DIFFERENCES BETWEEN BEHAVIOR SIMULATION AND SPACE SYNTAX IN THE STUDY OF URBAN TEXTURE

Considering the Street System and Property Right Plots

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Abstract. The study applies two methods of behavioral simulation and space syntax to study waterfront accessibility from the urban texture levels of street system and property plot, exploring two methods' differences, advantages and disadvantages in terms of simulation principle, fitting precision, and calculating results. The North Bund area of Shanghai is selected as the research sample. And the software of AnyLogic and Depthmap which are mostly used in the fields of behavior simulation and space syntax are used. The results are:Behavior simulation can visually reflect the usage condition of specific spaces through micro behavior data such as pedestrian flow, walking time, etc. But it has limitation in precision and stability of calculation, and the model need much time to construct and run if the site is large. Space syntax is more mature in accessibility analysis with high precise indexes such as choice and integration degree. However, the fitting precision between the output and real situation is lower than behavior simulation, and it can't directly evaluate the capacity and service level of the urban space. In general, both behavior simulation and space syntax can be applied to urban space research and have their own advantages and disadvantages, and complementary in between.

Keywords. Behavior simulation; space syntax; method comparison; urban texture; waterfront.

With the waterfront redevelopment around the world, and the functions of waterfronts have gradually shifted from industry to recreation. In 2017, the 45-kilometer waterfront spaces on both sides of the Huangpu River in Shanghai had been connected, which now become important leisure places for citizens. In 2020, Secretary-General Xi Jinping visited Yangpu Binjiang and proposed the urban construction policy of "People's cities are built by the people, and people's cities are for the people". He emphasized that people-centered development idea must be implemented, and the approach should be based on humanism and make urban design more scientific and refined (Xie, 2020).

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However, there are still problems in waterfronts and surrounding areas. For example, destruction of traditional road network cuts the connection between waterfront and hinterland; super blocks reduce the accessibility, which may affect walking experience and reduce people's willingness to go to waterfronts. So, how to improve walking environments in such areas is worth studying.

Behavior simulation and space syntax are two typical tools used to study space accessibility. Behavior simulation relies on simulation platform to construct scenarios and agents to simulate self-organizing behaviors in urban spaces, which may reflect the conditions of space usage. Space syntax describes the spatial pattern of cities and analyzes space through topological calculations, which may reveal local and overall spatial accessibility and relevance.

This research chooses the software of AnyLogic and Depthmap which are mostly used in the fields of behavior simulation and space syntax to study waterfront accessibility, focusing on the urban texture levels of street system and property plot. It compares the two methods in the simulation principle, operation process, fitting precision, etc., which can help construct waterfronts more scientifically and delicately.

1. Key issues and solutions

1.1. HOW TO UNDERSTAND THE WALKABILITY OF URBAN SPACE FROM THE URBAN TEXTURE?

As a complex system, urban texture is not feasible to understand the interaction of its constituent elements as a whole. Only by decomposing it into several levels according to certain principles, and discovering the correlation between elements, can the overall nature of the urban texture be realized (Fang, 2008). After the urban texture is hierarchized, the quality of each "resolution" has a profound impact on the walkability of urban space. The Italian School believes that urban texture can be decomposed into levels of house types, land parcels, street elements, etc., and the sequence of different levels is inherently connected to achieve layered analysis (Nicola, 2002). The Conzen School believes that urban texture is formed by streets, plots, and buildings, etc. By linking the building and plot through the urban texture, it is possible to fully understand the structure, form, and historical evolution of the city (Conzen, 1960). On this basis, Karl Kropf added more micro-scale levels and proposed eight levels of overall urban texture, urban texture unit, plot sequence, plot, building, room, structure and tectonic node, material, etc. The higher the resolution level, the more specific the urban texture description is (Karl, 1996). The above viewpoints are based on different evaluation criteria, but what is the same is that they all have the levels of building, plot, and street.

Considering the operability of behavioral simulation and space syntax, this research takes two urban texture levels, street system and property plot to study the accessibility of waterfronts.

1.2. HOW TO EVALUATE WALKING SPACE?

Walking space evaluation systems have different perspectives. For example, Ewing scored 48 commercial street videos and determine the impact of street

space elements on pedestrian performance. The influence system consists of five aspects: imagery, enclosed space, human scale, transparency and complexity, including dozens of quantifiable indicators such as passage width, visibility, and architectural diversity (Ewing, 2009); Chen divided the evaluation system into three aspects of accessibility, convenience, walkability, and quantitative indicators of walking distance, walking time, walking psychology, etc (Chen, 2012); Xu sorted out the evaluation factors for the quality of walking activities in commercial streets, and summarized them into four indicators of diversity, connectivity, pleasantness, communication, and pointed out seven important influencing factors such as continuous shop-front, dense road network, sitting facility (Xu, 2017).

According to the objectives, objects and characteristics of this study, walking space evaluation system based on the AnyLogic simulation platform is established including operability, safety, convenience and comfort (figure 1). The evaluation based on space syntax is relatively mature. Depthmap provides many indicators, among which Choice and Integration can visually express accessibility, so this study chooses these two for accessibility analysis.

Pedestrian demand	Influencing factors	Evaluation index based on Anylogic
Operability	Intermittent sidewalk conditions	Pedestrian particle detour situation
	Occupation of sidewalks	Pedestrian particle congestion
Safety	Separation of people and vehicles	Pedestrian particle distribution
	Crowd distribution facility	Pedestrian particle distribution, pedestrian density
Convenience	Sidewalk density	Pedestrian particle distribution, walking time
	detour distance	walking time
Comfort	Sidewalk	Pedestrian flow rate

Figure 1. evaluation system based on Anylogic.

1.3. HOW TO EXPLORE THE DIFFERENCES BETWEEN BEHAVIORAL SIMULATION AND SPACE SYNTAX?

Taking Shanghai North Bund area as sample, the study use behavior simulation and space syntax to analyze the waterfront accessibility from two urban texture levels: street system and property plot. Simulation principle, operation process and fitting precision of two experimental procedures and results are compared.

Behavior simulation has been increasingly used in urban design in recent years. Scholars interpreted the simulation results and used them as the basis for the evaluation of urban environment or design schemes, gradually forming a research process of "simulation-evaluation-optimization" cycle verification (Shcherbyna, 2016; Wang, 2018). On this basis, the study first establishes pedestrian and environmental models in Anylogic through the translation of pedestrian parameters and environment modules. Then, the relationship between pedestrians and environment is showed by simulating walking behaviors. The outputs can help evaluate walkability and the site problems may be found. According to it, some strategies can be proposed and renovation design may be made and simulated again to predict the effectiveness of the design.

Space syntax is widely used in the research of walking space. Existing researches mostly focus on street networks and analyze in a mesoscale perspective (Chen, 2019). In recent years, spatial syntactic analysis integrating multi-level urban texture elements has become the focus. Based on the GIS platform

and built-in spatial syntax analysis plug-in, some scholars evaluated the urban pedestrian network from multiple levels (land use, accessibility, street design, etc.) by the output indicators such as connectivity, integration, and choice (Lee, 2020). On this basis, the study establishes models in Depthmap to calculate the integration and choice, and analyzes the accessibility of different street networks.

2. Research based on behavior simulation

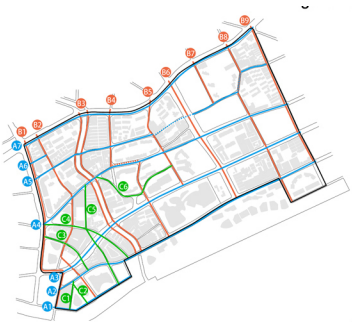
2.1. SITE DATA COLLECTION

2.1.1. Pedestrian flow of road section

It selects the morning peak hours of one workday 2019 and records the pedestrian volume of each road section to obtain current pedestrian flow data (figure 2).

2.1.2. Regional pedestrian volume

It establishes a pedestrian travel OD (origin-destination) model by constructing the pedestrian relationship among metro station, bus stations, waterfront area, office neighborhoods, residential neighborhoods, commercial neighborhoods, and external interfaces. During simulation, OD and DO data are combined to be the pedestrian volume (figure 3).



Pedestrian flow in morning peak hours (7:30 - 9:00 am)												
A1 Huanggu Road	20/40	20/20	20/20	20/20	20/20							
A2 Daming Road(North)	60/100	60/100	60/100	60/100	40/140	40/140	40/140	40/100	110/140	220/20	120/80	60/100
Daming Road(South)	40/140	40/140	40/140	40/140	40/100	40/100	40/100	40/340	100/80	20/100	220/40	40/20
A3 Changzhi Road(North)	20/40	20/40	40/20	40/20	460/60	460/60	300/120	400/340	100/140	80/100		
Changzhi Road(South)	20/50	20/50	10/10	10/10	10/10	40/10	680/180	680/180	60/80	60/80		
A4 Hanyang R - Tangshan R	140/80	140/80	140/80	280/180	280/180	280/180	280/180	60/100	60/100			
A5 Yuhang Road	200/80	200/180	240/200	120/80	120/80	80/140	120/180	120/180				
A6 Maplin Road	100/120											
A7 Zhoujiazui Road (South)	80/60	80/60	80/60	80/80	80/80	80/80	40/40	40/40				
B1 Wusong Road (East)	60/140	60/140	60/140	80/120	80/120	80/120	80/120	100/140				
B2 E'mei R - Wuchang R	160/100	160/100	160/100	100/260	100/260	100/260	60/140	140/100	140/100			
B3 Jiulong Road	160/260	140/160	120/80	40/60								
Liyang Road	160/260	340/320	140/120	100/80								
B4 Wuzhou R - Lvshun R	80/100	120/180	280/60	320/100	360/80							
B5 Shangqiu Road	100/120	100/120	200/80	200/80								
B6 Xinjian Road (West)	160/180	320/140	360/140	740/200								
Xinjian Road (East)	100/80	80/10	240/80	180/120								
B7 Tongzhou Road	80/100											
B8 Gaoyang Road	80/100	80/100	10/10	10/10	80/120	80/60						
B9 Dantu Road	40/60	40/60	80/60	40/60	80/100							
C1 Jinshan Road	60/20											
C2 Tiantong Road	60/20											
C3 Minhang Road	100/80	160/100	100/100									
C4 Tanggu Road	460/80	460/80	460/60	80/60								
C5 Nanxun Road	120/140	10/10	80/60	40/20								
C6 Xi'an Road	260/140	80/100										

Figure 2. current pedestrian flow data.

D \ O	North Bund Park	Metro Station	Bus Stop	Living Plots	Working Plots	Commercial Plots	Externals
North Bund Park	/						
Metro Station	√	/					
Bus Stop	√	×	/				
Living Plots	√	√	√	/			
Working Plots	×	√	√	×	/		
Commercial Plots	√	×	√	√	×	/	
Externals	√	√	√	√	×	√	/

North Bund Park	External A	External B	External C	External D	External E
Pedestrian Number (in / out)	36/12	108/24	120/12	108/36	132/48

North Bund Park	Walking	Metro	Bus	Car/Taxi	Bicycle
Percentage	80%	0	10%	10%	0

Metro Station	External 1	External 2	External 3	External 4	Total
Pedestrian Number (in / out)	400/280	180/1600	280/1480	80/1320	940/4680

Bus stop	1	2	3	4	5	6	7	8	9	10
Pedestrian Number	60	96	48	24	30	24	18	18	18	

Externals	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pedestrian Number	60	280	340	220	160	420	100	320	180	200	160	120	220	80

Figure 3. flow of people at OD elements.

2.1.3. Demographic data

When constructing the pedestrian flow related to residential and office neighborhoods, it is necessary to allocate proportionally based on the population

data of different neighborhoods. The residential neighborhoods are mainly divided into three types and calculated separately: old-style lanes, multi-level determinant communities, and high-rise communities. The office neighborhoods are recorded the number of people who enter the office building during 8:00-9:30 on working days and estimate the total number of people in each office block.

2.2. MODEL CONSTRUCTION AND FITTING

2.2.1. Model construction

Based on AnyLogic platform, the behavior simulation model mainly includes three parts: 1)Pedestrian modeling is to define pedestrian particle parameters such as the size, speed, and distance between particles; 2)Environmental modeling is to translate urban space elements into environmental modules such as Wall and Area; 3)Behavioral process modeling is to construct the moving process of pedestrian particles, inputting the data of pedestrian flow and distribution methods obtained in different time sessions of the survey. Finally, statistical analysis components such as Ped Flow Statistics, Density Map, and Time Measure are placed in the AnyLogic model to facilitate better reading and analysis of simulation results (figure 4).

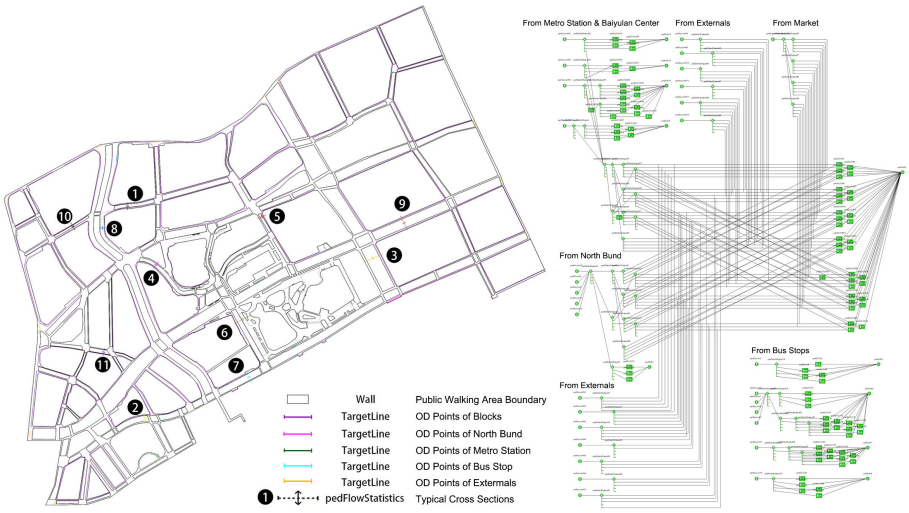


Figure 4. Anylogic model constraction.

2.2.2. Model fitting

The simulation is carried out for test, and 11 typical road sections are selected as samples to fit the pedestrian flow. If some output data are not fit for the current situation, adjustments are made by modifying the pedestrian distribution ratio, controlling the path direction or supplementing the relationship between pedestrians. For example, pedestrian flow on the red path is too high and the purple path is too low. Through site survey, it is found that pedestrians between

the metro station and the Block W24 mostly choose the purple path, which does not match the simulation. By adjusting the allocation ratio of pedestrian flow, the data get more realistic (figure 5). After some adjustments, the model achieves a high degree of fitting, which proves that it can be used as a basis for further research.

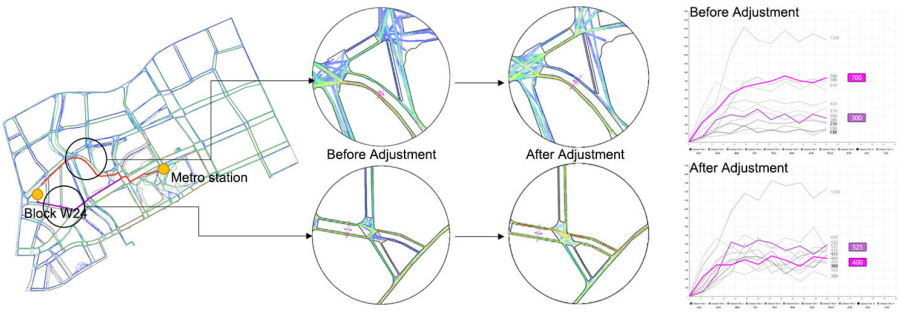


Figure 5. improvement of fitness.

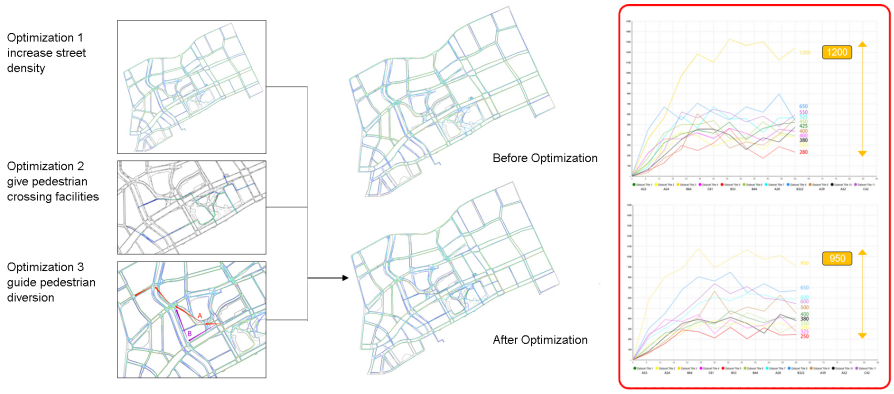


Figure 6. study on the level of street system.

2.3. STUDY ON THE LEVEL OF STREET SYSTEM

2.3.1. Evaluation of road network service level

It selectes the morning peak hours to perform simulation calculations, comparing the current situation with that in 1948. Three main problems in the current road network are found: The reduced road network density leads to serious detours; The grading of the road network leads to deterioration of the traversability; The misalignment of the sidewalk system results in low efficiency of the road network.

2.3.2. Street system optimization and re-simulation

To optimize the above three issues, it proposes some strategies including increasing street density, adding pedestrian crossing facilities, and adjusting the

sidewalk system. Then it simulates again to verify the effectiveness of strategies. Comparing the re-simulation results with the previous one, it can be found that the overburdened traffic decreases, the distribution of pedestrians within the site is more even, and the entire road network is more efficient (figure 6).

2.4. RESEARCH ON THE LEVEL OF PROPERTY PLOT

2.4.1. Evaluation of road network service level

The same peak hours and comparing way are used to study property plot. Two main problems in the current property plot organization are found: The disparity in scale leads to the big gap in the accessibility of different regions; The confused division method changes some accessible roads to cul-de-sacs.

2.4.2. Property plot optimization and re-simulation

Some strategies are proposed. From the perspective of the feasibility of actual land rezoning, one is to open over-sized plots, and to open roads within the land as much as possible (Yang, 2018). The other is to make the division of existing plots better and make more scientific land parcels in planning plots. Through re-simulation, it is found that the allocation of pedestrian flow is more scientific and efficient (figure 7).

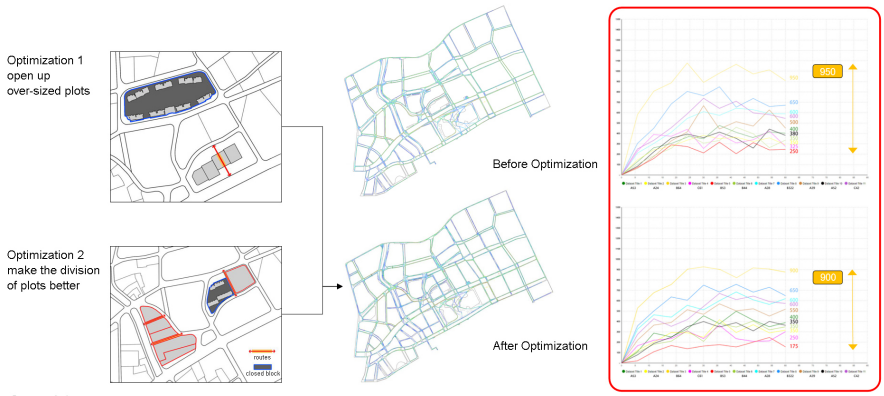


Figure 7. study on the level of property plot.

3. Research based on space syntax

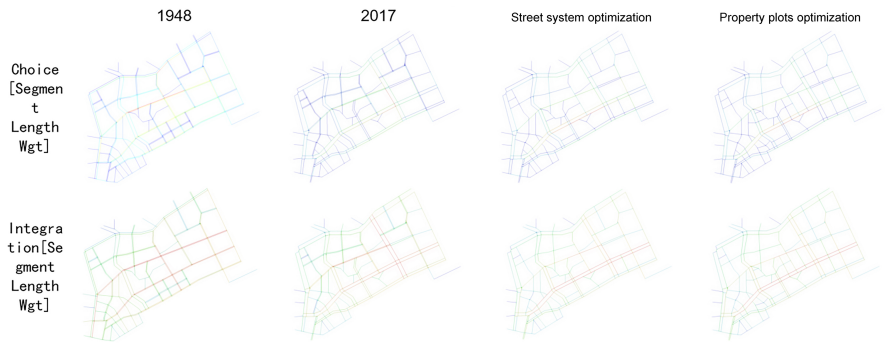
3.1. MODEL CONSTRUCTION

It depicts the pedestrian network cad files of 4 scenarios including year 1948, year 2017, after the optimization of the street system, and after the optimization of the property plot. Among them, the wider roads and high traffic roads are drawn by two lines, while narrow roads, pedestrian and vehicle mixed roads are drawn with a single line. The axis unit is broken into independent line at crossings to translate the current pedestrian space better. It imports the cad file into the Depthmap and

build the space syntax model.

3.2. STREET SYSTEM AND PROPERTY PLOT EVALUATION

It analyzes the Choice (Segment Length Wgt) degree and Integration (Segment Length Wgt) degree of the whole street network and waterfront streets. The road network calculation focuses on the average data. The standard deviation is used as a reference to reflect the evenness of accessibility. The result of the waterfront streets is obtained by taking the average data of the A8-11 south part of East Dongdaming Road which is adjacent to waterfront (Figure 8).



	Whole street network Choice[Segment Length Wgt] Average	Whole street network Choice[Segment Length Wgt] Standard deviation	Whole street network Integration[Segment Length Wgt] Average	Whole street network Integration[Segment Length Wgt] Standard deviation	Waterfront street Choice[Segment Length Wgt] Average	Waterfront street Integration[Segment Length Wgt] Average
1948	1. 958E+13	1. 789E+13	15838753	2433581	3. 062E+13	17547100
2017	1. 862E+13	1. 852E+13	13263304	2014104	4. 363E+13	14802025
Street system optimization	1. 92E+13	1. 931E+13	13449676	2059501	3. 776E+13	15233340
Property plots optimization	2. 032E+13	2. 033E+13	13770555	2138679	3. 875E+13	15543940

Figure 8. Depthmap experiment and result analysis.

The results show that the accessibility including traversability and reachability of the street network are the highest in 1948 and the lowest in 2017. However, through the optimization of the street network and the property plot, the data has ascended, indicating that the optimization has been effective. In terms of standard deviation, the results of 1948 and property plot optimization both indicate that the road network in some areas has never been highly accessible. The reachability of the waterfront streets has been improved through the optimization of the street network and property plot, which proves that the optimized scheme is beneficial for pedestrians from the hinterland to waterfront.

4. Comparison of behavior simulation and space syntax

4.1. SIMULATION PRINCIPLE

The principle of behavior simulation is space behavior theory, which simulates the real behavior activities in space through the model, including micro behavior data such as pedestrian flow, walking speed, and walking time. It visually reflects the usage status and service level of walking space. Space syntax abstracts three-dimensional space into topological graphics, and evaluates accessibility through indexes such as choice, integration, and depth.

4.2. OPERATION PROCESS

Behavioral simulation model requires detailed site research to ensure the effectiveness of the model. The model construction work is relatively large, but the AnyLogic platform is well developed and the operation is simple and easy to understand. The space syntax model is simple to construct, fast in calculation, and the output data can accurately reflect the accessible degree of the space.

4.3. FITTING PRECISION

Based on the bivariate correlation analysis by SPSS of 11 typical road sections, it calculates the fitting degree between the space syntax selectivity data and actual pedestrian volume, the fitting degree between behavior simulation results and actual one as well. It is found that the space syntax fits a little bit lower though it also meets the fitting requirements, while the behavioral simulation has a higher fitting degree and can make the simulation data more realistic through continuous modification.

4.4. LIMITATION

In terms of behavior simulation, the social force model of AnyLogic is less flexible in simulating leisure walking behavior and requires secondary development to realize certain details. In addition, the calculating precision is limited, the output data is unstable, the model construction is more complicated, and the calculating speed is slow. The limitation of space syntax is that the fitting between the simulation results and the real situation is not as good as the behavior simulation. When the research area is small, the drawing method of road network will have a certain degree of influence on the calculating results. On the other hand, the space syntax has an indirect connection with micro pedestrian behavior so it is not easy to evaluate the capacity and service level of the urban space in a certain way.

Technical	Operation	Fitting precision degree	Advantage
Behavior simulaiton	Based on real space	First-time simulation is moderate with the fitting precision degree of 0.744. After continuous optimization, fitness can reach 0,876, which is high.	1.Include indicators such as walking time, pedestrian flow, etc. 2.Reflect the service level of the pedestrian space
Space syntax	Based on topological distance and actual distance	Fitting precision degree is moderately 0,685, mainly because it does not consider the function ad capacity distribution of different plots.	1.Accurate quantitative results 2.Fast model construction and calculation

Figure 9. comparation of two technics.

But in general, both behavior simulation and space syntax can be applied to space research on the scale of urban design. Behavior simulation can visually reflect the usage of spaces, while space syntax is more mature in accessibility analysis. Both methods have their own advantages and are complementary (figure 9).

5. Research conclusions

Taking two urban texture levels of street system and property plot as examples, this research uses behavioral simulation and space syntax to conduct parallel

experiments and comparative studies on waterfront accessibility. It is found that:

(1) The traditional behavioral simulation is mainly applied to the scenarios of indoor evacuation and pedestrian crossing at intersections. In this research, the OD travel model is used to analyze the rules of walking around a 140-hectare urban waterfront area. It shows that this method is valid in micro behavior simulation, which proves that behavior simulation application can be extended to larger-scale outdoor studies, making urban design more scientific and refined.

(2) The traditional urban texture research was mainly carried out from the perspectives of map-base relationship and topological relationship. Taking the view of self-organization behavior, this research combines the urban texture research with pedestrian behavior, which breaks through the qualitative analysis of traditional urban texture and provides a new way of quantitative research.

(3) It compares behavioral simulation and space syntax from the urban medium scale and found that the two technologies have their own advantages and disadvantages. Behavior simulation is good at visually evaluating and predicting the pedestrian capacity within urban space, while space syntax is better in calculating efficiency and quantization precision. If the two are combined to use, it can make research more convincing.

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