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A model for rolling migratory locust swarms

We construct an individual-based, kinematic model for rolling migratory locust swarms. The high-dimensional ODE model incorporates pairwise social interactions of attractive-repulsive type, gravity, wind, and the impenetrable boundary formed by the ground. The parameters controlling the social interactions determine whether the group is in the H-stable or catastrophic statistical mechanical regime. We simulate both cases. In free space, an H-stable group forms a crystalline lattice of individuals and with gravity it forms a grounded lattice.

Wind smears the swarm out along the ground until all locusts are stationary. In contrast, a catastrophic group forms a densely packed structure in free space. With gravity, the swarm forms a bubble-like shape with a group of airborne locusts and a dense layer of grounded locusts below them. With wind, the swarm migrates in a rolling motion.

The rolling structure is similar to that observed by biologists, and includes a takeoff zone, a landing zone, and a stationary zone where grounded locusts can rest and feed. To further understand the vertical structure of the swarm, we formulate a one-dimensional continuum problem describing a vertical slice. We use variational methods to minimize the energy for this problem and find exact solutions of the resulting integral equation. These exact solutions agree closely with simulations of the discrete problem.