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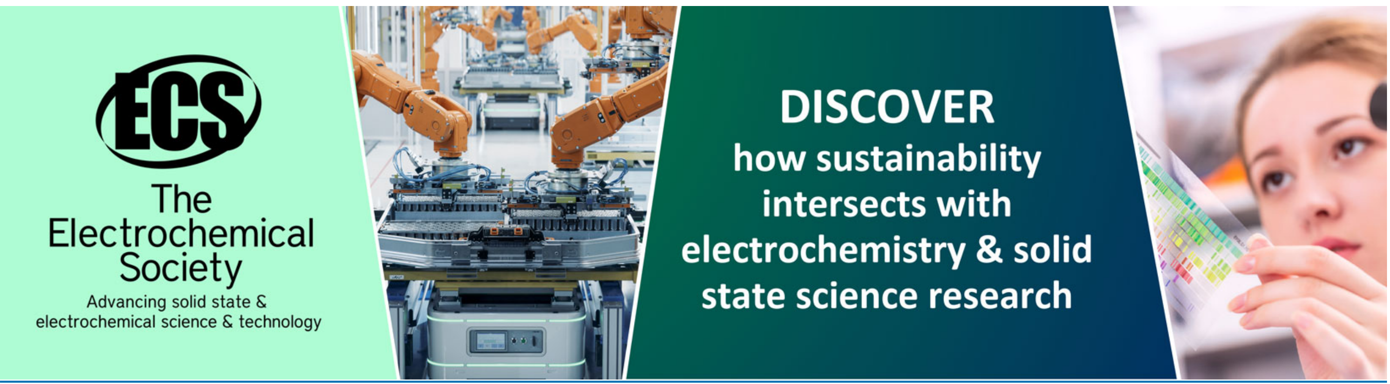

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Parametric generation and multi-objective optimization of stilted building in Zhuang residence

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Abstract. The construction techniques and construction methods of traditional stilted dwellings are facing the danger of being lost. This paper proposes a parameterization method of stilted dwellings taking the digital construction of stilted dwellings as the starting point to improve the parameterization process of the original stilted dwellings, expanding the construction logic of shape grammar and combining with the multi-objective optimization algorithm. This method takes topography and land range as external constraints, takes economic technical index and total construction cost as optimization objective, also takes building type, floor number and room area ratio as parametric variable. Then using genetic algorithm for multi-objective optimization. Comparing with the original generation method, new method can match a given condition to a suitable form. By changing the original design mode "users demand–design digital model- adjusting size–layout model " to "Input condition–computer generating model – multi objective optimization –layout model and indicator ", the design process is systematized and the evaluation system is discussed. It provides a design tool for the architects to intervene in the rural construction and also makes the design of stilted dwellings easier.

1. Introduction

The construction of traditional dwellings in Northern Guangxi follows the construction mode dominated by traditional craftsmen. As more and more young villagers work in cities, the techniques and construction methods of traditional dwellings are facing the risk of lost. A stilted building generation system according to the site conditions and the villagers' need provides tools to design stilted buildings, and has practical significance to protect the traditional village. In the study of the parameterization about traditional buildings, shape grammars have been tried in the classical major carpentry, bamboo-house in Guangdong, Dong Nationalities Drum-tower and waterfront spaces of Chiang-Nan water country. However, the original research still has the following shortcomings:

1. The types of parametric model generation are not abundant so they cannot provide the appropriate form of construction according to the given site conditions.

2. Staying on the digital model generation, research is in the qualitative rather than quantitative. And the model can't conclude performance indicator.
3. the model does not considered optimization.

Therefore, considering the site factors and the villagers demand as evaluation index, this paper attempts to combine traditional shape grammar with multi-objective optimization. We put forward a generation system based on the Rhinoceros& Grasshopper platform, using python script and octopus (SPEA2& HpyE algorithm), which changed The original pattern of "demand target-building the stilted residential model-adjusting the size data to meet the demands" into "site condition - substituting the system generation model- multi-demand targets optimization model"

2. Method

Three key problems which about the parametric formation and multi-objective optimization need to be determined. First, the generation logic of the model need to be confirmed; Second, the combination of performance indicators and calculation methods need to be to determined; Third, optimization objective and optimization performance evaluation need to be selected.

2.1. Models generate logic
Based on grasshopper, the system generates the axis of residential structure according to the reference points by site condition first. And then, brep is generated by axis. Such a generation method requires a model library you build and write boundary conditions in python to realize the selection of model library artifacts.

2.2. Performance indicator and calculation method
The module outputs model information list, and the indicators of the residential will be calculated statistically. Meanwhile, different performance analysis modules can be extended to carry out analysis and calculation. At present, four submodules, including economic and technical indicators, project cost, project benefit evaluation and housing rationality, are used to calculate the performance indicators according to the issues which are most concerned by villagers in building rooms. The indicators can help villagers to evaluate the houses they will build directly:

Table 1. Performance indicator

Performance	Evaluation indicator	Units
Economic-technical indicator	Gross floors area	㎡
	Area of each room	㎡
	Plot ratio	/
	Room rate	/
Engineering cost	Material cost	m^3
	Labor cost	Day
	Earthwork cost	m^3
Project benefits	Annual earnings	￥
Rationality	Room area uniformity	/
	Room aspect ratio	/

2.3. Optimize objective and optimized performance evaluation
The optimization objective is mainly reflected in three aspects. Under these targets, the optimal solution set is obtained by adjusting the form base on component database and the proportion of width and depth.

Table 2. Optimize objective

Optimization direction	Evaluation index	Indicator range	
		Min	Max
model adopt the most economical way	Cost per unit area	400	1000
Less project cost	Guest room rate	0	200
Room is as reasonable as possible	Guest room area uniformity	0	0.5
	Guest room aspect ratio	0	8

The optimization performance of the scheme is reflected in two aspects, optimization rate and The number of optimal solutions:

$$R=\frac{x_{G\cdot i}-x_o}{x_o}\times 100\% \quad (1)$$

The optimization rate R is for quantitative evaluation of optimization results. $x_{G\cdot i}$ is the evaluation index for the i-th solution to the G generation optimum solution set and x_o is the performance evaluation for the initial scheme. R_{op} is the optimization rate of cost per unit area, R_{tp} is the optimization rate of guest room aspect ratio.

N_{op} is the number of model that are not repeated in the optimal solution set of each generation, this indicator can quantitatively evaluate the degree of optimization schemes that can be selected by the designer; N_{tp} refers to the number of schemes with the same opening, the same framework form, but different sizes.

3. Platform framework

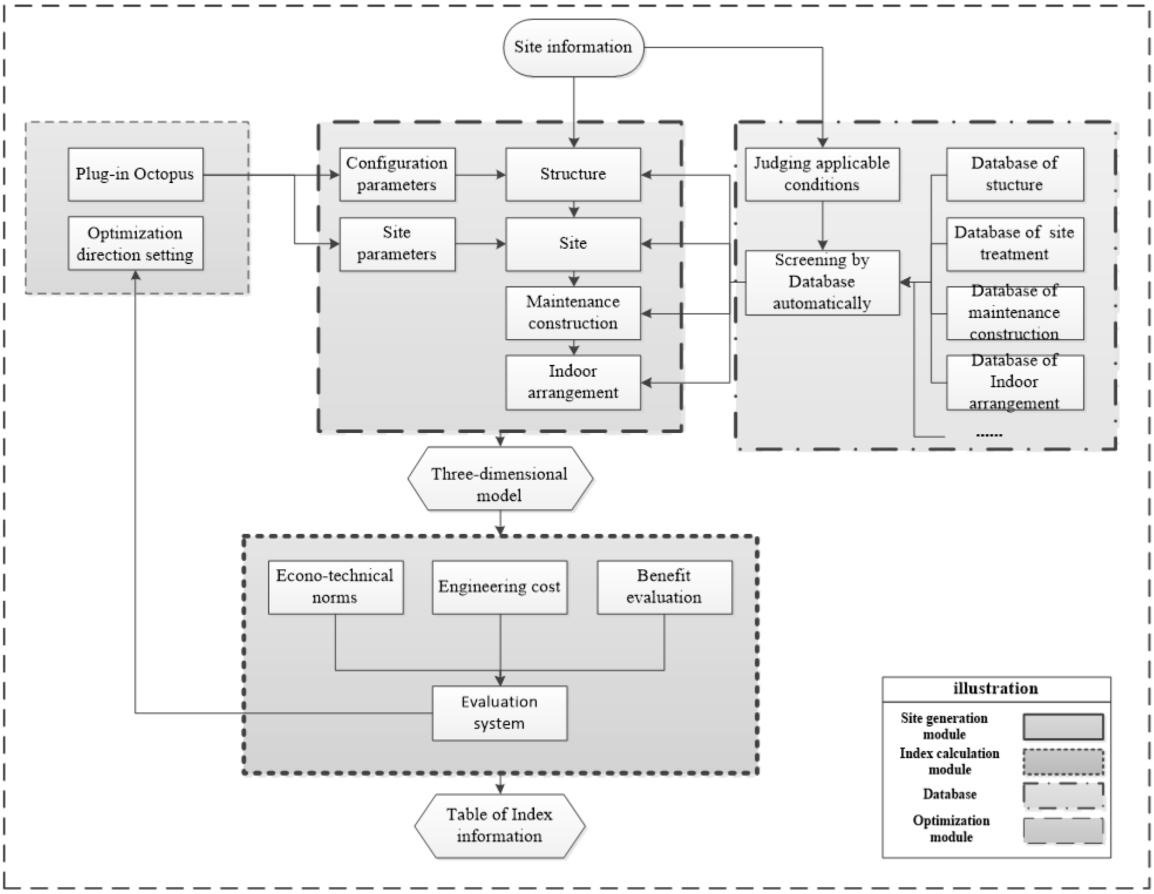


Figure 1. Framework diagram

According to above research, this paper proposes the framework based on the Rhinoceros &Grasshopper. The platform consists of four parts: parameter generation module, database, performance indicator calculation module and program optimization module:

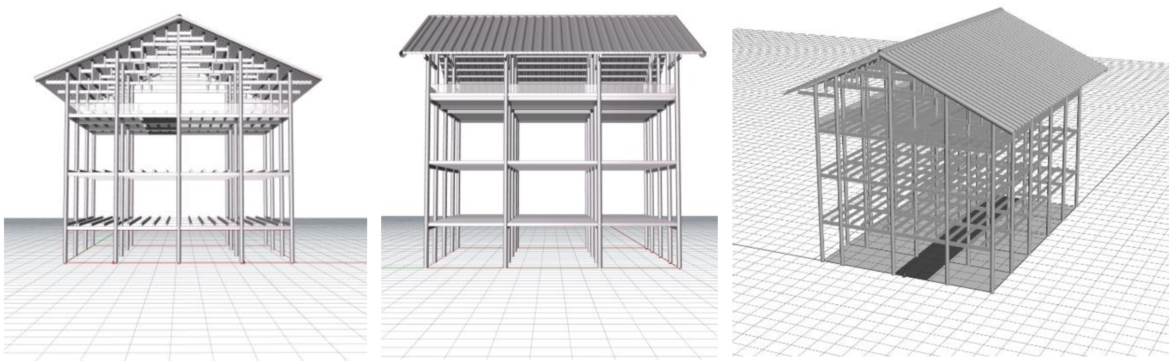
3.1. Generation module and database

The generation module can be divided into three submodules. Each submodule has its corresponding database. The system will be based on the input conditions to select the default database first, and also can choose other types of databases according to their own needs:

Table 3. Database

Type	Generate submodule	database	Screening basis
Structure generation module	Structure	3steps/4steps/5steps	Building Outline
	Component joint mode	2lin/3lin/4lin/5lin	Length of step
	Component-fabrication methods	Rectangle、Circle、Short column	Types
Site adaption module	Site generation	Mesh grid、Mesh、brep	Default mesh grid
	Site adaption	/	Gradient、Entrance height
Maintenance construction module	Roof generation	Traditional roof	/
	Outer walls generation	Traditional window style、Modern window style	/

3.2. Optimization of typical stilted building



Right view Front view Perspective view

Figure 2. Typical Stilted building

Taking the traditional stilted dwellings with 4-purlin beam and three bays as the optimized object. The width is three bays, 12.6m. The depth is 4-purlin beam, 12.24m. There are three steps of water between the positive column and the golden column. Each step of water size is between 64~80cm. The width of each bay is between 3.3~4m. There are three floors. The height of first layer is 2.5m. The second is 3m and the third is 2.8m. Because of user requirements, the new stilted building often regards the third layer as guest rooms. But the room size that the structure separate does not suit to be guest room. How to optimize stilted building which fits the needs of modern life is the purpose of this optimization.

3.3. Optimization setting

The optimization adopts the HypE Reduction iteration algorithm which set 100 data as a generation. This optimization adopts 7 variables to participate. has 1620 (5*4*3^4) possibilities. The optimization parameters include the building width, length and the proportion of the distance between each 'step'. The optimization goal is as described above.

Table 4. Optimize variable's influence

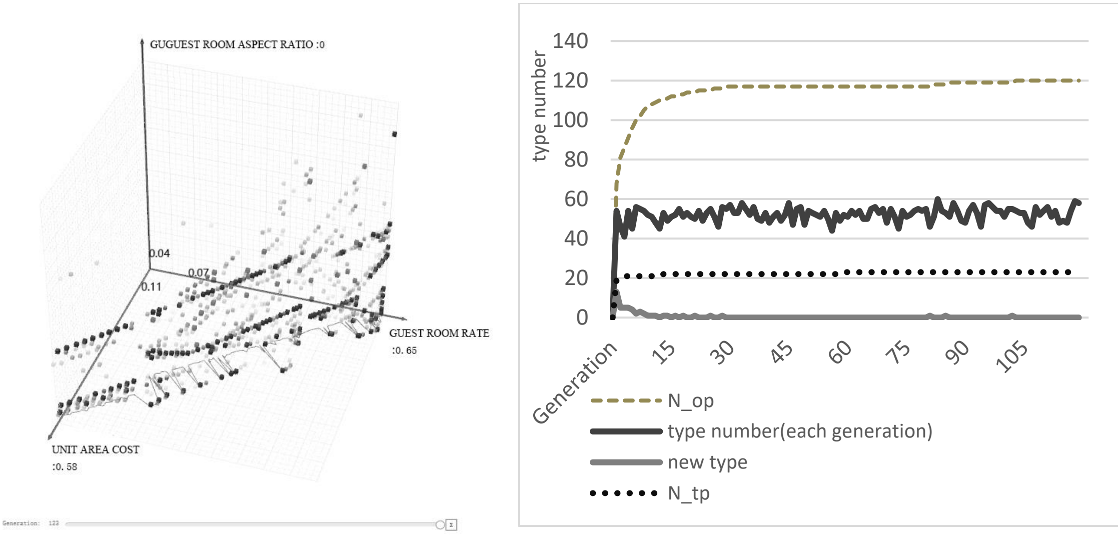
Variables	Range	Unit	Result				
			Step number	area	form	Gust room number	Gust room proportion
Width	12-16	m	●	●	○	●	●
Length	12-30	m	○	●	●	○	●
Step's Proportion	2-5	/	○	○	●	○	●
Bay's parity check	Even/odd	/	●	○	○	●	●

4. Results and discussion

The optimization module runs 12122 times and has 120 generations.

Table 5. Layout in generations

Generation	N_{tp}		N_{op}	
	Number	Ratio	Number	Ratio
1	16	69%	36	30%
2-10	21	91.3%	105	87.5%
total	23	100%	120	100%



120 generation's result Type number-generation

Figure 3. Results and type of layout

4.1. Optimization convergence judgment

The convergence of optimization is judged by the change trend of optimization rate. Taking cost per unit area and Guest room aspect ratio as examples, the extremum and average value of the optimization performance indicators of the optimal solution set of each generation are shown in Table (6). The optimization rate of the first 10 generations increased by 18%, the 10~60 generation increased by 6.25% and the 61~120 generation increased by 3%.

Table 6. Optimization rate

Generation	*optimization rate*	
	R_{op}	R_{tp}
0-10	18%	28%
11-60	*6.25%*	*10.91%*
61-120	3%	5.7%

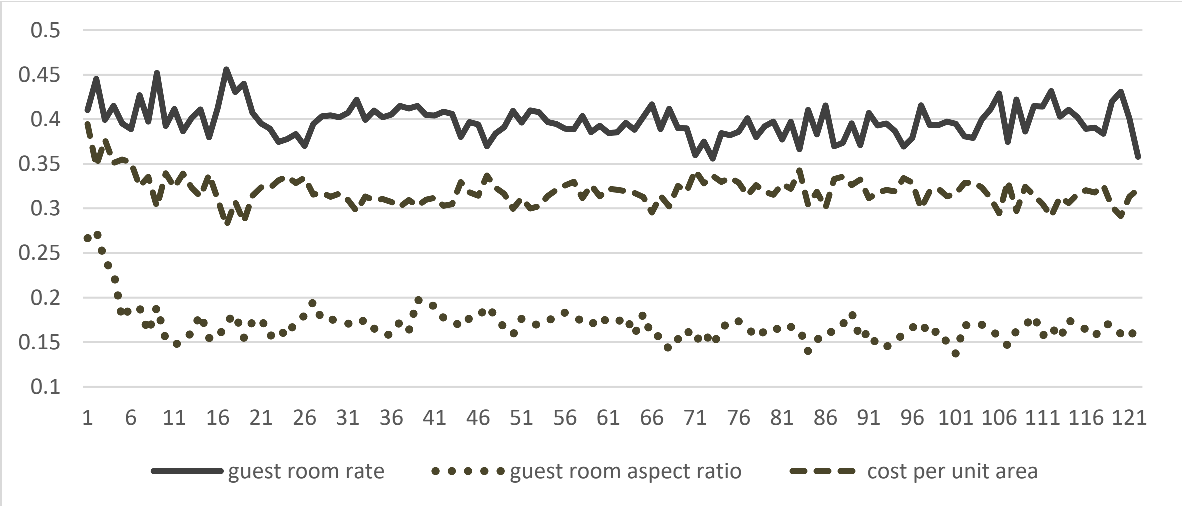


Figure 4. average of each generation

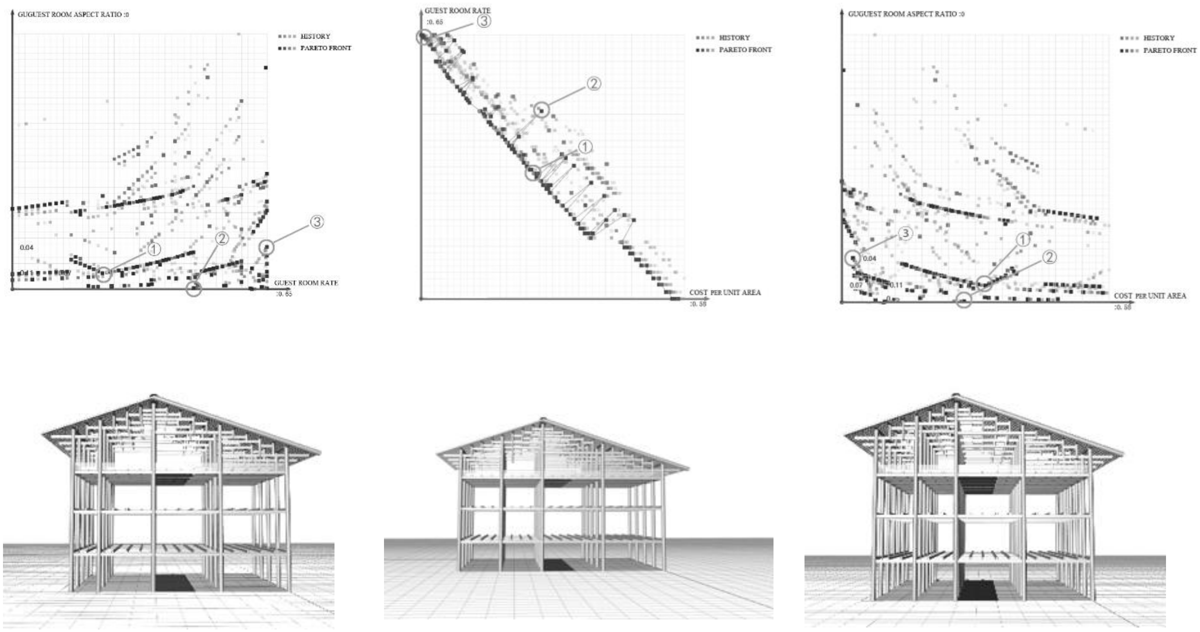
4.2. Optimized performance analysis

The solution set closing to the origin has superior performance, and the further has worse performance. Three representative preeminent solutions were selected for comparison:

Table 7. Optimization rate of Pareto Front

Generation	Performance indicator			*optimization rate*		
	Cost per unit area (¥/㎡)	*Gust room Ratio*	*Gust room proportion*	*Cost per unit area (¥/㎡)*	*Gust room Ratio*	*Gust room proportion*
Original	*668.7*	*0.0126*	*0.2151*	----	----	----
①	*576.88*	*0.0122*	*0.0462*	*13.7%*	*3.33%*	*78.5%*
②	*595.81*	*0.0102*	*0.2824*	*10.9%*	*19%*	*-31.28%*
③	*480.53*	*0.0069*	*0.1024*	*28.14%*	*-45%*	*52.4%*

When the new functional requirements are promised, the possibility of some structural changes of stilted structure in reasonable grammar logic and three different architecture forms have unique advantages and disadvantages on different performance. But it is better than the performance of the traditional stilted building in total.



a) Pareto Front b) Pareto Front c) Pareto Front

Figure 5. Pareto Front result

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6. Conclusion and implications
In this study, the generation of digital protection in the traditional building is discussed, which simplifies the design parameters. Based on the Rhino platform, the framework can be developed and equiped with different analysis and calculation modules. It also supports the definition and storage of database construction methods. In addition to the output of three-dimensional information model, the corresponding index parameters can be output at the same time such as economic and technical indicators and so on. At the same time, this optimization preliminarily verified the feasibility of applying the optimization method in the stilted dwellings. By optimization analysis, the results is obtained were verified consistent with actual construction experience so the wisdom of traditional craftsman is proved too. This method is expandable. In the future, different analytical and computational models can be used to meet the requirements of experiment and engineering application. It has a broad application prospect.

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