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Winner and Abstract

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Modeling group formation and activity patterns in self-organizing communities of organisms

In this thesis, we investigate the formation and movement of self-organizing collectives of animals in homogeneous environments. For this, we propose a general modeling framework that incorporates how individuals perceive information from neighbors, and the amount of information perceived. In particular, we construct and analyze a new one-dimensional nonlocal hyperbolic model which assumes that the interactions with neighbors (that is, attraction towards individuals that are far away, repulsion from those that are nearby, and alignment with individuals at intermediate distances) are determined by the information perceived. The model is used to investigate the effects of these social interactions on the emergence and the structure of group patterns.

For the first part of the thesis, we assume that the social interactions influence only the individuals' turning behavior. In this case, the one dimensional model generates a wide range of spatial and spatiotemporal patterns. More precisely, the model displays at least 13 different patterns which depend on the assumptions we make about how individuals receive information from their neighbors. Some of these patterns are classical, such as stationary pulses, traveling pulses, or traveling trains. However, the majority of these patterns are novel, such as the patterns we call zigzag pulses and feathers. To investigate the conditions under which these patterns arise, the transitions between them, as well as the structure of the patterns, we use numerical and analytical techniques such as bifurcation theory, linear and weakly nonlinear analysis.

In the last part of the thesis, we assume that the social interactions influence the turning rates, as well as the individual's speed. To compare the effects of these two assumptions, namely density-dependent speed, and density-dependent turning rates, we use formal parabolic limit, linear analysis and numerical simulations.

This modeling framework presents a unitary approach for the investigation of animal group formation and movement. More precisely, \textit{all the patterns} obtained with other parabolic and hyperbolic models existent in the literature can be understood in terms of a single model operating in different parameter regimes, represented by different communication mechanisms.