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Development of an agent-based model for movement and foraging of sheep flock

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Abstract: Flocking sheep can produce impressive visual displays with movements that are synchronised and coordinated, allowing the group to move as a cohesive unit. These movement patterns emerge without a central point of control and are shaped by the interactions and decisions of the individuals participating in the flock. Collective movement serves a functional purpose, as it allows the flock to move efficiently and stay together, providing protection from predators by diluting the risk of attack to the individuals. This study builds upon previous work (Ginelli et al., 2015) by investigating the emergent collective movement properties exhibited by small flocks of sheep and inferring the underlying interactions that drive the observed emergent behaviours. An agent-based collective motion model has been developed to simulate the movement dynamics of a small flock. This model captures a range parameters that control individual motion, such as movement speed, maximum turning speeds and distances over which individuals experience social forces (e.g. repulsion/attraction). The model uses discrete steps where individuals update their position according to the motion parameters. The agents transition between 3 different states that reflect the flocking and movement behavior of the group. In the *grazing* state, individuals experience close-range repulsion from their neighbors, and longer-range alignment forcing them to disperse and break into smaller sub-groups as they graze. From the grazing state, individuals can transition to the *standing* state, reflecting periods when individuals are stationary (potentially ruminating and assessing surroundings), or to the *flocking* state where a long-range attraction force towards the center of the flock is applied to the individuals, pulling the flock into a tight formation. The transitions between these states are controlled with probabilities that can be tuned through sensitivity analysis. Results from initial investigations demonstrate that this simple set of states and the associated modeled forces between the individuals is sufficient to replicate the group-level expansion and contraction patterns that can be observed in collected data and by the work in (Ginelli et al., 2015).

This motion model has been extended to include a foraging model whereby individuals are able to perceive pasture in their immediate vicinity and adjust their motion to forage the most attractive zones. The pasture is simulated using a 1m x 1m grid where each grid square is assigned a value reflecting the available biomass in the square. Agents adjust their motion while in the grazing state by selecting the most attractive square (i.e. highest biomass square) adjacent to their current location and modifying their movement direction to align with a vector pointing to a randomized location within the selected square. Agents interact with the pasture grid by consuming the biomass from a square at a specified rate when in the grazing state. As time progresses in each simulation, the consumption of the biomass alters the pasture grid, creating complex emergent group-level behaviors. This research represents a novel contribution by combining a foraging model and collective motion model (with multiple behavioral states), allowing for experimentation and hypothesis development across these drivers of emergent flock behavior.

Initial results on homogeneous pasture grids indicate that a flock's initial movement pattern is random (reflecting the homogeneous biomass) with later movement patterns exhibiting a gradient-following behavior as the pasture grid becomes sparser. Transitioning to the flocking state (i.e. where the flock returns to the tight formation) tends to trigger a re-position of the whole flock, interrupting the grazing paths of individuals. Further analysis is underway to determine how these perturbations to the system impact the rate of biomass consumption of the individuals and spatial patterns that emerge within pasture grid.

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