From individual to collective information processing in fish schools

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Abstract: Swarms of insects, schools of fish and flocks of birds display an impressive variety of collective behaviors that emerge from local interactions among group members. These puzzling phenomena raise a variety of questions about the interactions rules that govern the coordination of individuals' motions and the emergence of large-scale patterns. While numerous models have been proposed, there is still a strong need for detailed experimental studies to foster the biological understanding of such collective motion. I will present the methods that we used to characterize interactions among individuals and build models for animal group motion from data gathered at the individual scale. Using video tracks of fish shoal in a tank, we determined the stimulus/response function governing an individual's moving decisions from an incremental analysis at the local scale. We found that both attraction and alignment interactions are present and act upon the fish turning speed, yielding a novel schooling model whose parameters are all estimated from data. We also found that the magnitude of these interactions changes as a function of the swimming speed of fish and the group size. The consequence being that groups of fish adopt different shapes and motions: group polarization increases with swimming speed while it decreases as group size increases. The phase diagram of model revealed that the relative weights of the attraction and alignment interactions play a key role in the emergent collective states at the school level. Of particular interest is the existence of a transition region in which the school exhibits multistability and intermittence between schooling and milling for the same combination of individual parameters. In this region the school becomes highly sensitive to any kind of perturbations that can affect the behavior of just a single fish.

Short bio: Guy Theraulaz is a senior research fellow at the National Center for Scientific Research CNRS) and an expert in the study of collective animal behaviors. He is also a leading researcher in the field of swarm intelligence, primarily studying social insects but also distributed algorithms, e.g. for collective robotics, directly inspired by nature. His research focuses on the understanding of a broad spectrum of collective behaviors in animal societies by quantifying and then modeling the individual level behaviors and interactions, thereby elucidating the mechanisms generating the emergent, group-level properties. He was one of the main characters of the development of quantitative social ethology and collective intelligence in France. He published many papers on nest construction in ant and wasp colonies, collective decision in ants and cockroaches, and collective motion in fish schools and pedestrian crowds. He has also coauthored five books, among which *Swarm Intelligence: From Natural to Artificial Systems* (Oxford University Press, 1999) and *Self-organization in Biological Systems* (Princeton University Press, 2001) that are now considered as reference textbooks.