The role of anticipation among pedestrians in the emergence of stop and go waves

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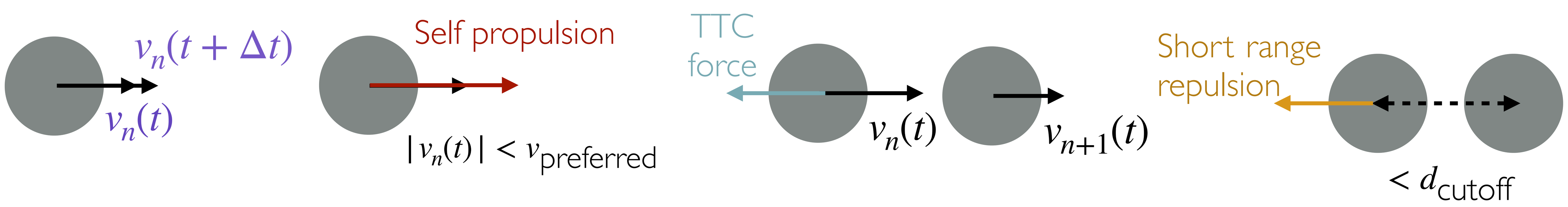
Context: Active matter notably deals with self-propelled multi-agent systems, i.e. systems capable of converting energy into work. Pedestrians are an example of such systems, even though they display some specificities such as anticipation, which contributes to the emergence of very interesting large-scale collective movements such as stop and go waves. The study of these systems is not only of theoretical interest for physicists but also of practical relevance for crowd management during social events. These two aspects are jointly explored and developed in the framework of the French-German Madras project, which addresses agent based modeling of dense crowds and their empirical observations.

Model: Each pedestrian is actively changing his own speed continuously in time by minimizing an energy. It includes an anticipation term based on time to collision (TTC) introduced by Karamouzas [1]. And distraction is accounted by the reaction time $\tilde{\tau}$.

2d

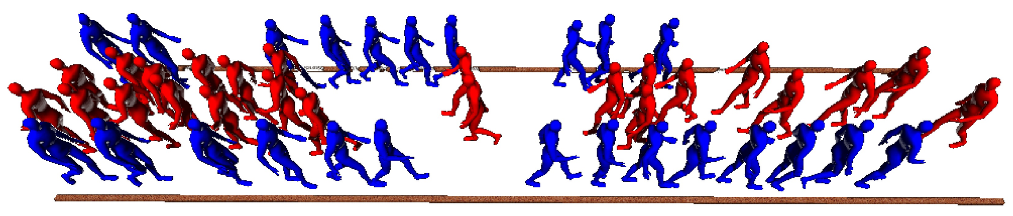
$$\mathbf{v_n}(t+\tilde{\tau}+\Delta t) = \underset{\mathbf{v}}{\text{argmin}}\ E_{\text{inertia}} + E_{\text{biomechanic}} + E_{\text{anticipation}} + E_{\text{private space}}$$

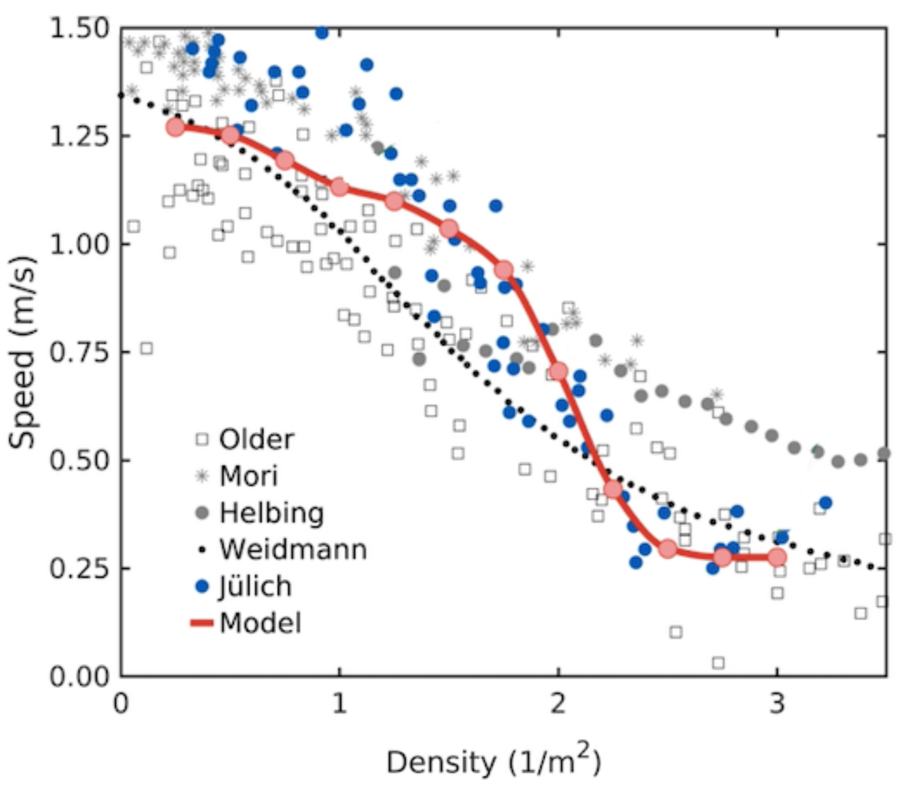


1d

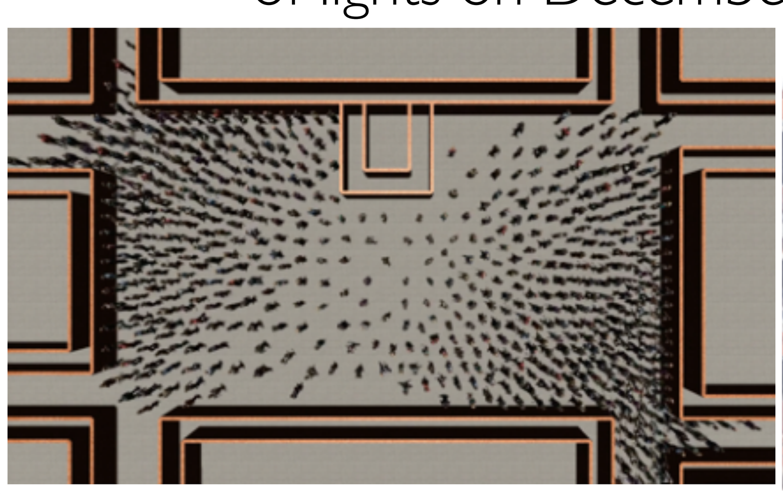
$$m\frac{\mathrm{d}v_n}{\mathrm{d}t}(t+\tilde{\tau}) = f(|v_n(t)|) + h\frac{v_{n+1}(t)-v_n(t)}{(2R+x_n(t)-x_{n+1}(t))^2}\Theta(\tau_n) - \frac{\eta}{(x_{n+1}(t)-x_n(t))^2}\Theta[d_{\text{cutoff}}-(x_{n+1}(t)-x_n(t))]$$

Test of the model [2,3]: Pedestrians trajectories on a corridor scenario have been compared to simulated ones through the fundamental diagram relating the mean velocity of agents to the overall density.

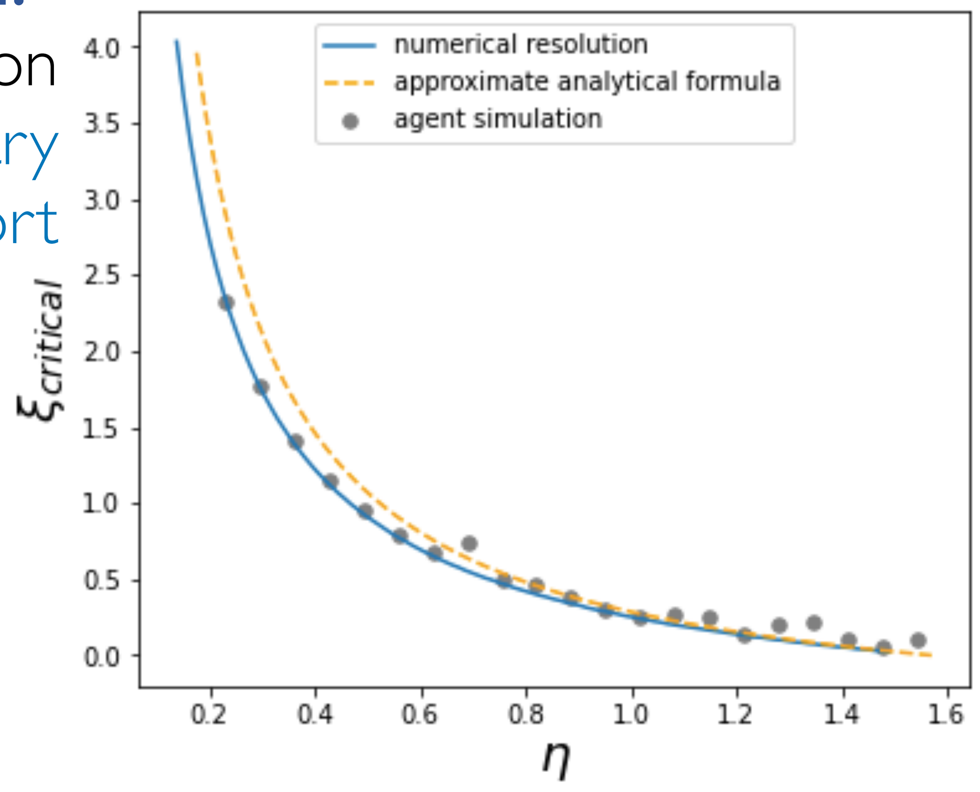




A simulation of a place in Lyon that will be compared to observational data during the festival of lights on December.



Results for single file motion: We performed stability analysis on the 1d model without asymmetry in the neighborhood nor short range interaction.



$$i\omega e^{i\omega\tilde{\tau}} = \frac{\xi}{m}e^{ik} - \frac{1}{\tau} - \frac{\xi}{m} \qquad \xi = \frac{\pi}{4\eta} - \frac{1}{2} \quad \text{(approximation formula)}$$

Notations $\eta = \frac{\tilde{\tau}}{\tau}$ $\xi \propto \frac{h}{(d-2R)^2}$ $\tau \propto m$

Conclusion: Anticipation is a key feature for stop and go waves as soon as the reaction time is smaller than the typical relaxation time of the system.

References:

[1] Karamouzas et al., PRL113, 238701 (2014)
[2] Julich, DOI : 10.34735/ped.2013.7
[3] Fehrenbach et al. AIMS-American Institute of Mathematical Sciences, 2015, 10 (3), pp.579-608

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