Reconstruction of Traditional Village Spatial Texture Based on Parametric Analysis

Jiulin Li, Jinlong Chu, Yongzheng Wang, Min Ma and Xingang Yang

1School of Architecture and Urban Planning, Anhui Jianzhu University, Hefei 230022, China
2Anhui Province Urbanization Construction Collaborative Innovation Center, Anhui Jianzhu University, Hefei 230022, China

Correspondence should be addressed to Jiulin Li; ljiul90@163.com

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Abstract

Chinese traditional villages, as the space carriers of Chinese excellent traditional culture, are a nonrenewable cultural heritage with rich value connotations. The primary consideration for the protection of the authenticity of traditional villages as a historical and cultural heritage is the continuation of spatial authenticity. The inheritance and shaping of traditional characteristics requires the study of the laws of traditional villages’ spatial form. Spatial texture is an important landscape resource for traditional villages, and it is also a space carrier to display and carry the historical and cultural characteristics of the village. However, the current practice of village planning and construction has destroyed this original spatial texture, resulting in a rupture of the inheritance of traditional characteristics of village space. The fundamental reason lies in the lack of emphasis on the subjectivity and regularity of village space and the lack of quantitative analysis and planning application of the inherent laws of spatial texture. Based on the integration of inheritance and transformation, this research proposes to use the advantages of digitization, visualization, and dynamics in parametric technology to quantitatively analyze the internal laws of the village spatial texture and assist the planning and design of the village spatial texture, in order to effectively promote the benign inheritance and optimization of the traditional characteristics of the village spatial texture which makes the planned spatial texture both traditional and modern. The research results show that (1) the parametric-based planning technology can better analyze the existing laws of the village spatial texture in a comprehensive, quantitative, and precise manner. (2) The parametric technology has a relatively high value in the planning and design of the village spatial texture. Due to strong applicability, it can invert the spatial form of the village and optimize the planning scheme by adjusting parameters and rules. (3) Although the parametric planning and design party has certain artificial intelligence, it cannot completely replace the human brain. The planning scheme generated by the method cannot be directly applied but can be used to assist the design scheme. It needs to be adjusted and corrected via the subjective initiative of people and wider participation.

1. Introduction

The spatial form of traditional Chinese villages shows respect for nature, sharing with society, integration with the same culture, and vigor [1]. For example, under the constraints of natural environment and productivity conditions, the spatial texture of the traditional Hakka villages in Meizhou is influenced by the integration of Central Plains culture and Hakka culture, showing various external forms such as belt-shaped, scattered-point, and face-shaped [2]. Under the influence of topography and the tenant-servant system, traditional Huizhou villages have formed various layout forms such as the scattered type, group type, line (belt) type, cluster type, and ladder type [3]. Compared with other regions, the layout of traditional Huizhou villages is not only affected by terrain, traffic, and society but also greatly influenced by the Huizhou merchant culture heyday [4]. In addition, the existing studies have also carried out a lot of research on the driving factors of village form, showing that indicators such as terrain, economic location, industrial status, and population density are the main factors affecting the evolution of the village form [5].

From the perspective of material form, traditional village boundaries can be divided into natural boundaries and
artificial boundaries. Natural boundaries mainly include mountains and water bodies, and artificial boundaries mainly include roads, dwellings, farmlands, and gardens, which are continuously formed, broken through, and reformed in the development of the village material form [6]. However, in the process of construction, the villages pay special attention to the integration with the natural landscape. Most of them do not have clear boundaries, which are complex, vague, and uncertain [7].

Existing research on architectural texture is mostly carried out from the aspects of building plane layout, building roof, building facade, and so on. Due to the influence of clan changes and production methods, the shape of the dwellings in the village has changed over time. The Song Dynasty courtyards in the Ningbo Zomatang Village were dominated by halls and corridors, the Ming and Qing Dynasties were dominated by “H” shapes, and in the Republic of China, most of them were Triple Court [8]. The layout of the building space is mainly determined by the orientation of the main house and the combination of the orientation of the gate. At the same time, the courtyard space also affects the trend of the streets and the texture of the plots [9]. The roofs of traditional village buildings are mainly different [10] in the roof style, roofing materials, and components. The research on building facade includes facade decoration and wall materials, including window position and style and facade carving.

In the research on the spatial texture of traditional villages, qualitative analysis was the main focus in the past, and quantitative analysis was relatively rare. In the quantitative analysis of the village plane texture, in the early days, the average area, average distance, and other indices were mainly used to describe the village texture form based on Euclidean geometry [11]. Based on the early research foundation, some methods of landscape morphology, statistics, and other disciplines were gradually introduced into the study of traditional village spatial texture. Among them, the shape index is often used to analyze the scale and boundary shape of the village [12]; in the quantitative description of the internal space of the settlement, the degree of dispersion can represent the richness of the space, and the fractal dimension value can represent the complexity and stability of the space [13]; and in recent years, many studies have been carried out on the integration degree, selection degree, and street density of traditional villages based on space syntax [14, 15]. However, the analysis of plane features is difficult to measure with a certain index and usually requires a comprehensive measurement of multiple indicators. From a macroperspective, the organizational structure of a village is often described using the plane shape aspect ratio, boundary coefficient, shape saturation coefficient, etc. The description of the combination of plots and building planes is usually based on comprehensive considerations such as building density and dispersion coefficient [16].

In recent years, the development and maturity of computer technology has also brought considerable convenience to the study of traditional village textures. GIS technology plays an important role in comprehensive integration, management, analysis, thematic mapping, etc, providing a scientific basis and reasonable workflow [17] for the study of village textures. With the in-depth analysis of village texture and the development of technology, parametric analysis and reconstruction based on the CityEngine platform [18, 19] have been gradually used. The digital surface model (DSM) data obtained by UAV remote-sensing technology provides a reliable basis for the research on the spatial texture of traditional villages [20].

This study is based on the integration of inheritance and change and uses the parametric planning method to quantify the inherent quantitative regular characteristics of the village spatial texture. These are used in the practice of village planning and construction to guide the planning of the village spatial texture. Design, through the improvement of technical methods, builds a bridge between tradition and modernity, promotes a harmonious transition between inheritance and change, and promotes the inheritance and continuation of nostalgia. The feasibility of parametric technology in the planning and design of village spatial texture is demonstrated, and the detailed technical process of this method is researched to provide effective and new technical means for the optimization of village spatial form planning methods.

2. Selection of Research Objects

Nanping Village is a famous historical and cultural village in China and the first batch of national-level traditional villages. It is located on the edge of the Yixian Basin, in the transition zone between mountains and plains (Figure 1). Mountains, plains, rivers, and the transition zone between mountains and plains reflect the art of site selection in Nanping Village. The mountains in the south form a safe barrier and pleasant scenery for the village; the plains in the north meet the survival needs of the villagers in the farming era; the rivers meet the needs of the villagers for drinking water and irrigation; the transition zone between the mountains and the plains prevents the villagers from suffering floods. Nanping Village has a history of more than 1,100 years. Since the surname Ye moved from the Baima Mountain in Qimen in the Yuan Dynasty, the village has expanded rapidly, and in the Ming Dynasty, the three clans of Ye, Cheng, and Li have been divided. Due to the competition among the three surnames, the construction of villages has been promoted. Especially after the middle of the Qing Dynasty, the number of officials and businessmen continued to increase, and the construction funds returning to their hometowns also increased, so that despite being a village with only a thousand people, it has 72 alleys, 36 wells, and more than 300 complete sets of dwellings. In addition, there is also a considerable scale of ancestral halls, branch ancestral halls, family ancestral halls, Shuikou gardens, private school academies, altar temples, and so on. The main roads of the village and the long streets and short alleys integrate the mountains, water, and the village. The buildings and courtyards in the village are freely arranged according to the mountains and waters.
3. Construction Ideas and Method Process

3.1. Parametric Reconstruction Ideas. The spatial texture of the village is formed under the combined influence of the natural ecological environment, social and cultural elements, and regional spatial systems. It is the external representation of the spiritual culture and natural form of the village. The continuation of the texture can guarantee the inheritance of the village culture to a certain extent. The texture of the village space can be deconstructed into three parts: point (architectural texture), line (road texture), and plane (plot texture). Based on the morphological perspective, the research attempts to quantitatively analyze, extract, and summarize the inherent characteristics of the traditional village spatial texture and import the extracted characteristic parameters into the parametric design platform. Therefore, the computer can quickly and dynamically reconstruct the village space layout plan that is in line with the original village texture based on the existing characteristic data of the village. The purpose of the research is to reveal the hidden internal laws behind the physical and spatial structures of traditional villages, to explore the feasibility of planning and application of parametric technology in the continuation of the spatial texture of villages, and to reveal the internal laws of traditional villages by modern means. The technical route of parameterized analysis and reconstruction is shown in Figure 2.

3.2. Rule Modeling Approach. CityEngine (hereinafter referred to as CE) is a city rapid modeling software; its main idea is to use the “programmed” rapid modeling method based on two-dimensional data based on rule language, by writing CGA (computer-generated architecture) rule program commands. The corresponding model can be established. CE integrates seamlessly with ArcGIS platform, has map projection function, and can directly use 2D provided by GIS.shp data.

CGA is a semantic-based modeling language and a core part of CE. By analyzing the structure of the model object and writing the corresponding CGA rules, the model can be defined, and the same rule can be assigned to multiple objects at the same time, so as to realize the rapid and batch generation of the model. The main process of creating a 3D model through CGA is as follows: (1) import or manually draw 2D plane data in CE, (2) deconstruct the model objects that need to be created and write the corresponding CGA rules, (3) assign CGA rules to the corresponding two-dimensional surface data and set an initial rule entry for it (start rule), (4) use the CE model generation tool to generate the corresponding model, and (5) interactively adjust the generated model and check the results before use or export.

4. Data Preprocessing and Parametric Analysis

4.1. Data Collection. The data mainly used in the parametric analysis and reconstruction of traditional villages include geographic image data, road data, building data, regional DEM data, and model texture map data.

The image data used in the research are mainly from the 19-level (highest level) image maps of the study area and its surrounding areas downloaded by LocaSpaceViewer and the images collected by aerial photography during field investigation. The image data in the study are mainly used to determine the building roof style.

CAD data of roads and buildings is provided by the Anhui Urban Construction Design and Research Institute,
which is obtained by surveying and mapping during the preparation of the Nanping historical and cultural village protection plan, including road texture, building outline, building height, and other information.

DEM data comes from the Geospatial Data Cloud (http://www.gscloud.cn/), and the data accuracy provided is 30 m.

The texture map data includes texture patterns such as building walls, doors, windows, columns, roofs, and floors, which are all obtained from the field survey in Nanping Village.

Since the original data obtained by the survey contains a lot of noise information irrelevant to this research, it is not conducive to the later feature analysis and parameter acquisition. Therefore, on the basis of the preliminary survey and data collection of Nanping traditional villages, it is necessary to preprocess the data. It mainly includes the correction of aerial images, the screening of current pictures, the extraction of village boundaries, and the processing of texture data. The research takes the WGS84 coordinate system as the benchmark, uniformly corrects the spatial coordinates of various data, and builds a traditional village spatial texture database based on the GIS platform.

4.2. Village Boundary Extraction. The parametric texture analysis and reconstruction must have a clear definition of the spatial scope, and the traditional villages in ancient Huizhou are different from the villages in the plain area. In the process of adapting to the natural growth of the mountain trend, the concept of site selection and layout emphasizes “adapting measures to local conditions, harmony between man and nature.” One, there are often village dwellings in nature and nature in village dwellings, paying attention to the transition and combination of nature and artificial space, which promotes the harmonious integration of artificial environment and natural environment, but at the same time leads to the relative complexity and blurring of the village boundaries. The absence of clear boundaries is not conducive to the conduct of research. Therefore, before analyzing and extracting the spatial texture of the village, it
is necessary to extract the detailed village boundary and define the spatial texture within the boundary as the research object.

For areas with clear lines of property rights, the definition of village boundaries is determined by property right lines; for areas with clear natural boundary lines (river), it is determined by natural boundary lines. If the distance between the natural boundary and the village building exceeds 5 meters, the village is close to the natural boundary. The building boundary line is correct; when there is a road between two buildings, first consider the connection between the building boundary and the road boundary and then consider the connection between the road boundary and the building boundary on the other side. Then, through on-site exploration, the extracted boundary lines are optimized and adjusted, focusing on the connection between the building boundary and the natural area. Based on the current situation of village construction and the topographic map of surveying and mapping, this study combines the above methods with on-site exploration and verification and finally determines the spatial texture research boundary of Nanping Village (Figure 3).

4.3. Road Spatial Texture Preprocessing and Feature Analysis

4.3.1. Road Texture Data Preprocessing. The current road space texture and form are relatively complex, and it is necessary to optimize the road intersection, road width, and road form. In the optimization processing of road intersections, the redundant areas in the intersection are mainly cut, the turning radius is optimized, and the intersections with a short distance are merged (Figure 4). Certain errors are allowed in the optimization process, but two principles must be ensured: one is that it will not have a significant impact on the spatial texture of the entire traditional village; the other is that the optimized shape should be easy for computer simulation.

In the natural growth of the village road network, the same road has different road widths, and the road alignment in some sections is too tortuous. The road width
optimization process uses the intersection as a node to disassemble the road into multiple road segments, conduct multi-point sampling on the road decomposed into segments, measure the width of each road segment, and use the average sampling value obtained by sampling and measurement as the width of the road segment.

We simplify the selected roads to extract the backbone parts. Since it is not necessary to retain all the spatial details to study the overall characteristics of the road network, the specific strategy is to divide the village roads into main roads, secondary roads, and street space. The width of the road between them is uniform, and the “Douglas-Peucker algorithm” is used to fit the straight line segment for the arc or curve segment [21, 22] (Figure 5).

4.3.2. Parametric Analysis of Road Texture Features. For the selection of the characteristic parameters of traditional village spatial texture, in addition to morphological considerations, it is also necessary to explore its cultural connotation and select characteristic parameters that can not only control the texture form but also display the cultural spirit. Under the influence of feudal etiquette and law ideas such as “shunting the sky, measuring the strength of the earth; due to the natural materials, the locality is convenient, and the road does not need to be on the right line” and other feudal etiquette and law ideas, the traditional village street network fully demonstrates the adaptability and coordination between the village construction and the natural environment. Its external appearance is mostly organic growth and an irregular shape. As the streets and alleys in traditional villages, due to differences in climatic conditions such as sunshine, the streets and alleys of northern villages are generally larger in scale [23]. Different scales such as the height and width of the street will bring different behavioral experiences to people and even affect people’s behavioral trends. The morphological features such as the direction, angle, and intersection of the street can not only make people feel different emotions but also control the trend and orientation of the village buildings. In addition to the simple traffic connection function, the village street space is more of a carrier and container for villagers’ lives, supporting people’s multilevel behavioral needs. By interpreting the characteristics of the street space, it can effectively restore the traditional village traffic exchange scene.

In addition, the water system is closely related to the formation and development of traditional Huizhou villages. The streets and alleys have the distinctive feature of “accompanying water.” The main streets or the streets at the edges of the villages are often arranged in combination with the natural water system, or ditches are dug according to the
### Table 1: Parameter set of traditional village road spatial texture [27].

<table>
<thead>
<tr>
<th>Types</th>
<th>Name</th>
<th>Definition</th>
<th>Extraction algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall road network form</td>
<td>Road network form</td>
<td>Organic road network (organic) Radial network Grid network ( raster)</td>
<td>According to the characteristics of the road network, the hybrid road network can combine the three forms of road network</td>
</tr>
<tr>
<td>Intersection</td>
<td>Village center</td>
<td>Number of village center areas</td>
<td>It is generally the public activity center of the village, and the road density of the village public center will be higher than that of other areas</td>
</tr>
<tr>
<td></td>
<td>Capture distance</td>
<td>Minimum distance between road intersections</td>
<td>Calculate the distance between each intersection and take the minimum value</td>
</tr>
<tr>
<td></td>
<td>Intersection ratio</td>
<td>The ratio between the number of major road nodes and the number of intersections</td>
<td>Intersection ratio = main road nodes/number of intersection nodes</td>
</tr>
<tr>
<td></td>
<td>Minimum angle of intersection</td>
<td>Minimum angle of road intersection</td>
<td>Statistical minimum angle value of road intersection</td>
</tr>
<tr>
<td>Road length</td>
<td>Longer road length $la$</td>
<td>Average over longer set of roads</td>
<td>Calculate the average of all road lengths, select the roads $l$ that are greater than the length $l$ as set A, select the roads that are smaller as set B, find the roads greater than $l$ as set A, and the average length of set B is the longer road length $la$. Greater than $l$ is replaced by less than $l$ value for shorter road length $lb$.</td>
</tr>
<tr>
<td></td>
<td>Shorter road length $lb$</td>
<td>Average over set of shorter roads</td>
<td>The average of the absolute values $l_a$ of the maximum and minimum values in set A can be selected to obtain the longer road elastic interval $la$, and similarly, the shorter road elastic interval $lb$ can be obtained</td>
</tr>
<tr>
<td></td>
<td>Longer road elastic zone $la$</td>
<td>The range within which the length of longer roads can fluctuate</td>
<td>The average of the absolute values $l_a$ of the maximum and minimum values in set A can be selected to obtain the longer road elastic interval $la$, and similarly, the shorter road elastic interval $lb$ can be obtained</td>
</tr>
<tr>
<td></td>
<td>Shorter road elastic zone $lb$</td>
<td>Shorter road lengths can fluctuate</td>
<td>The average of the absolute values $l_b$ of the maximum and minimum values in set A can be selected to obtain the shorter road elastic interval $lb$, and similarly, the shorter road elastic interval $lb$ can be obtained</td>
</tr>
<tr>
<td>Road width</td>
<td>Main road width $d_1$</td>
<td>Average width of main road</td>
<td>Determine the road grade, select three points in a section of road to calculate the average width of the road, calculate the average width of the main road $d_1$, the width of the secondary road, and the width $d_2$ of the street $d_3$; calculate the difference between $d_1$, $d_2$, and $d_3$ and the maximum and minimum values of the road width. The average absolute value of the road elasticity interval $d_1$, $d_2$, and $d_3$</td>
</tr>
<tr>
<td></td>
<td>Secondary road width $d_2$</td>
<td>Average width of secondary roads</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Main road elastic zone $d_1$</td>
<td>The main road can float up and down the flexible range</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Secondary road elastic zone $d_2$</td>
<td>The flexible interval that the secondary road can float up and down</td>
<td></td>
</tr>
<tr>
<td>Road declination maximum</td>
<td>Smaller value of angle between roads</td>
<td>Count the number of smaller angles at the intersection of two roads, remove extreme values, and take the maximum value as the &quot;maximum road declination angle&quot;</td>
<td></td>
</tr>
<tr>
<td>Number of roads</td>
<td>Number of road segments</td>
<td>Through the Douglas-Peucker algorithm, the arc road is decomposed into segments of straight roads, and the total number of roads is counted</td>
<td></td>
</tr>
</tbody>
</table>
streets to divert water into the village. The analysis of the street space texture reflects the water system characteristics of traditional Huizhou villages to a certain extent.

The CE platform has integrated a complete road generation module, but its construction idea is only based on graphics, it lacks a good connection to the actual situation, and there are certain deficiencies in the application. It mainly manifests in the unclear inner meaning of its parameter values and the limitations of limited parameter variables. However, the existing parameters have been able to control the spatial texture of village roads morphologically. In addition, combined with Ge Dandong and others’ [24, 25, 26] research on village road parameterization and a large number of related experiments, the extraction of village road parameterization is finally determined to be five aspects including the following: overall road network form, road intersections, road length, road width, road number, and road declination (Table 1).

4.4. Spatial Texture Preprocessing and Feature Analysis of Plots

4.4.1. Parametric Analysis of Block Texture Features. Huizhou traditional villages are mostly inhabited and attach great importance to religious etiquette. The layout of the village has a strong centripetal and hierarchical nature. The center of the village is mostly clan ancestral halls, and the secluded areas on the edge of the village are often arranged with educational places such as academies. The clan ancestral hall undertakes the functions of worshiping ancestors and connecting with clans. It has the function of condensing the village culture and strengthening the clan concept. It is the symbol of the Huizhou people’s clan and the core of the village [28]. From the perspective of spatial plane texture, the plots where the ancestral halls and other public buildings are located are generally larger in size, have a relatively regular shape, and are located in the center of the village. The residential buildings in the village are arranged around the ancestral hall, which also makes the building density in the central area of the village relatively high. At the same time, under the influence of the functional properties of different plots, there are also certain differences in the texture of roads and plots in each area of the village.

Therefore, interpreting the characteristics of plot groups and the functional composition of plots from an overall perspective can clearly identify the core of the village and show the geographical situation of the village, the traditional feng shui concept, and the clan culture of living together. In addition, the analysis of the shape and scale characteristics of a single plot from a local perspective can fully demonstrate the development process of village construction and the cultural influences during the construction process. Comprehensive analysis of texture from the
perspective of the whole and part is conducive to excavating the evolutionary logic of the growth of traditional village texture and can trace the cultural context associated with the construction of the village, activate the cultural genes of the village, and reproduce the cultural landscape of the traditional village.

There are two main ways to generate the spatial form of traditional villages. One is the spatial expansion type; that is, with the increase of family population, the inherited homestead continues to expand outwards, and new houses are built. This way also includes the adjacent original site. There are two types of block growth and enclave growth. The second is intraplot classification; that is, with the inheritance of descendants, the ownership of the original plot is continuously subdivided into more small plots (Figure 6). From the perspective of graphics, traditional village block groups can be roughly divided into “grid type,” “inward retreat type,” and “skeleton type” (Figure 7).

The grid-type plots are generally relatively large in scale, the land in the group is relatively compact, and the residential units grow adjacent to each other. Most of the plots in the group are not directly adjacent to the village roads, and the internal residences mostly rely on the narrow alleys between the building walls to maintain traffic. The inner retreat type is mostly enclosed by village roads, the center is mostly open space or public buildings such as ancestral halls, and the surrounding plots are mostly directly connected to the road. The skeleton type is mostly affected by terrain conditions and is generally distributed in strips, with one or both sides connected to the road.

<table>
<thead>
<tr>
<th>Parameter type</th>
<th>Parameter name</th>
<th>Parameter meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of plot group</td>
<td>Grid type, internal retreat type, skeleton type</td>
<td>The type of combination of individual parcels within the parcel</td>
</tr>
<tr>
<td>Plot area parameters</td>
<td>Maximum area of land</td>
<td>The largest parcel size among all parcels</td>
</tr>
<tr>
<td></td>
<td>Minimum land area</td>
<td>The smallest parcel size among all parcels</td>
</tr>
<tr>
<td></td>
<td>Average land area</td>
<td>Average parcel size for all parcels</td>
</tr>
<tr>
<td>The size of the plot</td>
<td>The percentage of land area</td>
<td>According to certain rules, the size of the plots is classified, and the proportion of the number of plots in each interval is counted</td>
</tr>
<tr>
<td>Plot angle</td>
<td>The maximum angle of the plot</td>
<td>The angle between the adjacent two sides of each vertex in the plot and the angles of all plots are counted, and the maximum and minimum angles are screened out</td>
</tr>
<tr>
<td></td>
<td>Minimum angle of plot</td>
<td></td>
</tr>
<tr>
<td>Lot side length</td>
<td>The length of the shortest side of the plot</td>
<td>The side length of the plot is assisted by the length and width of the minimum circumscribed rectangle of the plot. In the parametric analysis, it is also necessary to count the length-width ratio of the minimum circumscribed rectangle of the plot</td>
</tr>
<tr>
<td></td>
<td>The length of the longest side of the plot</td>
<td></td>
</tr>
<tr>
<td>The functional characteristics of the plot</td>
<td>The proportion of the number of different types of land</td>
<td>The proportion of residential building plots, public building plots, vegetable plots, green space, open space, and other plots within the village boundary</td>
</tr>
<tr>
<td>Plot direction</td>
<td>Side of the smallest circumscribed rectangle of the plot</td>
<td>is the plot direction</td>
</tr>
</tbody>
</table>

Through the statistics of the plot area of Nanping Village, it is found that more than 55% of the plots are in the range of 60 to 200 m². The overall block area presents an inverted U-shaped distribution. At the same time, through the analysis of the spatial characteristics of the distribution of the size of the plots, it is found that the plots in the central area of the village are generally larger than those in the marginal areas, and the density of the central and central areas is higher than that of the marginal areas (Figure 8).

Through the analysis of the characteristics of the plot texture, combined with the actual requirements of the protection and development of traditional villages, and the types of parameters that the City Engine platform can support and control, the characteristic parameters for optimizing the spatial texture of traditional village plots are selected as shown in Table 2.


The unique natural and geographical environment and long historical heritage of the ancient Huizhou area have derived the unique style of Huizhou architecture. The architectural texture is the most intuitive visual medium for people to
Figure 10: Buildings in Nanping Village.

Figure 11: Obstacle map.

Figure 12: The spatial texture of roads in Nanping Village.
Table 3: Results of parameterized analysis of road spatial texture in Nanping Village.

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter value</th>
<th>Parameter name</th>
<th>Parameter value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection capture distance (m)</td>
<td>6.56</td>
<td>Main road width (m)</td>
<td>3</td>
</tr>
<tr>
<td>Intersection ratio</td>
<td>2.56</td>
<td>Main road elastic zone (m)</td>
<td>1</td>
</tr>
<tr>
<td>Minimum angle of intersection (°)</td>
<td>59.9°</td>
<td>Secondary road width (m)</td>
<td>2</td>
</tr>
<tr>
<td>Longer road length (m)</td>
<td>33.89</td>
<td>Secondary road elastic interval (m)</td>
<td>1</td>
</tr>
<tr>
<td>Longer road elastic interval (m)</td>
<td>70.92</td>
<td>Number of roads (strips)</td>
<td>323</td>
</tr>
<tr>
<td>Shorter road length (m)</td>
<td>11.08</td>
<td>Maximum road declination (°)</td>
<td>27.3°</td>
</tr>
<tr>
<td>Shorter road elastic interval (m)</td>
<td>16.67</td>
<td>Main road patterns</td>
<td>Organic type</td>
</tr>
<tr>
<td>Secondary road morphology model</td>
<td>Organic type</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 13: CE road generation module parameter panel.
perceive architectural culture. It reflects the social life status and historical evolution characteristics of the Huizhou area. The architectural space texture is divided into two aspects: plane texture and facade texture. The plane texture includes architectural space, courtyard space, and street space, and the facade texture includes information such as platform foundation, house body, and roof.

4.5.1. Parametric Analysis of Architectural Plane Texture Features. Influenced by traditional agriculture, traditional
Chinese villages often need to consider the combination of production and life when constructing buildings. In addition, the land resources in the ancient Huizhou area are tight, and the building construction is relatively compact. Through the analysis of the building base, the basic layout of Huizhou ancient dwellings is summarized as follows: the “one,” “concave,” and “hui” shapes are the main ones (Figure 9), of which the “concave” shape is the pattern of “one entrance and a patio,” and the main building is “one front and two compartments”; the “hui” shape is the “two into one well” pattern.

The analysis of the scale characteristics of the building base requires statistics of the base area of all buildings within the village boundary and statistics of the distribution characteristics of this value, including the proportion of building quantities in different base area intervals and the base area distribution of various types of buildings. At the same time, when analyzing the scale of the building base, it is also necessary to count the depth and surface width of the building base to extract the maximum and minimum values.

The building courtyard space is mainly enclosed by the building boundary and the plot boundary. The courtyard is a residential building that bears a certain space for breeding and planting and is also a semipublic space for communication. The layout of the courtyard is mainly influenced by the personal concept of the owner of the dwelling, and it exists in the form of a front yard, a back yard, and a side yard. The four-to-range is often characterized by analyzing the distance to the boundary of the building setback.

The orientation of buildings in traditional Huizhou villages is mainly affected by two factors. One is the influence of the natural environment such as sunshine. In order to meet the sunshine, the south orientation is chosen. The buildings are arranged towards the public buildings. Due to the influence of various factors, and the fact that the
buildings in traditional Huizhou villages are mostly one or two floors, which are generally low, the orientation of buildings in the village is relatively random and insignificant.

4.5.2. Parametric Analysis of Building Facade Texture Features. The appearance of building materials in space after a certain combination of rules and order is the texture. Traditional villages in Huizhou use a lot of regional materials in construction, and the use of brick, wood, stone, etc., has shaped distinctive regional architectural characteristics and promoted the harmonious integration of villages and nature. The white walls and black tiles with horse-head walls have become synonymous with Huizhou-style architecture.

Building height is divided into two aspects: one is the height of the building and the other is the number of floors. Through on-the-spot investigation and statistics, it is known that the building heights of traditional Huizhou village dwellings are generally between 2.8 and 4.0 m, with an average floor height of about 3.2 m. The land available for building houses is extremely limited, so the buildings in traditional Huizhou villages are mostly two-story buildings. The variable building heights make the village space more abundant, and the village skyline is flexible and changeable.

The roof styles of traditional Chinese buildings are changeable, such as the top of the temple, the top of the mountain, the top of the hanging mountain, and the top of the hard top. However, the economic conditions in the ancient Huizhou villages were relatively backward, and at the same time, they were restricted by climatic conditions (Figure 10).

The region in advance and make an obstacle map to control whether the texture is generated or not. For example, there are many restrictions on road layout. These restricted areas may be ecological land or areas with extremely unsuitable terrain conditions such as elevation and slope. No streets or buildings can appear in these areas. In order to simulate these situations in CE, an obstacle layer needs to be created to control CE. The dark areas in the default obstacle layer represent obstacles. The higher the obstacle value, the lower the probability of generating roads and buildings, and the light areas are normal.

Based on the GIS platform, the DEM data, ecological land data, soil data, etc. in the study area and surrounding areas are evaluated for land use suitability such as slope and terrain factors, and according to the "Resource and Environment Carrying Capacity and Land Space Development Suitability" issued by the Ministry of Natural Resources, the "Technical Guidelines for Property Evaluation (for Trial Implementation)" will classify the suitability of land use into grades. At the same time, the ecological land within the extracted area will be defined as the area with the highest barrier value, thus preventing roads from being

| Table 4: Parametric analytical structure of the spatial texture of Nanping Village block. |

<table>
<thead>
<tr>
<th>Type of plot group</th>
<th>Types Proportion</th>
<th>Grid type</th>
<th>Recursive</th>
<th>Skeleton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum area of land</td>
<td>9 19.03 m²</td>
<td>Irregularity</td>
<td>91.6%</td>
<td>0.7</td>
</tr>
<tr>
<td>Minimum land area</td>
<td>4 1.30 m²</td>
<td>The maximum angle of the plot</td>
<td>2.5%</td>
<td>142°</td>
</tr>
<tr>
<td>Average land area</td>
<td>1 96.62 m²</td>
<td>Minimum angle of plot</td>
<td>5.9%</td>
<td>72°</td>
</tr>
<tr>
<td>The length of the shortest side of the plot</td>
<td>3.12 m</td>
<td>The degree of calibration of the plot to fit the terrain</td>
<td>91.6%</td>
<td>A level</td>
</tr>
<tr>
<td>The length of the longest side of the plot</td>
<td>5 3.83 m</td>
<td>Maximum plot aspect ratio</td>
<td>2.5%</td>
<td>3.8</td>
</tr>
<tr>
<td>Proportion of public buildings</td>
<td>1.5%</td>
<td>Minimum plot aspect ratio</td>
<td>5.9%</td>
<td>1.25</td>
</tr>
<tr>
<td>Land area range and proportion</td>
<td>Section (m²)</td>
<td>40-60</td>
<td>60-100</td>
<td>100-200</td>
</tr>
<tr>
<td>Proportion</td>
<td>8.1%</td>
<td>15.5%</td>
<td>39.9%</td>
<td>19.8%</td>
</tr>
</tbody>
</table>

Figure 17: CE control panel.
generated within the ecological land. And we normalize the resistance map of each single variable to avoid excessive influence of a certain factor. Finally, each single resistance grid map is superimposed to become an obstacle map (Figure 11). Before refactoring in CE, we first import terrain data, texture data, and obstacle maps to create an environment for village texture reconstruction.

Shuikou space is not only an important element in the structure of ancient Huizhou villages, but also, often because of its natural trend of mountains and rivers, pavilions are

Figure 18: The plot texture scheme generated by CE simulation.
built and roads and bridges are paved, making it a natural and harmonious organic whole and a part of the village. It is a delightful sight to behold.

The Shuikou of Nanping Village used to be a well-known and wonderful place. Due to poor protection, the sluice building has been severely damaged. Nanping Shuikou is located in the northeast of the village. Dozens of towering ancient trees stand majestically, so it is called “Wan Pine Forest.” When analyzing the texture of the village, it is necessary to consider the spatial location of the outlet space, the scale of the outlet space, and the content contained in the outlet space. It can be found that the outlet space of the village is the entrance and exit of the village water flow. The nozzle also naturally forms an independent spatial form.

For the above considerations, it is necessary to write the CGA rules of the sluice space separately in the reconstruction stage, and through the import command, the newly generated village texture can fully consider the influence of the sluice space in the traditional Huizhou villages. Since this study starts from the overall texture of the village and mainly considers the trend and pattern of the village water system, the morphological characteristics of the single nozzle space are not the focus of this study. Therefore, the water system in the reconstructed texture is mainly reflected by the environmental map and road texture.

5.2. Road Space Texture Extraction and Parametric Reconstruction. The spatial layout of roads, streets, and lanes in Nanping Village is flexible (Figure 12), and there are different road widths in different sections of the same road. According to the optimization idea of road space texture
mentioned above, the extracted original road texture of the village was optimized, and the results were obtained, as the picture shows. According to the road spatial texture and its node graph obtained after optimization, the road spatial texture is parameterized and analyzed, and the results are shown in Table 3.

The goal of parametric reconstruction of the road spatial texture is to calculate and deduce a road spatial texture that is in harmony with the original village texture and meets the needs of modern life according to the extracted parameterized attribute values. CE provides a relatively complete road network generation rule. We input the extracted characteristic parameters into the road network generation module, and the computer can quickly and automatically simulate a new road network model (Figure 13). At the same time, it is also possible to import the original village road network texture first, choose to extend it in the original road network model, and introduce relevant random variables into the internal rules. Different schemes can be obtained for each generated road network model.
network model, which is beneficial to multiple schemes. The parameters of the new road network are the same as those of the original village road network, and the original village road spatial texture is maintained.

The extracted road texture parameters are imported into the CE platform for automatic computer simulation according to the ideas mentioned above, and several road texture schemes are generated (as shown in Figure 14).

Since there are certain randomness and deficiencies in the scheme of automatic simulation with a computer according to the rule language, it is necessary to select a more reasonable scheme from a large number of reconstruction schemes generated by automatic simulation and make corrections manually. CE provides a more convenient manual interaction environment. Modifying a certain road will also adjust the surrounding road network shape in real time, which is conducive to the judgment of the rationality of the road network structure during manual adjustment. Therefore, after the simulation scheme is selected, the research is directly adjusted in CE. Figure 15 is the optimized scheme after manual adjustment based on scheme 2, which is used as the basis for the generation of the block skeleton.

5.3. Spatial Texture Extraction and Parametric Reconstruction of Block. Since there are many adjacent buildings in Nanping Village, it is difficult to accurately delineate the texture of the parcels by only relying on image maps and mapping topographic maps, so field exploration was arranged during the study to ensure accurate clarification of spatial ownership and use and thus clarify the parcel boundaries.

From the spatial texture of the extracted plots, the overall spatial structure of Nanping Village is in the form of a grid, and a few plots are recursive and skeletal. There are many ancestral halls in the village, occupying a large area of land, and they are the center of each land group. There is an ancient temple with double eaves and dignified majesty. During the field investigation, it was found that many ancestral halls or dwellings owned by large families in history occupy a large area of land, such as the Order Hall, Ye Kuiguang Hall, Shangsu Hall, Cheng Family Ancestral Hall, "Xiaoyang Building," and Bingling Pavilion. Its historical and cultural value is high, and it is inherited that you did not divide according to the current building ownership in the land plot division, resulting in some large land plots in the plot area statistics. After optimizing the spatial texture of the block according to the method described above, the texture of the block was extracted as shown in Figure 16, and the relevant characteristic parameter values were obtained as shown in Table 4.

The core objective of the plot spatial reconstruction is to first analyze the original village plot texture and then reconstruct the plot layout that is compatible with the original village texture and meets the needs of modern life. CE calculates and reconstructs the road spatial texture and also generates the plot groups (Lot) enclosed by roads. From the technical point of view, the spatial reconfiguration of the plot is the result of the gradual subdivision of the Lot based on the extracted parameters of the plot texture features, written and used in the CGA rule language.

CE provides three built-in functions for plot division: recursive subdivision, offset subdivision (internal subdivision), and skeleton subdivision, and provides corresponding control parameters, so in writing, the CGA rule is to directly call three functions to subdivide various types of plots, so as to simulate the new plot spatial texture that matches the original village plot texture. The proportion
of the three types of land subdivisions can be obtained by substatistics on the types of land parcels in Nanping Village, so the "proportion function" can be used to control the number of land parcels of each type. Its code is implemented as follows:

In addition to the control of the subdivision type, the texture of the plot also includes the size of the plot, the largest (smallest) side length of the plot, the area where the public buildings (ancestral halls, etc.) are located, the proportion of building types in the plots of various areas, irregularities, etc. Some of these properties can be operated directly through CE’s control panel (Figure 17). The remaining properties can be controlled by writing CGA rules.

First of all, for the proportion of building types in various areas, the rules can be written with the help of the built-in geometry function of CE. The core code of its realization is as follows:

The core idea of this code is to arrange the content of the parcel by identifying the area of the parcel. For example, the meaning of the first line of code is as follows: when the area of the parcel is less than 60 square meters, there is a 50% probability of generating a one-line building on the parcel, with a 20% probability of generating a "concave"-shaped building, a 15% probability of generating a "hui"-shaped house, a 10% probability of becoming a green space, and the remaining probability of generating an open space. By substituting the relevant parameters obtained from the analysis, it is possible to control the plots of different sizes to generate corresponding content information, thereby simulating the proportion of building types generated in the plots of various areas that fit the original village.

In addition, after dividing the plot types such as building plots and vegetable plots, the plot where the ancestral hall is located is generally the village center, and the corresponding code can also be written based on the built-in distance function of CE:

The core idea of this code is to select the probability of generating various types of buildings by judging the distance between the plot and the geometric center of the village, so that the public plots such as ancestral halls can be more accurately arranged in the center of the reconstructed village plot texture area.

According to the manually adjusted road network shape and the extracted characteristic parameters of the land parcels, and through the cooperation of the CE interactive panel and the CGA rules, the computer automatically simulates several land parcel division methods. This paper selects two groups of land parcel spatial texture reconstruction schemes to display, as shown in Figure 18.

During the simulation process, the generation of the plot is subject to the combined action of parameters such as the maximum and minimum side lengths of the plot, the angle of the plot, and the scale of the plot. Therefore, it is necessary to manually revise the scheme of computer reconstruction. For the study, scheme 2 in the above figure is selected for
5.4. Architectural Space Texture Extraction and Parametric Reconstruction. According to the topographic map of the surveying and mapping and the optimization processing method of the building space texture mentioned above, the building plane space texture of Nanping Village is obtained as shown in Figure 20. In the village, there are mainly “one”-shaped buildings, followed by “concave”-shaped buildings. There are a small number of “hui”-shaped buildings, mainly public buildings such as important ancestral halls in the village. The courtyard space of residential buildings is generally less, and the base area of residential buildings is relatively small.

Secondly, from the perspective of the facade texture, most of Nanping Village are two-story buildings, the height of the cornice is about 7 meters, the width of the streets is 1-2 meters, the space ratio of the streets and alleys is 1:3.5-1:7, and the streets are deep, quiet, and peaceful. Most of the buildings in the village are Huizhou-style buildings, with double-sloping roofs as the main, and the colors are mainly black, white, and gray. The characteristic parameters related to the extracted building texture are shown in Table 5.

The reconstruction of the architectural space texture is based on the subdivision of the plot. The single building is divided into several components. By writing CGA rules for each component, and according to a certain logic, it will act on the subdivided small plots, thereby generating a new architectural texture. The specific steps are generally as follows:

1. According to the shape, scale, depth, width, setback, and other parameters of the building base, the subdivided parcel is determined by the setback, offset, split, and other commands to determine the scope of the main body of the building, the horse-head wall, and the courtyard, street, and alley. The core code is implemented as follows:

2. According to the parameters such as the building height and the number of floors, the three-dimensional form of the building is generated by...
commands such as extrude (stretching) and comp (splitting) for the main base of the building. Its core code is implemented as follows:

The idea of this code is to stretch the "concave" shape of the main building base and divide the surfaces of the generated three-dimensional model, which are represented by various colors, as shown in Figure 22.

(3) For each surface of the generated three-dimensional, according to the parameters such as wall skin and roof shape, the main body of the building is further refined through commands such as texture (map) and i (model replacement), so as to complete the reconstruction of the architectural space texture (Figure 23). Among them, the building roof can be directly realized by using the built-in roof functions roofGable (double-slope roof), roofHip (four-slope roof), and so on. The source files used for texture maps are all from the actual shooting in Nanping Village, which can ensure that the newly generated architectural texture is in harmony with the original texture to the greatest extent. Its code implementation is as follows:

In the process of compiling CGA rules to reconstruct the model, it is necessary to continuously debug various parameters and make further refinements until the final building model is produced.

GA rules written according to the building texture parameters are assigned to the subdivided plots, and the computer will quickly generate a three-dimensional building model, as shown in the figure (Figure 24). When writing CGA rules, you can interactively control the building shape, height, texture, etc. by defining variables. After the model is generated, you can select a building and perform attribute transformation in the attribute panel. The model effect can be updated synchronously (Figure 25).

6. Discussion

Traditional village culture and spatial texture are not independent of each other, and village culture depends on the space to continue. Conventional planning can continue the humanistic spirit of the village through planning methods such as pictograms and metaphors through the planner’s personal perception of culture. The idea of CE parametric-aided design needs to be refined and implemented through a series of index parameters for the relationship between culture and space. The workload is extremely huge, and due to the lack of emotional temperature of digital parameters, it is difficult to continue the culture.
The implementation of the scheme is based on a solid investigation and reasonable planning. The parametric design needs to analyze the ownership information of each building and the use of each public space. Therefore, the parametric design is more efficient than the traditional planning method. Therefore, it is necessary to invest more energy in the research stage, carry out extensive and in-depth research, and collect comprehensive and detailed village information. Through the communication with the villagers during the research process, we can have a deeper understanding of the needs of the villagers. Therefore, planning can maximize public participation while implementing the planning intentions of superiors, which is conducive to planning implementation.

After the plan is confirmed, CE can export a variety of display effects such as scene model, node bird’s-eye view, plane texture, and 3D animation, which is conducive to collecting public opinions and suggestions on the plan. And because of the strong interactivity of CE parametric design, the scheme adjustment is more flexible and convenient.

7. Conclusion

The ultimate purpose of the parametric analysis and reconstruction of the village spatial texture is to solve and optimize the problems existing in the current village planning and construction, the bridge between the analysis and reconstruction of research results and the practice of village planning and construction. Taking Nanping Village as a case, this study further discusses the methods and ideas of using parametric planning technology to solve problems. The results of the analysis and reconstruction of the village spatial chemistry parameterization are sorted out and summarized, and the main results are considered to be the parameter sets generated to describe and control the village spatial texture and the reconstructed village spatial texture.
The parametric results can be used to guide the conceptual design of the overall spatial form of the village, guide the detailed scheme design of the village spatial form, and assist and optimize the current village planning technology.

The texture and form of the village space is not only the landscape element of the village but also the external expression of the internal order of the village. When planning conventional schemes, the regularity of the plot is usually considered first, so as to facilitate the construction of sites, roads, buildings, etc. and improve the efficiency of land use. However, the regular plot will inevitably lose the interest brought by certain spatial texture changes, which is not conducive to the inheritance of the village context. The spatial texture reconstructed by CE is more abundant in plane layout and three-dimensional effect. The building volume, style, density, and other aspects continue the original village characteristics, avoiding the homogeneity of the scheme design and increasing the identifiability of villages. At the same time, through the reconstruction of the original texture parameters, it is more in line with the regional environment and more harmonious with the natural environment.

In the design process of traditional schemes, the means of formulating land use indicators, delineating road red lines, and specifying building height limits are usually used to guide the planning and construction of villages. This method can strictly ensure that all land use indicators meet the relevant requirements, but the flexibility of the scheme is easily restricted and the original charm and characteristics of the village are lost. The parametric design first extracts the relevant parameters by analyzing the original village texture and adjusts the optimization parameters reasonably according to the actual needs of the current villagers’ production and life. Implementing the parameter indicators into each block through the writing of rules ensures the scientific and reasonable land use indicators on the one hand; on the other hand, due to the powerful simulation capability of the computer, a large number of alternative planning schemes are added, which greatly broadens the thinking of planning and design.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References


