Bidirectional pedestrian fundamental diagram

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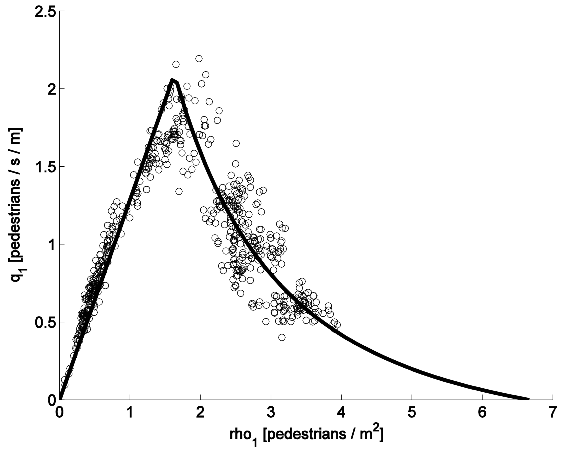
The modeling of pedestrian traffic flow is relevant for the design and operation of pedestrian facilities as well as for emergency and evacuation planning. This work exclusively focuses on the modeling of bidirectional flow. This phenomenon is separated from higher-level walking processes such as path following or route/destination choice by considering flows in long channels only.

The concrete approach taken is to first specify an utmost simple cellular automaton (CA) of the bidirectional flow process and to then analytically derive the corresponding bidirectional fundamental diagram (FD). The resulting FD relies on a minimal set of readily interpretable parameters (maximum walking speed, jam density, a collision avoidance parameter). It covers the entire density range in that it provides for all possible bidirectional density configurations separate flow rates in either direction. The FD has the following mathematical properties:

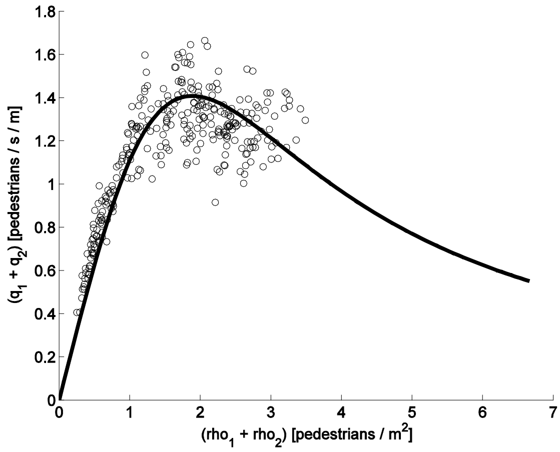
- The flows depend continuously on densities and parameters.
- The model has one and only one solution for each feasible density and parameter configuration.
- The flows are non-negative.
- Negative densities cannot be attained.
- The jam density cannot be exceeded.

The FD maintains these properties when its parameters are made density-dependent, providing a basic structure from which a wealth of alternative specifications can be derived. For density-independent parameters, the unidirectional projections of the FD are triangular.

Further, a structural relationship between two collision avoidance parameters (the safety gap to a lead pedestrian and the conflict delay resulting from moving around a counter-flow pedestrian) is established based on (i) behavioral considerations stating that pedestrians move as smoothly as possible, (ii) mathematical considerations requiring the continuity of an FD, and (iii) comparisons to real data. The practical importance of this relationship stems from the fact that it provides a one-on-one mapping between uni- and bidirectional pedestrian FD parameters.



(a) Fit of FD against unidirectional data



(b) Fit of FD against bidirectional data

Figure 1: Fit against real data

The proposed FD is validated against the social force model and an empirical dataset. A very good fit against the data is obtained in either case. Figure 1 shows the FD's fit against two real data sets. On the left-hand side, uni-directional flows are plotted over unidirectional densities. On the right-hand side, bidirectional flows are plotted over bidirectional densities. Both fits are obtained with *the same FD parameters*, meaning that Figure 1 shows the fit of a single bidirectional FD against both a unidirectional and a bidirectional data set.

In summary of all experiments, including those not presented in this abstract, the following observations can be made:

- The FD reproduces the empirically observed single-peaked shape of a unidirectional FD if one density vanishes.
- The FD reproduces the empirically observed persistence of substantial flow levels in the balanced bidirectional case even for high densities.
- The FD smoothly interpolates between unidirectional and balanced bidirectional flows based on first principles.