Pedestrian choice behavior analysis and simulation of vertical walking facilities in transfer station*

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Considering the interlayer height, luggage, the difference between queuing pedestrians, and walking speed, the pedestrian choice model of vertical walking facilities is established based on a support vector machine. This model is verified with the pedestrian flow data of Changchun light-rail transfer station and Beijing Xizhimen transfer station. Adding the pedestrian choice model of vertical walking facilities into the pedestrian simulation model which is based on cellular automata, the pedestrian choice behavior is simulated. In the simulation, the effects of the dynamic influence factors are analyzed. To reduce the conflicts between pedestrians in opposite directions, the layout of vertical walking facilities is improved. The simulations indicate that the improved layout of vertical walking facilities can improve the efficiency of pedestrians passing.

Keywords: vertical walking facilities, pedestrian choice behavior, support vector machine, cellular automata

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1. Introduction

Escalators and stairways are vertical walking facilities in transfer stations. As a main pedestrian passage in a hub, it is also the main bottleneck. According to actual observation and the existing research,[1] in general, pedestrians prefer to take the escalator. Due to this, the uses of escalator and stairway are always out of balance. The number of pedestrians choosing the escalator is more than that of choosing the stairway. Analyzing and simulating the pedestrian choice behavior between escalator and stairway is useful in planning and designing the facilities.[1]

There are two normal methods in simulating the pedestrian choice behavior between escalator and stairway: setting the choice ratio based on experience and planning the walking path when pedestrians appear. However, these two methods could not simulate pedestrian choice behavior well.[2] Generally, pedestrians make choices according to the walking environment when they are right in front of these facilities. That is to say, pedestrians analyze the walking environment, then make a decision.[3,4] The pedestrian choice behavior simulation of vertical walking facilities can be divided into two parts: the pedestrian choice of vertical walking facilities, and the pedestrian simulation.

On the research of pedestrian choice of vertical walking facilities, the logit model based on utility maximization theory has been widely used.[5–7] Cao[5] analyzed the pedestrian flow data of Beijing, and built the pedestrian choice model of vertical walking facilities based on the logit model. Li *et al.*[6] considered the scene that pedestrians chose the stairway or escalator, and established an extended binary logit model. The logit model based on utility maximization theory has the defect that the calibration results are influenced by the quantity of data.[1]

The pedestrian flow is studied by using the modes of experiment, observation, and simulation.[8–12] On the research of pedestrian simulation, the cellular automata model[13,14] and social force model[15,16] are usually used. The cellular automata model is easy to implement, and the simulation effect is good. Cellular automata (CA) is used to build many pedestrian simulation models in different scenarios, such as the pedestrian counter flow on a crosswalk,[17] the crowd dynamics during tawaf,[18] the road in front of elementary and middle school gates when students are going to school,[19] the collision avoidance model for pedestrian dynamics,[20] and so on. In crowded conditions, many CA-based crowd models have been established and validated with the real data.[21–24] Seyfried *et al.*[25] and Johansson *et al.*[26] respectively investigated the fundamental diagram of pedestrian and crowd dynamics of pedestrian flow based on suitable video data, and these characteristics of pedestrian flow could be shown in the

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CA-based simulation model.

In this paper, a support vector machine, which is better in solving the problems of a small sample, and nonlinear classification are used to build a pedestrian choice model. The choice result is added into the pedestrian simulation model which is based on cellular automata. The size and pedestrian flow data of Changchun light-rail transit station are obtained to build the simulation scenario. On this basis, the simulation of pedestrian choice behavior is realized and the vertical walking facilities layout is improved to reduce the pedestrian conflicts.

2. Choice model of vertical walking facilities

2.1. Influence factors

The pedestrian choice behavior between escalator and stairway is a complex process and can be influenced by individual characteristics, pedestrian flow conditions and facilities conditions.[27–29] Pedestrian individual characteristics mainly include gender, age, luggage, walking speed, etc. Pedestrian flow conditions mainly include the difference between queuing pedestrians, the degree of crowdedness, etc. Facilities conditions mainly include the interlayer height, the width of stairway, the width of escalator, the speed of escalator, etc. Different pedestrians have different decision-making psychologies, for example, the pedestrian who carries a large amount of luggage tends to choose the escalator, the older pedestrian tends to choose the escalator, and the pedestrian in a hurry tends to choose the stairway.

Because the factors that have an influence on the pedestrian choice behavior between escalator and stairway are multiple and there may be collinearity and interdependence among these factors, it is necessary to select the key influence factors.[2]

Based on the relevant research,[1–7] the pedestrian flow data of the transfer passage are gathered. Four main factors which include the interlayer height, luggage, the difference between queuing pedestrians, and walking speed, are selected by the method of Regression Analysis Stepwise (RAS) and are added into the choice model as characteristic variables. The model variables are listed in Table 1.

Table 1. Introduction of model variables.

Type	Characteristic variable	Characteristic value
Independent variable	Interlayer height	The actual value
	Luggage	1: without luggage or a little amount 2: a moderate amount of luggage 3: a large amount of luggage
	The difference between queuing pedestrians	The difference in the number between queuing pedestrians in front of escalator and stairway
	Walking speed	1: low speed: $v \leq 1.3$ m/s 2: moderate speed: 1.3 m/s $< v \leq 1.7$ m/s 3: high speed: $v > 1.7$ m/s
Dependent variable	Vertical walking facilities	−1: escalator 1: Stairway

2.2. Establishment of choice model

As the relationship among influencing factors of pedestrian choice behavior is nonlinear, so the problem of pedestrian choice of vertical walking facilities in a transfer station is regarded as a nonlinear classification problem. The support vector machine has the ability to solve the problems of a small sample and nonlinear classification.[30–32] So, the support vector machine is used to build the pedestrian choice model.

According to the analysis results of influence factors for pedestrian choice behavior, interlayer height, luggage, the difference between queuing pedestrians, and walking speed are the key influence factors. The pedestrian characteristic vector is described as follows:

$$x_i = [x_{i,1},\, x_{i,2},\, x_{i,3},\, x_{i,4}]^{\mathrm{T}}, \tag{1}$$

where x_i is the pedestrian characteristic vector, $x_{i,1}$ is the characteristic value of interlayer height, $x_{i,2}$ is the characteristic value of luggage, $x_{i,3}$ is the difference between queuing pedestrians, and $x_{i,4}$ is the characteristic value of the walking speed.

The pedestrian sample set can be described as follows:

$$A = \{(x_1, y_1), \ldots, (x_i, y_i), \ldots, (x_n, y_n)\}, \tag{2}$$

where n is the number of pedestrian samples and y_i is the choice result.

The problem of pedestrian choice of vertical walking facilities in a transfer station is regarded as a nonlinear classification problem, and pedestrian samples cannot be separated linearly. So, it needs to map the samples into the high dimensional feature space through the mapping function $\phi(x)$, and the nonlinear classification problem can be transformed into a linear separable problem.

In the support vector machine, as for the linear binary classification problem, the purpose of model optimization is to find a hyperplane to separate two kinds of samples. The

hyperplane is described as follows:

$$\omega\phi(x)+b=0, \tag{3}$$

where ω is the normal vector of the hyperplane, $\omega \in R^m$; b is the constant, $b \in R$.

According to the structural risk minimization principle, the minimum risk is achieved when the classification interval becomes largest during the separation. And according to the relevant research, the problem of searching for the optimal hyperplane is transformed into the problem of optimization, which is described as follows:

$$\begin{aligned} &\min \tfrac{1}{2}\|\omega\|^2 + C\cdot\sum_{i=1}^{n}\xi_i \\ &\text{s.t.} \begin{cases} y_i\left(\omega^{\mathrm{T}}\varphi(x_i)+b\right)\geq 1-\xi_i, \\ \xi_i \geq 0,\ i=1,2,\ldots,n, \end{cases} \end{aligned} \tag{4}$$

where C is the penalty factor, $C>0$; ξ_i is the slack variable; n is the number of pedestrian samples; y_i is the choice result, $y_i \in \{-1,1\}$.

The Lagrange multiplier method is used to solve the problem of optimization. The optimal classification decision function is obtained as follows:

$$f(x)=\operatorname{sgn}\left(\sum_{i=1}^{n}\alpha_i y_i(\phi(x)\cdot\phi(x_i))+b\right), \tag{5}$$

where α_i is the Lagrange multiplier.

To overcome the curse of dimensionality, according to the Mercer theorem, the kernel function $K(x,x_i)$ is used to replace $\phi(x)\cdot\phi(x_i)$, namely $K(x,x_i)=\phi(x)\cdot\phi(x_i)$. Radial basis function (RBF) is selected as a kernel function, and the formula is given as follows:

$$K(x,x_i)=\exp(-g\cdot\|x-x_i\|^2),\ g>0, \tag{6}$$

where g is the normalization parameter of Euclidean distance among samples.

2.3. Model validation

The pedestrian samples data of Changchun light-rail transfer station and Beijing Xizhimen transfer station were collected by recording videos on August 16, 2015 and August 17, 2015, respectively. According to Table 1, we transfer the video data into pedestrian sample data by artificial means. 880 pedestrian samples for each of the upward and downward directions are selected out, randomly. Each pedestrian sample contains the real situation of the interlayer height, luggage, the difference between queuing pedestrians, walking speed, and the choice result.

The prediction process of pedestrian choice behavior is as follows:

Step 1 Data preprocessing

According to Table 1, we should transform the pedestrian samples which contain the real situation of the interlayer height, luggage, the difference between queuing pedestrians, walking speed, and the choice result into the corresponding characteristic values. For example, if the pedestrian carries no luggage or a little amount, we set the characteristic value of luggage to 1; if the walking speed of the pedestrian is 1.5 m/s, we set the characteristic value of the pedestrian walking speed to 2.

Step 2 Parameters optimization

With the increasing of the value of C, the empirical risk decreases and generalizing ability weakens. So, under the premise of high accuracy, a smaller C is needed. With the increasing of the value of g, the empirical risk increases, and the empirical risk increases and the generalizing ability strengthens. So, a suitable g is needed. The optimal parameters of C and g are achieved through a genetic algorithm, and the processes are shown in Figs. 1 and 2. In the upward direction, the optimal value C_{up} is equal to 2.531 and g_{up} is equal to 0.359. In the downward direction, the optimal value C_{down} is equal to 4.055 and g_{down} is equal to 0.392.

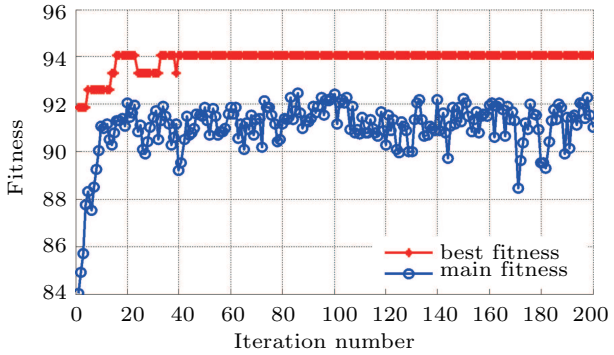


Fig. 1. (color online) Parameters optimizing process in the upward direction.

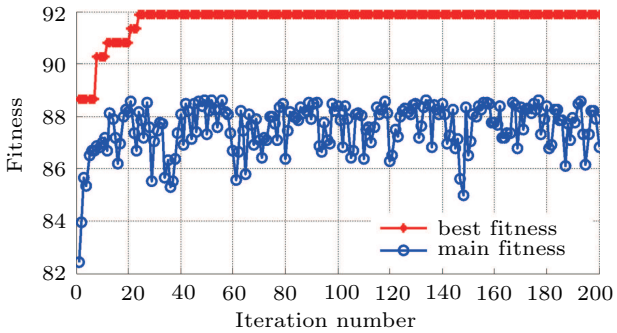


Fig. 2. (color online) Parameters optimizing process in the downward direction.

Step 3 Prediction and accuracy analysis

Based on the survey data, we select 800 pedestrian samples for each of the upward and downward directions randomly as the training set. On the platform of the Libsvm toolbox in MATLAB software, with the training set and the optimal parameters C_{up}, C_{down}, g_{up}, and g_{down}, the Svmtrain function is used to solve the optimization problem of formula (4).

And the pedestrian choice results of the remaining 80 pedestrian samples for each of the upward and downward directions are predicted by the Svmpredict function. The prediction results are shown in Table 2.

Table 2. Predicted results of pedestrian choice behavior.

	Upward	Downward
Number of samples	80	80
Prediction accuracy/%	91.25	87.50
Mean prediction accuracy/%	89.38	

From Table 2, it is noted that the prediction accuracies of pedestrian choice behavior in upward and downward directions are respectively 91.25% and 87.50%. The prediction results of pedestrian choice behavior are good.

3. Simulation model of pedestrian choice behavior

3.1. Assumption conditions

There are five assumptions in the process of pedestrian simulation.

Assumption 1 There is no sojourn time when pedestrians make a decision in front of the escalator and stairway.

Assumption 2 All pedestrians make their decision of choosing escalator or stairway in the choice zone.

Assumption 3 All prediction results of the pedestrian choice model of vertical walking facilities are correct.

Assumption 4 The expectation speeds of all pedestrians are the same.

Assumption 5 The different forms of movements on stairs and escalators are not considered.

3.2. Simulation scenario

Scenario A The transfer passage of Changchun light-rail transfer station is selected as a research object. We set the size of a cell to be 0.4 m×0.4 m, which is the typical space occupied by a pedestrian.[33] With the actual measurement, the simplified simulation scenario is shown in Fig. 3. In Fig. 3, the length of the passage is 118 cells and the widths of both entrance and exit are all 9 cells; the width of the upward escalator is 2 cells; the width of the downward escalator is 2 cells; the widths of upward and downward stairways are both 5 cells; the lengths of escalator and stairway are both 46 cells. The upward and downward escalators are on the same side of the passage.

Scenario B Generally, the number of pedestrians choosing the escalator is more than choosing stairway, and the escalator is narrower than the stairway. Therefore, the density of pedestrian flow is larger and there always appears the phenomenon of queuing in front of the escalator. As the actual observation, the upward and downward escalators on the same side would lead to more conflicts and increase the pedestrian delay time. In order to reduce the conflicts between pedestrians coming from opposite directions, the upward and downward escalators are set separately on both sides of the passage and the stairway is set in the middle with the same size as shown in Fig. 4. Scenario B is the improved Scenario A.

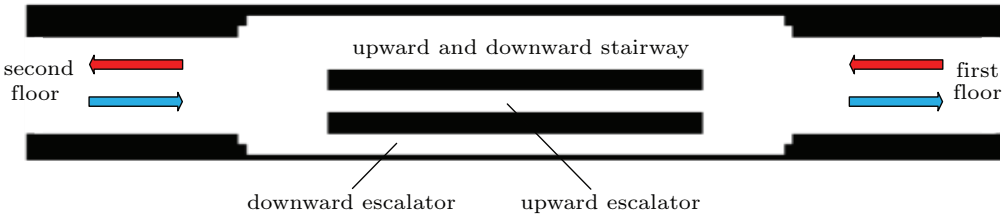


Fig. 3. (color online) Scenario A.

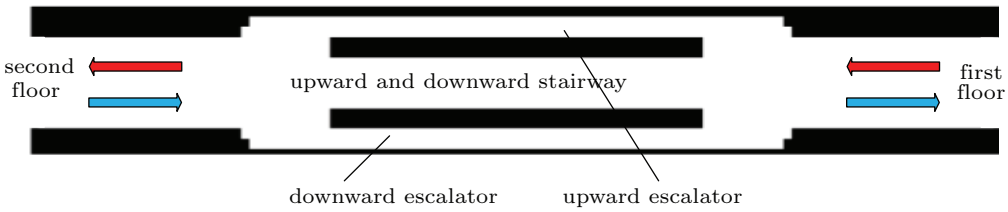


Fig. 4. (color online) Scenario B.

3.3. Floor field

In the process of calculation of the floor field, when pedestrians can only walk in the horizontal and vertical directions, the minimum step between cell$(i,\ j)$ and exit m is denoted by f_{ij}^m. When pedestrians walk in horizontal, vertical, and diagonal directions, the minimum step between cell$(i,\ j)$ and exit m is denoted by g_{ij}^m. The weighted distance to the exit m is denoted by $d_{ij}^m = \varepsilon \cdot f_{ij}^m + (1-\varepsilon) \cdot g_{ij}^m$.

The detailed generation process of static floor field is described as follows.[33,34]

Step 1 Initialize f_{ij}^m and g_{ij}^m. For arbitrary cell$(i,\ j)$, set

$f_{ij}^m = -1$ and $g_{ij}^m = -1$ if the cell$(i,\ j)$ is wall or barrier, and $f_{ij}^m = 0$ and $g_{ij}^m = 0$ otherwise.

Step 2 Set $k = 1$; calculate the distance to the exit in four directions (horizontal and vertical).

Step 2.1 Check grids in four directions around the exits, namely, front, rear, left, and right, denoted by $(i',\ j')$; if $f_{i'j'}^m = 0$, then set $f_{i'j'}^m = k$;

Step 2.2 For an arbitrary cell where $f_{ij}^m = k$, check cells in four directions around it, namely, front, rear, left, and right, denoted by $(i',\ j')$; if $f_{i'j'}^m = 0$, then set $f_{i'j'}^m = k+1$, $k = k+1$;

Step 2.3 If $\exists i, j,\ f_{ij}^m = 0$, repeat Step 2.2; otherwise, go to Step 3.

Step 3 Set $k = 1$; calculate the distance to the exit in eight directions (horizontal, vertical and diagonal).

Step 3.1 Check the cells around the exit in eight directions, denoted by $(i',\ j')$; if $g_{i'j'}^m = 0$, then set $g_{i'j'}^m = k$;

Step 3.2 For an arbitrary cell where $g_{ij}^m = k$, check $(i',\ j')$ around it in eight directions; if $g_{i'j'}^m = 0$, then set $g_{i'j'}^m = k+1$, $k = k+1$;

Step 3.3 If $\exists i, j,\ g_{ij}^m = 0$, repeat Step 3.2; otherwise, go to Step 4.

Step 4 Calculate the weighted distance $d_{ij}^m = \varepsilon \cdot f_{ij}^m + (1-\varepsilon) \cdot g_{ij}^m$.

Step 5 Calculate the static floor field value $S_{ij}^m = (\max\limits_{i,\ j} d_{ij}^m) - d_{ij}^m$.

In the choice zone, simulate the pedestrian choice behavior by switching the floor field, and set the weight coefficient ε to be 0.4. Before choosing escalator or stairway, the LP (Pedestrians generated on the left side of the passage) have the probabilities to walk on the downward escalator or stairway, but they cannot walk on the upward escalator. So, we can set the upward escalator as the barrier.

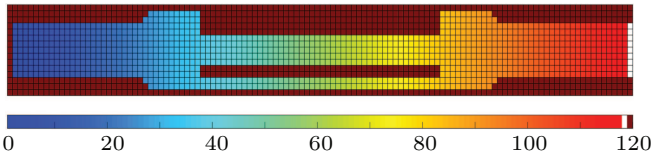


Fig. 5. (color online) Floor field for LP without choosing escalator or stairway in Scenario B.

Figure 5 shows the floor field for LP without choosing vertical walking facilities in Scenario B. With choosing the downward escalator, the LP only has the probability of walking on the downward escalator. So, we can set the upward escalator and stairway as the barrier.

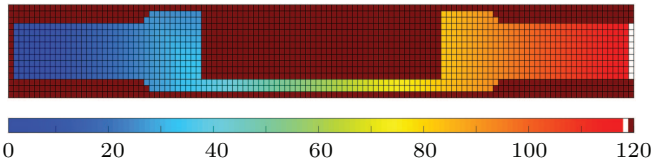


Fig. 6. (color online) Floor field for LP with choosing escalator in Scenario B.

Figure 6 shows the floor field for LP with choosing the escalator in Scenario B. In the same case, for the LP with choosing the stairway, we set the upward and downward escalator as the barrier. Figure 7 shows the floor field for LP with choosing the stairway in Scenario B. The white cell represents the exit of the passage, and the dull-red cell refers to wall or barrier.

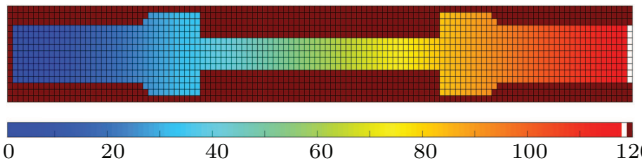


Fig. 7. (color online) Floor field for LP with choosing stairway in Scenario B.

3.4. Transition probability

In general, cellular automata Moore motion rule is widely used.[35] In Fig. 8, including the position occupied by himself, there are nine positions for a pedestrian to go. The transition probability of a pedestrian to each position is shown in Fig. 9.

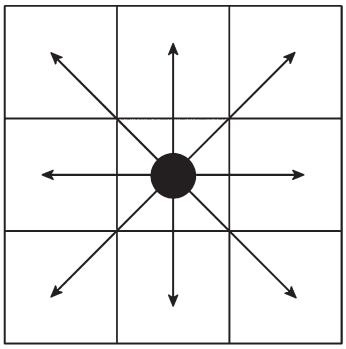


Fig. 8. Moore motion rule.

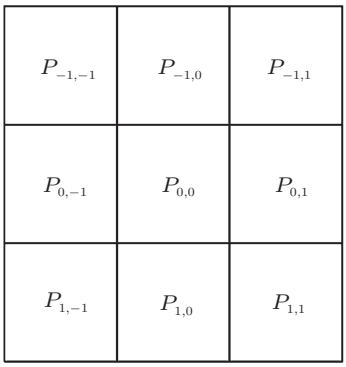


Fig. 9. Transition probability.

With the cellular automata Moore motion rule,[36] the transition probability of a pedestrian is calculated as follows:

$$P_{ij}^m = N \cdot \exp\left(k_{\mathrm{S}} \cdot S_{ij}^m\right) \cdot \exp\left(k_{\mathrm{D}} \cdot D_{ij}^m\right) \cdot (1-\mu_{ij}) \cdot \xi_{ij}, \tag{7}$$

$$N = \left[\sum_{i,\ j} \exp\left(k_{\mathrm{S}} \cdot S_{ij}^m\right) \cdot \exp\left(k_{\mathrm{D}} \cdot D_{ij}^m\right) \cdot (1-\mu_{ij}) \cdot \xi_{ij}\right]^{-1}, \tag{8}$$

where N is the normalized parameter; S_{ij}^m is the value of static floor field at cell$(i,\ j)$ formed by exit m; D_{ij}^m is the value of

dynamic floor field at cell$(i,\ j)$ formed by exit m; k_{S} is the coefficient of static floor field, which reflects the degree of pedestrian familiarity to the inherent characteristics of the scenario; k_{D} is the coefficient of dynamic floor field, which reflects the following trend of pedestrians in procession; μ_{ij} is the parameter which judges whether the cell is occupied by a pedestrian, and $\mu_{ij} = 1$ if cell$(i,\ j)$ is occupied and $\mu_{ij} = 0$ otherwise; ξ_{ij} is the parameter which judges whether the cell is occupied by wall, barrier, and $\xi_{ij} = 0$ if cell$(i,\ j)$ is occupied and $\xi_{ij} = 1$ otherwise.

The k_{S} and k_{D} have a remarkable influence on the distribution of the floor field values. In the process of simulation, k_{D} reflects the following trend of pedestrians. Since the scenario discussed in this paper is the transfer passage of the station, we can treat pedestrians as people who have a specific aim. There is no need to consider the aimless following phenomenon. So, we set the coefficient of dynamic floor field k_{D} to be zero. If k_{D} is set to be a fixed value, when k_{S} increases gradually, the pedestrian motion time would decrease in a nonlinear way.[37] When the coefficient of static floor field k_{S} is equal to 3, the pedestrian motion time is a well acceptable value and the walking features of the pedestrians would appear in the simulation, for example, pedestrians gather in front of the narrow exit and present an arched shape close to the narrow exit. So, we set the coefficient of the static floor field k_{S} to be 3.

3.5. Addition of pedestrian choice model

According to the actual observation, the capacity is larger at the position where the passage becomes wider, and the change of pedestrian flow state gives a 'message' to each pedestrian. Most pedestrians make a choice between escalator and stairway at the position where the passage becomes wider. According to the actual observation, we set the width of the choice zone to be 2 cells and the probabilities of pedestrian choice behavior occurring in 2 cells are equal. The choice zone of Scenario B is shown in Fig. 10.

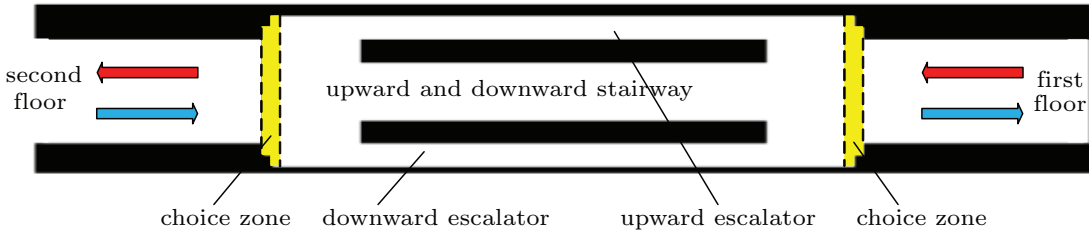


Fig. 10. (color online) Choice zone in Scenario B.

There are two rows of cells in the choice zone, so we set the probabilities of pedestrian choice behavior in the first and second row cells as both 0.5. When a pedestrian arrives at the first row cells of the choice zone, a random number $R(R \in [0,\ 1])$ is generated. If $0 \leq R \leq 0.5$, the pedestrian chooses to take the escalator or take the stairway according to the pedestrian choice model in the first row cells of the choice zone. If $0.5 < R \leq 1$, the pedestrian chooses to take the escalator or take the stairway according to the pedestrian choice model in the second row cells of the choice zone. In this way, the pedestrian choice model of vertical walking facilities is added into the pedestrian simulation model and the pedestrian choice behavior is simulated.

Pedestrians are generated on both sides of the passage, and walk towards the escalator and stairway. When pedestrians arrive at the choice zone, the real-time characteristics of height, luggage, the difference between queuing pedestrians, and walking speed are extracted. Based on these four influence factors, the pedestrian choice model is used to make the choice between escalator and stairway, and the pedestrian choice behavior is simulated by switching the floor field.

Pedestrians generated on the left side of the passage are marked as LP. Pedestrians generated on the right side of the passage are denoted as RP.

Taking the LP in Scenario B for example, the transition probability calculation of LP is dependent on the floor field which is described in Fig. 5 at the beginning. When they arrive at the choice zone, they choose to take the escalator or take the stairway according to the pedestrian choice model of the downward direction. If the pedestrian chooses the escalator, the transition probability calculation of the pedestrian is dependent on the floor field described in Fig. 6. If the pedestrian chooses the stairway, the transition probability calculation of the pedestrian is dependent on the floor field described in Fig. 7.

4. Simulation analysis and discussion

The pedestrian choice model of vertical walking facilities is added into the pedestrian simulation model. The pedestrian choice behavior is simulated by switching the floor field.

Considering the intermittent arrival of a rail transit vehicle, the pedestrian flow of transfer passage comes in waves. In the simulation, the LP are generated first on the left side of the passage. After 70 steps, the RP are generated on the right side of the passage. The pedestrian flow simulations in Scenarios A and B are realized. Five stages of pedestrian flow simulation in Scenario B are shown in Fig. 11.

The first stage: On the left side of the transfer passage, the LP are generated and walks towards the right side.

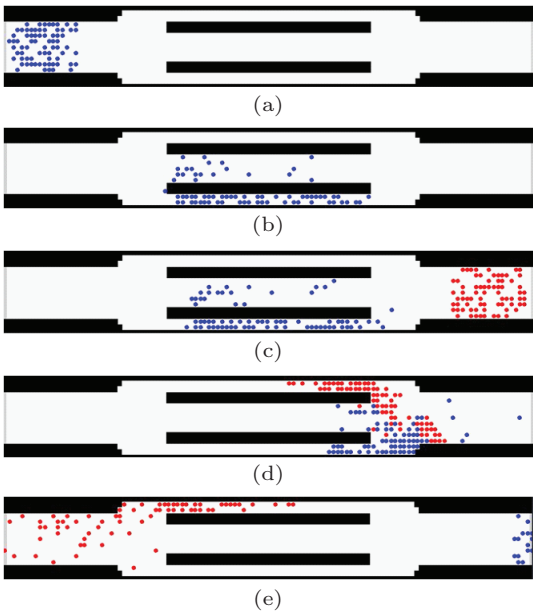


Fig. 11. (color online) Each stage of the pedestrian flow simulation in Scenario B. (a) LP are generated on the left side of the passage; (b) LP choose vertical walking facilities; (c) RP are generated on the right side of the passage; (d) RP choose vertical walking facilities and conflict with LP; (e) LP and RP walk away.

The second stage: LP arrive at the choice zone and they choose to take the escalator or take the stairway according to the pedestrian choice model of the downward direction. The floor field is changed based on the choice results to simulate the choice behavior of LP.

The third stage: After 70 time steps, on the right side of the transfer passage, RP are generated and walks towards the left side.

The fourth stage: RP arrive at the choice zone and they choose to take the escalator or take the stairway according to the pedestrian choice model of the upward direction. The floor field is changed based on the choice results to simulate the choice behavior of RP. LP meet RP and the conflicts appear in the passage.

The last stage: With time going on, the pedestrians pass through the weaving zone, LP and RP arrive at their exits respectively and walk away.

The spatial and temporal distribution of the pedestrian flow in Scenario B are shown in Fig. 12. The z axis denotes time (steps), the x axis represents the long side of the research region, and the y axis refers to the short side of the research region. Different colors of the triangles represent different groups of pedestrians. The blue and red triangles respectively represent LP and RP. The LP are generated on the left side of the passage and walks towards the right side. The RP are generated on the right side of the passage and walks towards the left side. From Fig. 12, at the beginning, there is no conflict, and the pedestrians walk towards their exits. With time going on, LP meet RP, and their conflicts appear (corresponding to Fig. 11(d)). Later, LP and RP respectively arrive at their exits and walk away.

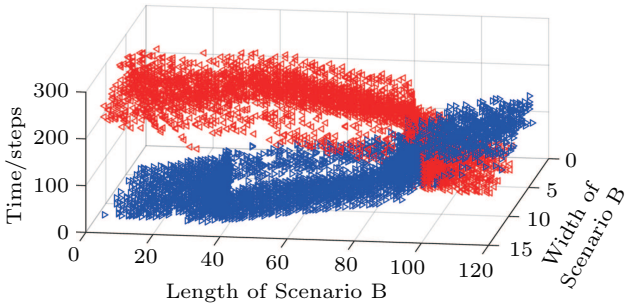


Fig. 12. (color online) Spatial and temporal distribution of the pedestrian flow in Scenario B.

Many pedestrians line up in front of the escalator. These phenomena are all consistent with the actual situation which we have observed. In Scenario A, due to the pedestrians tending to take the escalator, some pedestrians would conflict in the weaving area. This phenomenon is also consistent with the actual situation which we have observed.

With the pedestrian samples of Changchun light-rail transfer station and Beijing Xizhimen transfer station, and the simulation, we can know that when the difference between queuing pedestrians is small, the pedestrians tend to choose the escalator. In the process of simulation, the difference between queuing pedestrians could not be controlled by us. So, we analyze the dynamic influences of the interlayer height, luggage and walking speed on pedestrian choice behavior.

Taking the upward direction for example, 200 pedestrian samples have been selected out from the survey data, and 200 pedestrians which have the same characteristics as those of the pedestrian samples, are generated in the simulation.

With the changing of the interlayer height, the number of pedestrians choosing the escalator is changed, and the relationship is shown in Fig. 13. Taking 50-times simulation experiments, we can find that with the increasing of the interlayer height, the number of pedestrians choosing the escalator is increasing. When the interlayer height is equal to 14.5 m, the number of pedestrians choosing the escalator is 193, that is to say, the ratio of pedestrians choosing the escalator increases up to 96.5%.

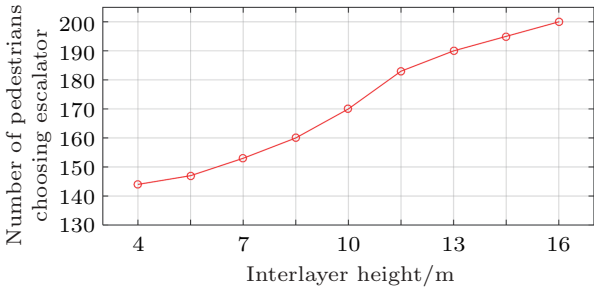


Fig. 13. (color online) Relationship between interlayer height and the number of pedestrians choosing the escalator.

The relationship between luggage and the number of pedestrians choosing escalator is shown in Fig. 14. In Fig. 14, the x axis represents the ratio of the pedestrians without luggage or a little amount, a moderate of luggage, and a large amount of luggage. For example, 100:0:0 represents that the number of pedestrians without luggage or a little amount accounts for 100% of the total pedestrians, the number of pedestrians with a moderate amount of luggage occupies 0% of the total pedestrians, and the number of pedestrians with a large amount of luggage is 0% of the total pedestrians. From Fig. 14, we can know that the ratio of the pedestrians with a large amount of luggage is bigger, the number of pedestrians choosing the escalator is bigger, that is to say, the pedestrian who carries a large amount of luggage tends to choose the escalator.

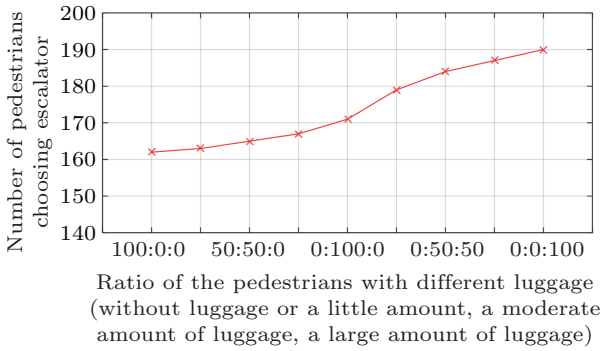


Fig. 14. (color online) Relationship between luggage and the number of pedestrians choosing the escalator.

The relationship between the walking speed and the number of pedestrians choosing the escalator is shown in Fig. 15. In Fig. 15, the x axis represents the ratio of the pedestrians with low speed, moderate speed, and high speed. For example, 75:25:0 represents that the number of pedestrians with low speed accounts for 75% of the total pedestrians, the number of pedestrians with moderate speed occupies 25% of the total pedestrians, and the number of pedestrians with high speed is 0% of the total pedestrians. From Fig. 15, we can know that the difference in influence between low speed and moderate speed is very small. When the number of pedestrians with high speed is bigger, the number of pedestrians choosing the escalator is smaller to a certain extent.

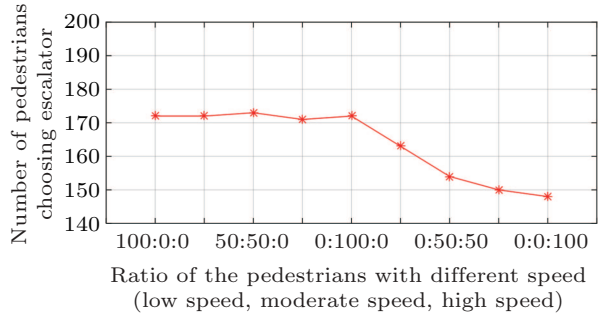


Fig. 15. (color online) Relationship between walking speed and the number of pedestrians choosing the escalator.

Taking 50-times simulation experiments on condition that the numbers of the pedestrians are fixed in Scenario A and Scenario B, respectively, the mean time taken by the pedestrians is obtained. The relationship between the number of pedestrians and the time taken is shown in Fig. 16.

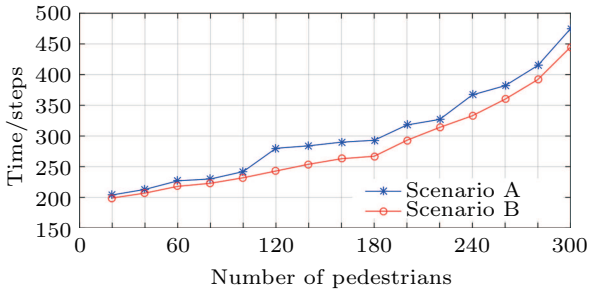


Fig. 16. (color online) Relationship between the number of pedestrians and the time taken.

From Fig. 16, it is noted that in the case of few pedestrians, there is little difference between the times taken in Scenarios A and B. With the number of pedestrians increasing, the difference between the two scenarios becomes obvious. The time taken by pedestrians in Scenario B is less than in Scenario A. Also, the curve of the relationship between the number of pedestrians and the time taken in Scenario B is more smooth than in Scenario A.

5. Conclusions

(i) The pedestrian choice model based on the support vector machine can well predict pedestrian choice behavior between escalator and stairway. The prediction accuracies of upward and downward direction are respectively 91.25% and 87.50%. The prediction results of pedestrian choice behavior are good.

(ii) Adding the pedestrian choice model of vertical walking facilities into the pedestrian simulation model which is based on cellular automata, pedestrian choice behavior is simulated. In the simulation, the effects of the dynamics influence factors are analyzed.

(iii) To reduce the conflicts between pedestrians in opposite directions, the layout of vertical walking facilities is improved. The simulation indicates that the improved layout of vertical walking facilities can improve the efficiency of pedestrians passing.

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