Cellular or Continuous?

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SMPS

Katedra matematiky FJFI ČVUT v Praze

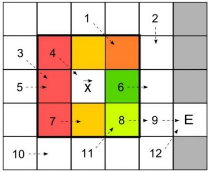
Program

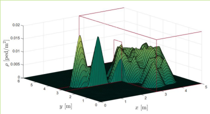
Obsah

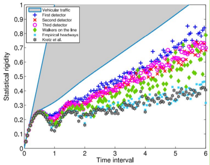
Historical overview

Brief pedestrian modeling history on FNSPE

- eigenvalue distance analysis [M. Krbálek]
- analytic solution of TASEP [P. Hrabák]
- cellular automata model implementation
- experimental analysis of pedestrian movement
- continuous rule based model [J. Vacková]







Requirements to models

Developer's dilemma

- engineering perspective:
  - reliability
  - simple calibration
  - reasonable calculation demands
  - focus to answer specific questions
- macroscopic perspective
  - infrastructure level
  - language of density, flow, total evacuation time
- scientific perspective
  - ”model to understand”approach
  - possibility to change the code
  - question not set
- microscopic approach
  - individual level
  - language of trajectory, travel time

Model classes

Selected approaches in historical order

- Hand calculations. Applying queuing theory or 'physical' mechanics, we can answer many elemental questions.
- Grid models. These models discrete in space and time are using simple movements rules. E.g. cellular automata
- Force based models. The interaction of pedestrians and infrastructure may be defined as the set of social forces.
- Agent based models. The most modern approach is based on intelligent agent moving in continuous space and time according predefined rules.
- Data driven models. New approach based on finding the best approximation of current situation with database of historical records.

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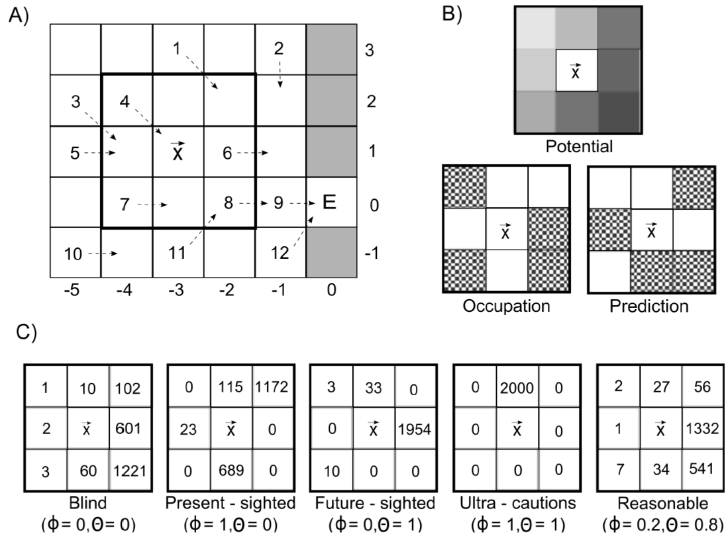
Cellular automata

brief definition

- rectangular matrix with cell size 0.5 m
- a cell is either empty or occupied by one pedestrian
- timespan is therefore set to 0.3 s
- pedestrian pick up desired cell based on profitability and randomness
- the profitability used to be composed of the distance to the exit, occupancy, conflict anticipation and other quantities
- potential conflicts (more pedestrian choose the same cell) are resolved

CA


A)
1
2
3
4
5
6
7
8
9
10
11
12
E
x⃗
3
2
1
0
-1
-5
-4
-3
-2
-1
0
B)
x⃗
Potential
Occupation
Prediction
C)
1 10 102
2 x⃗ 601
3 60 1221
Blind
(ϕ= 0,Θ= 0)
0 115 1172
23 x⃗ 0
0 689 0
Present - sighted
(ϕ= 1,Θ= 0)
3 33 0
0 x⃗ 1954
10 0 0
Future - sighted
(ϕ= 0,Θ= 1)
0 2000 0
0 x⃗ 0
0 0 0
Ultra - cautions
(ϕ= 1,Θ= 1)
2 27 56
1 x⃗ 1332
7 34 541
Reasonable
(ϕ= 0.2,Θ= 0.8)

Rule based continuous model

brief definition

- timespan can be as small as desired and the velocity or course change can as smooth as numerically possible
- each pedestrian has set a checkpoint that he/she wants to reach (an exit, a counter, ...)
- timespan is therefore set to 0.3 s
- rules itself should hierarchically follow ”natural”behavior

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Environmental issues – size

- model pedestrian size should correspond to real one
- pedestrians should not overlap

CA

- pedestrian = cell .. no issue

RBC

- individual (dynamic) radius
- individual assessment of radius
- function checking actual situation

Environmental issues – Anisotropy

- model should ignore translation or rotation of the coordinates

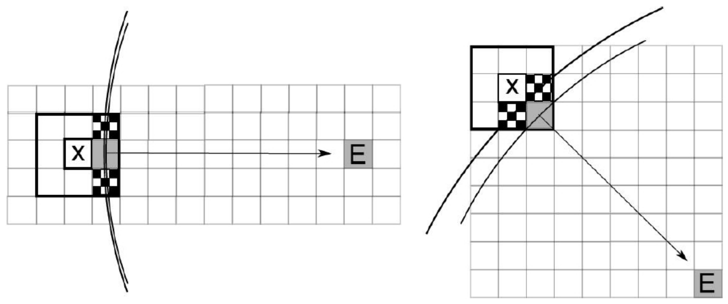
CA

- grid makes any ”skew”trajectory partially rectangular
- diagonal motion allowed $\rightarrow$ two kind of steps
- time penalization implemented (to normalize velocity)
- probability penalization implemented (to normalize probability of deviations)

RBC

- standard mechanic used .. no issue

Dynamic timespan



Environmental issues – Synchronization

- Model should enable normal velocity distribution

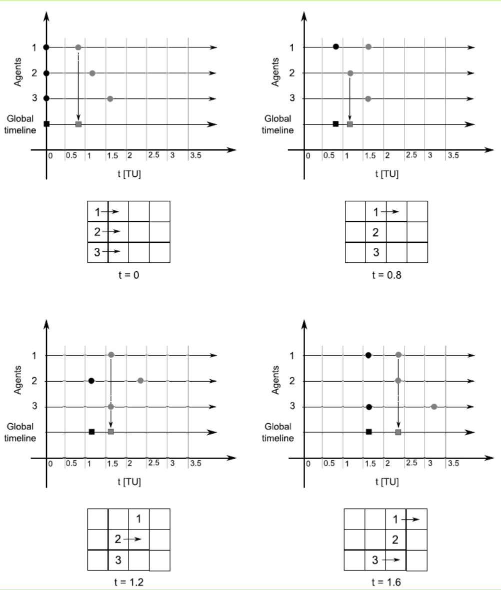
CA

- fixed step length $\rightarrow$ velocity must be modeled by frequency
- time penalization implemented $\rightarrow$ at least semi-integer approach
- dynamic time span:
  - each pedestrian has ”time of next update”
  - independent model clock
  - all agents with $T_a < T_M$ are updated

RBC

- model timestep does non correspond to velocity .. no issue

Dynamic timespan



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Continuous movement

- Model must handle the two pedestrians selected the same spot

CA

- neighborhood profitability is deformed to reduce the change of the conflict
- restrain each other only when they select the same cell
- In such case, friction function is applied to test whether this conflict blocks the motion of all pedestrians

yes: none moves
no: one random/prefered pedestrian selected

CO

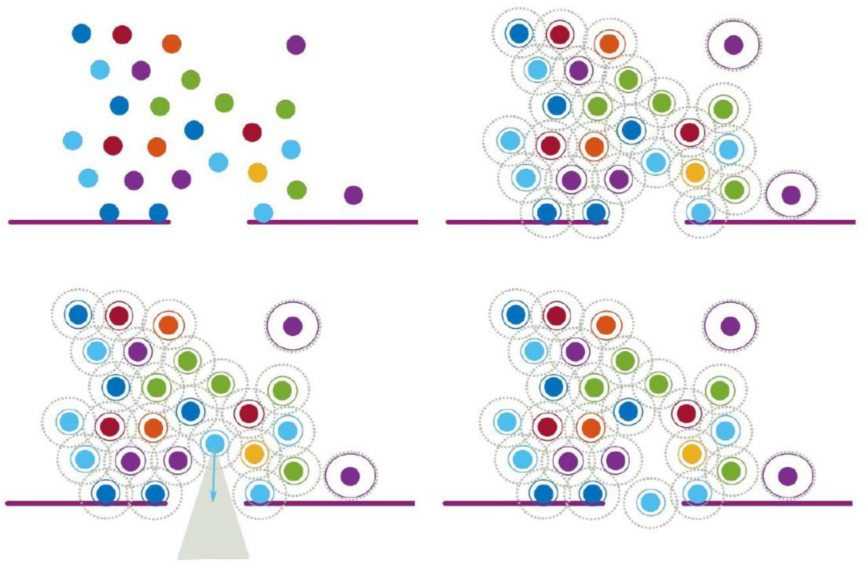
- rules applied level by level
- If this position is blocked the next rule is applied:
  - naive: a pedestrian walks towards checkpoint by desired speed or is accelerating
  - maneuvers: direction or speed adjusted
  - downsizing: pedestrian reduce his/her velocity up to certain level
  - jump: pedestrian jumps to empty space toward the exit, if reachable

Rules

Figure 2: Operational phase: collision avoidance by course change - the blind velocity, searching for admissible positions, the final position.

Figure 3: Operational phase: collision avoidance by slowing down - the course change does not work, searching for positions by shortening the blind distance, the final position.

Rules



Packed movement

- Motion is observed even there are no gaps

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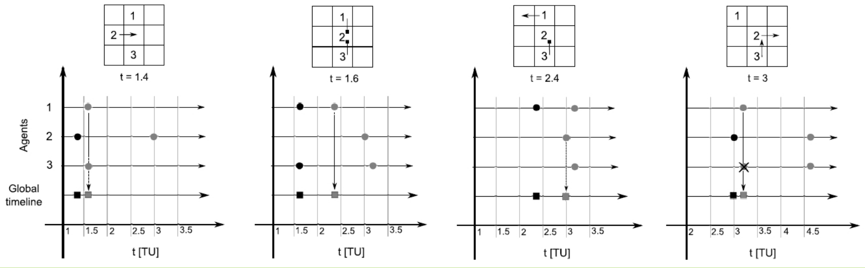
- agent may pick up occupied cell
- bond to the agent is created
- whenever an leader moves, follower moves as well
- standard conflict procedure is applied in case of more followers

RBC

- small timestep + serial update .. no issue

Rules



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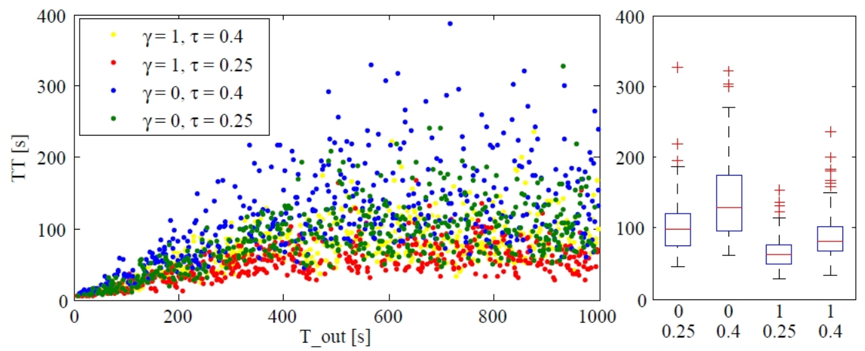
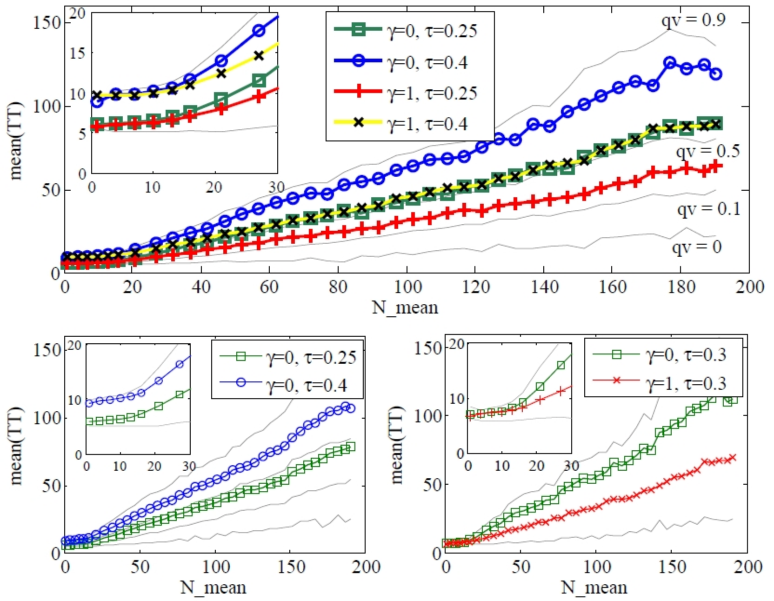
Heterogeneity

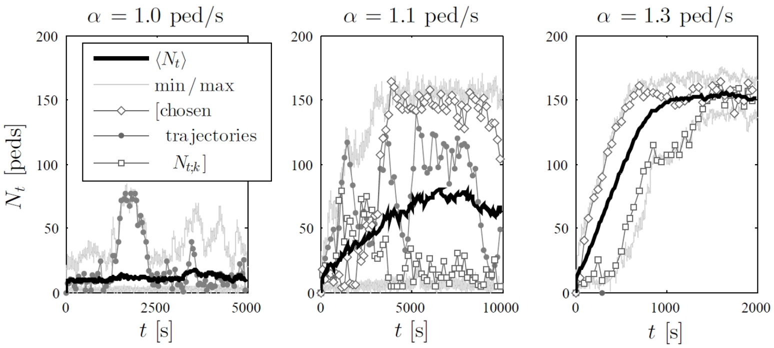


Individual travel time for heterogeneous population, development in time. $\gamma = 1$ refers to aggressive behavior, τ is the update period.

Heterogeneity

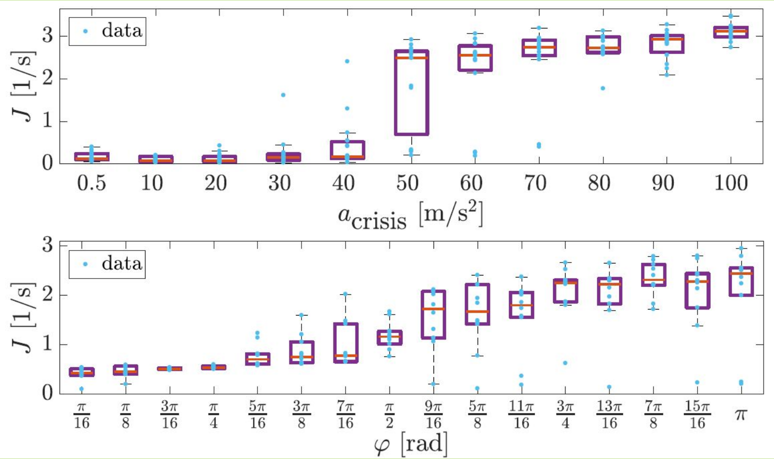


Phase transition



Trend of occupancy in time for different values of friction parameter.

Calibrability



The outflow with respect to critical acceleration and course change range

Thank you for your attention!

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