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Reading 9: Synchronization and Flocking

Paper 1: Synchronization of pulse-coupled biological oscillators, Mirollo and Strogatz, SIAM J. Appl. Math. 1990

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?

I love this paper! I have been wanting to pick up the book Sync by Strogatz. He also gave a great Ted talk about synchronization and flocking: https://www.ted.com/talks/steven_strogatz_on_sync/details#t-1294473. As he put it, the synchronous animals are choreographing themselves.

The book and the Ted talk aim towards a general audience. This paper gives me the quantitative perspective of this work on exploring synchrony in biological systems. Mirollo and Strogatz present a simple mathematical model for the synchronous firing of identical oscillators. The authors' contemporary literature included works on synchronization under the assumptions that the interactions between oscillators are smooth. The authors set out to study interactions that are episodic and pulse-like, seen in biological oscillators such as fireflies who exhibit synchronous flashing patterns. I find it fascinating that regardless of initial conditions, the population of oscillators reach a state of synchronous firing. Figure 2 shows a clear depiction of the model with 2 oscillators, who interact by the pulse-coupling rule. After B reaches the firing threshold and fires, it jumps back to 0. A follows the same rule as it makes its way to the threshold on a fixed curve, fires, and then falls back to 0.

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

The first paragraph of the introduction is quite amazing to me. I never see such an expressive tone in scientific papers. This paragraph is really a "hook" that makes me want to read this paper. I wonder if this style of writing is welcomed/acceptable nowadays or can only really daring and skillful authors pull it off?

One weakness of this paper

I might have missed it, but I'd like to better understand how the threshold is determined. I'm assuming it's chosen as x = 1 as an arbitrary but convenient threshold for this model. Overall I am interested in how we pick values for parameters for our bio-inspired models so they reflect reality. Anyway, I thoroughly enjoyed this paper and have no actual critiques. Besides the clear mathematics for the model, this paper has reminded me of what clear and engaging writing looks like.

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

Most papers we have read thus far treat the individuals in a collective as identical to one another. Is this more an assumption of these models to simplify and gain understanding from biological systems, or have researchers been able to empirically test this hypothesis somehow? In this vein, can we still achieve such emergent collectives we observe if individuals are not identically programmed, by nature or humans?

Does a system that has become synchronous remain synchronous? What can disrupt the synchrony? This is shown in the Ted talk and it's fascinating: Fish schools can avoid predators. The individual fish moves out of the way of the predator in random directions, and because of the rule of attraction, the school can reform. Strogatz pointed out that although it looks like individuals appear to be cooperating to escape the predator, each is actually moving at random to save themselves from collision/predation and by this rule gives rise to the group's escape.

Paper 2: Effective leadership and decision- making in animal groups on the move, Nature, 2005

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 is as awesome as the first. Throughout our readings, I have been wondering about whether leadership is an applicable concept in collective biological systems. This paper is my answer! The authors present a model that shows information transfer within groups traveling together with no signaling. Furthermore, interestingly, there appear to be a few group members who play the role of the experienced guides who have information about the travel route. The authors address two questions: How is the information of the travel transferred within a group? And how do individuals achieve consensus when informed individuals may differ in preferences, in this model, for a direction of travel?

The model includes a weighting term to balance the informed individuals' social interactions and the influence of their preference. The accuracy of the group is also quantified. The results of the model are interesting: The accuracy of group motion in a direction increases as the proportion of informed individuals increase and eventually reaches an asymptote. This is nonlinear as group size is increased, indicating that the larger the group, the smaller the proportion of informed individuals is needed for the group to reach the asymptote of accuracy. Furthermore, the authors created two subsets of informed individuals with different preferred directions. If the size of the subsets are equal, the group moves depending on the difference between the preferred directions. As the difference increases, the group chooses randomly one direction rather than follow the average of all informed individuals. If one subset has more informed individuals, the group will prefer the direction of the majority.

Short answers to the questions below

One major strength of the paper

This paper was a pleasure to read with its clarity and succinct style (probably because of *Nature* constraints). This week we have well-written papers that show me how to write concisely but sufficiently. Thanks!

One weakness of this paper

I would like a clearer explanation of what signaling means when the authors describe their model as containing no signaling. What would be the manifestation of the informed individuals displaying their preference of direction? I thought this would be a form of signaling, albeit limited.

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

For the experiment where we have two subsets of informed individuals, how are they distributed throughout the group? Would proximity to one subset lead to divisions within the population of uninformed individuals?

Maybe a bit obvious: I wonder if body size of individuals is a factor to the typical size of a collective. Honey bees swarm are functional and cohesive with thousands (?) of individuals, but we probably don't see this number of individuals grouping together in other species.

P.S. That cut off paper on page 516 "Insects breathe discontinuously to avoid oxygen toxicity" sounds so interesting!