Global models of swarming

Complexity Mini project offered by Dr M S Turner

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Swarming is a behavioural phenomenon observed throughout the animal kingdom; flocking in birds, swarming in insects, shoaling in fish and herding in mammals. Most previous attempts at understanding this assume that members of a swarm align their velocity with those of a few neighbours. Such local models seem plausible, mainly on the grounds that it is unfeasible for an individual to follow the positions and velocities $\mathbf{v}_i$ of all other members of an arbitrarily large swarm. However, all existing models have known pathologies (flocks evaporate in time [1]) or serious limitations.

We have recently analysed the possible role of a biologically plausible global measurement of the swarm in which each individual observes a *projection* of the swarm [2]. A simple class of candidate models arises naturally. To date we have only analysed them in 2D but we believe that they are qualitatively compatible with experimental data (in 3D) [3]. In particular the following features arise naturally: (i) anisotropic inter-bird orientational correlations (ii) super-diffusive information transfer across the swarm (iii) large swarms become highly anisotropic forming spatially extended arm-like structures beyond a critical size. All three of these features are observed in large flocks of starlings [3]. Finally our model suggests a mechanism for swarms to self-select a particular density at which the swarm is *marginally opaque*. This corresponds to a non-trivial relationship between the number of individuals in a swarm and its size. Our model therefore promises to make several experimentally testable predictions when extended to 3D.

The student will analyse this model [2] in 3D by using Monte Carlo computer simulation.The student will write the code required to analyse the role of these non-local terms, e.g. in C. Some experience with computing is therefore required. The student will then compare their results with published data for variation of the order of the swarm $\alpha = |\sum_{i=1}^{N} \mathbf{v}_i|$ and its density ρ with the number of birds in the flock N. The hope is that we can characterise the behaviour of different bird species by three control parameters, ϕ_a controlling the strength of alignment of a bird with its neighbours, k the number of such neighbours that it interacts with and ϕ_m the strength of the term describing the global projection of the whole flock on the bird's velocity. The student will investigate whether data for $\rho(N)$ and $\alpha(N)$ accurately determines these terms and the extent to which the resulting description appears complete. There are numerous avenues for a PhD for students with some affinity for computing.

References

[1] T. Vicsek, A. Czirok, E. Ben-Jacob, I. Cohen, and O. Shochet. Novel type of phase transition in a system of self-driven particles. *Physical Review Letters*, 76:1226–1229, 1995.

[2] http://www.warwick.ac.uk/ phscz/research/poster.pdf.

[3] Andrea Cavagna, Alessio Cimarelli, Irene Giardina, Giorgio Parisi, Raffaele Santagati, Fabio Stefanini, and Massimiliano Viale. Scale-free correlations in starling flocks. *Proceedings of the National Academy of Sciences*, 107(26):11865–11870, 2010.