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Calculating the stable steady states of multispecies non-local advection-diffusion models using energy functionals

In many biological systems, it is essential for individuals to gain information about their local environment, not only to sense environmental features, such as food, but also to detect other individuals in a local spatial neighborhood. Interestingly, this feature is not only restricted to higher level species, such as animals, but is also found in cells, which interact non-locally by extending long thin protrusions, probing the environment.

The process of gaining information about presence of other species in the environment is intrinsically non-local and mathematically the non-local sensing of neighboring individuals leads to non-local advection terms in continuum models.

In this talk, I will focus on a class of nonlocal advection-diffusion equations modeling population movements generated by inter- and intra-species interactions. After a brief discussion of the well-posedness of this problem, I will show that the model supports a great variety of spatio-temporal patterns, including stationary aggregations, segregations, oscillatory patterns, and irregular spatio-temporal solutions. However, if populations respond to each other in a symmetric fashion, linear stability analysis shows that the only patterns that emerge from small perturbations of the stable steady state are stationary. In this case, the system admits an energy functional that is decreasing and bounded below, suggesting that patterns remain stationary for all time. I will show how to use this functional to gain insight into the analytic structure of the stable steady state solutions. This procedure reveals a range of possible stationary patterns, including various multi-stable situations, which we validate via comparison with numerical simulations.