ANALYSIS AND CONSERVATION METHODS OF TRADITIONAL ARCHITECTURE AND SETTLEMENT BASED ON KNOWLEDGE DISCOVERY AND DIGITAL GENERATION

A Case Study of Gunanjie Street in China

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Abstract. In the conservation plan of traditional architecture and settlement, the mismatch between design and construction is an inevitable problem. The mismatch commonly shows as the variations in the cognition of the traditionality of architecture feature. In most cases, the evaluation of historical feature is made based on designers’ subjective perception, experience, and understanding of the traditional style. Also, without an appropriate guide and unified control, it could make the conservation plan less efficient in practice. Therefore, a quantitative method for conservation plan is needed, which is expected to be effective especially for massive non-key but traditional ordinary buildings. In this study on Gunanjie Street, in Yixing, China, a new method of feature analysis and generative design was developed to regenerate the district. The proposed method first adapted new data acquisition and processing techniques to gather information and build the database. Cognition investigation and morphology analysis were then implemented to quantify and evaluate the features of historical characteristics, as well as the knowledge discovery tools, were further used to abstract the rules of the traditional facade. With these phases, the proposed method was able to generate the referable design schemes quantitatively and establish generally accepted conservation plans and guidelines.

Keywords. Traditional architecture and settlement; historical feature; Knowledge Discovery; digital generation; conservation.
1. Introduction

1.1. BACKGROUND

In the conservation work of traditional architecture and settlement, each actor has different knowledge backgrounds, which leads to a deviation in the cognition of the historical features of the traditional architectural settlement as the research object. For example, the discrimination and evaluation of the existing features are restricted by the designers’ personal understanding of the historical style and elements; the guidelines presented by the drawings and words are also abstract and expatiatory for ordinary residents. The gap between design and construction caused by differences of individual cognition, barriers to the transmission of professional information and lack of evaluation standards reduces the significance of planning for protection. On the other hand, due to the lack of practical design and optimisation tools, many design tasks in the traditional architecture and settlement renovation work, homogenised design schemes and long design period are inevitable. The result of its implementation even destroyed the existing area to some extent.

1.2. RELATED RESEARCH

With the developing of intelligent technologies, objective and effective design method based on the seamless integration of information acquisition, automatic analysis and computational design can be implemented more and more smartly supported by data and algorithm (Hovestadt, 2009; Carpo, 2017). Regarding data acquisition, new digital technology about data collecting, handling, storage, and consultation can adapt the mapping information into knowledge in architecture design and urban plan, besides the conventional measurement for drawing or exhibit for display. Regarding automatic analysis and design, increasing theories and technologies are developed targeted at objective designs, such as Knowledge Discovery by Data Mining in Artificial Intelligence field and generative design in Computer-Aided Design field. For example, Japanese researchers applied the Rough Set Theory to museum space design and the space quality evaluation (Munemoto, 2006; Wang et al. 2010). Other researchers introduced Ontology to the assessment of facade, as part of a historic district renovation in Kyoto (Saito et al. 2006). Researchers can complete obscured facade using synthesis texture by case learning (Zhang, 2013; Fan, 2014). Many other researchers also focused on traditional buildings modelling (Xue, 2009), plots organisation (Guo and Li, 2014) and village texture generation (Li et al. 2015) using generative design method.

However, we haven’t noted any combination of these related methods, especially in architectural heritage conservation research. In this study, we proposed to use these digital technologies to connect works in conservation planning and establish a conservation procedure mainly based on knowledge discovery and generation design tools.

1.3. CASE SITE

Gunanjie Street is located in the northeast of Dingshu Town in Yixing City, Jiangsu Province. Taking the advantages of rich material production and convenient
transportation, Gunanjie Street developed gradually with purple clay industry from the 10th Century, Song dynasty. The research area in this study is the core part of Gunanjie (Figure 1), in which most of the production, commerce, and residence activities of residents are performed. In the past decades, the purple clay industry was declining, and the purple clay product teapot was back to the individual handicraft production. The change of teapot production and the rise of cultural tourism increased the demand for business, tourism, and living of local people. This change also magnified the conflicts between the conservation of traditional architectural feature and locally spontaneous development suffered from lack of guideline and reference. Thus, the overall traditional features are gradually eroding in this process.

Figure 1. Map of Gunanjie Street, with research area highlighted.

1.4. PURPOSE

The goal of this study is to establish an objective method to format a conservation plan of traditional architecture and settlement, utilising the advantages of digital technology to quantify the morphological features of the description and generation of settlements. Through quantitative analysis, the information can be transmitted accurately and the results can be generated quickly by computer simulation, which provides efficient and feasible technical means for practice.

2. Methodology

The proposed conservation process has been solved in a systemic method including three parts: information acquisition and integration according to the site situation; features analysis, description and rule extraction based on Knowledge Discovery; and new features generation by digital generative design, and applying for solving the problems.
With the photography, mapping, 3D scanning and other data acquisition and processing technology, information was collected and built as the database. The evaluation was used to get various attributes labels of data—such as traditionality cognition questionnaire, expert scoring to mark their culture value, physical performance or property. Morphology and other features analysis were used to code and describe the features of historical characteristics in different data structure and form. The knowledge discovery tools were used to extract rules of both the morphological and other non-morphological features. Accordingly, the referable models and relevant data were generated by programming. The result can be applied for real practice in guideline (Figure 2). In this workflow, the features are transmitted to digital data using code to ensure its integrity in the connection and exchange process between each step. The knowledge discovery and digital generation are used to enhance its intelligence and efficiency (Tang et al. 2018).

Figure 2. Proposed conservation workflow.

Focused on analysis, description and reproduction traditional features by mathematical and programming tools from an objective perspective, this paper mainly addressed the following issues in the case study:

1. Analysis and description methods of morphological features.
2. Extraction methods of traditional morphological features rules and the results.
3. Generative design methods of traditional features in different scales and situations.

3. Case study
3.1. PREVIOUS INVESTIGATION AND RESEARCH

Each house on the street was photographed to record the façade information. And key dimensions were measured directly, including the size of plots and the size of façade elements. The photogrammetry by DJI drone was also introduced to get the 3D model of the whole site automatically (Figure 3). Then the images of the entire street facade were built by splicing the photographs according to the results of surveying and mapping. In addition, traditional construction experiences and literature about Gunanjie Street and surrounding areas were also considered as a reference (Figure 4).
3.2. SOLUTION TO FAÇADE RENOVATION

Facade restoration involves traditionality evaluation. As an experiment, 48 samples were selected to represent all buildings, presented in the questionnaire for traditionality assessment investigation to respondents with and without an architectural background. The judgements made by various people according to their cognition are analogous to the label of data. In the meantime, the facade was decomposed into a variety of elements and combination modes described by code, which can be learned by computer. Then, the coding matrix with features and traditionality attributes could be calculated by knowledge reduction and rule mining based on Rough Set Theory, which can extract rules of traditional facade elements and their combination modes (Figure 5). According to the rules, the façade can be generated by programming in Processing (Tang et al. 2018).

Basically, for part of elements style or some material was old, damaged or
untraditional by inappropriate retrofitting, the designer only needed to update the new traditional facade feature (Figure 6a). If the functions of a building were changed, windows and doors openings also needed adjustment for commercial operation or cultural exhibition. The possible references were also provided.

Furthermore, in some cases, the building facade was damaged severely, the location of windows and doors are unreasonable, walls or roofs and other vital elements were destroyed. In another case, a new building needs to be built in a vacant lot. In above two situations, the designer needs to confirm the width and height by the remaining structure to generate the new facade by the program according to the geometrical characteristic of a typical facade and traditional facade elements combination rules (Figure 6b). Moreover, it is available for designers to change the quantities, locations and styles with different size interactively in a real-time way in the programme (Figure 7).

3.3. SOLUTION TO BUILDING RECONSTRUCTION

Based on the façade research, the reconstruction of the single building or dwelling focuses on the volumes relationship and the group layout. The tree diagram is used to describe the growth and partition relationship of the morphological elements as the mutual attribute constraints. And the geometric constraints of the elements themselves are obtained by statistics. This kind of rule also conforms to the logic of generation by Computer Generated Architecture (CGA) grammar in CityEngine. For a single building, the entire volume was divided into subitems at different levels according to its morphology and construction characteristics. For a set of buildings for a big family, eight kinds of the dwelling were generalised according
to the dimension and combination mode (Figure 8, 9).

In the rebuild case mentioned in façade research above, just thinking in 2D perspective is insufficient. For example, the height of the gable roof depends on the depth rather than façade width. So solving this kind of problems for heritage conservation, namely, generation in 3D perspective is essential. It is available in the programme to make various types of combination with different building volumes according to the location and dimension of the plot. With the statistics of types and their proportion in this district, the optimal scheme could be generated conforming to the surrounding texture (Figure 10).

3.4. SOLUTION TO BLOCK RESTORATION
The restoration of blocks needs to consider the relationships and characteristics of roads, plots, and buildings. In the present study, the tree diagram model is
still used to describe it. Actually, the characteristics of the spatial texture of the block are very complicated. But some basic and obvious results are still obtained by combing the existing data, which are regarded as the corresponding attributes constraints and geometric constraints. For example, we exacted the geometric dimension like street width, geometric features like corner style, and plot mode like subdivision type (Figure 11).

![Figure 11. CGA grammar of road texture.](image)

It is mainly used to repair the damaged area of texture, and to connect it with the preserved area, especially for the absence of street boundaries and the destruction of regional texture due to several buildings damaged, as well as for the expansion of regional boundaries. In Gunanjie Street, the east and west area are typical, whose features and texture damaged seriously (Figure 12). In this paper, we used this method to generate new spatial texture under the existing road frame and compared it with the present situation (Figure 13).

![Figure 12. Solution to restoration.](image)
4. Discussion

In this research, a systematic route for the conservation of traditional architecture and settlement was developed. Its feasibility was proved, which seamlessly integrates data acquisition and processing, morphology analysis and evaluation, generative design and scheme presentation. Compared with conventional paradigms of architectural heritage conservation, these quantitative and digital methods guarantee that the traditionality could be transmitted precisely and the effect as well as the efficiency of design could be improved.

However, more detail researches and further improvements are still expected in this study.

Regarding the case study itself, more cases are needed for the richness and authenticity of the learning sample in this data-driven knowledge discovery process. And plot organization and special texture need more deeply analysis, which influences the whole feature significantly. It is also an important field for many researchers now. What’s more, other functions and code optimization of the generative program are needed, supported by other effective algorithms.

Regarding the entire workflow, because of the diversity of different cases, applying this method to dealing with local culture relies on more advanced technologies in each step. Apart from the digital design tools by programming, some new survey and analysis technologies, such as 3D scanning to engineering drawing, image recognition and even deep learning, were expected to be introduced into the frame of automatic workflow in the future. It is ideal to develop an integration programme system in one platform for the sake of data exchange, or having the interfaces to connect different platforms at least.

5. Conclusion

This study established an objective and effective method to evaluate the design based on knowledge discovery and digital generation. The proposed method was expected to improve the serious situation of historical districts conservation. Compared with conventional methods, an impersonal design system has been
proposed based on the objective information to reduce the deviation between
the design scheme and the implementation effect of the conservation plan. This
method also has the advantages of using high precision mapping information
and research data on traditional architecture and settlements deeply and making
the starting point and direction of design relatively objective and controllable.
The procedure can be used as a relative universal tool in guideline compilation,
acceptance evaluation, and compensation decision.

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