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Empirical analysis on external factors affecting pedestrian dynamics in high-density situations

HUU-TU DANG¹, BENOIT GAUDOU¹, NICOLAS VERSTAEVEL¹

¹UMR 5505 IRIT, University Toulouse 1 Capitole, Toulouse, France
Corresponding author: huu-tu.dang@ut-capitole.fr



Motivation

- In **high-density scenarios**, the increased number of neighbors leads to more interactions among pedestrians.
- Existing approaches primarily model pedestrian interactions using either **relative positions, velocities**, or both with respect to neighbors.
- Predicting pedestrian dynamics in **crowded environments** is a complex task as pedestrian speed is influenced by multiple **external factors**.

Objectives

- Propose a set of **perspective variables** and extract data of these features from **Jülich experiment** [1].
- Investigate the impact of the proposed variables on **pedestrian walking speed**, and subsequently **identify the key factors** affecting pedestrian walking speed in the high-density situations.

Data preparation

Proposed variables are extracted for **K nearest neighbors**:

- Fundamental Information (**FI**): $FI = \{||v_i||, \Delta x_{ij}, \Delta y_{ij}, \Delta v_{x_{ij}}, \Delta v_{y_{ij}} | 1 \leq j \leq K\}$
- Environmental Effect (**EE**): $d_W = \sqrt{(x_i - x_W)^2 + (y_i - y_W)^2}$
- Time-to-Collision (**TTC**) [2]: $TTC = \min_{1 \leq j \leq K} \tau_{ij}$
- Mean Distance (**MD**): $d = \frac{1}{K} \sum_{j=1}^K \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$
- Frontal Effect (**FE**): FI_{Front}

Method

- Neural network (NN): a Multilayer Perceptron (**MLP**) with hidden layers $h = (6, 3)$
- Different types of input are fed into the neural network:
 $I_0 = FI, I_1 = (FI, d_W), I_2 = (FI, TTC), I_3 = (FI, d), I_4 = FI_{Front}$
- Training and testing: $s(t + \Delta t) = NN(I_i(t))$
- Evaluation metric: Mean Absolute Error (**MAE**)

Results

- **Frontal Effect** and **Mean Distance** exhibit a noticeable improvement in accuracy in both unidirectional and bidirectional scenarios in the Jülich datasets.
- **Better accuracy improvement** is observed in the **unidirectional** dataset, which has less complex interactions compared to the bidirectional dataset.
- In high-density scenarios, neural networks are unable to achieve improved accuracy by incorporating **Time-to-Collision**.

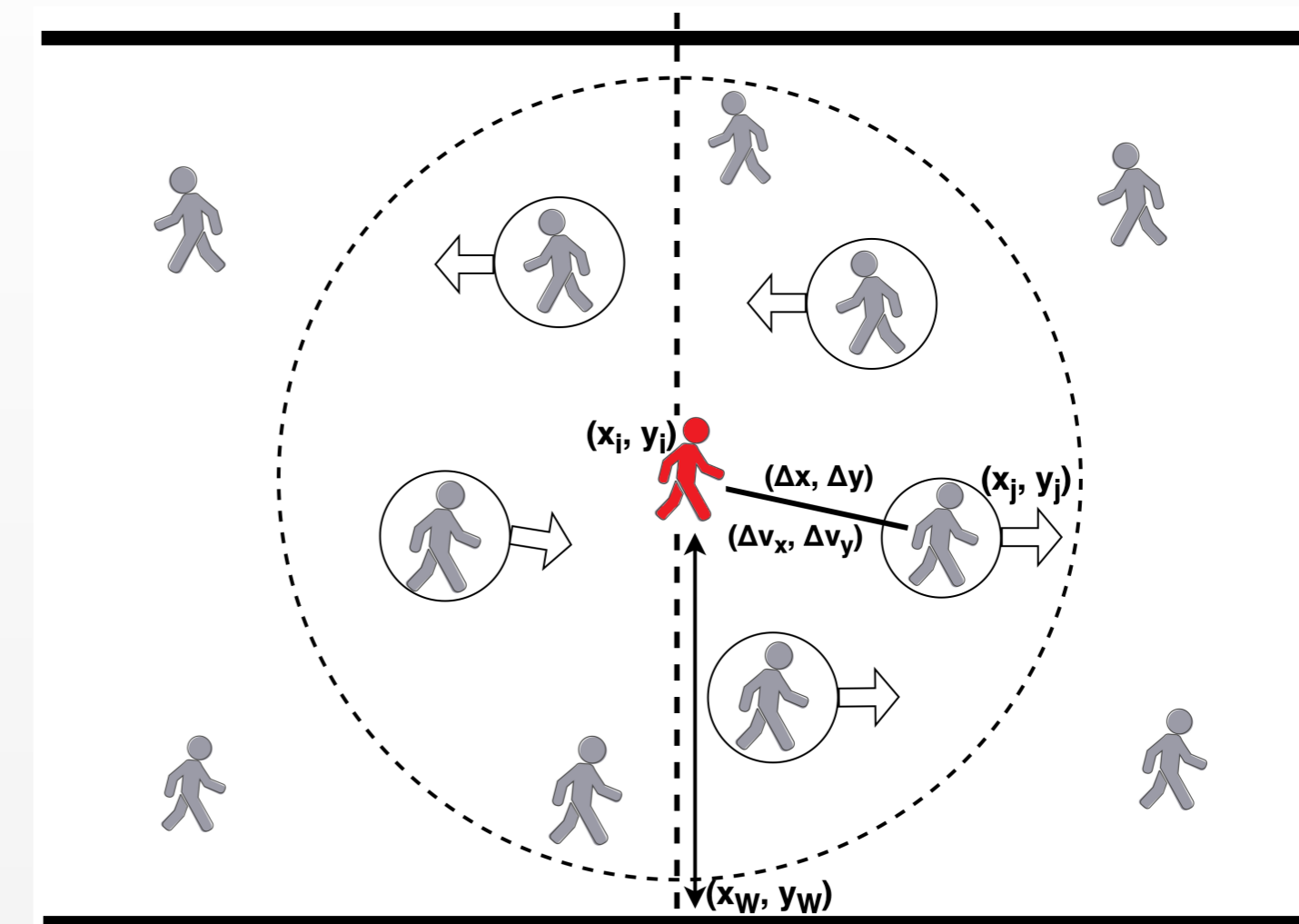


Fig. 1: Data preparation for $K = 5$.

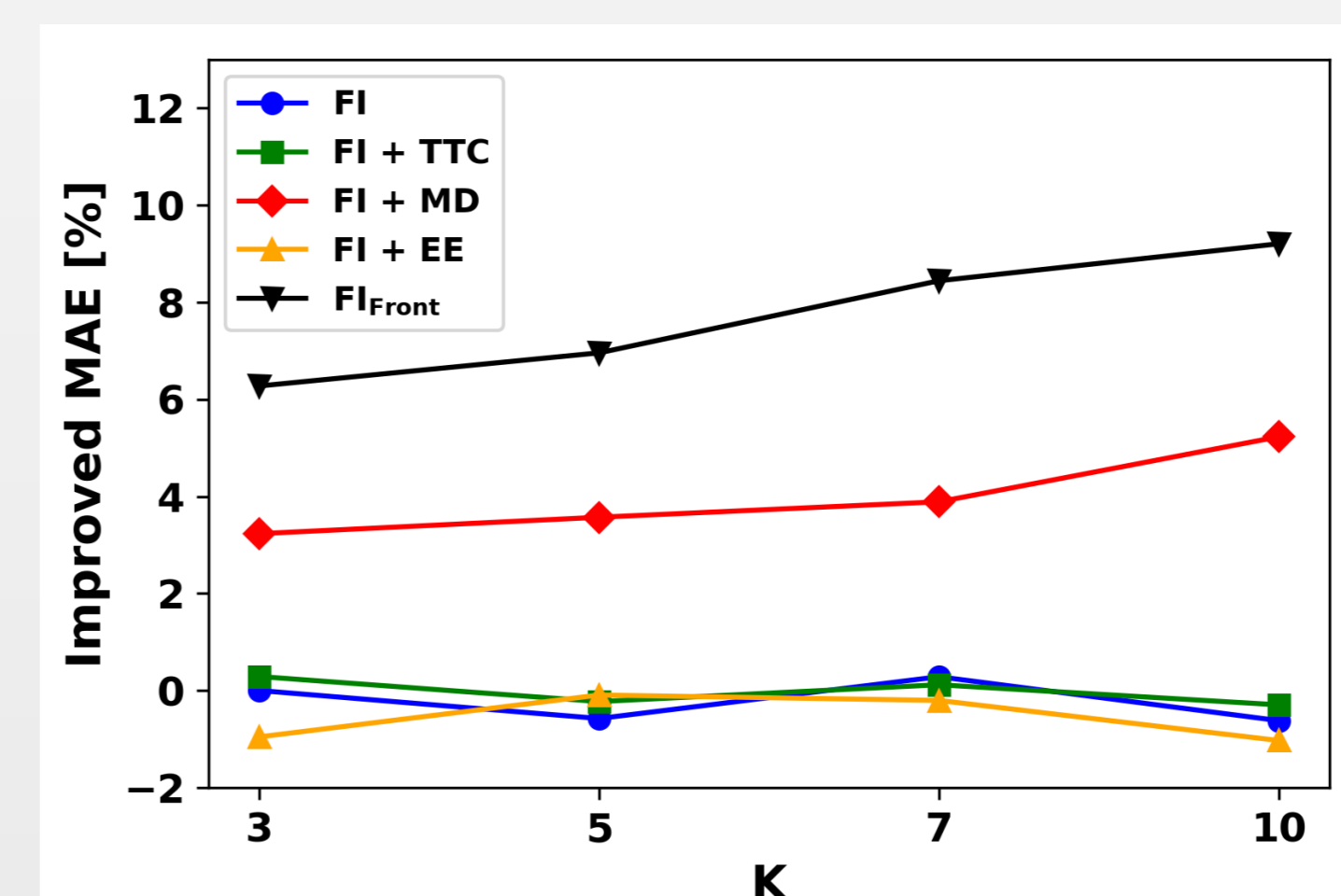


Fig. 2: Unidirectional flow, $\Delta t = 0.4$ s.

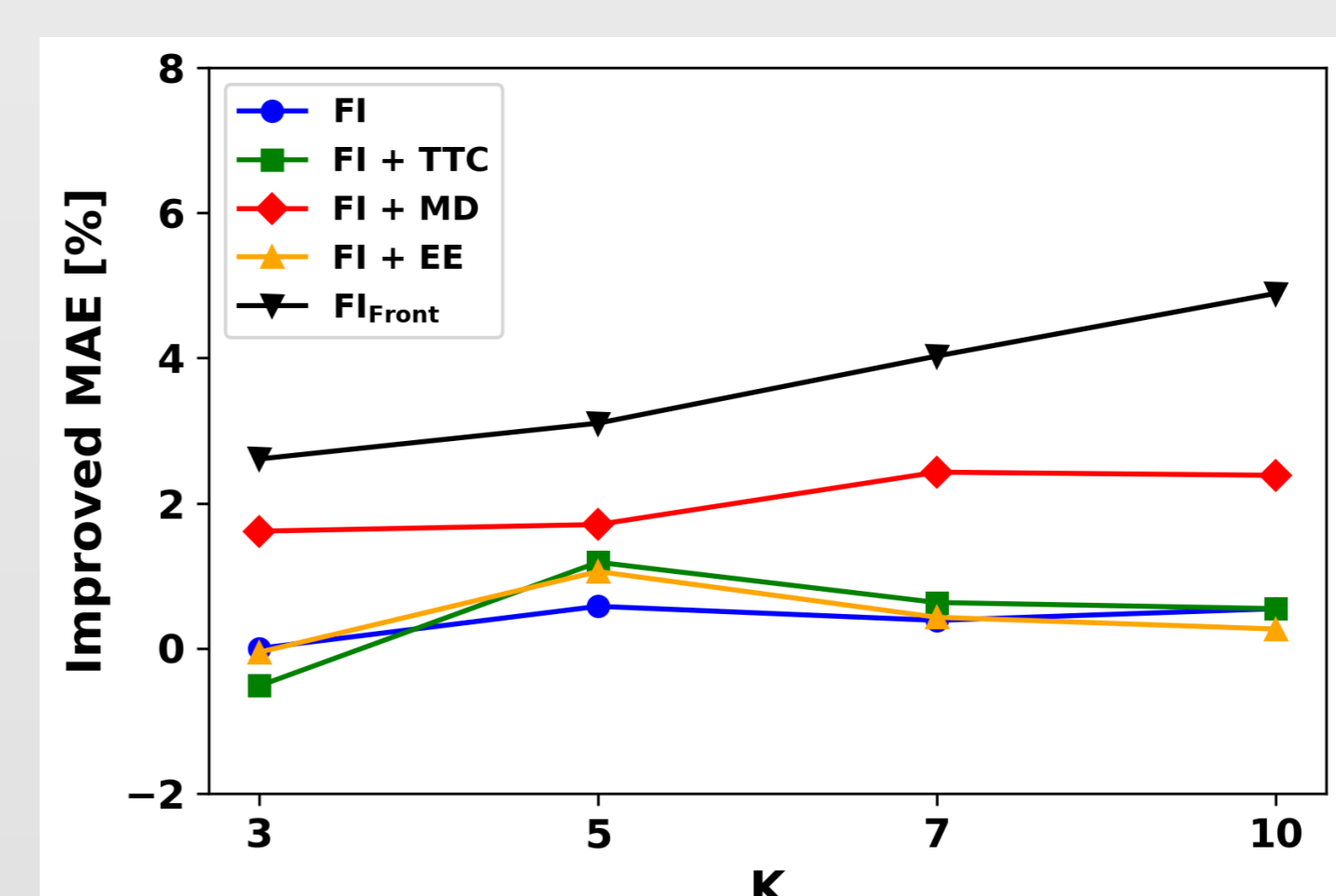


Fig. 3: Bidirectional flow, $\Delta t = 0.375$ s.

Future works

- Conducting a **sensitivity analysis** to determine the relative importance of the key variables.
- Comparing results with those from **low-density datasets**.
- Incorporating useful variables as **additional features** in pedestrian simulation models.

References

- [1] Cao, S., Seyfried, A., Zhang, J., Holl, S. & Song, W. Fundamental diagrams for multidirectional pedestrian flows. *Journal Of Statistical Mechanics: Theory And Experiment*. **2017**, 033404 (2017)
- [2] Karamouzas, I., Skinner, B. & Guy, S. Universal power law governing pedestrian interactions. *Physical Review Letters*. **113**, 238701 (2014)