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Peer Review

Review of: "Active Matter Flocking via Predictive Alignment"

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This article delves into the Vicsek model, a minimal model that can demonstrate flocking and collective phenomena in an interacting system of mobile agents. The article is clearly written with a comprehensive introduction. It also covers both old and new references effectively.

In the original model of Vicsek, agents move with constant speed in discrete time steps. However, they take care of the orientations of their neighbors and adapt themselves to move along the average direction of their neighbors.

In each step of discrete jumps, and within the framework of Vicsek's original model, only the current neighboring agents are used to define a local average stream along which the agent reorients.

A novel aspect of this work is the predictive strategy employed by the agents to identify their neighbors. Each agent uses its current velocity to estimate its future position and then recognizes its new neighbors to calculate a predicted local stream corresponding to its predicted neighbors. Subsequently, this strategy allows the agent to adjust its motion to align with the stream of its anticipated future neighbors.

The novel ingredients incorporated into the Vicsek model, as evidenced by the numerical results presented in this article, enhance the flocking's robustness, resulting in effective cohesion among the active particles.

One crucial message we can derive from the Vicsek model is the possibility of observing ordered phases in two dimensions. This contrasts with our conventional understanding of equilibrium systems with short interactions, which preclude the existence of ordered phases in two dimensions. Interestingly, in systems with mobile agents, the moving particles can detect distant agents, which can be interpreted as an effective long-range interaction between active particles. This long-range interaction serves as the primary source that may enable a two-dimensional system to transition into an ordered state.

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I think the modifications discussed in this article enhance the model's realism, making it more comparable to living systems. What I observe is an improvement or enhancement in the effective interaction between particles, which are more long-range than those considered in the original Vicsek model.

This understanding may differ from the argument presented in the discussion section, where the authors discuss the fundamental difference between the predictive strategy and potential-based models. However, from another perspective, I agree with the authors. Considering the framework of MIPS (motility induced phase separation), the ordered state (moving flocks) achieved in this work is macroscopically time-reversal symmetry breaking. This suggests that at the coarse-grained level, nonlinear and non-potential terms should be incorporated into the dynamical equations to accurately represent the existence of such moving, ordered phases.

It is known that the flocking transition in the ordinary Vicsek model is a kind of discontinuous transition with hysteresis. How does such a picture persist in the current extension of the model?

It's not easy to establish a direct relation between the spreading time presented in section 2 and the calculations conducted in section 4. Personally, I find it more convenient to retain all formulas in their dimensional form.

Finally, I notice the absence of a physical or intuitive interpretation for the V-shaped and rounded flocks observed at zero and finite noise strength.

Declarations

Potential competing interests: No potential competing interests to declare.

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