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EDITORIAL
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Editorial: Modelling Collective Motion Across Scales

Nicole Abaid [1], Raluca Eftimie [2], Axel Hutt [3] and Lennaert van Veen [4]*

[1] Department of Mathematics, Virginia Tech, Blacksburg, VA, United States, [2] Laboratoire Mathématique de Besançon, UMR-CNRS 6623, Université de Bourgogne Franche-Comte, Besançon, France, [3] MLMS, MIMESIS, Université de Strasbourg, CNRS, INRIA, ICube, Strasbourg, France, [4] Ontario Tech University, Oshawa, ON, Canada

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Editorial on the Research Topic

Modelling Collective Motion Across Scales

Collective behavior of organisms is readily observed in nature. How such organization emerges from the rules that individual organisms follow and the way they interact is a long-standing question. There is no overarching theoretical description of emergent behavior across space and time scales. Most research is either based on experimental observations or on computer simulations. These simulations can be performed at a variety of scales and produce different types of descriptions of emergent behavior. This Research Topic brings together experts in modeling, experimental and computational techniques to formulate research questions of interest, explore the strengths and weaknesses of current approaches, and draw up a road map for future interdisciplinary research efforts, ultimately aiming at a unified theory of emergent behavior, its origin, mechanisms, and control. Models of collective behavior can be thought of in two classes: agent-based and continuum. The former prescribe rules for each individual, thus allowing for a detailed description of the underlying dynamics, while the latter describe the evolution of population densities directly. For many research questions, the simulation of sufficiently many agents over a sufficiently long time scale is not feasible and continuum modeling is a more promising approach. Conceptually, continuum models could be considered in the thermodynamic limit of agent-based models. However, an exact link is hard to establish in the presence of complicated interactions, inhomogeneous media, and other such complications.

In this Research Topic we investigate a few questions:

- How are agent-based and continuum models related? Both a priori links, i.e., a derivation of one from the other, and a posteriori links, i.e., a comparison of predictions, are of interest. Secondly, we relate predictions (either based on numerical simulations or mathematical analysis) from either model type to experimental observations of aggregation of organisms at a large and small scale.
- Can we compare emergent behavior of different organisms, using different communication strategies?

McClure and Abaid demonstrate **the importance of domain structure on collective movement**. The authors investigate the impact of geometric constraints as given by static obstacles inside the domain of the classical Vicsek model [1] and explore how the presence of various domain obstacles alters the scaling behavior of the model and implicitly the phase transitions.

Weighted multiple sensory information, and its impact on collective behaviors is the research focus of Roy and Lemus. The authors considered a modification of the Vicsek model which includes weighted auditory and visual sensing modalities. It has been shown that, for the sub-case of pure vision, the particles display weak polarization at small sensing angles.

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Isao T. Tokuda, Ritsumeikan University, Japan

****Correspondence:***
Axel Hutt
axel.hutt@inria.fr

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The aspect of **weighted averaging of neighbor velocities and its impact on collective behaviors** is also considered in Wirth and Warren, but this time it is applied to pedestrian velocities that are weighted over a specific distance. In experiments human participants were asked to walk with a virtual crowd in a Virtual Reality environment. All these experiments confirmed that the weighted average assumption is sufficient to recruit human pedestrians into collective motion.

Strömbom and Tulevech have contributed a work on **the role of attraction vs. alignment in collective behaviors**. The authors investigated the role of individual alignment on the polarization of the whole group of individuals and showed, inter alia, that the models containing explicit alignment led to exponential group polarization.

Tuqan and Porfiri studied the **impact of psychoactive substances (e.g., caffeine) on collective behaviors**. The authors proposed a model for the effect of caffeine administration on fish movement in the context of social interactions with its neighbors (via attraction and alignment). The numerical results did not show any impact of caffeine on freezing and locomotion parameters, in particular for zebrafish with neighbors not treated with caffeine (which was in contrast with the expectations). The social interactions between fish might explain the reduced anxiogenic effect of caffeine.

In Ayalon et al. the authors have investigated the **impact of sequential decisions in collective cognition in ants**. To this end, the authors have studied a decision-making process in ants in the context of cooperative transport of large foods. They have proposed to generalize a conventional biased random-walk version by using a run-and-tumble approach.

Suveges, Chamseddine et al.; Suveges, Eftimie et al. have investigated **multi-scale aspects during the collective movement of cells** in the context of spatio-temporal evolution of solid tumors. They have considered two models considering multi-scale interactions between tumor cells and the extracellular matrix. The model from 2022 was continuous while the model from 2021 was hybrid.

To conclude, we note that a few ideas emerged across the papers published in this Research Topic:

- The importance of the domain structure (e.g., fixed obstacles in McClure and Abaid, extracellular matrix fiber orientation in Suveges, Chamseddine et al., or spatial region of macrophages re-polarization in Suveges, Eftimie et al.) on the overall movement of particles/cells, and on the transitions between different types of collective behaviors they exhibit.
- The impact of weighted averaging of information from neighbors on collective behaviors (e.g., weighted averaging of visual and auditory cues in Roy and Lemus, or weighted averaging of movement direction in Wirth and Warren).
- The importance of studying the role of combined stimuli (e.g., visual, auditory, tactile, chemical) and strategies (e.g., attraction, alignment) for social interactions (see Ayalon et al.; Roy and Lemus; Strömbom and Tulevech; Tuqan and Porfiri).

Half of the articles in this Research topic incorporated experimental data (see Wirth and Warren; Tuqan and Porfiri; Ayalon et al.). The other half used numerical simulations to propose new hypotheses that can explain some of the observed collective behavior in nature. This is because: (i) it is still not fully known what are the biological/ecological mechanisms that lead to collective behavior across species and scales, and (ii) it is still difficult to collect multi-scale data to parametrise the more complex multi-scale models (e.g., for collective movement of cells). We expect that in the future more data will be collected (across various scales), and more theoretical studies will parametrise their models with collected data.

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