From micro to macroscale in anticipative active matter: merging agent-based and Mean Field Game descriptions of crowd dynamics

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I Context

A detailed understanding of crowd dynamics is a societal necessity, both for safety reasons (evacuation, panic movements in large gatherings) and for the design of public spaces (train stations, shopping malls). For physicists, this raises the question of active matter in interaction, with the added complexity of the pedestrian's ability to anticipate the future movements of other pedestrians.

At the microscopic level, pedestrians can be described by "agent-based" models [1, 2], which essentially aim to avoid collisions with other pedestrians or obstacles. On a larger scale, an optimization of the choice of trajectory is contained in the so-called desired velocity field, which indicates the optimal velocity at each point in space and time. In many models, this velocity is determined by the shortest path to the goal, or by an optimization that only considers the current density of pedestrians [3]. In this approach, the desired velocity appears as an external parameter to the microscopic model, and the two levels of description are essentially decoupled.

The decoupling of the microscopic (operational) level and the (tactical) optimization level may be valid for low pedestrian densities, where mutual avoidance can be considered as a small perturbation of pedestrian trajectories, or in a quasi-permanent regime, where pedestrian anticipation can be performed with the current time distribution of pedestrians. On the other hand, it seems very unlikely that it would be applicable in circumstances with higher pedestrian densities and fast dynamics, such as room evacuation or train boarding. It is therefore necessary to build a model of pedestrian motion that actually takes into account the ability of pedestrians to anticipate, through a description that combines agent-based models with a mean-field game theoretic approach [4, 5].

II Project

The goal of this internship is to tackle this program for a simple version of the microscopic/agent-based description of pedestrian motion. In particular, this will involve relating the agent-based models to some equivalent kinetic and hydrodynamic models, and developing the corresponding mean-field game. The internship will include both analytical and numerical works.

III Environment

The internship takes place within a collaboration between the LPTMS (https://www.lptms.universite-paris-saclay.fr/) and the IJCLab (https://www.ijclab.in2p3.fr/). The possibility of continuing the internship with a Ph.D. can be discussed.

References

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