APPLICATION OF MULTI-AGENT SYSTEM IN URBAN RENEWAL DESIGN

DLA THESIS BOOKLET

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PREFACE

As cities expand, many old towns face the threat of being renovated or demolished. In recent years, the drawbacks of extensive urban renewal have become increasingly apparent, and the focus of urban development is gradually shifting from efficiency to quality. This study aims to combine urban renewal with Multi-Agent System (MAS) to address the dilemma between efficiency and quality in urban renewal. Modern design disciplines frequently use more effective intelligent technologies and complicated computers due to the advancement of information technology. In order to provide clients additional value-added services, the industry for urban and architectural design has been transformed attributable to the research of intelligent technologies. While computer design techniques have achieved success, there is still untapped potential for MAS in urban and architectural design.

The worldwide urban population, which made up 56% of the world's population in 2021, is predicted to increase to 60% and 68% in 2030 and 2050, respectively, by the United Nations. China is where the trend of increasing urbanization is most obvious. In 2021, the urbanization rate of China's permanent population is 64.72%. Researchers predict that China's total urban population will increase by 255 million in 2050 [1].

[1] Undesa P. World urbanization prospects: the 2018 revision[J]. Retrieved August, 2018, 26: 2018.

[2] Image source: https://m.jiemian.com/article/5509325.html

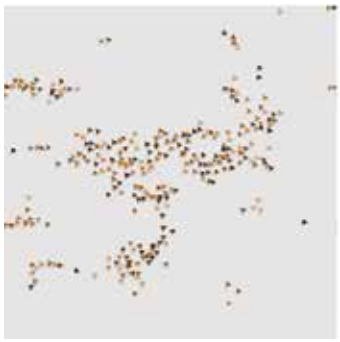
1. INTRODUCTION

RESEARCH BACKGROUND

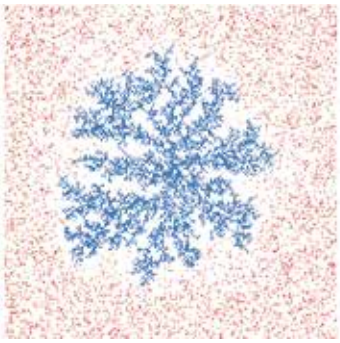
As urbanization continues to develop, the function of urban renewal is becoming increasingly prominent. It is considered an effective method for increasing land value, improving environmental quality, and strengthening social connections. Faced with limited productivity and the rapid growth of urban renewal projects, some cities in China blindly pursued design efficiency and extensively adopted the approach of massive demolition and reconstruction to update the outdated urban areas. In recent years, the drawbacks of extensive renovation methods have become increasingly apparent in urban renewal, such as erasing historical memory, polluting the environment, damaging social stability, and wasting resources. China's urban development is gradually shifting from a focus on quantity to quality, which has led to an increased emphasis on urban renewal and preservation as important factors for evaluating urban quality. However, traditional design methods limit design efficiency. With increasing work pressure, designers have no extra energy to improve the design quality of projects, leading to a dilemma between protection and reconstruction in urban renewal.

RESEARCH OBJECTIVES

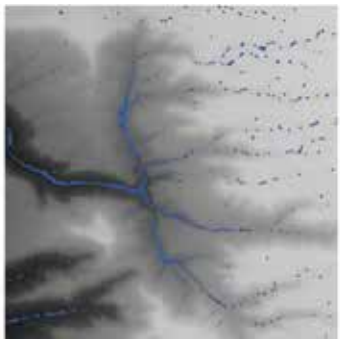
The methods used by researchers to create scientific models have undergone significant changes as a result of the advancement of computer technology, and scientists have become able to investigate models that are more complex. Complex systems are made up of various, precisely defined, tiny agent units. In the simulation process, multiple agents are act autonomously, all the agents are updated asynchronously in parallel. Simple agents are capable of creating complex structures, and intelligence can be explained as the result of a combination of non-intelligent agents. This complex structure is referred to as a MAS. MAS uses computers to simulate and provide decision-making recommendations, and has recently become a popular technique for simulating complex systems. It can be used to automatically generate new complex systems and investigate the functioning of existing complex systems in nature. This study aims to combine urban renewal with emerging technologies to address the dilemma between efficiency and quality in urban renewal. MAS functions as a decentralized, bottom-up, self-organizing dynamic modeling approach, which is well-suited to modeling the complex, decentralized, and dynamic nature of human activity. Compared with traditional machine learning, MAS may have higher efficiency in urban environment design.



Artificial bird flock



DLA model



Stream model

Nordhavnen model

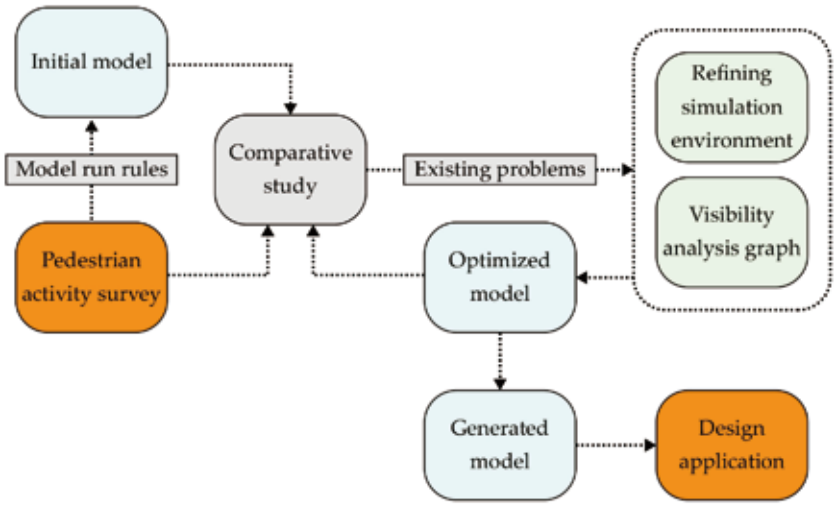
1. INTRODUCTION

RESEARCH SIGNIFICANCE

Most research needs to be completed on existing analysis software platforms. These static models based on graph theory and topology can only output fixed results, lacking creativity. Additionally, most dynamic multi-agent models are used to predict macro-level changes in urban development, but overlook the potential application of this technology in micro-level urban construction. Evacuation models are most commonly studied at the micro-scale, with the shortest path algorithm as the core representation of activities, ignoring the influence of internal states and vision on activities. Although incorporating internal states and visual features into the core of the algorithm has further improved simulation accuracy, the model operates in a 3D environment with lower efficiency. Moreover, the above models still belong to the category of evaluation and analysis and cannot automatically generate corresponding design results. Building a dynamic model with automatic generation capabilities is of great significance for improving the efficiency of designers.

RESEARCH METHOD

To address the issues of inadequate accuracy in evacuation model simulations and low efficiency in 3D modeling, this study proposes a dynamic pedestrian activity model based on a MAS that incorporates visual features. The research first conducts a survey of pedestrian activity paths in historical blocks to identify the significant influence of visual factors on pedestrian behavior. The survey results serve as the foundation for model development and also as a critical reference for verifying simulation accuracy. By comparing simulation results under different parameters with actual pedestrian activity paths and using VGA to refine static information in the simulation environment, the study obtains simulation results that closely match reality paths. Subsequently, based on the optimized agent activity rules of the pedestrian model and dynamic pheromone theory, the study develops a model that automatically generates design result in urban renewal projects. By constructing a simulation environment conducive to agent interaction through dynamically distributed pheromone, the model achieves its goal through competition, stimulation, and optimization. The study ultimately verifies the rationality of the generated results through design practice and demonstrates that the automatic generation model is more efficient, cost-effective, and widely applicable than traditional design methods. This technology can promote urban renewal and the preservation of historical blocks and provide technical support for achieving sustainable development.



2. THESIS STATEMENTS

Thesis 1

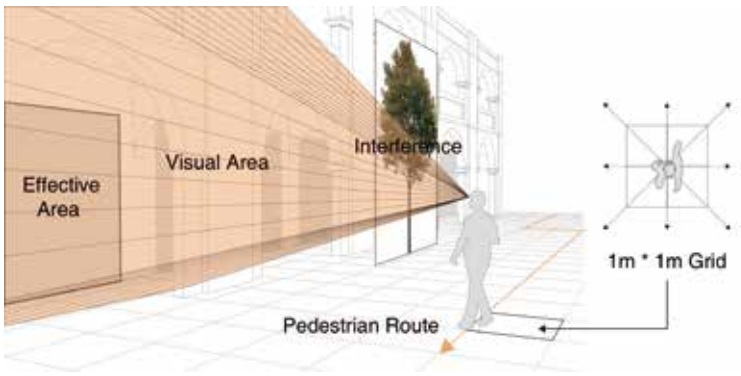
MAS is beneficial to the simulation of human activities, and the construction of dynamic models with automatic generation capabilities still has great potential. (Charter 1)

MAS may find unique intelligent models for resolving difficult design issues. Furthermore, the system functions as a decentralized, bottom-up, self-organizing dynamic modeling approach, which is well-suited to modeling the complex, decentralized, and dynamic nature of human activity. Currently, most dynamic multi-agent models are used to predict macro-level changes in urban development, but overlook the potential application of this technology in micro-level urban construction. In addition, many models on the micro scale use the shortest path algorithm as the core representation of activities, ignoring the impact of internal states and vision on activities. Thus, developing a pedestrian activity model with visual features has great research potential.

Thesis 2

Visual quantification is of great significance for building a refined pedestrian activity simulation model. (Charter 2)

The evacuation model uses the shortest path algorithm as the core representation of activities, ignoring the influence of internal state and vision on activities. Related studies have proved that incorporating internal state and visual features into the pedestrian model can further improve the simulation accuracy. Therefore, the study of visual quantification in the environment has great research significance for the construction of pedestrian activity simulation models.



Pedestrian route selection (PR)			
PR^1	Route anchor	A square grid with a width of 1 meter divides the area	
PR^2	Route direction	Simplify 360 degrees into 8 directions	
Observation point selection (OP)			
OP^1	Number of observation points	Number of grid points on the route	17
OP^2	Observer height	Z coordinate direction of observation point	1.6 m
Observer parameters (OP)			
OP^3	Camera position	Observer position	1-17
OP^4	Lens length of camera		28 mm
OP^5	Viewing angle of camera		75°
OP^6	Focal length of camera		20 m
Visual simulation (VS)			
VS^1	Number of ray for simulation	Rays projected on the object	12*9=108
VS^2	Visual object score (VOS)	Rays projected on the visual object	
VS^3	Building score (BS)	Rays projected on the building	
VS^4	Object visibility ratio	EVR = VOC / BC * 10	

1
2 3

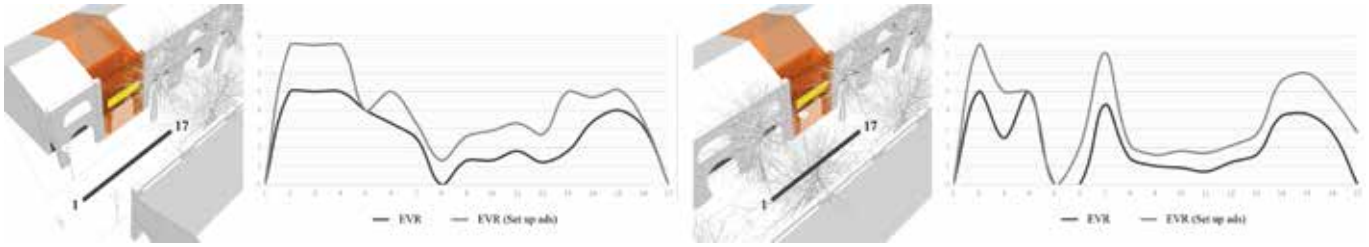
1. Research object-Zhanjiang Minzhu Road Historical Block
2. Visual quantification simulation process
3. Model design and value input

2. THESIS STATEMENTS

Thesis 3

Use the EVR value to quantify the visibility of different areas to evaluate their commercial value and realize the effective allocation of resources. (Charter 3)

The multi-agent evaluation system developed based on the Grasshopper platform has considerable practical value in the evaluation field of historic blocks and historical buildings. Research has proven that EVR can clearly and accurately reflect the visibility of each store. Designers can use the EVR value to quantify the visibility of different areas, evaluate their commercial value, and realize the effective allocation of resources. However, the model needs to run in 3D environment, so it cannot be used in the early stage of design, and can only be used in the evaluation process at the end of the design process. And, the complexity of 3D simulation leads to insufficient applicability of algorithmic models.



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3	4

1. EVR for setting up ads without interference
2. EVR for setting up ads under the influence
3. Visibility evaluation of historical buildings
4. Advertisement settings for store

2. THESIS STATEMENTS

Thesis 4

The VGA model has higher efficiency in the quantitative analysis of the visibility of the micro-environment. (Charter 4)

To address the issues of low efficiency in 3D modeling, this study proposes to use VGA to carry out visual quantitative analysis on the spatial structure of the factory's key renovation area, and compare the simulation results with the real situation, demonstrating that VGA, a two-dimensional, flexible and widely applicable visual evaluation method, has higher application value in urban landscape design. Although the VGA model can more quickly complete the quantitative analysis of visibility in the micro-scale space environment, it is still in the category of static models, and cannot be used as an independent algorithm model to generate design results, nor does it have predictive capabilities.

1

2 | 3

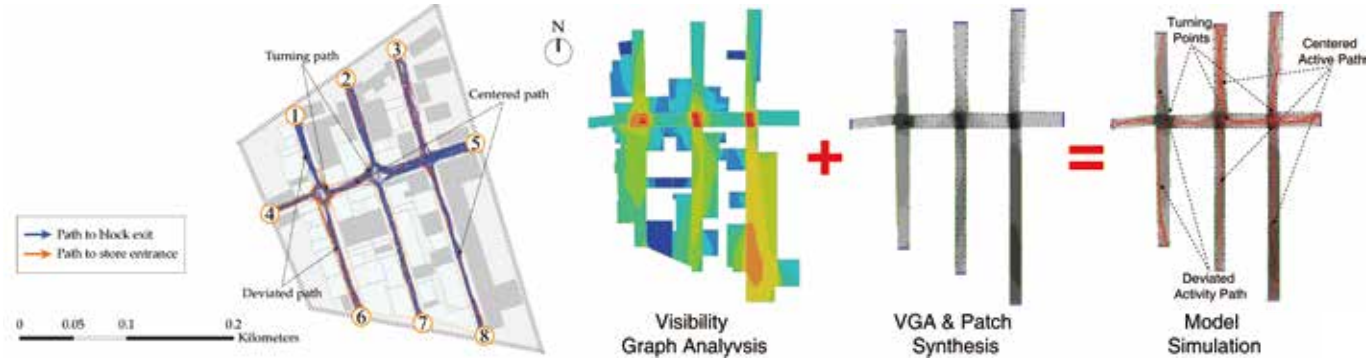
1. Aerial photography of Zhanjiang Steel Factory
2. Cold rolling garden seating area
3. Cold rolling garden corporate cultural display area

2. THESIS STATEMENTS

Thesis 5

VGA has a significant optimization effect on the MAS of pedestrian activity. (Charter 5)

The author conducted field research and recorded pedestrian activity information and patterns, and used this as a basis to construct a pedestrian activity model. Comparing the simulation results of the model with the recorded pedestrian activity paths, it was found that some sections and nodes did not achieve the expected results. To optimize the model and obtain simulation results that are closer to reality, the author combined the basic model with VGA and further refined the gravity in the patches through static pheromone gradient, achieving more accurate path guidance and demonstrating the feasibility of VGA in improving the simulation accuracy of the pedestrian activity model. But the essence of the model remains an analytical tool with predictive properties. Automatic model generation often requires a large number of iterative operations to finally form a relatively stable simulation result. Although the model realizes the interaction between the agent and the environment, it does not realize the linkage between the agent, the environment and other agents. A model that lacks communication cannot form competition, stimulation and optimization, which are the core of automatically generated models.



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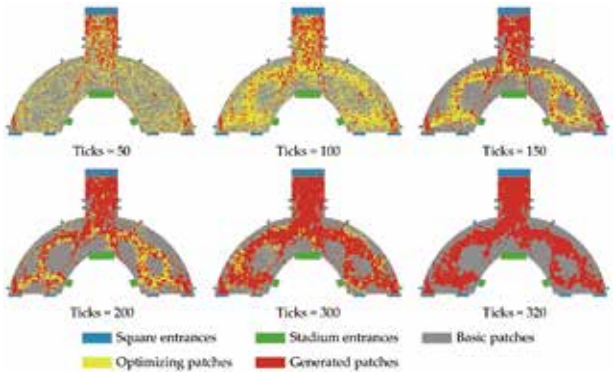
1. Realistic pedestrian activity path analysis
2. Optimizing pedestrian activity models using VGA
3. Renovation rendering of historical districts

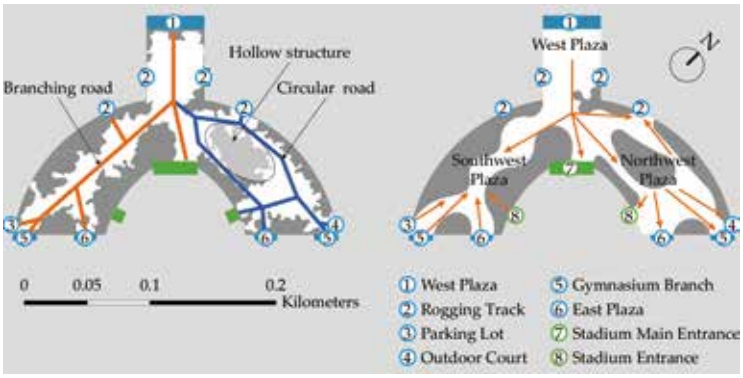
2. THESIS STATEMENTS

Thesis 6

Using pheromones to stimulate the competition, stimulation and optimization of models can effectively construct automatic generation models for urban space design. (Charter 6)

Based on the pedestrian activity model, the author independently developed a self-generating model that can be used for urban renewal design by combining dynamic pheromone theory. The dynamic distribution of pheromone is advantageous in constructing a simulation environment where multiple agents can interact with each other. Agents influence and change the environment by releasing pheromone during the activity process, and the changes in the environment in turn affect new agents. This interactive communication process is more conducive to stimulating the competition, stimulation, and optimization of the model. The new model finally forms a relatively stable simulation result through a large number of iterative operations, achieving the goal of self-generation. This study also tested the feasibility and rationality of the self-generating model through design practice and demonstrated its application value in real urban renewal design work. Compared with the traditional empirical design approach, MAS has higher efficiency, lower investment cost, and a broader range of applications. This technology can effectively promote urban renewal and the protection of historical districts, and provide technical support for achieving sustainable urban development.





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1. Simulation process of generative model
2. Application of simulation results in design
3. Southwest square rendering
4. Square convex space rendering


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