On time scaling and validation of a stochastic CA pedestrian dynamics model

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Abstract This paper deals with a problem of time scaling and validation of a mathematical model of a pedestrian flow. We focus on stochastic cellular automata approach. What kind of tests should be applied to say that model ``works"? In this paper some our tests and time scaling observations are presented.

Introduction

Modeling of pedestrian dynamics is an actual problem today. Different approaches from the social force model based on differential equations to stochastic CA models are developed [1]. They reproduce many collective properties and are an important basis for pedestrian modeling. But there are still things to be done.

There is still no common set of test to verify models from uniform positions. Validation of models with fundamental diagrams doesn't solve this problem completely. For example, diffusion of the flow can't be reproduced by the model and can't be checked consequently.

Here we present our attempt to investigate dynamics of our model and some observations about time scaling. Note that very simple case studies are used; they don't allow for all aspects of model dynamics to be pronounced. So it is only starting (but obligatory) point for complex investigation of the model.

Model

The model is stochastic discrete CA model and supposes short-term decisions made by the pedestrians [3]. From the comprehensive theory of pedestrian dynamics [1] such model may be refereed to tactical level. (The model was presented at the PED2008.)

The space (plane) is known and sampled into cells $40cm \times 40cm$ which can either be empty or occupied by one pedestrian (particle) only [2]. Cells may be occupied by walls and other nonmovable obstacles.

The model imports idea of a map (static floor field S) from the floor field (FF) CA model [2] that provides pedestrians with information about ways to exits. Our field S increases radially from exit cells. It doesn't evolve with time and isn't changed by the presence of the particles.

A target point for each pedestrian is the nearest exit. Each particle can move to one of four its next-neighbor cells or to stay in present cell (the von Neumann neighborhood) at each discrete time step $t \to t+1$; i.e., $v_{\max} = 1[step]$.

A typical scheme for stochastic CA models is used in our model. There is step of some preliminary calculations (field S is computed). Then at each time step transition probabilities are calculated, and directions are chosen. If there are more then one candidates to one cell a conflict resolution procedure is applied, and then a simultaneous transition of all particles is made.

Because of a restricted volume we omit here update rules and probability formulas. We only note here that normal (not emergent) directed evacuation was investigated; i.e., pedestrian sees, knows, and wants to go to the exit very much. This supposes strong influence of the static floor field S, therefore $k_S = 4$ (k_S is a sensitivity parameter of the field S).

Case study

The following case studies were used, see Fig.1. We considered long rooms $2m \times 50m$, $2m \times 100m$, and $2m \times 150m$. Set of initial numbers of particles N was considered, see Table 1. For each room for each initial density ρ_0 100-500 runs were made (initial positions of particles were fixed).

Observables obtained during experiments are the following: total evacuation time (in steps) distribution (as an estimate of the total evacuation time (T_{tot}^{50}, T_{tot}^{100}, T_{tot}^{150}) we use mode of each time distribution); direction frequencies distribution over series of experiment for each ρ_0 for each room; $\tilde{T}_{tot}^{50} = T_{tot}^{50}[st]$, $\tilde{T}_{tot}^{100} = T_{tot}^{100} - 125[st]$, $\tilde{T}_{tot}^{150} = T_{tot}^{150} - 250[st]$ (see Table 1). We calculated the flows $J^{50} = N / \tilde{T}^{50} / 2$, $J^{100} = N / \tilde{T}^{100} / 2$, $J^{150} = N / \tilde{T}^{150} / 2$.

Table 1.

ρ_0 [1/m^2]	ρ_0	N	$\tilde{T}_{tot}^{50}$	$\tilde{T}_{tot}^{100}$	$\tilde{T}_{tot}^{150}$
0,25	0,04	25	130	133	141
1	0,16	100	132	138	141
2	0,32	200	140	150	157
3	0,48	300	154	170	184
3,5	0,56	350	166	193	206
4	0,64	400	190	213	229
4,5	0,72	450	211	234	247
5	0,80	500	232	261	275
5,75	0,92	575	265	291	311

For the 50 m room we have $\min \tilde{T}_{tot}^{50}(\rho_0^{\min}) = 125$, $\min \tilde{T}_{tot}^{50}(\rho_0^{\max}) = 250$ (due to exclusion principle). Shifts that the model gives (see Table 1, column $\tilde{T}_{tot}^{50}$) are coursed by not strictly one-dimensional motion and stochastic nature of the model. Nevertheless Figure 2 shows strong prevalence of the right side movements with gradually increasing ``No" leaving present position under increasing density. Left direction (opposite to exit) has a miserable value and decreases with increasing initial density. Such behavior of virtual people may be refereed to realistic.

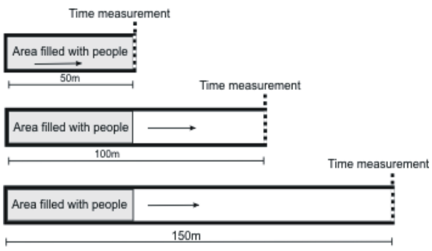

Fig. 1. Case study.

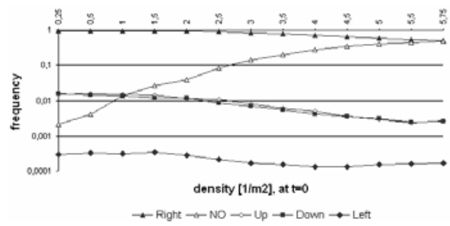

Fig. 2. Direction frequency distribution, 50 m.

Experiments with 100m and 150m rooms show diffusion of the flow (decompression). In such environment a real people flow has diffusion and it's more pronounced with increasing initial density. Divergence of data from columns $\tilde{T}_{tot}^{100}$, $\tilde{T}_{tot}^{150}$ with corresponding values from column $\tilde{T}_{tot}^{50}$ says that the model realizes the diffusion. Diffusion doesn't present directly in the model. This effect is simulated indirectly, and the main contribution is given by the stochasticity of the model. Figure 3 shows that flows J^{100}, J^{150} are lower then J^{50} and it becomes more pronounced under higher ρ_0; non of the flows reach maximal possible value 1.252.

Figure 4 gives some observations on time scaling problem in CA models. For the 50 m room line 3 is the flow $J = N/T/2 \approx v\rho$ after the data of Predtechenskii and Milinskii, which may be considered as an upper bound of the flow in this case study. Line 1 is the flow $J^{50} = N/\tilde{T}^{50}/2$, which may be considered as a low bound of the flow. Line 4 gives flow $J^{50} = N/(\tilde{T}^{50}_{tot} \cdot 0.3)/2$, which is unrealistically higher than the estimated upper bound. Therefore timescale $\Delta t = 0.3[s] = 0.4[m]/1.3[m/s]$ is not proper starting with $\rho_0 > 1[per/m^2]$. Line 2 corresponds to the flow $J^{50} = N/(\tilde{T}^{50}_{tot} \cdot \Delta t(\rho_0))/2$, where

$$\Delta t(\rho_0) = \begin{cases} 0.4/v(\rho_0), & \rho_0 \le 3; \\ 0.4/v(\rho = 3), & \rho_0 > 3. \end{cases}$$

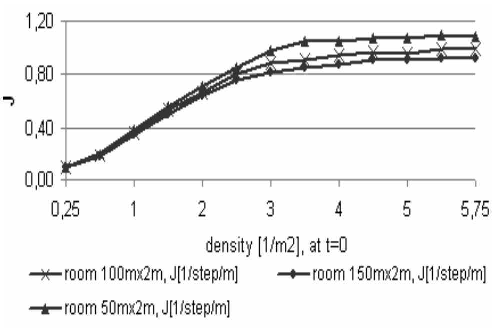

Fig. 3.

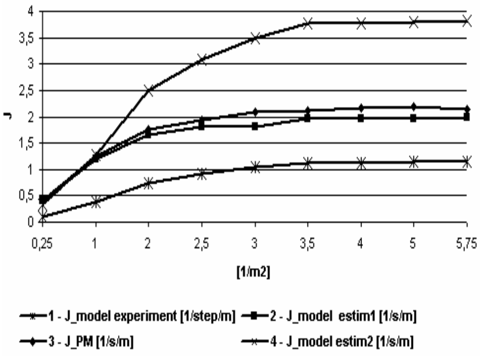

Fig. 4.

Thus our experiments (tests) show that model (under certain parameters) provides directed movement of the particles, diffusion of the flow. For this case study one better method of time scaling is proposed. But these results don't describe all the dynamical properties of the model. Turning flows are not still mentioned, and influence of turnings to model dynamics is not investigated.

References

1. Schadschneider, A., Klingsch, W., Kluepfel, H., Kretz, T., Rogsch, C., and Seyfried A.: Evacuation Dynamics: Empirical Results, Modeling and Applications, Encyclopedia of Complexity and System Science, Springer. (2009).

2. Schadschneider, A. and Seyfried, A.: Validation of CA models of pedestrian dynamics with fundamental diagrams, Cybernetics and Systems, **40** (5), 367-389. (2009).

3. Kirik, E., Yurgel'yan, T., and Krouglov, D.: The Shortest Time and/or the Shortest Path Strategies in a CA FF Pedestrian Dynamics Model, Journal of Sib. Fed. University, Mathematics and Physics Series, **2** (3), 271–278. (2009).