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Simulation study on evacuation strategy for Vulnerable pedestrians

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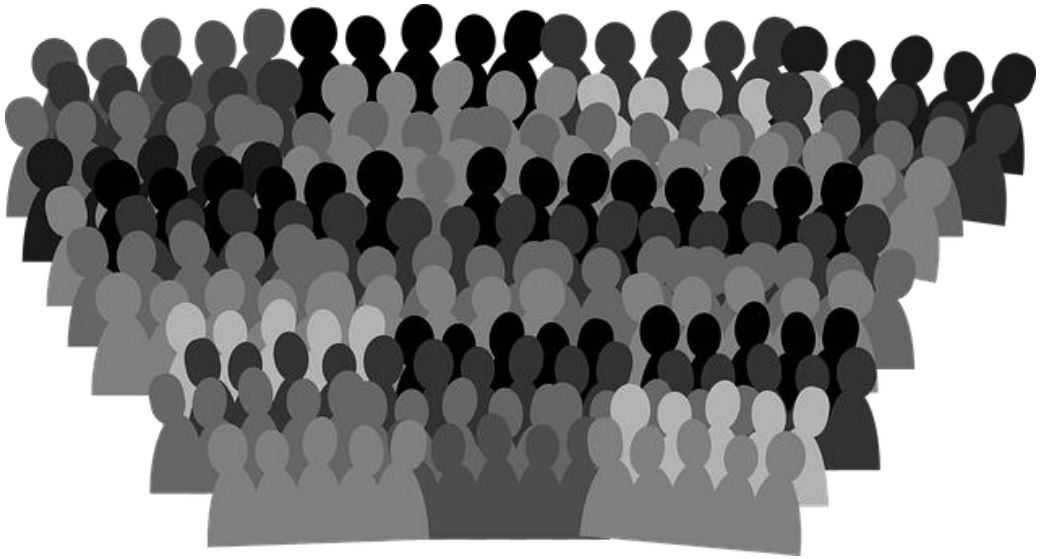
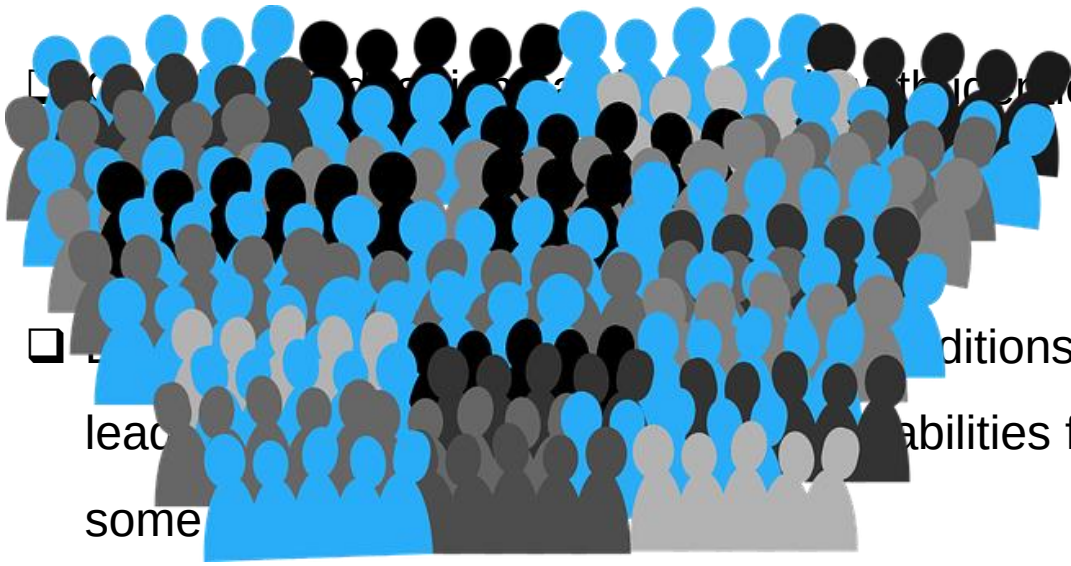
Motivation



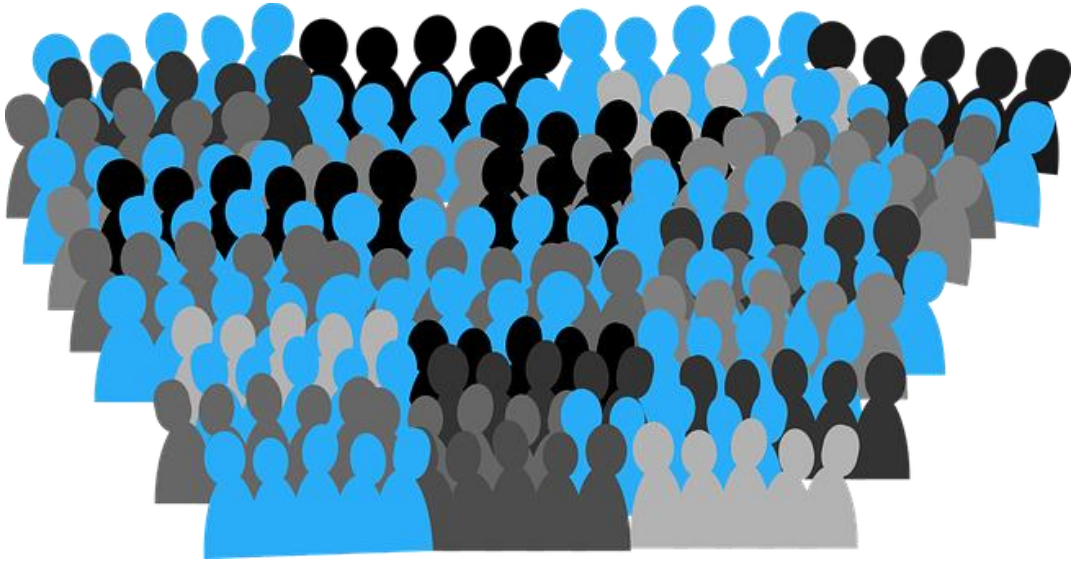
Individuals with identical characteristics



- ical
- ditions
- abilities for

Vulnerable pedestrians are involved

Research questions



- Can we develop evacuation strategy for helping vulnerable pedestrians?
- What factors affect the effectiveness of the strategies we developed?

Not Focus on:

The mechanism behind pedestrian behaviors

Seeking the optimal strategy

Vulnerability

- **Distance-based** vulnerable pedestrians

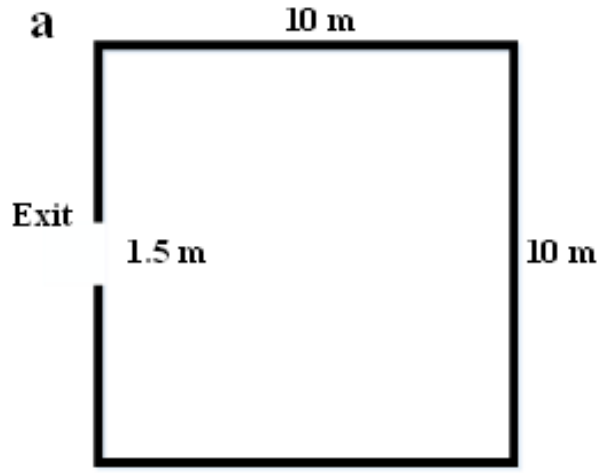
  who are further away from exits

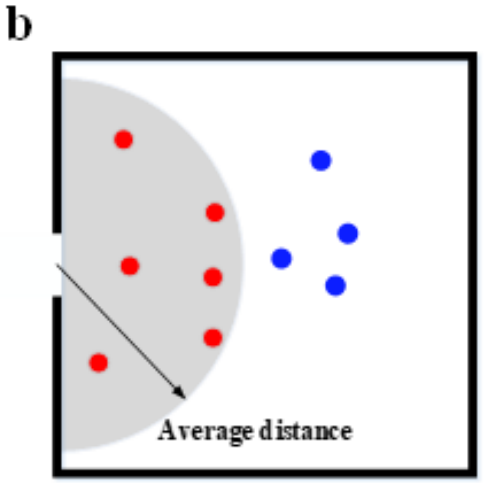
  -- depends on pedestrian initial distribution

- **Velocity-based** vulnerable pedestrians

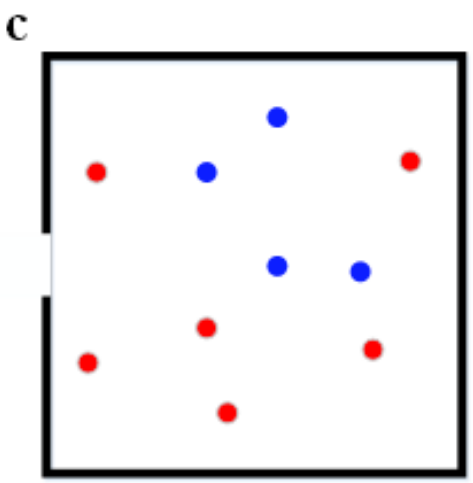
  who have lower speeds

  -- pre-assigned





Distance-based

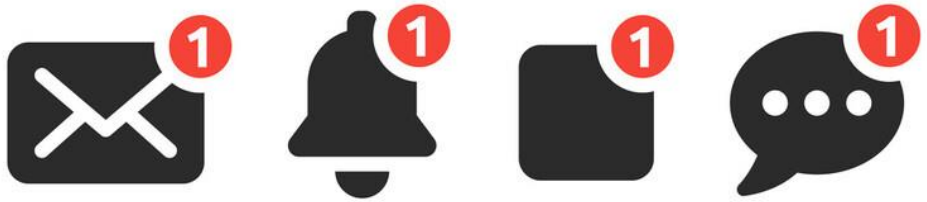


Velocity-based

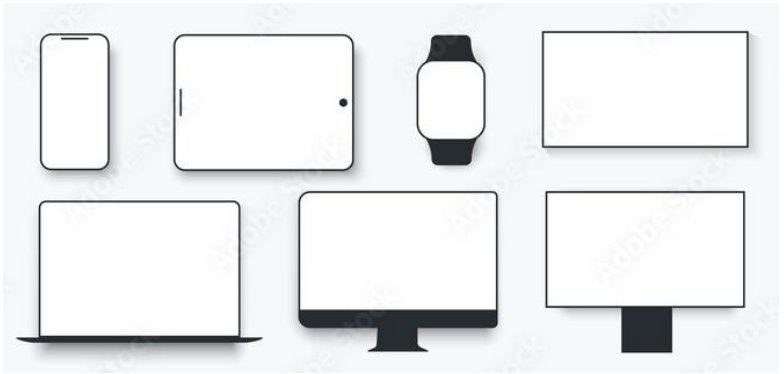
Strategies at different evacuation stages

pre-evacuation stage	• allowing vulnerable pedestrians to respond quickly
response stage	• giving vulnerable pedestrians priority for exit assignment
evacuation phase	• placing an obstacle in front of exits

Strategies at different evacuation stages



Notified with 100% accuracy



Modern devices

Modelling

Social force model

- Driving force:

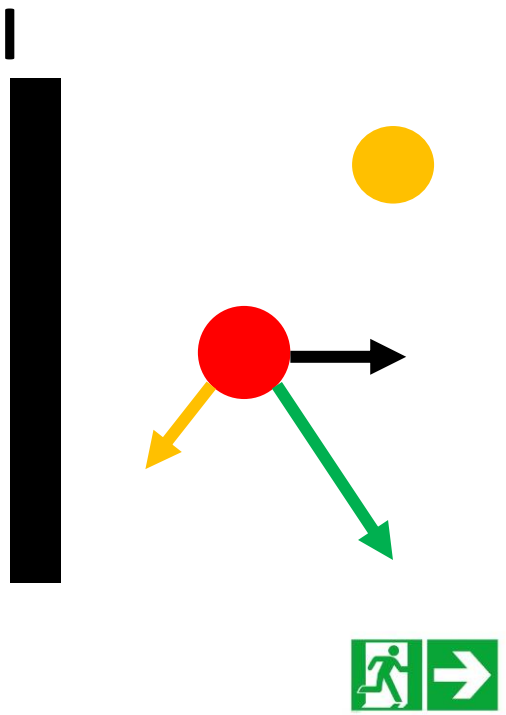
$$m_i \frac{d\boldsymbol{v}_i}{dt} = m_i \frac{v_i^0(t)\boldsymbol{e}_i^0(t) - \boldsymbol{v}_i(t)}{\tau_i} + \sum_{j \neq i} \boldsymbol{f}_{ij} + \sum_W \boldsymbol{f}_{iW}$$

- Interactions with wall

$$\boldsymbol{f}_{ij} = \{A_i \exp[(r_{ij} - d_{ij})/B_i] + kg(r_{ij} - d_{ij})\}\boldsymbol{n}_{ij} + \kappa g(r_{ij} - d_{ij})\Delta v_{ij}^t \boldsymbol{t}_{ij}$$

- Interactions with others

$$\boldsymbol{f}_{iW} = \{A_i \exp[(r_i - d_{iW})/B_i] + kg(r_i - d_{iW})\}\boldsymbol{n}_{iW} + \kappa g(r_j - d_{iW})(\boldsymbol{v}_i \cdot \boldsymbol{t}_{iW})\boldsymbol{t}_{iW}$$



Helbing, Dirk, Illés Farkas, and Tamas Vicsek. "Simulating dynamical features of escape panic." Nature 407.6803 (2000): 487-490.

Strategies at different evacuation stages

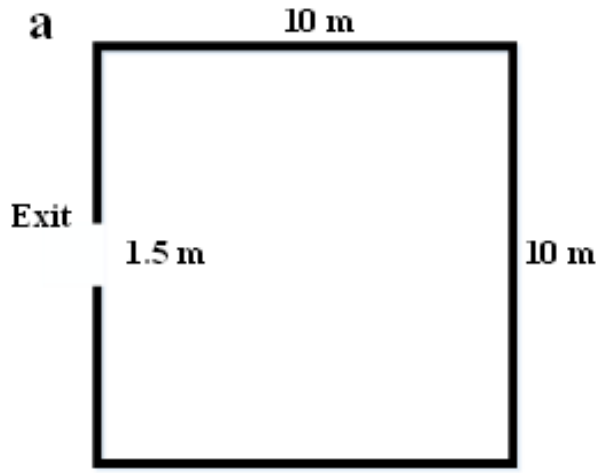
pre-evacuation stage	• **allowing vulnerable pedestrians to respond quickly**
response stage	• giving vulnerable pedestrians priority for exit assignment
evacuation phase	• placing an obstacle in front of exits

Example 1: Allowing vulnerable pedestrians to respond quickly

1. Example 1: pre-evacuation stage

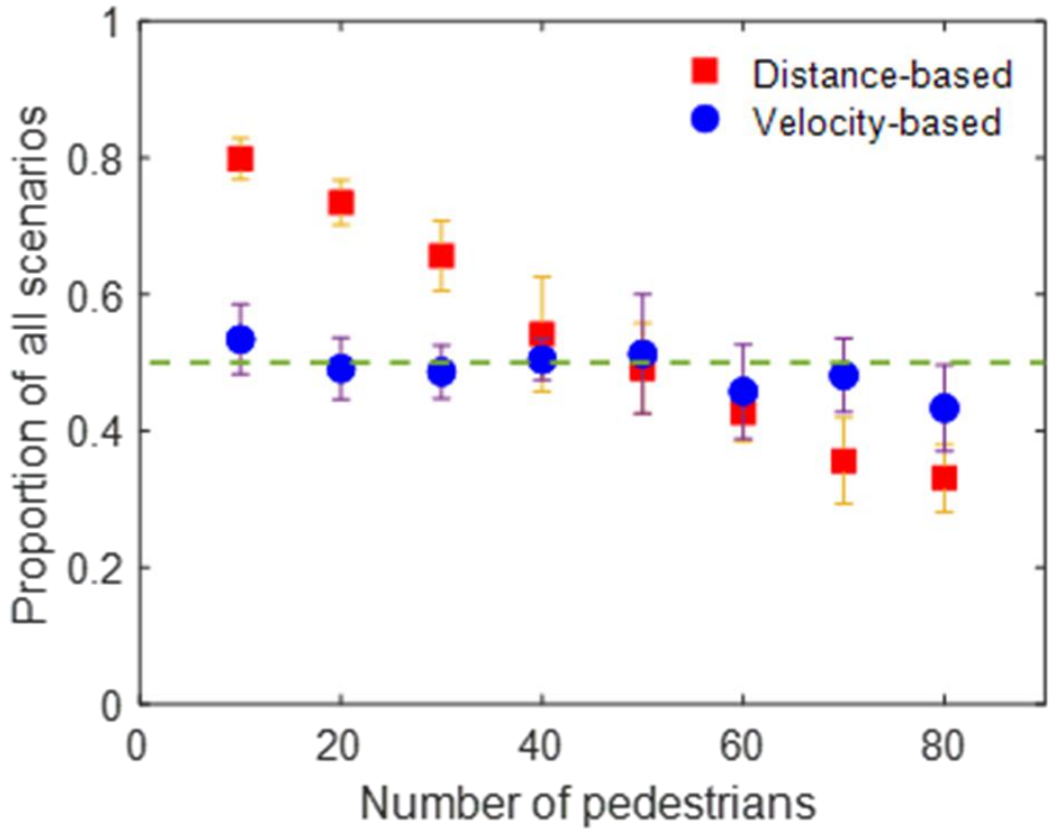
- pedestrians have not begun evacuation strategy
- allowing vulnerable pedestrians to respond quickly

- ✓ Quick-response strategy: vulnerable pedestrian can move earlier
- ✓ Normal strategy: randomly selected equivalent number of pedestrians can move earlier



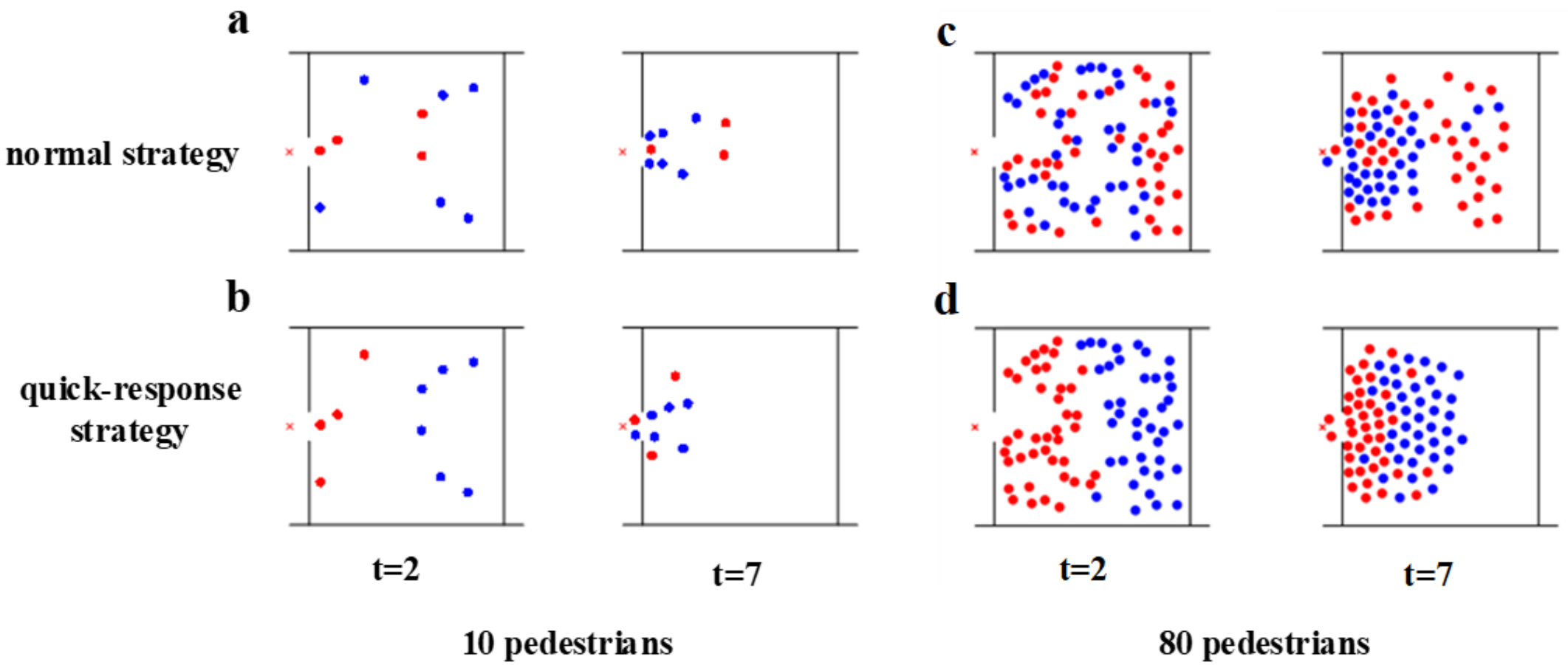
- ✓ Pedestrians are randomly distributed (1000 trails)
- ✓ Sceneries with 20% velocity-based vulnerable pedestrians
- ✓ Sceneries with distance-based vulnerable pedestrians

Example 1: Allowing vulnerable pedestrians to respond quickly



- No effects on scenarios with velocity-based pedestrians.
- Beneficial for crowd evacuation when distance-based pedestrians are involved.
- The effectiveness decreases as the crowd size increases.

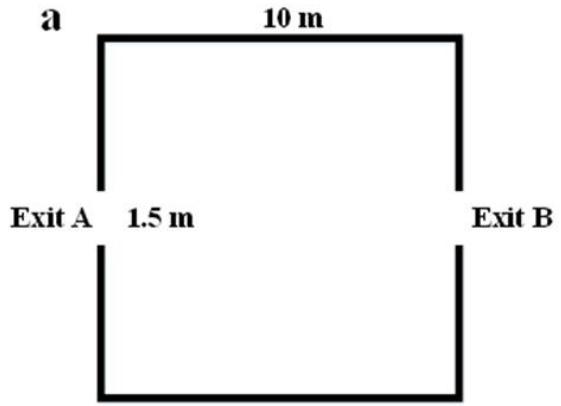
Example 1: Allowing vulnerable pedestrians to respond quickly

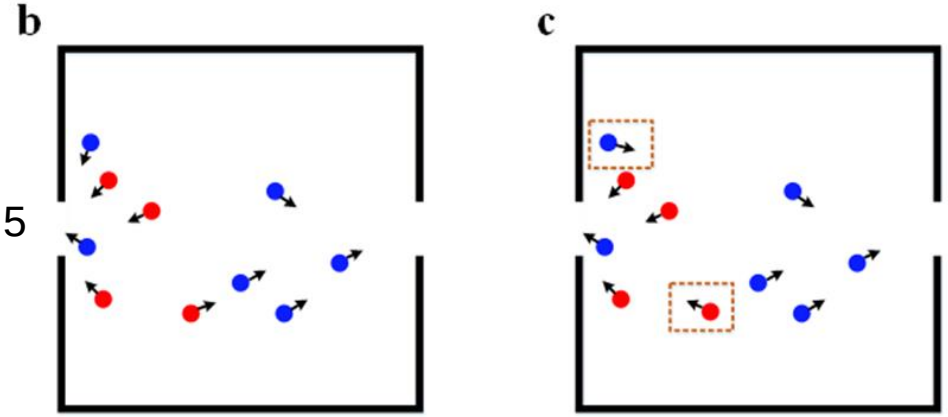


Strategies at different evacuation stages

pre-evacuation stage	• allowing vulnerable pedestrians to respond quickly
response stage	• **giving vulnerable pedestrians priority for exit assignment**
evacuation phase	• placing an obstacle in front of exits

Example 2: Giving vulnerable pedestrians priority for exit assignment





Exit quota: 5

Normal strategy

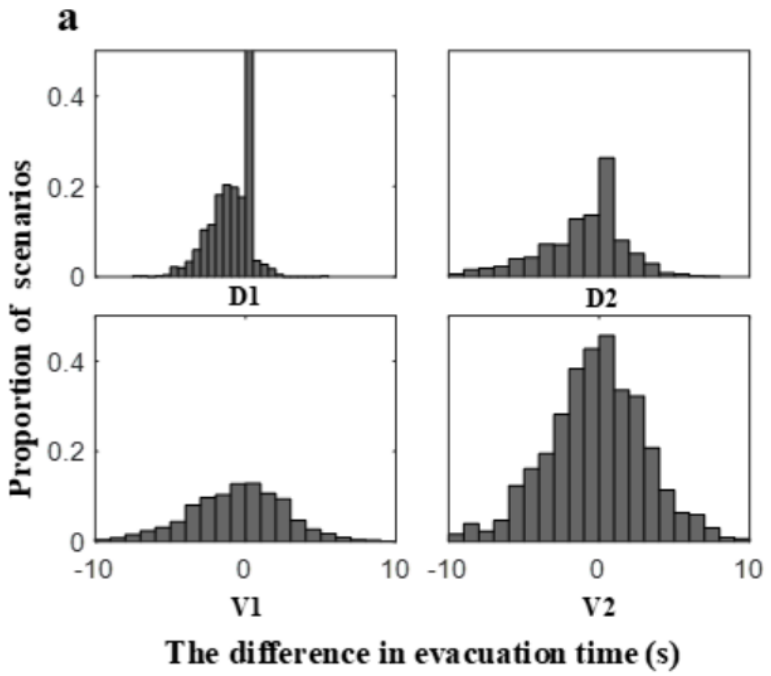
Priority strategy

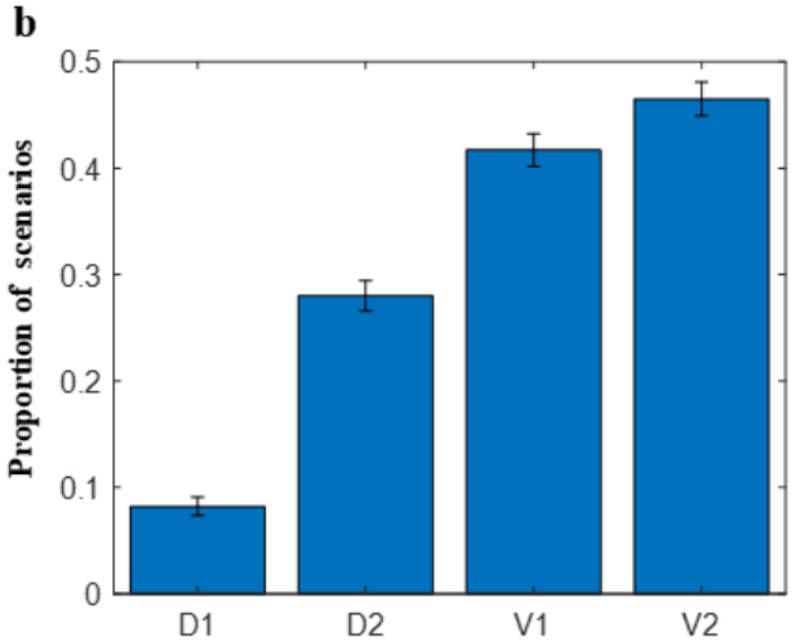
Assumptions

- Evacuation resources are limited
- Each exit has a quota indicating maximum number of pedestrians can be evacuated
- Subsequent pedestrians have to take suboptimal exit if their preferred exit has been completely used.

Example 2: Giving vulnerable pedestrians priority for exit assignment

Scenario name	Vulnerability	Vulnerability proportion	Crowd size
D1	Distance-based	\	10
D2	Distance-based	\	50
V1	Velocity-based	0.2	50
V2	Velocity-based	0.5	50





Example 2: Giving vulnerable pedestrians priority for exit assignment

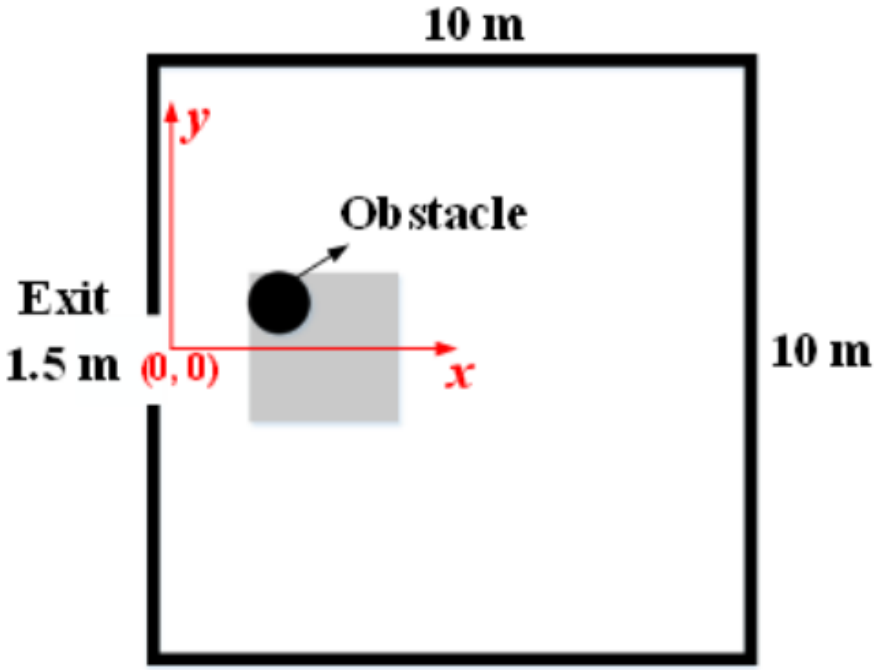
Prediction accuracy of different methods for four scenarios. The highest accuracy in each scenario is in bold.

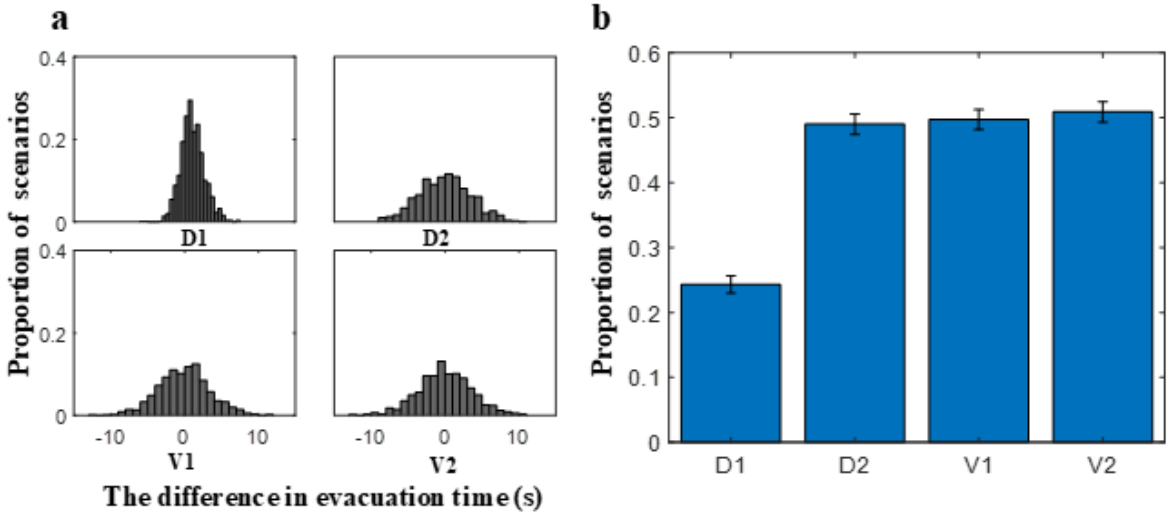
Methods/Scenarios	D1	D2	V1	V2
Coarse tree	84.8	61.2	55.5	49.8
Linear discriminant	87.1	59.5	54.0	50.1
Logistic regression	**87.3**	59.8	53.9	51.2
Kernel naïve Bayes	**87.3**	64.9	**56.9**	**51.8**
Linear SVM	**87.3**	64.6	54.4	51.1
Course KNM	86.8	**65.4**	**56.9**	49.6

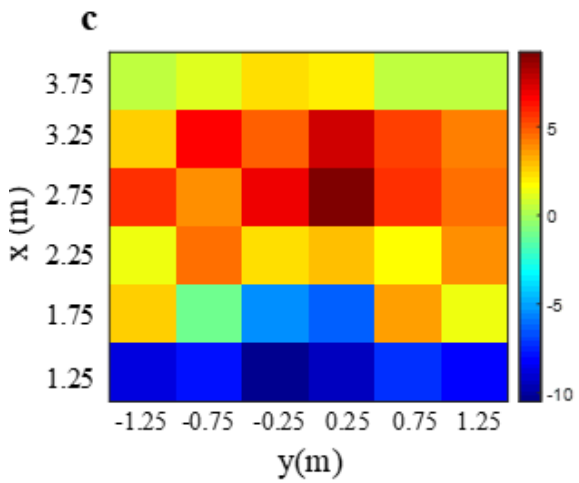
Strategies at different evacuation stages

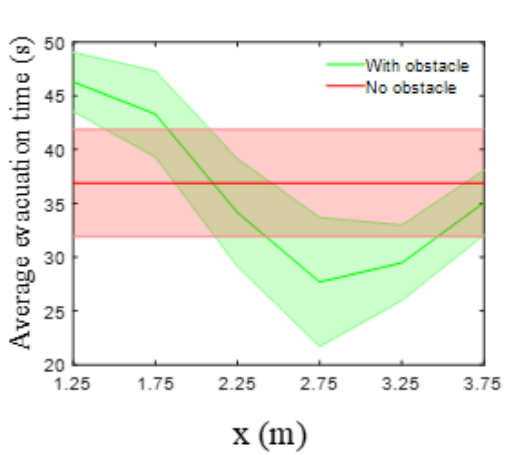
pre-evacuation stage	• allowing vulnerable pedestrians to respond quickly
response stage	• giving vulnerable pedestrians priority for exit assignment
evacuation phase	• **placing an obstacle in front of exits**

Example 3: Placing an obstacle in front of exits









Summary

- Can we develop evacuation strategy for helping vulnerable pedestrians?

  Yes, we can develop strategies in different evacuation stages, but they can only work in certain scenarios for certain vulnerable pedestrians.

- What factors affect the effectiveness of the strategies we developed?

  The potential of strategies to improve evacuation efficiency depends on the context (e.g., crowd size and pedestrian initial distribution)

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Thank you for attention!

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