RESEARCH ON THE INFLUENCE OF MICROCLIMATE ON RECREATION BEHAVIOR IN URBAN WATERFRONT PUBLIC SPACE

Based on Multi-agent Behavior Simulation

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Abstract. Microclimate is one of the important components of the city environment. Previous researches on public space focused on the influence of spatial forms on user behavior, while ignoring the microclimate elements. This makes it difficult to be authentic of further recreational behavior simulation. The study puts forward a new path to study the influence of microclimate on recreational behavior. Taking the waterfront public space as an example, through the combination of field investigation and microclimate simulation, the influence of wind, temperature, and sunshine environment on residents' recreational is explored, and the influence will be merged into the recreational behavior simulation. In the process of behavior simulation, the microclimate environment classification evaluation map is used. The study committed to achieve a higher degree of adaption between behavior simulation results and actual conditions. The study introduced microclimate influence factors on the basis of the influence of urban spatial form and service facility elements on behavior activities in the past. Based on that, we optimize the simulation method of urban public space recreational behavior, and improve the accuracy of space diagnosis through showing the impact of microclimate on the behavior of people in the space more objectively and intuitively.

Keywords. Behavior simulation; Microclimate; Waterfront public space.

1. Introduction

Urban waterfront public space has a special microclimate effect, which can make people directly experience the environment in the space. Meanwhile, people's

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choice of suitable microclimate environment for outdoor activities results in differences in the use of public space .

GEHL J et al. (1987) first studied the relationship among outdoor microclimate, thermal comfort and behavior. Relevant studies have shown that pedestrians' responses to microclimate are unconscious, but often lead to different use of urban space (Li SG, 1994). But the current research methods of microclimate and behavior are mostly based on mathematical models, whose expression is relatively abstract and lack of intuitive visual expression.

In recent years, behavior simulation has gradually expanded from evacuation behavior simulation to public space recreation behavior simulation (Kevin M et al, 2019). Although more and more scholars are beginning to use visual and refined behavior simulation methods to diagnose existing problems in public spaces, it still ignore the influence of environmental factors such as microclimate on human psychological and physiological feelings. This paper uses computer simulation analysis to study the relationship between waterfront space recreational behavior and microclimate, so as to obtain more refined experimental conclusions.

The microclimate defined by climatology refers to the small-scale climate of the ground boundary layer, which is affected by ground vegetation, soil, topography, water bodies and artificial structures (Landsburg H, 1974). This article focuses on the microclimate conditions that have a significant impact on crowd behavior, namely wind speed, temperature and sunshine. In terms of the relationship between people's behavior value of microclimate conditions, this research is based on the comprehensive environmental perception-behavior theoretical model proposed by Fisher et al. (1984). This theory involves the causes and changes of the microclimate environment's influence on public space behavior. In addition, the crowd itself has a certain degree of self-regulation ability, and people will choose a relatively good microclimate environment to continue outdoor activities; when the microclimate factors exceed the self-regulation ability of the activists, it will affect the degree of occurrence, duration and frequency of space activities (Figure 1).

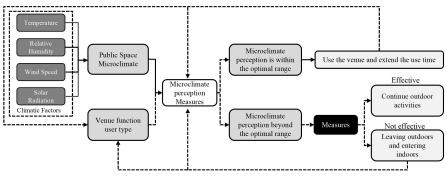


Figure 1. A model of the influence of microclimate on the behavior of people in public space.

This study explores the impact of microclimate environment on the recreational behavior of urban waterfront public spaces and incorporate this effect into the recreational behavior simulation to optimize the behavior simulation method. Through the method of behavior simulation, it can objectively and intuitively show the influence of microclimate on the behavior of people in the space and accurately diagnose the existing problems in the space.

2. Methodology

2.1. RESEARCH OBJECT

Shanghai has a subtropical monsoon climate with obvious seasonal changes. In 2020 , the summer in Shanghai continued from May 11 to October 4. In order to fully investigate the relationship between microclimate and crowd behavior, this study selected October 2nd, a holiday with a large number of people in the space with abundant activities. The sunrise time of the day is 05:48 and the sunset time is 17:38. Taking people's outdoor activities and sunset time into account, the specific research time is determined to be 7:00˜17:00. The study area selects a public space of 100*100m around the public square on the east bank of the Huangpu River in Shanghai, which has a richer internal space form (Figure 2).

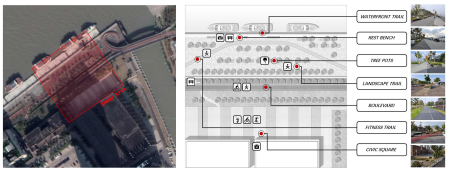
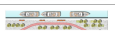
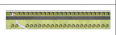


Figure 2. Study area and spatial element distribution.

2.1.1. Types of spatial patterns

Due to the large changes in the spatial form and many spatial elements in the site, in order to facilitate observation and investigation, the site is divided into strip-shaped space and planar space according to its characteristics, and divided into 4 spatial areas according to the waterfront to the remote water (Table 1). We determine the current status of the main spatial elements in each site for detailed research.

Table 1. Current status of physical space environment in public space.

Space type	Ribbon space		Planar space	
Space code	T1	T2	T3	S1
Features	Waterfront road (near water)	Landscape road (next to water)	Forest road (far from water)	Public square (far from water)
Photos				
Floor plan				
Facilities	Bench	Bench	Bench, drinking fountain	None

2.1.2. Characteristics of crowd recreational behavior

In this study, there are two main methods for obtaining crowd recreational behavior. One is to conduct "behavioral mapping" on recreational activities of people in different spaces in the venue; the other distributes questionnaires to obtain the crowd's demands through the use of space in the venue, and provide data support for subsequent behavior simulations.

According to the “behavioral mapping”, behaviors in the venue mainly include strolling, cycling, viewing, resting, etc. Among them, young people have a wide range of behavioral activities. The behavioral activities of middle-aged and elderly people mainly focus on strolling, viewing and resting. Teenagers mainly focus on cycling and strolling, and most of them along with their parents.

According to the questionnaire statistics, people have a high evaluation of the microclimate status of the waterfront public space, and people have the most significant feelings about changes in sunshine (35%), wind speed (26%), and temperature (24%). Therefore, this study chooses sunlight, wind environment and temperature as the most microclimate influencing factors, and explores their impact on the behavior of people in the space.

2.2. RESEARCH PATH

Firstly, through field research, understand the current situation of the site and the current state of recreational behavior.

Secondly, we use Envi-met and Ladybug for grasshopper software to simulate the temperature, wind speed and sunshine of the public space. In order to facilitate the spatial evaluation of the microclimate of the public space, and to facilitate the spatial evaluation of the distribution of wind in the public space, the public space is uniformly divided into a grid of 10m*10m (the grid size is determined by facilitating the distinction between the sites The difference between stroke, temperature and sunlight helps to simulate the behavior after overlay analysis, and also avoids the calculation complexity caused by too many grids). From the perspective of outdoor climate comfort, based on the simulation results of temperature, wind speed and solar shadows in the site, the site is graded and scored by comfort, and the microclimate conditions of the square are completed through means of superposition analysis on various microclimate elements evaluation.

Finally, different attractiveness parameters are set for spaces and facilities under different microclimate conditions, and Quelea for grasshopper is used to simulate the behavior of people in the waterfront public space site. Through multiple fitting adjustments, clear simulation method are established, then through the analysis of the output image, the existing problems in the public space are diagnosed. The specific process is shown in Figure 3.

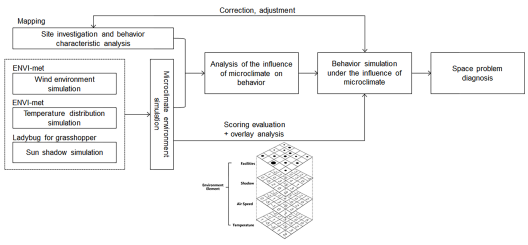


Figure 3. Research path diagram.

2.3. SIMULATION METHOD

2.3.1. Numerical simulation method of wind environment and temperature

Envi-met is the most commonly used microclimate simulation method in existing research. In recent years, many related studies have compared measured data and simulated data to prove that Envi-met has good accuracy for small and medium-scale microclimate simulations in Shanghai (Jiang YF et al, 2019).

The simulation area of each space is established in the ENVI-met4 software. The model is mainly used to establish a grid corresponding to the actual the location and height of the building, the underlying surface material of the public space as well as the type and location of vegetation and set the relevant climate and boundary parameters of the site. The grid of the simulation space is set as 50 (x) × 50 (y) × 20 (z). The latitude and longitude are set according to the geographic location of the citizen square, and the air temperature and humidity are limited based on the data from the Shanghai BaoShan Meteorological Station that day.

2.3.2. Field Sunshine Simulation Method

We use the modeling plan exported by Envi-met as the background base map of Rhino6 to establish a 3D volume model of the same size, and build a 3D model of the trees in the site according to the tree position and actual crown and stem size of the base map, and at the same time to fully reflect the interior of the site Shading conditions, the modeling scope extends a part of it, including all buildings that cast shadows on the site. Using the Ladybug plug-in of Grasshopper to build a battery pack that analyzes the duration of sunshine.

2.3.3. Behavior simulation method

In this study, the Quelea plug-in in Grasshopper was used to simulate crowd behavior. Quelea can release particles regularly according to a certain trajectory through preset particle parameters, and the particles can be used as a simulation of human behavior to provide the possibility of environmental optimization. We use Quelea to simulate the behavior of waterfront activities under the influence of microclimate and compile the activity trajectory of waterfront public space, so as to better cope with the complexity of the urban waterfront space environment and the randomness of behavior activities.

3. Analysis of the influence of wind environment, temperature and sunshine on recreational behavior

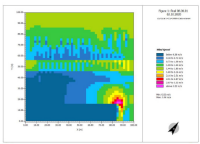
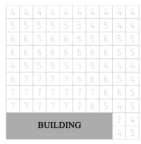
3.1. WIND ENVIRONMENT SIMULATION AND ANALYSIS

3.1.1. Field wind environment simulation

The simulation results from 7:00-17:00 of the day (Table 2) show that the wind environment of the waterfront public space is comfortable. In terms of wind speed distribution, only the north side of the citizen square (S1) is caused by the formation of a vortex effect due to the wind obstruction, resulting in local strong winds. According to the effect of different wind speeds on human comfort, the

simulated wind speeds at each point are divided into 7 levels. The determination of the levels is mainly based on the Soligo standard (Soligo MJ et al, 1998), and based on the simulation results and the weather conditions of the day. It is refined on the basis, and the specific levels are shown in Table 4. And because the wind speed in each space does not change significantly in a day, it is combined into the same one public space wind speed level distribution evaluation map.

Table 2. Wind seed simulation and wind grading diagram.

Wind speed simulation	Wind grading diagram
	

3.1.2. The impact of field wind environment on recreational behavior

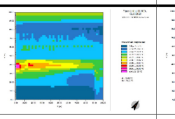
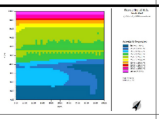
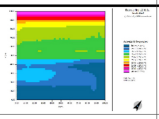
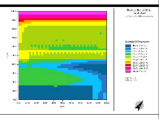
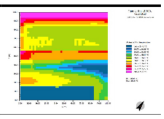
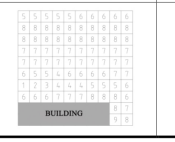
From the comparison of the wind environment classification evaluation map and the survey results, it can be seen that the wind environment has more influence on the behavior in the flat square in the waterfront public space than that in the strip space. According to the survey, the behavior in the square is mainly in the form of tennis, badminton and other sports, with longer stays and higher requirements for wind speed; while the behavior in the strip space is mostly dominated by walking and riding. The feeling of wind speed is not obvious and lack of autonomy and selectivity. In addition, the influence of wind speed on sitting and resting behaviors has different effects due to different recreational purposes. Sitting and resting for the purpose of viewing often choose a space with a closer waterfront landscape, which is less affected by the wind environment. Sitting and resting for the purpose of socializing and resting, they are more inclined to choose less wind speed and surrounding highly compatible space.

3.2. SIMULATION AND ANALYSIS OF SITE TEMPERATURE DISTRIBUTION

3.2.1. Simulation of field temperature distribution

In terms of temperature distribution, the T3 belt space has a high canopy closure and abundant plants, which has a significant cooling effect on the site during the day. On the contrary, T1 and T2 have a larger hard pavement area, so the temperature during the day is higher. Square S1 is different in daytime temperature due to changes in architectural shadows and wind environment, but this change often does not cause differences in space usage. Also in order to facilitate the evaluation of the temperature distribution in the space, according to the range of the simulated temperature results, the temperature of each point obtained by the simulation is divided into 10 levels (Table 3).

Table 3. Simulation of temperature distribution of the field by time period.

Time	7:00-9:00	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00
Temperature simulation					
Temperature grading diagram					

3.2.2. The influence of field temperature distribution on recreational behavior

The impact of temperature on crowd behavior is often manifested in a more macroscopic form, such as the relationship between temperature changes in a year and the number of people in the site. This study can be seen from the statistical data of the temperature and the number of people in different periods of the site (Table 4). The period of the highest temperature and the strongest sunlight between 11:00 and 13:00 is the period with the least number of people in the site. From 13:00 to 15:00 in the afternoon, the site temperature drops, the sunshine weakens, and the microclimate comfort level rises. At this moment, the number of people reaches its peak, and after 17:00, there are still a large number of people coming here to take a walk and rest, which matches the high daytime temperature and low at night.

Table 4. Comparison table of filed temperature and number of people (5min).

Time	7:00-9:00	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00
Temperature（max）/℃	24.12	25.96	27.44	26.53	25.51
Number of people	32	42	26	75	65

Since the human body responds slowly to temperature changes in space, in most cases, the influence of temperature on behavior is often reflected in shadow areas that can be directly recognized by people. This phenomenon is common in striped spaces (such as jogging, cycling) is particularly prominent.

3.3. SIMULATION AND ANALYSIS OF FIELD SUNSHINE HOURS

3.3.1. Simulation of field sunshine hours

The sunshine situation is related to the height and form of the building on the north side of the area. In the design of waterfront public space, the distance, height and density of waterfront buildings largely determine the duration of sunshine in the public space. In the survey site, most of the trees in the belt-shaped space are planted in one row, among which the distance between T1 and T2 trees is relatively too far, causing strong sunlight at noon. The space of the planar square is affected by the shadow of the building, and the sunshine conditions change strongly within a day, which can provide a certain shade and cool space for the area in the hot summer. In this study, the sunshine duration within 2 hours was also used as the standard to evaluate the comfort of the sunshine environment in the site, the score

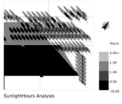
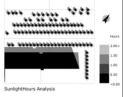
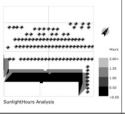
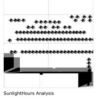
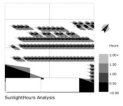
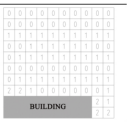
decreased with the increase of sunshine duration (Table 5).

3.3.2. The impact of field sunshine on recreational behavior

Sunshine can generally be judged visually, so it has the most direct impact on crowd behavior. This influence is mostly reflected in the choice of route in the strip space. People judge the shadow range before entering the space and choose the space with better shading conditions to continue their behavior activities. This choice causes the difference in the number of people in the space at the same time. In the belt-shaped space, the influence of shading on behavior increases as people stay in the space for longer.

And this kind of shadow-seeking behavior is particularly prominent in the planar S1. The area of people's activities in the space increases with the increase of the shaded area (Table 5). In the evening, because the absence of sunlight, the sort of activity on the square became abundant which present an irregular distribution.

Table 5. Simulation of sunshine hours, activity type and area in the field.

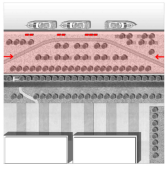
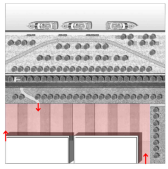
Time	7:00-9:00	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00
Shadow simulation					
Shadow grading diagram					
Activity type (area)	Dance, ball sports (About 1088 m²)	Ball games (About 385 m²)	Walk the dog, walk (About 125 m²)	Pass (About 20 m²)	Walk the dog, walk (About 97 m²)

4. Simulation and diagnosis of recreational behavior under the influence of microclimate

4.1. SIMULATION OF RECREATIONAL BEHAVIOR UNDER THE INFLUENCE OF MICROCLIMATE

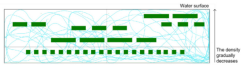
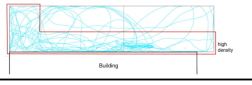
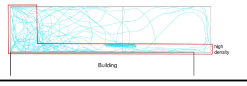
First, the study input the data obtained by the questionnaire as a control parameter into the simulation system. Because there is a height difference between T3 and T1, T2, and S1, and the distribution of attraction points in T3 is extremely limited. Therefore, only T1, T2, and S1 were selected for the simulation experiment of recreational behavior. And the connection between T1 and T2 is relatively high, so they are simulated uniformly. According to the current situation of the site, we set the bench as a attraction point. In this process, the influence of microclimate on behavior is not considered, and the simulation results are shown in Table 6. It can be seen from the simulation results that the distribution of pedestrians is relatively even, which cannot completely match the "Behavioral Mapping" in the survey.

Table 6. Simulation of recreational behavior ignoring microclimate elements.

Space code	T1 & T2	S1
Simulation area, attraction point and agent emission point		
Recreational behavior simulation ignoring microclimate factors		

The study incorporates the influence of microclimate elements into the simulation of recreational behavior, and selects two time periods when microclimates have a greater impact on behavior during 11:00-13:00 and 13:00-15:00. In this process, there are mainly two ways to adjust the behavior simulation results: First, by adding an attraction factor in the center of the grid with a better graded evaluation. Second, adjust the existing parameters of attracting particles, such as setting the bench in different graded evaluation grids to different attractive parameters. So as to form a behavior simulation result that matches the actual situation with a higher degree (Table7).

Table 7. Simulation of recreational behavior ignoring microclimate elements.

	11:00-13:00	13:00-15:00
T1 & T2		
S1		

4.2. DIAGNOSIS OF SPACE USAGE UNDER THE INFLUENCE OF MICROCLIMATE

According to the simulation results in Table 7, from 11:00 to 13:00, due to the strong sunshine on the site, the recreational behaviors of T1 and T2 are mostly concentrated on the far water side with more trees, resulting in a lack of activities on the water side. At this time, the venue is mostly passing behavior and people avoid discomfort caused by staying in the venue for a long time. From 13:00 to 15:00, the site's sunshine intensity decreases and the temperature drops, so the recreational behavior approaches the waterfront side. And due to the lack of retention points on the far water side, the corresponding spatial vitality is reduced. As for the S1 space, most recreational behaviors occur in the shadow space close to the building, and the overall utilization of the site is very limited. The distance between the site and the waterfront landscape is relatively long, and the interior lacks shading facilities and recreational facilities. As a result, the interior is mostly used for walking, cycling, and dog walking. The quantity of residences is small, and the daytime space in the site lacks vitality.

5. Discussion and conclusion

The purpose of this research is to propose a new approach to study microclimate and recreational behavior. In the past, during the process of recreational behavior simulation in public spaces, the impact of microclimate on human physiology and psychology was often ignored, and it was difficult to keep consistent with the behavior of people in the real environment. In the process of behavior simulation, this study uses the hierarchical evaluation map of the microclimate environment to adjust the results of behavioral simulation by two methods: one is to adopt the method of adding spatial attraction points in the grid with higher hierarchical evaluation. The second method is to adjust the parameters of attracting particles in different microclimate evaluations, so that the behavioral simulation results can form a higher degree of adaption with actual conditions. This research can be improved from the following aspects:

(1) In order to obtain enough recreational behavior samples in the selection of the survey date, this study selected the microclimate data of the late summer during the holidays in early October. At this time, residents' behaviors showed more acceptance of microclimate. Subsequent research can investigate the influence of microclimate on behavior during the hot summer season as a comparative study.

(2) Subsequent research will set different weights for wind environment, temperature environment and sunshine hours when superimposing microclimate elements to reduce the error caused in the evaluation.

(3) We need more discussions on the individual attributes, such as the impact of microclimate on people of different genders and different ages. Besides, Quelea as simulation software of behavior and residence behavior is relatively limited. Subsequent research can use Pedsim for grasshopper in combination with it to better simulate the behavior of space under the influence of microclimate.

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