Driven Granular Flows as a Model for Crowd Movement

Matthew Turner (Warwick)
Oksana Koltsova (Legion Consultancy)

Pedestrians form an important component of **a multi-modal transportation system**. Planning and design of pedestrian amenities (multimodal points, airports, shopping malls, theaters etc) demand efficient, comfortable and safe walking operations for the pedestrians. In contrast to vehicular movements, pedestrians interact continuously with other pedestrians and their surrounding infrastructure/environment, changing their direction and speed frequently. To represent this complex movement behavior of pedestrians, various models has been proposed. The modeling, qualitative analysis, and simulation of crowd dynamics appears to be a challenging research field which is rapidly growing. It provides mathematical tools that can be used to study and optimize some of the needs of our society such as evacuation dynamics in conditions of danger and panic.

The modeling approach can be developed at three classical scales; namely, **the microscopic scale**, where the dynamics of each pedestrian is modeled individually in relation to other pedestrians, **the macroscopic scale**, which refers to the dynamics of locally averaged quantities such as density, momentum, and energy, and **the mesoscopic (kinetic) scale**, which corresponds to the dynamics of a probability distribution over the microscopic state of the pedestrians. A multiscale approach is therefore necessary to obtain a detailed description of the complex dynamics of pedestrians in unbounded and bounded domains. This challenge, bridging the gap between different scale aspects can be resolved using **a hybrid multi-scale model** unifying the advantages of the single layers and overcoming their limitations.

In this project, we propose a basic research task regarding one of macroscopic models - **a driven granular flow**. We envisage the project involving a literature review, the development of a proposal for future study and the analysis of some simple simulations, perhaps, making contact with simple analytic or scaling estimates where possible.

Granular flows are flows involving physical objects that can be as small as colloids (microns) and larger than cm or more. A key industrial applications is in hoppers and grain silos etc which can have a tendency to jam. This is understood to be due to the formation of stress-carrying bridges across the walls of the silo. This converts the downward force due to gravity acting on the particles to an outward force on the walls of the silo and these then sometimes even fail catastrophically as a result.

Granular flows in a bottleneck occur in many other scenarios, including, block caving and transport of granular material in conveyor belts. Here we are interested in using the methodology of frictional interactions in driven systems with soft interactions and/or friction to model the motion and escape dynamics of pedestrians, e.g. in panic situations. The forces produced via interactions between particles in granular flow are similar to the physical contact between pedestrians in panic-driven situations. Unlike bodies in granular flow, pedestrians are self-driven as opposed to gravity-driven; however there are still similarities between the behaviour of pedestrians and granulates. Gravity defines both the desired acceleration and the direction of the pedestrians, and the terminal velocity for grains is analogous to the desired velocity of self-driven pedestrians.