

Anxiety effects on pedestrian social group dynamics in egress

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INTRODUCTION & AIM

INTRODUCTION :

- Crowd dynamics modeling is essential for improving **safety in evacuation and high-risk situations**
- Reliable simulation tools help design safer environments and evacuation strategies
- Crowd behavior is studied at different scales:

Microscopic
(individual level)

Mesoscopic
scale using
kinetic theory

Macroscopic
(continuum level)

Recent studies show that pedestrians often move in social groups (families, friends), which significantly affects crowd dynamics. Behavioral effects such as stress and anxiety can strongly influence movement patterns during evacuation.

AIM OF THE WORK :

Develop a kinetic model for pedestrian social groups in a bounded domain with multiple exits

Incorporate key behavioral features:

- Social group interactions
- Heterogeneous walking strategies
- Exit preferences

Introduce anxiety effects by modifying pedestrians' preferred velocity:

- Increased urgency under stress
- Possible loss of coordination

Analyze the impact of anxiety on evacuation:

- Evacuation efficiency
- Congestion formation
- Collective dynamics

METHOD

We consider a kinetic theory framework to model the collective dynamics of interacting pedestrian social groups.

The microscopic state of pedestrians is described by the distribution function: $f_i(t, \mathbf{x}, \mathbf{v})$, of the i -th social group at time t , position \mathbf{x} , and velocity \mathbf{v} .

The evolution of the system is governed by the kinetic transport equation:

$$(\partial_t + \mathbf{v} \cdot \nabla_{\mathbf{x}}) f_i(t, \mathbf{x}, \mathbf{v}) = Q_{ii}(f_i, f_i)(t, \mathbf{x}, \mathbf{v}) + \sum_{k=1, k \neq i}^n Q_{ik}(f_i, f_k)(t, \mathbf{x}, \mathbf{v}).$$

Where:

$\mathbf{v} \cdot \nabla_{\mathbf{x}} f_i$: transport of pedestrians in the physical space (movement in position \mathbf{x} with velocity \mathbf{v}).

$Q_{ii}(f_i, f_i)$: self-interaction operator describing interactions within the same social group.

$Q_{ik}(f_i, f_k)$: interaction operator describing interactions between different social groups.

Interaction operators:

$$Q_{ii}(f_i, f_i) = \eta_{ii} \left[\int_{\mathbf{v}'} P_{ii}[\rho_i, \xi_i](\mathbf{v}' \rightarrow \mathbf{v}) f_i(t, \mathbf{x}, \mathbf{v}') d\mathbf{v}' - f_i(t, \mathbf{x}, \mathbf{v}) \right]$$

$$Q_{ik}(f_i, f_k) = \eta_{ik} \left[\int_{\mathbf{v}'} P_{ik}[\rho_i, \rho_k, \xi_i, \xi_k](\mathbf{v}' \rightarrow \mathbf{v}) f_i(t, \mathbf{x}, \mathbf{v}') d\mathbf{v}' - f_i(t, \mathbf{x}, \mathbf{v}) \right]$$

Preferred velocity (desired direction)

$$\mathbf{v}^{(p)} = \rho_i \mathbf{v}^{(\text{vacuum})} + (1 - \rho_i) \frac{\beta_i \mathbf{v}^{(\text{stream})} + (1 - \beta_i) \mathbf{v}^{(\text{target})}}{\|\beta_i \mathbf{v}^{(\text{stream})} + (1 - \beta_i) \mathbf{v}^{(\text{target})}\|}$$

Where: β level of anxiety

RESULTS & DISCUSSION

Evacuation Dynamics (Time Evolution)

Spatial-temporal evolution of the crowd during evacuation

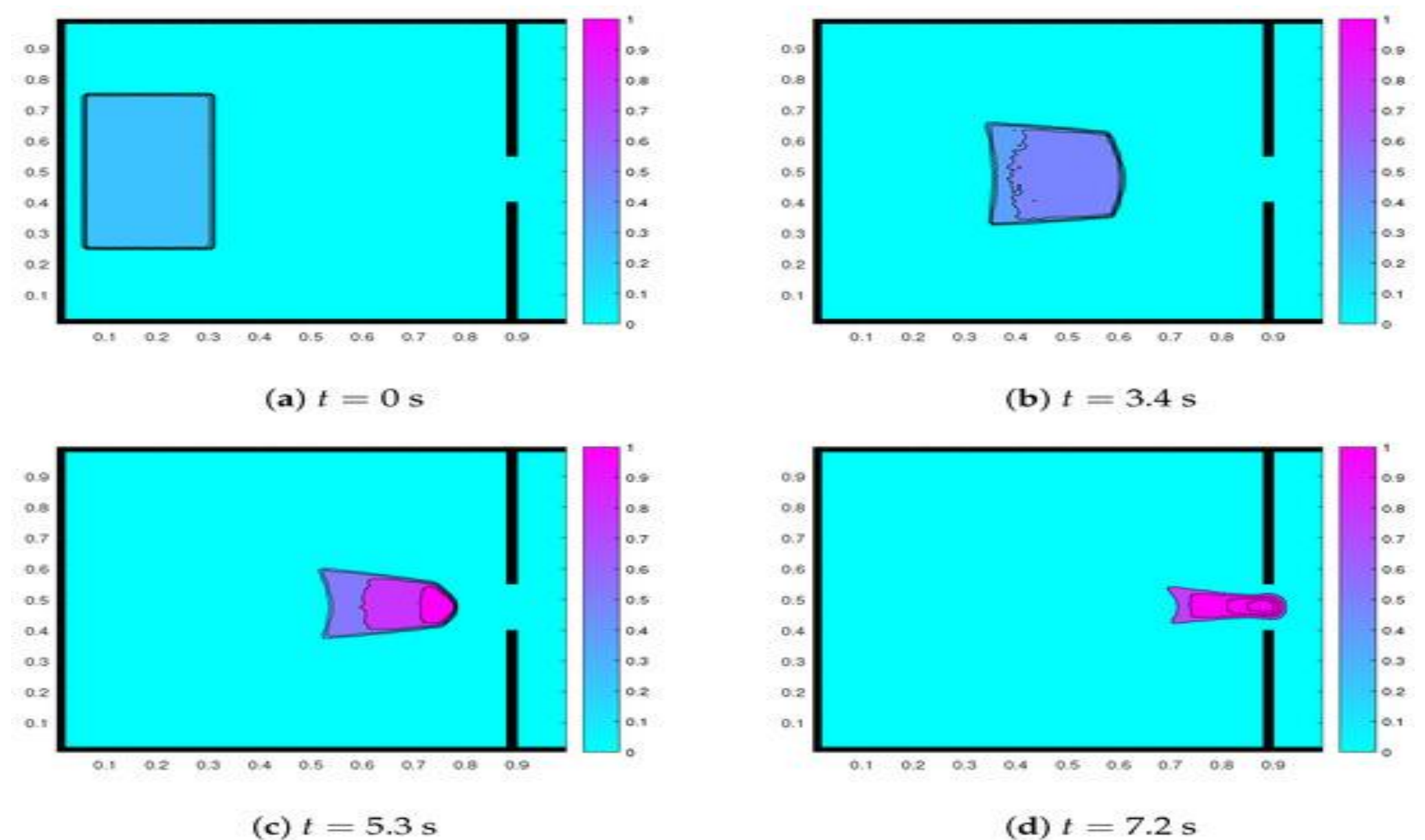


Figure 1: Formation, congestion, and evacuation over time.

Insight: Congestion emerges dynamically from social interactions.

Evacuation Time vs Anxiety Level

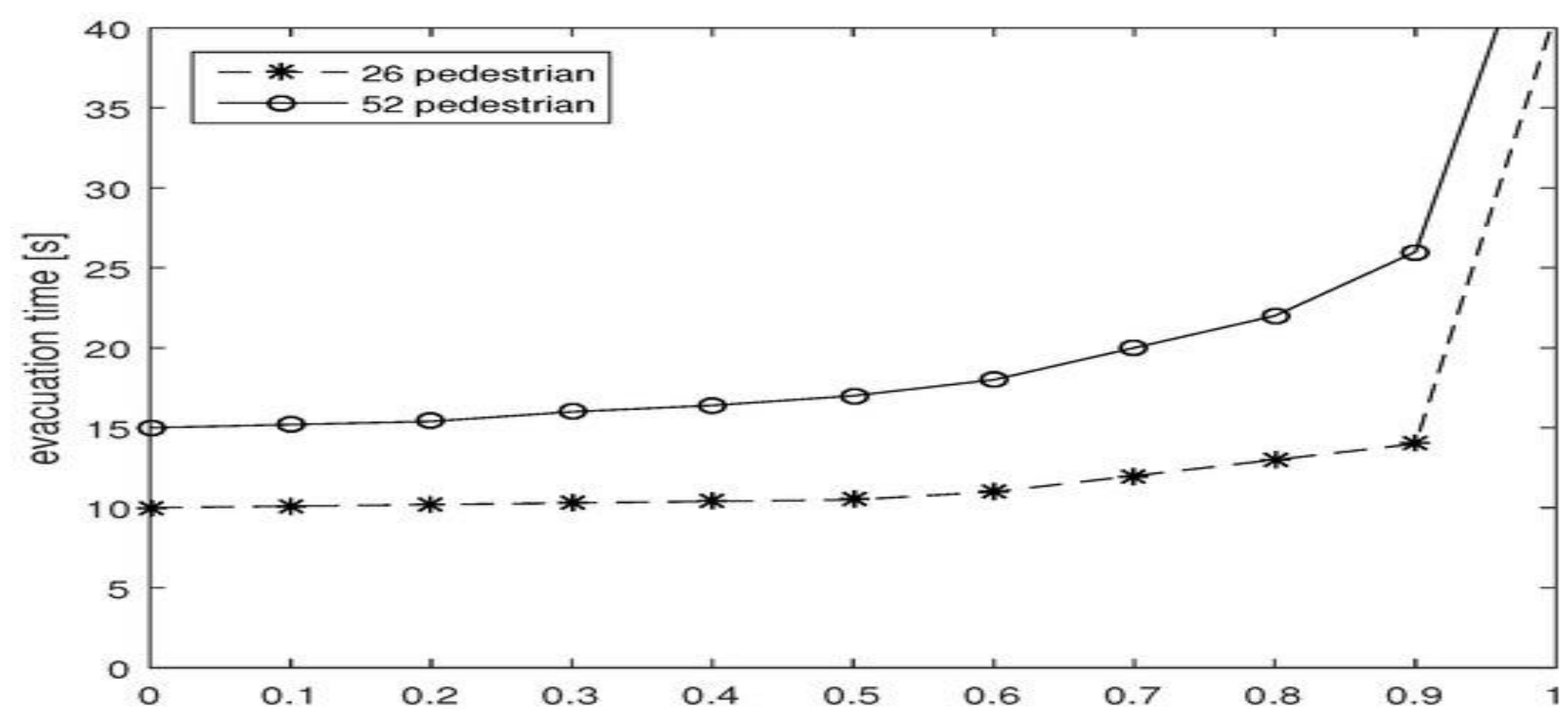


Figure 2: Dependence of evacuation time on anxiety level and crowd size.

Insight: Evacuation time increases with higher anxiety due to reduced decision-making efficiency and movement performance.

CONCLUSION

- Kinetic model for socially structured crowds
- Anxiety strongly influences evacuation efficiency
- Monte Carlo method enables scalable simulation
- Results useful for safety and evacuation planning

REFERENCES

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