Research Internship (M2)

Varying Anticipation in Pedestrian Crowd Models

Denis Ullmo (denis.ullmo@universite-paris-saclay.fr)
& Cécile Appert-Rolland (Cecile.Appert-Rolland@ijclab.in2p3.fr)
in collaboration with Etienne Pinsard & Jean-Luc Paillard (LCPP)

The organization of large events raises security issues that require a better knowledge of dense crowds dynamics. In the field of pedestrian modeling, the focus until now has been put on low or moderate densities. However, there is now an attempt to shift towards higher densities and larger crowds.

In order to model a limited number of pedestrians, microscopic models allow to simulate individual trajectories. These models are mainly based on collision avoidance; and in the most sophisticated versions pedestrians anticipate until the next most threatening possible collision. This microscopic approach is, however, not suitable for large crowds, for which macroscopic models are more appropriate. These models describe the evolution of the density and mean velocity of the crowd thanks to PDEs expressing in particular mass conservation.

Though there was a belief that beyond a certain density, crowds behave like granular matter, some experiments [1] have shown that this is not the case, and that pedestrians anticipate for example the passage of an obstacle much beyond the next collision time scale. Such an anticipation in a competitive setting (as pedestrians compete for space) can be described in the frame of Game Theory. Actually, as it would be too costly to describe the strategy of each individual, dealing with long term anticipation for crowds dynamics is again best performed in the context of macroscopic models. A tool of choice for this endeavor is the theoretical framework of Mean-Field Games (MFG) in which each pedestrian sees the others only through a macroscopic density field [2]. These MFG models have proven to be relevant tools for predicting pedestrian crowd dynamics in circumstances where anticipation plays a central role [3].

In general, MFG models assume that each person anticipates over an infinite time horizon and has the full knowledge to allow for this anticipation. It is however possible, in the frame of MFGs, to add in the optimized cost a discounting factor [Butano et al.] that gives a higher weight to events close in time, while decreases their importance exponentially in future times. Further models interpolating between an total absence of anticipation and the full anticipation of MFGs can also prove to be sufficient in a large variety of configurations, while being much less heavy to simulate.

The aim of this internship is to identify, for a couple of configurations of practical interest, which of these models is best adapted to the size and necessary degree of anticipation, so that the model contains just the right amount of anticipation in order to capture the main characteristics of crowd behavior without being unnecessarily heavy in terms of numerical cost.

This work will be performed in collaboration with the Laboratoire Central de la Préfecture de Police (LCPP) which will provide relevant situations of interest that could be explored. The internship will have both a significant analytical component, involving understanding the properties of the different models and how they relate one to each other, and a strong numerical component.

The internship takes place within a collaboration between the LPTMS (https://www.lptms.universite-paris-saclay.fr/), IJCLab (https://www.ijclab.in2p3.fr/), and the LCPP (https://www.prefecturedepolice.interieur.gouv.fr/presentation/les-directions-et-services/directions-de-securite-civile/le-laboratoire-central-de-la-prefecture-de-police). The possibility of continuing the internship with a Ph.D. can be discussed.

[1] A. Nicolas, M. Kuperman, S. Ibánez, S. Bouzat, and C. Appert-Rolland, Sci. Rep. **9**, 105 (2019).
[2] J.-M. Lasry and P.-L. Lions, Comptes Rendus Mathema-tique **343**, 679 (2006).
[3] T. Bonnemain, M. Butano, T. Bonnet, I. n. Echeverr ́ıa-Huarte, A. Seguin, A. Nicolas, C. Appert-Rolland, andD. Ullmo, Phys. Rev. E **107**, 024612 (2023).