Role of Conflicts and Friction in Cellular Automaton Models of Pedestrian Dynamics

Andreas Schadschneider

Institute for Theoretical Physics

University of Cologne, Germany

and

Interdisziplinäres Zentrum für

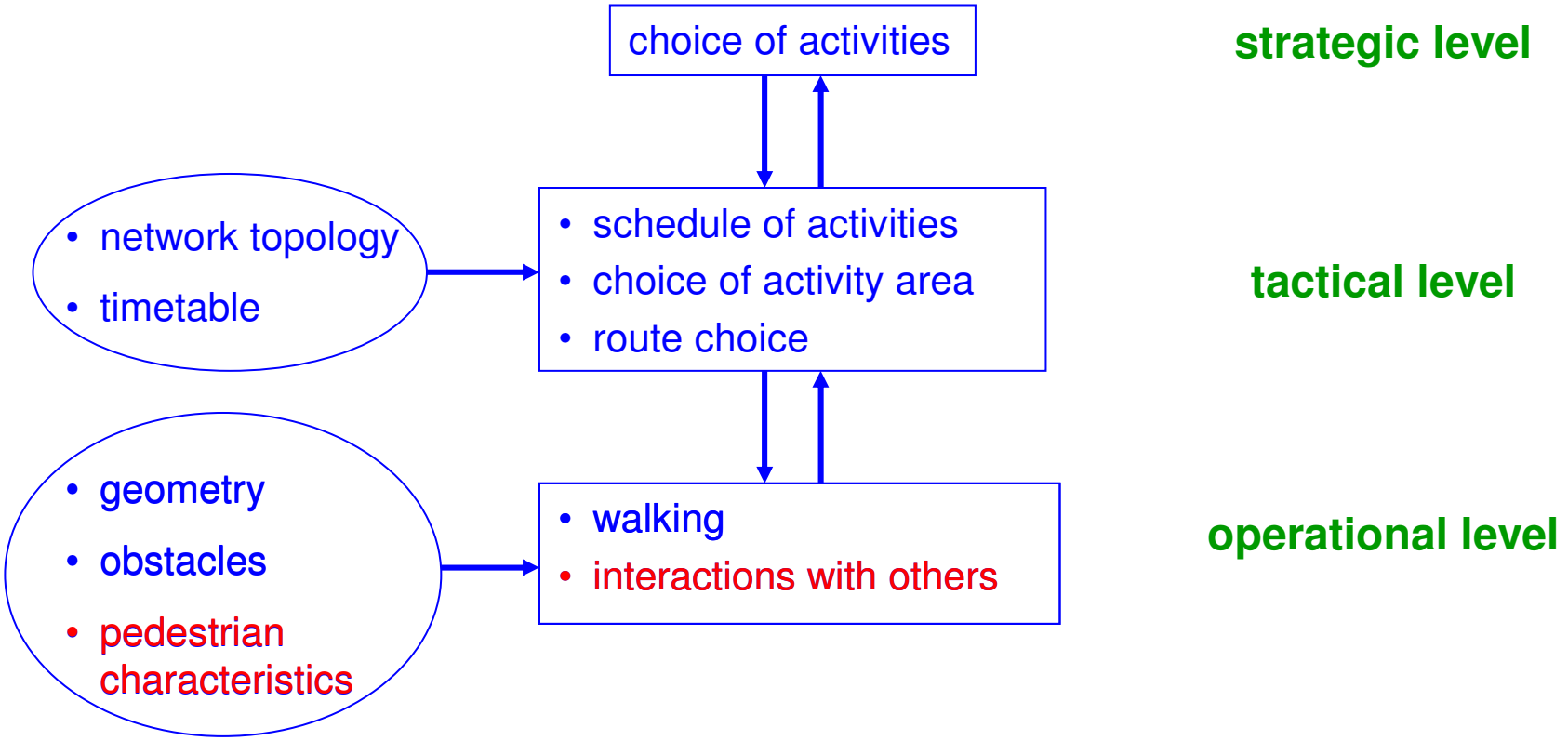
Komplexe Systeme, Bonn, Germany

www.thp.uni-koeln.de/~as

www.thp.uni-koeln.de/ant-traffic

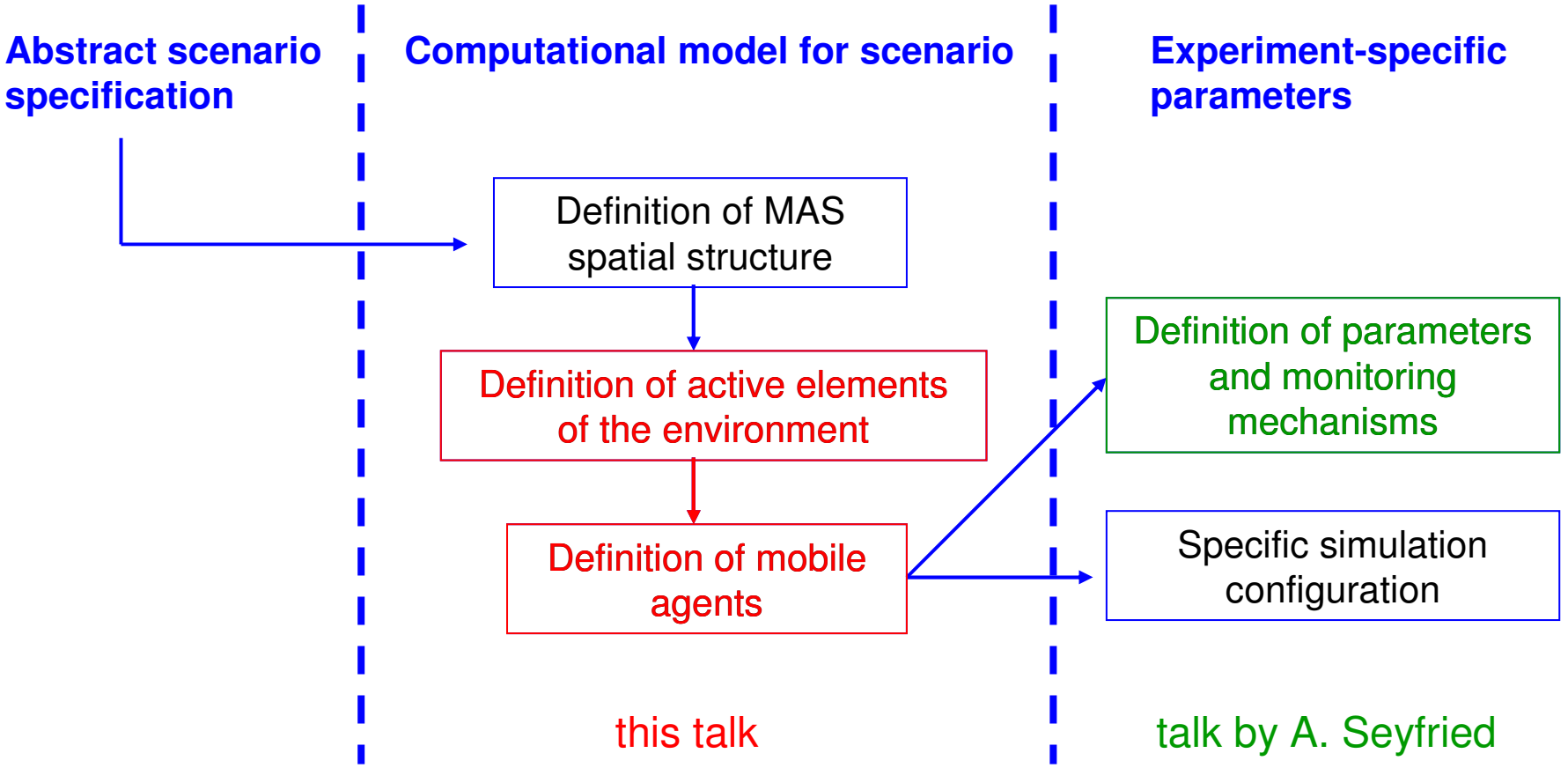
Introduction

Levels of Modeling



MAS Modeling Methodology

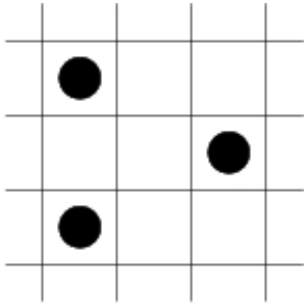
after Bandini/Federici/Vizzari 2007



Cellular Automata and SCA

Cellular automata (CA) are discrete in

- space
- time
- state variable (e.g. occupancy, velocity)



In transport and traffic models:

exclusion principle: only one agent per cell

→ extended to Situated Cellular Agent (SCA)

Discretization

Space discretization: cells of 40*40 cm^2

Exclusion principle: no more than one agent per cell

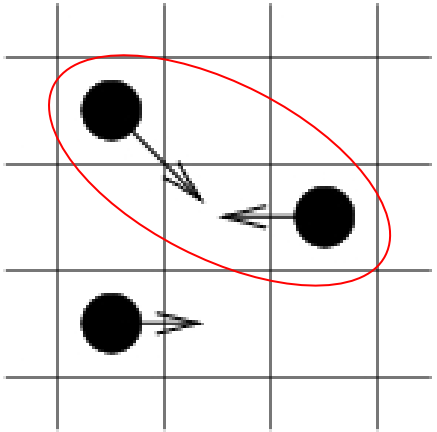
Discrete time (turn-based):
parallel (synchronous) update (= agent activation strategy)

reflects existence of natural timescale, e.g. reaction time

➡ calibration and quantitative predications possible!!

Conflicts

Conflict: 2 or more agents choose the same target cell



Consequence of discreteness in time and exclusion!!

Conflicts have to be resolved in some way

➡ reduce computational efficiency

What's the Problem ?

Generic problem in traffic-type models: conflicts

Are conflicts (i) artefacts or (ii) essential for dynamics?

(i): controlled by environment
(ii): property of the agents

(see also Schumacher/Ossowski 2006, Bandini/Vizzari 2007)

intrinsic part of real dynamics ⟶ resolve on operational level

conflicts not intrinsic ⟶ part of the environment
(agent activation strategy)

Conflicts and Friction

Conflicts: Artefact or Real Effect ?

Long debate in pedestrian modelling community!

Conflicts reduce efficiency of simulations

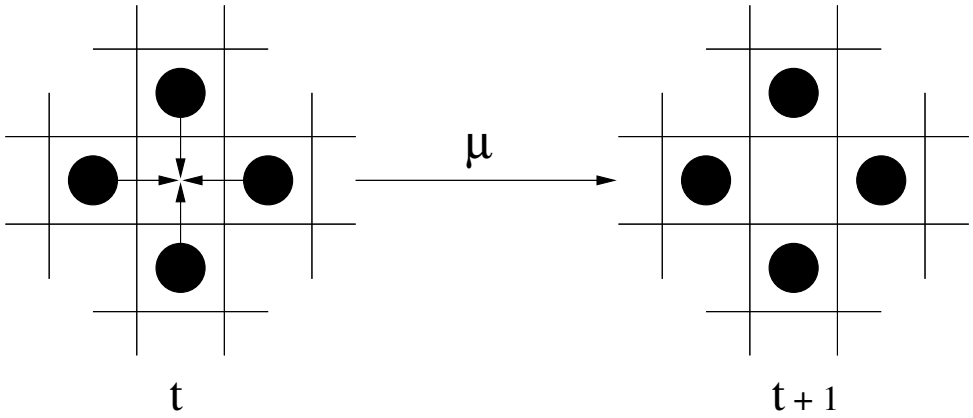
$\longrightarrow$ often avoided by special update choice (sequential agent activation strategies)

Problem: no proper timescale (calibration??)

However: Conflicts relevant for more realistic description !!

Friction

Friction: not all conflicts are resolved! (Kirchner, Nishinari, Schadschneider 2003)



friction constant μ = probability that no one moves

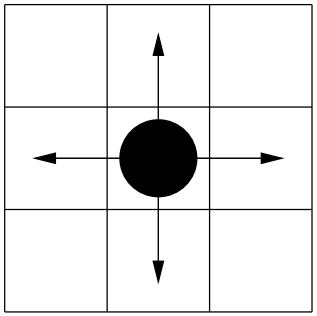
Conflicts and friction correspond to real effects, e.g.

- physical contact
- moment of hesitation

Floor Field Model

Transition Probabilities

Stochastic motion, defined by transition probabilities



0	$p_{-1,0}$	0
$p_{0,-1}$	$p_{0,0}$	$p_{0,1}$
0	$p_{1,0}$	0

3 contributions:

- Desired direction of motion
- Reaction to motion of other pedestrians (interactions)
- Reaction to geometry (obstacles, walls, exits etc.)

Floor Field Model: Unified description of these 3 components

Floor Field Cellular Automaton

Floor field CA: only local interactions

reproduces known collective effects (e.g. lane formation)

Interaction: virtual chemotaxis (similar to insects, e.g. ants)

long-ranged interactions in space are translated into local interactions with "memory"

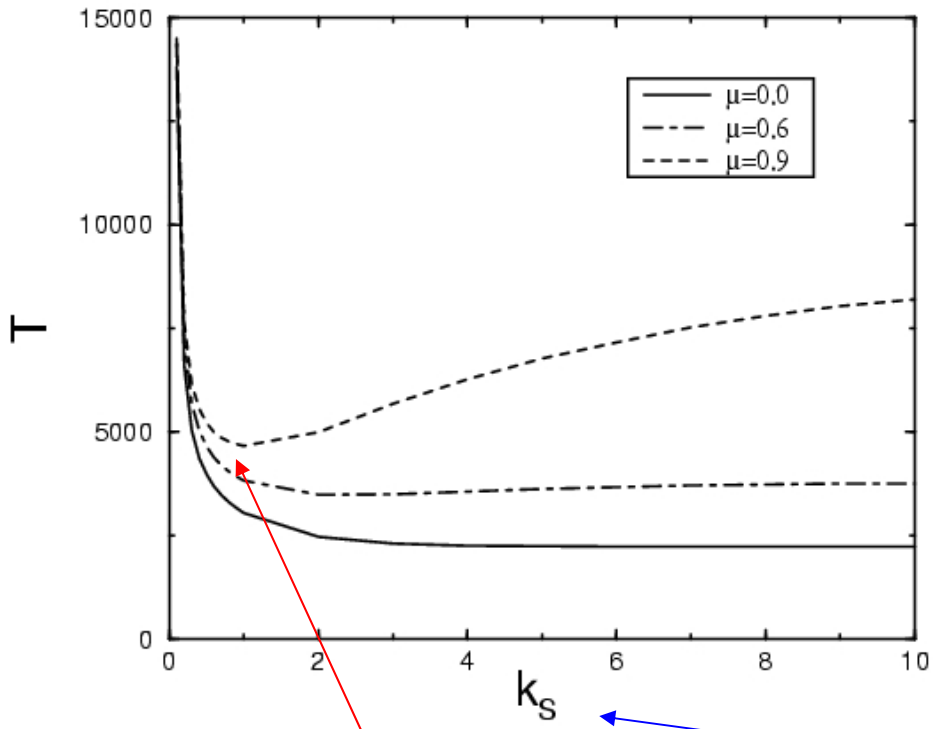
dynamic + static floor fields

interaction with pedestrians and infrastructure

General principle: motion into direction of larger fields is preferred


Evacuation
Simulations

Evacuation Scenario With Friction Effects



(Kirchner, Nishinari, Schadschneider 2003)

evacuation time

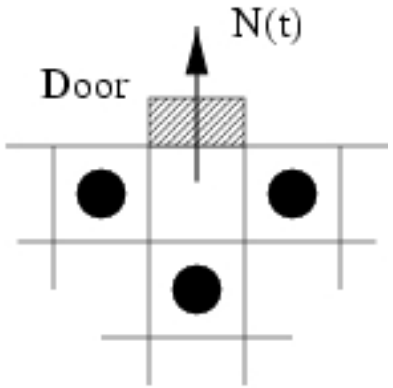
effective velocity

Faster-is-slower effect

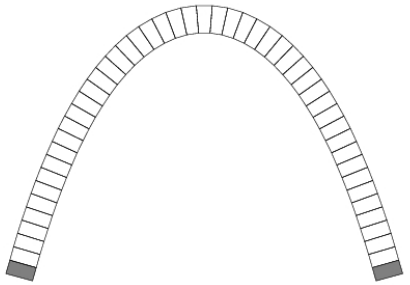
Friction at Exits

Friction at exits increases evacuation times by reducing the outflow

→ increases evacuation times



Granular materials: Arching



away from exits it can even have positive effects, e.g. because jamming at door is suppressed

→ Faster-is-slower effect

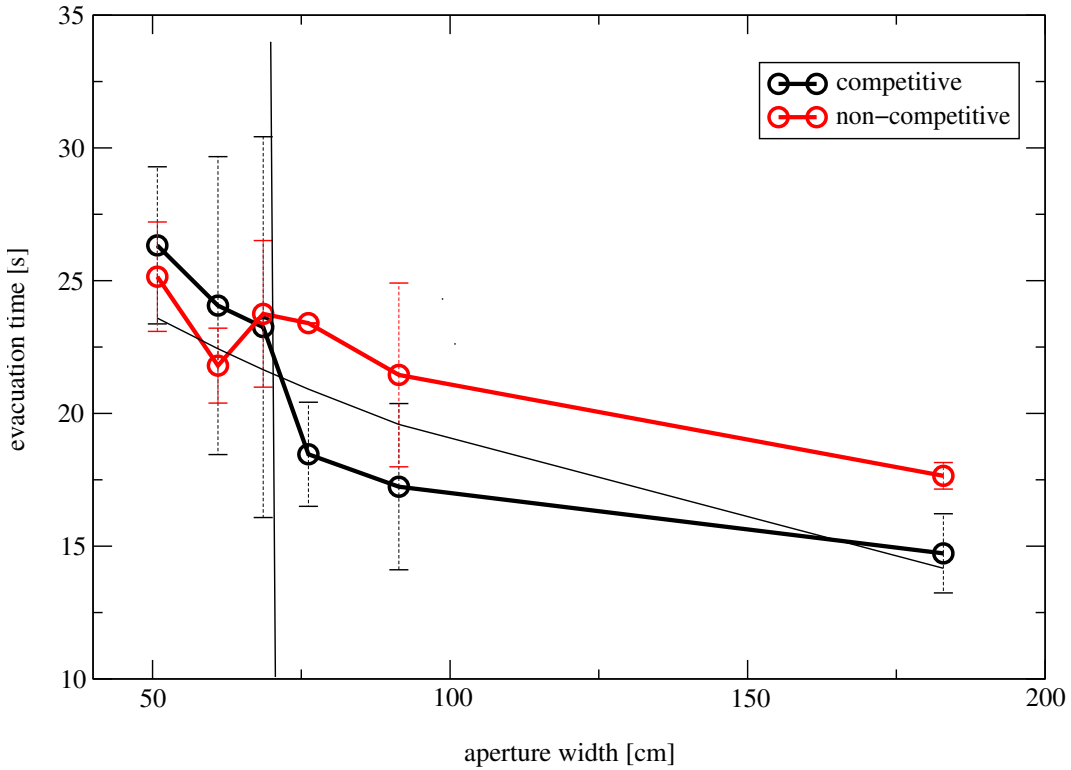
Competitive vs. Cooperative Behaviour

Experiment: egress from aircraft (Muir et al. 1996)

Evacuation times as function of 2 parameters:

- motivation level
  - competitive (T_{comp})
  - cooperative (T_{coop})
- exit width w

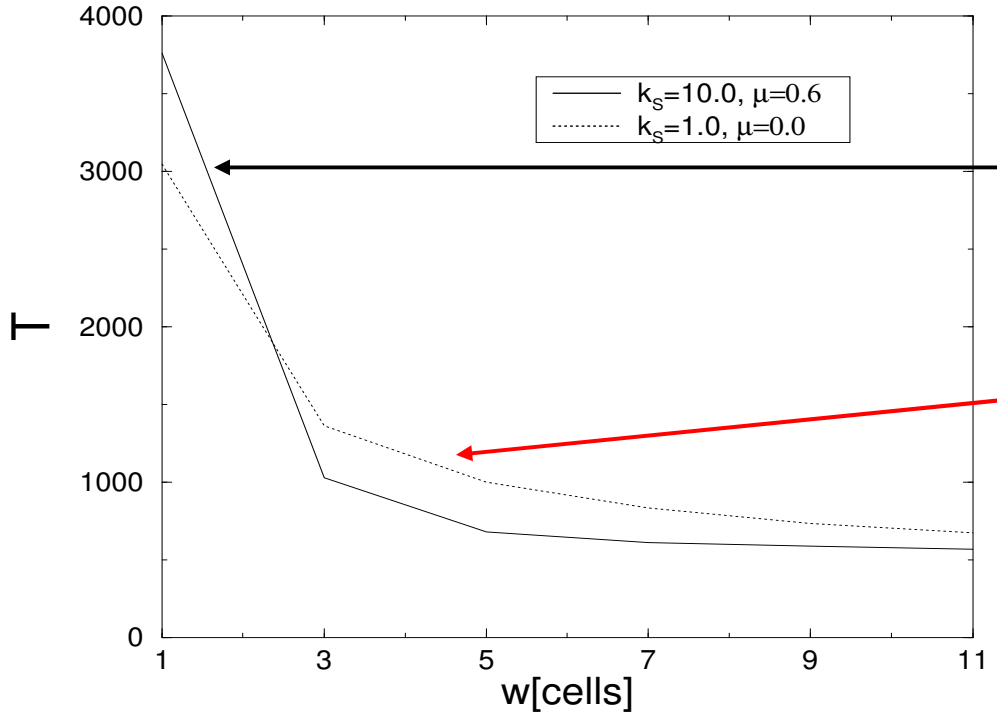
Empirical Egress Times



$T_{comp} > T_{coop}$ for $w < w_c$

$T_{comp} < T_{coop}$ for $w > w_c$

Model Approach



Competitive behaviour:

large k_S + large friction μ

Cooperative behaviour:

small k_S + no friction μ=0

(Kirchner, Klüpfel, Nishinari, Schadschneider, Schreckenberg 2003)

Summary and Conclusions

Summary

Relevance of conflicts and friction in pedestrian dynamics

- no artefact of discreteness of the underlying model
- reflects effects of physical contact and hesitation
- important in high-density situations, e.g. at bottlenecks in evacuation scenarios
- explains surprising behaviour observed in evacuation experiments