Modeling and Simulation

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Micro traffic flow modeling based on human behavior

TCA: Nagel-Schreckenberg (NaSch) model

- One of TCA model is NaSch model:
  - The NaSch model is called a *minimal model*, in the sense that all these rules are a necessity for mimicking the basic features of real-life traffic flows;
  - It was able to reproduce several characteristics of real-life traffic flows, e.g., the spontaneous emergence of traffic jams.

Rule of NaSch model[1,2]

- (R1) acceleration and braking

$$v_i(t+1) \rightarrow \min\{v_i(t)+1, gs_i(t), v_{\max}\}$$

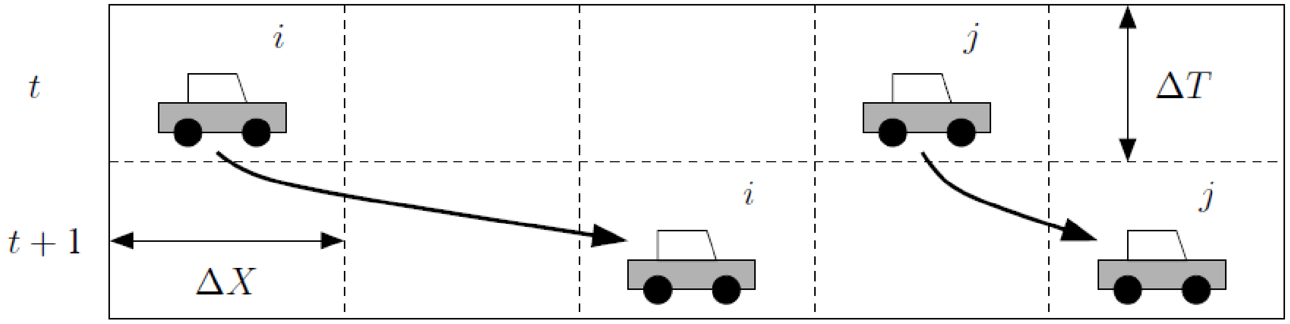
- (R2) randomization

$$v_i(t+1) \rightarrow \max\{0, v_i(t)-1\}$$

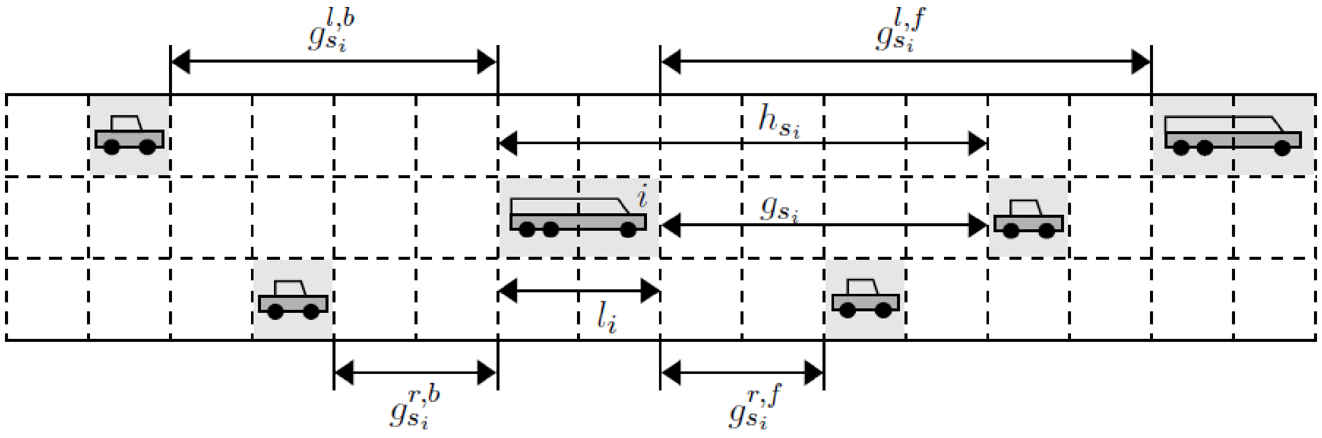
with probability *p*

- (R3) vehicle movement

$$x_i(t+1) \rightarrow x_i(t)+v_i(t+1)$$



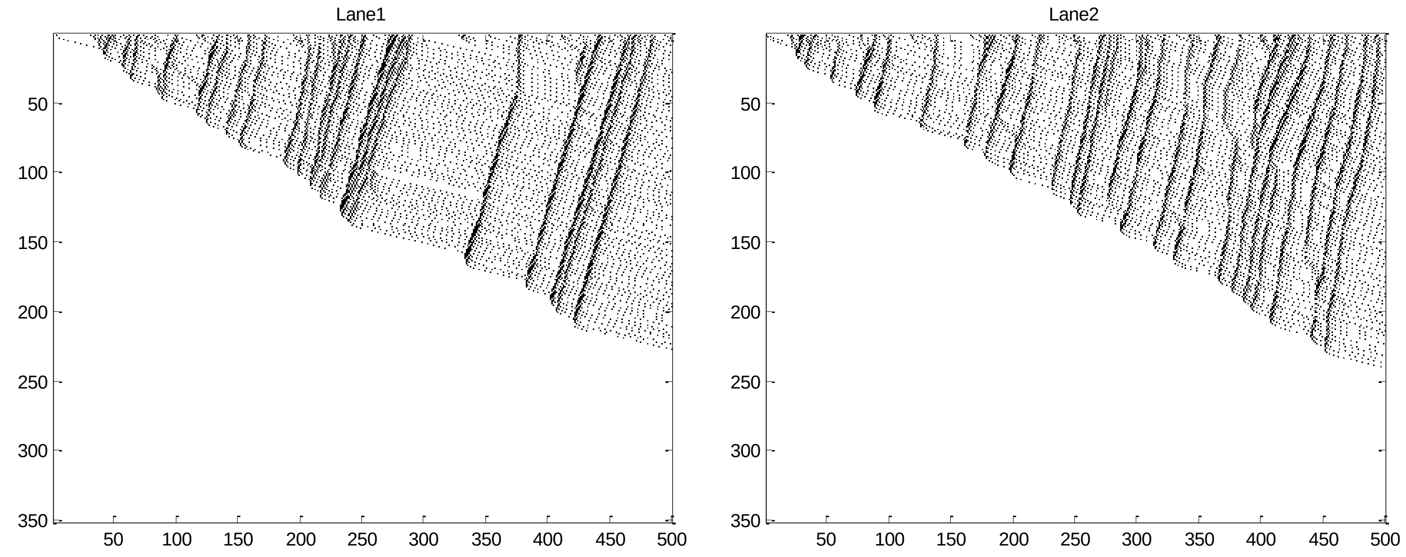
Pergerakan 1 jalur dari *t* ke *t*+1



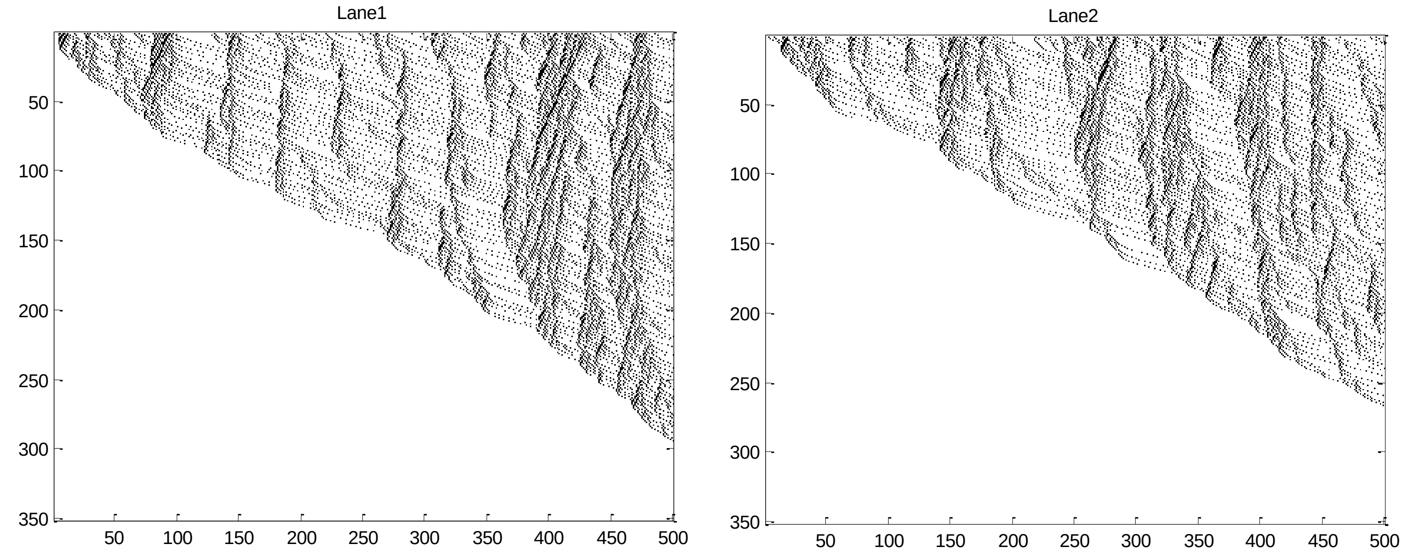
Posisi 6 kendaraan dg 3 jalur dg kendaraan pusat *i*

[1] Nagel, K. & Schreckenberg, M.: A cellular automaton model for freeway traffic, *Journal Physics I France*, 2(12), pp. 2221-2229 (1992)
[2] Maerivoet, S. and De Moor, B.: Cellular automata models of road traffic, *Physics Reports*, 419(1), pp. 1-64 (2005)

Time-Space Diagram of NaSch Model



- One example of NaSch model:
  - road length $L = 500$
  - density $k = 0.2$
  - max. speed(=5) $v_{max} = 5$
  - slowdown prob. $p = 0.1$
  - prob. of lane-changing LC=1



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Our additional parameters → (Modified NaSch Model)

- Diligent driver,
- Deceleration in advance,
- Lane-changing → security criterion,
- Panic parameter.

Diligent driver characteristic

- There is additional speed *c* in diligent drivers

$$c = [0:1]$$

Deceleration in advance[1)]

- a vehicle will decelerate in advance when its velocity is higher than the leading one;
- a driver estimates the velocity difference Δv^e;
- $\Delta v^e > 0$ means that the current (following) vehicle is approaching the leading one.

the driver will decelerate in advance

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1) Xin-Gang Li et al., Deceleration in advance in the Nagel-Schreckenberg traffic flow model, Physica A, 388, pp. 2051-2060, 2009

Deceleration in advance

- Then estimated space gap at time step t+1 is determined by

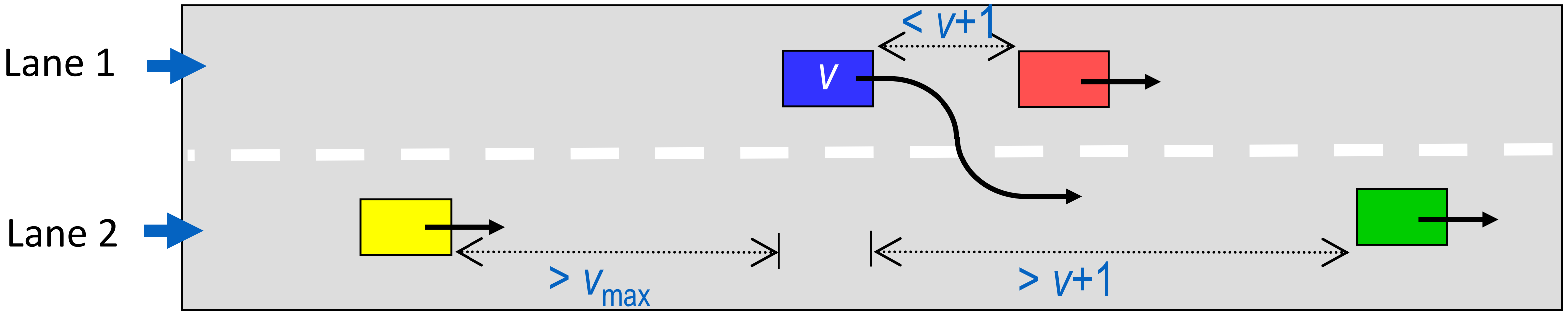
$$gs_i^e(t) = \max(0, gs_i(t) - \lfloor \alpha \Delta v^e \rfloor)$$

$gs_i = x_{i+1} - x_i - 1$: the number of empty cells in front of the vehicle i;
x_i : the position of the vehicle i

$\lfloor x \rfloor$ is defined by the largest integer no larger than x

α is a constant value → we used 0.5

Lane-changing[1,2] → Security criterion



with probability of lane-changing p_{lc}

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[1]M. Rickert et al., Two Lane Traffic Simulations using Cellular Automata, Physica A, 231(4), pp. 534-550, 1996
[2]K. Nagel et al., Two-lane traffic rules for cellular automata: A systematic approach, Physical Review E, 58(2), pp. 1425-1437, 1998

Panic parameter[1)]

- Referring to Dirk Helbing et al., 2000;
- A panic situation is determined by probability of panic P_p;
- A panic situation influences the vehicle speed;
- In a panic situation: there are two behavior of the driver; individualistic and herding behavior

1) Dirk Helbing et al., Simulating dynamical features of escape panic, Nature, Vol. 407, pp. 487-490, 2000

Panic parameter

- We assume the vehicle speed under the panic situation is a mixture of individualistic and herding behavior; and weighted with P_p;

$$v_{i,j}(t) = \underbrace{(1 - P_p) v_{max}}_{\text{Individualistic behavior}} + P_p \underbrace{(0.1 v_{max})}_{\text{Herding behavior}}$$

Individualistic behavior

Herding behavior

P_p is small → Individualistic behavior

P_p is large → Herding behavior

Our modified traffic flow model based on human behavior

- Referring to the estimated gap (at deceleration in advance) and lane-changing parameter, also human behavior (diligent and panic driver), our proposed model by the rules as follows:
  - (R1) determine the estimated gap
  - (R2) acceleration and braking;
  - (R3) randomization;
  - (R4) vehicle movement *with/without lane-changing*.

Our modified traffic flow model based on human behavior

Note for R1:

- (R1) determine estimated gap

$$\Delta v_{i,j}^{e} > 0 \Rightarrow gs_{i,j}^{e}(t) = \max\left(0, gs_{i,j}(t) - \lfloor \alpha \Delta v^{e} \rfloor\right)$$

else $\quad gs_{i,j}^{e}(t) = gs_{i,j}(t)$

with $\alpha = 0.5$

Comparison between Nagel's Rule and its Modified

Nagel's Rule

- (R1) acceleration and braking

$$v_i(t+1) \rightarrow \min\{v_i(t)+1, gs_i(t), v_{max}\}$$

- (R2) randomization

$$v_i(t+1) \rightarrow \max\{0, v_i(t)-1\}$$

with probability p

- (R3) vehicle movement

$$x_i(t+1) \rightarrow x_i(t)+v_i(t+1)$$

its Modified

- (R1) determine estimated gap

$$\Delta v_{i,j}^e > 0 \Rightarrow gs_{i,j}^e(t) = \max(0, gs_{i,j}(t) - \lfloor \alpha \Delta v^e \rfloor)$$

else $gs_{i,j}^e(t) = gs_{i,j}(t)$

with $\alpha = 0.5$

- (R2) acceleration and braking

$$v_i(t+1) \rightarrow \min\{v_i(t)+1, gs_i(t), v_{max}\}$$

- (R3) randomization

$$v_i(t+1) \rightarrow \max\{0, v_i(t)-1\}$$

with probability p

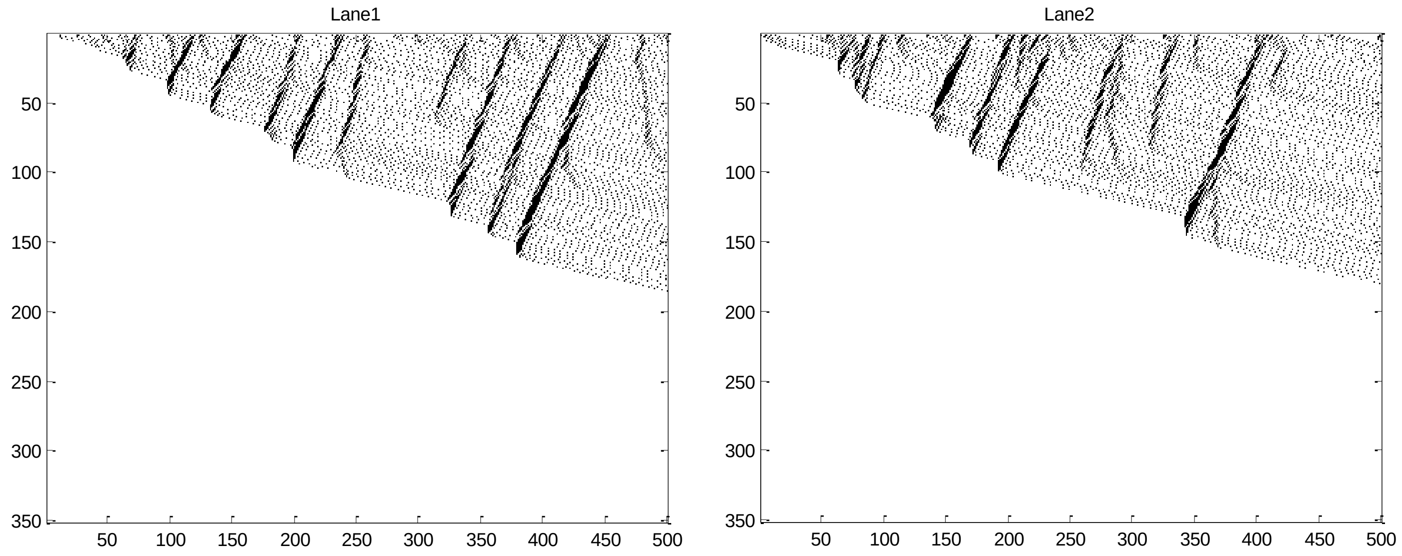
- (R4) vehicle movement

$$x_i(t+1) \rightarrow x_i(t)+v_i(t+1)$$

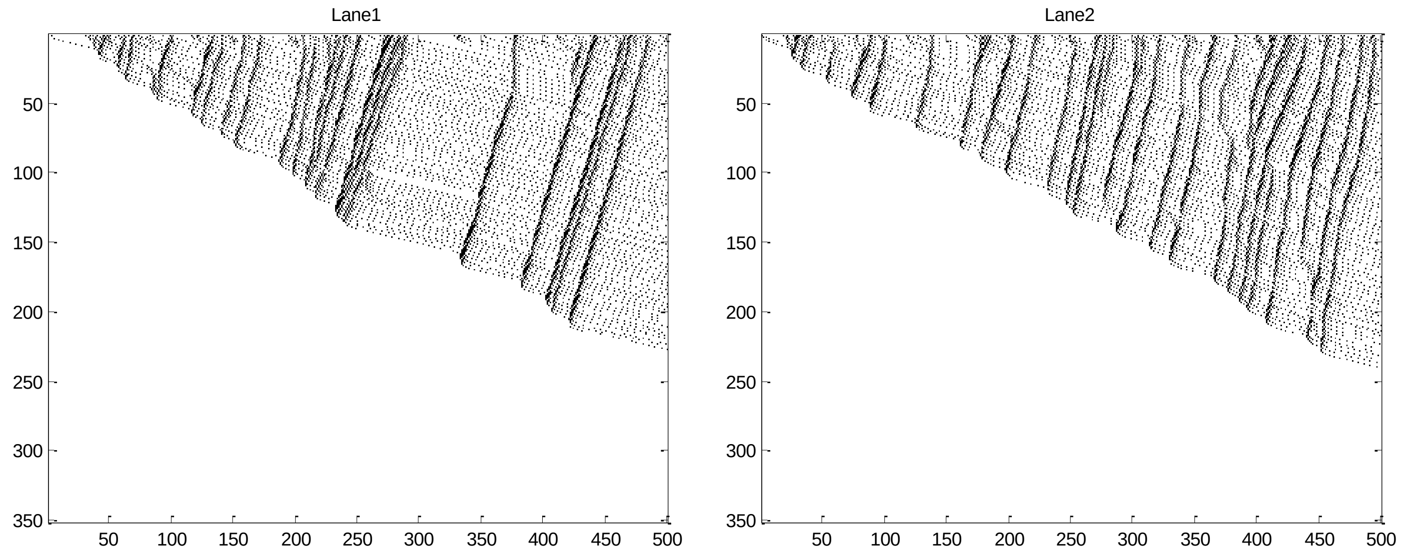
Simulation →Specifications

- road length (based on the traffic measurement) is 3.5 km (3500 m),
- each lane of the road is divided into L sites/cells of equal size,
- using two-lane traffic,
- L is assumed to be 500,
- the length of one site (cell) is set to 7 m (be assumed each vehicle occupies about 7m of place = length of one site).

Comparison between Modified Model and Nagel Model



- **Modified model:**
  - road length $L = 500$
  - density $k = 0.2$
  - max. speed(=5) $v_{max} = 5$
  - slowdown prob. $p = 0.1$
  - prob. of lane-changing $Lc = 1$
  - Prob of diligent driver $dd = 0.8$
  - WITHOUT DECELERATION



- **NaSch model:**
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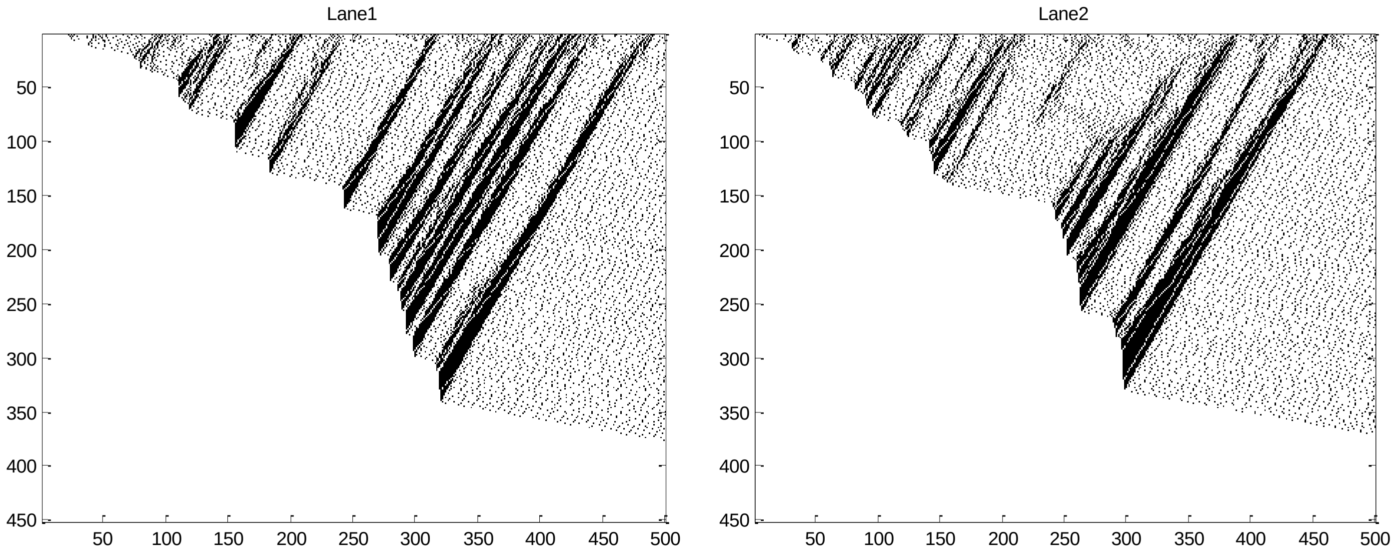

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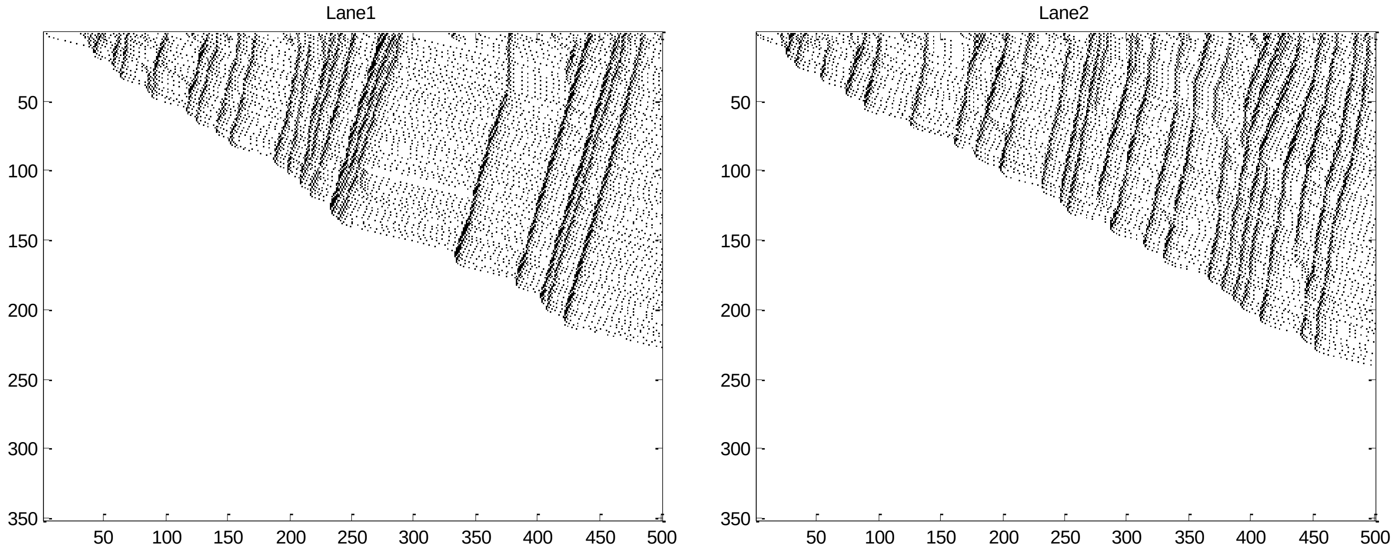

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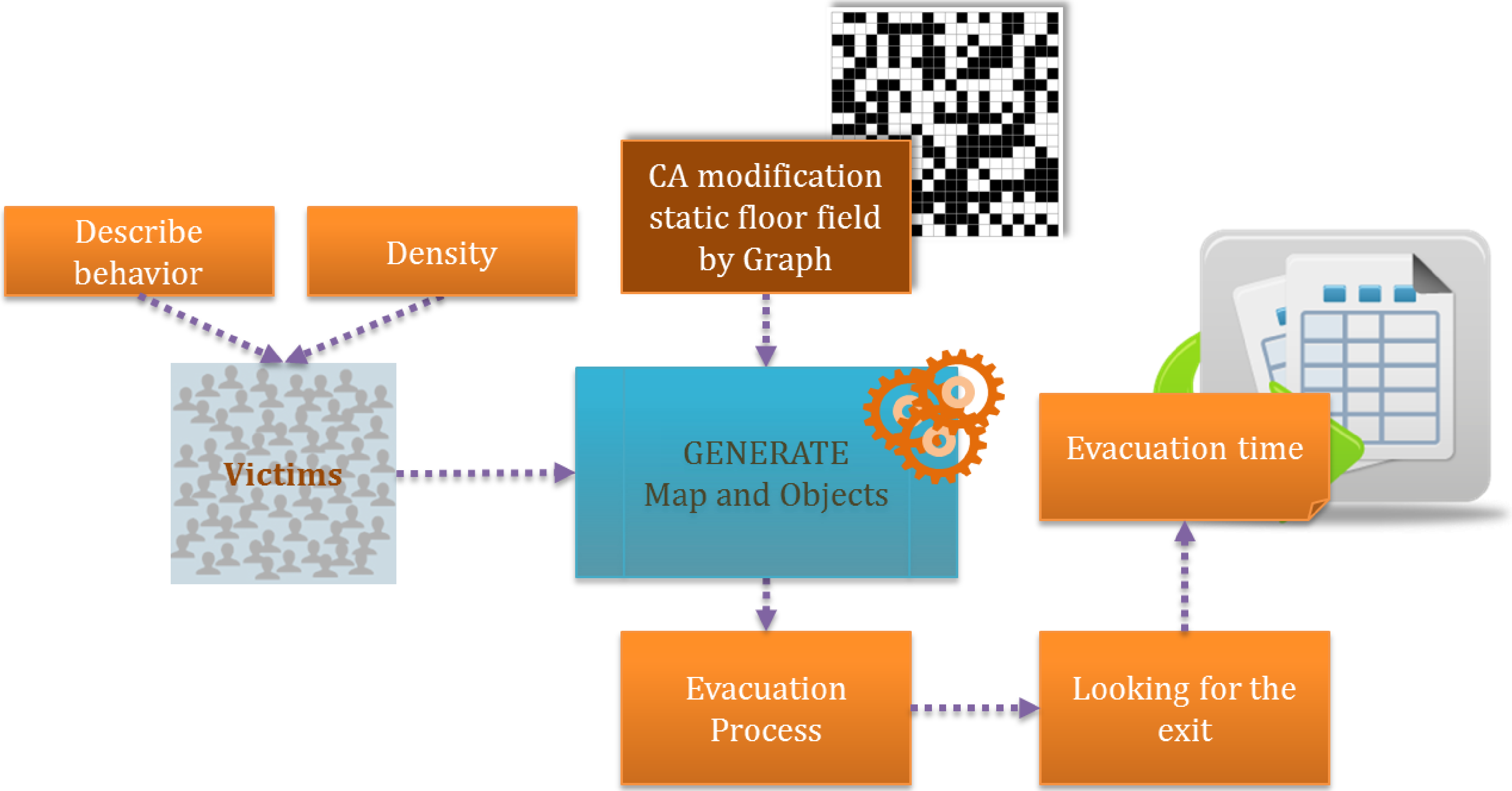
Evacuation System In The Building Using Cellular Automata For Pedestrian Dynamics

System Design



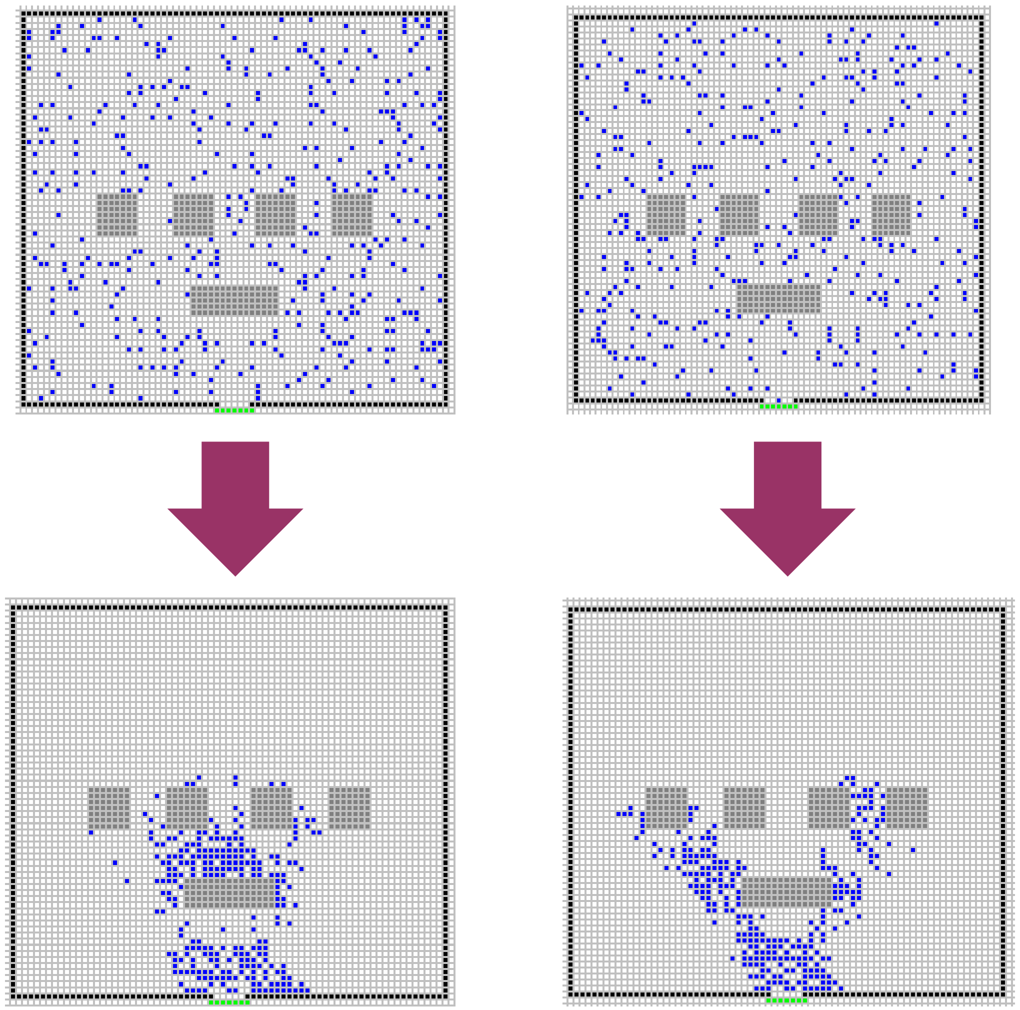
Describe Human Behavior – Density

- If $ks \leq 1$ → pedestrians do not have sufficient knowledge about the environment. It suggests that the pedestrians are confused to find the exit and assume that the room is full of smoke, in case of fire. For vanishing ks, the pedestrians will perform random walk and just find the door by chance.
- If $ks \geq 1$ → pedestrians have sufficient knowledge about the environment and know the location of exit.
- If $kd \geq 1$ → It has the effect that the pedestrians follow each other
- Normal Pedestrians → If value of $ks > kd$ and value of $ks > 1$.
- Panic Pedestrians → If $kd > ks$, the greater value of kd would make follow each other (*herding behavior*).

Describe Human Behavior - Density

- We refer to *Surabaya Local Government* rules about shopping center
- Surabaya Local Government divides category of shopping center density of visitors into three parts:
  - *low density* (on Monday, Tuesday, and Wednesday),
  - *middle density* (visitors on Thursday and Friday),
  - *high density* (visitors on Saturday and Sunday (weekend))

CA Modification → Floor Field

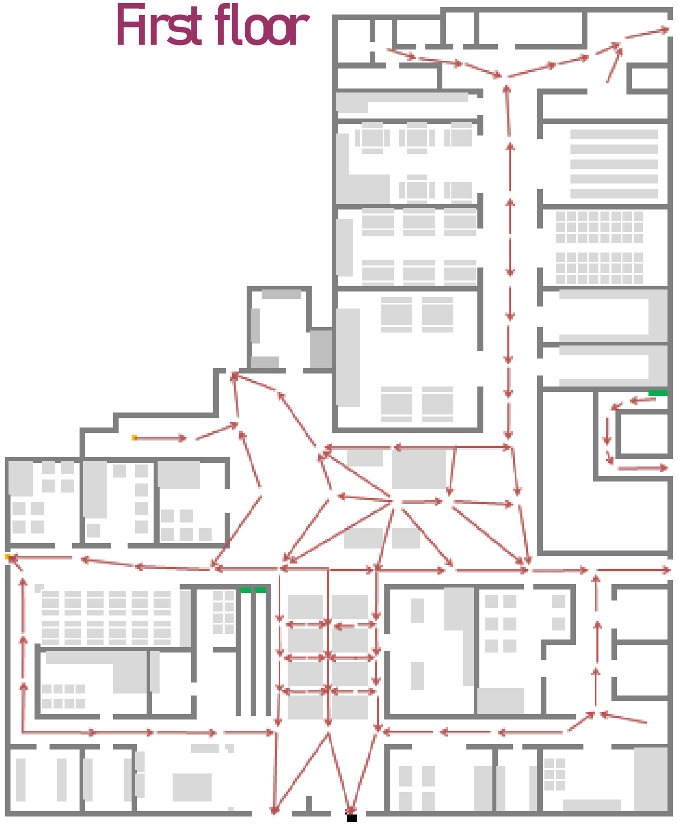


Generate Map and Objects → Marina Plaza Surabaya

- Preprocessing of the Plaza Marina Map in the first and second floor on the two-dimensional matrix
- The first floor has six doors.
- The second floor has three doors.

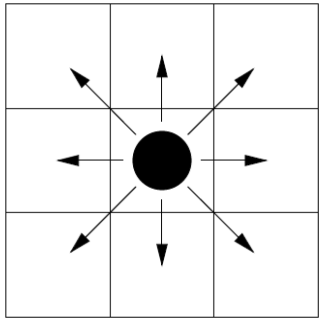
Generate Map and Objects → Initial Graph in the case study

First floor



Second floor

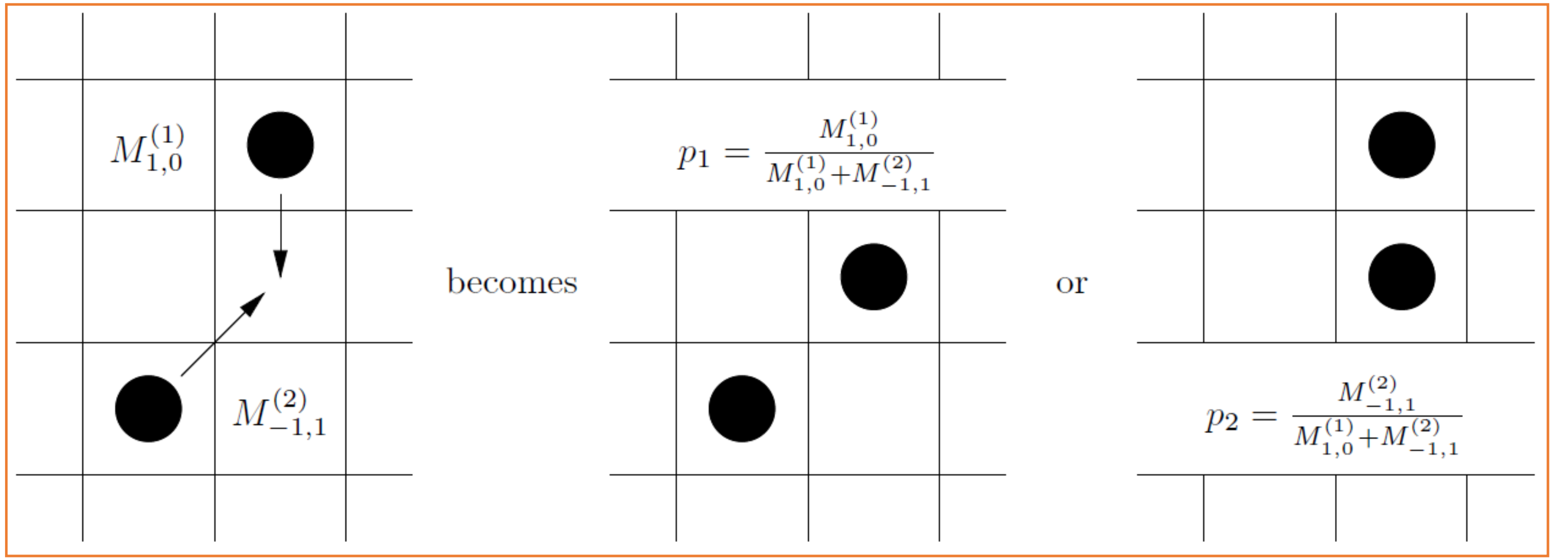
Evacuation Process → Basic rules



$M_{-1,-1}$	$M_{-1,0}$	$M_{-1,1}$
$M_{0,-1}$	$M_{0,0}$	$M_{0,1}$
$M_{1,-1}$	$M_{1,0}$	$M_{1,1}$

A particle, its possible transitions and the associated matrix of preference $M = (M_{ij})$.

Two particles will move to the same target



Evacuation Process → Transition Probabilities

1)

$$P_{ij} = NM_{ij}D_{ij}S_{ij}(1 - n_{ij})$$

P_{ij} : transition probability

N is a normalization factor to ensure $\sum_{(i,j)} p_{ij} = 1$

M_{ij} : Matrix preferences

D_{ij} : Value of matrix dynamic floor field at index i,j.

S_{ij} : Value of matrix static floor field at index i,j.

n_{ij} : Indicator of neighboring cell, 1 if any pedestrian and 0 if empty.

2)

$$p_{ij} = N \exp(k_D D_{ij}) \exp(k_S S_{ij})(1 - n_{ij})\xi_{ij}$$

obstacle number: $\xi_{ij} = \begin{cases} 0 & \text{for forbidden cells, e.g. walls} \\ 1 & \text{else} \end{cases},$

normalisation: $N = \left[\sum_{(i,j)} \exp(k_D D_{ij}) \exp(k_S S_{ij})(1 - n_{ij})\xi_{ij} \right]^{-1}$

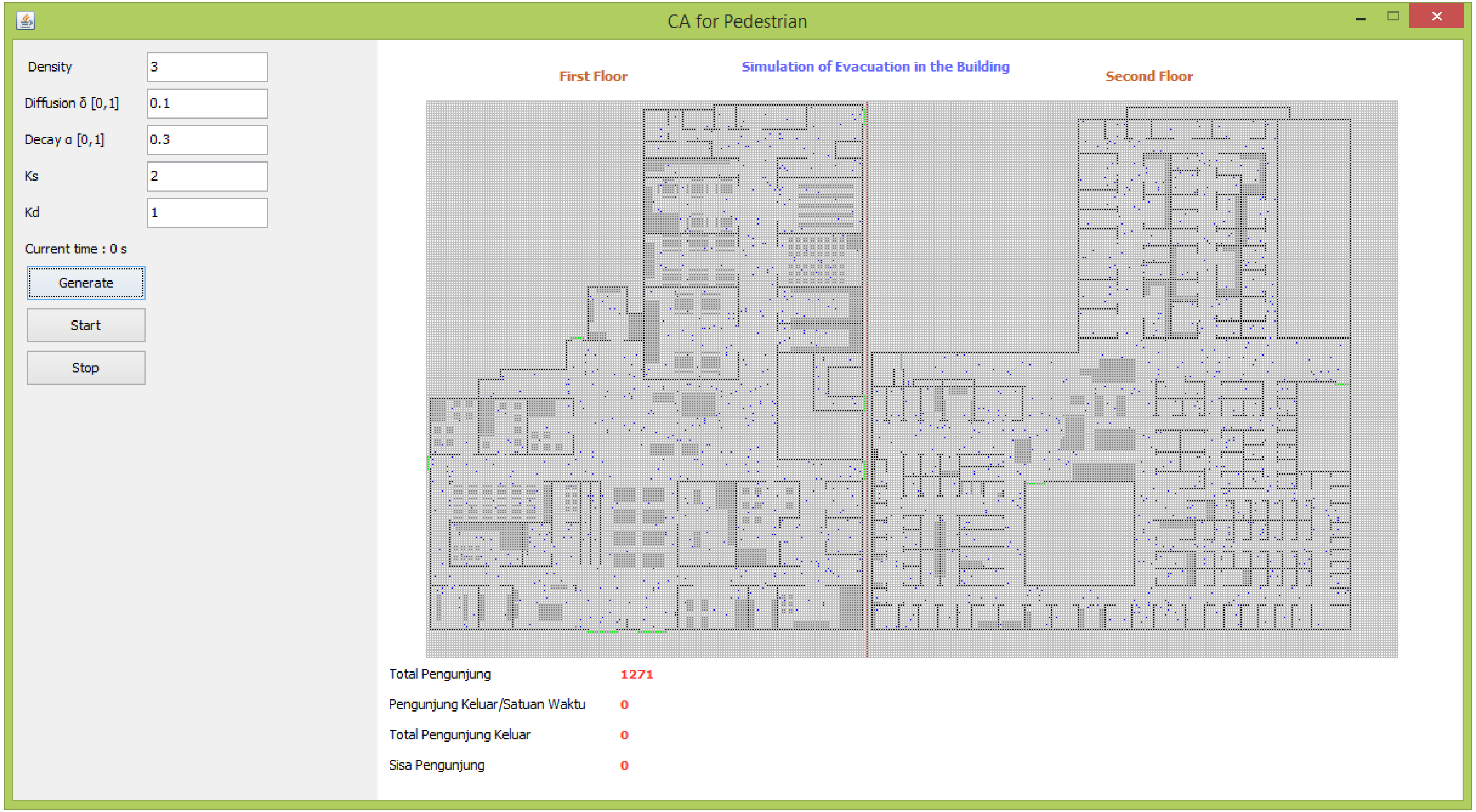
$k_S \in [0, \infty[$ and $k_D \in [0, \infty[$: two sensitivity parameters

1. Burstedde C, Klauck K. **Simulation of Pedestrian Dynamics Using a Two-dimensional Cellular Automaton,** Institut fur Theoretische Physik, Germany, 2001. *Physica A 295 (2001) 507–525*
2. Kircher A, Scadscheneider A. **Simulation of Evacuation Process Using a Bionics-inspired Cellular Automaton Model for Pedestrian Dynamics**. Koln University, Germany, *Physica A 312 (2002) 260 – 276*

Evacuation Process → Update rules

- The dynamic floor field *D* is modified according to its diffusion and decay rules
- For each pedestrian, the transition probabilities for a move to an unoccupied neighbour cell (i, j) is determined by the matrix of preferences and the local dynamic and static floor fields
- Each pedestrian chooses a target cell based on the probabilities of the transition matrix $P = (pij)$
- The conflicts arising by any two or more pedestrians attempting to move to the same target cell are resolved
- The pedestrians which are allowed to move execute their step
- The pedestrians alter the dynamic floor field of the cell they occupied before the move

Initial view, before running the program



The program is running

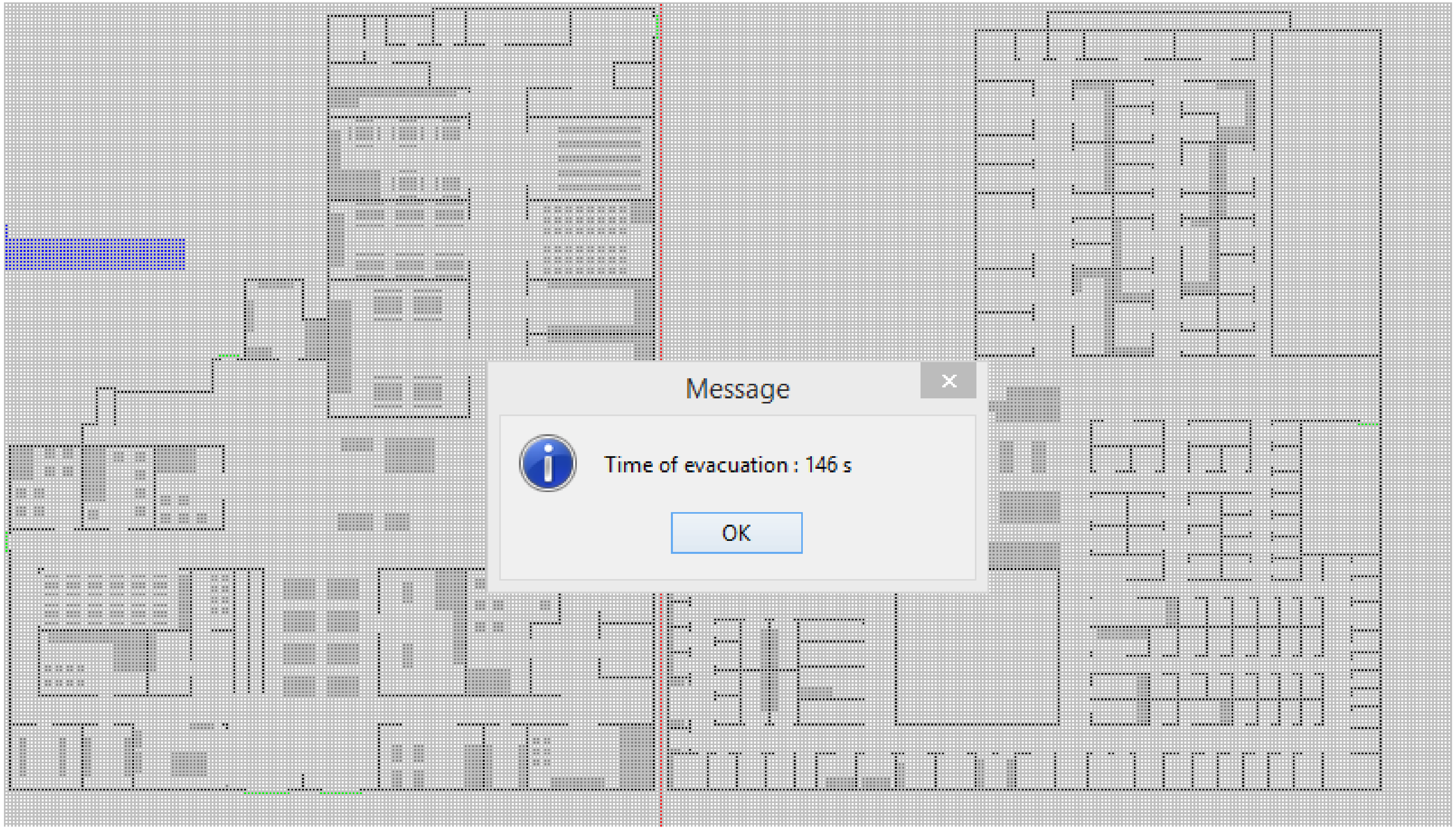
50 time steps

150 time steps

200 time steps

300 time steps

Evacuation time from simulation results



The end of the Program shows the evacuation time = 146 seconds (= 438 time step)

Other studies

- Modeling/generating panic in a person.
- Visually Realistic Rain Modeling Optimization for VR Application.
- Pemetaan Resiko Gempa Bumi dg Penggabungan Deskriptif, Prediktif, dan Asosiatif Mining.

Thank you