PEDESTRIAN DYNAMICS AND BOTTLENECK FLOW

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DATUM

Mitglied der Helmholtz-Gemeinschaft

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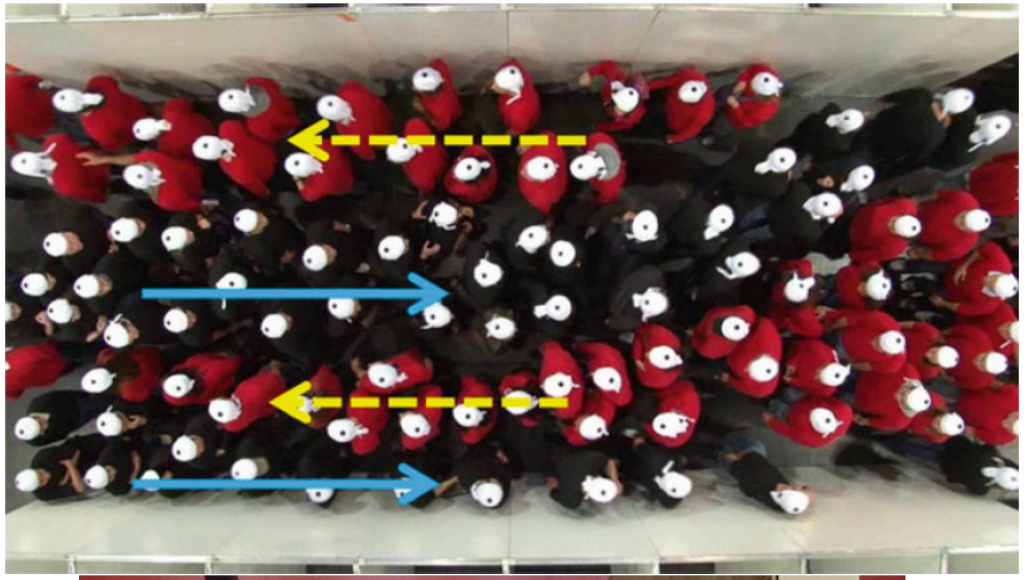
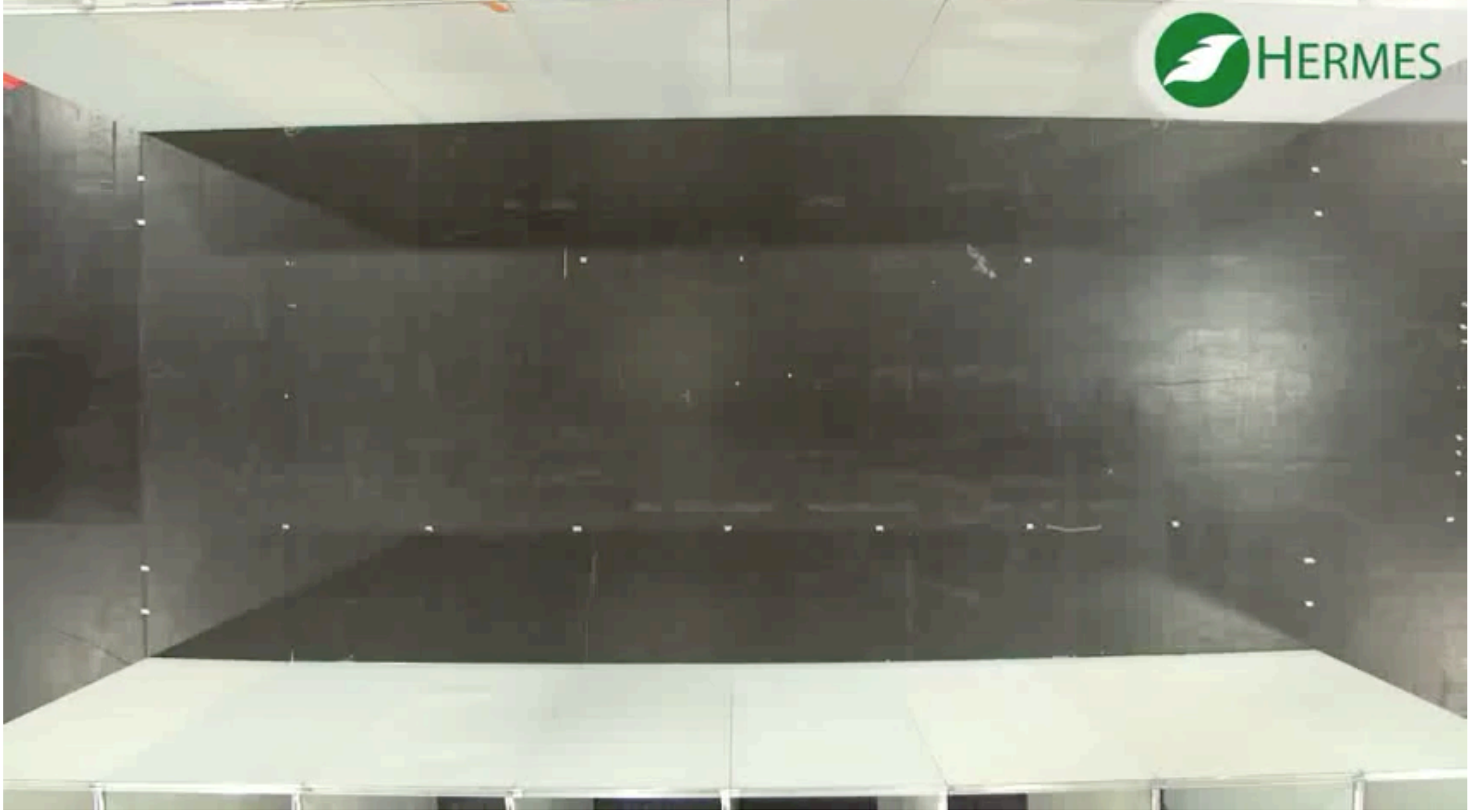
Source: Wikipedia.org

PHYSICS PERSPECTIVE

Self-organising phenomenon and collective effects

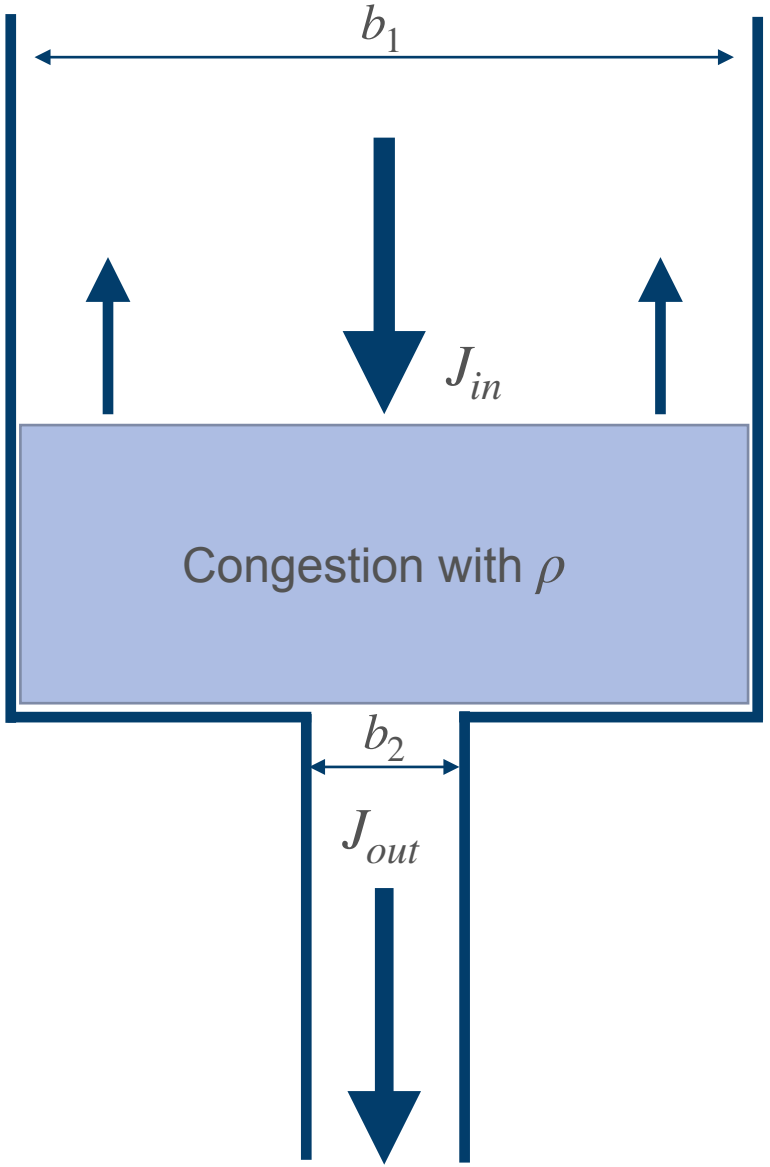
- Observe macroscopic effects that result from microscopic interaction
- Examples:
  - Lane formation in counterflow
  - Oscillation in counterflow at bottlenecks
  - Stop and go waves
  - Clogging and Jamming at Bottlenecks




HERMES

BOTTLENECK SITUATION

- Process definition
  - Unidirectional movement of pedestrians passing a bottleneck
  - Incoming flow J_{in} vs. outgoing flow J_{out}
- Phenomena
  - $J_{in} > J_{out}$ leads to congestion
  - Density ρ increases till a threshold ρ^* when the congestion area grows in the opposite direction
  - Clogging



CLOGGING IN GRANULAR MATTER AND ARCHITECTURE

Immortal Bridge near Mount Tai in China

Roman aqueduct near Tunis

(source wikipedia.org)

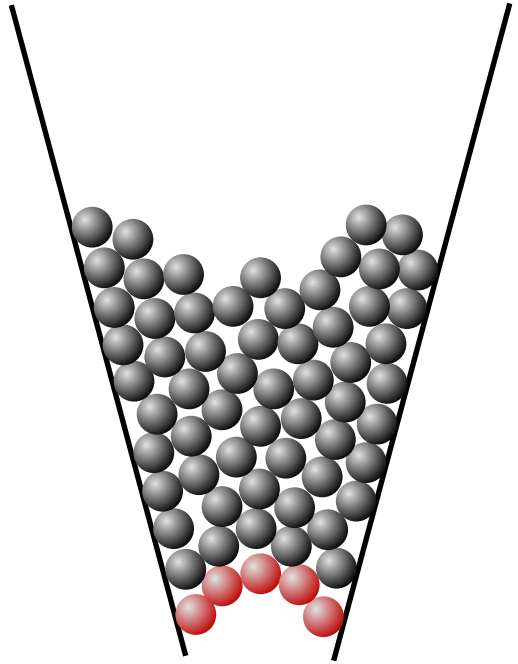


Illustration of clogging in granular matter

- Evacuation experiment through a bottleneck with sheep
- Narrow door leads to food source
- The sheep are highly motivated and show no cooperation
- Clogging occurs

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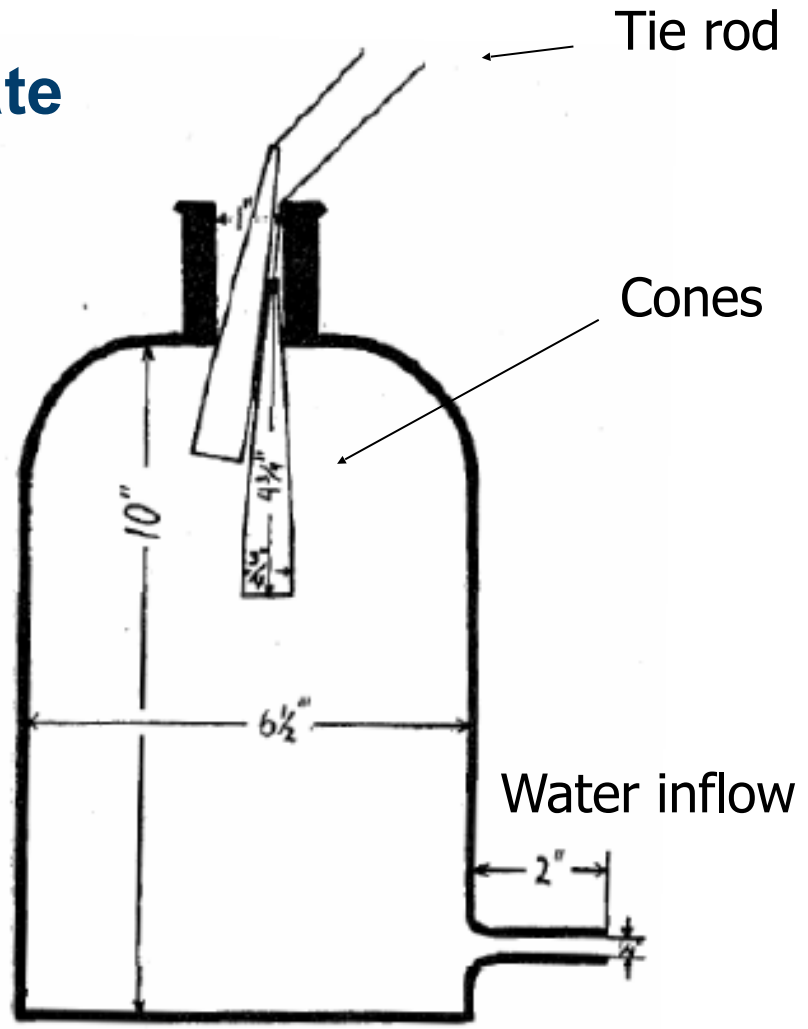
MOTIVATION AND COOPERATION

Motivation influences the insensitive to cooperate

- Experiment of Mintz
  - Groups of 15-21 students
  - Task: Pull out cones dry
  - only one cone at the time without clogging
- Different setups and instructions
  - With and without reward (money)
  - With and without opportunity to discuss
  - With and without special arousal (swaring and noise)
- Without reward: No clogging
- With reward: clogging



Source: A. Mintz, *Non-adaptive group behaviour*, The Journal of abnormal and social psychology 46 150 (1951)

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INFLUENCE OF MOTIVATION ON CLOGGING

Low motivation | *Medium motivation* | *High motivation*

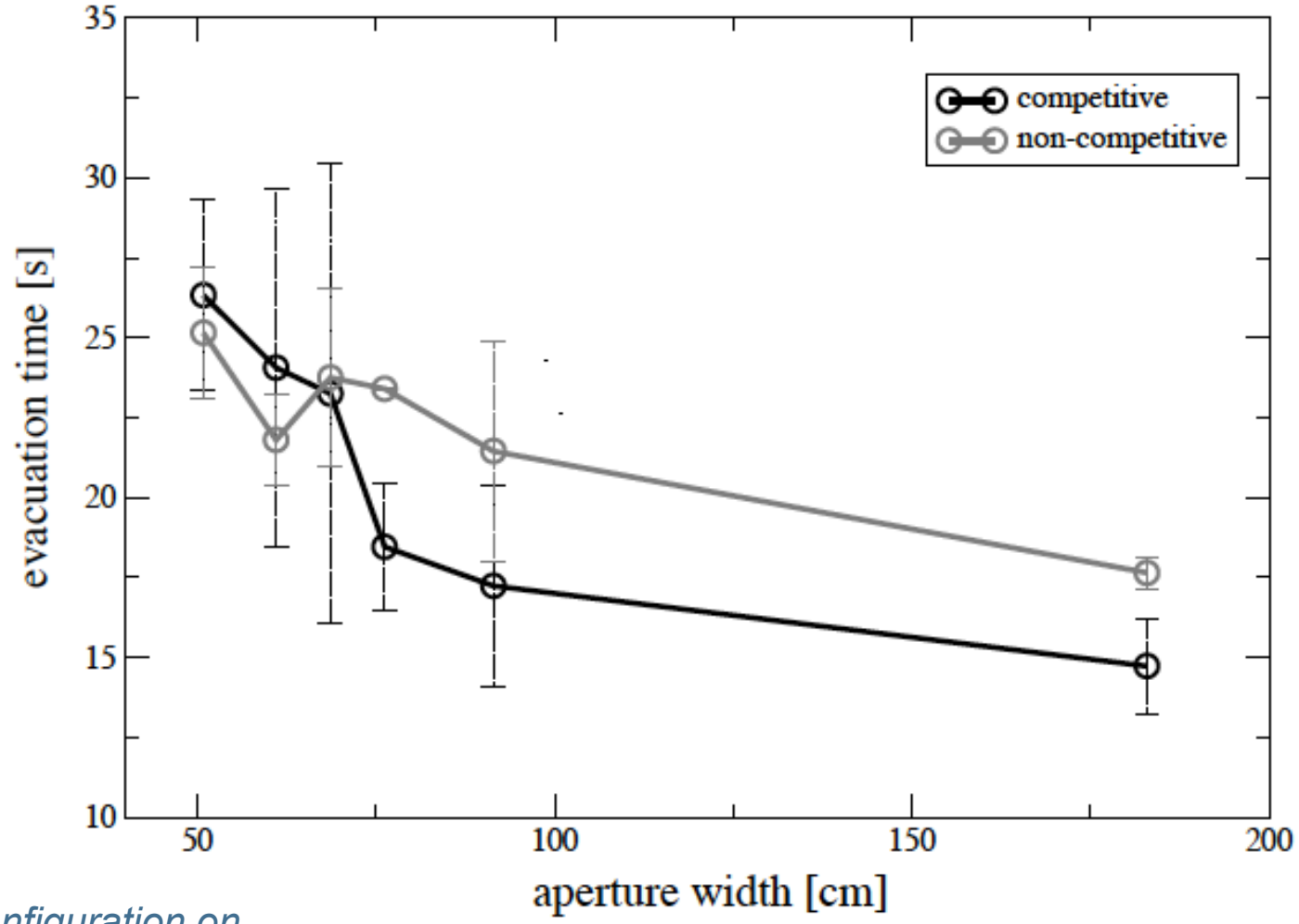
Source: Garcimartín, Parisi, Pastor, Martín-Gómez, Zuriguel, *Flow of pedestrians through narrow doors with different competitiveness*, J. Stat. Mech, 043402, 2016

BOTTLENECK EXPERIMENT

Video: Experiments performed by Majid Sarvi, University of Melbourne, Australia, 2018

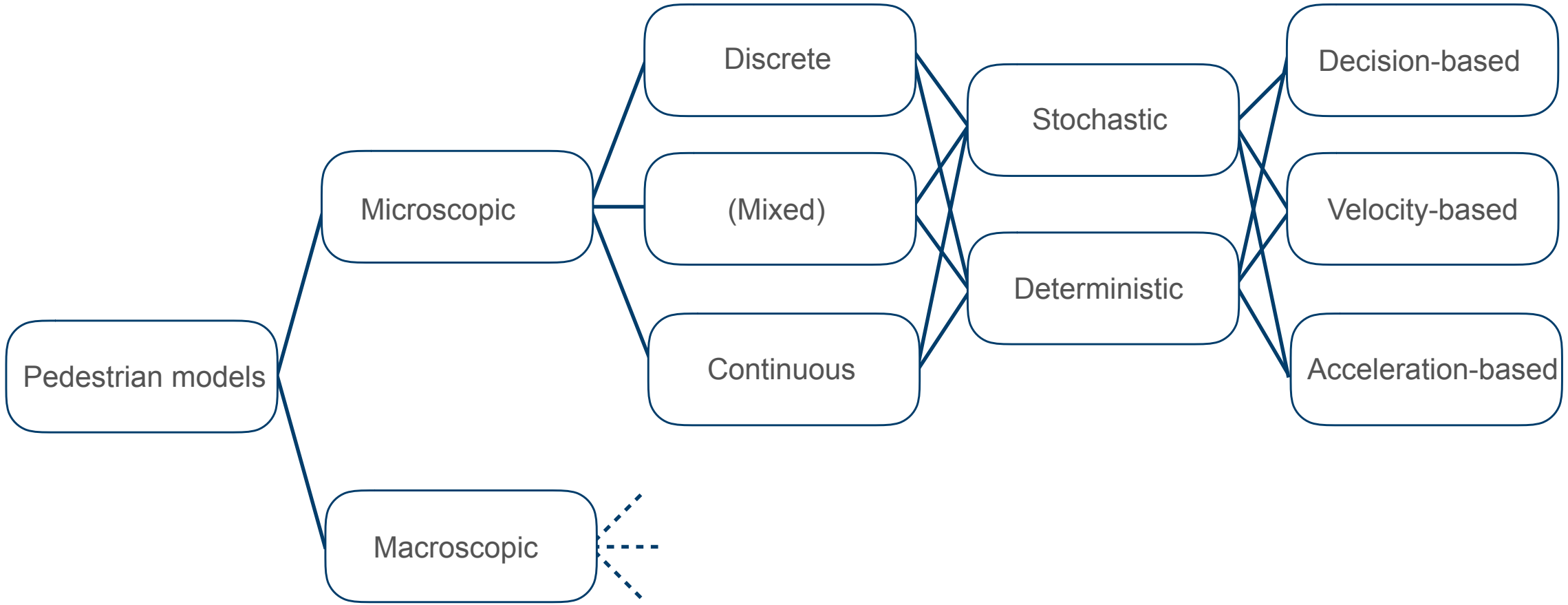
BOTTLENECK EXPERIMENT

- Evacuation of an aircraft
  - Competitive and non competitive situation (money as reward)
  - variable exit width w_c
  - $t_{comp} > t_{non-comp}$ if $w < w_c$
  - $t_{comp} < t_{non-comp}$ if $w > w_c$



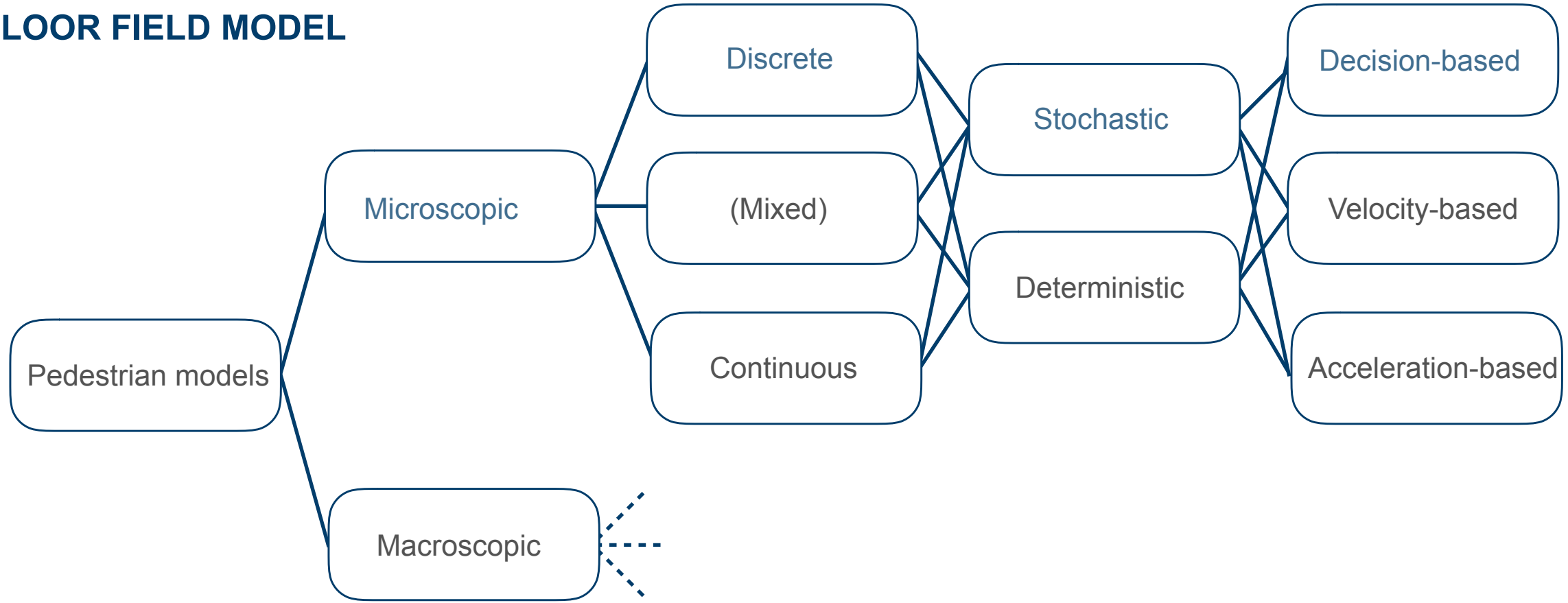
Source: Muir et al., *Effects of Motivation and Cabin Configuration on Emergency Aircraft Evacuation Behavior and Rates of Egress*, The Int. J. of Aviation Psychology, 6, 1996

MODELLING APPROACHES



MODELLING APPROACHES

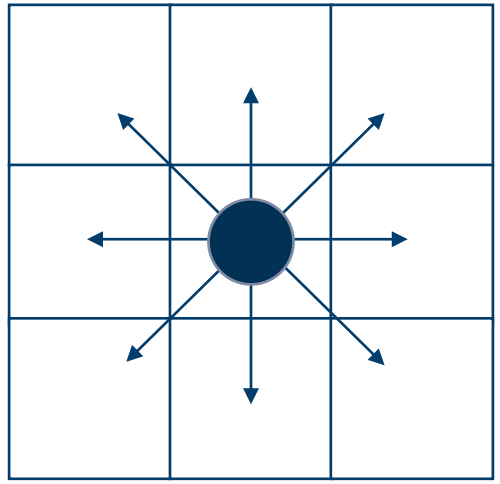
FLOOR FIELD MODEL



MODELLING APPROACHES

FLOOR FIELD MODEL

- Cellular automata model discrete in space and time with parallel dynamics
- Space is divided into cells which can only be occupied by a single agent
- At each time step an agent can transition to one of the neighbouring empty cells with a certain probability fixed by the *floor field*



$S_{-1,-1}$	$S_{-1,0}$	$S_{-1,1}$
$S_{0,-1}$	$S_{0,0}$	$S_{0,1}$
$S_{1,-1}$	$S_{1,0}$	$S_{1,1}$

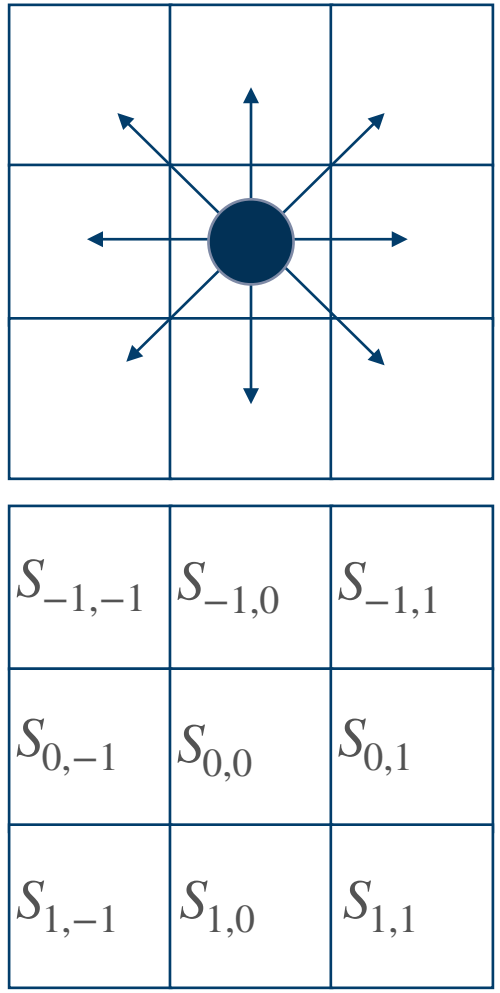
MODELLING APPROACHES

FLOOR FIELD MODEL

- Example: An empty cell closer to the destination has a higher transition probability than one further away

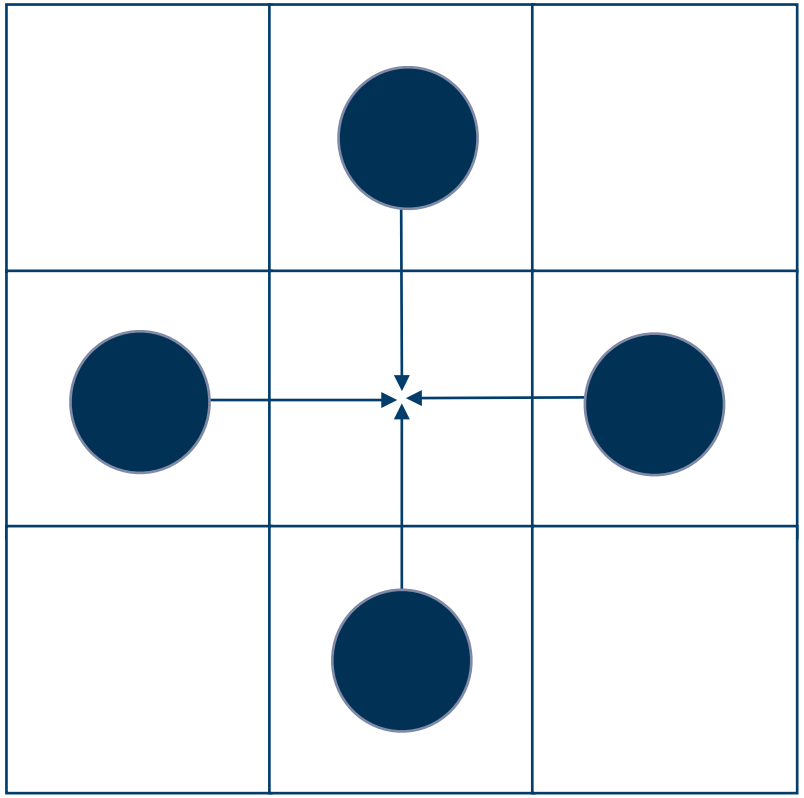
$$p_{ij} \propto (1 - n_{ij})\exp(k_s S_{ij})$$

- $n_{ij} \in 0,1$
  - 1 occupied, 0 unoccupied
- S_{ij} increases closer to destination
- k_s sensitivity parameter $[0,\infty)$



MODELLING APPROACHES

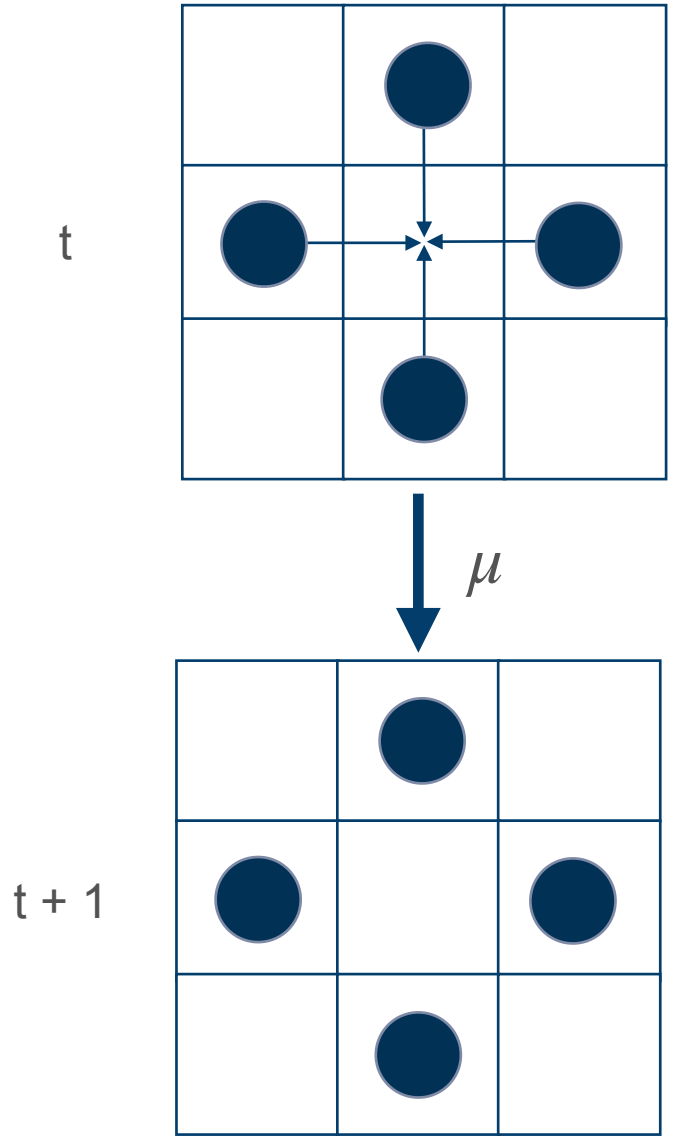
Floor field model with friction



MODELLING APPROACHES

Floor field model with friction

- Conflict resolution
  - No conflict: $p_{ij} \propto (1 - n_{ij}) \exp(k_s S_{ij})$
  - Conflict: pedestrians can not move with probability μ
  - probability $1 - \mu$ one of the pedestrians can move into the cell
  - pedestrian chosen randomly with equal probability



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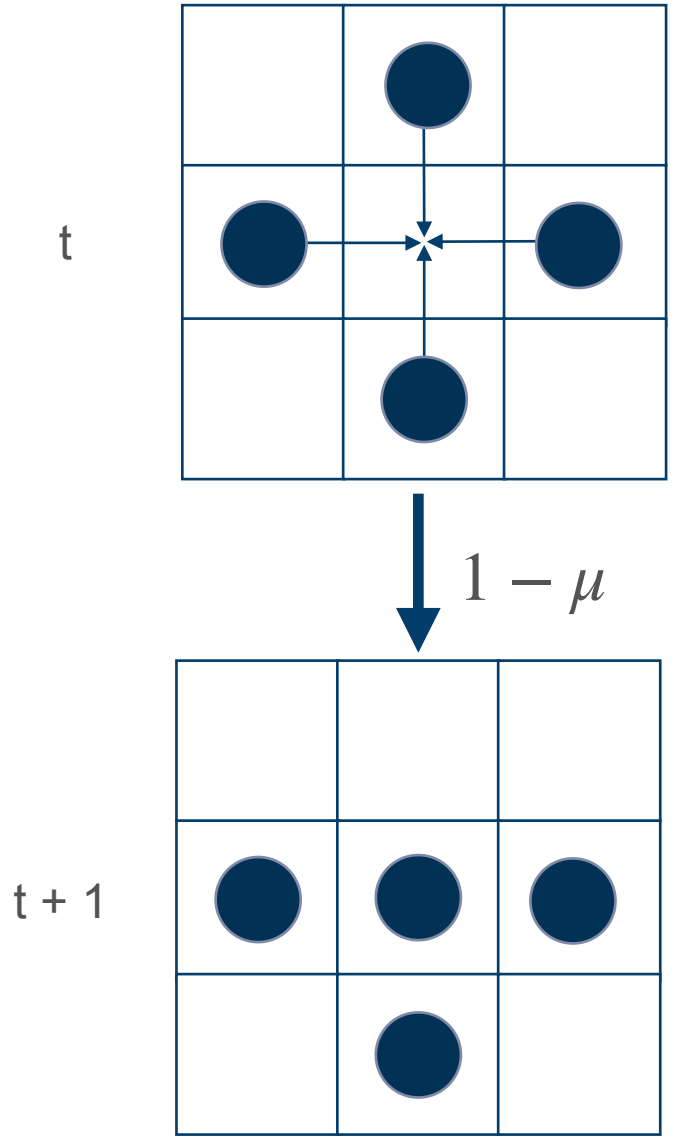
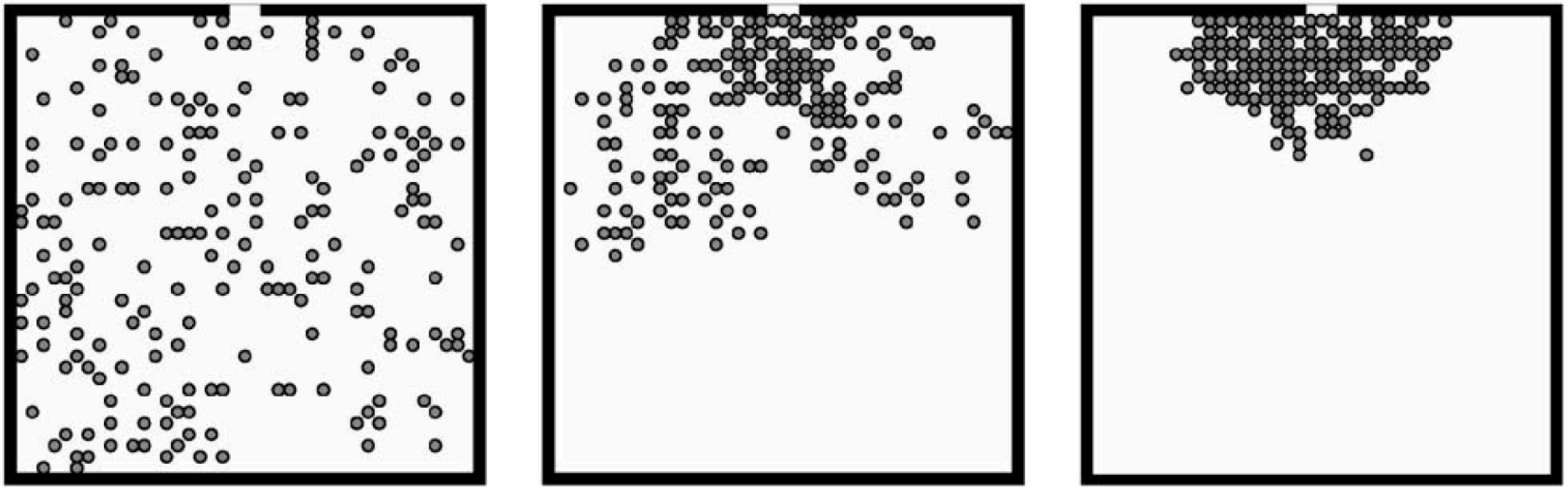


MODELLING APPROACHES

Illustration of a floor field simulation



Source: C. Bursedde, K.Klauck, A. Schadschneider, J. Zittartz (2001), *Simulation of pedestrian dynamics using a two-dimensional cellular automaton*, Physica A 295 (2001) 507–525

MODELLING APPROACHES

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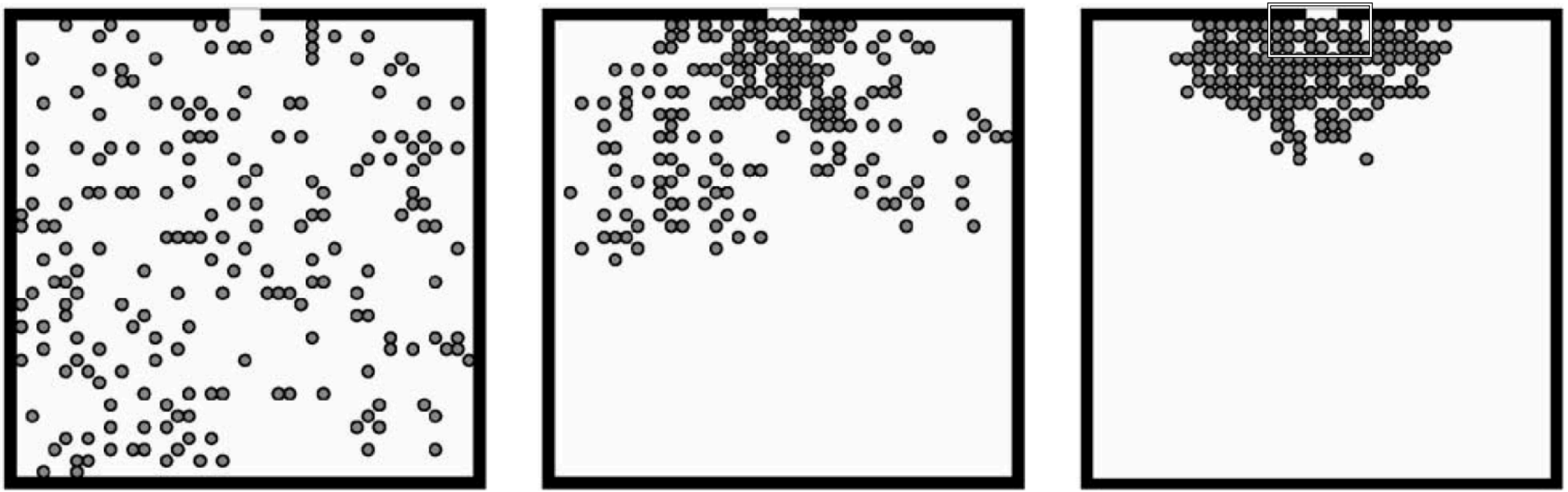

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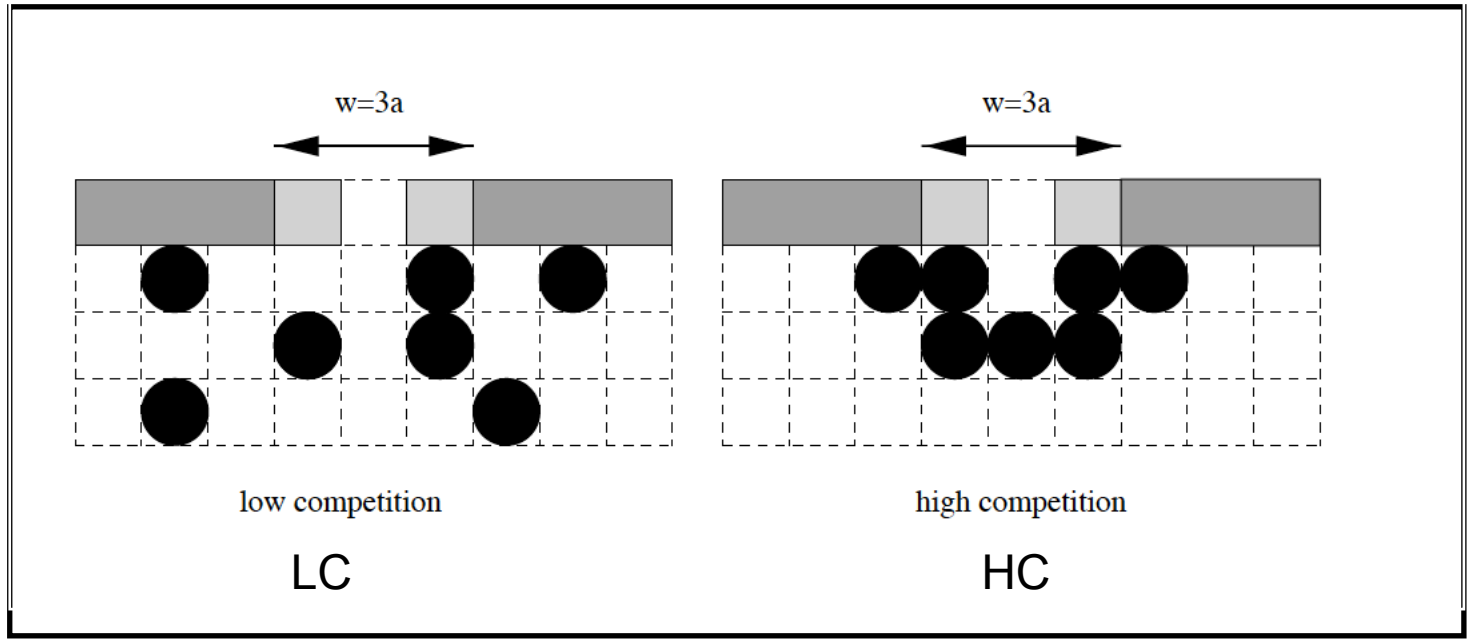
MODELLING APPROACHES

Illustration of a floor field simulation

$$p_{ij} \propto (1 - n_{ij})\exp(k_s S_{ij})$$

- $\mu_{LC} < \mu_{HC}$
- $k_{s,LC} < k_{s,HC}$



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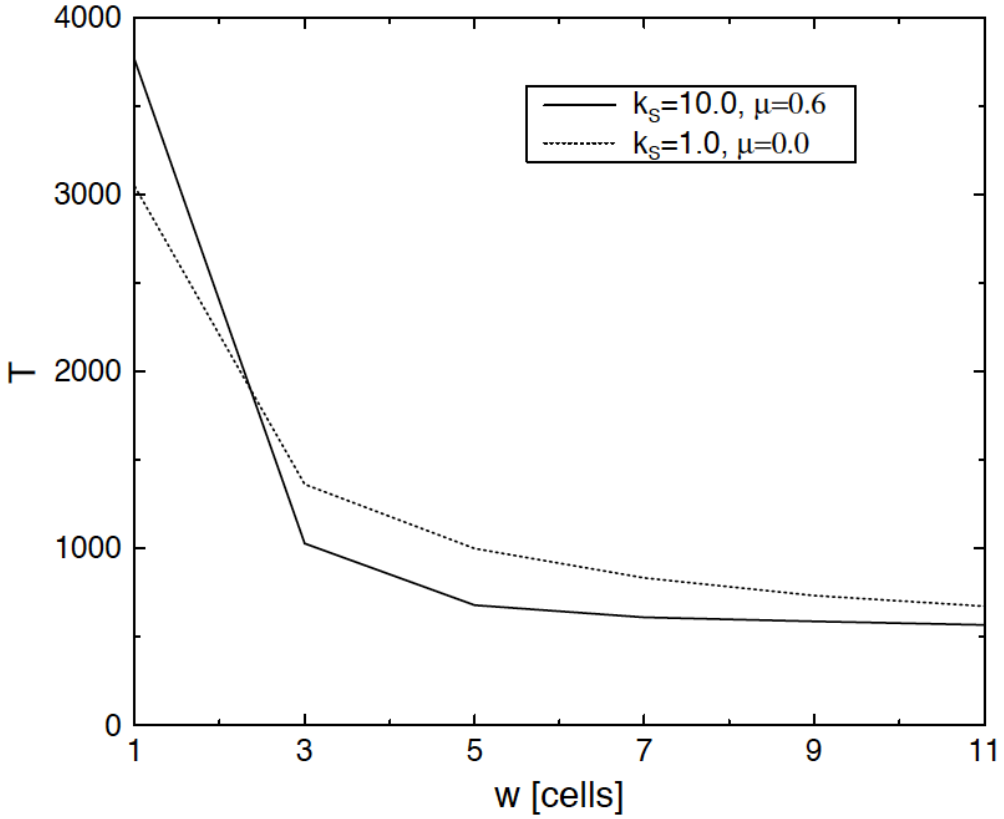

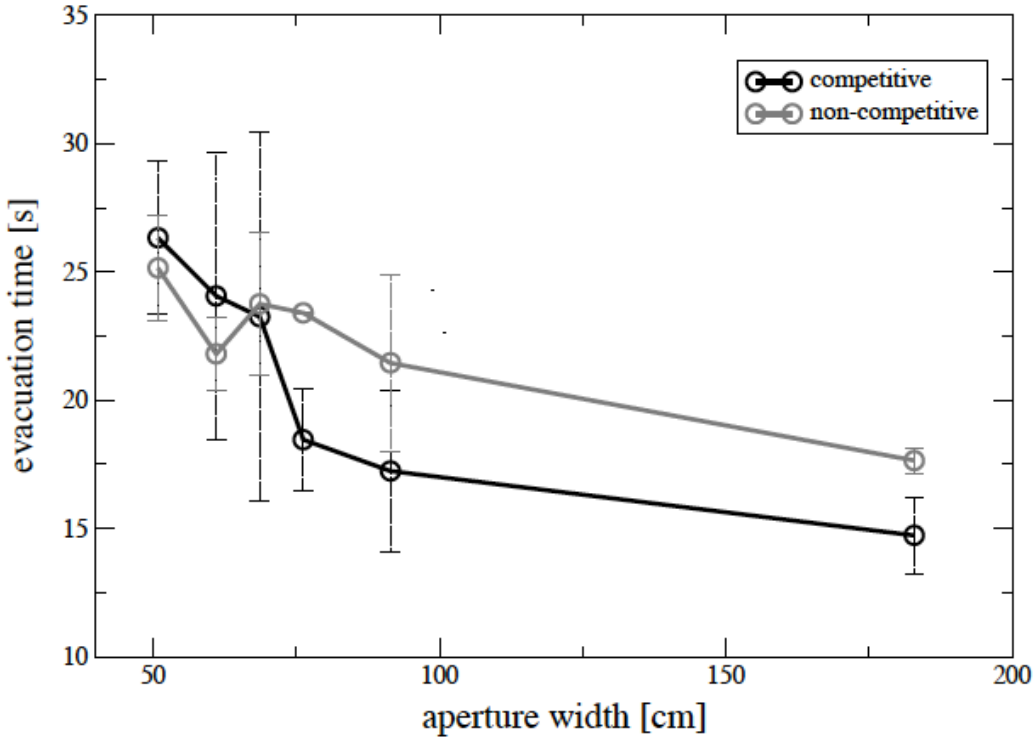

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SUMMARY

THANK YOU FOR LISTENING