Modeling of People Flow in Public Transport Vehicles

Bartłomiej Gudowski and Jarosław Wąs

AGH University of Sciences and Technology, Institute of Automatics,
al. Mickiewicza 30, 30-059 Kraków, Poland
{bart, jarek}@agh.edu.pl

Abstract. Nowadays, there is a big necessity of modeling groups of people behavior. The knowledge of crowd dynamics is very useful in developing different facilities. The article contains a description of a model of passengers flow in public transport vehicles. The model is created on the basis of tram NGT-6, used by MPK SA in Krakow (Public Transport Company). The model proposed is based on Cellular Automata Technology combined with Multi-Agent theory. The interactions among passengers (agents) are included. The dimensions and the shape of an agent make it possible to take into account the real behavior of a passenger.

1 Introduction

Over the last years, an increasing interest in the movement patterns of groups of people could have been observed mainly, because the knowledge of people behavior is necessary for developers of all public facilities. In the article, the authors propose a simulation model of passengers movement in public transport vehicles, particularly for trams and buses.

There are two possible ways of modeling people movement: continuous and discrete. Generally, discrete models seem to be better for describing detailed passengers behavior, while most of the models are based on Cellular Automata (CA). Let us describe some of them. In 1992 Nagel and Schreckenberg proposed a 1D CA model of vehicles movement (on the road). Probably, the first work, which describes collision avoidance in movement of people was proposed by Fukui and Ishibashi in 1999 [1]. Another multi-directional pedestrian walkway models were presented by Blue and Adler in 1999 and 2000 [2]. In 2001 Burstedde at al., proposed a model which included two kinds of floor fields: a dynamic and a static one [3]. Dijkstra et al. proposed a multi-agent model of people movement in a shopping center (2001, 2002) [4, 5]. In 2003 Klüpfel proposed model of vessel evacuation based on static potential field [6]. In 2004 Gloor et al. proposed a simulation of hikers behavior in Alps [7]. Another interesting paper written by Narimatsu et al. (2004), presents patterns of collision avoidance [8]. In 2004, 2005 Wąs and Gudowski presented a model including strategical abilities in pedestrian movement [9, 10].

R. Wyrzykowski et al. (Eds.): PPAM 2005, LNCS 3911, pp. 333–339, 2006.

2 Some Assumptions of the Model

A simulation of the behavior of a crowd of passengers in a public transport vehicle requires a different set of assumptions, than the classical models based on Cellular Automata. The first important difference is space discretization. The majority of the known models use a quadratic lattice (or hexagonal), in which an agent is represented by a circle inscribed in a cell of the lattice. For models of smaller size, this is an excessive simplification. The authors propose a more precise representation of agents by the shape of ellipse. This could work better for imaging the interactions among agents. Each pedestrian is represented by an ellipse which occupies two cells (an agent is standing Fig. 1a), two cells plus some parts of other two cells (an agent is standing across Fig. 1b, 1c), or four cells (an agent is sitting on a seat). Geometry and possible movement directions are presented in Fig. 1.

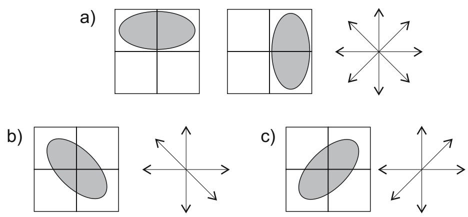

Fig. 1. Agent representations and their possible movement directions

A single cell has dimensions of 0.25×0.25m. The size of cell is based on average human dimensions, according to WHO data: shoulder breadth: $X = 0.45$m, body depth $Y = 0.27$m (Fig. 2).

The second assumption is connected with the movement in the model. The authors propose 1 cell/time-step-slice in all possible directions. A conclusion is that the movement could be realized in complex Moore neighborhood, composed of two simple Moore neighborhoods. Thus, space discretization is similar to Margolus neighborhood (Fig. 3).

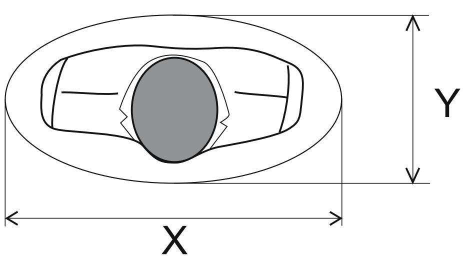

Fig. 2. Body dimensions of an agent, and ellipse of the body (according to WHO data)

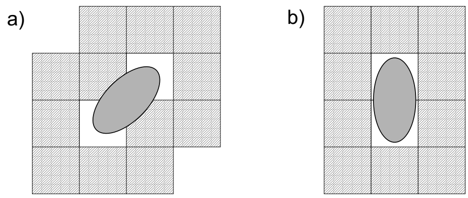

Fig. 3. Complex Moore Neighborhood, connection of two simple Moore neighborhoods

The description of the neighborhood proposed is shown below:

$$X(a, \lambda) = N(l, \lambda) \cup N(r, \lambda) \tag{1}$$

$X(a, \lambda)$ - neighborhood of an agent a,λ - radius of neighborhood X,
l - left side (arm) of a pedestrian,
r - right side (arm) of a pedestrian,
$N(l, \lambda)$ - Moore neighborhood of the left side of pedestrian,
$N(r, \lambda)$ - Moore neighborhood of the right side of pedestrian,
λ - radius of Moore neighborhood.

Value of parameter $\lambda = n$ describes the possibility of movement in n time steps. One of main reasons for using elliptic shape of agents is the problem of crowd compressibility, which could be better reflected with the application of the ellipse.

3 Model Description

The situation analyzed is passenger movement in public transport vehicles. Let us consider NGT-6, a low-floor tram used by MPK SA (Kraków Public Transport Company). The tram runs between two tram terminals. In each stop it opens the doors and some passengers exit it and some enter it. All the time, the passengers/agents have the possibility of moving inside the tram, for example validate tickets or to look for and take a seat etc. There are some places in the tram which could attract a passenger: validating machines, seats, places situated near doors etc.

3.1 Formalization

Let us apply in this work the following formal definition of Cellular Automata: (L, S, N, f), where: L - Set of cells of the lattice, S - Set of states, N - Set of neighbors, f - transition function (Weimar 1998). Although the model presented is an extension of classical Cellular Automata, the majority of mechanisms from CA are taken into account.

A configuration $C_t\colon L \to S$ is a function which associates each state with a grid cell. An equation of changing configuration is shown in term (2) with a supplement (3).

$$C_{t+1}(r) = f\left(\{C_t(i) | i \in N(r)\}\right) \tag{2}$$

where:
$N(r)$ - Set of neighbors of cells r,
r - Current cell number,
t - $t = t + 1$ discrete time step,
i - Single cell.

$$N(r) = \{i \in L | r - i \in N\} \tag{3}$$

3.2 Space Discretization

Presented model has 2D graphics. The surface in the model is divided into a quadratic lattice. There are distinctive cells in the model such as: walls, exits/entrances, inter-mediate aims (seats, ticket validating machines etc.). Marked edges, which indicate mean prohibited pass between two cells, represent various barriers. The figure below presents the layout of the tram NGT6 in the form of a model lattice (Fig. 4). Black cells represent walls, grey cells represent seats and blue cells represent open doors.

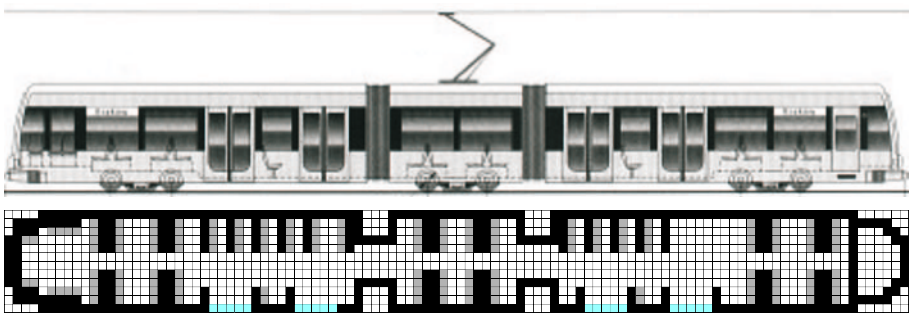

Fig. 4. Layout of tram NGT6 adapted to a model

3.3 Movement Algorithm

Tram runs between two terminals and it stops and opens doors at every tram stop. Agents are randomly generated with a random set of features such as destination (length of journey), the necessity of validate the ticket (single or periodical ticket), age. Agents can move in the model all the time (both when the tram moves and stops). Agents' features determine movement characteristics. For instance, if an agent is elderly, and their journey is of long distance, they want to take a seat. If an agent has a single ticket, they want to validate it immediately after getting to a vehicle. If an agent's journey is short, they stay in a short distance to the door. Thus, there are some defined cells in the lattice which represent intermediate aims (seats, validators, neighborhood of doors etc.). These cells are referred by authors as tarpits, because they stall agents. Every agent has a defined set of priorities and a timetable of tarpits.

Agents could move in the directions shown in Fig. 1. They can turn round, but the center of rotation could be situated only in the center of cell. General movement algorithm is presented below in the Fig. 5. In this case we have a model with the maximum pedestrian speed $V_{\max}$ is larger than 1 simulation has to proceed within a time-step-slice given by formula $t/V_{\max}$, where t is a time step, and it usually equals 1 second [4]. Agents with the velocity V_p less than $V_{\max}$ do not move at every time-step-slice. The authors propose a simple way of creating automatically a movement structure for every agent with a given velocity. For every agent an integer part of ratio $V_{\max}/V_\mathrm{p}$ determine the time interval (measured in time-step-slices) between the movements. The fractions are

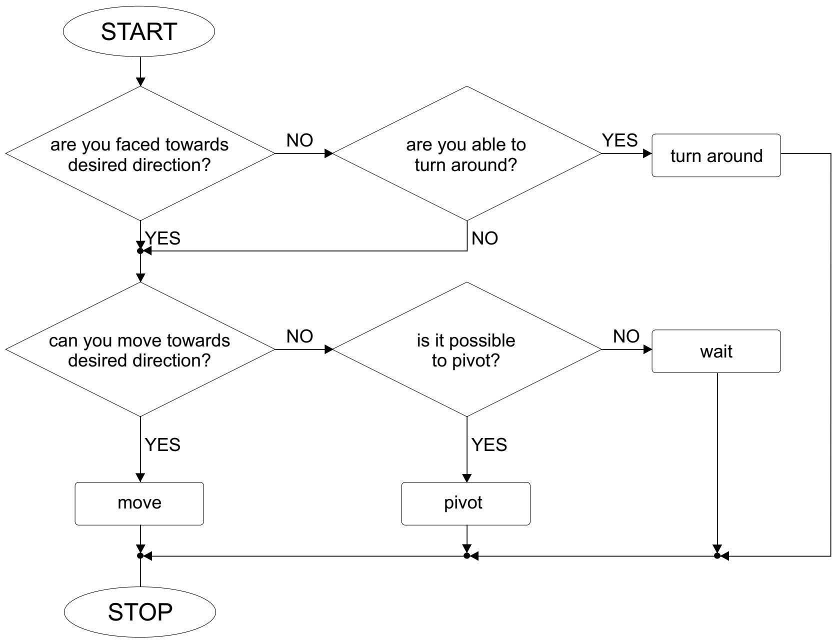

Fig. 5. General movement algorithm

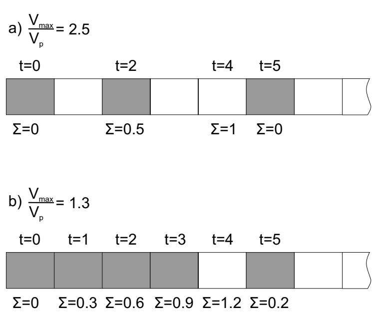

Fig. 6. Example of automatic movement structure creation

accumulated and when their total equals one or becomes larger, the agent waits one additional time-step-slice. Then, we subtract one from the total and proceed as described above. In Fig. 6, two cases of described method are presented. Gray fields indicate time-step-slices (t) in which movement occurs.

4 Application Description

The model described has been implemented as C++ application. The MFC library has been used for developing a user interface. The simulation model is represented by C++ class SModel.

The components of the model are: a grid with known length and heigth (class SGrid), a set of cells (class SCell), a set of agents (class SActor with its derivative SPassenger).

5 Simulation Results

In the current stage of research the authors want to formulate a set of rules which would reflect a real behaviour of passengers in public transportation vehicles. The model proposed seems to be accurate. The figures below present two cases. In the first we can observe passenger flow when vehicle's doors are open in the tram stop. And in the second we can see a situation inside a vehicle moving between the stops.

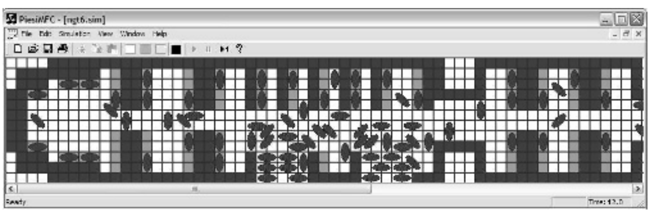

Fig. 7. Screenshot. Passengers flow during stopping at a tram stop.

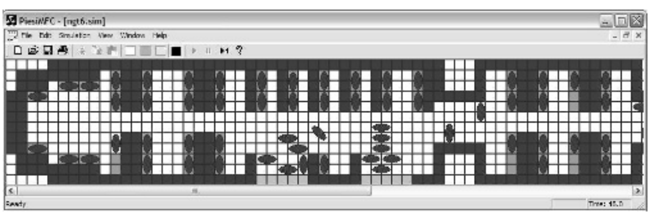

Fig. 8. Screenshot. Passengers flow between tram stops.

6 Conclusions

The model presented describes passenger movement in public transport vehicles. The simulation shows, that the agents behavior of the model is quite similar to the behavior of passengers in reality. But there are some limitations to the model which should to be developed and finally validation should be executed. One of the biggest difficulties in the model is crowd compressibility. The authors plan to apply described model in order to minimize the a tram needs to wait for the passengers to get on (average waiting time at a stop), minimize the evacuation time of a crowded vehicle, and make ticket punchers more available. These goals could be achieved by evaluating the quantity and the placement of doors and punchers and the arrangement of space inside a vehicle (seats, barriers, etc.).

The approach presented is based on Cellular Automata with substantial modification - not only local by also global relations are taken into consideration. Every agent occupies not one, but two cells or four cells. Therefore, besides progressive movement, rotation is also permitted. Thus, passenger can squeeze through the crowd. Tarpit cells are introduced which allows us represent intermediate aims in simulations.

References

1. Fukui M., Ishibashi Y.: Self-organized phase transitions in CA-models for pedestrians. J. Phys. Soc. Japan (1999) 2861–2863
2. Blue V., Adler J.: Bi-directional emergent fundamental flows from cellular automata microsimulation. Proceedings of ISTTT, Amsterdam (1999) 235–254
3. Burstedde C.K., Klauck K., Schadschneider A., Zittartz J.: Simulation of pedestrian dynamics using a 2-dimensional cellular automaton, Phys. Rev. A 295 (2001) 507–525.
4. Dijkstra J., Jessurun A.J., Timmermans H.: A multi-agent cellular automata model of pedestrian movement, Pedestrian and evacuation dynamics, Springer-Verlag Berlin (2000) 173–181.
5. Dijkstra J., Jessurun A.J., Timmermans H.: A multi-agent cellular automata system for visualising simulated pedestrian activity, Proceedings of TPICA 2000, (2001) 29–36.
6. Klüpfel H.: Cellular automaton model for crowd movement and egress simulation, Doc. thesis Duisburg-Essen (2003)
7. Gloor C., Stucki P., Nagel K.: Hybrid techniques for pedestrian simulations, Proceedings of 6th International Conference on Cellular Automata for Research and Industry, Amsterdam (2004) 581–590
8. Narimatsu K., Shiraishi T., Morishita S.: Acquisiting of local neighbour rules in the simulation of pedestrian flow by Cellular Automata, Proceedings of 6th International Conference on Cellular Automata for Research and Industry, Amsterdam (2004) 211–219
9. Wąs J., Gudowski B.: The application of cellular automata for pedestrian dynamic simulation., Automatyka Journal AGH-UST, Kraków (2004) 303–313
10. Wąs J., Gudowski B.: Simulation of strategical abilities in pedestrian movement using Cellular Automata, Proceedings of 24th IASTED MIC Conference, Innsbruck (2005) 549–553