

Monitoring physical distancing for crowd management

real-time trajectory and group analysis

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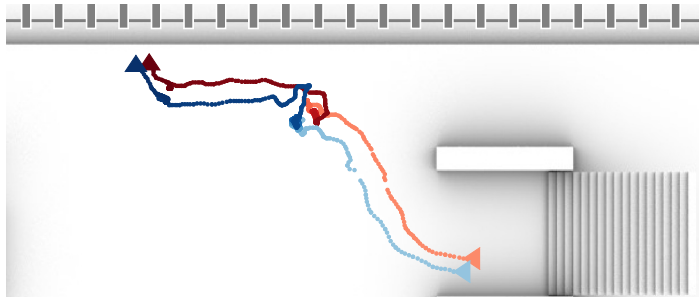


Figure 1: Detected clique consisting of two nodes representing two people traveling together. The hue of the trajectories is proportional to the time spent on the platform.

real-time tracking of pedestrian dynamics in public spaces is a growing reality, it is natural to leverage on these tools to analyze the adherence to physical distancing and compare the effectiveness of crowd management measurements. Typical questions are: “in which conditions non-family members infringed social distancing?”, “Are there repeated offenders?”, and “How are new crowd management measures performing?”. Notably, dealing with large crowds, e.g. in train stations, gets rapidly computationally challenging.

In this work we have a two-fold aim: first, we propose an efficient and scalable analysis framework to process, offline or in real-time, pedestrian tracking data via a sparse graph. The framework tackles efficiently all the questions mentioned above, representing pedestrian-pedestrian interactions via vector-weighted graph connections. On this basis, we can disentangle distance offenders and family members in a privacy-compliant way. Second, we present a thorough analysis of mutual distances and exposure-times in a Dutch train platform, comparing pre-Covid and current data via physics observables as Radial Distribution Functions. The versatility and simplicity of this approach, developed to analyze crowd management measures in public transport facilities, enable to tackle issues beyond physical distancing, for instance the privacy-respectful detection of groups and the analysis of their motion patterns.

Physical distancing, as a measure to contain the spreading of Covid-19, is defining a “new normal”. Unless belonging to a family, pedestrians in shared spaces are asked to observe a minimal (country-dependent) pairwise distance. Coherently, managers of public spaces may be tasked with the enforcement or monitoring of this constraint. As privacy-respectful

Benchmarking pedestrian tracking for research and real-time crowd monitoring

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High-fidelity pedestrian tracking in real-life conditions has been an important tool in fundamental crowd dynamics research allowing to quantify statistics of relevant observables including walking velocities, mutual distances and body orientations. As this technology advances, it is becoming increasingly useful also in society. In fact, continued urbanization is overwhelming existing pedestrian infrastructures such as transportation hubs and stations, generating an urgent need for real-time highly-accurate usage data, aiming both at flow monitoring and dynamics understanding. To successfully employ pedestrian tracking techniques in research and technology, it is crucial to validate and benchmark them for accuracy. This is not only necessary to guarantee data quality, but also to identify systematic errors. Currently, there is no established policy in this context.

In this contribution, we present and discuss a benchmark suite, towards an open standard in the community, for privacy-respectful pedestrian tracking techniques. The suite is technology-independent and it is applicable to academic and commercial pedestrian tracking systems, operating both in lab environments and real-life conditions. The benchmark suite consists of 5 tests addressing specific aspects of pedestrian tracking quality, including accurate line-based crowd flux estimation, global density estimation, individual position detection and trajectory accuracy. The output of the tests are quality factors expressed as single numbers. We provide the benchmark results for two tracking systems, both operating in real-life, one commercial, and the other based on overhead depth-maps developed at TU Eindhoven, within the CrowdfLOW topical group. We discuss the results on the basis of the quality factors and report on the typical sensor and algorithmic performance. This enables us to highlight the current state-of-the-art, its limitations and provide installation recommendations, with specific attention to multi-sensor setups and data stitching.

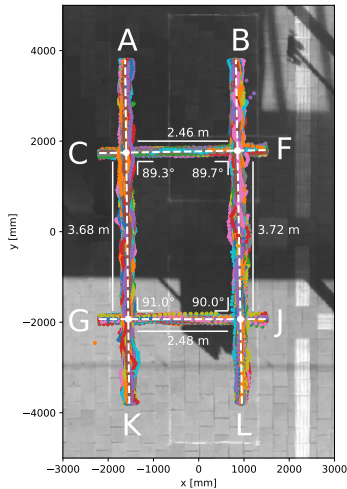


Figure 1: Trajectories recorded to test the localization accuracy of the pedestrian tracking system.

The dynamics of pedestrian boarding

High statistics analysis at a real-life train platform

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Traffic and Granular flow Conference [Presentation](#)

Continued urbanization and global goals to reduce greenhouse gas emissions increase the urgent need for safe, sustainable, and efficient public transport systems. It is expected, that the demand for public transport will autonomously grow by 30-40% in the next decade. To prepare for this prospect it is essential to assess the capacity bottlenecks in the already overloaded existing infrastructure. One of the limiting factors in the context of rapid transit networks is the transfer of pedestrians between different transportation lines/

modes. An inefficient alighting and boarding process is a source of delay and potentially causes congestion in significant parts of the transport network. Additionally, the perceived comfort and efficiency of the boarding process impact traveler experience to a great extent.

In this contribution, we provide an in-depth analysis of the train alighting and boarding process by evaluating real-life train (de)boarding events at a Dutch train station. Leveraging on data collected by an optical-based high-fidelity pedestrian tracking network capturing the trajectories of (de)boarding pedestrians across 20000 unique train doors. From the recordings, we extract emergent group structures, e.g. queues of boarding pedestrians, and files of deboarding travelers (cf. Fig 1). Specifically, we assess the safety, efficiency, and comfort within the observed group structures based on physics observables such as pedestrian fluxes, Voronoi densities, and pair-wise mutual distances. We show how the structure and dynamics of the boarding groups depend on crowd densities and proximity to infrastructural features such as stairs and escalators. This opens up the possibility of observing the impact of emergent collective and individual behaviors on the transfer process.

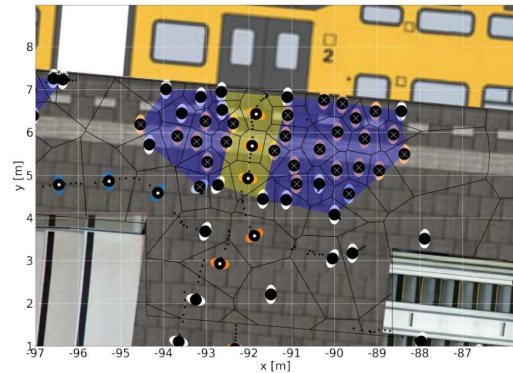


Figure 1: Overhead image of a real-life train boarding process with two groups of waiting pedestrians (blue) and a group of deboarding pedestrians (yellow).

Physics-driven trajectory restitching for high-fidelity real-life crowd tracking

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Traffic and Granular flow Conference **Presentation**

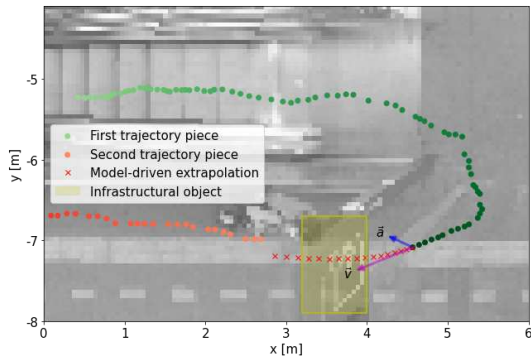


Figure 1: Overhead image of two trajectory pieces (green and red dots). Additionally, we show the extrapolation of the first trajectory piece (red crosses) based on its velocity (purple arrow) and acceleration (blue arrow).

and occlusions, either behind infrastructural objects, e.g. signs, lights, or trusses, or behind other pedestrians. The last issue is unavoidably amplified in conditions of high crowd density. To ensure high data quality, it is essential to develop an algorithm that reconnects the separate trajectory pieces thereby recreating the full pedestrian paths.

In this contribution, we propose a stitching algorithm that leverages environment-specific knowledge and physics-based pedestrian models to identify and reconnect interrupted trajectories. We employ a model-driven trajectory extrapolation to find the best matching trajectory pieces using only a few free parameters and with linear time complexity. To validate our approach we provide a stitching benchmark composed of real-life and artificial datasets for which the ground truth is known [1]. This allows us to test different extrapolation policies and report the results using a synthetic score based on reconnection accuracy. According to our benchmark, we can reconnect trajectory pairs with approximately 90% accuracy. This enables us to increase the data quality for both in-lab and real-life pedestrian trajectory data.