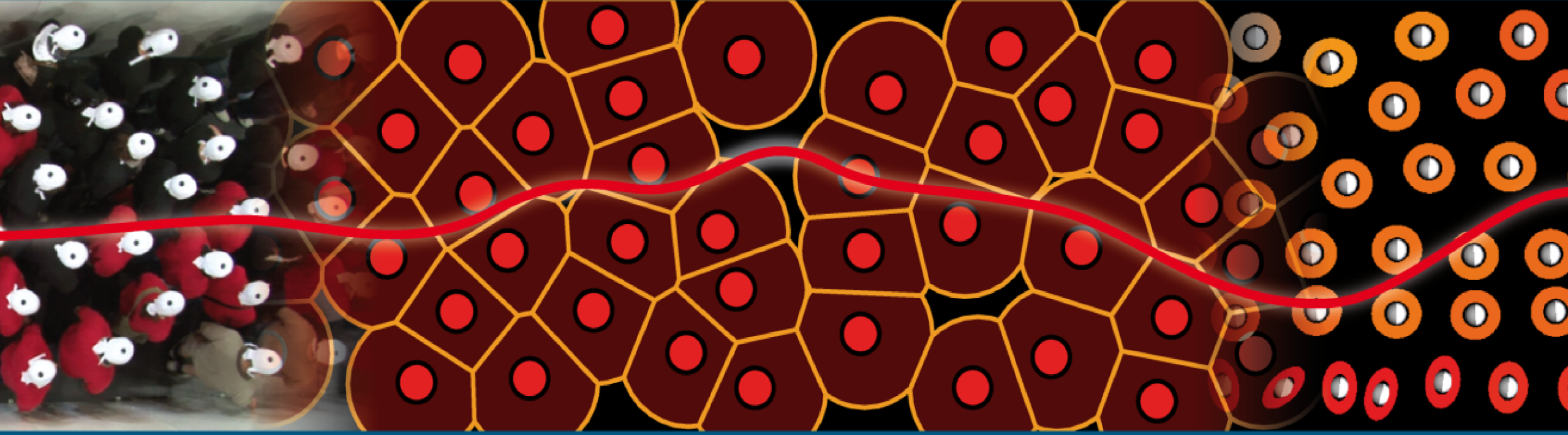

EXPERIMENTALLY DRIVEN MODELLING OF PEDESTRIAN DYNAMICS

Workshop on Pedestrian Traffic and Evacuation Dynamics 2019

08.09.2019 I MOHCINE CHRAIBI | INSTITUTE FOR ADVANCED SIMULATION - CIVIL SAFETY RESEARCH

Mitglied der Helmholtz-Gemeinschaft

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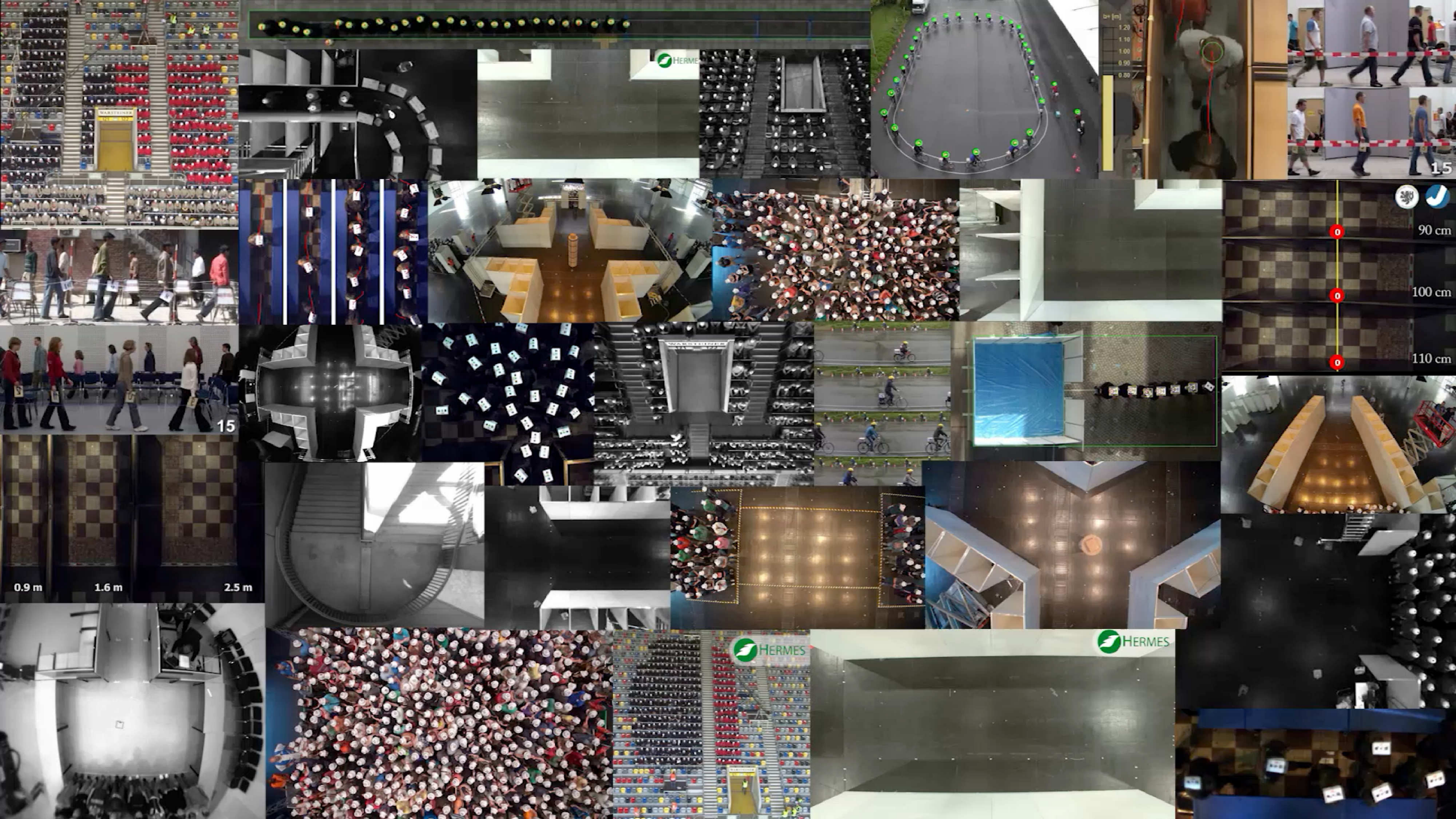
INTRODUCTION

Modeling of Pedestrian Dynamics

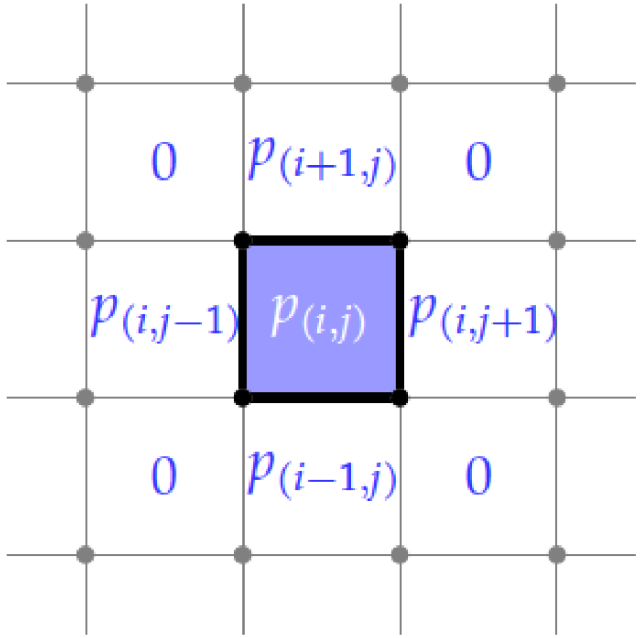
- Why is modeling of pedestrian dynamics necessary?
- What is the inspiration behind a mathematical model?
- Can we learn from observation and empirics?


HERMES
HERMES
HERMES
90 cm
100 cm
110 cm
0.9 m
1.6 m
2.5 m
15
15


Wir bauen für Sie
Mehr Platz.
Mehr Komfort

CELLULAR AUTOMATA

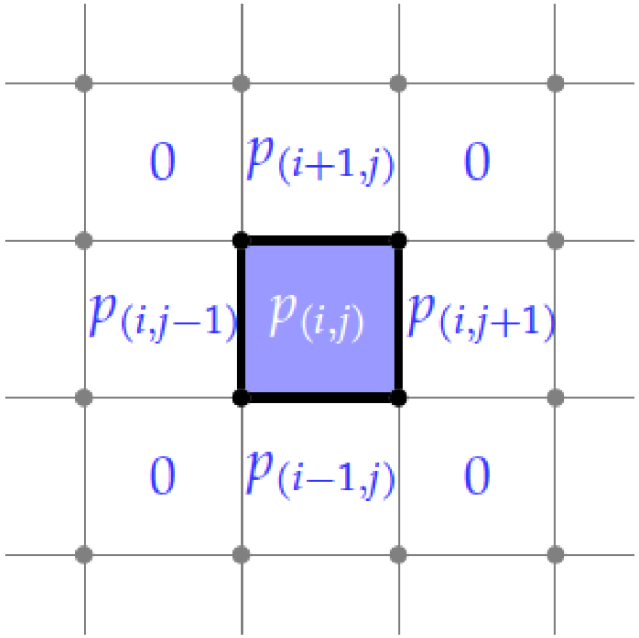
Definition and properties



CELLULAR AUTOMATA

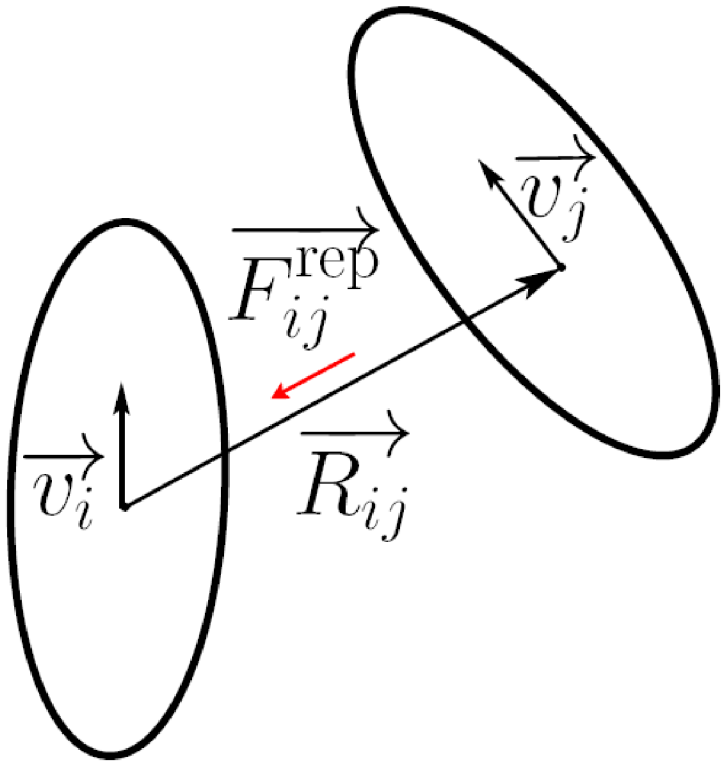
Definition and properties

- Space divided into cells (40cm x 40cm)
- Discrete in space, time, state variables
- Generically: stochastic, rule-based dynamics
- Exclusion principle: at most one pedestrian per cell



FORCE-BASED MODELS

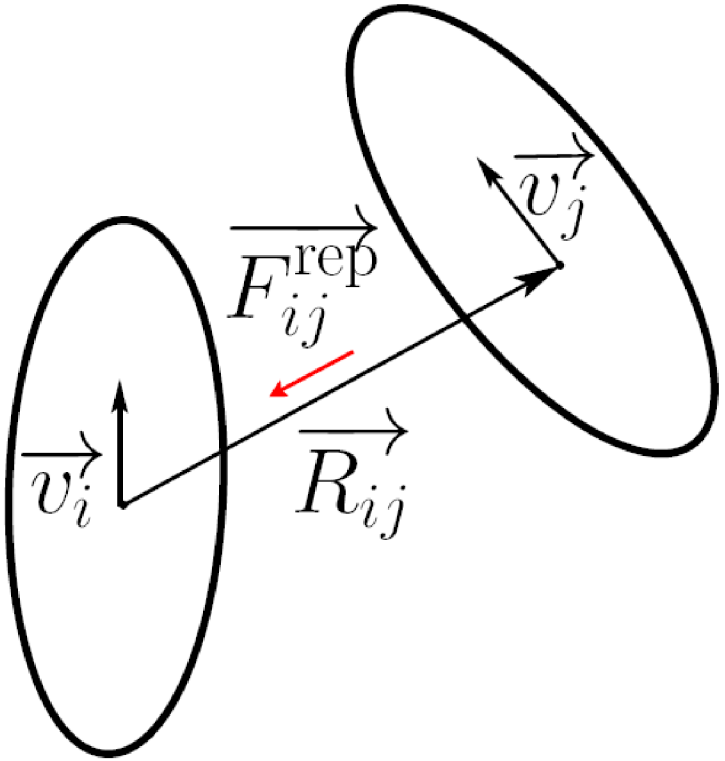
Definition and Properties



FORCE-BASED MODELS

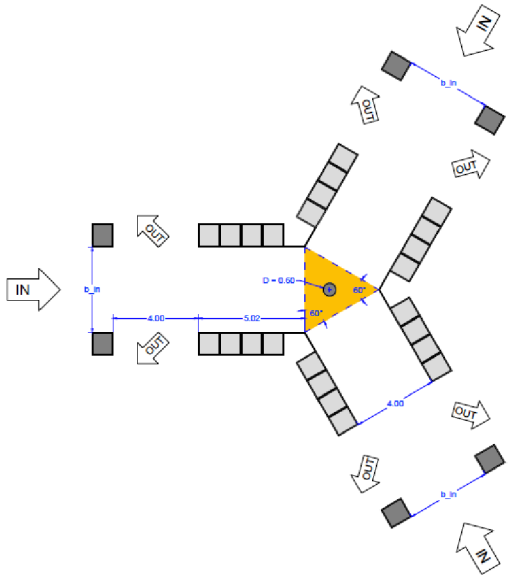
Definition and Properties

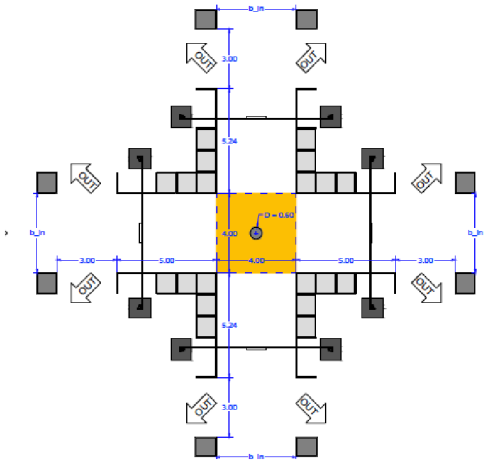
- Continuous in space, time, state variables
- Presence of other persons/objects leads to changes in the direction of motion
- “Social” forces + Physical forces

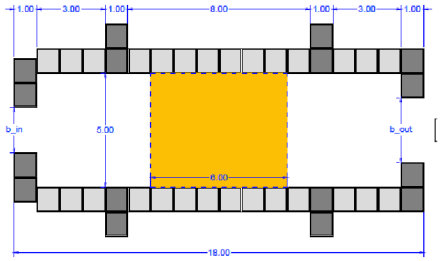


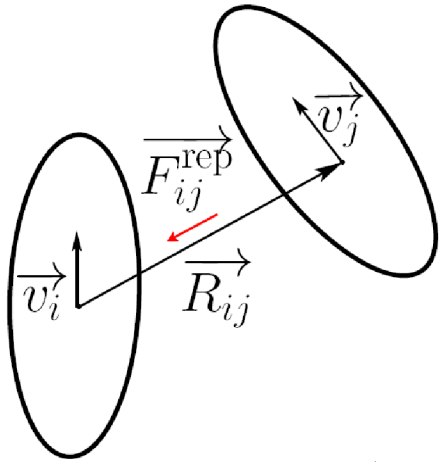
EXPERIMENTS VS MODELING

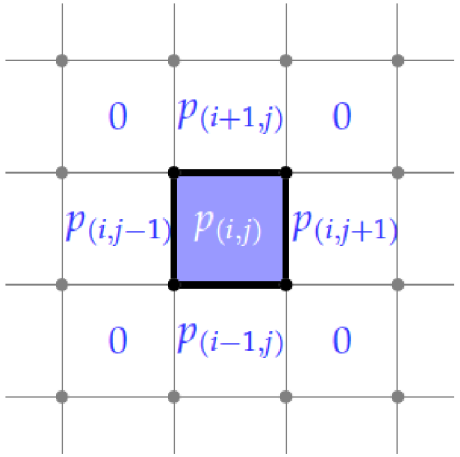
Interaction











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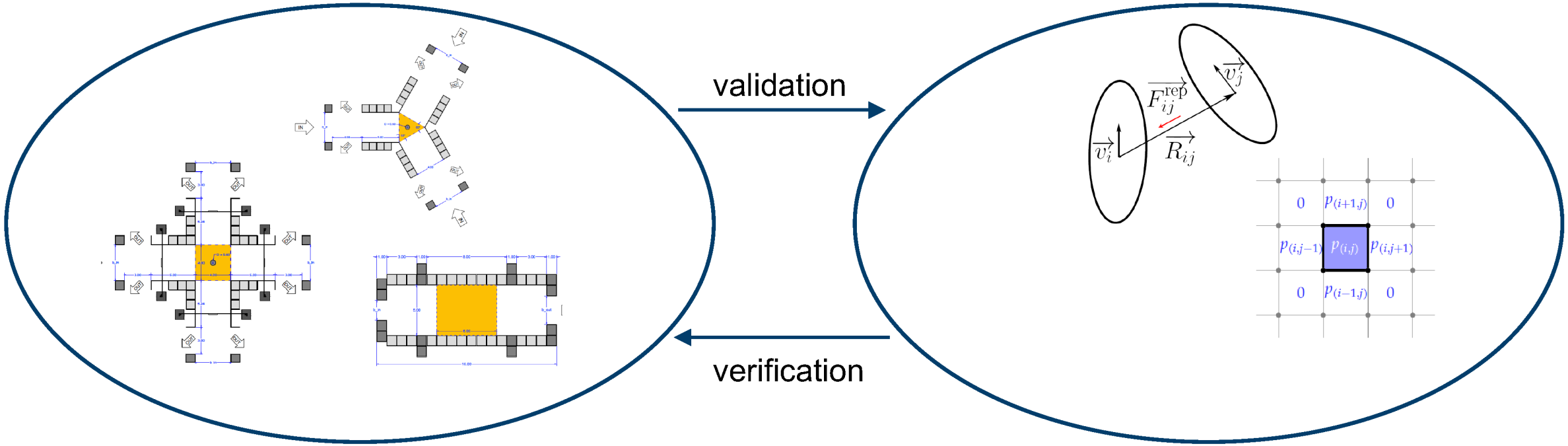
EXPERIMENTS VS MODELING

Interaction



COLLISION-FREE VELOCITY MODEL

first order model continuous in space

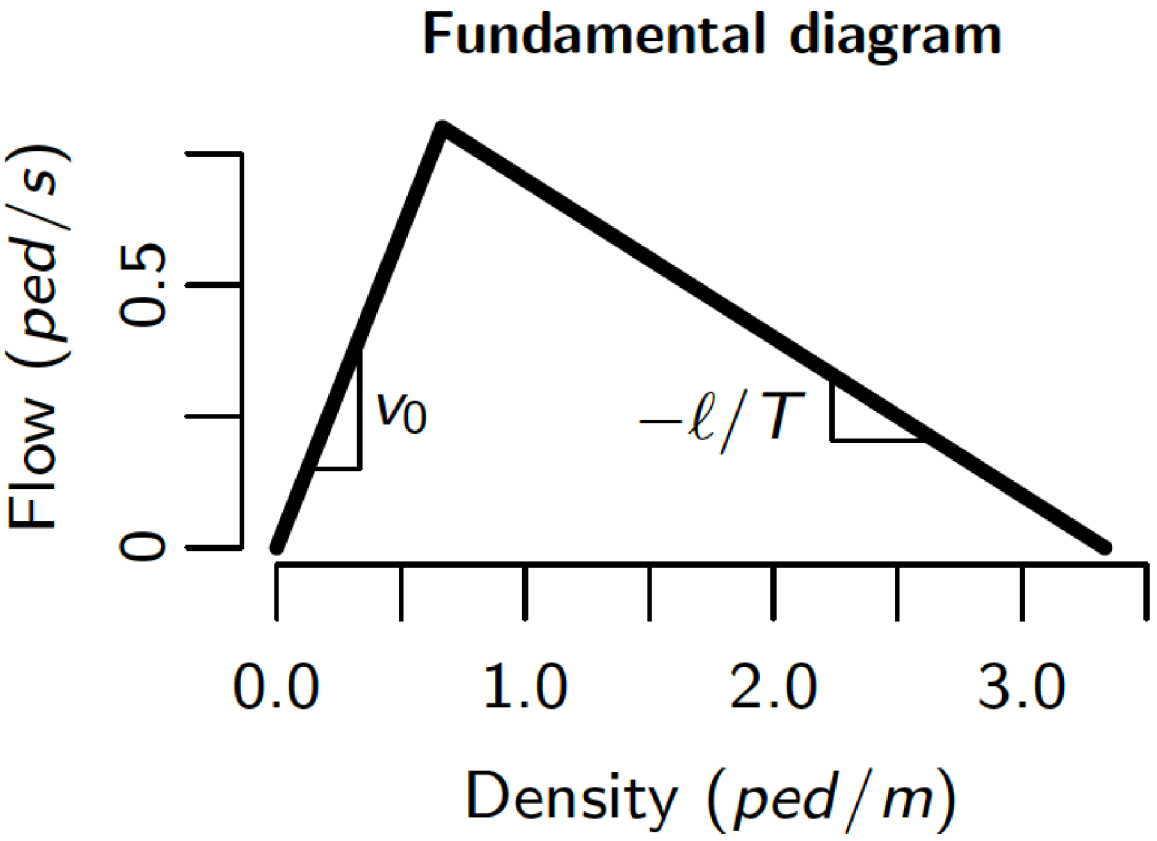
COLLISION-FREE VELOCITY MODEL

Motivation

- Continuous in space
- Reasonably simple!
- Per definition collision-free

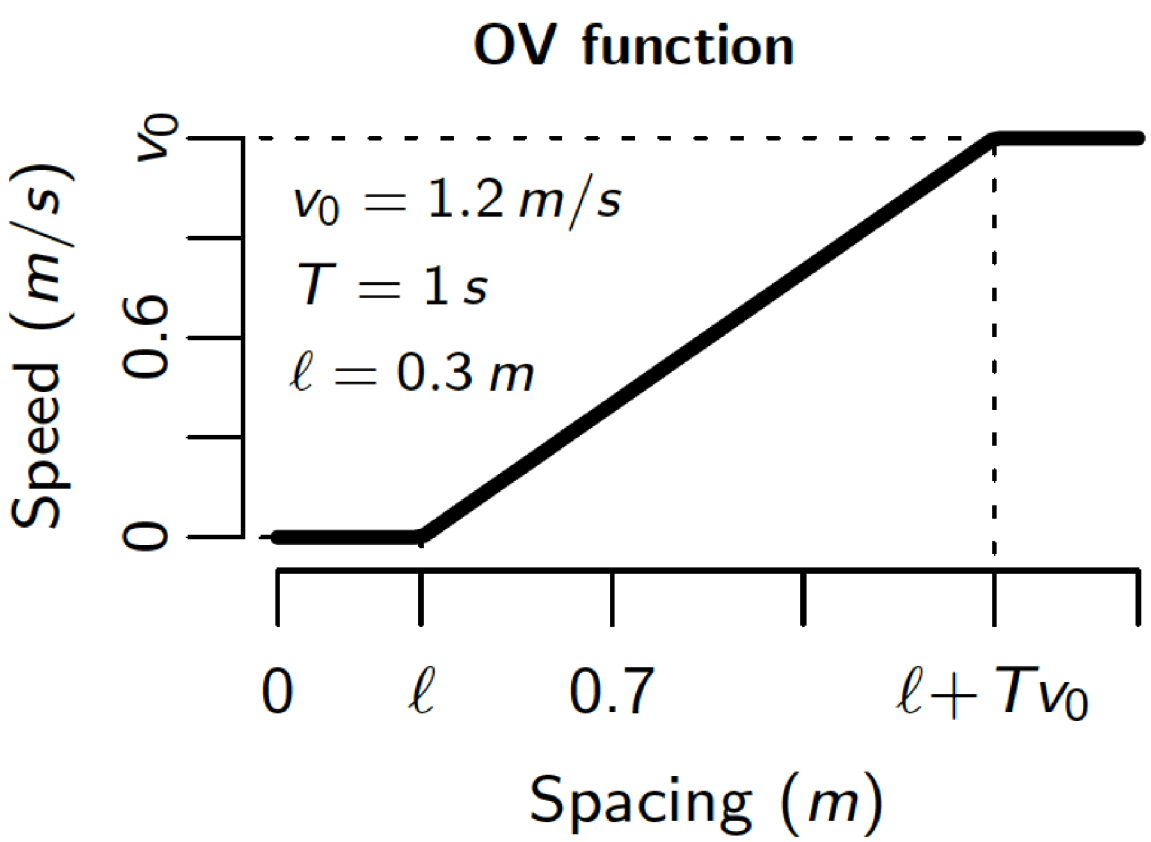
COLLISION-FREE VELOCITY MODEL

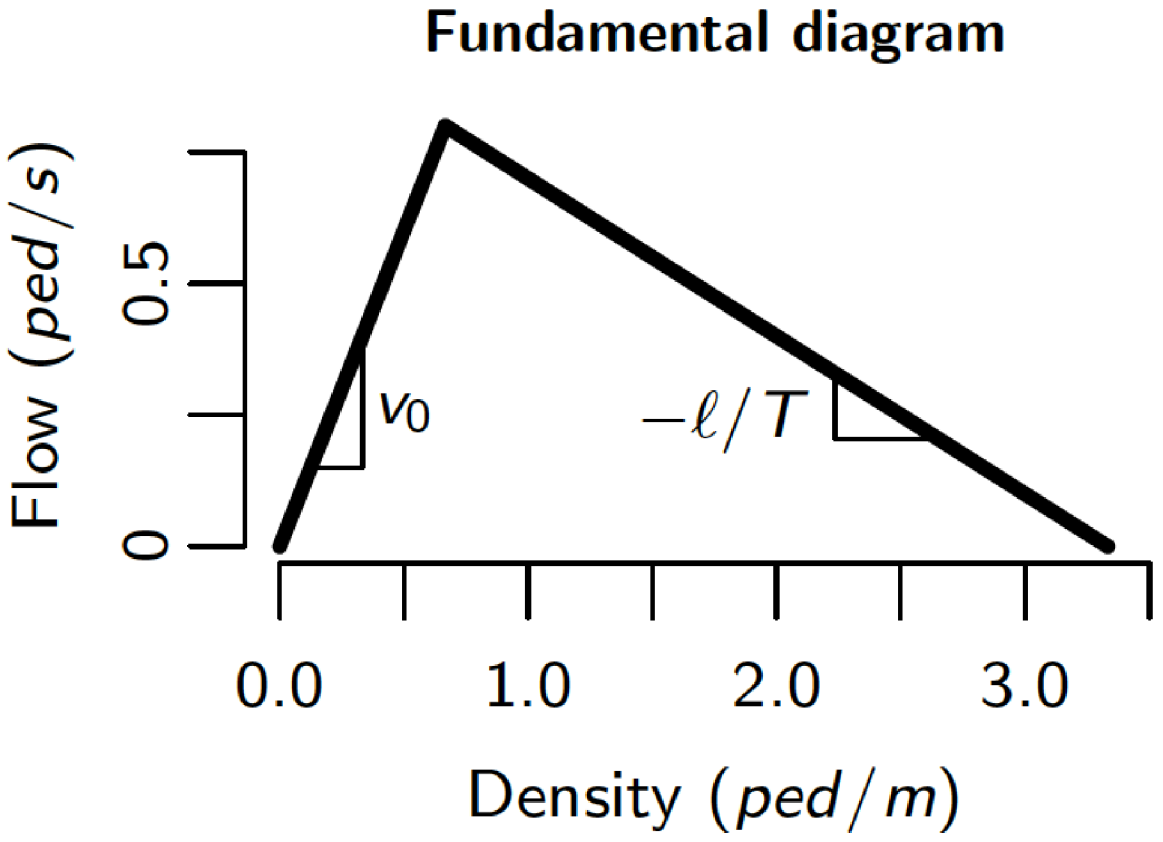
Speed function



COLLISION-FREE VELOCITY MODEL

Speed function





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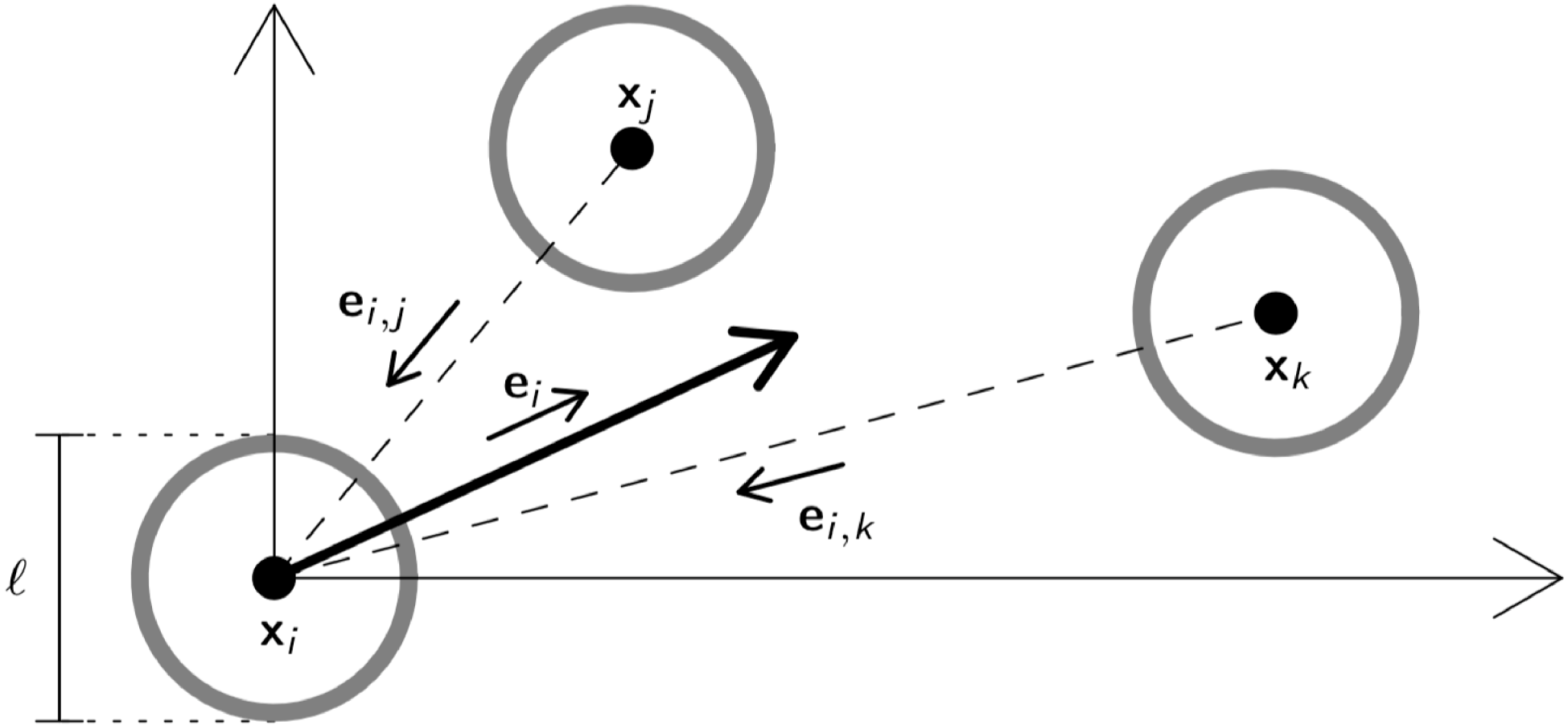
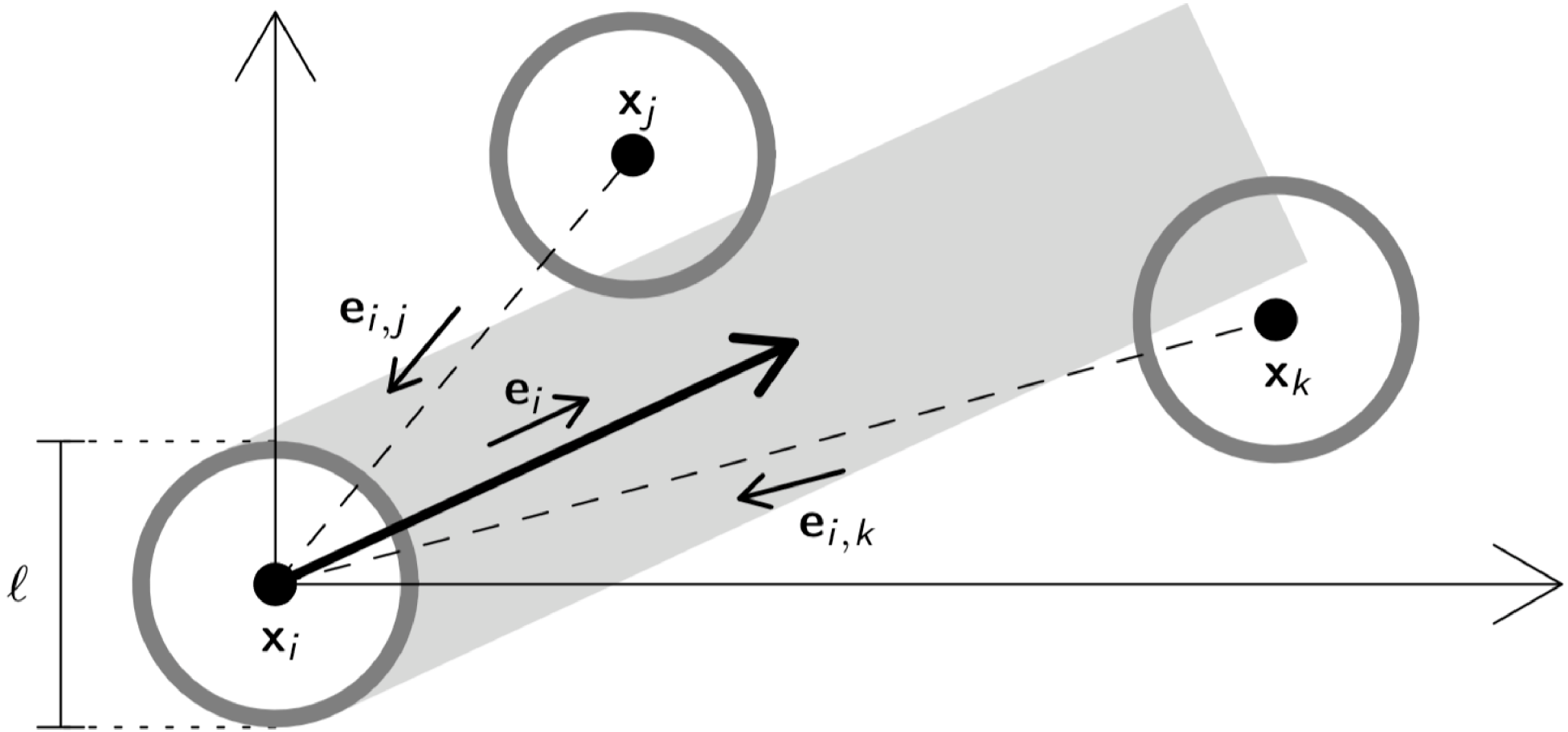
COLLISION-FREE VELOCITY MODEL

Circular shape



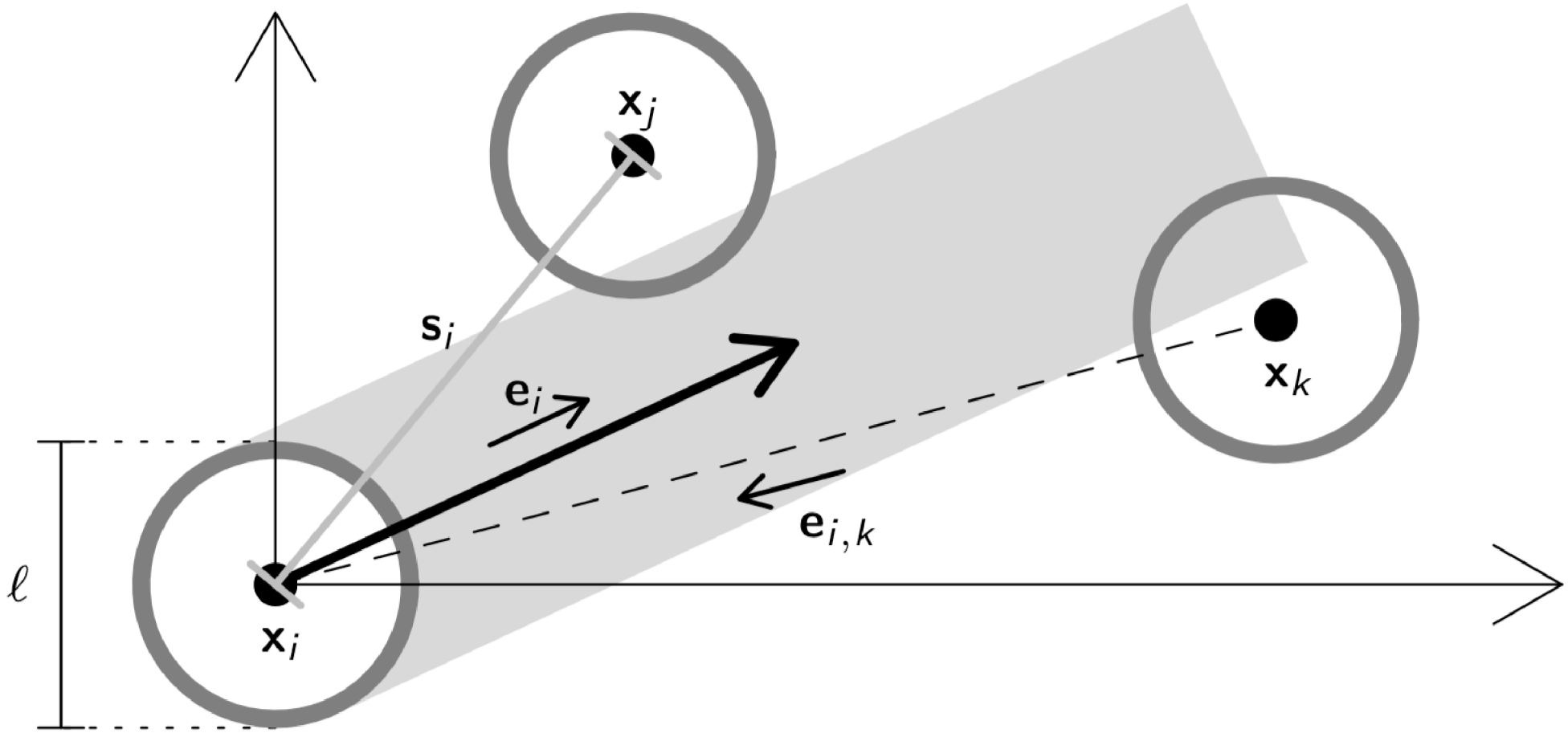
COLLISION-FREE VELOCITY MODEL

Neighbours on collision course



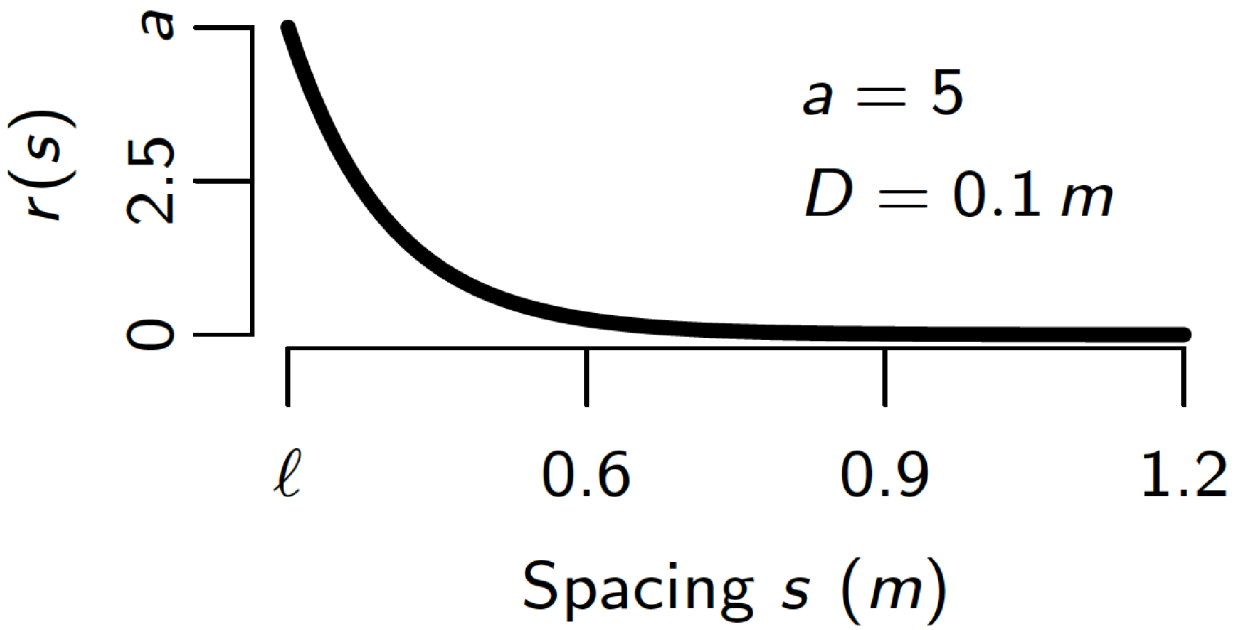
COLLISION-FREE VELOCITY MODEL

Spacing to closes neighbour



COLLISION-FREE VELOCITY MODEL

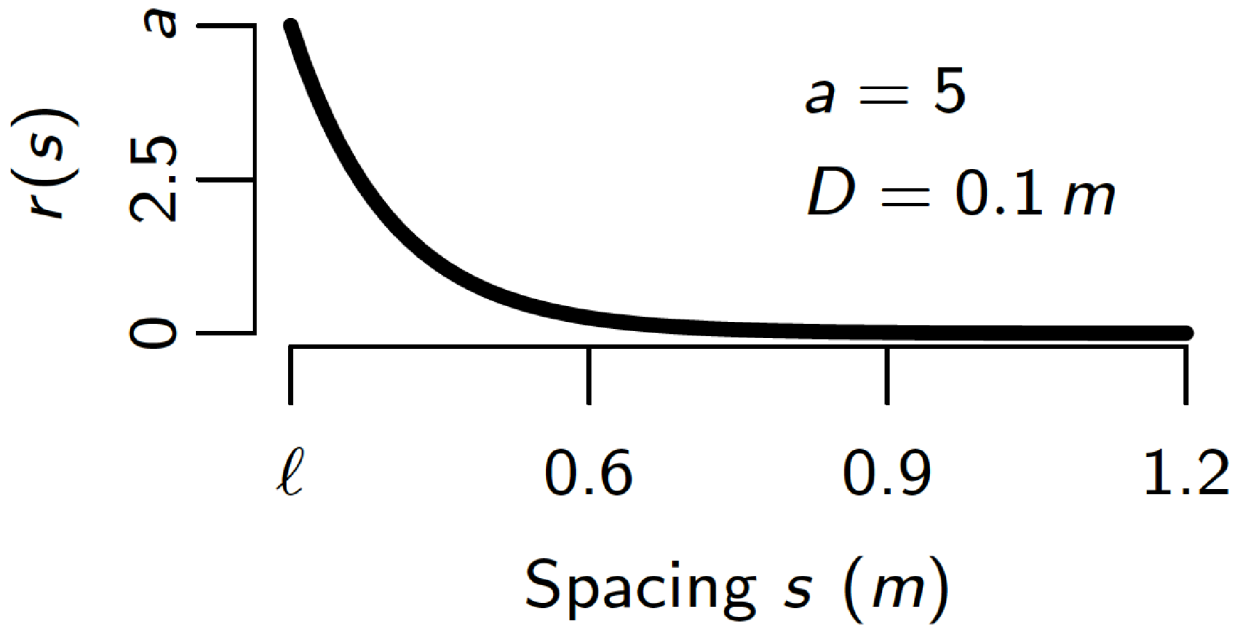
Direction submodel



COLLISION-FREE VELOCITY MODEL

Direction submodel

$$\overrightarrow{e}_i = \frac{1}{N}\left(\overrightarrow{e}_i^0 + \sum r(s_{i,j}\overrightarrow{e}_{i,j})\right)$$



COLLISION-FREE VELOCITY MODEL

Advantages

- Model is collision-free
- Produces qualitatively and quantitatively empirical phenomena
- Computationally effective (fast)

COLLISION-FREE VELOCITY MODEL

Disadvantages

- Model is collision-free (–> clogging)
- Definition is restricted to shape (–> circles)
- Many other problems (–> oscillation of direction, etc)

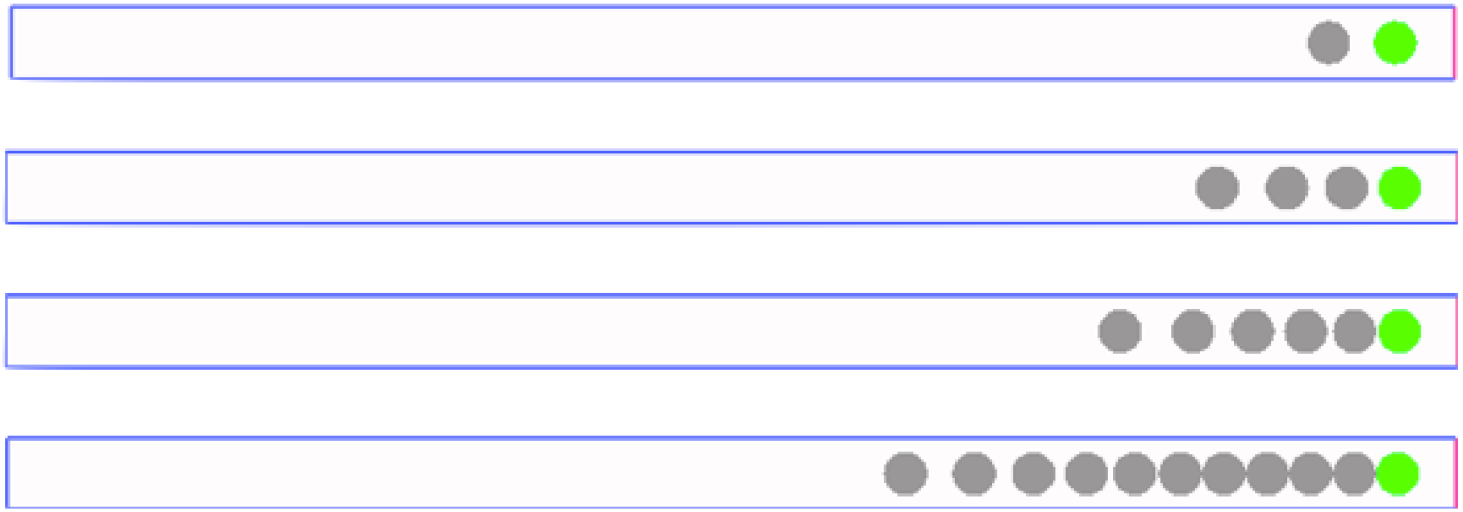
COLLISION-FREE VELOCITY MODEL

Pushing (?)



COLLISION-FREE VELOCITY MODEL

Pushing



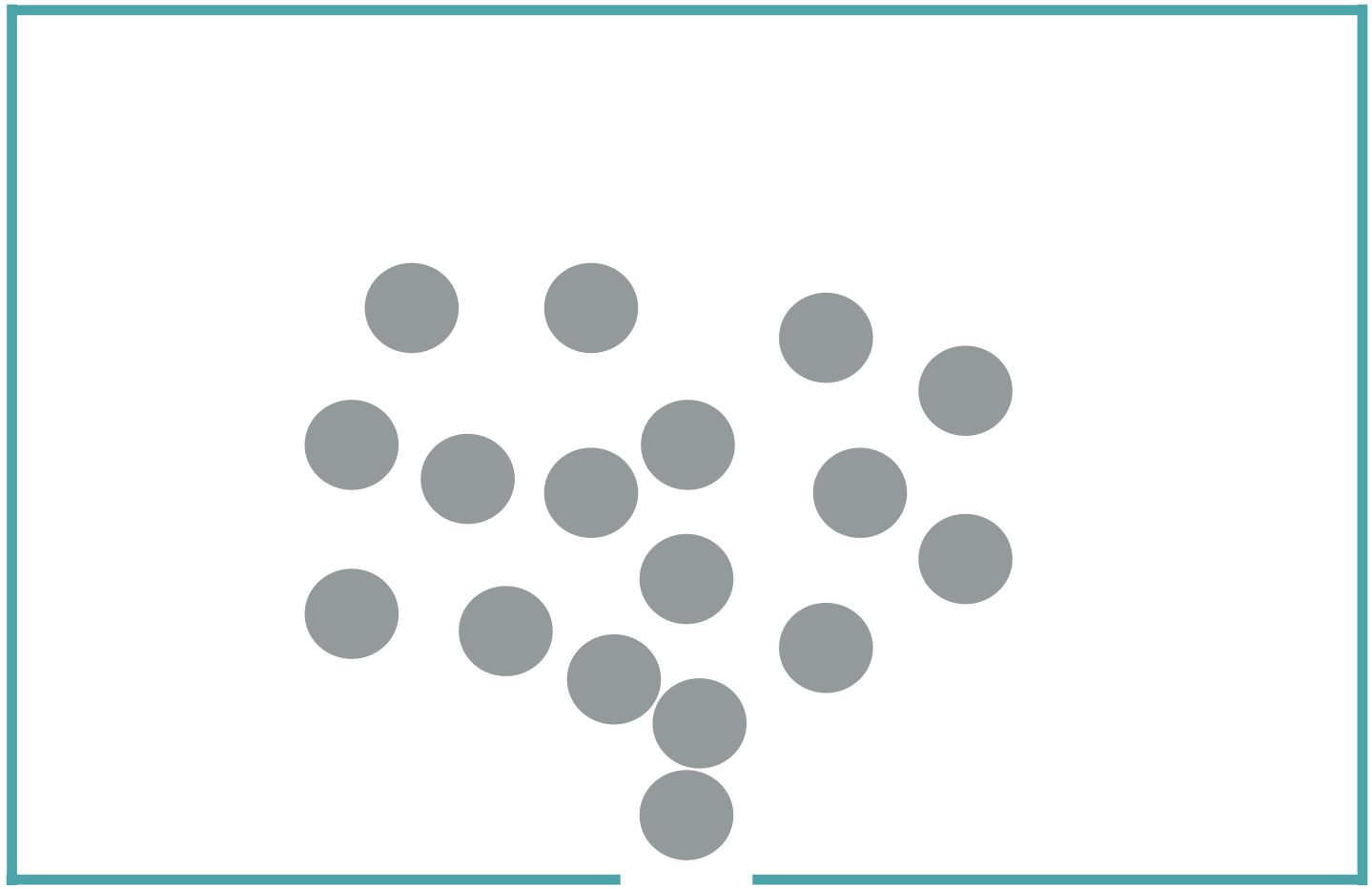
COLLISION-FREE VELOCITY MODEL

Pushing



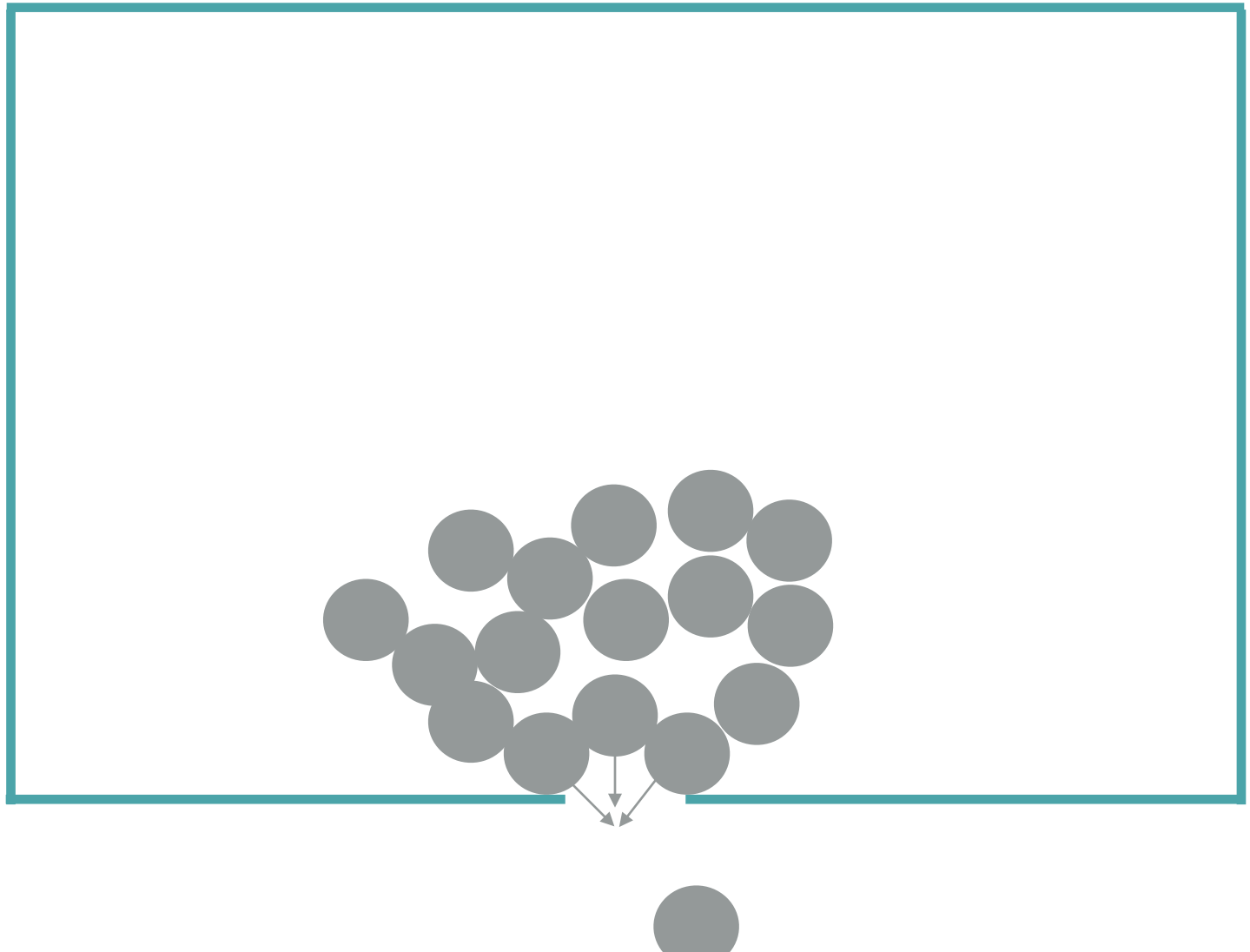
CLOGGING

Evacuation through a bottleneck



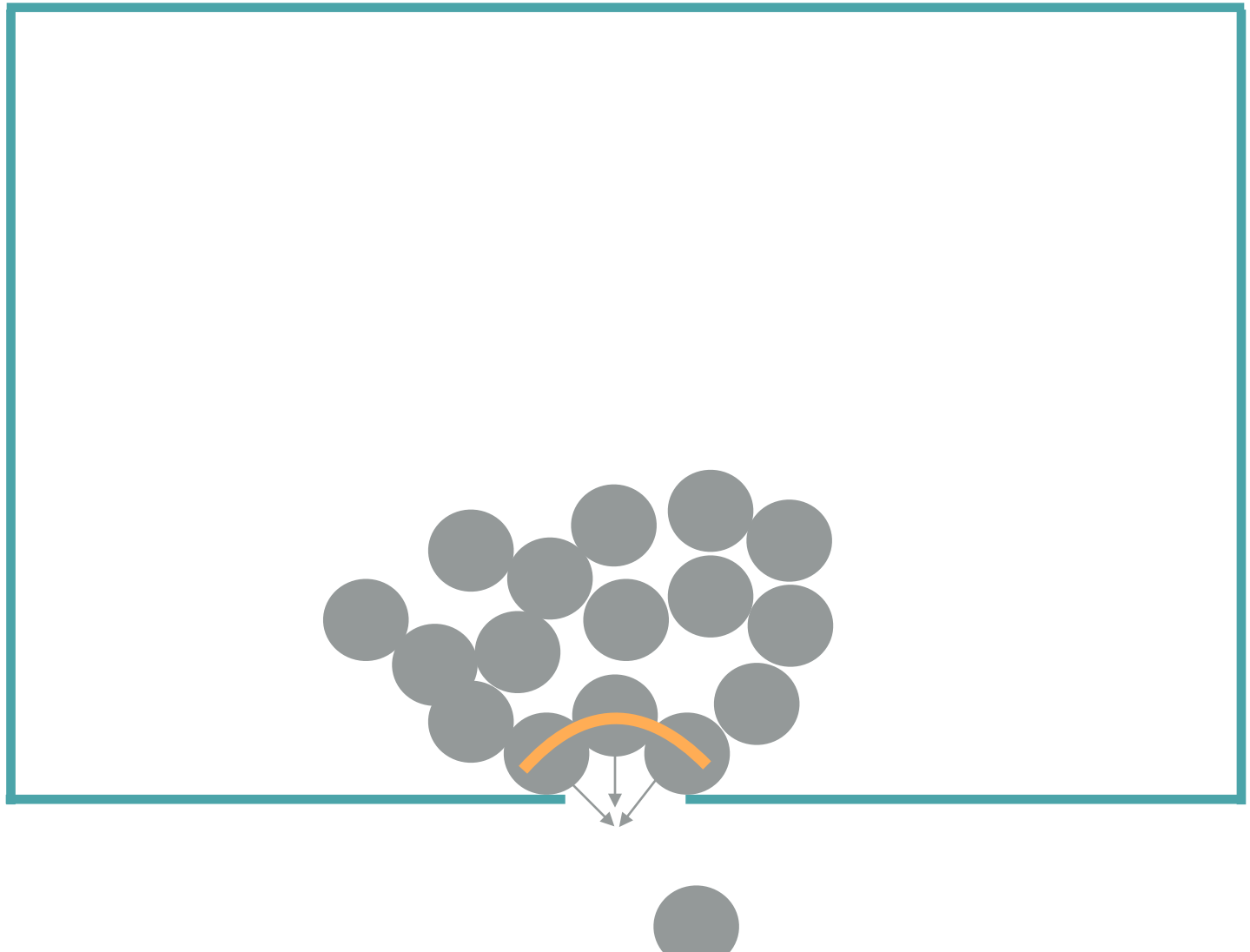
CLOGGING

Evacuation through a bottleneck



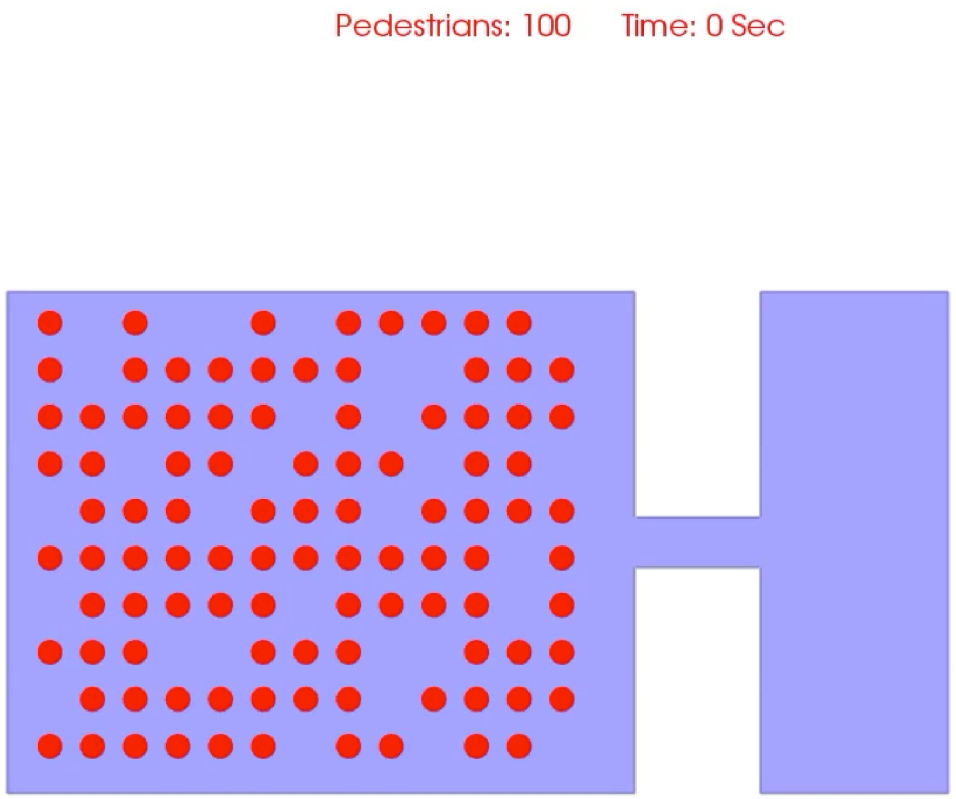
CLOGGING

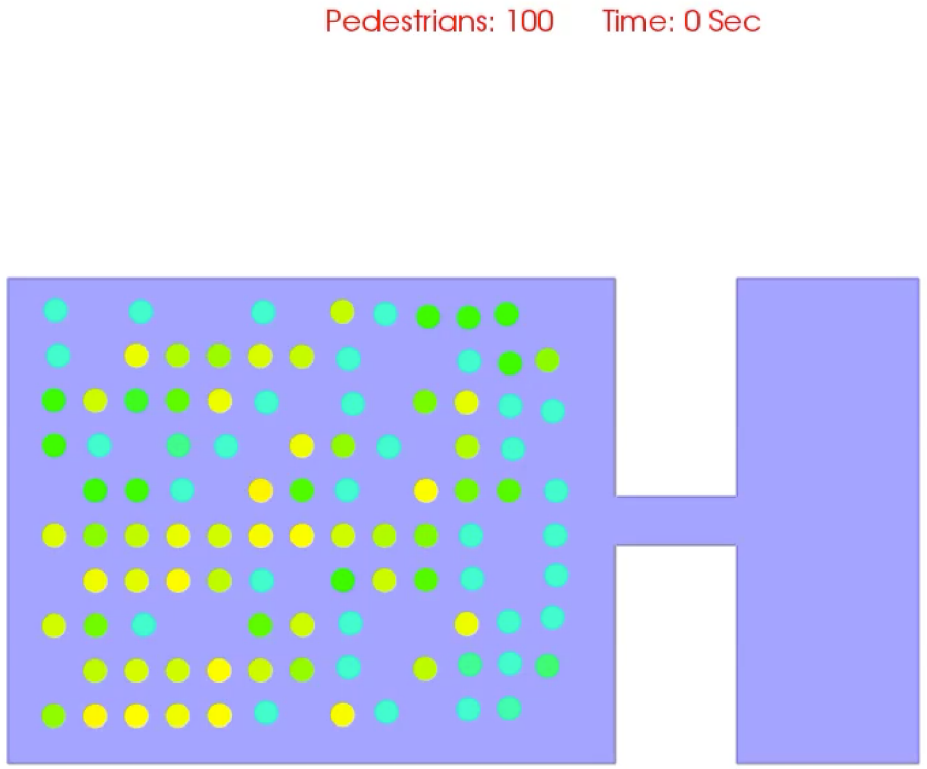
Evacuation through a bottleneck



COLLISION-FREE VELOCITY MODEL

Clogging





ANALYSIS OF EMPIRICAL DATA

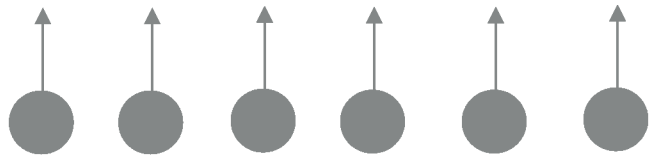
Observables

- Polarization

$$\phi = \left\| \frac{1}{N} \sum_{i=1}^{N} \frac{\vec{v_i}}{|\vec{v_i}|} \right\|$$

$$\phi = [0, 1]$$

$\phi = 1$



- Alignement

$$\phi_d = \left\| \frac{1}{N} \sum_{i=1}^{N} \frac{\vec{v_i}\vec{u}_i}{|\vec{v_i}|} \right\|$$

$$\phi_d = [-1, 1]$$

ANALYSIS OF EMPIRICAL DATA

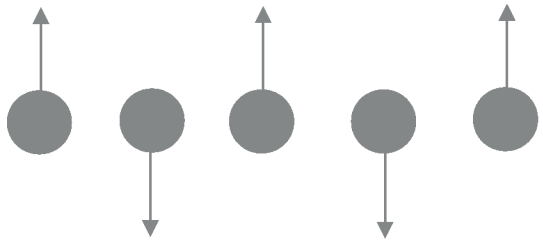
Observables

- Polarization

$$\phi = \left\| \frac{1}{N} \sum_{i=1}^{N} \frac{\vec{v_i}}{|\vec{v_i}|} \right\|$$

$$\phi = [0, 1]$$

$\phi = 0$



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ANALYSIS OF EMPIRICAL DATA

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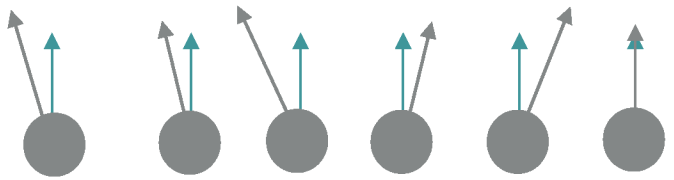
- Alignement

$$\phi_d = \left\| \frac{1}{N} \sum_{i=1}^{N} \frac{\vec{v_i}\vec{u_i}}{|\vec{v_i}|} \right\|$$

$$\phi_d = [-1, 1]$$

$\phi_d < 1$



ANALYSIS OF EMPIRICAL DATA

Observables

- Polarization

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- Alignement

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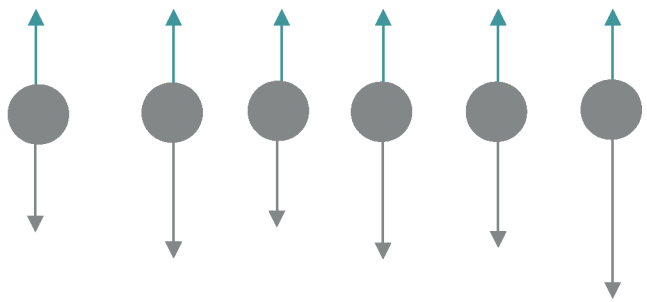
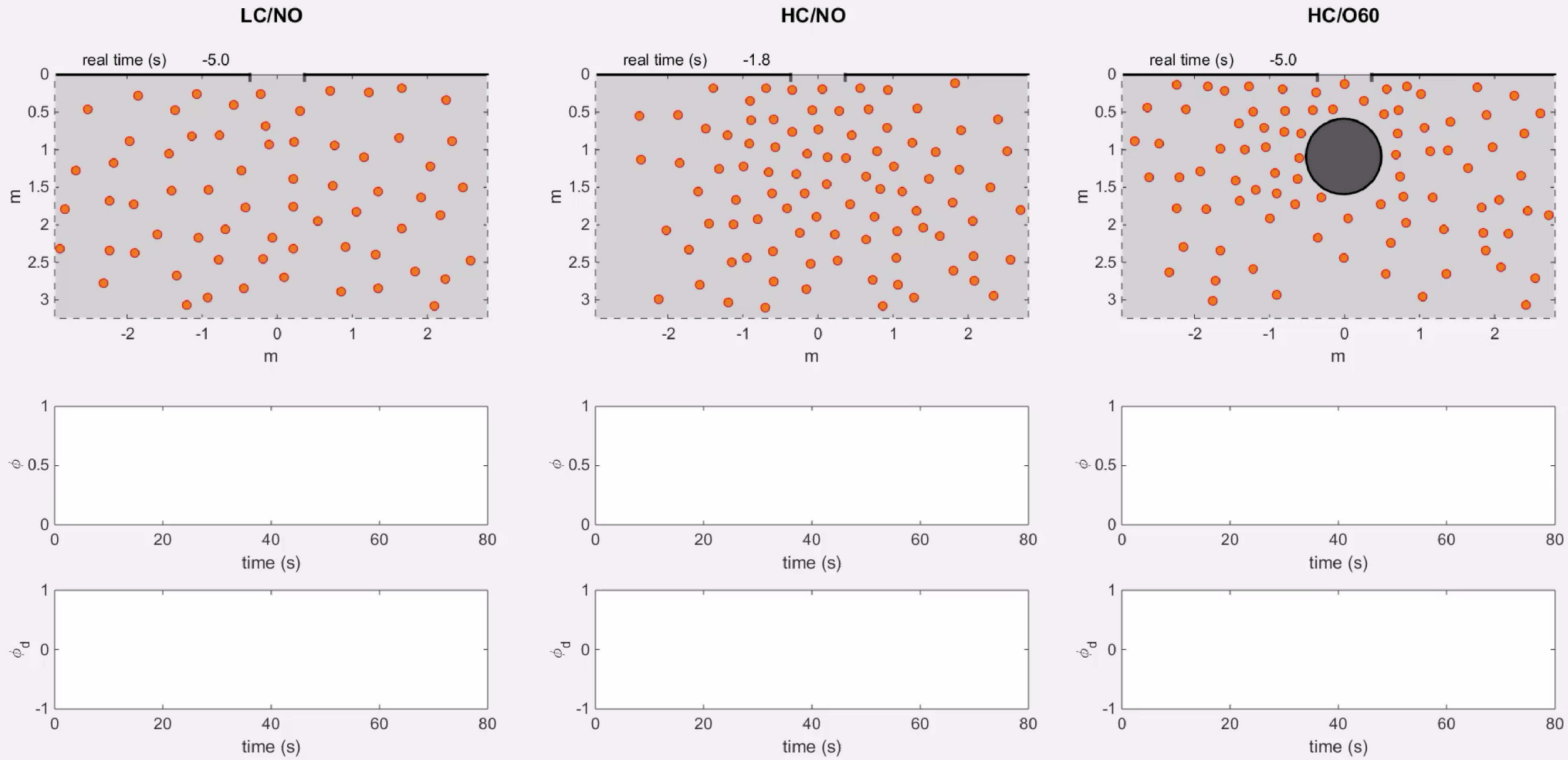
$$\phi_d = [-1, 1]$$

$$\phi_d = -1$$





A Garcimartín et al 2018 New J. Phys.20 123025

COLLISION-FREE VELOCITY MODEL

Limitations of the model + Experimental observation — New models

- Better direction sub-model
- General definition of minimal distance
- Clogging treatment: cooperation vs competition

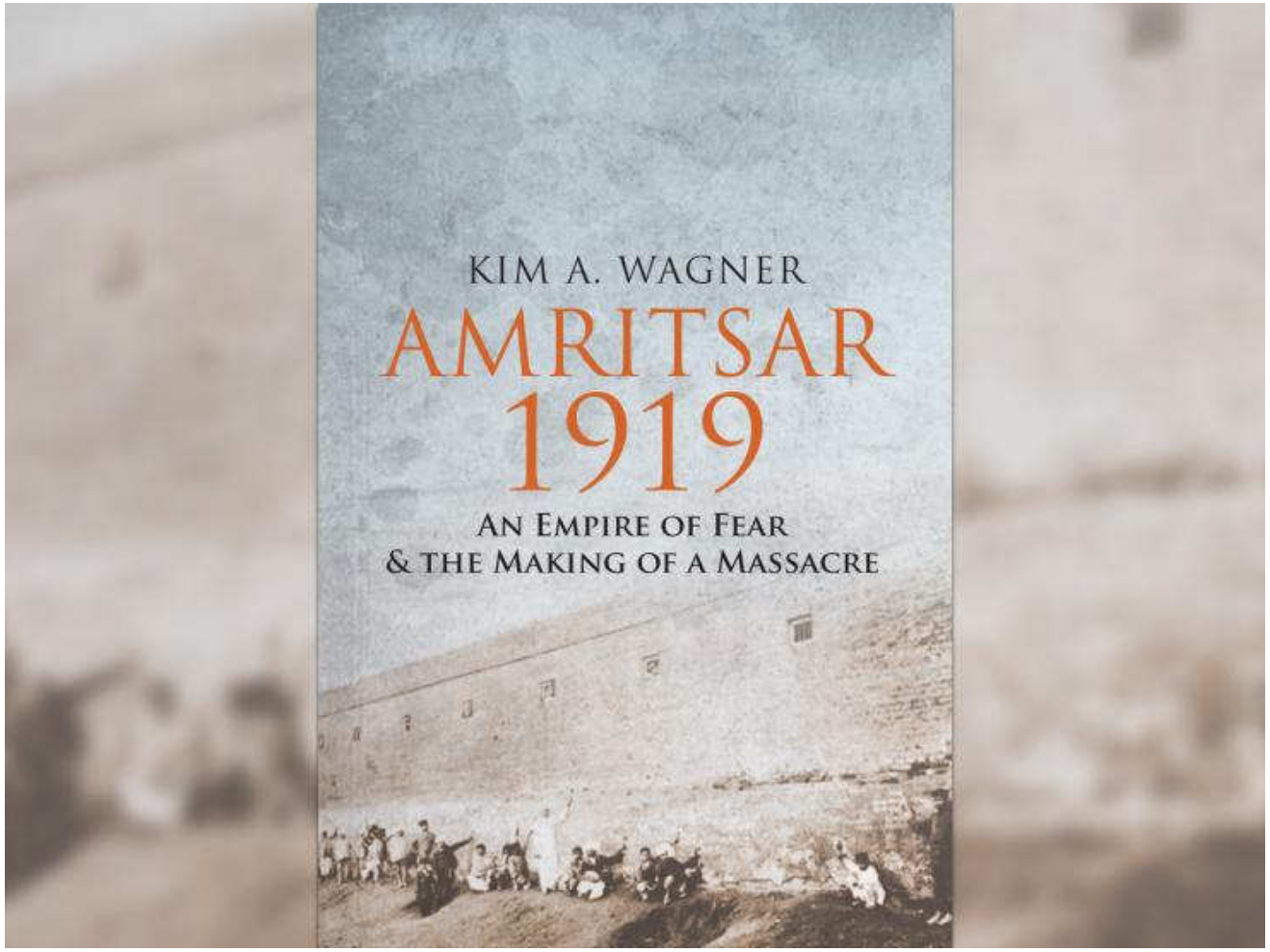


AMRITSAR MASSACRE

Case study: Jallianwala Bagh, 1909

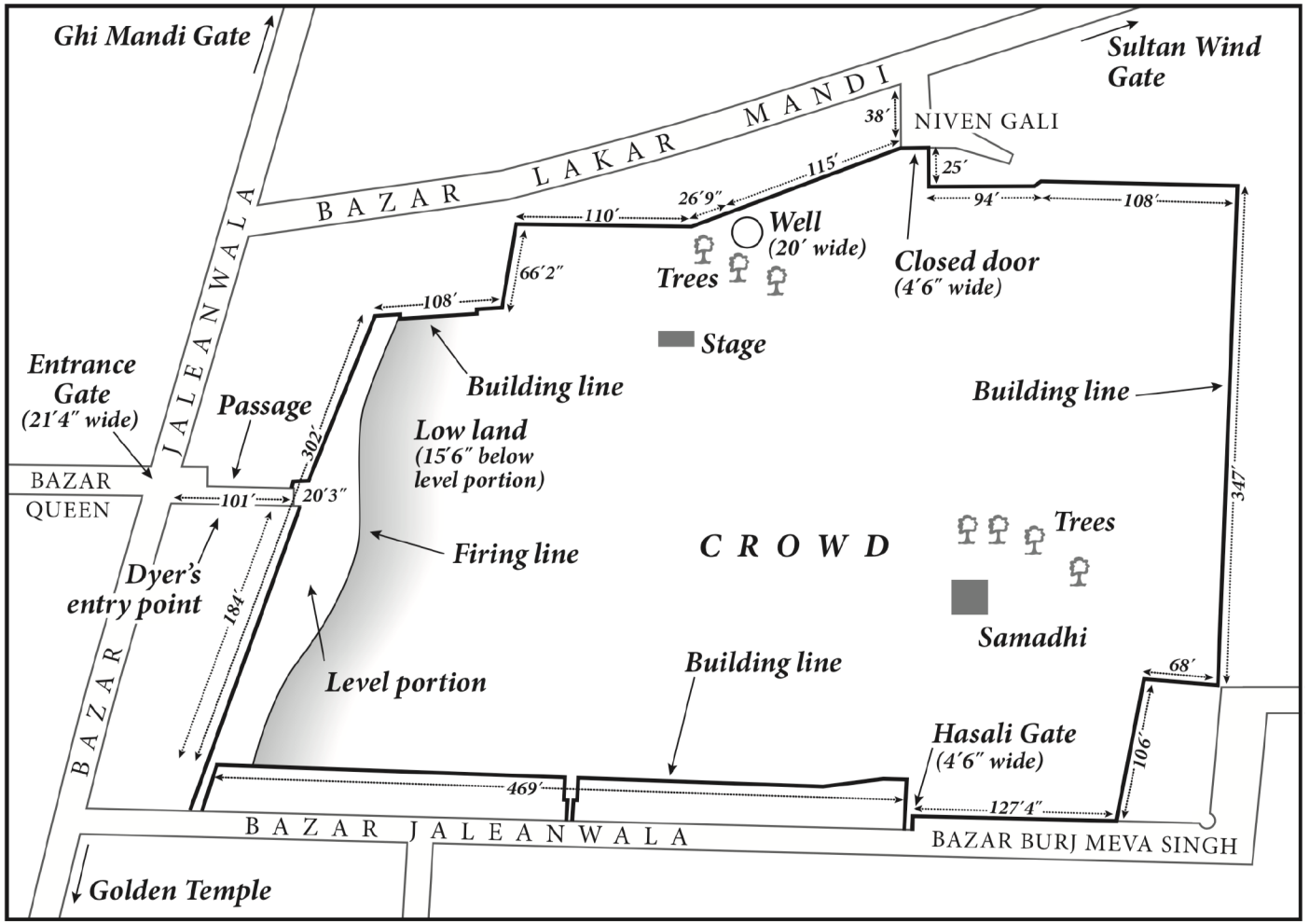
SIMULATION OF AN HISTORICAL EVENT

Amritsar **1919:** An Empire of Fear and the Making of a Massacre



JALLIANWALA BAGH

Ground plan - 1919



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COLLISION-FREE VELOCITY MODEL

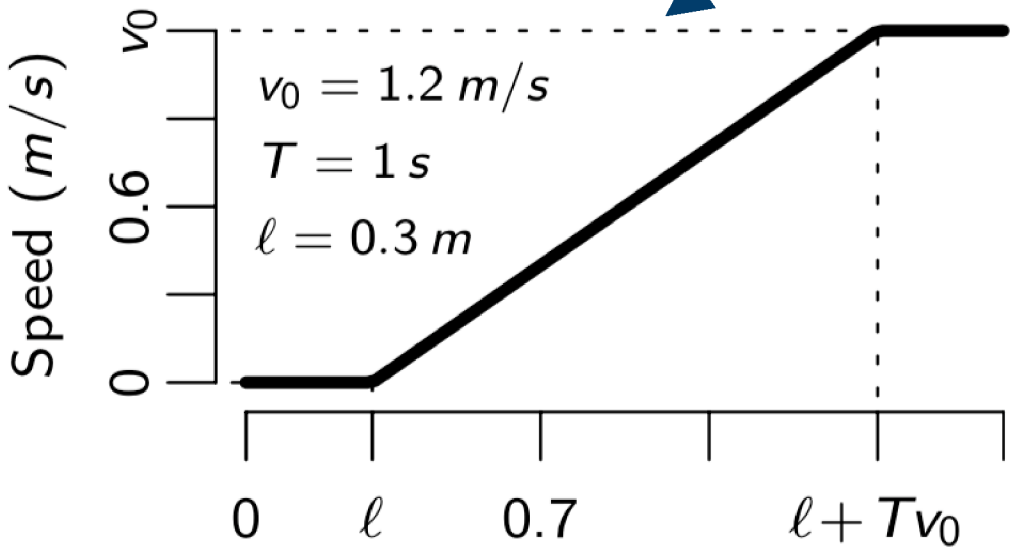
Reminder

$$\dot{x}_i = V(x_i, x_j, \cdots) \times \overrightarrow{e_i}(x_i, x_j, \cdots)$$

COLLISION-FREE OV MODEL

Two sub-models

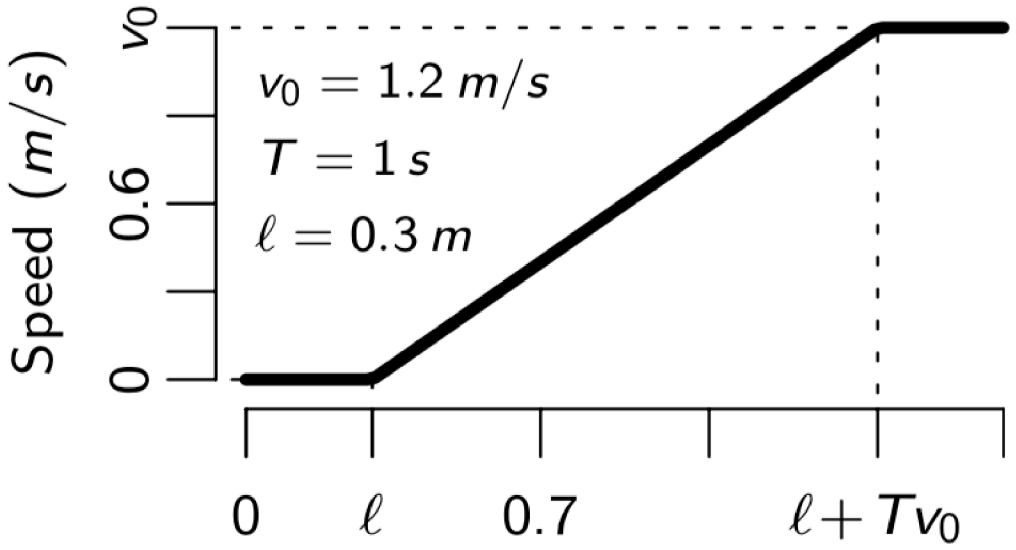
$$\dot{x}_i = V(x_i, x_j, \cdots) \times \vec{e}_i(x_i, x_j, \cdots)$$

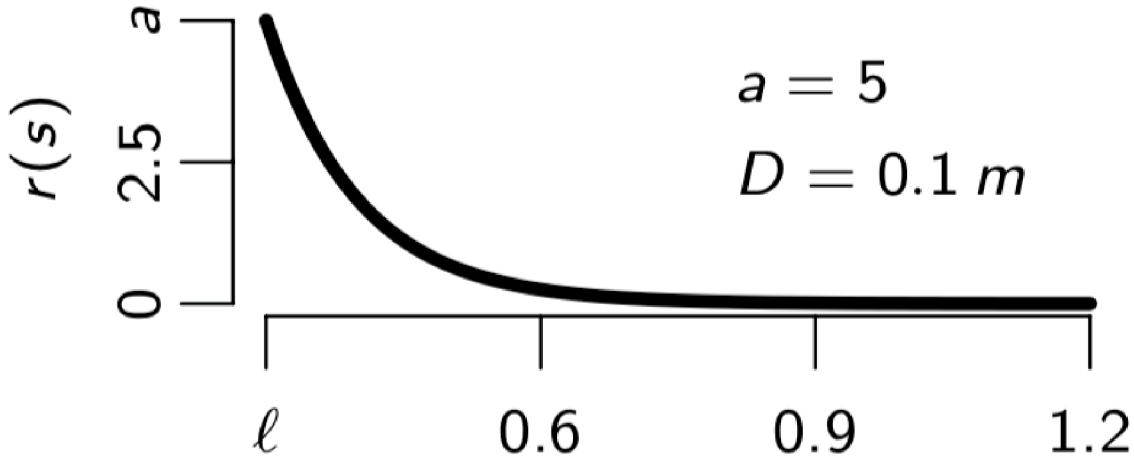


COLLISION-FREE OV MODEL

Two sub-models

$$\dot{x}_i = V(x_i, x_j, \cdots) \times \vec{e}_i(x_i, x_j, \cdots)$$





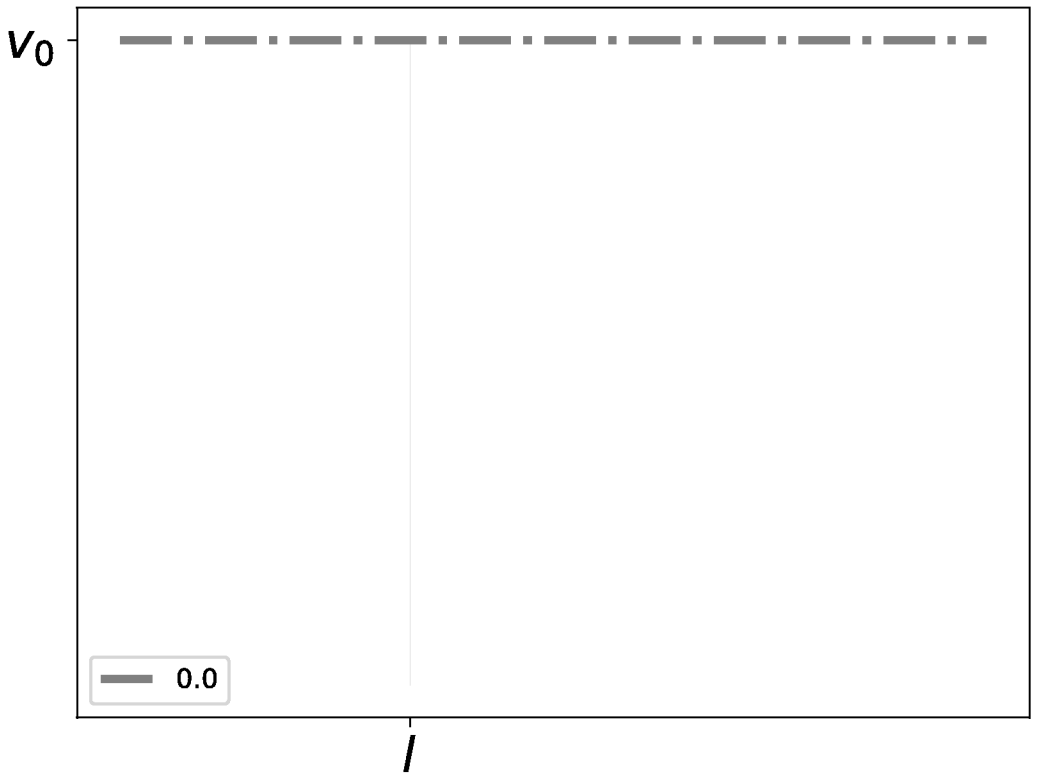
DEATH FACTOR

Probability of death is exponentially proportional to the distance

$$\dot{x}_i = \left(V(x_i, x_j, \cdots) + (1-\alpha)v^0 \right) \times \alpha \, \vec{e}_i(x_i, x_j, \cdots) \qquad \alpha \in [0,1]$$

DEATH FACTOR

Probability of death exponentially proportional to the distance

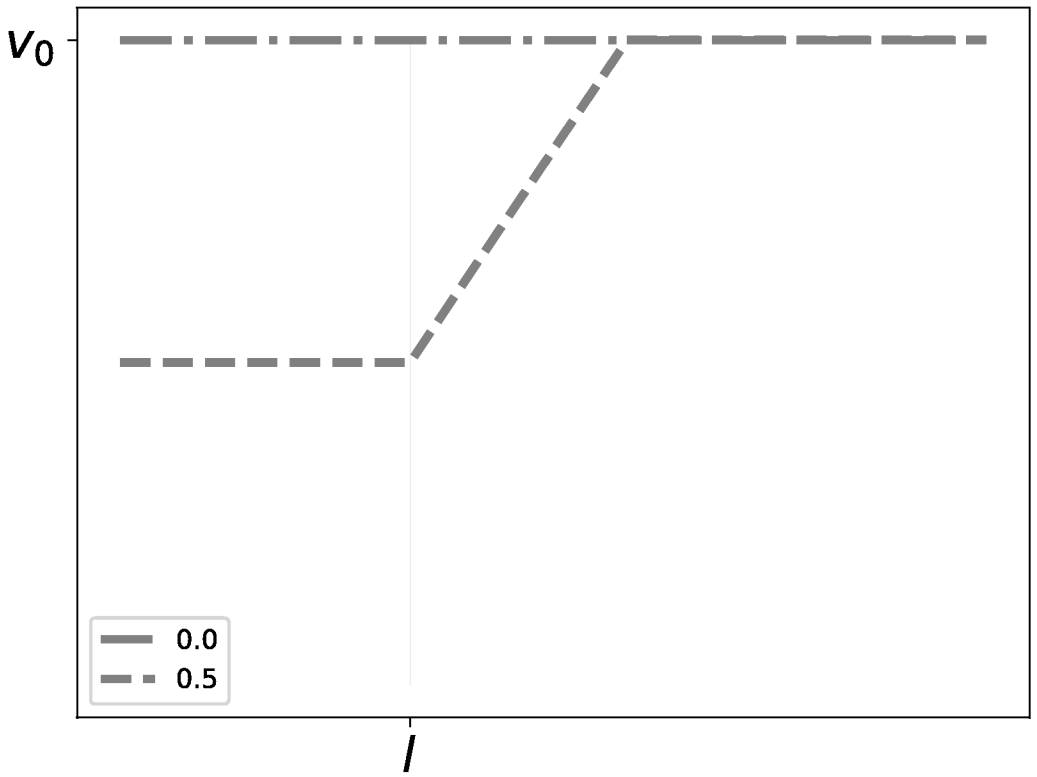


$\alpha = 0.00$



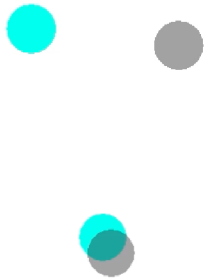
DEATH FACTOR

Probability of death exponentially proportional to the distance



$\alpha = 0.05$

$\alpha = 0.00$



DEATH FACTOR

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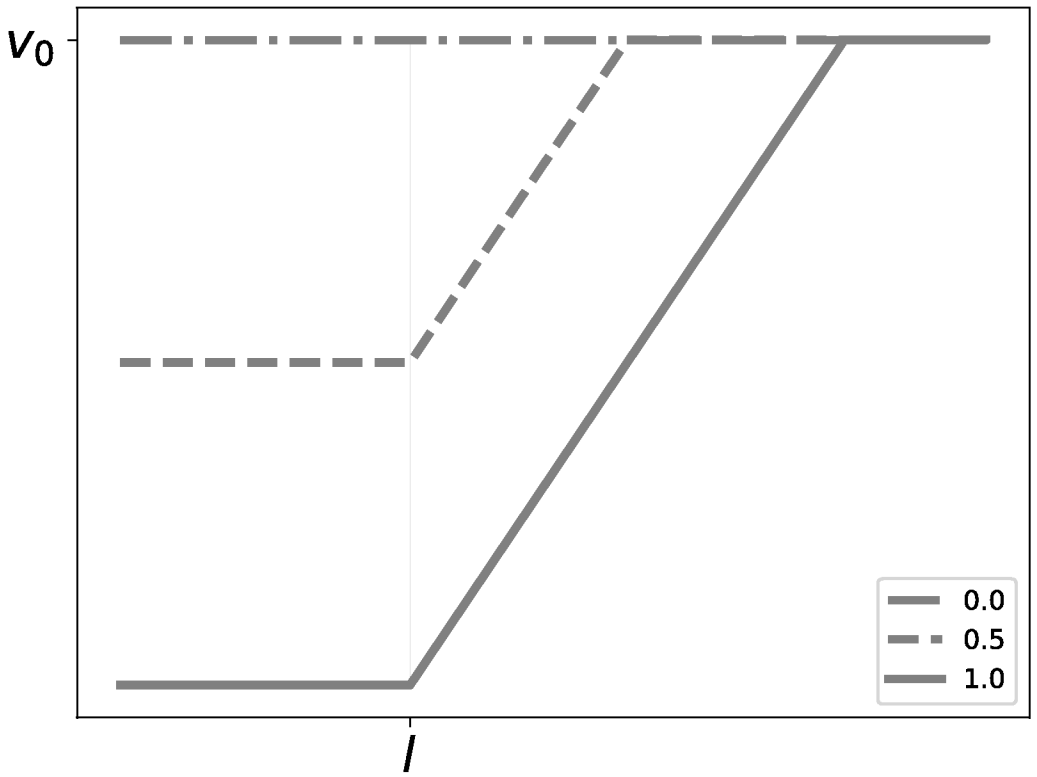


$\alpha = 1.00$



$\alpha = 0.05$

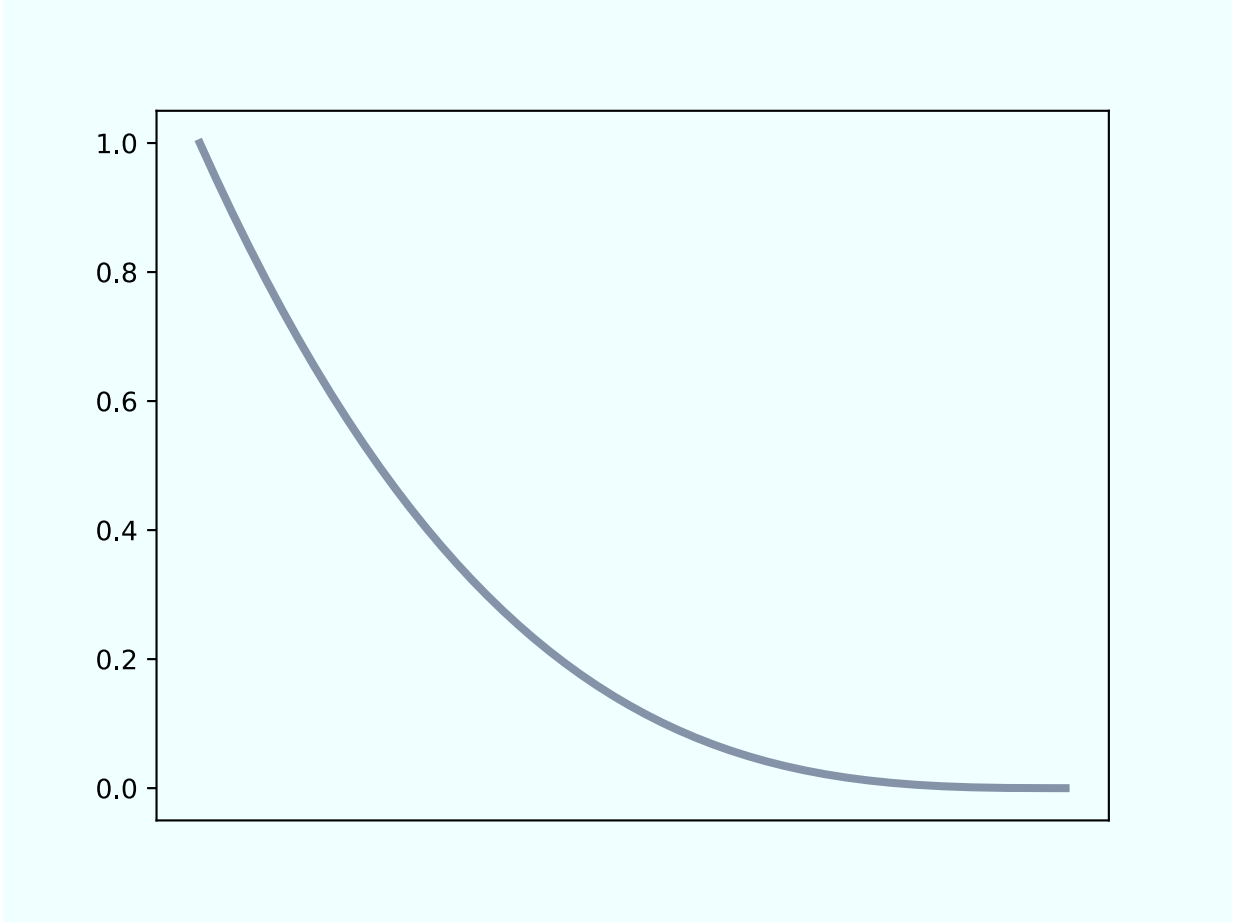


$\alpha = 0.00$



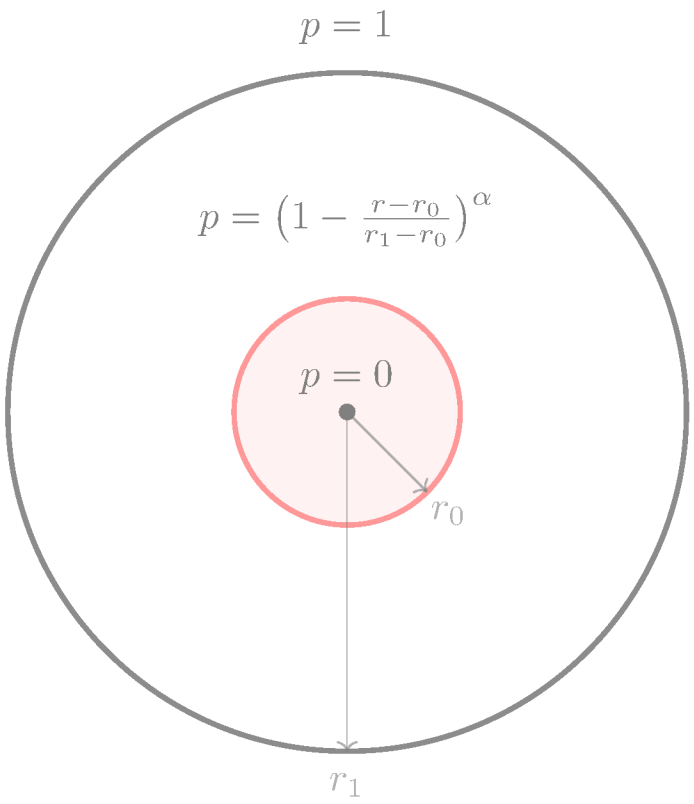
DANGER LINES

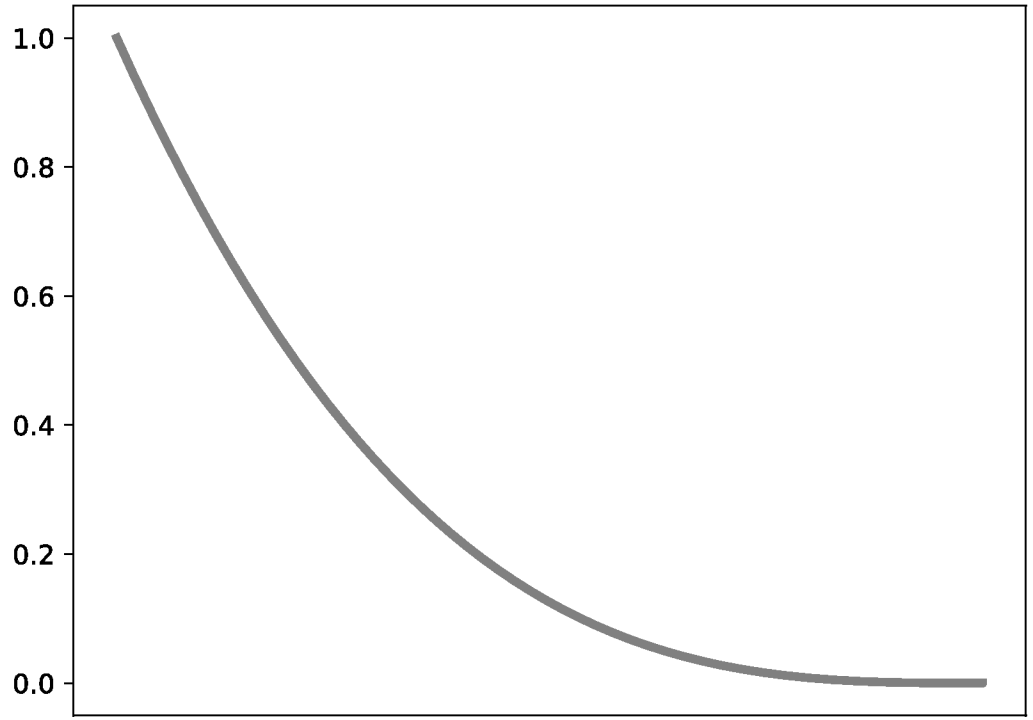
Probability of death exponentially proportional to the distance



DANGER LINES

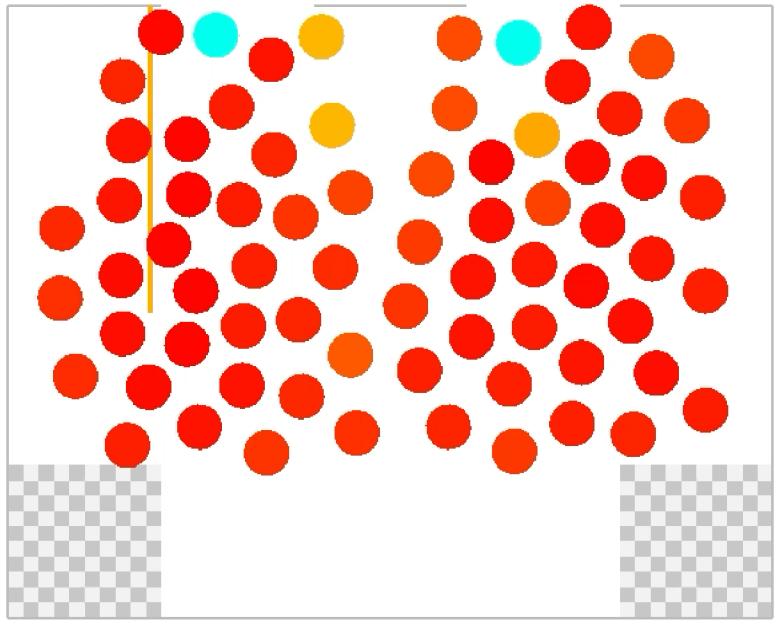
Probability of death exponentially proportional to the distance

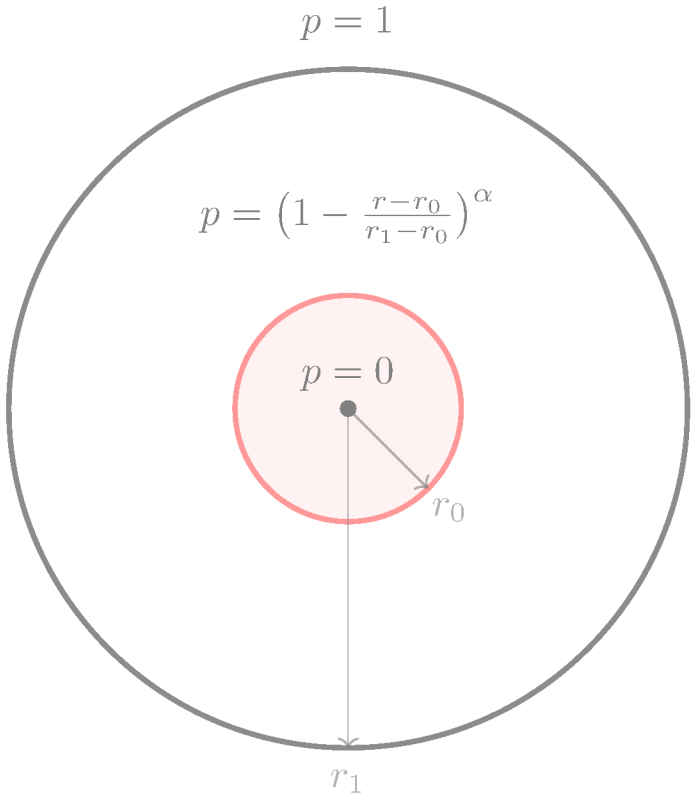




DANGER LINES

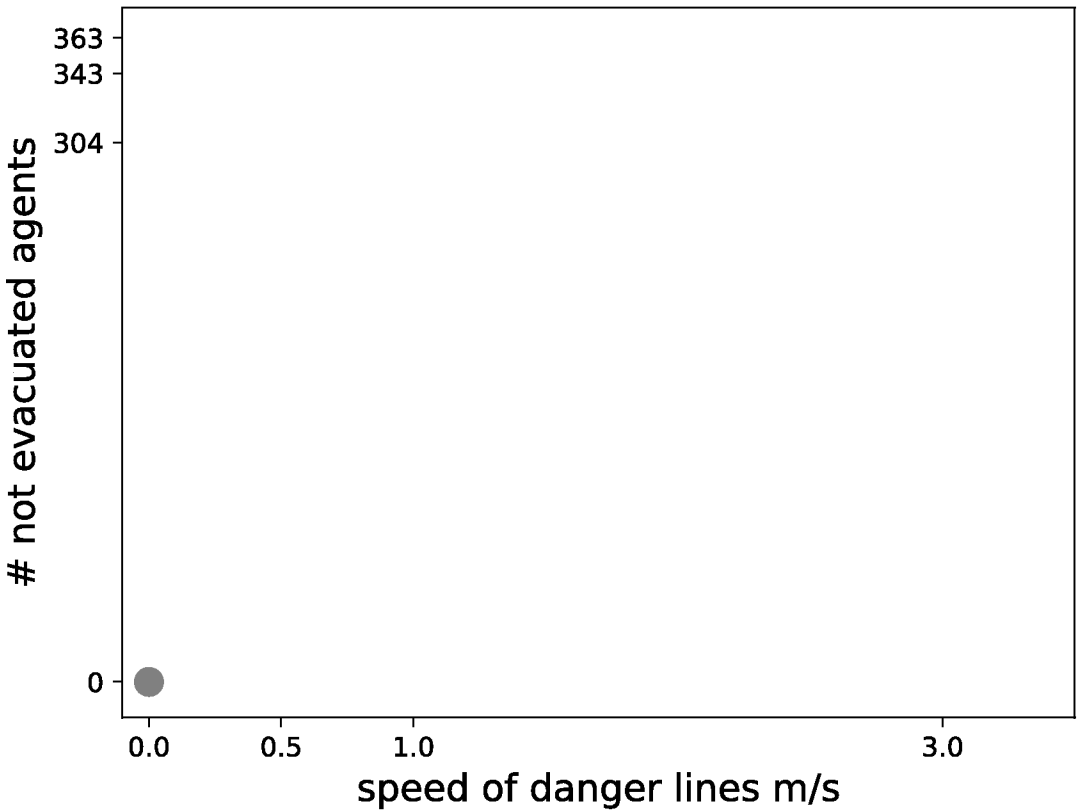
Probability of death exponentially proportional to the distance

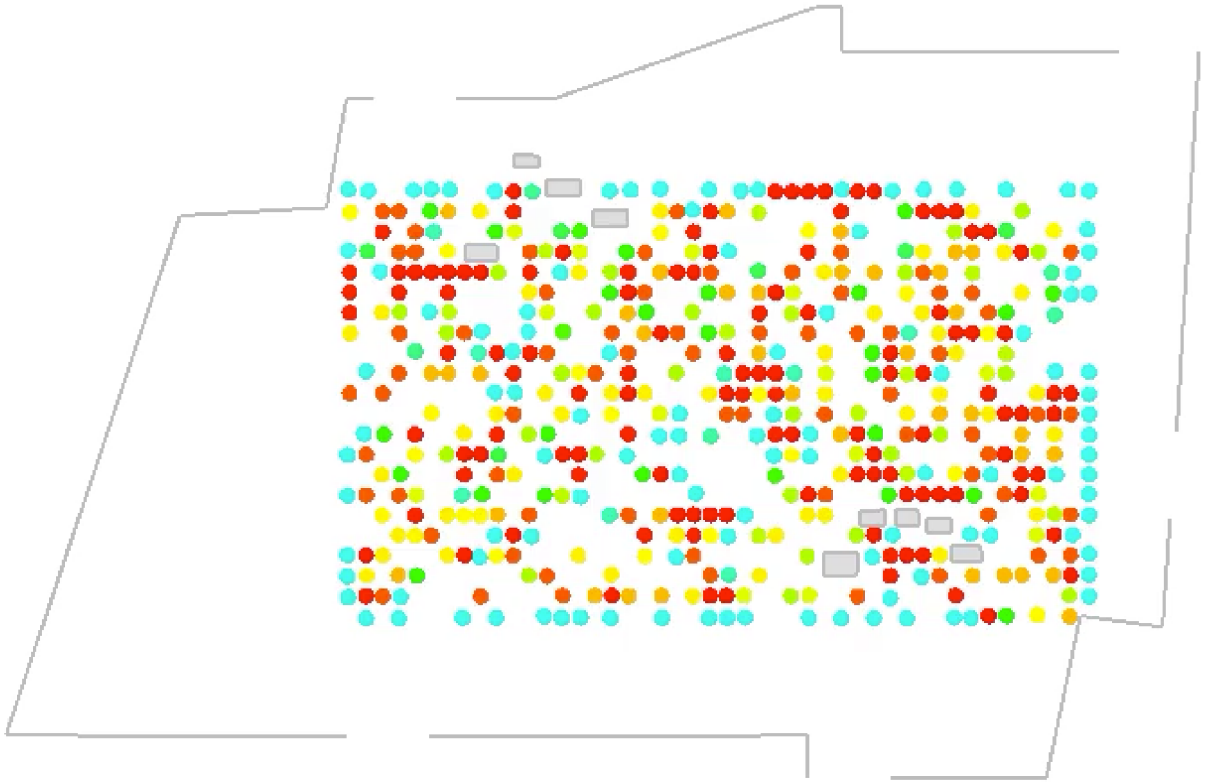




DANGER LINES

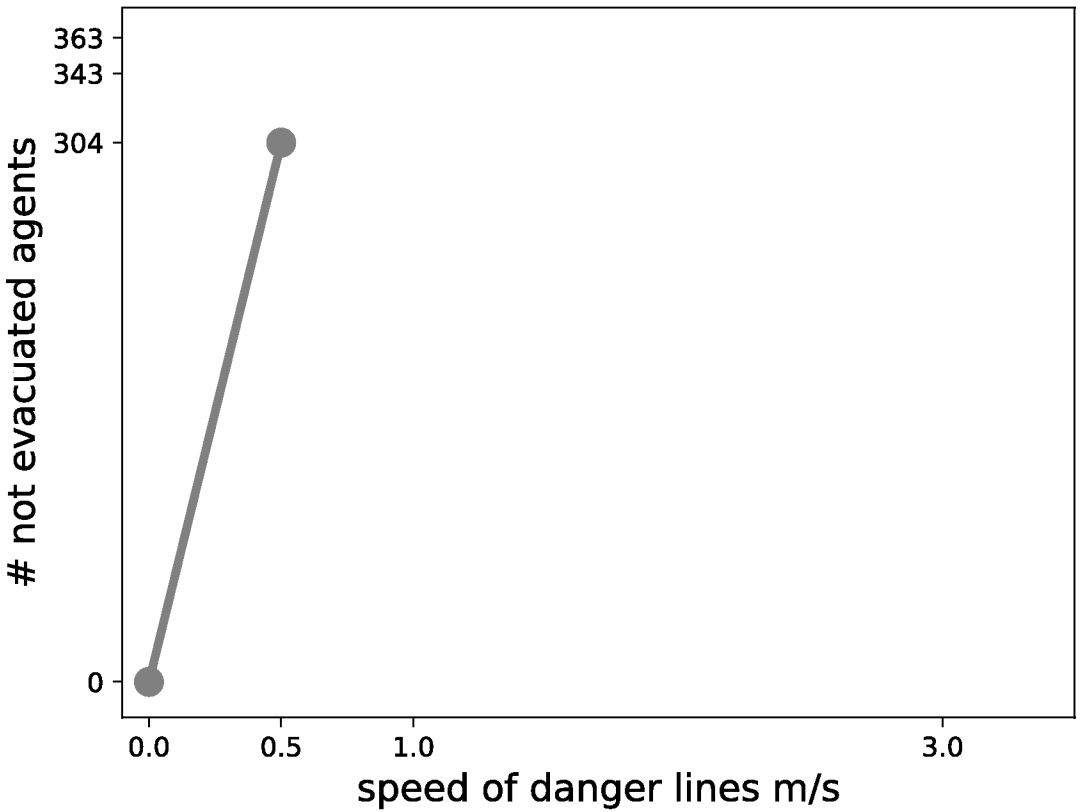
Influence of different speed of movement

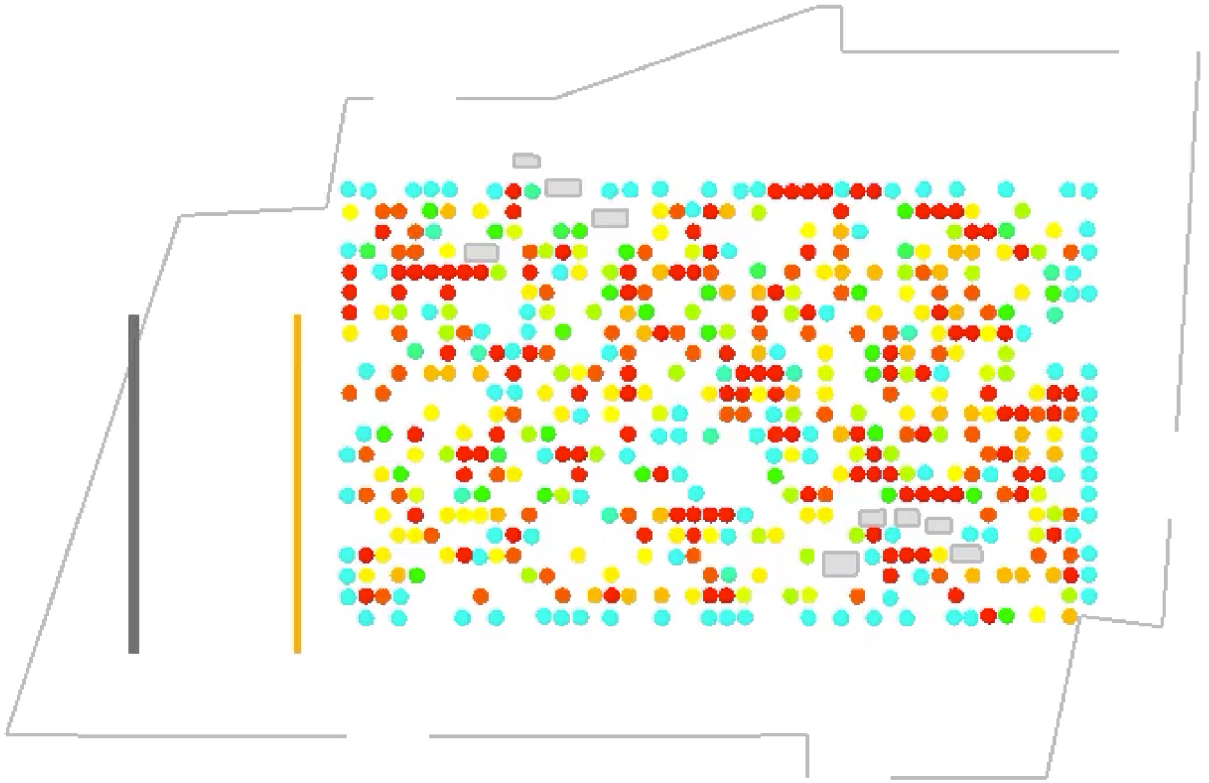




DANGER LINES

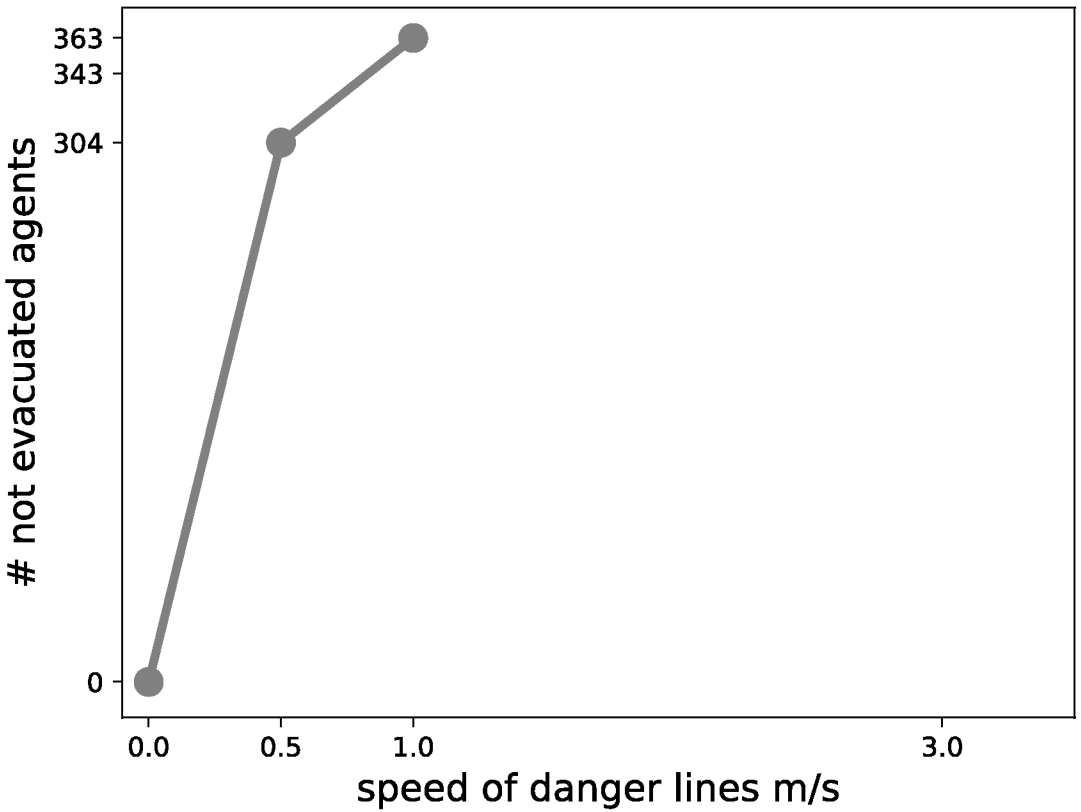
Influence of different speed of movement

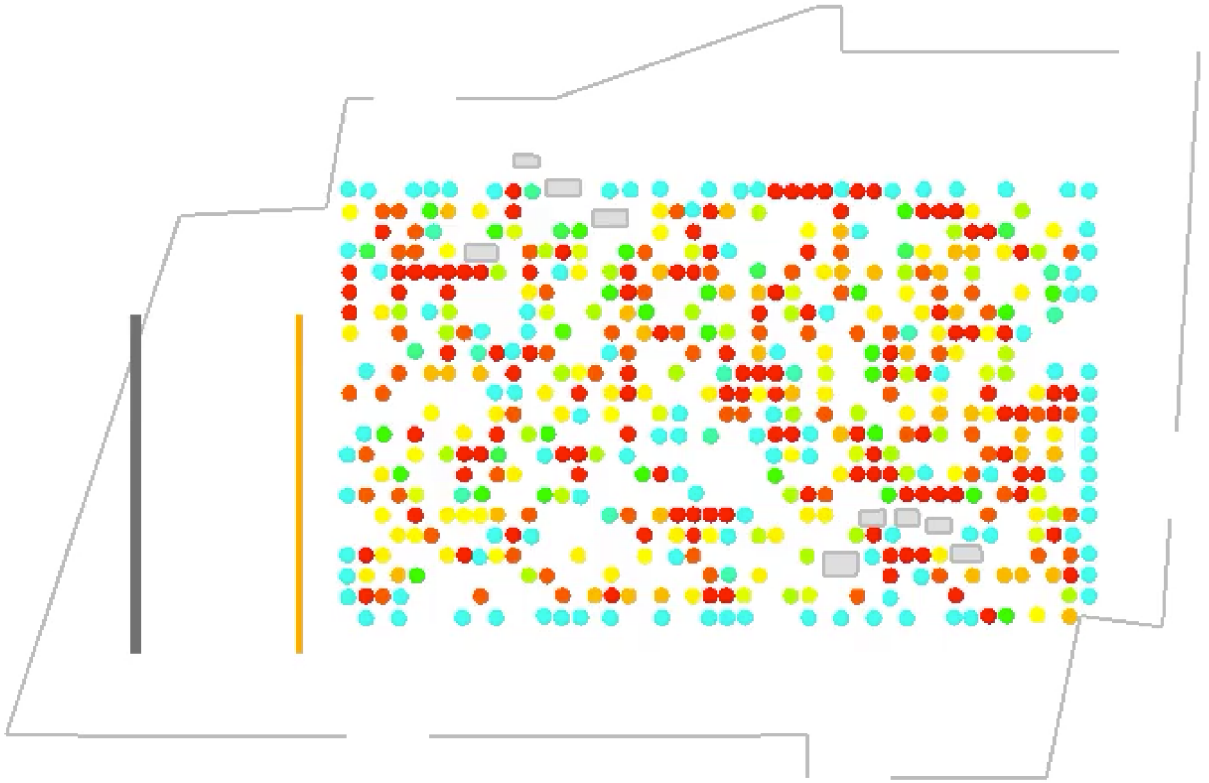




DANGER LINES

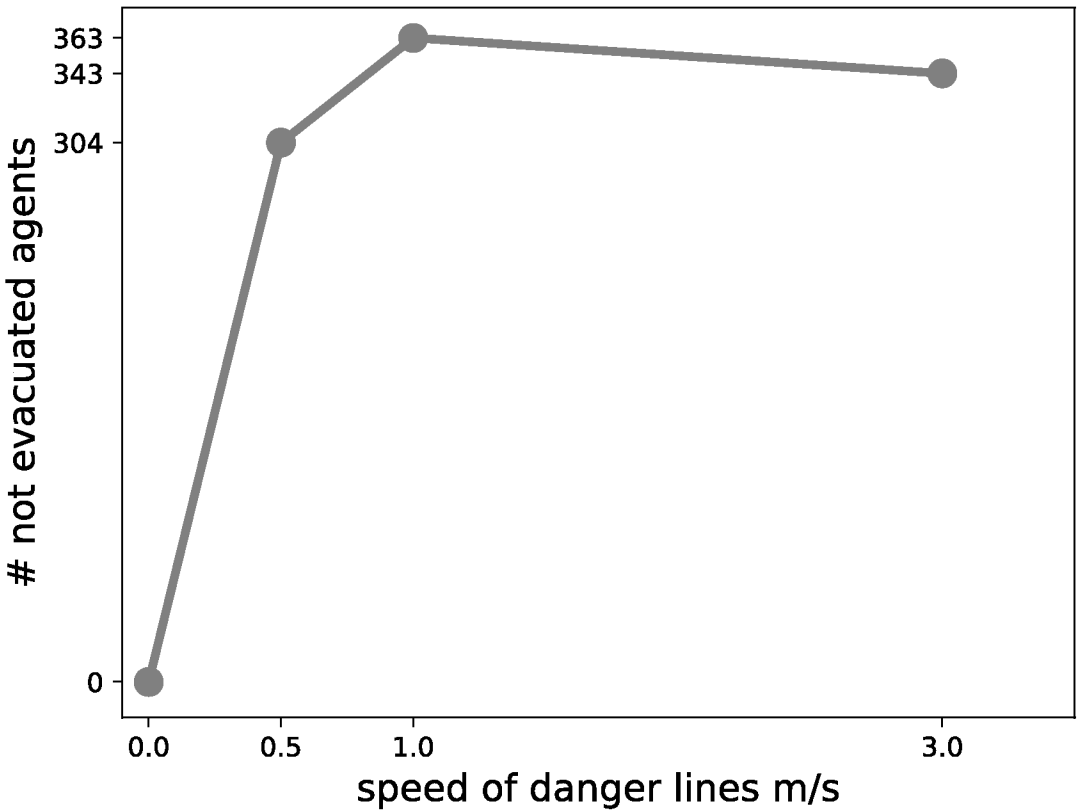
Influence of different speed of movement

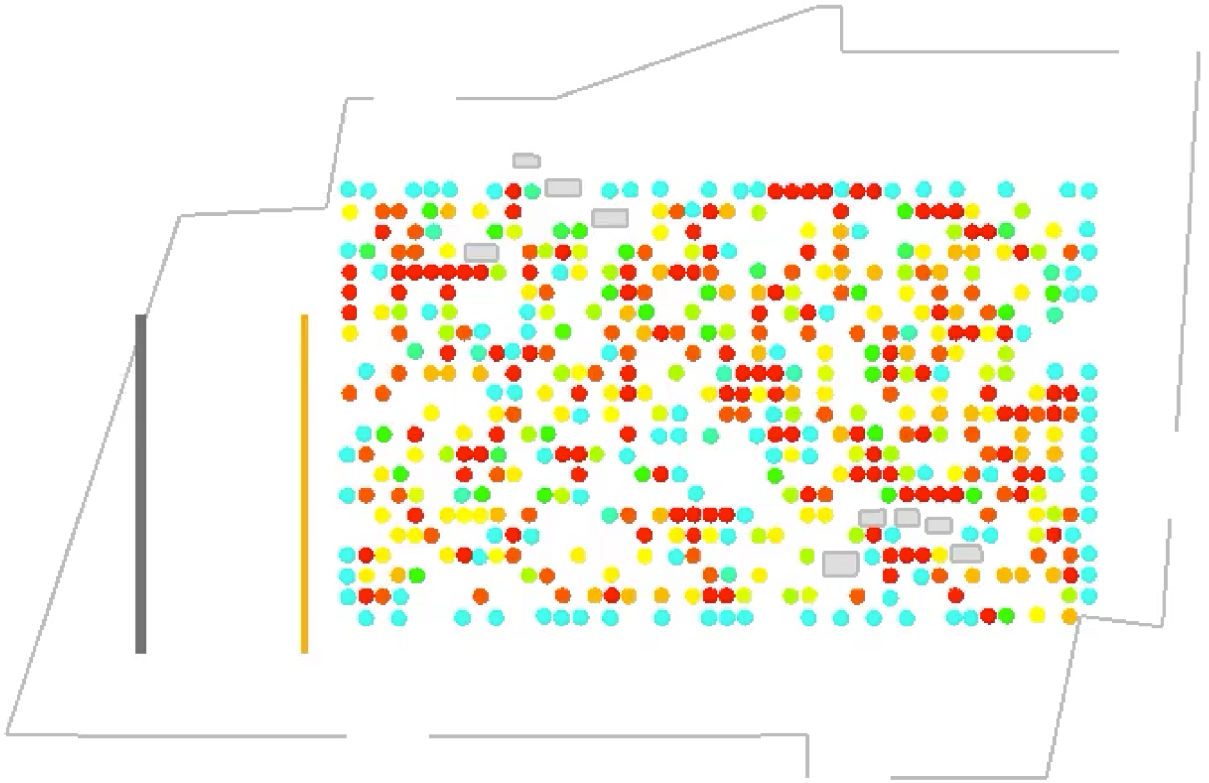




DANGER LINES

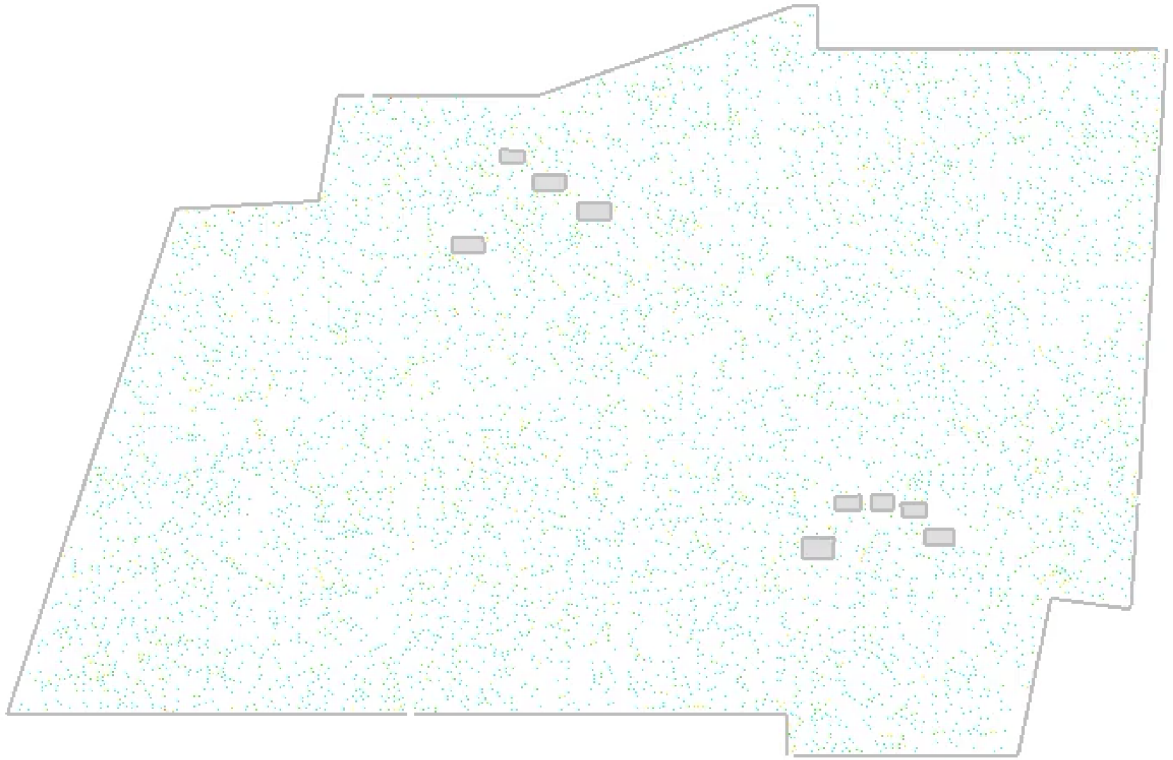
Influence of different speed of movement





DANGER LINES

Influence of different speed of movement



$t = 0\ s, \quad n = 10.000$

$t = 153\ s, n = 8986$

CONCLUSION

and references

CONCLUSION

Key take-aways

- Look into your data!
- Watch a lot of movies!
- Identify and scrutinise problems!
- Develop better (and simpler) models

REFERENCES

Open-access data and Open-access software

- Framework for pedestrian dynamics simulations

  http://jupedsim.org

- Automatic trajectory extraction software **PeTrack**

  http://ped.fz-juelich.de/petrack

- Open-access **database**

  http://ped.fz-juelich.de/da


感谢您的关注！ 请大家随便提问题