Peer Review

Review of: "Active Matter Flocking via Predictive Alignment"

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General Evaluation

This study proposes a model of collective behaviour with alignment interactions that depend on the field of view, aiming to reveal the influence of individuals predicting each other's movements. It provides a simplified investigation of orientational transitions in visually guided biological groups. The authors' objective is clear, and the emergence of phenomena such as V-shaped formations is intriguing.

However, the rationale for the proposed model could be more clearly articulated. While the approach is intriguing, some of the modelling assumptions may benefit from further theoretical justification, as they currently come across as somewhat ad hoc. Certain descriptions in the manuscript are ambiguous, and aspects of the data presentation and analysis may not yet fully support the conclusions. To elevate the manuscript to the level of a major contribution, substantial clarification and additional work would be beneficial.

Major comments

The central idea of the study is conceptually straightforward. However, the proposed model lacks adequate theoretical justification, and the Introduction does not sufficiently situate the work within the broader context of existing literature. A more comprehensive review of self-propelled particle models and Vicsek-type models—particularly those incorporating memory effects—is required. Additionally, the manuscript should clearly articulate the novelty and key insights of this model, particularly in relation to empirical findings from real biological systems.

- How does this model differ from Vicsek-type models that incorporate memory or prediction? What is the theoretical basis for introducing a one-step prediction offset? This choice may introduce artificial effects and warrants further justification.

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- Consider providing a summary of the types of collective behaviour reproduced by the model, accompanied by visual illustrations. Also, organise their dependence on model parameters.
- For validation, compare the simulated behaviours with empirical data from biological systems.

Minor comments

I offer the following comments and questions for the authors' consideration prior to acceptance:

Abstract / Introduction

> Alignment interactions are essential for flocking, yet alone, they are generally considered insufficient to maintain cohesion against noise, forcing traditional models to rely on artificial boundaries or added attractive forces.

- The term *"insufficient"* may overgeneralise. In some cases (e.g., motility-induced phase separation), cohesion can emerge from repulsive or alignment-only mechanisms. Please clarify the scope and context of this claim.

> We report the first model to achieve cohesive flocking using purely alignment interactions...

- While the model emphasises alignment, assumptions such as a fixed interaction radius and a restricted field of view may also play crucial roles. Clarify whether these elements have empirical support and discuss their relevance to actual biological systems.

> In the stable regime, flock size scales linearly with interaction radius...

- The assumption that agents align based on predicted future headings requires empirical motivation. Are there studies showing that animals engage in this form of prediction? Introduce such motivations earlier to clarify biological relevance.

> We implement alignment based on the sociological rule “copy the other”...

- Clarify the biological justification of this decision rule. How does it affect model dynamics compared with other plausible social decision-making strategies?

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Models

- Equations (1) and (2) specify that $\eta \in [-\pi, \pi]$ is stated, but the purpose of Strategies I, II, A, and B is not clearly explained. Their graphical representations are also difficult to interpret. Provide concrete behavioural examples if possible.
- In Equation (3), clarify the meaning of r_i, r_j^t and v_i. If these quantities vary between strategies, this should be explicitly stated.
- In the update rule for $v_i^{t+\Delta t}$, should noise be included? Why is Equation (2) not applied here?
- How are the predicted values determined? Are they interpolated to maximise the correlation C_i^t? If so, provide justification for this choice.
- The definition of the correlation function C_i^t in Equation (3) is fragmented and may be difficult for new readers to interpret.
- I suggest adding a table before or after Equations (1)–(3) that summarises the physical meaning and dimensions of each variable (e.g. ζ= interaction radius; η = noise width).
- Why is C_0 treated as zero or as a constant?
- The choice of $L = 4\zeta$ appears quite small. What motivated this choice? Given its influence on dynamics, a sensitivity analysis would be useful.

Results

- **Figure 1**: Expand the caption to explain what "seven possible reorientations" refers to.
- **Figure 2**: If the intent is to highlight differences between the Vicsek model and your proposed strategies, overlapping all lines in one plot is ineffective. Consider separating curves, using subpanels, or changing the scale (e.g., logarithmic). Revise the caption accordingly.
- **Figure 3**: The criterion for defining the transition from flocking to disorder is unclear. State it explicitly.
- Clarify how clusters are computed. If using distance from the centre of mass, consider spatial–temporal methods like radial distribution functions, which offer more rigorous structure analysis.
- If V-shaped formations are only observed in Model II A, highlight this clearly. Show representative snapshots or time evolution in Fig. 2g to illustrate the formation process.
- **Figure 4a**: The colormap is not informative. Instead, plot mean cluster size versus noise level on a logarithmic scale, averaged over replicas.

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- **Figure 5**: Explain how leaders are selected (randomly? arbitrarily?). Cite related literature and detail the leader assignment rule in the Methods.
- The flock's response to a leader under noise is interesting, but the leader's motion protocol is undefined. Specify if the leader undergoes, e.g., sinusoidal motion, random walk, or constant angular acceleration. Compare how followers respond under each condition to explore robustness and potential applications.

Discussion

> The model is scalable, and the resulting flock shapes resemble those observed in nature.

- Cite specific empirical studies that support this statement, such as those on bird flocks, fish schools, or insect swarms.

> Our algorithm provides a plausible strategy that intelligent agents with given physical and cognitive abilities might employ to efficiently align with their neighbours.

- Discuss which aspects of Strategies A/B or I/II contribute to the plausibility of the model in biological terms. How do these mechanisms relate to known animal behaviours?

Methods

- In the section on "Diffusive Spreading", clarify the nondimensionalization process and define ζ explicitly. Ensure consistency of definitions across all sections.

Supplementary Information

- When referring to the Supplementary Information (SI), specify the section and figure numbers (e.g., "SI Sec. S1, Fig. S3") for clarity and ease of reference.

Bibliography

- In addition to biological studies, include citations from applied fields such as **swarm robotics**. A brief review of relevant algorithms in that domain would help position the study in a broader interdisciplinary context.

Declarations

Potential competing interests: No potential competing interests to declare.