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

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***Abstract*—This paper deals with a problem of time scaling and verification of mathematical model of a pedestrian movement. We focus on stochastic cellular automata (CA) approach. What kind of tests should be applied to say that model "works"? In this paper our set of tests and some time scaling observations are presented.**

***Keywords*-Cellular automata; pedestrian dynamics; transition probabilities; verification, statistical analysis**

I. INTRODUCTION

Modelling of pedestrian dynamics is an actual problem at present days. Different approaches from the social force model based on differential equations to stochastic CA models are developed [1]. They are an important and remarkable basis for pedestrian modelling. But there are still things to be done.

There is still no common set of test to verify models from uniform positions. Single validation of models with fundamental diagrams don't solve this problem completely. Moreover, there are various of data where flow is connected with density (ρ) ([1], [2]). The data vary very much and can't be used for model validation as an uniform approach.

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 be pronounced. So it is only starting(but obligatory) point for complex investigation of the model.

II. 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 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.

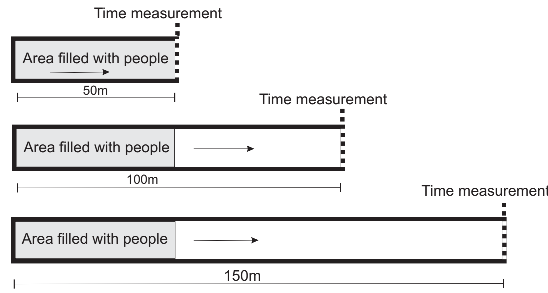

Figure 1.

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 $t \rightarrow t+1$; 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 f ield S).

III. CASE STUDY

The following case studies were used, see Figure 1. We considered long rooms $2m \times 50m$, $2m \times 100m$, and $2m \times 150m$ ($5cells \times 125cells$, $5cells \times 250cells$, and $5cells \times 375cells$ correspondingly). 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).

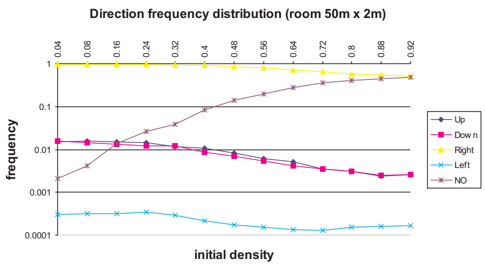

Figure 2.

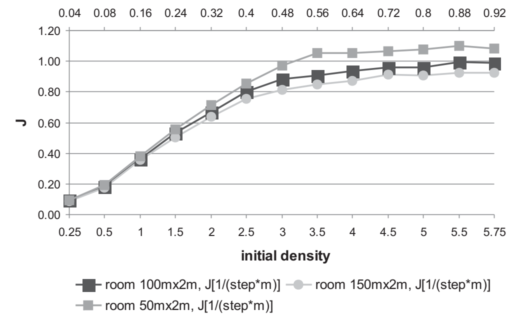

Figure 3.

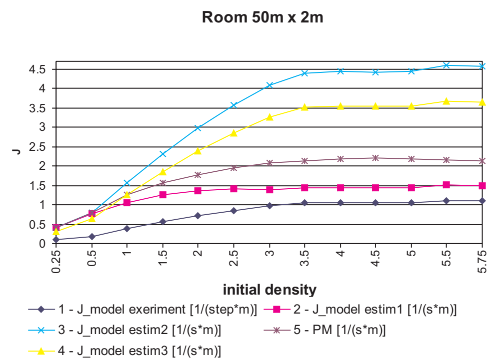

Figure 4.

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

$\rho_0[1/m^2]$	ρ_0	N	T^{50}_{tot}	$\tilde{T}^{100}$	$\tilde{T}^{150}$
0.25	0.04	25	130	133	141
1.00	0.16	100	132	138	141
2.00	0.32	200	140	150	157
3.00	0.48	300	154	170	184
3.50	0.56	350	166	193	206
4.00	0.64	400	190	213	229
4.50	0.72	450	211	234	247
5.00	0.80	500	232	261	275
5.75	0.92	575	265	291	311

Table I

Minimal total number of steps to leave the 50m room is 125; minimum of maximal (under maximal initial ρ_0), 250 steps (due to exclusion principle). Shifts that the model gives (see Table 1, column T^{50}_{tot}) are due to not strictly one-dimensional motion and stochastic nature of the model. Nevertheless Fig. 2 shows strong prevalence of the right side movements with gradually increasing "No" leaving present position under increasing density. Such behavior of virtual people may be refereed to realistic.

Experiments with 100m and 150m rooms shows such characteristic of the model as diffusion of the flow (decompression). In such environment a real people flow has the diffusion and it's more pronounced with increasing initial density. Divergence of data from columns $\tilde{T}^{100}$ and $\tilde{T}^{150}$ with corresponding values from column T^{50}_{tot} says that the diffusion is realized by the model. The main contribution is given by the stochasticity of the model. Fig. 3 shows that flows J^{100}, J^{150} are lower then J^{50} and it becomes more pronounced under bigger ρ_0; non of them don't reach maximal possible value 1.252.

Fig. 4 gives some observations on time scaling problem in CA models. Line 5 is the flow $J = N/T/2$ after the data of Predtechenskii and Milinskii which may be considered as an upper bound of the flow in such case study; line 1, the flow $J = N/T^{50}_{tot}/2$ which may be considered as a low bound of the flow. The lines 3 and 4 gives the following flows correspondingly $J = N/(T^{50}_{tot} \cdot 0.24)/2$ and $J = N/(T^{50}_{tot} \cdot 0.3)/2$. They are unrealistically significantly higher than the estimated upper bound. Therefore timescales $\Delta t_{PM} = 0.24 = 0.4[m]/1.6[m/s]$, $\Delta t = 0.3 = 0.4[m]/1.3[m/s]$ are not proper starting with $\rho_0 > 0.1$. Line 2 corresponds to the ¤ow $J = N/(T^{50}_{tot} \cdot \Delta t(\rho_0))/2$, where

$$\Delta t(\rho_0) = \begin{cases} 0.4/v(\rho_0), & \rho_0 < 0.5, \\ 0.4/v(\rho_0 = 0.5), & \rho_0 \geq 0.5. \end{cases}$$

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