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IDENTIFYING PEDESTRIAN INTERACTIONS IN CROWDS

Ir. Mario Campanella[1], Prof. dr. ir Serge Hoogendoorn[1], Dr. ir. Winnie Daamen[1]
[1]Faculty of Civil Engineering and Geosciences, Department of Transport and Planning, Delft University of Technology, the Netherlands

ABSTRACT

Most data on interactions are obtained in experiments with very few pedestrians participating due to the difficulty in identifying these behaviours. This paper proposes a score that expresses the necessity of evasion between any number of pedestrians. It assumes that pedestrians will need to evade if their trajectories will lead to very short distances in a near future (short time-to-collision). This so called evasion score is calculated using the longitudinal and lateral distances between pedestrians over time (proximity scores) and the time available to apply the evasion manoeuvres (urgency score). The scores calculated for two sets of empirical trajectories showed a good correlation with the presence of interaction behaviours.

KEYWORDS

Pedestrian behaviours, interaction movements, walking models

INTRODUCTION

Experiments on pedestrian behaviours in real life situations contain important information about individual interactions (Costa (2010), Sobel & Lillith (1975)). However, due to the difficulties that natural environments present, the scope of the studied behaviours is limited. Experiments in controlled environments reveal complex interaction mechanisms (Moussaïd et al. (2009), Versluis (2010)). Until now, most of these experiments forcefully create the interactions by setting collision courses between very few pedestrians and extrapolating the results for situations with many pedestrians. By doing so, these researchers assume that the scaling of interaction behaviours is applicable to describe what happens in crowded situations. However, this is not true and interactions are influenced by macroscopic features of the traffic such as local densities and self-organised lanes in bidirectional flows.

The study of collective pedestrian interactions requires that pedestrians that are interacting must be identified. The identification of what moments pedestrians are interacting is not an easy task specially when there are several pedestrians in the vicinity. The situations in which pedestrians interact are very different: following another pedestrian, evading in case of collision course and passing sideways and there is no accepted definition of what identifies pedestrians interactions. This paper proposes that: *pedestrians are interacting when they are not far from each other and their current trajectories are such that if no velocity change is applied the probability that a collision or close contact will occur is high*.

The main contribution of this work is the definition of a evasion score that estimates the probability of interaction. In case of the presence of several pedestrians in the vicinity the score for a certain pedestrian is the one with the highest probability of interaction. Two different experiments namely a bidirectional flow and a $90°$ crossing flow were used to show how the scores can be used to assess the interaction behaviours.

EVASION SCORE

The evasion score is based on the constraint criterion developed by Daamen & Hoogendoorn (2006) Daamen & Hoogendoorn (2006) that distinguishes free flowing and constrained pedestrians. The constraint criterion consists of two principles: 1) two pedestrians at a sufficiently long distance may hinder each other if their trajectories approach too much in the near future (proximity constraint) and 2) this potential hindrance will be more difficult to be avoided if the time that the pedestrians have left to avoid each other is short (urgency constraint). Both constraints are implemented in a fuzzy logic algorithm with two membership functions: the ”proximity membership” and the ”urgency membership” that are used to calculate the degree of constraint for each pedestrian.

The evasion score is defined using the same principles. However, small absolute distances are not a good indicator of a necessity for evasive movements. Figure 1 shows two cases in which the absolute distances between pedestrians are equal, but the probability of evasion is different. In case (a) the pedestrians are on a collision route while in case (b) they will just pass sideways.

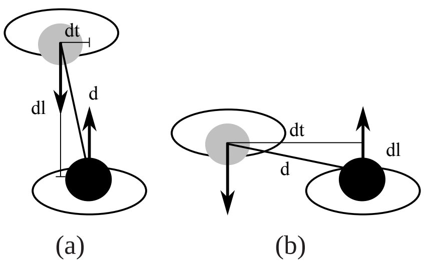

Figure 1: Two situations with distinct probabilities of evasions: case (a) high probability and case (b) low probability

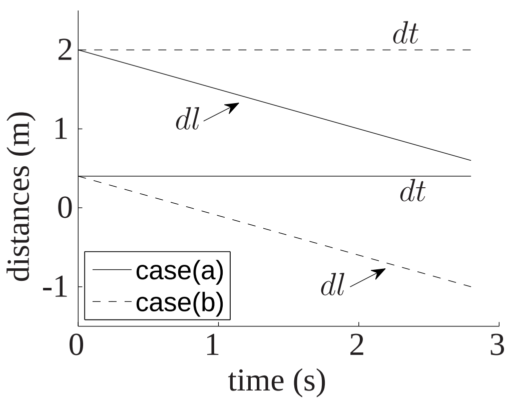

Figure 2: The longitudinal distance dl and lateral distance at for the two interaction cases over time

Therefore, two proximity memberships using the projections of the distance d into the velocity direction are introduced: 1) the longitudinal distance dl membership and 2) the lateral distance dt membership. The evasion score will only be high indicating that a evasion manoeuvre is probable if both distances have a simultaneous high probability of becoming small if no evasion is performed (case(a) in figure 2).

The evasion score is calculated by projecting future positions of the pedestrians in a similar manner as the time-to-collision estimates considering no changes in the walking direction and velocity. The lateral and longitudinal distances are measured and input in the proximity membership functions. The same is done for the urgency membership function that receives the time in which the projected distances are occurring. The score is calculated as the maximum value of the product of the three membership values for each step of the projection. Each membership varies between 0 representing no degree of proximity or urgency and 1 with total degree of membership. If more than one pedestrian is causing a non zero value of the score, than the largest value is taken.

IDENTIFYING INTERACTIONS

In this section we present some results of scores calculated in trajectories obtained in experiments in normal walking conditions. Two sets of trajectories were used: a bidirectional corridor with dimensions $10m \times 4m$ and a $8m \times 8m$ $90°$ crossing experiment (for details refer to Daamen & Hoogendoorn (2003)).

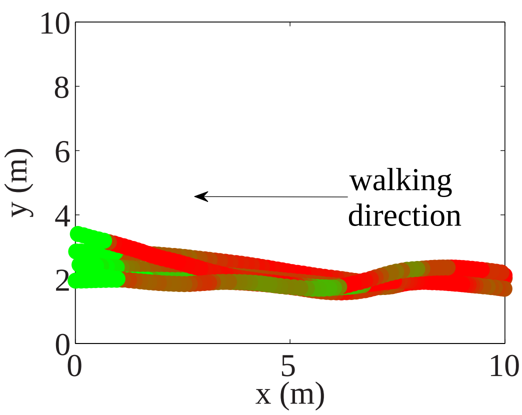

Figure 3: Five superimposed trajectories of pedestrians walking in lane. The colours represent the evasion score: red is a high score, light green is a low score

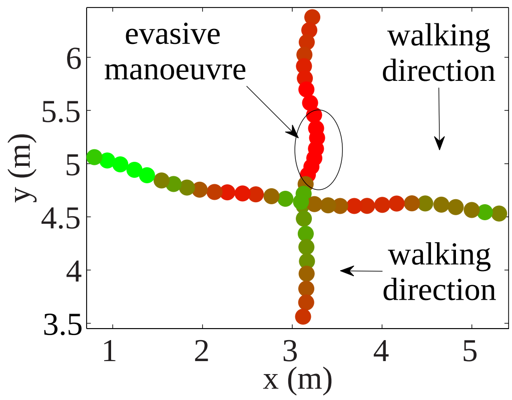

Figure 4: Two crossing trajectories with the pedestrians walking from the top to the bottom realising the evasion manoeuvre until the score decreased

Figure 3 shows that the evasion score is able to capture the lane behaviour for a bidirectional flow. The colours of the dots representing pedestrians are coded red for high score (large probability of collision) and light green when pedestrians are free. In lanes pedestrians maintain very short lateral and longitudinal distances from the leading pedestrians and therefore get a red colour. However, it is possible to notice regular variations of the score for some pedestrians indicating a oscillatory behaviour in the longitudinal axis. Figure 4 shows a pedestrian performing evasive manoeuvres in a crossing flow exactly when the score was the highest. The manoeuvres finished almost at the same moment as the value of the score dropped showing a good agreement between the interactions and the scores.

CONCLUSION

In this investigation we proposed a new evasion score that measures the probability that pedestrians will need to perform an evasive manoeuvre. Results for a bidirectional and a crossing flows presented good agreement between the values of the score with situations in which pedestrians are interacting. These preliminary results encourage the application of the evasion score for the analysis of pedestrian interacting behaviours. As an example we found that 56 % of all pedestrians in the bidirectional flow walked at least half of the corridor behind another pedestrian forming a lane. The average value of the score in these lanes was 0.52 with standard deviation equal to 0.22.

The applications of the evasion score for detailed analyses on interaction behaviours is promising. Future work will include the investigation of behaviours under the influence of external conditions such as local densities and types of walking flows.

REFERENCES

Costa, M. (2010) Interpersonal distances in group walking, in: *Journal of Nonverbal Behavior*, 34, Number 1, pp. 1573–3653.

Daamen, W., S. Hoogendoorn (2003) Controlled experiments to derive walking behaviour, in: *European Journal of Transport and Infrastructure Research*, 3(1), pp. 39–59.

Daamen, W., S. Hoogendoorn (2006) Free speed distributions for pedestrian traffic, in: *PrePrints (CD-ROM) 85th Annual Meeting Transportation Research Board*.

Moussaïd, M., D. Helbing, S. Garnier, A. Johansson, M. Combe, G. Theraulaz (2009) Experimental study of the behavioural mechanisms underlying self-organization in human crowds., *Proceedings of the Royal Society B: Biological Sciences*.

Sobel, R. S., N. Lillith (1975) Determinants of nonstationary personal space invasion, in: *Journal of Social Psychology*, 97, pp. 39–45.

Versluis, D. (2010) *Microscopic interaction behavior between individual pedestrians*, Master's thesis, Delft University of Technology.