From individuals to mass migration: a theoretical and experimental study of locust hopper bands

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Locusts are infamous for the amount of devastation that they can bring during their mass migration. Before they form flying swarms as adults, locusts collectively march in groups known as hopper bands, which can contain millions of individuals stretching over kilometres. Using a combination of simulations and experiments, we have shown that locust collective movement undergoes a rapid transition from disorganised movement at low densities to a highly aligned state above a critical density. This was the first empirical confirmation of such a phenomenon originally observed in models known as "self-propelled particles" (SPP) models. By analysing the spatial distribution of the individuals and comparing them to various versions of SPP models, we have inferred that locusts only interact with their neighbours within a local radius of less than 20cm, within which they tend to be repulsed below 3cm while they align within 13.5cm and are probably attracted to neighbours beyond that range. However, our recent field studies revealed that our current models of collective motion are still lacking crucial elements to account for the structure and dynamics of real locust bands, which are characterised by dense fronts followed by a looser comet-like tail which can stretch over long distances. By marking individuals in various parts of small locust bands and observing their location 2h later, we have shown that individuals move faster than the band front and rapidly diffuse along the direction of group movement. Using parallel computing on GPUs (CUDA), we explored a SPP model parameterised using our empirical data and simulating up to millions of locusts. We found that aggregation and rhythmicity in locust locomotory behaviour might be key mechanisms explaining the shape and dynamics of locust bands. To test our model, we are currently developing new field tracking methods using Unmanned Aerial Vehicles to quantify both individual and group trajectories across locust species.