Simulations on Passenger Behaviours at Train Stations

Ming-jun Liao[1]
1 Post-doctoral Research Center of Traffic College, Jilin University, Changchun 130012, China; Department of Civil Engineering, Beihua University, Jilin, 132013, China.

Kai-ying Wang[2*]
2 Department of Civil Engineering, Beihua University, Jilin, 132013, China. (*correspondence author)

Ying Liu[3]
3 China Academy of Transportation Sciences, Beijing, 100029, China.

Abstract—**In China, governments take public transit very seriously, therefore many urban rail transit lines are built in major cities, at the same time, more and more rail stations are built along the rail transit lines. Passengers' evacuation and capacity of the facilities in rail station are increasing concerns during rush hours. When passengers walk, passengers prefer shortest path and follow other passengers in the strange or constrained environment from Passenger's Psychology and Physiology. In the paper, static floor field index model is used to model the behavior of choosing shortest path relating to walking goals (goal direction) and dynamic floor field for the behavior of following other passengers. Based on cellular automaton model (CA), a behavior model for passenger orderly activities considering goal direction, static floor field and dynamic floor field, microscopic motion and behavior decision is presented. The framework of simulation is also described based on the characteristic of station. The model and framework are testified and it is feasible.**

Keywords- passenger; urban rail station; orderly activities; cellular automaton

I. Introduction

In China, the construction of urban track transportation has developed very fast in recent years. According to the planning of Shanghai, Beijing, and China, The mileage of urban rail transit lines is still increasing [1]. In 2007, the mileage of Shanghai urban rail transit lines is 236 km with 163 stations. In 2020, the mileage of Shanghai urban rail transit lines will increase to 970 km with 524 stations. The mileage of Beijing urban rail transit lines reaches 200 km in 2008, and will increase a total of 1000 km with the number of about 800 stations in 2020. In addition, urban rail network in the planning all over the country has reached the total mileage of 5,000 km, and the amount of investment is over 800 billion Yuan [2]. In the urban rail transit network, the station is more important and complicated than other parts of the urban rail transit network. Therefore, it is important that a reasonable and advanced method or visual tool should be studied to guide the planning and design of urban rail transit station. However, during station planning and management, designers of stations accommodating large passenger flows nowadays still use simple rules of thumb [3]. Although many efforts from macroscopic are made to demonstrate the law of passenger flow, the increasing needs of these designers for more advanced assessment tools are urgent.

In recent years, with the advance of complicated system, artificial intelligence, and computer technology, a series of methods is applied in pedestrian behavior modelling, in which there are three main types [3]: cellular automaton model[4,5], the models based on math and physic equation [6], and model based on agent or rules of motions or decision-makings[7-9]. Cellular automata divide the simulation domain into cells. These cells have to be regular, so that they form a regular grid. Every cell has one certain state value from a finite set of possible states. The probably best known example for a cellular automaton is the "Game of life" by John Conway. A rectangular grid is considered. A cell has just two possible states, namely dead or alive. The change in the states are by the cells in the direct neighborhood. The time development from generation t to generation $t + 1$ is determined by the transition rules and transition possibility function. The most famous model based on math and physic equation is named as social force model [6, 7]. The social force model (SFM) assumes that the social force drives the passenger movement. The basic idea is to model the elementary impetus for motion with forces, which is similar to Newtonian mechanics. The forces, which influence the passenger motion, are caused by his/her intention to reach his/her destination as well as by other pedestrians and obstacles. Thereby, other passengers can have both an attractive and a repulsive influence. A pedestrian's motion which is strongly influenced not just by the present position of neighboring pedestrians, but by their anticipated future positions, at the same time, pedestrians walking in parallel directions exhibit almost no acceleration, even when their mutual separation is small. However, the SFM cannot explain those phenomena. Karamouzas [7] presents a universal power law based on data-driven, statistical mechanics-based analysis can account properly for the anticipatory nature of human interactions. However, the form of the universal power law is similar as the SFM.

The most of the above behavior models are for emergent situation (evacuation), few models are for simulating activities (normal situation) in urban rail transit station.

Therefore, the study of passenger flow behavior model of urban rail transit station from microscopic view is necessary.

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The paper first analyses the facilities and the corresponding activities in urban rail transit station, then describes the characteristics of the psychology and physiology (static floor field and dynamic floor field) and the behaviors of the pedestrian(decision-making and motion). In the end, the framework of simulation and behavior is presented.

II. THE FACILITIES AND ACTIVITIES IN TRACK STATION

Station is composed of service facilities, passenger-passing space and management facilities. Passenger traffic network is defined as the topology with limited capacity that is consisted of nodes and links. The nodes of network can be considered as starting points or destinations, passing infrastructure node, and activity nodes such as ticket machines, ticket checks, newspaper stands or retail outlets. All nodes in an infrastructure element are connected by links of some length, which are homogeneous. The links in station include walking links, waiting links and serving links. Different facilities function differently. In order to model passenger simulation, the function and characteristic of facilities should be analyzed.

The space in station is a closed passenger space in which passengers are interfered little. The goal of passenger is to catch train or depart station in time. The processes (shown in Figure 1) in station include arriving or departing, queuing for servicing, walking on passing space (passage, stair, or escalator), waiting in the platform, boarding or de-boarding. In addition, there are some processes such as buying food or newspaper, or inquiring or reading information [1].

The different activities be described with different behavior models. Theses behavior can be categorized into three levels: microcosmic, middle and macroscopic views corresponding to strategic, tactical, and operational levels [3, 11].

From macroscopic view, the activities and the order of processes are defined. As to the factors of passenger flow simulation, only the external factors are considered, and the interactions between pedestrians and interactions between passenger and facilities are neglected. The span of time is relatively large. The research on the simulation from macroscopic view is little [3].

The middle level is a link between macroscopic level and microscopic level. Based on macroscopic level, the middle level considers the short-term decision behavior of passengers, for example, timetable of activities, the choice of activity regions, and the choice of paths.

At microscopic level, the behavior of a single passenger is analyzed as a unit. The immediate decision behavior of the next time step is determined. The motion behavior and interactions between passenger, facility, environment, and other traffic are also considered.

In the three levels, the degree of the detail of the microscopic models, which include the decision behaviors and motion behaviors of single passenger, is most high. The models of middle level provide the information about timetables, event lists, the choice of regions, the conditions and scenes of microscopic motion behaviors, and interactions. The macroscopic models provides the overall information or planning, such as OD table, the links of trips, the lists of activity choices, the statistical rules and relationship of passenger traffic flow. The three levels are not existent in isolation. They have interfaces of transmitting information or data and receiving mutual feedbacks. The passenger flow is a macroscopic phenomenon because of aggregating of single passenger interaction of microscopic behaviors. The relationship of passenger flow is an input and output of passenger simulation, and a criterion of passenger flow simulation model. The different models from different levels have different parameters of input and output and have different assessment indicators. At last, the results are presented according to the forms of macroscopic level.

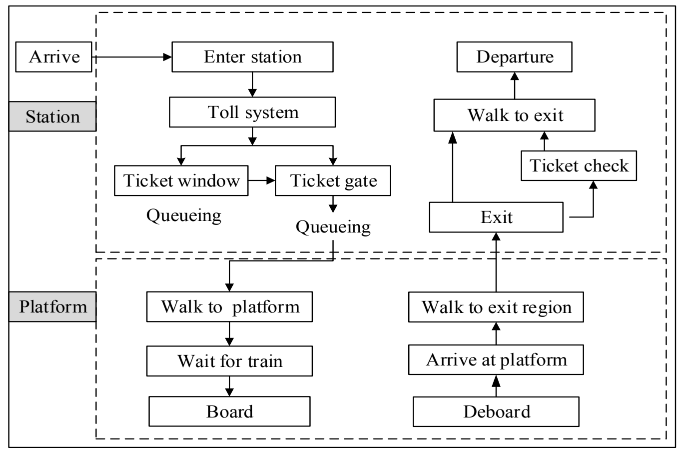

Figure 1. The activities and processes in station

III. 3 THE FRAMEWORK OF PASSENGER FLOW SIMULATION

Passenger simulation model is alike vehicle simulation and abides by a certain mode in the model framework, but passenger is more random, complicated, and intelligent. Therefore, the passenger simulation models should consider the special behaviors of passenger. The overall framework of passenger simulation models is given in the Figure 2. The modules include: visual interface; physical facility module (edit and modify passenger passing spaces and architectures); passenger agent module (define attributes and behavior parameters of passengers); passenger motion module (position updates based on decision behaviors); result output (report, graph or animation).

Passenger agent in simulation is modelled according to the same simulation process. The process of a passenger agent is illustrated in Figure 3. The process is given as follows:

- The initialization of physical environment and passengers—mainly initialize the attributes of physical environment, CA spaces or initial states of physical environment or passengers.
- The choice of activity point—according to the drive of time or goals, and path choice model, choose activity points.

- Updating the positions of passenger agents—considering the rules of motion, transition probability matrix, and the result of transition possibility function given in equation (2) choose the next cell and update the positions of passenger agents.
- The judgment of goals—mange the simulation's life cycles of passenger agents. If a passenger agent reaches the destination, the agent will be deleted from the list given at macroscopic level.
- The end—if the simulation time is up, or all the passenger agents reach the goal, the simulation will end.

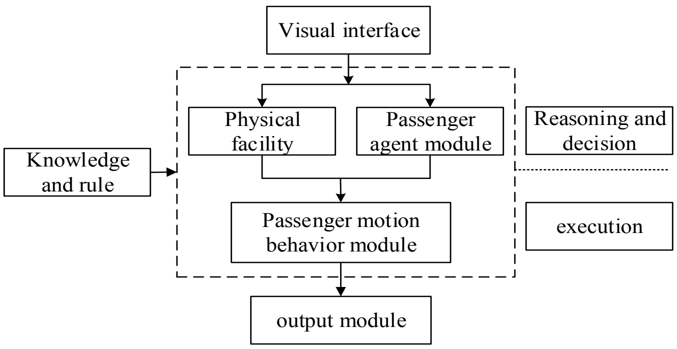

Figure 2. Framework of passenger flow simulation

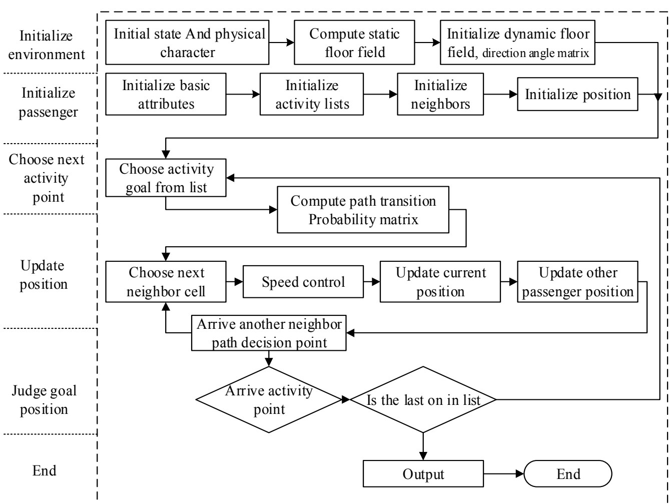

Figure 3. The process of passenger behavior simualtion

IV. BEHAVIOUR MODEL OF PASSENGER

In the passenger simulation, the decision and behavior models are the most important behavior models. In the section, the microscopic behavior of a single passenger is described.

In microscopic simulation phase, the current passenger has the attributes of goal, self-characteristics, environment of geometry and traffic states, and obstacles. Based on the previous information, the task of the passengers is to determine the direction, position, and speed of the next step. After a simulation step, the position of passenger is updated, and the trajectory is formed after connecting those positions. At each current step, passenger has eight directions (given in Figure 4 and equation (1)) to move, for example, up, down, left and right [12].

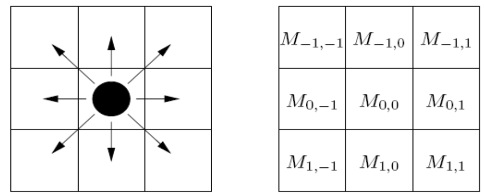

Figure 4. Transition preference matrix M_{ij}

$$P = \begin{bmatrix} p_{i-1,j-1}, p_{i-1,j}, p_{i-1,j+1} \\ p_{i,j-1}, \quad p_{i,j}, \quad p_{i,j+1} \\ p_{i+1,j-1}, p_{i+1,j}, p_{i+1,j+1} \end{bmatrix} \tag{1}$$

Transition possibility, that is, evolvement rule, is the core of CA model. According to the computed result of the function, agents can move from current location to new position.

In the specified environment, agents are engaged with orderly activities. Therefore, the direction of goal is the important factor in modelling transition possibility function. Agents walk along the line toward goal. According to Moore neighbor, agent has eight directions of movement. Each direction has an included angle with direction of goal. Agent is inclined to choose the neighbor cell with the minimum included angle as the direction of movement. Based on above analysis, transition possibility function is built as follows:

$$p_{ij} = NM_{ij}\{\exp(k_D D_{ij})\exp(k_S S_{ij})\exp(k_\theta \theta_{ij})\}(1-n_{ij})\xi_{ij} \tag{2}$$

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

$$n_{ij} = \begin{cases} 0, & \text{vacant} \\ 1 & \text{occupied} \end{cases}$$

$$\xi_{ij} = \begin{cases} 0 & \text{wall or other obstacles} \\ 1 & \text{no obstacles} \end{cases}$$

where p_{ij} is possibility of cell (i,j), N is the normal factor to assure $\sum_{(i,j)} p_{ij} = 1$, M_{ij} is Matrix of preference , n_{ij} is the occupied state of cell, ξ_{ij} is the state to judge if there are obstacles, θ_{ij} is the modified and included angle(the detail is given in reference [13]), and k_θ is the sensitive factor of direction. The bigger is k_θ, the more random is the movement of agent, when it is enough big, the evolvement rule is determinate. D_{ij} is the dynamical floor field, and S_{ij} is the static floor field. Floor field simulates the habit of group following and choosing shortest path (for details, see reference [14, 15]; k_D and k_S are the coefficients of D_{ij} and S_{ij} , respectively.

V. IMPLEMENTATION OF PASSENGER BEHAVIOUR MODEL

A case of ticket-hall in subway station is chosen to illustrate the development of passenger flow simulation. In order to implement passenger behavior model, several class is develop as follows:

- Cell class, a serial,kizable class— the function of the class is to define size, position, floor field, and the method of drawing etc.
- Hall class—it is made up of cells. The function of it is to define the attributes of passing space, and some methods, such as, floor field computing, hall drawing.
- Passenger agent class—it is an important class. The class mainly defines the attributes of passenger, such as, traffic characteristic, behavior parameters, and position and transition probability of passenger. In addition, a series of methods, such as, path search, queue choice, and agent drawing, are also defined.
- Queue class—it is inherited from queue. The class is to simulate the queuing activity of passenger in station, for example, queuing for ticket and passing ticket gate.

Utility class (for details, see Figure 5)—it is mainly a statistical class for passenger generator, initialization, etc. Random number is generated in it. There are several types of random number listed, such as, Uniform distribution, Poisson distribution, Exponent distribution and Normal distribution. In addition, sampling method, Roulette method, and some often used methods are also included.

In equation (2), D_{ij} and S_{ij} are two important parameters in decision behavior model of passenger. The probability of move directions of passenger is calculated based on the two parameters. The result of the ticket hall case is shown in Figure 6.

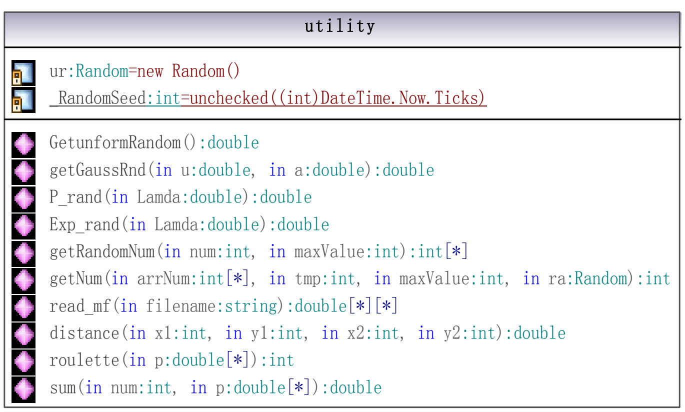

Figure 5. Utility class

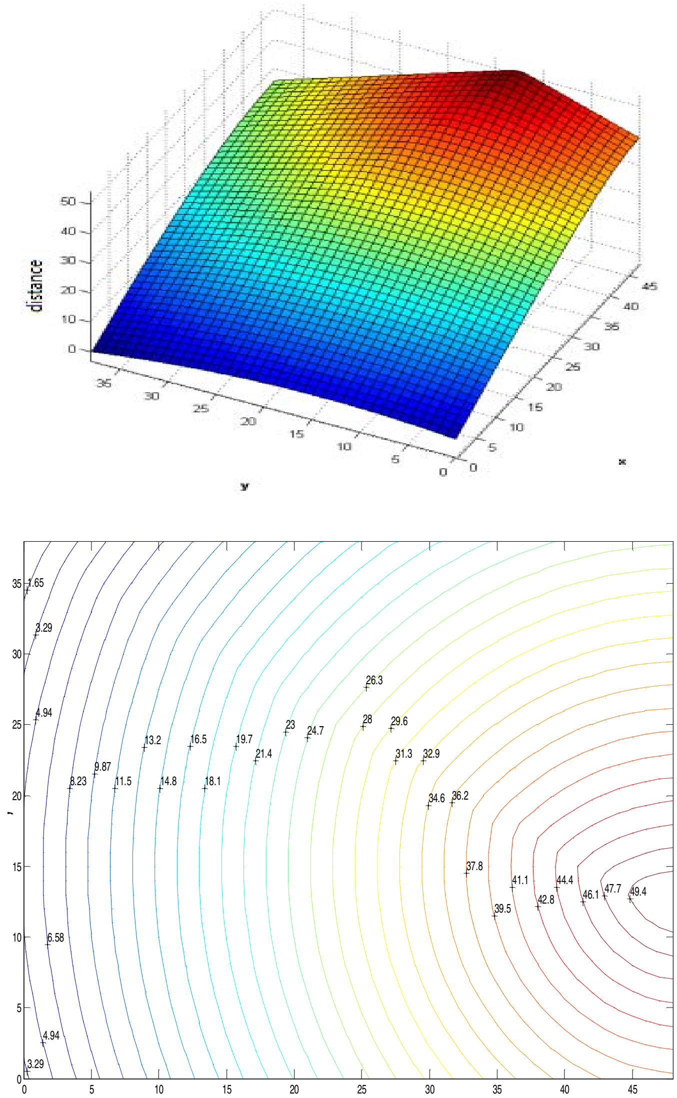

Figure 6. Contour map of ticket gate floor field

VI. CONCLUSION

There are many activities in station. In the paper, the path choice decision and motion behavior are modeled, and the overall framework and implementation of passenger behavior model are presented. The queuing behavior is given in reference (13). Equation (2) is suitable for the cases of both evacuation and normal situation. From the results of the floor field, it demonstrates that the crowded passengers will arch during passing narrow passage. It is consistent with the real facts.

Though progresses are made in pedestrian motion behavior model, and some decision behavior models, modelling the emotion behaviors is still a challengeable job. In future, the authors will focus on agent modelling. In addition, there are many obstacles, for example, pillars, facilities, and dynamic queues. In the paper, we do not consider the dynamic obstacles' influences which will be studied later.

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