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Spatial patterns and multi-stability in non-local models of interacting species

Abstract
Understanding the mechanisms underlying the spatial distribution of organisms is a central issue in both ecology and cell biology, and mathematical models can help to provide a deeper insight. In nature, every individual, be it a cell or an animal, inspects its territory before moving. The process of acquiring information from the environment is typically non-local, i.e. individuals have the ability to inspect a portion of their territory. Interestingly, this ability is not restricted to animals, but is also observed in some cells that interact non-locally by extending long thin protrusions. In recent years, a growing body of empirical research has shown that non-locality is a key aspect of movement processes, while mathematical models incorporating non-local interactions have received increasing attention for their ability to accurately describe how interactions between individuals and their environment can affect their movement, reproduction rate, and well-being. In this talk, I will present a study of a class of advection-diffusion equations that model population movements generated by non-local inter- and intra-species interactions. Using a combination of analytical tools, I will show that these models support a wide variety of spatio-temporal patterns that are able to reproduce segregation, aggregation and time-periodic behaviours commonly observed in real systems. I will also show the existence of parameter regions where multiple stable solutions coexist and hysteresis phenomena. Finally, I will analyse the phase transitions driven by non-local interactions. All the analytical results are supported by numerical simulations. Overall, I will describe various methods for determining the pattern formation properties of these models, which are fundamental for answering the question of how organisms position themselves in space.