12th International Conference on Pedestrian and Evacuation Dynamics (PED 2025)
Prague, Czech Republic – September 9-12, 2025

Pedestrian behavior model considering gaze and head direction

Ryo Sasaki[1], Shohei Yasuda*[1], and Takashi Fuse[1]

[1]Department of Civil Engineering, Faculty of Engineering, The University of Tokyo

Abstract Evidence suggests that pedestrians' gaze direction influences their movement as they look at advertisements, shop windows, and other pedestrians in facilities. However, the existing Social Force Model, which is widely used for facility design, has not quantitatively addressed this relationship. This study introduces a simulation framework that integrates pedestrians' gaze fluctuations and the resulting movement changes. The model's performance is validated against real-world data, demonstrating that incorporating gaze and head direction into the Social Force Model has a measurable impact on pedestrian flow simulation.

Keywords Pedestrian dynamics, Head direction, Gaze direction, Social Force Model

Introduction

As the urban population continues to grow globally, ensuring that various facilities are safe and comfortable for pedestrians has become increasingly important. Microscopic pedestrian behavior models enable the distinction of individual pedestrians and the simulation of their movement, thereby facilitating the evaluation of multiple design proposals. Among microscopic pedestrian behavior models, the Social Force Model (SFM) [1] is particularly notable for its lack of spatial resolution constraints, ease of implementation, and high interpretability, making it widely used for facility design. The SFM conceptualizes pedestrian movement through the application of virtual forces and determines acceleration using equations of motion.

Despite suggestions that pedestrians' gaze direction influences their movement [2], existing SFM has not quantitatively addressed the relationship between gaze and locomotion, or only discrete visual attentional state (looking at a store or not) has been addressed [3]. Since pedestrians in facilities direct their gaze toward various objects, such as advertisements, shop windows, and other pedestrians, incorporating gaze into the SFM used for facility design holds significant potential.

Methodology

This study examines the relationship between pedestrian movement, head orientation, and gaze direction using data from a laboratory experiment [4]. Specifically, it analyzes angles between the head and gaze direction vectors, originating from the pedestrian's position, and the movement direction vector on a top-down 2D plane (θ for head and φ for gaze), speed over one second divided by 90 percentile (V), and directional change over the same period (ψ).

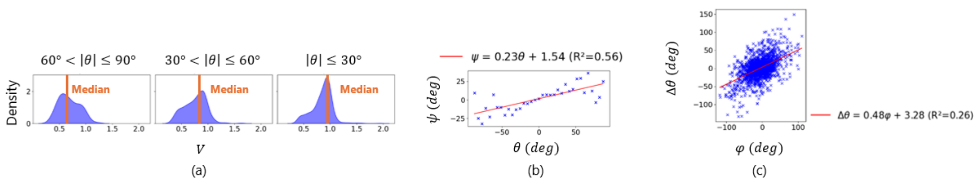

Figure 1: (a) Kernel density distribution of V across different θ, with orange lines indicating medians. The median values follow a ratio of 0.75:0.9:1.0. (b) Relationship between θ and ψ, where θ is binned in 5° intervals, and ψ represents the bin-wise average. (c) Relationship between φ and $\Delta\theta$ (change in θ).

The analysis in Figure 1 indicates that pedestrian speed and movement direction changes are influenced by θ, which in turn is affected by φ. Based on this, the simulation framework was designed to predict movement using a modified SFM, where φ is impacted by visual attractors in the environment (Figure 2).

*Email of the corresponding author: `s.yasuda@civil.t.u-tokyo.ac.jp`

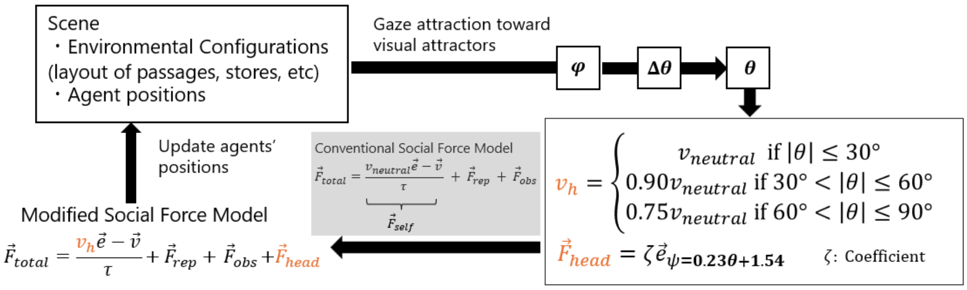

Figure 2: The simulation framework. The conventional SFM is from equations(7)-(10) in [5]. $\overrightarrow{F}_{total}$: The total force. $\overrightarrow{F}_{self}$: The driving force. $\overrightarrow{F}_{rep}$: The repulsive force of other pedestrians. $\overrightarrow{F}_{obs}$: The repulsive force of obstacles. τ : The relaxation time. $\overrightarrow{v}$: The current speed vector. $\overrightarrow{e}$: The unit vector toward a destination. $\overrightarrow{e}_{\psi=0.23\theta+1.54}$: The unit vector in the direction of $\psi = 0.23\theta + 1.54$.

At each time step, given agent positions and environmental configurations, φ is sampled based on gaze attraction toward visual attractors, while θ is updated via $\Delta\theta$ sampled from the normal distributions centered at the regression line in Figure 1(c). This θ induces a reduction in the desired speed $v_{neutral}$ following Figure 1(a) and a virtual force $\overrightarrow{F}_{head}$ in the direction of $\psi = 0.23\theta + 1.54$. These effects are incorporated into the conventional SFM to formulate the modified model, which then updates agent positions.

Result and Conclusion

A 45-minute bidirectional pedestrian flow dataset in an underground metro station corridor [3] was used for the model evaluation. A convenience store on one side of the corridor serves as a visual attractor, with the dataset providing binary labels indicating whether pedestrians look at the store at each time step. The corridor is divided into 12 parallel lanes, each approximately 45 cm wide. For each lane, the proportion of pedestrians looking at the store is calculated, and when simulating, φ is sampled accordingly from a distribution oriented either toward the store or along the current speed vector.

In the dataset, lane-wise average speed decreases as the lane gets closer to the store. To evaluate the model's ability to reproduce this spatial distribution, lane-wise Mean Absolute Errors (MAE) between the dataset's average speed and the simulated average speed over a 45-minute simulation were computed using both the modified and conventional SFM.

As shown in Table 1, the modified SFM achieves lower MAE in the majority of lanes, suggesting that quantitatively incorporating head and gaze direction enhances the model's ability to simulate pedestrian flows.

Table 1: MAE (cm/s) for each lane, averaged over 100 simulation runs with different random seeds for agent initial positions, φ, and $\Delta\theta$ samplings. Lane 1 is closest to the convenience store, with distance increasing as the lane number grows. The smallest MAE values for each lane are highlighted.

Lane	1	2	3	4	5	6	7	8	9	10	11	12
Modified	13	**4.6**	1.3	**1.3**	**1.6**	**2.8**	**3.8**	**4.4**	**1.5**	**1.5**	**2.0**	16
Conventional	13	6.3	**1.2**	8.9	13	17	14	9.3	12	2.2	3.0	**4.5**

Bibliography

[1] Helbing Dirk and Molnar Peter, *Social force model for pedestrian dynamics*, Physical review E **51**, 4282, 1995.

[2] Mark A Hollands and Aftab E Patla and Joan N Vickers, *"look where you're going!": gaze behaviour associated with maintaining and changing the direction of locomotion*, Experimental brain research **143**, 221-230, 2002.

[3] Li Danrui and Schwartz Mathew and Sohn Samuel S and Yoon Sejong and Pavlovic Vladimir and Kapadia Mubbasir, *Microscopic modeling of attention-based movement behaviors*, Transportation Research Part C: Emerging Technologies **162**, 104583, 2024.

[4] Schreiter T and Rodrigues de Almeida T and Zhu Y, *THÖR-MAGNI: A large-scale indoor motion capture recording of human movement and robot interaction*, The International Journal of Robotics Research **0**, 0, 2024.

[5] Xu Chen, Martin Treiber, Venkatesan Kanagaraj and Haiying Li, *Social force models for pedestrian traffic – state of the art*, Transport Reviews **38**, 625-653, 2018.