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Reading 4: Self-Assembly - Mechanics

Paper 1: Army ants dynamically adjust living bridges in response to a cost-benefit trade-off, PNAS, 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?

Army ants are architects and their building materials are their own bodies. I am so impressed by how these ants link themselves to create bridges that provide shortcuts over gaps in the foraging paths. This self-assembly behavior in the ants is a fine demonstration of the ability of social insects in particular, and complex systems in general, to form sophisticated high-level structures from individuals with limited capabilities. The army ants initiate bridges when they sense path deviations and gaps, and modify these shortcut structures to respond to the traffic levels of foragers and environmental geozmetry. Myrmecologists probably have observed this bridge assembly behavior in army ants in their natural environments, but the authors of this paper provide a controlled laboratory view of this behavior, which they characterize as a response to a cost-benefit trade-off at the colony level. The cost is in the number of workers removed from the foraging task to contribute to the bridge, balanced by the benefit if foraging efficiency with the shortcuts for gaps along the trail. The authors show a mathematical geometric model of the cost-benefit tradeoff that can explain the final location of the bridge. Per the model's implications, the ants as a collective can recognize the bridge position where the cost exceeds the benefit, although the authors mention that they cannot be certain that the final bridge locations in their experiments indicate the optimal positions predicted by the model. What the model is successful in predicting in terms of experimental observations is 1) the distance that the bridge moves decreases as the angle of the apparatus increases and 2) the bridge moves further as the traffic increases, for all angles.

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

I love this paper. Yet another testament to how marvelous the social insect world is. Besides the model to somewhat explain and predict the ants' bridge-building behavior in a quantitative manner, I also like the authors' explanation of how the bridges respond to the environment: possibly due to individual ants joining and leaving the structure based on interaction rates. I wonder, are the interactions based on pheromones as well as physical contact?

One weakness of this paper

Not really a weakness of the paper as all models require assumptions, but I'd like to point out that the authors' model treats all the ants equally while, as they themselves pointed out, there are differences between the ants that build the bridge and the ones that don't. The authors' preliminary observations indicate something interesting: that the bridge-building ants tend to be younger and less experienced in foraging. I'd like to see follow-up studies examining this observation! Furthermore, the model could take into count the differences in cost if this observation is true, since younger ants that build the bridge don't cost as much as more experienced foragers when they are used for the bridge instead of foraging.

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'd love to learn more about how artificial self-assemblages can learn from and improve upon the methods of these army ants. Have anyone modeled robots after these ants?

As the authors suggest in the conclusion, understanding global dynamics of these ant bridges necessitate a look beyond a single local bridge. A study of a whole network of bridges would be interesting. Do the characteristics of the bridges differ as the gaps/obstacles vary? Also, do the same ants seem to be the bridge builders? Overall, how consistent are the roles of the foragers (bridge-building vs non-bridge-building)?

Furthermore, do the ants modify the bridges' width and robustness based on the size of the prey?

Paper 2: Fire ants perpetually rebuild sinking towers, R. Soc. O. Sci., 2017

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?

Like the first paper, this paper shows us another species of ants, the fire ants, that are architects that respond to their environment. In this case, in rainy seasons and particularly after floods, the fire ants use their bodies to build rafts that anchor to vegetation and from there, build towers. The towers are of constant strength, and this is the ants' solution to not having the tower crush at the bottom. The authors present a math model that predicts the growth rate of the tower: as the support/base diameter increases, the growth rate decreases. What I find most interesting about this paper is the finding that the tower is parameterized by solely the strength of an ant (three ants), which is constant across building times and different rods. This finding speaks to the decentralized concept of a social collective that we have been studying. Based on an individual ant's strength, the unstable portions that are due to the individuals' exceeding their max force collapse, leaving the tower with constant strength and therefore as a stable structure overall.

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

The X-ray spectroscopy of the ant towers sounds awesome! Turning the ants into dark spots for the machine is a solution to tracking them as particles.

I also like their hypothesis of why the towers tend to widen from bottom to top rather than be constant size: individual ants have a max weight they can bear. It's interesting that this coincides with Timoshenko's "Towers of constant strength."

One weakness of this paper

I would've liked more discussion on the utility of a tower-like structure for robotic applications. How can we transfer the findings in this paper to practical applications? Also, can we find some connections between the model for the towers and models for other assemblies, such as bridges?

Also, the authors did not track the ants by size, but as they noted, body size may affect building speed and stability of the tower. Likewise, the authors idealized the tower as being consisted of layers, when real ant towers may not show clearly delineated layers.

Short discussion of

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

How did the authors decide on 10g of ants to sample as tower builders?

In nature, can the ants usually find rod-like objects that are robust as the rods used in the lab? The paper mentions that they challenge the ants with a slippery Teflon rod, with varying diameters. I’m curious if the rod stiffness be a factor to shape and growth rates of their towers.