DIGITAL APPLICATION OF TYPO-MORPHOLOGY IN THE CONSERVATION AND RENEWAL OF HISTORIC AREAS

A Case Study of Hehuatang Historical and Cultural Block in Nanjing, China

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Abstract. The conservation and renewal of historic areas are facing many complex and scattered problems, which are not suitable to be completed by a unified method. Designers tried to use the typo-morphology to analyse the morphology of each micro unit to carry out targeted conservation and renewal actions. However, any adjustment of spatial structure may affect the morphological characteristics of the whole block and each micro unit, designers need an efficient method to control the dynamic changes of the block in real-time. Based on the hierarchical structure of typo-morphology, a digital model of the historic areas was built. This model can be perfected as a morphological analysis tool and analyse the block's spatial morphological evolution during its conservation and renewal process. In the renewal design work of Hehuatang historical and cultural block in Nanjing, this method helps designers test each strategy's rationality and find a more scientific scheme to guide the further detailed design. The involvement of digital methods enables typo-morphology to assist design work more accurately and promote the working mode to gradually change from "experience-based artificial induction" to "data-based pattern extraction".

Keywords. Historic Area, Conservation and Renewal, Typo-Morphology, Hierarchical Structure, Digital Model

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1. Introduction

1.1. TYPO-MORPHOLOGY METHOD IN THE CONSERVATION AND RENEWAL OF HISTORIC AREAS

Historic areas are the material carriers of the historical memory of a town. The conservation and renewal of historic areas are crucial to the improvement of the urban living environment and the inheritance of urban history and culture (Wang, 2022). However, historic areas often have a long history, so the spatial characteristics and property rights are very complex. Designers should pay more attention to the authenticity of the environment and the continuity of residents' lives in their actual work. For the above reasons, designers can't simply use a unified method to complete the design of the entire block but should carry out different conservation and renewal actions according to the morphological characteristics of each micro unit (Dong et al., 2021).

In this process, typo-morphology showed its value. Yao Sheng, Tian Yinsheng and others explored the morphological research methods of Chinese traditional settlements by using Conzen's theory of urban morphology (Yao et al., 2013). Fitrianty Wardhani and Samsul Bahri accomplish a comparison study between Bengkulu and Singapore with historical linkages in terms of identifying patterns and characteristics of its city morphology (Wardhani and Bahri, 2021). Han Dongqing and others paid more attention to practice and applied typological methods to the conservation and renewal of Nanjing Xiaoxihu historical and cultural block (Han, 2022). Designers can sort out the spatial structure of historic areas from the perspective of multi-scale hierarchical structure in the field of typo-morphology, and make a clear quantitative expression of the morphological characteristics of spatial elements to guide the design. However, the quantitative morphological analysis also brings a lot of computational work. Any adjustment of spatial structure in the process of these works may affect the morphological characteristics of the whole block and each micro unit, which makes designers need to constantly re-analysis. The conservation and renewal work needs an efficient method to control the dynamic changes of the block in real-time.

1.2. DIGITAL APPLICATION IN THE CONSERVATION AND RENEWAL OF HISTORIC AREAS

With the rapid development of information technology, scholars began to use digital methods to solve complex problems in the conservation and renewal of historic areas. Wu Jiayu, Lu Yutian and others used ridge regression and LightGBM with multi-source big geospatial data to explore whether urban morphological elements that affect the vitality of heritage and urban areas are consistent or have different spatial distributions and daily variations (Wu et al., 2022). Marra Adriana and Fabbrocino Giovanni built a crowd-based tool for indirect condition assessment and conservation of cultural heritage, this work has promoted the participation of diverse groups in the renewal design of historic areas (Marra and Fabbrocino, 2021). Wang Xiao, Tang Peng, and others develop a new method of feature analysis and generative design to regenerate the district in the study on Gunanjie Street, in Yixing, China. The proposed method generated the referable design schemes quantitatively and established

generally accepted conservation plans and guidelines (Wang et al., 2019). Siew Leng Leong and Patrick Janssen proposed an innovative participatory design approach through a web application and assisted the co-design and co-decision process in heritage conservation (Leong and Janssen, 2022).

Through the above research, the digital method shows its great potential to enhance the scientific design, optimize the method flow and improve the work efficiency in the conservation and renewal of historic areas. This study built a digital model, which can calculate and store the analysis results of all micro units in the field of morphological typology. Based on this model, an analysis tool had been constructed and used in the conservation and renewal of the Hehuatang historical and cultural block in Nanjing. In this study, typo-morphology controls the dynamic changes of historic areas in real-time through digital methods. While the conservation and renewal work has received accurate support, the applicability of the theory has also been improved.

2. Research Method

2.1. THE HIERARCHICAL STRUCTURE AND MORPHOLOGICAL ANALYSIS OF HISTORIC AREA

The analysis of morphology always starts from the description of morphology (Han, 2013). The scale hierarchical structure in the field of typo-morphology provides a clear framework for the description of the morphology of historic areas. The spatial structure of Chinese historic areas is complex, but the spatial elements still show the characteristics of a hierarchical structure. This study follows Kropf's multi-level diagram and uses the hierarchical structure of " blocks - tissues - street and plots series - plots - areas and buildings " to recognize Chinese historic areas (Kropf, 2011) (Figure 1). Each historic area is composed of multiple simple tissues, a single street and the plots connected on both sides constitute a simple tissue. The plot also contains buildings and courtyards. Among them, tissues, plots, and buildings, as the most important three levels, are most closely related to the conservation and renewal of historic areas.

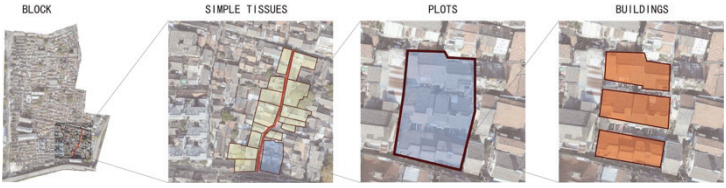

Figure 1. The hierarchical structure of Chinese historic areas

In this hierarchical structure, the research focuses on the characteristics of tissues, plots, and buildings in two aspects. On the one hand, the study analysed the morphological characteristics of space elements themselves, such as the length and width of roads, plot ratio of plots, building floor area ratio, etc. In this study, they are named Self Morphological Characteristics (Hereinafter referred to as SMC). SMC are helpful for designers to cognition and understand the spatial characteristics of renewal objects themselves, and respond with appropriate strategies. On the other hand, the

study focuses on the connection between spatial elements and their relationship with the outside. This connection relationship is expressed quantitatively by the depth value, connectivity value and other values based on the space syntax (Hillier and Hanson, 1989). In this study, they are named External Connection Characteristics (Hereinafter referred to as ECC). ECC reflects the topological structure between the spatial elements in the block and can reflect the publicity and connection tightness of each spatial unit. It can help designers to give each spatial element corresponding functional positioning and development orientation. The specific morphological analysis framework based on the hierarchical structure is shown in Figure 2.

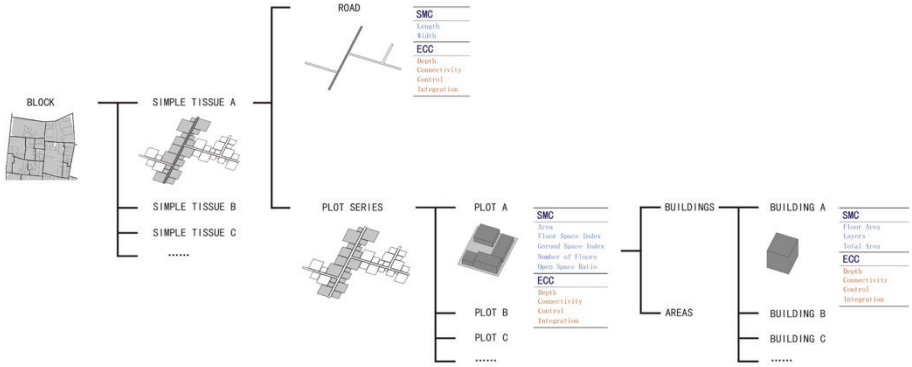

Figure 2. Morphological analysis framework based on the hierarchical structure

After obtaining the morphological analysis results corresponding to each spatial element, this study classifies the spatial elements according to the morphological characteristics. Classification can help to recognize the space through types and control the future design orientation. K-means clustering algorithm is introduced to determine the type, and all spatial elements at the same level are clustered according to their own SMC and ECC. The use of the clustering algorithm eliminates the human factors in manual classification and obtains more accurate type characteristics of the whole block.

Based on morphological typology, this study has formed a morphological cognition and analysis framework of "deconstruction-analysis-classification" of Chinese historic areas. This framework combed the relationship between spatial elements in the historic areas and presented the results of morphological analysis and type characteristics. In this framework, the connection between spatial elements is clear, and the characteristics are also expressed by quantitative values, which is very suitable for digital reproduction.

2.2. DIGITAL MODEL OF MULTISCALE HIERARCHICAL STRUCTURE

This study uses Java language programming to construct the corresponding digital model with the scale hierarchical structure as the basic framework. The classes in Java can be used to express things with the same attributes. Therefore, corresponding classes are defined in the digital model for the spatial elements at each level, and different objects of one class are used to represent multiple spatial elements of the same level. In addition to the morphological information of space elements at this level, the attributes of each class also include the objects of the space elements at the next level.

For example, the attributes of one plot object include the objects of buildings which are in this plot. This structure realizes the data linkage of all levels in the digital model (Figure 3).

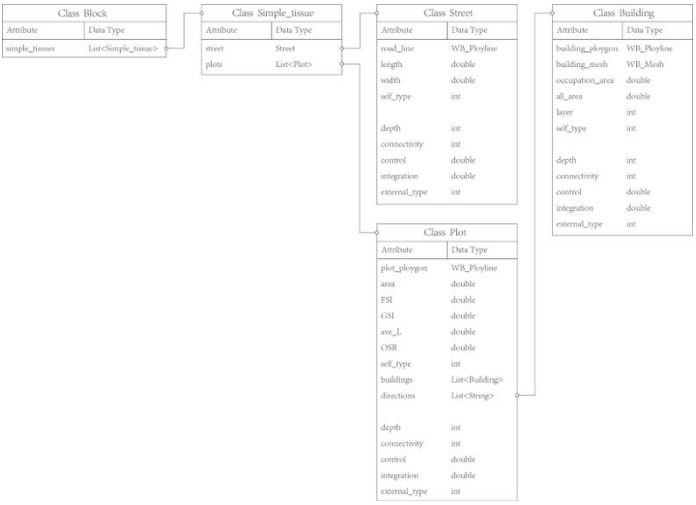

Figure 3. The structure of the digital model

The program cannot directly identify the historic areas' actual shape, so the geometric information of the spatial elements is extracted from a map file. The program reads the geometric information of each layer from the dxf file and translates it into corresponding class objects, which are stored in different data sets.

The morphological analysis and classification of spatial elements are completed in the digital model. In this study, the morphological analysis method is transformed into the corresponding geometric algorithm, and then into the Java program function. Each time the program runs, it can quickly calculate the morphological analysis results of all spatial elements at all levels. Then the program runs the K-means clustering algorithm and quickly gives the type characteristics of spatial elements at the same level according to the morphological analysis results.

In order to make full use of the real-time update and fast feedback characteristics of the program calculation, the functions of spatial structure adjustment and cycle update are also added to the digital model. The data sets of roads, plots and buildings in the mathematical model can be increased or decreased at any time. This function corresponds to the road network adjustment, plot division and building demolition in the process of conservation and renewal of historic areas. The digital model can be updated and calculated in real-time according to the adjusted spatial state, and new morphological analysis and classification results can be obtained. At this point, a digital model of historic areas has been constructed. It can store and link spatial elements information at multi-scale levels and update morphological analysis results in real-time according to changes in spatial structure (Figure 4).

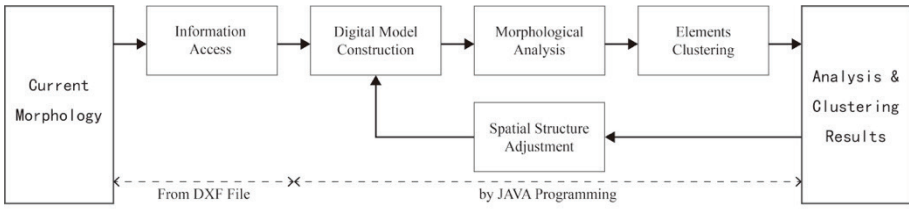

Figure 4. Operation process of the digital model

3. Analysis Tool Applied to Practice

3.1. MORPHOLOGICAL ANALYSIS TOOL BASED ON DIGITAL MODEL

After the completion of the digital model, a more direct medium is still needed to connect the model with the actual workflow, so that the analysis results can quickly assist the design. The digital model has an operation interface, thus becoming an interactive decision-making tool.

The centre of the tool interface is the general map of the block. The program draws the corresponding geometric figures according to the geometric information of each spatial element in the digital model and displays the morphological type of the spatial element through colours. The general map includes SMC and ECC modes. Each mode can be switched between the plot view or the building view, as well as the corresponding 2D or 3D perspective. In the tool interface, designers can view the detailed information of a space element according to the actual needs. The detailed data of a road, plot or building can be displayed in the right data bar to ensure that the morphological analysis results accurately guide the design (Figure 5).

Figure 5. Multiple data display modes of the tool

The addition of the adjustment and update module is an important step for the tool to face the actual workflow. A buttoned operation panel is added on the left side of the tool interface, and the buttons are linked with the corresponding space adjustment and update methods in the digital model. The users can complete the adjustment of the morphology of the block through simple operations in the tool interface, including the increase or decrease of streets, merging, splitting, and adjusting the entry direction of plots, and the demolition of buildings. After each adjustment, the updated general analysis map can be obtained in real-time (Figure 6).

Figure 6. Complete tool interface with adjustment and update functions

On the one hand, the tool provides visual morphological analysis results, and users can view the real-time information of the whole block or a certain spatial element at any time to make more scientific design decisions. On the other hand, the tool highlights the characteristics of real-time updating of digital models. Users can obtain the analysis results in real-time during the design update process and conduct a rapid comparison to verify the rationality of the design strategy.

3.2. PRACTICE IN THE CONSERVATION AND RENEWAL OF HE-HUATANG

The method section introduces how to build a digital analysis tool based on the digital model, which is consistent with the actual workflow. This research is based on the actual work process of the conservation and renewal of Hehuatang historical and cultural block in Nanjing and verifies the effectiveness of the tool in practical work.

Located in Nanjing, Jiangsu Province, China, Hehuatang historical and cultural block has a history of hundreds of years and has always been an important residential area in the south of Nanjing. Hehuatang covers an area of about 12.57 hectares, and its interior is mostly one to three storey old houses. Due to its long history, its internal roads are narrow and its living environment is dilapidated and chaotic (Figure 7). In particular, the plots have become very fragmented due to the continuous redistribution

of property rights, which makes the shape of the block very messy. Efficient shape analysis tools are urgently needed in the process of conservation and renewal.

In this study, several designers who participated in the renewal design of Hehuatang were selected to try out the tool based on the actual project design work. Firstly, the designers made operations such as adding roads, deleting roads, and resetting the road width in the tool interface. The road network of the block had been re-planned. The tool can provide new road network analysis results which were adjusted based on different design strategies so that designers can quickly compare and select multiple road planning schemes. After the new road network had been determined, the designers reorganized the morphology of all plots in the tool interface. Through the re-division and combination of the plots, the original plots divided based on property rights will be integrated into a form that is convenient for subsequent design updates. Finally, the designers determine the future functional orientation of each new plot based on its own morphological characteristics and get the new layout and function positioning map of the block. This map will be used as the working base map to guide the specific design scheme in the follow-up work (Figure 8).

Figure 7. Map and current environment of Hehuatang historical and cultural block

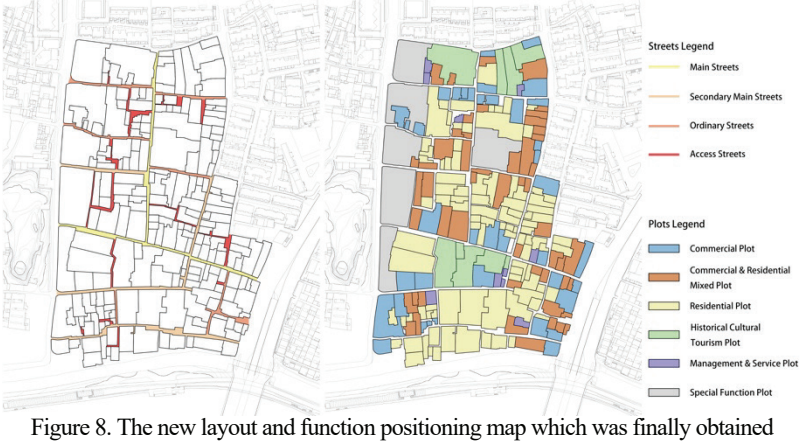

Figure 8. The new layout and function positioning map which was finally obtained

3.3. DISCUSSION ON APPLICATION PRACTICE

Through this practice, the application value of this morphological analysis tool has been confirmed. Designers can compare and choose road planning and plot division schemes more efficiently and scientifically.

The designers who participated in the practice also pointed out the limitations of the current method. Firstly, the conservation and renewal design of historic areas is not only based on the results of morphological analysis but also needs to consider more social and cultural issues. Therefore, the results of the morphological analysis can only be used as a partial reference for design. Secondly, the design is decided by the designer. However, through this method, designers can only make modifications according to their own preferences or morphological characteristics data. This process is still a subjective decision process with incomplete consideration. Finally, the essence of this research is still the analysis process before the design. The results which were provided do not involve the subsequent actual design process. In the follow-up work, the generative design method under the guidance of morphological analysis should be introduced. This research can be better applied to practice.

4. Conclusion

The conservation and renewal of historic areas is an eternal topic. The spatial structure in the historic area is fragmented and the social needs are complex. Designers need to carry out accurate morphological analysis of micro units, in order to complete the updated design more in line with the wishes of residents and other relevant users. Under this background, this study applies the theories of typo-morphology to the conservation and renewal of Chinese historic areas and constructs a morphological research process of "cognition-analysis-classification". Then the analysis framework is translated into a digital model, which can be expanded into a real-time morphological analysis tool. The involvement of digital methods enables the conservation and renewal of historic areas to obtain real-time and accurate morphological analysis references. The application field of digital methods has been expanded, and the theoretical research of typo-morphology and design practice are better integrated.

With the people-oriented design concept gradually becoming popular, the design scheme of historic areas is no longer based on the value judgment of a designer, but a more accurate result obtained after a comprehensive analysis of complex information. The morphological analysis must provide analysis reference for design in real-time, and data has become a powerful medium. The involvement of digital methods makes each step of the conservation and renewal of historic areas connected by data streams. The connection and interaction between morphological analysis and morphological design are formed. The transformation of the working mode from "experience-based artificial induction" to "data-based mode extraction" has become an important technical significance revealed by this study.

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