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Peer Review

Review of: "Active Matter Flocking via Predictive Alignment"

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The authors introduce a new Vicsek-type model for particle dynamics which is based on alignment with the future orientation of neighbors (theirs), rather than the average velocity of neighbors (classic Vicsek). They state that such a model exhibits "cohesive flocking" using purely alignment interactions. As a work in theoretical physics, I believe the paper has some interesting points. This would be interesting to compare to other Vicsek-type models, such as the "milling" (vortex) model of Andrea Costanzo. Unfortunately, the authors do not compare to other recent Vicsek-variant models, but only to the original Vicsek model.

The primary issue, I feel, is that many biological claims are made which are not explored or substantiated. For example: "foraging birds... where cohesion and flexibility are prioritized over aerodynamics." No references are made. Or the claim "bird flocks involve a subgroup of leaders," referring to [16], which is not about birds, and [26], which is about pigeons. Leadership has been demonstrated to be dynamic, where the idea of a fixed subgroup of leaders is generally not true of active flocking (e.g., Starlings). The main problem is that claims are made with respect to biology that are not investigated or discussed in any depth.

The model section is mathematically detailed yet a bit confusing. Strategies IA, IB, IIA, and IIB are not defined. A very clear mathematical distinction between the classic Vicsek and the authors' model would be really helpful. The authors conclude that theirs "fundamentally departs from prior models," where their model is really a variant of Vicsek. They also claim "the first cohesive flocking model based solely on alignment" – which is certainly too strong. The Vicsek model itself is based solely on alignment yet exhibits some degree of cohesion. The authors claim that classic Vicsek will always diffuse, but this is not true. The method section (4.4) for this is just wrong, in my opinion. Yes, two particles *with constant

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velocity* will diffuse, but at the next timestep in Vicsek, their orientations are updated. The Vicsek model may or may not diffuse depending on neighborhood density, noise level, etc. The novelty of classic Vicsek is attributed to the fact that it *was* the first to exhibit some emergent cohesion. I think the authors are exploring how this could be guaranteed, which is interesting.

The authors conclude by saying that “flock shapes resemble those found in nature.” As an author in this field, who has studied this in depth (see Flock2, Hoetzlein, 2024), I have to disagree. Vicsek models are simplified dynamics for pure active matter. They do not account for cohesion, peripheral exposure, or real aerodynamic flight, which are state-of-the-art for replicating real flocks, and must refer strongly to biological studies.

As a work more closely related to pure physics, I believe the paper has some interesting contributions – that is, as a study of particle cohesion. The claims with respect to real flocks, leadership, biology, and even the deviation from Vicsek are exaggerated. Comparisons to other Vicsek-type models would be helpful to understand that class of models better. At least keeping the claims within the domain of theoretical physics would be beneficial.

Declarations

Potential competing interests: No potential competing interests to declare.