Modeling and analysis of complex systems — with a basis in zebrafish patterns

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Abstract

Many natural and social phenomena involve individual agents coming together to create group dynamics, whether the agents are drivers in a traffic jam, cells in a developing tissue, or locusts in a swarm. Here I will focus on the specific example of pattern formation in zebrafish, which are named for the dark and light stripes that appear on their bodies and fins. Mutant zebrafish, on the other hand, feature different skin patterns, including spots and labyrinth curves. All of these patterns form as the fish grow due to the interactions of tens of thousands of pigment cells. The longterm motivation for my work is to better link genes, cell behavior, and visible animal characteristics — I seek to identify the specific alterations to cell interactions that lead to different mutant patterns. Toward this goal, I develop agent-based models to simulate pattern formation and make experimentally testable predictions. In this talk, I will overview my models and highlight several future directions. Because agent-based models are not analytically tractable using traditional techniques, I will also discuss the topological methods that we have developed to quantitatively describe cell-based patterns, as well as the associated nonlocal continuum limits of my models.