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Research Article

Study on the Weaving Behavior of High Density Bidirectional Pedestrian Flow

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Weaving area may be the critical risk place in the subway transfer station. When improving service level of the weaving area, the characteristic of pedestrian weaving behavior should be systemically discussed. This paper described the mechanism of weaving behavior on high density pedestrian which was analyzed by the collection data of controlled experiment. Different weaving behaviors were contrasted due to different volumes in the bidirectional passageway. Video analysis was conducted to extract pedestrian moving behavior and calibrate the movement data with SIMI Motion. Influence of the high density weaving pedestrian was studied based on the statistical results (e.g., velocity, walking distance, and journey time). Furthermore, the quantitative method by speed analysis was announced to discriminate the conflict point. The scopes of weaving area and impact area at different pedestrian volumes were revealed to analyze the pedestrian turning angle. The paper concluded that walking pedestrians are significantly influenced by the weaving conflict and trend to turn the moving direction to avoid the conflict in weaving area; the ratio of stable weaving area and impact area is 2 to 3. The conclusions do provide a method to evaluate the transfer station safety and a facility layout guidance to improve the capacity.

1. Introduction

Transfer station is the essential node that handles over 40% of total volumes in subway transit network of Beijing, China. With the increasing volumes of transfer pedestrians, the transferring service level in urban public transfer stations is decreasing sharply due to the crowded and interweaved pedestrian flow. As the bottleneck of facilities (e.g., passageway and platform), weaving areas with different streamlines usually are critical risk places in the subway station optimization. Consequently, the pedestrian weaving behavior in high intensity weaving area should be discussed systemically in order to evaluate the weaving intensity, improve the walking comfort, and, in particular, guarantee the safety of pedestrians.

Previous research has consistently shown that the pedestrian weaving behavior in the subway station, stadium, and the evacuation or panic escape under emergency circumstance can perform as self-organization phenomena as follows. (1) Lane: pedestrians moving in opposite directions are generally organized into lanes; number of the lanes could be changed due to the pedestrian volume and speed [1]. (2) Stripe: when the intersection angle of different walking streamlines is not strictly opposite, the individual dodging behavior and overtaking behavior will occur to avoid collisions with other pedestrians in different directions [2], which reflect the behavior as the conformity phenomenon of human. (3) Arch: when the actual capacity cannot afford the volume requirement at bottlenecks of the facility, pedestrians will form a distribution like an "arch" automatically [3], and this phenomenon seriously impacts the pedestrian walking comfort and causes the physical injury. Self-organization phenomenon is the underweaving behavior which has been widely studied by the scholars around the world in the past decades, but the weaving mechanism analysis from individual pedestrian moving factors at weaving area and influence area is rarely discussed. Besides the quantitative discrimination method of the conflict point and weaving area is not mentioned in the previous research papers.

Traditional pedestrian behavior analysis method contains the investigation and pedestrian experiment. With the development of the computer technique, numerical simulation becomes widely used in the pedestrian movement studies [4–6], but the complicated parameter calibrate procedure relies

on the basic data which is collected by the investigation and experiment, and the simulation results may be inaccurately due to the limitation of the simulation model. Compared with the other two methods, the controlled experiment is more practical and accurate in analyzing the mechanism in a particular situation.

The purpose of this paper is to analysis the moving behavior of the high density weaving pedestrians in the weaving area by controlled experiment. A pedestrian experiment with different volumes was proposed to contrast the weaving behavior in high density condition. Statistical results were discussed to analyze the influence of the weaving conflict. With the efficient discrimination and division methods, turning angle of the pedestrian in weaving area was analyzed based on weaving stage division. The self-organization phenomenon is also proved through turning angle analysis.

The remainder of the paper is structured as follows. A brief review of related literature is presented in Section 2. Then an overview is given of the performed pedestrian experiment, including the experiment scene setup, participants compose and followed by a detailed description of the experiment procedure. Then, the data collection method is introduced. The next section describes the discriminant method of conflict point and division method of weaving area, followed by the characteristic analysis results and the comfort evaluation of pedestrian. Conclusions are conducted in the last section.

2. Literature Review

Crowded pedestrians' movement can be described as self-organization phenomena through various observations [3, 4]. Then a series numbers of studies show that these characteristics of pedestrian flow could emerge in different forms on macroscopic aspect. Helbing et al. [1, 2] revealed and explained that pedestrians moving in opposite directions are normally organized into lanes of which are analyzed by statistical physics and modeling framework methods; in addition he found that the lanes of the weaving pedestrians would change dynamically when the volume is changed. Hoogendoorn and Daamen [5] proposed the case of oversaturated bottlenecks or crossing pedestrian flows, pedestrians could be formed into arch. Pedestrian behavior at bottlenecks is described in detail, and different lanes are formed due to different environments [6]. For Guo and Wong's studies [7, 8], moving pedestrians with same desire directions would form a group to avoid collisions with others with different directions; moreover, different "stripe" shapes are formed due to different flows of the intersecting pedestrian flows with different angles (e.g., 45 degrees, 90 degrees, 135 degrees, and 180 degrees).

Based on the knowledge of macroscopic characteristic behaviors of the pedestrian flows, field investigations, controlled experiments, or numerical simulations were successfully applied to analyze the microscopic behaviors and mechanism of the intersection pedestrians. Helbing et al. [9] developed a model of pedestrian motion by investigating the formation of trail system in public areas, and this model can be used to predict pedestrian traveling path by evaluating typical parameter values. Yu and Song [10] found that pedestrians prefer to walk on a certain side by analyzing the walking behaviors about Chinese and Japanese with the investigations and counterflow models. Compared with field investigation methods, quantitative experiments, even to get the accurate moving data by controlling experiment environment and impact factors, would be more efficient. Ma et al. [11]discussed the moving characteristic of Chinese and French in the corridor by moving experiments; he found pedestrians always keep about 0.4 m distance to the wall. Quantified analysis about intersection pedestrians shows that people who locate on the right-forward direction does not change much, while those who locate on the left-forward direction varies with the increase of distance. Lam et al. [12] found the bidirectional pedestrian is affected by walking speed and capacity through the controlled experiment. Xie et al. [13] developed and calibrated the bidirectional pedestrian stream model with an oblique intersecting angle by the experiments. Lam et al. [14] analyzed the effect of bidirectional pedestrian flow at signalized crossing. In addition, a data collection method by video and errors process method by video are also described in his paper. With the development of computer technology, numerical simulation is widely used in the research studies of pedestrians' moving behavior to study the conditions which could not be achieved in reality [7, 15, 16].

With the theoretical and methodical analysis of pedestrian flow, the phenomena of self-organization have been scientifically studied. In recent years, the features analysis of the crowded pedestrian in weaving areas of public places (e.g., subway transfer stations, squares, shopping malls, etc.) was proposed in order to improve the capacity and walking comfort and even guarantee the safety of pedestrian. Yao et al. [17] revealed the relationship between pedestrian crowd volume, speed, and density of interweaving phenomenon by field investigation. The correlation curve proved that the weaving behavior evolved into three basic states (begin, spread and dissipated) but the threshold values of each state were not concerned in this paper. In Wu and Lu's study [18], some controlled experiments were applied to grasp the influence of walking condition on pedestrian weaving flows; the t test result shows that the speed of in weaving area is significantly lower than before and after weaving, which is decreased by 10% to 35%. Weng and Feng [19] built a simulation platform to simulate unidirection weave pedestrian from volume, density, and other feature parameters. In addition, he reported that the capacity of the weave area decreases by 20–40%; the delay of pedestrian flow turning 90 degrees is the minimum.

In order to grasp the operation status and efficiency of the weaving area in the subway station, some indexes were put forward to evaluate the comfort, service level, or safety. Wu and Lu [18] evaluated the operation of weaving area intensity, trajectory offset ratio, and distribution density factor of weaving points. Moreover, based on the three indexes, pedestrian negative utility model was established. The result shows that the pedestrian negative utility is decreased by 34.5% after improving the exit design. Homogeneity and uniformity velocity are performance indexes to measure the number of pedestrian who acts the same way with the agent and the velocities between the actor pedestrian and

(a) Experiment site

(b) Experiment scene

(c) Experiment facility

Figure 1: Overview of the experiment.

the other pedestrians, respectively. These indexes are applied in the pedestrian simulation software which is produced by Teknomo. Besides, Teknomo et al. [20] proposed some indexes (e.g., speed, uncomfortability, delay, dissipation time, etc.) to evaluate the pedestrian on performance and sensitivity levels.

As a brief summary of the four aspects, the characteristic of self-organization phenomena has been analyzed primarily in terms of how regularly it appears to be with crowded pedestrians. The previous studies regarded the density or speed as the main research contents of the weaving pedestrians, but fewer research projects were paid on the analysis of pedestrian individual factors (e.g., acceleration and angle) under a high density situation of the passageway in subway transfer station. However, there has been no research studies that proposed a discrimination method for the conflict point, even a boundary determination method of weaving area. Furthermore, because the quantitative threshold boundary of weaving process is not mentioned in any literatures, the paper will give an effective method to describe the conflict point and weaving area on analysis of the characteristic of weaving pedestrian by experiment, and the factors difference among different sections of weaving process is also explored. Critical values of self-organization in weaving area are analyzed by the moving angle change of each time slice. The paper also discusses the weaving intensity of the each weaving stage in order to evaluate the weaving impact.

3. Pedestrian Experiment

The pedestrian experiment consists of three aspects. Scenario depicted in the first part is used for introducing the experiment conditions. And participants' information is presented later. Besides, organization and process of experiment are discussed in detail at last.

3.1. Scenario. In order to study the mechanism of weaving behavior of the high density pedestrians in the subway transfer station passageway, controlled experiments of high density counter flow have been conducted in the playground of Beijing University of Technology on May 21st, 2013 (Figure 1(a)). Two walls were located vertically to both sides

of the passageway; The wall is 1.85 meter high so that experimenters can perceive the reliability of scenarios at mental level (Figure 1(b)). A digital camera was put perpendicular in the middle above the passageway at 6 meter height in order to extract pedestrian behavior data with the fewer original errors.

3.2. Participants. Totally 50 participants of experiment were selected from the university. 25 of participants are males, while the others are females (mean age ± SD = 21 ± 1.6 years, range 19–23 years; mean height ± SD = 168.18 ± 8.12 cm, range 155–184 cm). Height of participates is strictly controlled under 1.85 meters in case of which all participants in the scenarios may be affected by the experiment environment. Other pedestrian variables with different weights, clothes, and bags are randomly selected. The population is large enough for a high density weaving behavior study in a period of time.

3.3. Experiment. According to the definition in Transit Capacity and Quality of Service Manual 2nd Edition (TCRP) Report 100 published by Transportation Research Broad (TRB) [21], the recommended capacity value of the bidirectional passageway is 4000 person/h/m. Compared with the investigation in the subway in China, this paper designs the pedestrian volumes as follows (3000 person/h/m, 4000 person/h/m, and 5000 person/h/m), and stream ratio is determined as 1 : 1. As is illustrated in the previous study [18], the passageway geometric features (passageway width and length) have no significant influence in weaving area. Thus, the passageway length and width are fixed as a 6 m ∗ 3.5 m rectangle which is similar to reality, to form high weaving intensity. Before every experiment, two group participants stand behind a red line which is 5 meters away from each side of the entrance.

The weaving experiment included three parts: (1) preparation; (2) preexperiment; (3) weaving experiments.

(1) Preparation. Two groups of these participants (25 in red hats and 25 in black hats) stood behind a start line which is 5 meters away from each side of the entrance (Figure 1(c)). The main purpose was to minimize the impact of a start delay. All participants were given the following three suggestions for taking these experiments: (1) imagining you are walking in the passageway of a subway station, two walls are located vertical to the both sides; (2) you can walk at the speed that you would like to; (3) you should begin when the walking command is released.

(2) Preexperiment. Before the weaving experiments, all participants walked through the scenario depending on their own speed twice so that they could be aware of the experiment process and experiment environment.

(3) Weaving Experiments. For the weaving experiments, participants were asked to complete the work with different pedestrian volumes. To ensure the result of experiments is close to reality, each volume is experimented for 3 times (Figure 2(a)).

4. Data Collection

During the experiment, the whole pedestrian behavior is recorded by the digital camera when participants enter the scenario. With the help of the SIMI Motion (Figure 2(b)), manual data collection method by video is used to extract the moving data accurately without errors caused by automatic data collection method. When a pedestrian enters the system, movement track data would be manually marked, so each pedestrian is marked from the time he enters the scenario until he goes out of the scenario with each time slice (0.02 seconds). In addition, all the pedestrians' moving behaviors are recorded in the database consisting of several fields, namely, as follows:

n = pedestrian number;

t = time from beginning to the end (0.02 seconds/time slice);

$length\ (t, t + \Delta t)$ = distance during each time slice of pedestrian n;

$p(n, t)$ = position (x, y) of pedestrian n at time slice t;

$v(n, x)$ = x-velocity component of pedestrian n;

$v(n, y)$ = y-velocity component of pedestrian n;

$v(n, abs)$ = instantaneous speed of pedestrian n;

$a(n, x)$ = x-acceleration component of pedestrian n;

$a(n, y)$ = y-acceleration component of pedestrian n;

$a(n, abs)$ = instantaneous acceleration of pedestrian n.

With these methods, pedestrian trajectory could be described in order to show the moving characteristic of each pedestrian in weaving area (Figures 2(c) and 2(d)).

5. Results

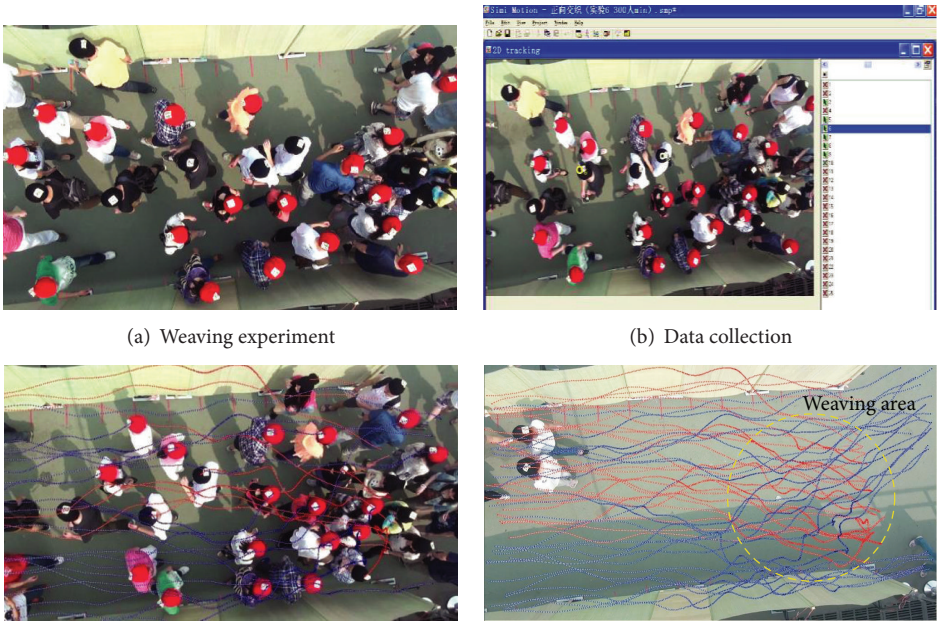
The purpose of this study was to analyze the pedestrian weaving behavior in high density situation. So, the analysis can be divided into three aspects.

(1) Influence of the weaving behavior: pedestrian movement can be delayed and conflict with the opposite direction pedestrians when high density flow is formed. It may impact the pedestrians who will go in and out of the weaving areas during the experiment.

(2) Discrimination of the weaving area: most of the pedestrian conflict happens in the weaving area. The weaving area is a stable zone when the different streamlines intersect together. the discrimination method is necessary for weaving pedestrian characteristic analysis.

(3) Characteristic analysis of the waving pedestrian: if pedestrians are willing to avoid the conflict with others, the turning angle will be formed. The turning angle is a necessary microscopic parameter to know the characteristic of the weaving pedestrian.

Results are presented in three parts: influence analysis, discrimination method of weaving area, and turning angle analysis.



(a) Weaving experiment (b) Data collection

(c) Trajectory calibration (d) Movement trajectory

Figure 2: Data collection of the experiment.

Table 1: Statistical result for pedestrian in different volumes.

Volume/(person·h^{-1})	Index	n	Min./(m·s^{-1})	Max./(m·s^{-1})	Median/(m·s^{-1})	Mean/(m·s^{-1})	Std. deviation/(m·s^{-1})
3000	Velocity	8365	1.064	2.438	1.757	1.751	0.259
	Length	50	6.078	6.922	6.345	6.373	0.281
	Journey time	50	2	4.8	3.651	3.640	0.474
4000	Velocity	13112	0.351	2.300	1.302	1.318	0.352
	Length	50	6.436	7.298	6.789	6.786	0.192
	Journey time	50	3.2	6.6	5.2	5.149	0.674
5000	Velocity	13021	0.011	2.485	1.261	1.238	0.441
	Length	50	6.008	7.382	6.488	6.415	0.355
	Journey time	50	3.4	8.0	5.032	5.183	1.103

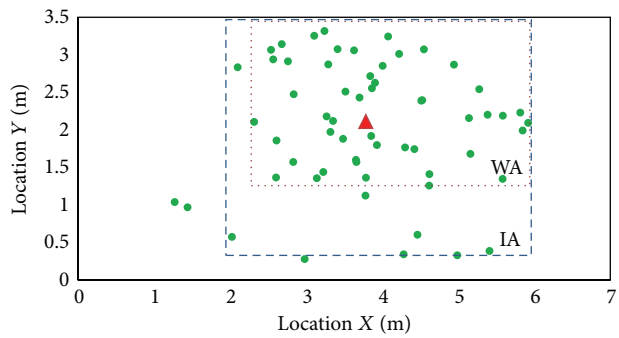
5.1. Influence Analysis. The statistic data used in SPSS is collected in the pedestrian weaving experiments, which aims to analyze the weaving impact on the pedestrian's moving indexes (e.g., velocity, journey time, and length). The statistical result of SPSS analysis (Table 1) can be concluded as follows.

(i) The pedestrian's speed with higher volume is much lower. The average speed at volume 5000 person/h is 1.238 m/s, which is much lower than the speed of 1.318 m/s at volume 4000 person/h and 1.751 m/s with volume 3000 person/h, respectively. The results show that the pedestrian speed is not only significantly influenced by the pedestrian flow, but also relate to the pedestrian conflict intensity. In addition, the standard deviation of higher volume is higher, which seems the pedestrian movement has been fluctuated strongly.

(ii) The pedestrian's walking length is much longer. As it is shown in the experiment description, the length of the passageway is 6-meter long. The average length of the result shows that most pedestrians have to walk long distance to avoid the conflict, which is caused by the opposite pedestrian.

(iii) The pedestrian's journey time with higher volumes is longer. According to the statistical result, the maximum value is 8 seconds which is quadruple the minimum value. It is because of that with the higher volume, lower speed, and longer walking distance, the journey time will be longer.

5.2. Discrimination Method of Weaving Area. The basic idea of weaving area discrimination is to confirm a critical value which would reflect the characteristic of the moving pedestrian. According to the research studies by Wu [22] and Sano and Shida [23], pedestrian average speed in weaving area is 10% to 30% less than that of nonweaving area. Meanwhile, the speed is one of the most important parameters in measuring the pedestrian moving behavior. By the field investigation

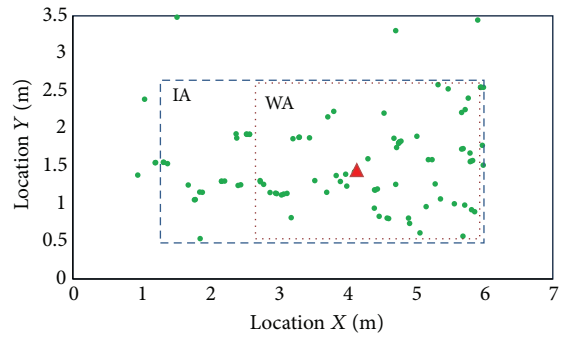


Weaving area (WA): x-axis: (2.10, 5.92) y-axis: (1.12, 3.31) Area: 8.37 m^2

Impact area (IA): x-axis: (2.03, 5.92) y-axis: (0.33, 3.31) Area: 3.26 m^2

Center of conflict: $(x, y) = (3.79, 2.11)$ conflict point: total: 60

(a) *Volume at 3000 person/h in the bidirectional passageway

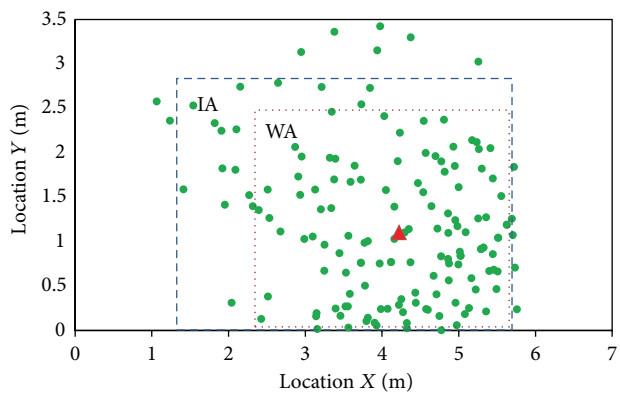


Weaving area (WA): x-axis: (2.78, 5.99) y-axis: (0.57, 2.58) Area: 6.46 m^2

Impact area (IA): x-axis: (1.38, 5.99) y-axis: (0.57, 2.58) Area: 2.82 m^2

Center of conflict: $(x, y) = (4.14, 1.45)$ conflict point: total: 102

(b) Volume at 4000 person/h in the bidirectional passageway



Weaving area (WA): x-axis: (2.32, 5.76) y-axis: (0.00, 2.46) Area: 8.46 m^2

Impact area (IA): x-axis: (1.41, 5.76) y-axis: (0.00, 2.79) Area: 3.64 m^2

Center of conflict: $(x, y) = (4.22, 1.10)$ conflict point: total: 159

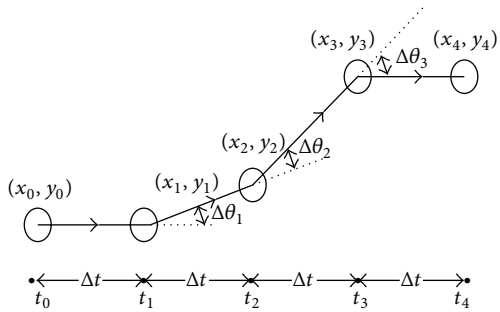
(c) Volume at 5000 person/h in the bidirectional passageway

Figure 3: Weaving area, impact area, and no impact area of different volumes. Note: *impact area is the rectangle area without weaving area, and the coordinate range is also not containing.

and experiment result, we take the speed as the factor to establish the discrimination methodology, which considers the position by which speed decreased by 30% during each time slice (0.02 s) as the conflict point. Referring to the regular statistic, the concept of 85th percentage was conducted, which considers that the area contains 85% of the conflict points, as the weaving area. At the same time, the area which contains 85~95% of the conflict points is regarded as the weaving impact area. The median point in the weaving area is considered as the center of conflict. By calculating the experiment data, the scope of weaving area and impact area of different volumes is determined as follows (Figure 3).

As is depicted in Figure 3, x-axis and y-axis constitute the area of the experiment scenario which is 3.5 m $*$ 6 m equals to 21 m^2; the blue rectangle represents the impact area, which is between the blue area and brown area; the brown rectangle represents the weaving area, which is the high risk area in daily subway transfer station operation and management; the remaining area is the no impact area; it seems that pedestrians in this area are usually steady. Besides, the red triangle is the center of conflict, which represents the highest intensity position in the weaving area.

By dividing the scope of the weaving area and impact area with different volumes, it can be clearly seen that all of the experiments with high density pedestrian can form a stable weaving area; the maximum weaving area is 8.46 m^2 at volume 5000, which occupies the 40% of the scenario and the impact area occupies the 17.3%; the ratio of stable weaving area and impact area is 2.32. Compared with the volume at 5000 person/h, the weaving area of volume at 4000 person/h is the least; the impact area is 2.82 m^2, which is 2.29 times less than weaving area. The weaving area of volume 3000 is 8.37, which closes to volume 5000, but the weaving intensity is less than it; the ratio of stable weaving area and impact area is 2.56.



$$\Delta\theta_1 = \arctan\frac{y_2 - y_1}{x_2 - x_1} - 0$$

$$\Delta\theta_2 = \arctan\frac{y_3 - y_2}{x_3 - x_{1,2}} - \Delta\theta_1 \quad (\Delta\theta_2 > 0)$$

$$\Delta\theta_3 = \arctan\frac{y_4 - y_3}{x_4 - x_3} - \arctan\frac{y_3 - y_2}{x_3 - x_{1,2}} \quad (\Delta\theta_3 < 0)$$

Figure 4: Methodology for calculating turning angle.

Table 2: Levene's test of equality of error variances.

Dependent variable: Turing angle			
F	df1	df2	sig.
8.489	8	603	0.000

It shows that the weaving area of the high density pedestrian ranges from 6 m^2 to 9 m^2 and the ratio of stable weaving area and impact area ranges from 2 to 3, nearby 2.5. The number of conflict point is related to the volume, but the weaving area is not.

5.3. Turning Angle Analysis

5.3.1. Methodology. Macroanalysis contributes to the facility distribution, while microdata is necessary to study the characteristic of the weaving behavior of the individual pedestrian. When the pedestrians encounter another pedestrian blocking their way, they are trended to turn the moving angle to avoid the conflict in weaving area. During this process, we consider that the pedestrian will walk straightly with the shortest path unless a force changed. In order to quantify the characteristic of the weaving behavior at the microscopic aspect and analyze the pedestrian weaving intensity, turning angle is introduced, which calculate the angle difference during each time slice.

To analyze the characteristic of the weaving behavior, this research proposed a methodology to calculate the turning angle, as shown in Figure 4. Pedestrian enters the passageway at t_0; he will change the moving direction at t_1 when he avoids the encounter pedestrian, so the turning angle $\Delta\theta_1$ is the difference of angle during t_0 and t_1. Turning angle is "+", when pedestrian turns to left. Otherwise, it is "−".

5.3.2. Statistical Analysis. The pedestrian turning angles of each 0.4 s are calculated by the position data which is collected in the weaving experiment. In order to analyze whether the pedestrian volumes and weaving areas are influenced by turning angles, variance test may be the benefit methodology. But variance test could not be applied because the turning angle data was not accepted by Levene's test (Table 2), Sig. = 0.00 < 0.05. Thus, the statistical analysis is conducted by the basic data statistics (Table 3).

Table 3 shows that the turning angles increase when the volume is higher; also it is higher than other areas. At volume 3000 person/h, the statistics show that the maximum, median, and standard deviation of weaving area are higher than other areas. The reason is because the volume is low to form a relative high density in other areas. At volume 4000 person/h, the results show that the turning angle in weaving area and no impact area have no significant difference. Volume 5000 person/h result shows that all the statistical results in the weaving area are higher than the others. It means that when the volume is at 5000 person/h, the pedestrian turning angle will change significantly. It is also the highest risk area of the experiment. Besides, comparing the standard deviation in each area at the same volume, the value in no impact area is lower, which means the pedestrian walking direction changes less in this area. It is easier to form the "Lane" phenomenon such as (Figure 2(c)). The results also show that the pedestrian would like to turn right to avoid the conflict in China.

6. Conclusion

This paper describes the microscopic characteristic of pedestrian behavior in the weaving area of the subway transfer station using trajectory data from controlled experiment. By analyzing the pedestrian weaving behavior is not only to identify pedestrian behavior in the weaving condition like subway station, but also to provide a method to evaluate the transfer station safety and a facility layout guidance to improve the capacity.

To come to the microscopic characteristic, the existent research studies have been carried out in order to explore not only the data collection method, but also the parameters of the weaving pedestrians. The scope divide method of weaving area and the discrimination method to confirm the conflict point are not solved in the search. And the turning angle analysis in the weaving area is also not recommended. Thus, from the pedestrian experiment, the pedestrian parameter collection and characteristic analysis in the high density weaving area can be done systematically.

The results of the influence analysis show that the pedestrian's speed with higher volume is lower, and the standard deviation analysis is conducted to prove that the higher volume may cause the strong fluctuation. By analysis of the walking distance and journey, the conclusions show that both of two parameters are influenced by the conflict.

The paper proposed a discrimination method to confirm the conflict point, which is calculated by the speed decrease and uses the 85% statistical value to divide the scope of the weaving area and impact area. Characteristic analysis of the weaving area is provided in the further study; the results show that the ratio of stable weaving area and impact area ranges

Table 3: Turning angle with different volumes in each area not included.

Volume	Area	n		Min.	Max.	Median	Mean	Std. deviation
3000	Weaving area	+	67	0.18	35.45	9.60	11.04	8.25
		−	91					
	Impact area	+	24	0.38	28.55	9.41	10.93	7.52
		−	26					
	No impact area	+	59	0.41	23.19	7.34	8.09	5.42
		−	63					
4000	Weaving area	+	82	0.11	42.22	15.27	17.14	10.84
		−	99					
	Impact area	+	43	0.27	49.10	15.80	17.09	11.48
		−	36					
	No Impact area	+	76	0.26	38.57	11.58	11.55	9.39
		−	112					
5000	Weaving area	+	133	0.22	55.58	14.33	17.44	14.05
		−	154					
	Impact area	+	45	0.33	31.68	12.21	13.24	10.06
		−	32					
	No Impact area	+	69	0.18	43.66	12.99	15.20	10.77
		−	59					

from 2 to 3 and the number of conflict point is correlated with the pedestrian flow.

The objective of the study is to analyze the pedestrian weaving behavior with the turning angle change. The study shows that turning angles will increase when the volume is higher. Besides, by analyzing the turning angle, the results show that the turning angle will be changed dramatically when the volume is changed. The analysis of turning angle in no impact area shows that the pedestrian self-organization phenomenon occurs.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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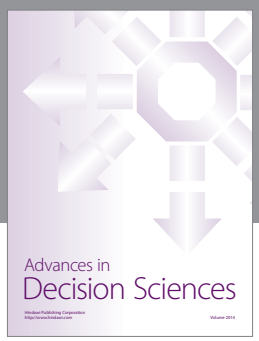

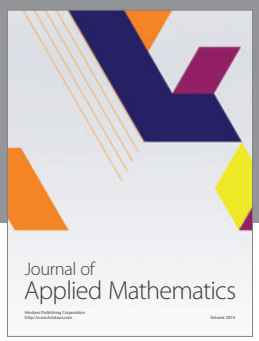

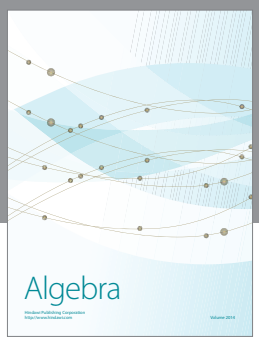

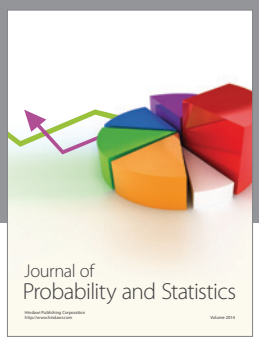

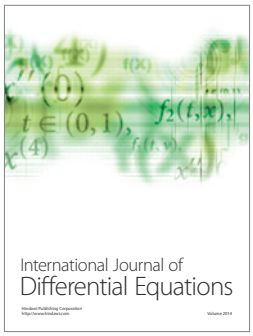

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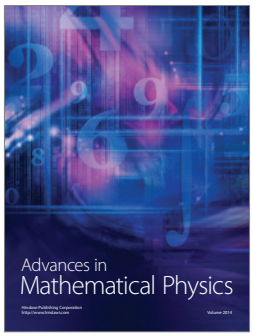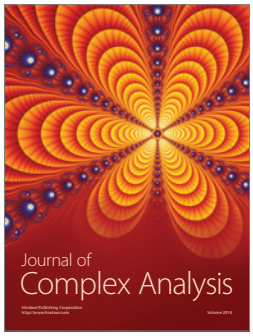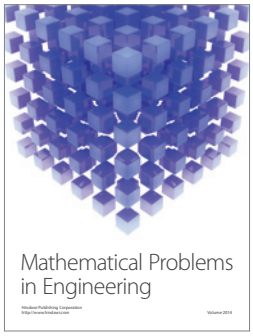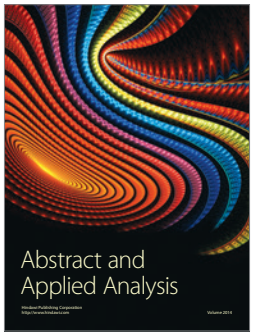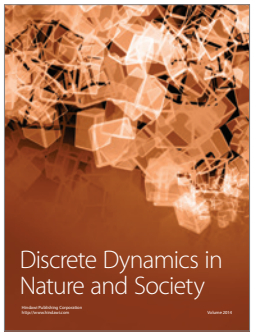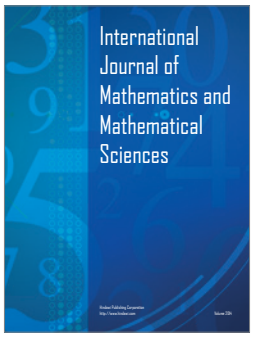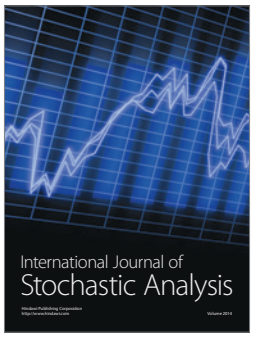
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