Single-file pedestrian flows with free density

Cécile Appert-Rolland*[1] and Julien Pettré[2]

[1]IJCLab, Univ. Paris-Saclay, CNRS, F-91405 Orsay, France
[2]Inria, Univ. Rennes, CNRS, IRISA, M2S, Rennes, France

Abstract We present single-file experiments in which the global density is not prescribed. It turns out that pedestrians choose their interdistances so as to be close to the jamming transition. Pedestrians seem quite efficient at forming a circle with unprescribed characteristics, though it implies collective decision.

Keywords Following behavior, fundamental diagram, decision making, single-file flow, headway

Pedestrian dynamics are quite complex as humans have little inertia and have a double control on their walking direction and speed. One-dimensional flows allow to restrict the dynamics to its longitudinal component, focusing on the following behavior between two successive pedestrians. Experiments investigating single-file (or one-dimensional = 1D) flows in controlled conditions [1, 2, 3] serve as a benchmark. They have allowed for example to compare the effect of cultural differences [4] or of age [5], or the influence of staircases [6] on 1D fundamental diagrams. They are intimately related to locomotion characteristics (step length, frequency) [7, 8, 9]. They can give rise to macroscopic phenomena such as stop-and-go waves [3, 10, 5]. Beyond 1D, following behavior can be involved in more complex flows as in large corridors [10]. Progress in pedestrian tracking allows now to compare controlled experiments with field data collected at real events [11].

While the first single file experiments were considering closed and prescribed trajectories, for which the total density is fixed, more recent ones have allowed to consider cases where pedestrians are free to choose their interdistance with the predecessor without global density constraint. We performed for example experiments in which pedestrians had to form a circle of unprescribed radius, or others in which pedestrians had to follow a straight line with freedom to choose the distance to the predecessor [12, 13].

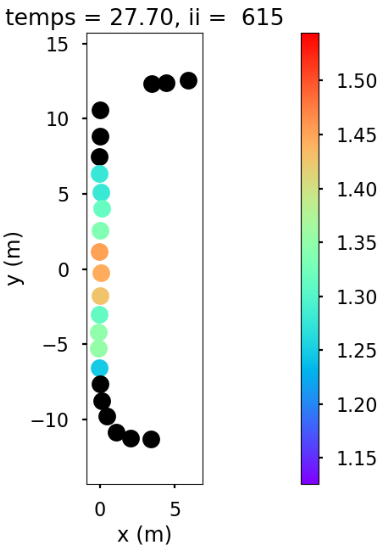

Figure 1: Top view of the line experiment at a given time. Each pedestrian is represented by a disk. Inside the measurement area, disks are colored according to the pedestrian's velocity.

We could have though that in the latter case, pedestrians would have chosen comfortable large interdistances. Actually it turns out not to be the case. Pedestrians rather seem to choose headways close to the jamming transition, possibly because of the social pressure coming from behind.

*Email of the corresponding author: `Cecile.Appert-Rolland@ijclab.in2p3.fr`

By giving instructions to the leader of the line, we could slow down the whole flow. We observe how the direction of propagation of density fluctuations switches from downstream at free speed to upstream at low speed.

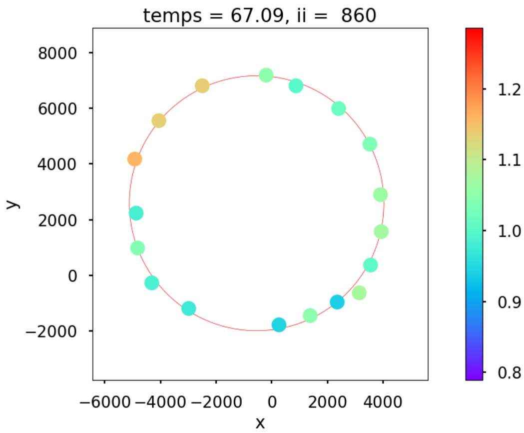

Figure 2: The circle experiment. (Left) Snapshots of the experiment, during the transient corresponding to the formation of the circle (Top) and once a permanent regime is established (Bottom). (Right) Top view of the circle experiment at a given time. Each pedestrian is represented by a disk colored according to the pedestrian's velocity. The line indicates the fitting circle.

While in the line experiment the decision about how much space to leave in front is individual, it is collective when the task is to form collectively a circle. Pedestrians seem quite efficient at this task, and for example the position of the circle center is quite steady. We present various observables allowing to characterize the circle formation process.

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