Multi-directional ASM for pedestrian traffic state estimation

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1 Introduction

In urban areas the active mode traffic flows, such as pedestrians, are steadily growing year by year. As a result of this growth, large crowd movements arise frequently at transport hubs during peak hours and at large-scale events. Recent events show that these large crowd movements can result in safety and accessibility problems (e.g. [1]).

Crowd monitoring schemes that make use of static sensor networks are more and more used to objectively monitor the movement dynamics of these large crowds. The goal of these schemes is to determine the pedestrian traffic state based on real-time data. Even though these schemes provide highly relevant information regarding the crowds movements, this information is usually spatially and temporally disperse and often only features directional flow counts.

Data-driven state estimation can provide a solution to this issue. Over the years, data-driven state estimation techniques have been developed vehicular traffic traffic, among others the Adaptive Smoothing Method (ASM) by [2]. However, due to the additional degrees of freedom of pedestrian traffic (e.g. multi-directional flows are allowed to interact), these data-drive estimation technique cannot be applied pedestrian traffic flows.

The Generalized ASM (GASM) is an extension of the ASM that is applicable for two dimensional flows and can be further extended for multi-directional flow compositions [3]. However, the GASM requires speed information for determining the speed regimes. Since speed and trajectory data are often not available in situations where crowd monitoring is necessary, the applicability of the GASM severely limited.

In this paper an extension of the ASM method is proposed. This extension allows for the state estimation of multi-directional pedestrian traffic flows, hereafter named Multi-directional ASM (MD-ASM).

2 Adaptations to the ASM method

The ASM method, as presented by [2], estimates any traffic state variable as a weighted average of the neighbouring estimated data in space and time. The weights of surrounding realisations of the data are determined by two kernels. The shape of these kernels is dependent on the directions in which the information regarding the traffic travels.

Given that crowd monitoring data often only consists of flow count data from counting cameras, the MD-ASM is designed to estimate the flow rate within an infrastructure. The procedure of the MD-ASM is depicted in figure 1. The MD-ASM estimates the pedestrian traffic flow in each of the flow directions separately based on flow counts at the boundary of the region. Here, a flow direction is defined as a flow of pedestrians with the same origin and destination that follow a similar path. As such, it is assumed that the walking directions of the pedestrians in each flow direction are known. Given that the velocity is the variable under consideration in most applications of the ASM, the weight estimation function has been adapted to estimate the flow (eq. 1). Here, the weight of the free-flow and congestion kernel is dependent on the maximum possible flow that can reach any point in space and time from all directions (eq. 2 & 3).

$$w_(x,t) = 0.5 \left[1 + tanh \left(\frac{q_{crit} - q_{total}(x,t)}{\delta q} \right) \right] \tag{1}$$

where

$$q_{total}(x,t) = \sum q_d(x,t) \tag{2}$$

$$q_d(x,t) = \max \left(q_{d,cong}(x,t), q_{d,free}(x,t) \right) \tag{3}$$

where q_crit refers to the critical flow rate at which the capacity of the infrastructure is reached, q_total the summed maximum flow rates per direction q_d that can reach location x at time t and δq a weight factor for the transition zone between the free-flow and congested regimes.

3 Ensuring flow conservation and attuning the capacity

This extension of the ASM produces two issues, namely the lack of flow conservation and the lack of a capacity restriction. The latter issue implies that the total flow rate is not restricted at the capacity, but can become larger than the capacity of the infrastructure as a result of equation 3.

Two procedures are introduced to overcome these two issues, being A) a balance of the total flow per time step to adhere to the flow conservation rule, and B) the back-casting of traffic jams based on the assumption of a maximum capacity q_{cap}. In the full paper these two essential procedures of the MD-ASM will be elaborated upon in more detail.

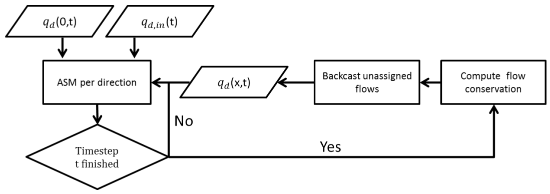

Figure 1: Visualisation of the flowchart of the MD-ASM

4 Case study and results

A preliminary test of the MD-ASM is performed by simulating a bi-directional flow in in a corridor of 5 meters wide and 50 meters long. From two sides of the corridor a pulse demand 4 P/s & 5 P/s are entering the corridor for the first 20 seconds. When the flows meet at the middle of the corridor, a queue is expected, which will eventually disappear again, since there is no demand on both ends of the corridor. Figure 3 illustrates that the model behaves as expected based on theory.

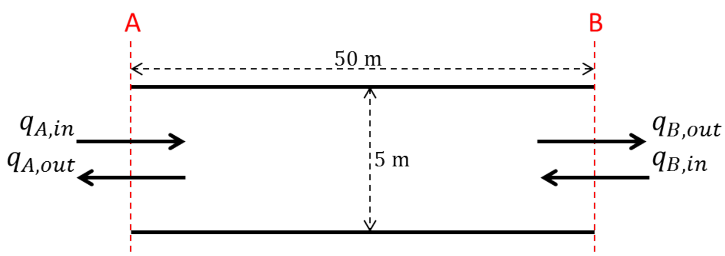

Figure 2: Layout of the case study

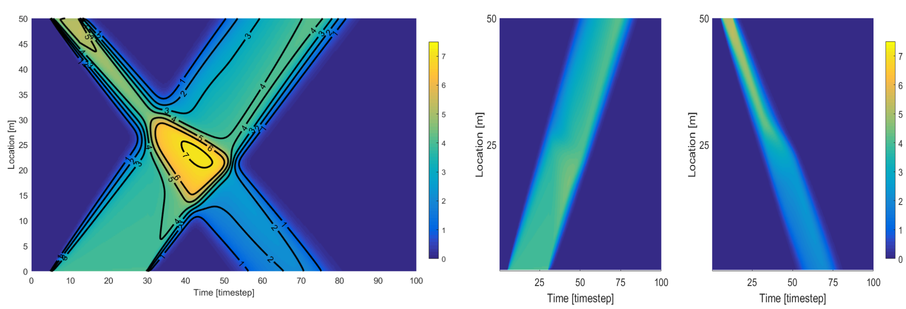

Figure 3: Results of the MD-ASM method, where the XT-plots are displayed for the total flow (left) and the flow rates in the separate directions (middle & right), where the colour indicates the flow rate in P/s

5 Conclusions

This extended abstract has presented an extension of the ASM of Treiber & Helbing (2003), which allows for the state estimation in multi-directional pedestrian traffic flows by means of counting camera data. The results of the preliminary tests are promising. In the full paper more sophisticated case studies will be performed to benchmark the MD-ASM, in which counting camera data from a large-scale event to test its applicability in real-life events and simulations from the microscopic simulation model Nomad are used to benchmark the algorithm against a ground truth data set.

References

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[3] Y. Yuan and S. Hoogendoorn. Generalized adaptive smoothing method for state estimation of generic two-dimensional flows. *Transportation Research Record*, (2561):18–24, 2016.