy for obstacle navigation during cooperative transport by ants, Journal of Experimental Biology, 2016

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?

"There is strength in numbers," the adage usually goes. I would add that there is strength in numbers when the individuals are programmed to act in concert and give rise to highly organized and effective emergent properties seen in the collective. This paper shows us one impressive aspect of the *Paratrechina longicornis* ant world: the ants' ability to exploit group cohesion and consensus to overcome physical obstacles during cooperative transport. Without a central leader, individual workers still collectively and effectively make a series of decisions to complete their goal of overcoming physical hurdles to carry an object back to their nest.

What I find fascinating in this paper is that although we (or I) might see the ants as stringently programmed by genetics and evolution to carry out tasks they were born to do, as the authors conclude, the ants' strategies in solving the obstacle-during-transport problem have a stochastic component. Ants in different trials eventually navigated the wall and the cul-de-sac, but no trajectory exactly matched another. The different levels of difficulty of the obstacle also demanded different solutions, and the transporting ants, as a collective organism, were able to cope with that, as the authors observed and noted in the strategy elements in table 3. They might still exhibit counter-productive behaviors, such as changing direction when they're almost to the end of the wall, but their problem-solving skill as a group is still admirable. I am intrigued by the idea of consensus among the individuals cooperating on the transport.

Like the authors, I am also as surprised to know that larger groups moved faster than smaller ones, but that the increase in speed did not equate to faster and more efficient obstacle navigation. Perhaps this is due to the need for consensus to change trajectory directions: the more individuals there are, the more impositions for new directions.

One major strength of the paper

I love that the authors have come up with worthy challenges for the ants. The 3 increasingly difficult obstacles (the wall, the cul-de-sac, and the trap) forced the ants to exhibit noticeable different problem-solving strategies that we can observe and characterize (and marvel at). The authors also have selected with care the important and interesting types of data to extract and analyze: speed, sinuosity, backward runs, sharp turns, and escape points.

One weakness of this paper

I am not sure if the concept of "consensus" is clearly defined here. I find myself wondering if the ants do come to 100% agreement, or is it the majority or a dominant rules? The paper, and perhaps others in the literature, seems to define consensus about travel direction in the transporting ants simply by their moving together. And speed and "stalls" were used to assess how well a group of ants maintain consensus. But the concept is fuzzy to me. Are there any papers that show a "voting" process among the cooperating ants?

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 probably know this: Did the ants in the trap eventually just give up trying to find their way back to the nest? What is the observable manifestation of that abandonment of mission? A decrease in group size as individual ants leave the effort to carry the object?

Future work directions for ant transports in general may explore different types of obstacles, such as uphills and downhills. Also, gaps! A bridge built by the *Eciton hamatum* (from Princeton):

Furthermore, what is the main mechanism behind the ants' ability to know the direction of the nest? Pheromones? Sight? Spatial memory? Theoretically, if we move the nest to a new area after the workers have gone out foraging, will the ants be able to find their way home?

Paper 2: Occlusion-based cooperative transport with a swarm of miniature mobile robots, IEEE TRAN, 2015

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?

This paper provides a counterintuitive proof of concept! We usually think that visibility of the goal and its location are among the most important factors to reach that goal. Lacking such visibility is a hurdle to overcome. Yet, the authors have designed a transport strategy in which minimalist and autonomous robots cooperatively transport a convex object large enough to occlude the robots' view of the goal. The robots only push the large object when the goal is occluded, and they will eventually transport the object to the goal.

The appeal of this computational strategy is its decentralized and stimergic nature, inspired by the ant species that exhibit similar cooperative transport strategies. With the individual robots being programmed the same way, they come together to complete this task without needing a dominant leader. The robots also need not be complex and sophisticated. As demonstrated, simple e-pucks with limited capabilities can form a swarm to complete a

common goal. The authors also show the robots' ability to transport objects of different shapes and sizes towards both a stationary and a moving target. They also include a simulation that shows possibility of 3D implementation, which would be awesome as this system might have practical applications, such as the one listed in the paper: delivery of drugs through a vascular network or removal of debris in pipelines.

Short answers to the questions below
One major strength of the paper

The experiments are very well thought out and the paper is organized and provides sufficient explanations and results. I especially like the authors' inclusion of experimenting a moving goal, to show that this occlusion-based transport system can succeed when the environment complexity is increased, especially with the walls that block direct sight for the object's change in positions.

One weakness of this paper

I'd to understand better why the chosen time limit for the robots to perform the task is 15 min. Table 1 shows that most of the trials, the robot swarms were able to reach the goal in around 200 sec, but for a larger experimental space in which the goal is farther away, how would we determine the time limit?

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 interested to know if, like the ants, group size of the robot swarms affected speeds as well as efficiency in transport strategy. Table 1 shows the completion times and path efficiency of the robot swarms facing the 3 different objects in the stationary goal experiments. We may conclude that the complexity and therefore efficiency of the robots in this problem-solving scenario is ordered: circular, triangular, and rectangular, with the rectangular object having the longest completion time and least path efficiency. It'd be interesting to assess whether size of the swarms is a contributing factor.

The experiments with a moving goal could make the corridor/space and the moving goal even more challenging. For example, if the goal is not simply unidirectional (moving from one end of the space to another) and can turn back at some point during movement, can the swarm of robots adjust their trajectory as well?

Also, the tele-operator for the moving goal experiments had direct visual interactions with the robots and objects in all trials. This makes sense, as the interactions help the operator guide the leader robot and the operator can take into account the paths and appropriate speed. But we can also look at the experiments from a human-robot interaction perspective. It'd be interesting to think about how an operator can interact with the robots without direct view of the whole experimental space.