Emergent Phenomena Induced by Avoidance Behavior in Multi-Directional Pedestrian Flows

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Abstract Collision avoidance in multi-directional pedestrian streams can lead to self-organisation phenomena. A prominent example is lane formation in counterflow. We study a 3-way intersection using methods from active particle systems theory. A rich phase diagram with four different phases is found as function of the maneuverability and vision angle of the agents.

Keywords multi-directional flows, active particles, intersection, emergence, lane formation

Introduction

The collision avoidance behavior in multi-directional pedestrian streams is complex and not fully understood yet. In these scenarios it often competes with personal goals of the individuals which can lead to various macroscopic effects, especially the emergence of self-organisation phenomena. This is already known from bi-directional streams where lane formation is observed at intermediate densities. In this contribution we study theoretically the next simplest case of a 3-way intersection. A thorough understanding of crossing flows might help to improve safety and comfort in large crowds through appropriate crowd management methods.

Model

For modeling we adapt ideas from the theory of active particles, especially the concept of cognitive agents and intelligent active Brownian particles (iABPs) [1]. The simulation setup, shown in Fig. 1, is similar to circular antipode experiments as described e.g. in [2, 3]. To simplify matters and reduce the number of parameters we focus on a symmetric layout where all three streams have basically identical properties.

Motion of the agents is described by the overdamped limit of a Langevin equation to mitigate artefacts arising from inertia effects seen in force-based models. The focus is on effects of steering, not velocity adjustment. The interactions between the agents are based on local vision-based self-steering through torques that alter the direction of motion [4]. Since inertia effects are usually not overly important in pedestrian dynamics, assuming a constant speed of all agents is a reasonable approximation in modelling which helps to reduce the number of relevant parameters. For more details of the model definition we refer to [4].

Important parameters of the model are the strengths of goal fixation K, which controls the steering torque towards the goal, and the influence of visual perception Ω. With these two quantities we define the relative maneuverability $\Delta = \Omega/K$. Furthermore the influence of the vision angle ψ is taken into account.

Results

When varying the relative maneuverability Δ and the vision angle ψ, the agents show different dynamical states as shown in Fig. 1(b). For small Δ, goal alignment dominates over collision avoidance and agents

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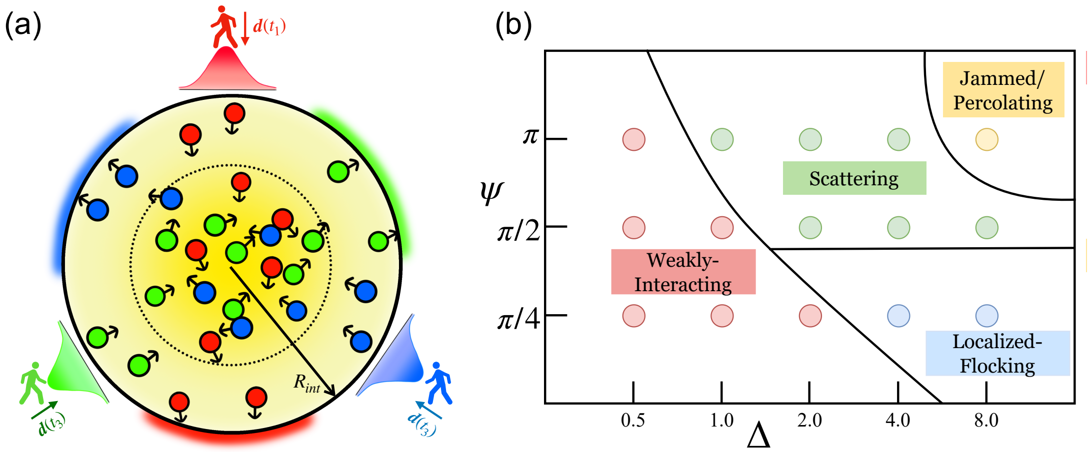

Figure 1: Model setup (left) and phase diagram (right).

head directly toward the goal. When Δ is increased, the agents in the stream interact more strongly with each other and more complex motion patterns evolve.

For large local avoidance Δ and narrow vision angles ψ, the agents in the interaction regime show avoidance-induced flocking. Neighboring agents with aligned motion can be arbitrarily close without noticing the presence of the other. If the vision angle is increased, agents start experience significant scattering and trajectories become convoluted. No stable order exists in this regime. If the vision angle is increased further, the systems enters a jammed state with percolated clusters where jamming is not caused by excluded volume effects but rather by strong steering avoidance.

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