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Research on the Coupling of Graphic Design Graphic Creativity and Spatial Function Based on the Decorative Arts of Housing Architecture

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Abstract Under the continuous improvement of people's demand for quality of life and personalization, creative and functionally adapted housing design concepts are more and more sought after by people. In this study, the Prim algorithm is used to analyze the house types and space planes in the housing construction project, and the creative design of the housing construction plane images in Grasshopper platform to get the draft graphic ideas of housing plane design. Then combined with the combination of spatial function module unit optimization scheme proposed based on housing architecture decorative art graphic design creativity and spatial function coupling scheme. The results of the case study of the housing architecture project found that the housing space program after the graphic and spatial coupling design was recognized by the tenants in terms of spatial creativity and functionality. The average satisfaction of tenants with the housing design program increased from 22.18% under the existing design program to 75.80%. This paper demonstrates the feasibility of graphic and spatial-functional coupling design based on the decorative art of housing architecture through examples, and lays the foundation for the coordinated development of artistic creativity and spatial-functional adaptability of housing design in the future.

Index Terms Prim algorithm, Grasshopper, spatial modular unit, housing architecture design, living space function

I. Introduction

In the field of graphic design, traditional design methods have become popular culture, and these popular graphic works are even more difficult to impress people. People's appreciation of traditional works is gradually numb, and people begin to pursue more personalized works [1]-[4]. Graphics as the world's common symbolic language, so that modern graphic designers began to try to integrate more graphic creative elements into the work, these diverse creative graphics to make the work become more innovative [5]-[7]. Graphic creativity belongs to a special form of expression in graphic design, which is a new effect formed through the innovation and creation of graphics, which is the core content of the works and the most attractive place in the works. It changes the traditional and inherent design mode, and changes the unchanging design elements [8]-[11].

Indoor space is the place where people live and work, and the design and use of its function is an important factor to improve the quality of life and work efficiency. The functions of indoor space include living function, office function, leisure function, entertainment function and so on. The design and arrangement of these functions directly affect people's physical and mental health and daily life [12]-[15]. Therefore, the division and functionality of indoor space plays a crucial role in architectural design. Reasonable space division can make the interior layout more reasonable, meet the needs of different functions, and provide users with a comfortable experience [16]-[19]. The design of interior space is a comprehensive process, which needs to fully consider the aesthetics, practicality and people's needs. In the design, spatial layout and functional planning are two important aspects [20]-[22].

This paper combines graphic creative design with spatial functional modularization design method, puts forward the coupled practice program based on the decorative art of housing architecture, and designs a housing space program that can meet the needs of multiple households. Based on the Prim algorithm, the planar house type and spatial structure of the housing construction project are calculated and designed, and the creative program design under the guidance of the decorative art of housing architecture is carried out in Grasshopper on the basis of the planar calculation image of the house type. Then divide the housing space functions into modular units, consider the mutual matching between the space functions, and optimize the combination between the modular units of space functions. Finally, the combination of graphic design and spatial function combination optimization scheme builds a practical path of graphic design and spatial function coupling based on the decorative art of housing architecture. This study selects a housing building relocation project as the object of analysis, and explores the

basic household type situation and the needs of the residents in the project. The coupling practice scheme is then used to design the residential space in the project, and the implementation effect of the coupling practice scheme is analyzed by comparing the satisfaction and enhancement degree of the tenants on the spatial function and design creativity in the original design scheme and the design scheme in this paper.

II. Method

II. A. Graphic design image generation based on Prim algorithm

The algorithmic logic of the Prim algorithm [23] on the Grasshopper platform [24] provides the basis for the generation of graphic creativity of graphic design coupled with spatial functionality in housing architecture. According to the division of the grid, a circle of modules immediately adjacent to the core can be used as an alternative module for the entrance, which generates a variety of basic cases from one floor of one household to one floor of multiple households, and there are also combinations of different orientations of the entrance module in each case of a fixed number of households.Prim algorithm's arithmetic results are linear, and each time the result of the operation of the internal space will be linked together as a single unit, and if we want to generate a number of different boundaries of the household type, the Prim algorithm will run several times, and each time the result of the operation will be linked together as a single unit. Prim algorithm will be run several times, each time only one house type is calculated, and each operation starts with the position of the entrance module. The user can choose the number of steps for each house type operation at this stage. The reason for choosing the number of house type operation steps instead of the number of house type modules is that the Prim algorithm does not expand the new space at every step in the operation process, some steps simply remove the case where both sides are walls, which is reflected in the space as a standing still. Therefore the number of house type modules produced each time will be less than or equal to the number of steps set by the user, which produces rich arithmetic results.

II. A. 1) Initial setup

Prim algorithm itself is an algorithm with stochastic characteristics, the results of the operation can not be predicted and can not be used directly, it is necessary to add human control outside the algorithm. According to the characteristics of the Prim algorithm, it is necessary to specify the starting point of the calculation and the set of the remaining points of the calculation. In this design, this paper simplifies the above planar form into a 6×6 planar point matrix before the algorithm operation. And according to the number of household types, the center point where the entrance module of the household type is located is used as the starting point of the algorithm. After removing the core, alternative starting points, the remaining set of points is then used as the remaining computable points for the algorithm of the house type operation.

II. A. 2) Operational procedures

According to the previous section, in the process of generating the coupling of graphic creativity and spatial functionality for housing architectural floor plan design, the Prim algorithm will be run several times, and the new set of floor plan house type points that will be generated after each operation will be removed from the remaining set of points, and the floor plan generation for the next house type will be generated in the set of floor plan points that remain after the removal of points from the previous house type. Due to this feature, the number of remaining points that can be computed for some of the house types at the time of computation is less than the number of computation steps set for them, so the results of the generated house types are also unpredictable, but the generation of specific planes can be controlled by the randomized seed list for each Prim algorithm run. Once the calculation of the house planes is complete, the graphic creative design is based on the house planes to generate a draft graphic creative design based on the decorative arts of housing architecture.

II. B. Optimization of the functional design of housing building spaces

II. B. 1) Spatial functional module units

The basic component unit of housing building space design under the decorative art of housing architecture can be regarded as a modular unit [25], and applying different combination methods to the modular unit to achieve the construction of residential space with perfect and reasonable spatial functions and good living experience is the main purpose of the combination of residential functions under this system. The research focus of this paper is to find potential functional combinations from the existing functional combinations of housing space that are universal and can be further standardized and applied, so that they can match the basic performance required by the system in the design of housing buildings, and lay the foundation for the next coupling design. The design points of combining and placing many living functions into modular unit space are divided into three parts: function matching, dynamic line organization and interface setting, and after optimization, a limited number of modular unit types and fixed size types are finally formed.

II. B. 2) Space function module matching

After the disassembly of the basic functions of the residence, the classification of the basic living functions include living module, bedroom module, kitchen module, bathroom module, dining room module and other single-function modules, which need to be combined and nested with other functions in the process of composing the modular unit due to its small size, and placed into the modular unit under the principle of intensification. In this combination of nesting process, it is necessary to consider the mutual matching between different functions.

Different spatial functions within the residence in the process of matching each other need to consider whether the combination is reasonable, analyze the compatibility of different types of functional space between each other, while avoiding the number of functional limitations and exclusivity caused by the irrational combination of functions. For example, it is impossible to have two kitchens in one housing type, and it is not appropriate to combine the dining room and bathroom into one modular unit. Different functions are expressed as code words, and the suitability of the function matching of each space is analyzed.

By analyzing the functional collocation of housing modules, it can be found that the main living spaces such as living room, bedroom and dining room are compatible with the auxiliary spaces including kitchen and bathroom, and the collocation of similar main living spaces does not have exclusivity. Living room, bedroom, dining room can be combined with kitchen or bathroom in the same box. The combination of living room, bedroom and dining room can also be established under the guidance of decorative art based on housing architecture. The living room, kitchen and bathroom cannot be combined with themselves due to the limitation of the number of functional spaces, and have the exclusivity of the same type, not more than one.

II. C.Graphic Design and Spatial Functional Coupling Framework

II. C. 1) Planar and spatial coupling ideas

In addition to meeting the needs of the residents and various spatial forms, the basic and extended modules of the housing living space function also need to meet the requirements of residential decorative art through the coupling between graphic creative design and spatial function. The coupling idea is divided into the following two steps, firstly, the three kinds of units in the basic module of space function (bathroom unit, kitchen unit, sitting unit) are combined to form a variety of basic modules that meet the user's needs and scale requirements. Secondly, two kinds of units (entertainment unit, work and study unit) within the extension module are combined to form a variety of extension modules. Parameterized design method is adopted in the coupling, based on the topological relationship of the functional units and the size of the site to carry out the creative design of the plane. Parametric method can be from the “function”, “spatial relationship”, “scale” three aspects of the module and the internal unit can be iterative quantitative analysis, through the designer to compare the iteration results by comparing the difference between the iterative results and the actual results in the process of using, it can provide theoretical and practical basis for residential design. Through parametric algorithms and visual analysis, designers can intuitively analyze the interrelationships between each functional module of housing space, which makes it easy to judge the possibility of inter-module combinations. At the same time, the position of each module is improved and optimized through iterative analysis of the algorithm, which greatly improves the efficiency of the designer and ensures the accuracy of the design.The RI (House Instance) component contains information such as the name of a single space, dimensions, and connecting attributes, while the HI component contains information such as the orientation of the site, and the location of entrances and exits, etc., and the M-FPG and S-ES components provide spatial combinations and analysis for the RI and HI. HI provide spatial combination and analysis. In Grasshopper [26], the RI and HI components are connected to form a database with house boundaries, entrance locations, and various spatial scales, and the database is connected to the M-FPG component to form a variety of spatial combinations in Rhinoceros, and finally iterative calculations are carried out in the S-ES component to ultimately form a spatially optimized design plan for housing space that meets the requirements. The final result is the optimized design of housing space that meets the requirements.

In the basic module of housing space function, the topological relationship between the three units determines the complex behavioral pattern of the occupants in this module, and the functional organization schematic of the basic module can be initially established by setting up the area of the site and the entrance point. The designer can deepen the design through the plan creative design drawings, so as to get the final basic housing architectural design plan, when the basic module of spatial function and the extended module design is completed, the residential plan and standard floor can be generated through the flexible layout form.

II. C. 2) Pathway basic framework design

In this paper, based on the above housing space function module optimization design scheme and graphic creative graphic design scheme, the graphic design graphic creative and spatial function coupling practice based on the

decorative art of housing architecture, the specific coupling practice path is shown in Figure 1. Housing architecture decorative art theory as a guide for housing architecture living space design practice. The principles of spatial efficiency, refinement, intelligence and personalization in the optimized design of housing space based on the decorative art of housing architecture correspond to the efficient storage of living space, composite basic modules and shared extended modules in the spatial function respectively. With the above principles as a guide for the creative design of the plane and the design of spatial function coupling, through the reasonable organization of the basic module and the extension module in the spatial function, it improves the living comfort and the artistic creativity of the living space. In the context of the new era, based on the decorative art of housing architecture, it creates a spatial functional space that meets the diverse needs of the residents and serves them more precisely.

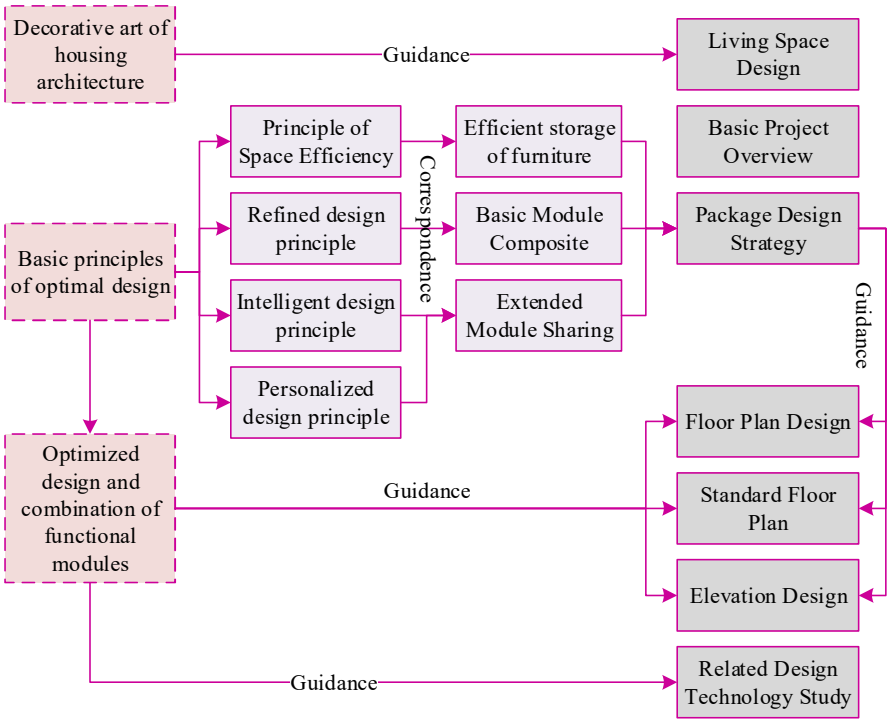


Figure 1: Graphic design and spatial functional coupling path

III. Results and discussion

III. A. Case Projects

III. A. 1) Project overview

Beijing W village relocation housing project site is located in Haidian District, Beijing, to be rerouted W village district land is divided into north and south, of which the planning and design of the southern part of the relocation east-west length of about 512m, north-south width of 120-160 meters between. The total land area is 50231.62m², except for the requisitioned land, the actual construction land area is 48526.36 m², the total construction area is 264815 m², except for the underground area and the supporting public building, the area of the relocation housing is 115,246 m².

III. A. 2) Background to upgrading

The original site of the W Village Renovation Project was a residential neighborhood established in the late 1970s. By the beginning of this century, the site and the surrounding houses were in serious decline, with problems such as old buildings, peeling off of the exterior wall skin, and corrosion of the pipelines abounding. Due to the long construction period, not only the aging facilities and old style of the housing caused various disputes, but also the serious lack of living space and irrational design of space functions in the housing caused difficulties in the residents' lives, making it a dangerous housing in need of urgent solution. In order to improve the living conditions of the residents, the Haidian District Government set up the leading group and site command department of the old city reconstruction project of the W Village neighborhood in 2018, and most of the residents agreed to relocate back to the original location after the statistics of the residents' willingness to reconstruct the neighborhood were solicited. The analysis of the statistical results for the ownership area shows that the type of set area required for the project

is more complex, and the original program takes the form of a retreat to cover the type of area, which has caused dissatisfaction among some tenants with the design of spatial functions in the housing space and the design of creative arts, thus affecting the progress of the project. Therefore, when redesigning the housing architecture space, the design strategy of coupling graphic design creative graphics and spatial function under the decorative art of housing architecture was adopted. It is hoped that through the spatial reconstruction of elasticity and artistry, the richness of the housing space function has been enhanced, and at the same time, it is hoped to solve the problems of insufficient creativity and artistry of housing in the original program. In addition, in the process of demolition and relocation, the tenants constantly put forward new demands, all of which are solved through the design strategy of coupling graphic design creative images and spatial functions in the new program.

III. A. 3) Analysis of project requirements

For the selected relocation projects in this study, the first and foremost demand faced is the precision and refinement of the return area; the richer the area range, the more the diversified needs of the residents' spatial functions and creative elements can be fully satisfied, and the more the principle of fairness is fully embodied, so as to reduce the disputes brought about by relocation to a different place. Therefore, it is necessary to be precise to have a corresponding resettlement housing option for each area after the compensation area and resettlement units are counted. The project involves a total of 1,192 households with a total population of 2,954. Through the statistics of each household's original home ownership area, the comprehensive area and house type comparison standard, the ratio of demolition and construction and high-rise common area and other factors, the original living room is divided into 14 area intervals, combined with the number of resettlement units corresponding to the 14 kinds of accurate return area, the interval corresponds to the situation as shown in Table 1. Among them, the number of resettlement units with original living room area ranges between 32.12 m²-35.37 m² and 34.76-39.94 m² are 36 and 25 units respectively.

Table 1: Interval correspondence

Serial number	Original bedroom interval (m^2)				Compensation factor	Optional area	Placement number
	Minimum	Maximum	Area difference	Interinterval median			
1	32.12	35.37	3.25	53.44	2.03	132	36
2	34.76	39.94	5.18	40.06	1.85	119	25
3	36.31	41.82	5.51	62.75	2.06	139	18
4	40.18	42.56	2.38	39.44	1.93	73	16
5	45.14	53.21	8.07	51.23	1.68	78	25
6	45.9	54.7	8.8	54.85	2.18	65	29
7	50.37	56.51	6.14	63.29	2.13	83	35
8	56.49	64.84	8.35	55.65	1.78	86	128
9	56.98	66.29	9.31	60.34	2.14	93	59
10	60.27	71.06	10.79	55.84	1.86	83	235
11	60.28	73.05	12.77	48.48	2.19	75	292
12	60.64	75.54	14.9	66.66	2.05	75	74
13	63.45	76.53	13.08	49.41	1.76	94	62
14	64.41	79.59	15.18	67.74	1.71	117	158
Total	——	——	——	——	——	——	1192

After the general layout design, 1192 households are divided into 7 residential buildings, and the specific area distribution is shown in Table 2. They are two 11-story small high-rise residential buildings (6# and 7# buildings), three 13-story and 15-story high-rise residential buildings (2#, 3# and 5# buildings) and two 25-story high-rise residential buildings (1# and 4# buildings).

Table 2: Area Distribution

Building	1#/4#, 25F		5#, 15F	
Household type	Area	Arbitrage	Area	Arbitrage
Two-bedroom	65/70	74/84	62/65	68/32
Three-bedroom	95/98	69/71	85/87	56/25
Four-bedroom	117	79	104/115/128	25/41/58
Total	——	377	——	305
Building	6#/7#, 11F		2#/3#, 13F	
Household type	Area	Arbitrage	Area	Arbitrage
Two-bedroom	59/62/74	31/59/22	65/72/78	54/59/21
Three-bedroom	88/95/98	52/48/26	95/97	62/58
Four-bedroom	——	——	112	18
Total	——	238	——	272

III. B. Analysis of Household Demand for Creative and Spatial Functional Designs

III. B. 1) Overview of the Housing Needs Study

(1) Research methods

Since the design of the housing space is mainly to meet the needs of the residents, it is necessary to accurately understand the requirements of the residents in the case residential construction project in terms of the function and artistry of the housing space. This paper uses a questionnaire to investigate and analyze this problem, and the questionnaire is divided into two parts: the basic information of households and residences and the feedback on housing quality. Among them, the housing space satisfaction evaluation covers a total of 45 status quo problems in nine categories, such as space applicability performance, house type organization relationship, kitchen and bathroom facilities configuration, etc., and each problem is set up with five evaluation options of "very satisfied", "relatively satisfied", "average", "dissatisfied" and "very dissatisfied" to measure the degree of satisfaction, and for each problem, the corresponding option of "can be further improved and improved" (multiple choices can be selected) is set to measure the degree of improvement of the problem. The satisfaction value is the percentage of the number of questionnaires that choose the "very satisfied" and "somewhat satisfied" options in the overall population to express the degree of recognition of maintaining the status quo. The upliftability value is the percentage of the total number of surveys that select the "upliftable" option to express the level of interest in improving the status quo. Through the comparison of satisfaction and the value of improvement, the corresponding problem of "improvement degree is greater than satisfaction" is selected as the main contradiction that housing should be prioritized for improvement or has more research value.

(2) Research Objects

This research is mainly conducted through the “Questionnaire Star” method of online release statistics and Excel data recovery processing. As of April 2022, 1,025 valid questionnaires were collected within the scope of the research. The results of analyzing the basic information of the households in the housing project are shown in Table 3. It can be seen that the main body of the use of this return housing construction project is dominated by couples with unmarried children (28.98%) and husband and wife (25.85%). The proportion of two-bedroom, three-bedroom and four-bedroom residential units is 45.37%, 44.10% and 10.54% respectively.

Table 3: Basic household information statistics

Basic information	Options	Corresponding questionnaire	Proportion
Age distribution	<34	264	25.76%
	35-49	269	26.24%
	50-64	265	25.85%
	65-79	158	15.41%
	>80	69	6.73%
Family structure	Singles	96	9.37%
	Husband and wife	265	25.85%
	Couple and children	297	28.98%
	Couples, children and grandparents	211	20.59%
	Other	156	15.22%
House type	Two-bedroom	465	45.37%
	Three-bedroom	452	44.10%
	Four-bedroom	108	10.54%

III. B. 2) Results of the analysis of living space needs

(1) Analysis of Satisfaction with Basic Residential Space Functions

In the survey interview on the use and layout of the basic residential space, the residents' satisfaction with each functional space of the residence in the original design scheme is shown in Figure 2. It can be seen that in the original design plan of the residential building project, the proportion of residents' satisfaction with the living room (45.52%) and bedroom (31.26%) in the living space is relatively large, indicating that the use of this part of the space is recognized by most of the residents. On the other hand, residents' satisfaction with the kitchen (22.36%), bathroom (21.42%) and dining room (19.56%) in the living space is relatively low, indicating that further improvements should be made in the area and functional design of the dining room and bathroom.

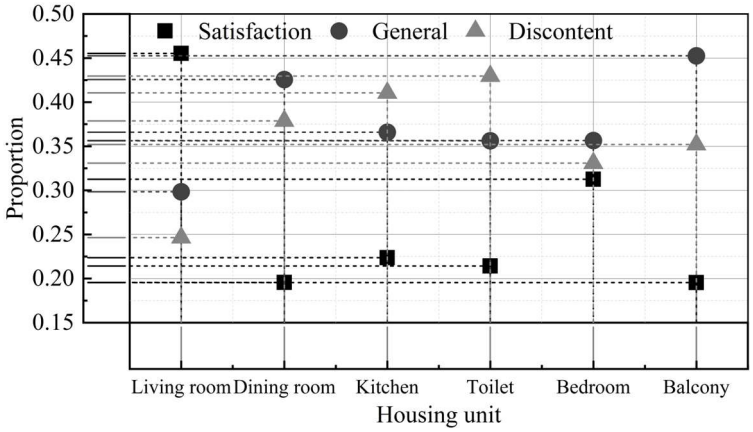


Figure 2: Analysis of residential spatial satisfaction analysis

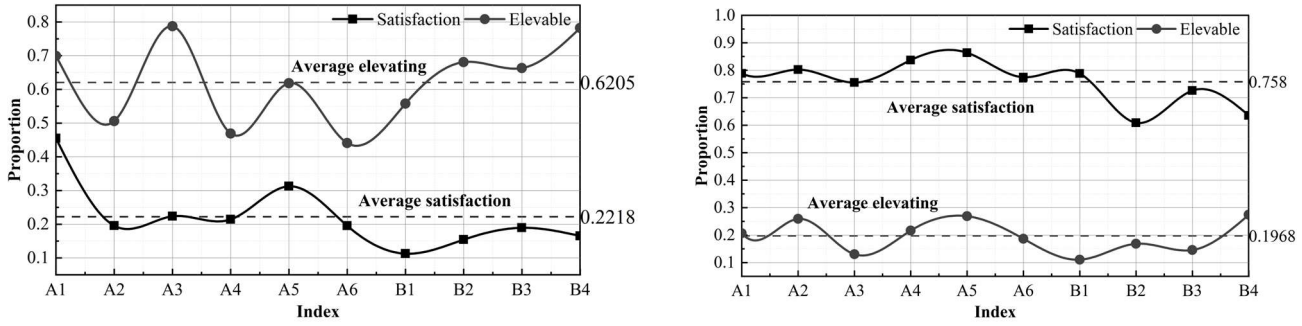
(2) Demand analysis of space function configuration

The residents of this housing construction project are satisfied with the area of the kitchen and bathroom as well as the kitchen and bathroom piping equipment in the original housing space design program, indicating that the conventional kitchen and bathroom arrangement can meet the residents' needs. Satisfaction with the waterproofing and ventilation of the kitchens and bathrooms was relatively low, indicating that waterproofing and ventilation should be fully considered in the design. As for the kitchen area, most of the residents said that because of the limitations of the location and size of the kitchen, there are irrational problems in the design of the operating surface. In the survey on the willingness to use the kitchen space, it was found that the kitchen and dining room locations of most households are used separately, and the kitchens are mostly in a semi-open relationship. In order to save living expenses, the frequency of householders firing and cooking at home is relatively large. Due to the constraints of some household types, their kitchens are mostly arranged in a zigzag arrangement. The respondents would like to have better communication with their family members while cooking and perceived the need to watch TV while dining. In addition, the interviews on comfort and creativity of basic space design showed that some households were less satisfied with their bedrooms. Some residents felt that the number of rooms in the residence did not meet their current living needs in the majority, and that the size of the bedroom required not only the ability to put down a bed, but also basic furniture. Residents generally responded that there was not enough storage space in the bedrooms, and the location of electrical outlets in the bedrooms was mostly remodeled at a later stage. In addition, some young residents reflected that the style of the living space in the existing design program was too single and could not satisfy their pursuit of creativity and art. These situations reflect that there is still room for improvement in the bedroom layout design of the original project design program.

III. C. Comparative analysis of satisfaction with housing design options

Combining the needs of residents for artistic creativity and spatial function, this paper carries out the design of residential programs based on the decorative art of housing architecture in the Grasshopper platform, and analyzes the satisfaction and enhanceability of various problem indicators of the residential space. Comparative study on the satisfaction and enhanceability of the living space under the existing design scheme and the design scheme of this paper, the analysis results obtained are shown in Figure 3, (a) and (b) represent the results of the analysis of the satisfaction of the residents under the existing design scheme and the optimized design scheme of this paper, respectively. In the figure, A1-A6 represent the living room function, dining room function, kitchen function, bathroom function, bedroom function, and balcony function in the spatial function, and B1-B4 represent the color matching,

spatial aesthetics, personalized decoration, and natural elements in the living space, respectively. It can be seen that the housing architectural space design program based on the graphic design of the decorative art of housing architecture and the spatial function of the coupling of the practice of the housing architectural space design program is more advantageous in terms of the relevant elements of the living space, and the satisfaction of the tenants with the design of the living space program on the whole has been improved to a certain extent. The average satisfaction and enhanceability changed from 22.18% and 62.05% under the existing design scheme to 75.80% and 19.68%, respectively. In addition, in the contracting activity after replacing the living space design strategy in this paper, the housing construction project achieved a 99.8% return contracting rate. Meanwhile, in carrying out the design of high-rise housing, the design scheme based on the graphic creative design of the decorative art of housing architecture coupled with the spatial function further optimizes the problem of household size. A certain range of adaptive changes was also set to enable continuous adjustment of the house types, so that the residents' satisfaction with the resettlement housing was taken to a higher level and they actively participated in the reconstruction activities.



(a) Both design and design

(b) Design of this article

Figure 3: Design satisfaction and scalability analysis of housing space

IV. Conclusion

This paper combines graphic creative graphic design method and spatial function module combination optimization method, based on the concept of decorative art in housing architecture to establish graphic design graphic creativity and spatial function coupling path. Taking the resettlement housing project in W Village in Beijing as a case study, it is found that the overall satisfaction of the residents in the project with the existing housing design scheme is low, and the satisfaction with the functional units of the kitchen, bathroom and restaurant space in the housing design scheme is between 19.56% and 22.36%, and some residents think that the living space style in the existing design scheme is too simple to meet their pursuit of creativity and art. This all indicates that there is still room for improvement in terms of creativity and spatial functionality of the design solutions with the project. After using the coupled practice program design in this paper to obtain the housing design solution, it was found that the average satisfaction of the occupants with the housing design solution increased from 22.18% under the existing design solution to 75.80%, and the degree of enhancement also decreased from 62.05% to 19.68%.

Based on the creativity of the decorative art of housing architecture and the functional adaptive design of space so that the housing living space can meet the needs of the occupants of the multi-level, diversified complex and continuous change, the development of creative and functional adaptive housing architectural design has a certain practical significance.

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