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The role of fluctuations and interactions in pedestrian dynamics

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Pedestrian dynamics

The **dynamics of pedestrian crowds** is a relevant topic for the design and safety of civil infrastructures and furthermore a fascinating subject deeply **connected** with many scientific disciplines, including **statistical physics** and **fluid dynamics**.

Even in simple geometries, individuals always display, in addition to **average behaviors**, **small fluctuations** and, more **rarely, large "anomalous" deviations**.

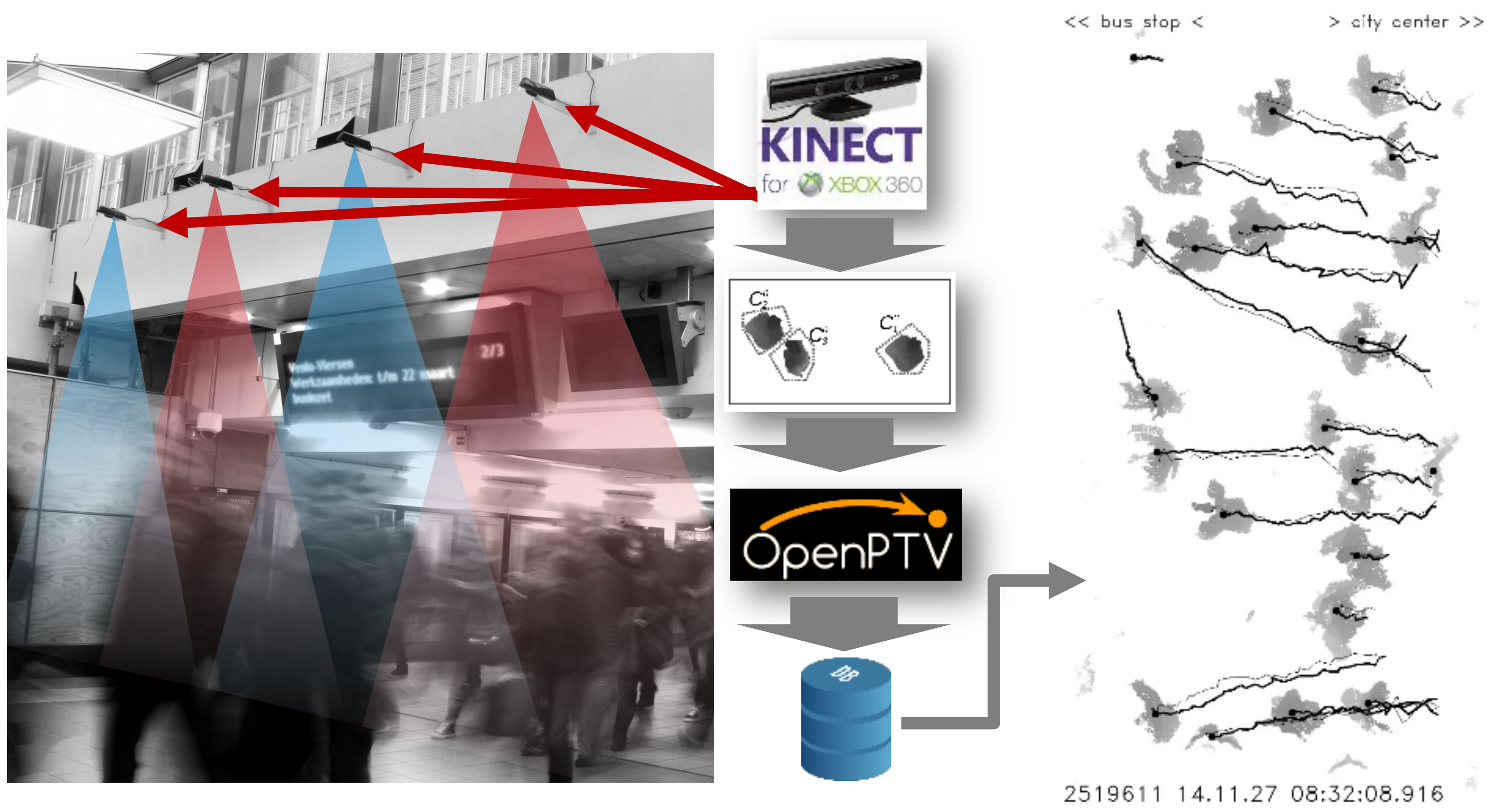

Figure 1: Real-life pedestrian tracking at Eindhoven train station. Raw data, as depth maps, is collected via grids of Microsoft KinectTM overhead sensors. Ad hoc algorithms are used to identify pedestrians that are tracked with Particle Tracking Velocimetry (PTV) techniques.

High statistics measurements

We expect observation of the crowds with **very high statistics** to reveal the **signature** of both **frequent** and **rare fluctuations**. To this aim, back in 2013 we started several year-long experimental campaigns in real-life settings. Performing **24/7 continuous pedestrian tracking** via ad hoc technologies in different locations, we collected an **unprecedentedly large database of human trajectories** (~10M) [1-3].

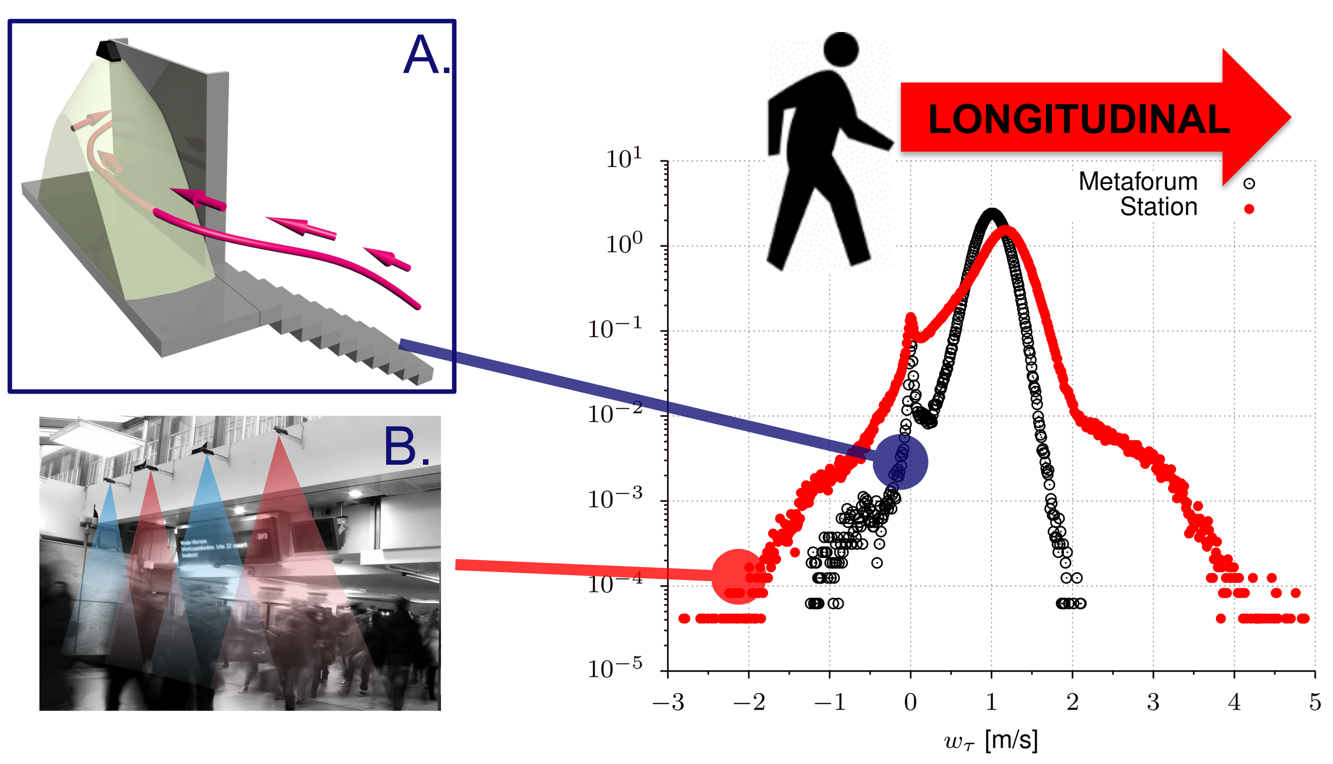

Figure 2: Probability distribution functions of (longitudinal) velocities of pedestrians walking *undisturbed* by others. Measurements from two locations are compared: A. corridor at Eindhoven university of Technology; B. Train station (cf. Fig. 1). In both cases **rare turnback** events emerge (negative velocities)

Fluctuations in the undisturbed dynamics: Langevin-like model

Based on the observed statistics we drew an **analogy** between **undisturbed pedestrians** (i.e. the diluted dynamics) and **active Brownian particles** and constructed a **generalized Langevin model** (1) that takes into account geometric restrictions, pedestrians' destination and turningback events [1,2].

$$\dot{u} = 4\alpha u(u^2 - u_p^2) + \sigma_x \dot{w} \quad (1)$$

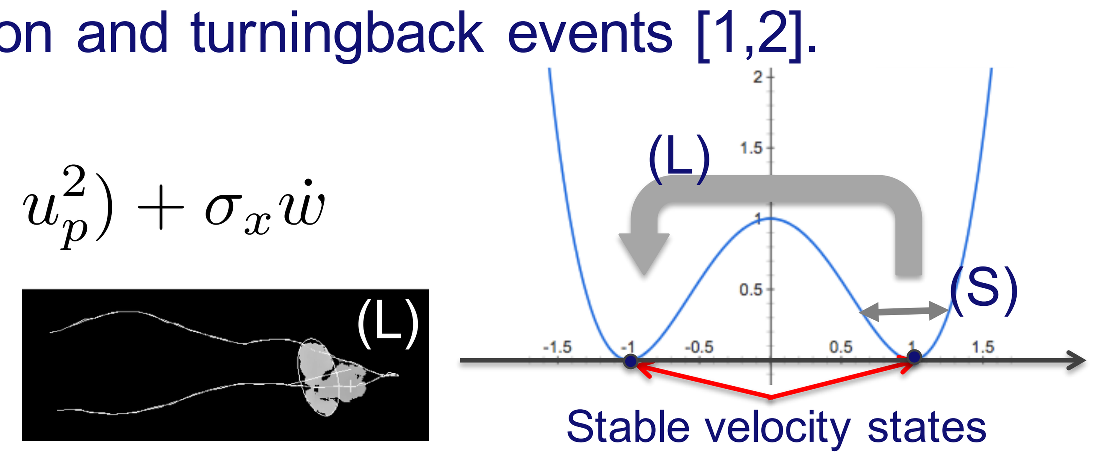

Figure 3: A Langevin model with a double-well velocity potential (1) enables frequent small fluctuations (S) and large, although rare, velocity leaps (L) to negative velocities, i.e. turningback events.

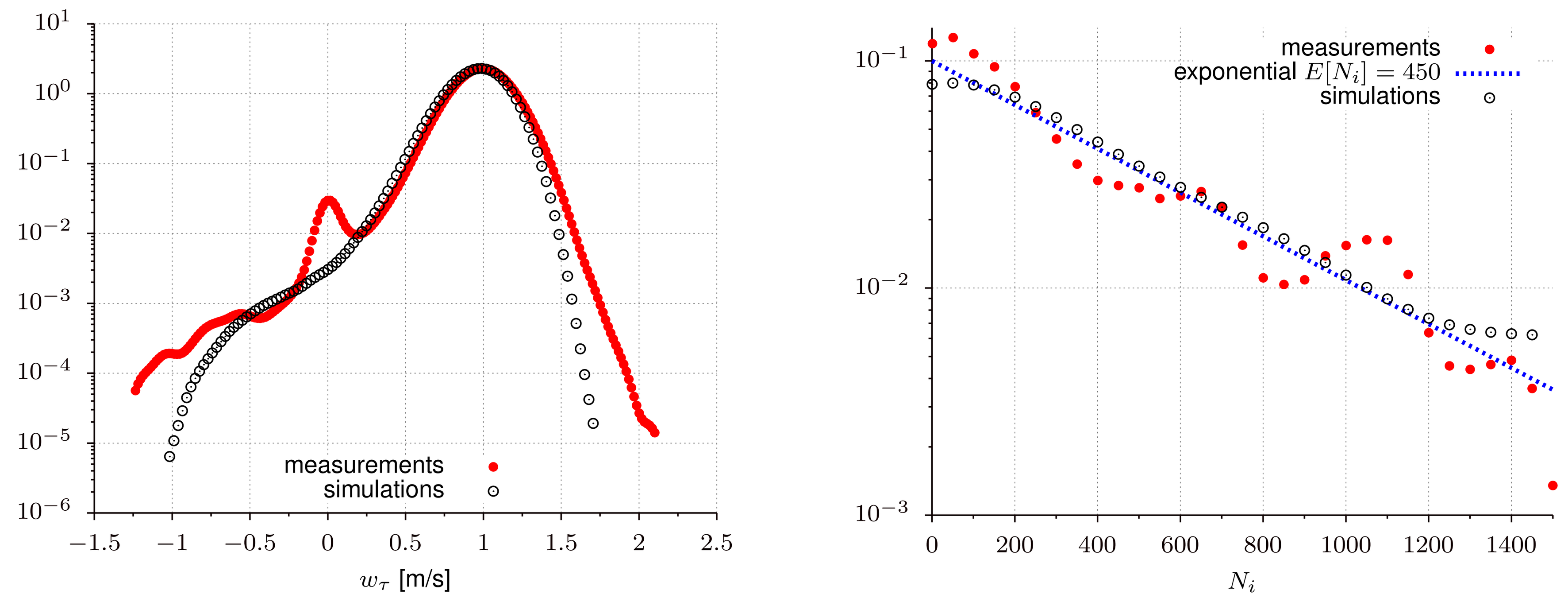

Figure 4: Comparison between the modeled and the measured dynamics in case of the corridor in Fig. 2A. (left) Probability distribution function of longitudinal velocities. (right) Number of pedestrians observed between two successive (rare) inversion events (roughly 1 in 450 on average, Poisson distributed).

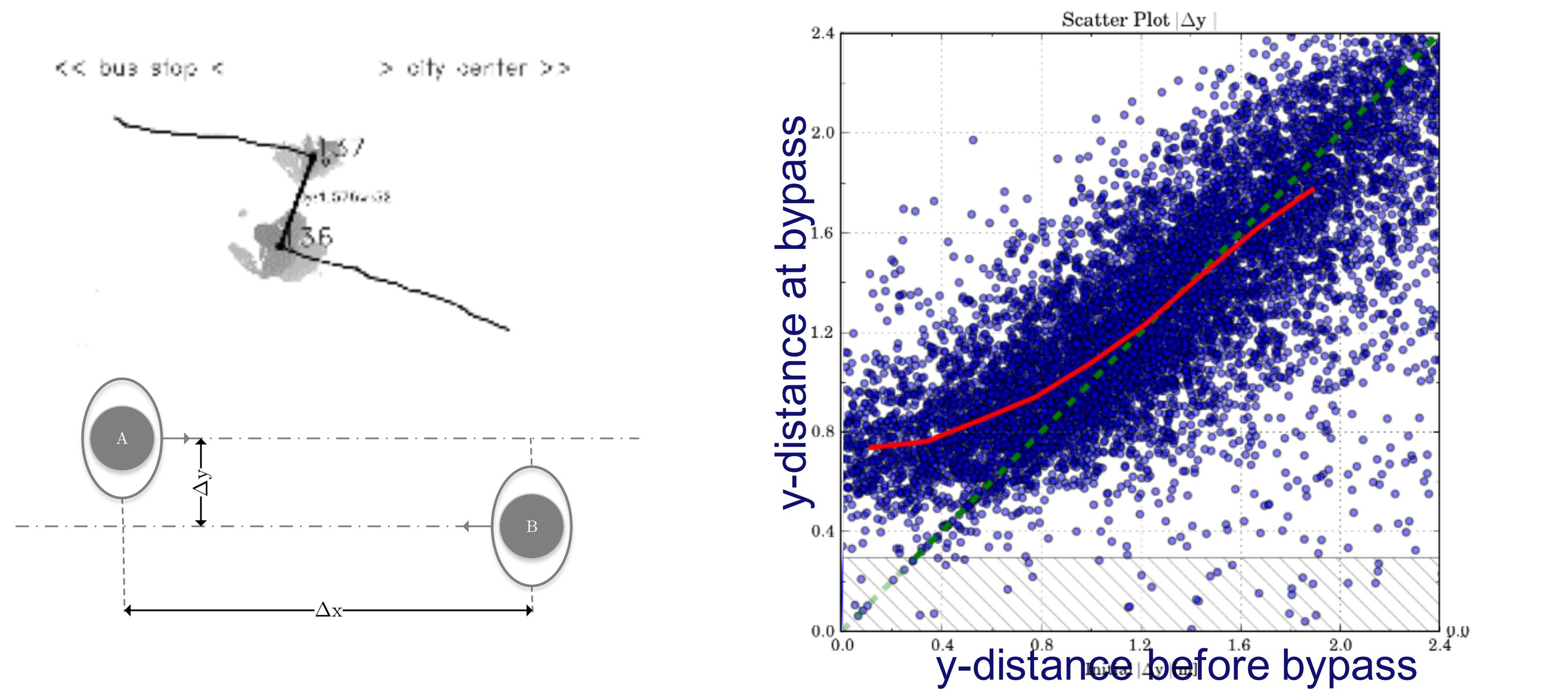

Figure 5: Binary avoidance interactions are measured considering the variation of transversal (lateral) distance before and at the mutual by pass.

Interactions and outlook

Quantitative stochastic model for the undisturbed, i.e. diluted regime as (1) are a first step toward quantitative models for entire crowds. The analysis of binary interactions, ongoing for our train station data (Fig. 5), is the next step in this direction.

References:

[1] A.Corbetta et al., 2016, Fluctuations around mean walking behaviours in diluted pedestrian flows, submitted, arXiv:1610.07429

[2] A.Corbetta, 2016, Phd. Thesis, Multiscale pedestrian dynamics: physical analysis, modeling and applications

[3] A.Corbetta et. al, 2014, High Statistics Measurements of Pedestrian Dynamics. Transportation Research Procedia 2, 96-104

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