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Applying Multi-Objective Evolutionary Computation for Optimal Feng Shui Layout in Interior Design

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ABSTRACT

Feng Shui principles have a profound impact in Asia, studies have shown that consumers often consider Feng Shui when purchasing property to arrange interior layouts. Balancing design requirements and cultural beliefs in the design process requires significant communication and calculation efforts, However, aside from repeated communication among Feng Shui experts, homeowners, and designers, there is currently a lack of efficient methods to incorporate Feng Shui into design. Therefore, this study establishes a decision model to provide layout recommendations for purchase property, design, and for existing property renovation planning. By references Feng Shui Compass School principles to assess the Feng Shui quality of dwelling interiors and considers spatial layout and area distribution rules to evaluate the feasibility of the solution. Multi-Objective Evolutionary Algorithm (MOEA) is then applied to optimize Feng Shui and design conditions in real-world case studies. The results show that the application can effectively optimize and balance Feng Shui and design conditions in a short period of time, also provides homeowners and designers with clear strategies during purchase, design, and renovation to meet the needs related to cultural beliefs.

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1. Introduction

Feng Shui culture is widespread in Asia [1, 2]. People's understanding of Feng Shui principles stems largely from the ancient compilation of environmental knowledge. It combines divination with scientific understanding, covering the knowledge accumulated by our ancestors in areas such as astronomy, natural phenomena and human behavior [3]. In Asian countries, people often refer to traditional Feng Shui principles when purchasing real estate. Numerous studies related to Feng Shui analyze from different perspectives including natural environments [4, 5], commercial activities [6-10], beliefs [11], and demographic surveys [12, 13].

One direct way to demonstrate the importance of Feng Shui is through real estate prices, there is a phenomenon of superstition affecting the price of items [14]. Previous studies have shown significant differences in the impact of different types of Feng Shui on house prices [15-20]. For instance, Tam *et al*. evaluated factors influencing real estate prices in Hong Kong and found that the correlation between Feng Shui and property prices was the highest [21]. In a study by Wu *et al*., real estate price prediction models that included Feng Shui variables provided more accurate price predictions than traditional models that only included common factors such as land price, building age, floor level, transportation, and environment [17]. These findings suggest that Feng Shui rules have an impact on both real estate prices and purchase intentions, indicating that cultural awareness can influence valuation methods and consumer behavior in the real estate sector.

Another direction of research is to evaluate whether Feng Shui influences consumers' willingness to purchase a property. Research has shown that Feng Shui has a significant impact on consumer satisfaction with purchasing behavior [18, 20]. Wu *et al*., utilized the Analytic Hierarchy Process questionnaire completed by Feng Shui experts and identified three factors—geographical environment, harmonious relationships, and internal arrangement—as the most critical standards for desirable residential locations. These factors can serve as reference indicators when evaluating Feng Shui conditions [18].

In fact, Feng Shui consists of different schools, and they can be applied to all scales of architecture, from large to small, including site planning [22], facade planning [23], interior layout [24], even furniture arrangement [25]. This research focuses on the process during interior layout planning, the two most used schools are the Form School and the Compass School. Among the previous researches, the number of studies focusing on the Compass School is significantly lower than those on other schools. This discrepancy is mainly due to the difficulty of applying the Compass School principle in modern design systems [26]. In particular, there is a lack of tools that translate core elements of Feng Shui - such as the positioning of celestial bodies, the client's birth date - into practical design solutions. Furthermore, the credibility of the Eight Mansions Theory, a critical component of the Compass School, has yet to be rigorously validated through empirical research [27].

In practice, interior layouts considering Compass School concept focus on directions and calculation rules when purchasing or renovating real estate, these considerations are widely integrated into the layout planning. This study explores how to perform interior layouts according to Compass School rules while considering spatial connectivity and feasibility, developing a model that automatically optimizes space layouts based on user conditions, functions, and space dimensions, serving as a decision support tool for interior planning or renovation.

2. Feng Shui Principles

2.1. Feng Shui Compass School

The development of the Feng Suai Compass School is believed to have originated with the discovery of magnets and the compass. It involves measuring magnetic north and assigning auspicious values to different directions to calculate scores, which are then used as rules for city or house planning [28]. Although this theory lacks a physical-scientific basis, and there is considerable debate as to whether Feng Shui should be considered a science [29, 30], and there are no strict constraints today requiring people to follow Feng Shui rules, research shows that urban or architectural planning still widely considers Feng Shui rules [31], showing that cultural consideration is an important aspect of the design process.

In fact, superstitions based on numbers exist in both Eastern and Western countries. Research shows that superstitions have a tangible impact on various international environments, as well as on mainstream industries in multinational corporations and their subsidiaries [32]. For example, the belief in lucky numbers and the rules derived from them can influence the pricing of goods [33, 24], some studies suggest that lucky numbers, such as stock codes, can amplify fluctuations in a company's stock performance [34], or that certain floor numbers may receive more favorable evaluations [35]. Furthermore, hotel management strategies often avoid floor numbers such as 4 or 13, which are associated with bad luck in both Eastern and Western cultures [7, 36], highlighting the cultural influence of numerology. This kind of cultural influence effectively explains why the Compass School plays such a significant role in interior layout. In fact, design can be defined by concepts either related or unrelated to the design itself to integrate the experience, beliefs and philosophy of the designer [26] to meet the physiological and psychological needs of users influenced by the socio-cultural values of the society to which they belong [37]. the contemporary design workflow lacks appropriate methodologies and tools for Feng Shui concepts.

The rules of the Compass School are based on the relationship between the occupant's personal hexagram and the directions, providing judgments on auspicious and inauspicious positions within the interior layout of the building. The resident's hexagram can be calculated using a mathematical formula based on their year of birth (Table **1**), which classifies them into either the East Group or the West Group [38]. In the traditional theory of the Compass School, the ideal building layout should be a complete square, with the interior divided into a 3x3 grid where each position has different meanings and corresponds to auspicious hexagrams. This study explores the application of Compass School auspicious directions in interior layouts. Since these directions vary for different hexagrams, the spatial configuration in a multi-occupant residence may not align with the auspicious directions for all occupant's, leading to layout trade-offs. To address the conflict of auspicious directions among residents, Juan *et al*., proposed a scoring method for building interior layouts according to Compass School rules, which evaluates the suitability of the layout for the residents based on their auspicious and inauspicious positions [39].

Table 1: Calculation of residents' hexagrams.

Male	Female
Assuming the birth year is 1995, (1+9+9+5)/9 = A...B Q = 11 − B *If Q = 5, then change the value to 2	Assuming the birth year is 1995, (1+9+9+5)/9 = A...B Q = B + 4 If Q > 9, then Q − 9 *If Q = 5, then change the value to 8.

Note: The cut-off date for the change of year is February 5th of each year. For births occurring between January 1st and February 4th at 11:59 PM, the hexagram number must be calculated based on the previous year.

In accordance with the interior Feng Shui rules of the Compass School, the East and West Groups of residents are respectively allocated auspicious and inauspicious directions based on their hexagram numbers, as calculated in Table **2**. The conflicts in spatial layout are then evaluated based on these calculations. Different spaces should be assigned to auspicious or inauspicious positions in accordance with the primary user or the collective hexagrams of all occupants, as illustrated in Table **3**. For instance, negative spaces like kitchens and bathrooms should be placed in inauspicious positions, while the main entrance, living room, and bedrooms should be located in auspicious positions [39].

Table 2: Calculation rules for east and west group hexagrams.

	Q Value	Auspicious Positions
East Group	2,5,6,7,8	W,NW,SW,NE
West Group	1,3,4,9,0	E,SE,N,S

Table 3: Examples of space and auspicious/inauspicious position pairings.

Space	Ideal Auspicious or Inauspicious Positions
kitchen	Primary User's Inauspicious Position
living room	Primary User's Auspicious Position
bathroom	Primary User's Inauspicious Position
main bedroom	Primary User's Auspicious Position
bedroom	Primary User's Auspicious Position
entrance	Primary User's Auspicious Position

Fig. (**1**) illustrates the auspicious directions for both the East and West Groups. In determining the optimal placement of a space within a domicile, the Compass School's guidelines consider the hexagrams associated with the primary user or collective users of the space, as well as the potential auspicious or inauspicious implications of its location. This assessment is conducted prior to assigning the space to a specific direction [39].

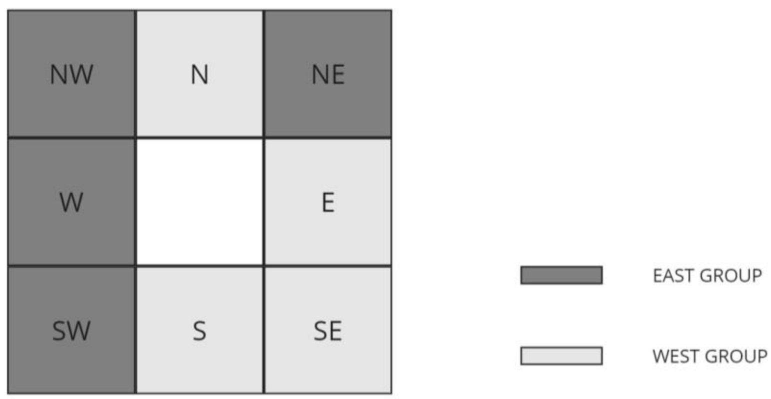

Figure 1: Compass school building layout and East-West group directions.

In recent years, rapid advancements in computer hardware and software have enabled the application of artificial intelligence to solve problems across various fields. Nevertheless, in the context of feng shui, while there are techniques for employing compass school formulas to calculate directions and ascertain auspicious and inauspicious positions, concurrently planning layouts and evaluating feng shui conditions is seldom a viable approach. The iterative adjustments required to optimize design plans are a time-consuming process. Accordingly, this study proposes a method for the replacement of manual evaluation and optimization. This method entails the execution of the Compass School rules for configuration and scoring, with the objective of providing reasonable results that can serve as a guide for designers in the creation of their layouts.

3. Methodology

Prior research has demonstrated the significance of Feng Shui in real estate purchase decisions. This study establishes a parameter-driven optimization and decision model, extracting rules from the Compass School as objectives for optimizing interior layouts. The decision-making process, as illustrated in Fig. (**2**), is based on the assessment items of Feng Shui that are considered during the purchase or planning of real estate. The process is divided into four distinct stages of tasks.

Phase 1: Input of Initial Conditions

Phase 2: Analysis of Interior Layout as Fitness Objectives (FO)

Phase 3: Optimization of Interior Layout

Phase 4: Scoring Results and Decision-Making

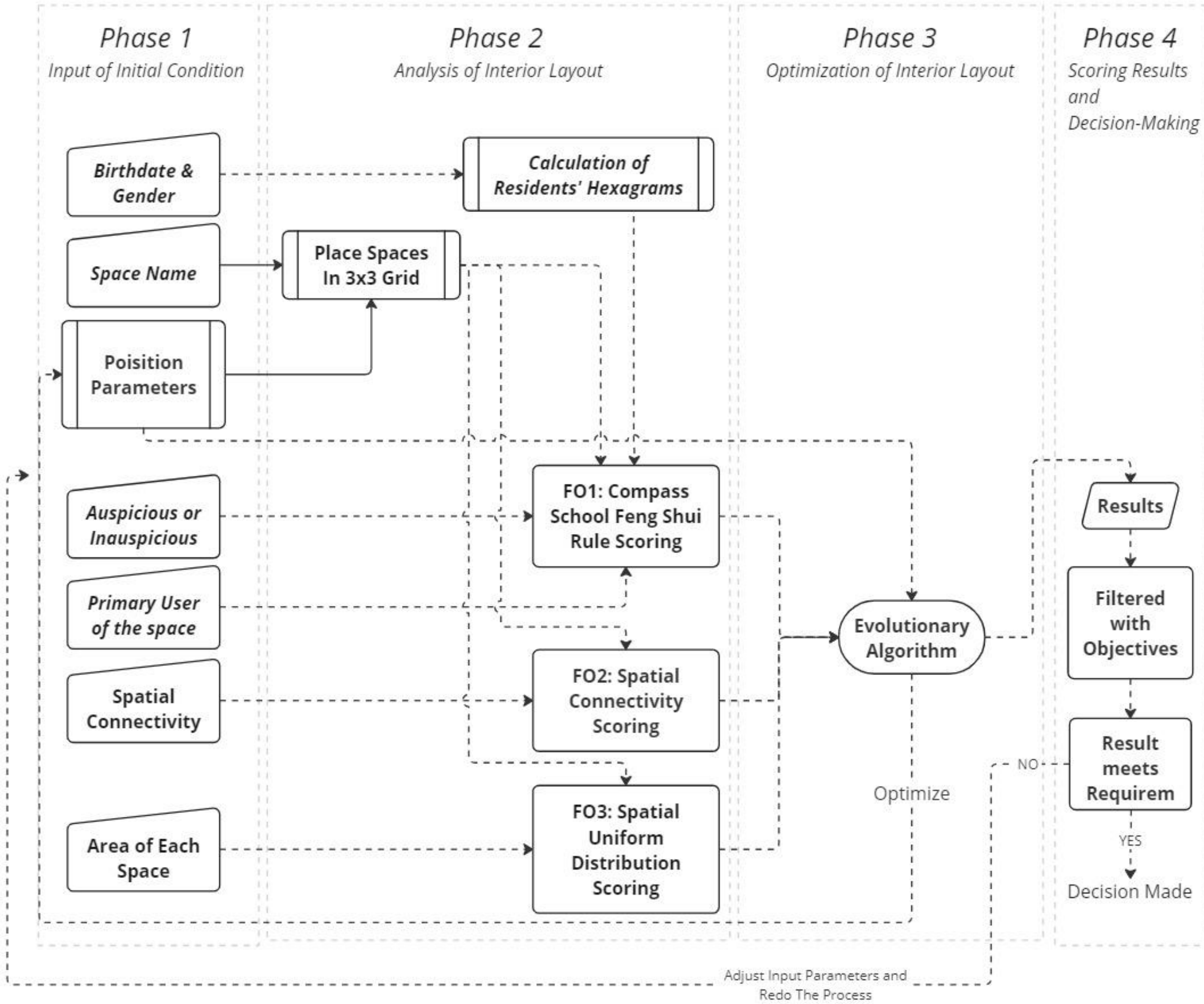

Figure 2: Decision model flowchart.

3.1. Methodology – Optimization through Evolutionary Algorithm

The research presented in this paper proposes a layout method that integrates the rules of Feng Shui's Compass School. This approach differs from previous studies that focus on generating layouts; instead, it emphasizes placing spaces in the most appropriate directions according to Feng Shui principles. It also ensures that the areas of space are reasonable and that the connections between spaces meet the necessary requirements. The study establishes three objectives to address the conflicts and trade-offs between Feng Shui directions, spatial connectivity, and spatial uniform distribution. Maintaining and optimizing the benefits of these factors will improve the feasibility of the proposed layout plans.

Evolutionary Algorithm (EA) is then used addressing multi- objective optimization problems, simultaneously considering multiple optimization objectives and seeking a balance between them [40, 41]. In previous related studies, evolutionary algorithms have been used to generate building layouts and optimize these results by setting specific objectives [41, 42]. These design objectives are typically related to customer preferences and needs, and often serve as benchmarks for evaluating design quality. By establishing an appropriate decision-making system, it becomes possible to assess the impact of different strategies on design objectives and further optimize based on these insights [43]. There are also precedents for the use of Feng Shui as a design objective; with properly defined conditions, algorithms can be applied to generate layouts that incorporate Feng Shui principles [44].

Additional benefits of using EAs include their global search capability, which allows exploration of a large solution space to identify multiple potential optimal solutions. This helps avoid being trapped in local optima and ensures that the solutions found have global optimality. Moreover, EAs maintain solution diversity by simulating natural selection and genetic processes [45], Fig. (**3**) illustrates the Muti-Objective Evolutionary Algorithm (MOEA) workflow. In this study, the complexity of Feng Shui rules and spatial configurations requires a flexible optimization method, and the adaptability of evolutionary algorithms makes them particularly well suited to such problems.

The role of the EA in this study is to attempt to optimize the layout , corresponding to Phase 3 in Fig. (**3**). At this stage, the EA records the parameters and variables input from Phase 2 and tracks the Fitness Objective (FO) values under different scenarios. By adjusting the position parameters from Phase 1 in segments, the EA produces different design solutions along with their corresponding FO scores (Phase 2). It then refines its strategies to find the optimal solution.

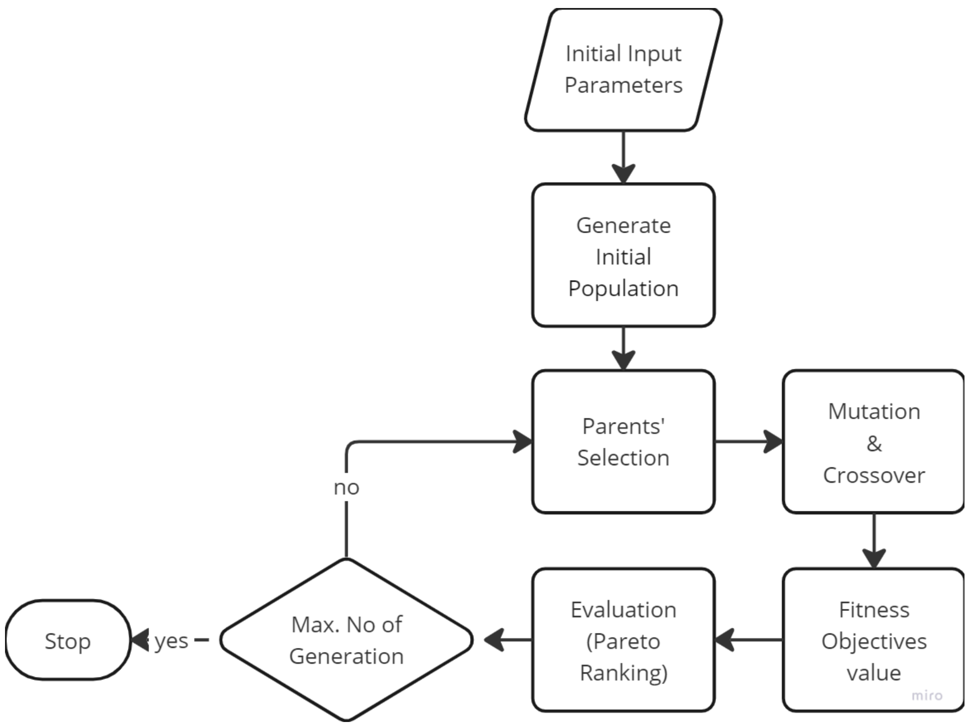

Figure 3: Muti-objective evolutionary algorithm flowchart.

3.1.1. Phase 1: Input of Initial Parameters

To integrate the conflicting hexagram numbers of different family members and the spatial layout requirements, this study refers to the hexagram calculation rules proposed by Lee & Castillo for each family member [38]. In addition, it adopts the spatial layout strategies proposed by Juan *et al*., to build a parameter-driven model [39]. This model applies Evolutionary Algorithms to optimize the interior spatial layout based on these rules.

By simultaneously considering Feng Shui rules and design requirements when calculating the interior layout, the process in this study inputs initial values that include seven factors: date of birth, gender, room name, spatial connectivity, room size, spatial auspiciousness, and the primary user of the room. Each room is assigned an adjustable variable that is positioned within a 3x3 grid (Fig. **2**), creating a parameter-driven spatial scheme.

3.1.2. Phase 2: Analysis of Interior Layout as Fitness Objectives (FO)

In this study, three fitness factors have been established as optimization objectives to ensure that the generated schemes meet the design requirements when searching for suitable layout using Feng Shui rules. These factors include Compass School Feng Shui rule scoring, spatial connectivity scoring and spatial uniform distribution scoring, as detailed below.

3.2. Compass School Feng Shui Rule Scoring

The scoring of Compass School Feng Shui rules follows the guidelines mentioned in section 2.1. This method compares the positions of the input rooms within the 3x3 grid to the auspicious and inauspicious positions of the primary user of the room, who could be one of the users or all family members. Since the auspicious and inauspicious directions for the East and West Groups are opposite within the grid, the ideal dwelling layout for several family members may conflict. The Compass School Feng Shui rule scoring system deducts one point for each instance where the placement of an individual room conflicts with the auspicious position of a family member. The cumulative deduction score is used to evaluate the quality of the layout scheme.

3.3. Spatial Connectivity Scoring

Space adjacency analysis is used to analyze the adjacency relationships of different functions in spatial layouts [46], forming a plan by determining the connectivity between various spaces. In this study, the connectivity rules are simplified to distance calculations. This scoring references the desired adjacent spaces defined by the operator in the first phase, as shown in Table **4**. After placing the rooms in the 3x3 grid by operating the variables from the first phase (Fig. **4**), the distances between adjacent rooms are calculated according to the adjacency rules formula (as shown in Equation 1) and used as the optimization objective for the algorithm. The lower these calculated distance values, the closer the desired adjacent spaces are, resulting in a layout closer to the ideal usage scenario. Since the purpose of scoring is to assess the adjacency of two spaces, spaces placed in the same position or adjacent positions will be scored equally.

Table 4: Spatial connectivity rules and distances.

Index	Adjacency Rule	Distance
rule 01	room a, room d, room b	Dad + Ddb
rule 02	room e, room c	Dec
⋮	⋮	⋮
rule n		

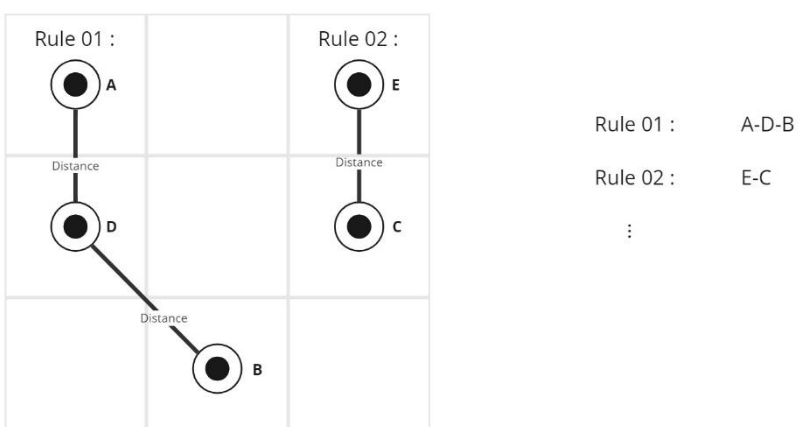

Figure 4: Definition of spatial connectivity rules.

Spatial Connectivity Rule Distance Calculation Formula:

$$D = \sum_{i=1}^{n-1} \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2)} \tag{1}$$

D: distance between two rooms

n: amount of rooms

3.4. Spatial Uniform Distribution Scoring

The spatial uniform distribution scoring is designed to prevent the algorithm from concentrating spaces in a single position. Ideally, according to the Compass School layout, the configuration should be square and without missing corners, meaning that the interior spaces of the building should be evenly distributed across different positions within the 3x3 grid, facilitating the creation of a balanced floor plan. The Uniform Distribution module first distributes the total area of all rooms equally across all positions as a baseline. It then calculates the area of each position in the 3x3 grid based on the spaces placed by manipulating the variables from the first phase. The smaller the difference between these values, the more evenly the squares are distributed. The calculation method is as follows:

Step 1: Calculate Total Floor Area

$$TFA = area1 + area2 + \cdots . + area\ n \quad (2)$$

Step 2: Calculate the Area of Each 3x3 Grid Cell by Evenly Dividing the TFA

$$G = TFA / 9 \quad (3)$$

Step 3: Sum the Differences Between the Allocated Area Values for Each Grid Cell and G in the Scheme.

$$Gdi = \sum_{grid\ i=1}^{9} |area\ i - G| \quad (4)$$

TFA: total floor area

n: amount of spaces

G: ideal area in each grid

Gdi: total difference between scenario

area i: Allocated area values in grid (positions)

3.4.1. Phase 3: Optimization of Interior Layout

The first and second phases of the research process provided parameter-driven interior layouts and criteria for evaluating their merits. In the third phase, the optimal layout is further searched. The experiment utilized Wallacei X to conduct multi-objective evolutionary simulations [47], which serves as the optimization engine, adjusting the input variables to explore different layout schemes. The scores of these schemes are then calculated through the parameter process and optimized by the algorithm.

3.4.2. Phase 4: Scoring Results and Decision-Making

After optimization using the evolutionary algorithm, the final decision-making process involves selecting the best solution by evaluating objective scores for each case within the population. This method can provide effective layout suggestions in the early design stages, reducing the complexity caused by Feng Shui considerations and allowing comparisons with existing design schemes. Ultimately, the user makes a decision based on the scores of various objectives and the acceptability of the spatial layout.

4. Case Study Implementation

In the study, the process in this research assists buyers in decision-making before purchasing or planning interior layouts through practical case studies. The conditions input into the model serve as the basis for reducing the search space when optimizing interior spaces. The case conditions are as follows:

4.1. Occupants Settings

The family members are father, mother and their son, totaling three people. Occupants' information (Table **5**) and room information (Table **6**). Using the calculations mentioned in Section 2.1, their respective auspicious directions are determined, serving as the basis for placing rooms within the 3x3 grid.

Table 5: Occupants information form.

Occupant	Gender	Birth
husband	male	08/Jan/1970
wife	female	30/Apr/1978
son	male	24/Oct/2001

4.2. Interior Spatial Information Settings

In this scenario, the expected spaces in the house are set, including the entrance, living room, dining room, kitchen, bathroom, master bedroom, bedroom 1, bedroom 2, and storage room, along with their respective areas. According to the interior Compass School evaluation method [39], each room is defined with a primary user from the family members and designated as either an auspicious or inauspicious direction based on their hexagrams. Additionally, for rooms without a specified primary user, calculations are performed for all family members. The input parameters for each room are adjusted based on actual needs of the operator.

Table 6: Spatial information form.

Room	Area	Main User	Ideal Auspicious or Inauspicious Positions
Entrance	5m³	husband, wife, son	Auspicious
MainBedroom	20m³	wife	Auspicious
Kitchen	15m³	wife	Inauspicious
Bathroom	10m³	husband, wife, son	Inauspicious
Bedroom1	15m³	son	Auspicious
Bedroom2	15m³	husband, wife, son	Auspicious
LivingRoom	25m³	husband	Auspicious
Storage	15m³	husband, wife, son	Inauspicious
DiningRoom	20m³	husband, wife, son	Auspicious

4.3. Spatial Connectivity Rules Settings

The spatial connectivity rules are used to establish the continuity of spaces. By inputting different connectivity rules, the operator can generate results that closely match the intended goals. For example, in this case (Table **7**), rule a specifies that the living room should be visible when entering the front door. Rule b indicates that the master bedroom, bedroom 1, and bedroom 2 should be placed as close together as possible. Rule c states that the living room, dining room, and kitchen should be adjacent to each other, while rule d specifies that the living room should be connected to the bathroom and storage room. These rules can be input into the algorithm based on spatial requirements or Feng Shui principles concerning adjacency or connectivity. By running the algorithm, various potential results can be obtained.

Table 7: Spatial connectivity rules form.

Rules	Spatial Connectivity
rule a	entrance, living
rule b	bed m, bed 1, bed 2
rule c	living, dining, kitchen
rule d	bath, living, storage

4.4. Evolutionary Algorithm Settings and Process

The experiments in this study were conducted under the following hardware and software environments. The hardware setup included a computer equipped with an Intel(R) Core (TM) i7-8750H CPU @ 2.20GHz processor and 32.0 GB of RAM. The operating system was Windows 11. On the software side, Rhino 7 and Grasshopper were used, along with WallaceiX 2.6 for multi-objective optimization. Fig. (**5**) shows the parametric process and the results obtained.

The algorithm parameters were set as follows in this study: The generation size was set to 100 results, and the generation count was set to 100 generations. The crossover probability was set to 0.9, the mutation probability was set to 0.02, and the crossover and mutation distribution was set to 10. The computation would terminate when the final population reached 10,000 results.

Additionally, there will be 9 genes each representing an input space, according to the conditions mentioned in chapter 4, each space can be assigned to a grid position numbered 0-8, representing the direction, resulting in a total gene range of 81 and a search space size of 3.9e9. The number of fitness functions used to evaluate and optimize during the computation is 6. The total computation time for the entire process was 2 minutes and 15 seconds.

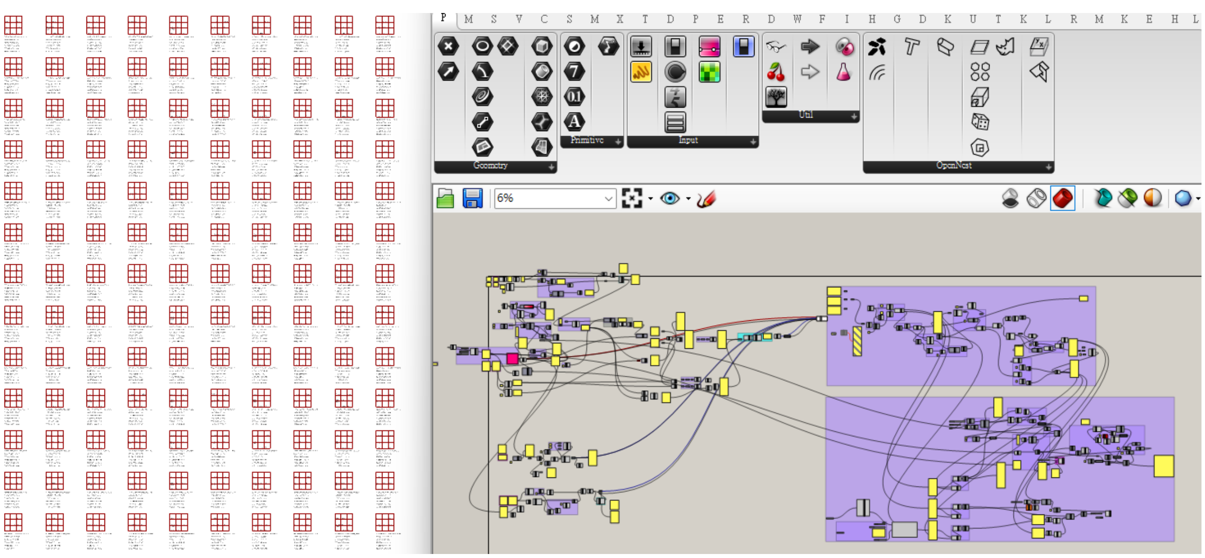

Figure 5: Parametric process and generated results.

5. Result and Discussions

5.1. Optimization Results Based on Objectives

After performing optimization calculations using the Evolutionary Algorithm, the trends of the three objectives—Feng Shui scores, spatial uniform distribution, and spatial connectivity—were examined throughout the optimization process. By analyzing the changes in the standard deviation distribution and the mean values in each generation, the effectiveness of the algorithm in optimizing according to each objective can be observed.

5.1.1. Standard Deviation Across Generations During the Optimization Process

By examining the standard deviation during the optimization process, we can overview the distribution of each objective in the solutions generated by the algorithm across different generations, thereby determining whether effective strategies were achieved for each objective. Fig. (**6**) displays the standard deviation distribution for six different objective functions, with color variations from 0 to 99 generations, initially shown in red gradually transitioning to blue. The standard deviations of objectives 01, 03, 04, 05, and 06 gradually decreased with iterations, and their medians shifted towards lower values (better solutions). This indicates that the algorithm found effective layout strategies for Feng Shui scores, spatial connectivity, and other goals during the iteration process. On the other hand, objective 02 exhibited a large standard deviation in the early stages of iteration, but the algorithm began converging towards the Pareto front in the mid-stages, indicating better solutions were found during this phase. The standard deviation increased again in the later stages of the computation, possibly due to the introduction of mutations or new explorations by the algorithm, attempting further optimization or avoiding local optima.

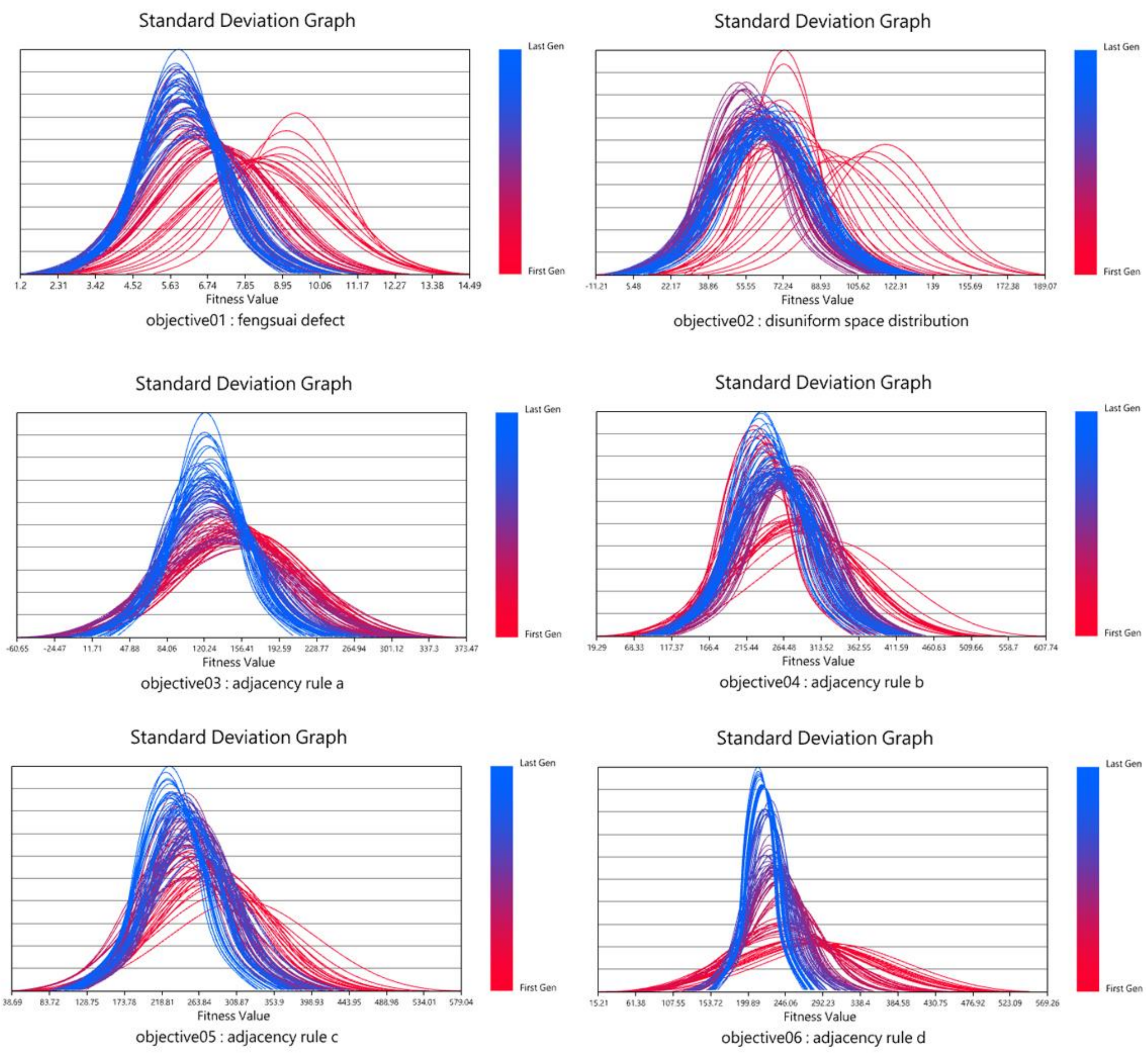

Figure 6: Standard deviation distribution of objectives across generations.

5.1.2. Trend of Mean Value During the Optimization Process

By interpreting the changes in the mean value of the trend lines for each objective, we can identify the optimization process. The changes in the trendlines and their slopes reflect the scores' quality and the algorithm's convergence dynamics. In Fig. (**7**), the mean trendlines of the six objectives all show a decreasing trend (Mean Value Decreasing). Since all the objectives in this study need to be minimized, this indicates that the values of each objective generally improved during the computation process, demonstrating that the optimization of the algorithm was effective.

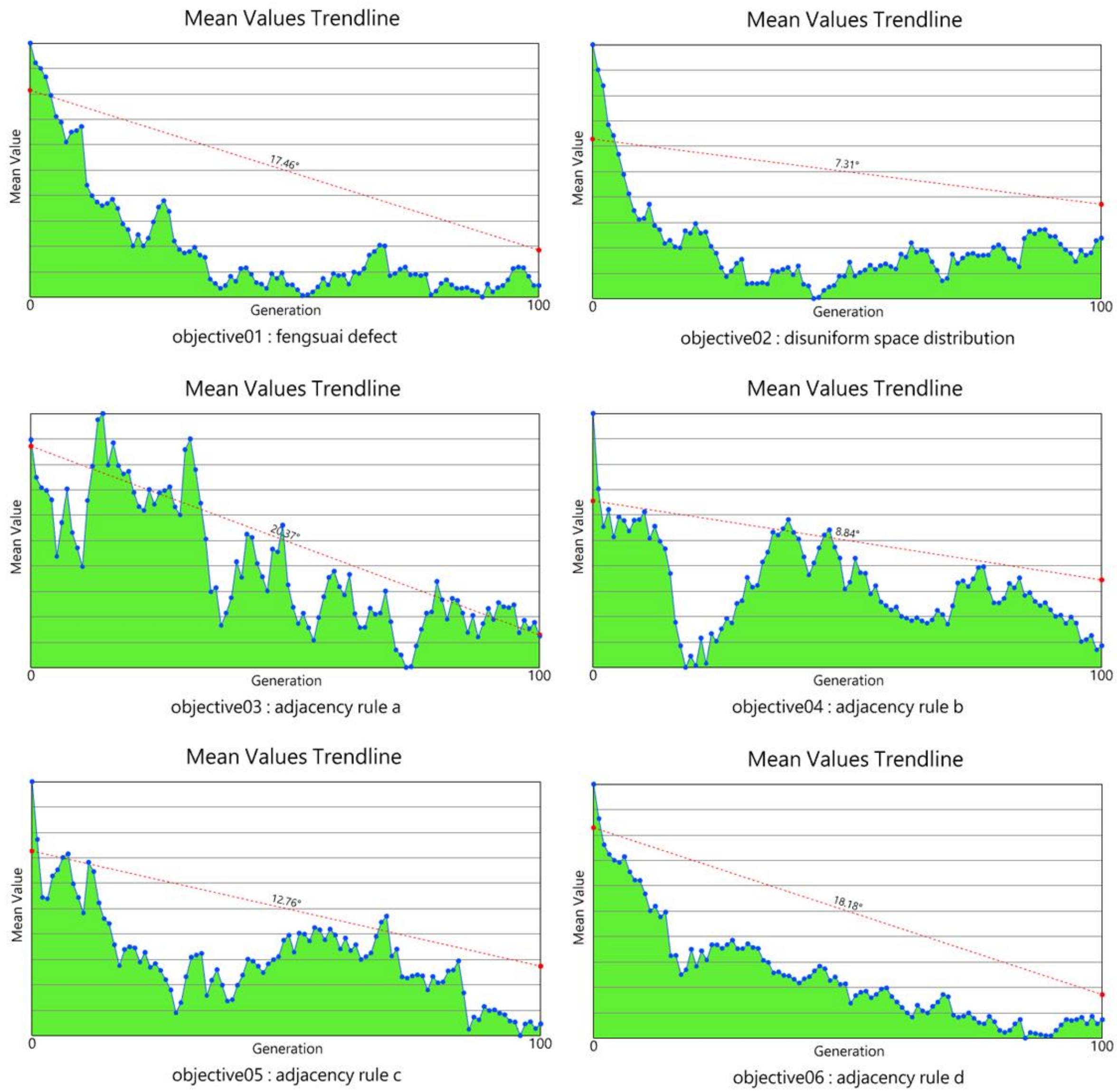

Figure 7: Trend of mean value of objectives across generation.

5.2. Decision-Making Method

After performing evolutionary computations, common methods for analyzing solutions include selecting based on Average of Fitness Ranks, Relative Difference Between Fitness Ranks, or specific Fitness Values. This study employs the Average of Fitness Ranks method to determine the results. This approach ranks all solutions for each objective from highest to lowest and assigns ranks start from rank 0. The ranks of each objective for a solution are then summed up to evaluate its overall quality. This method helps identify solutions with generally better ranks within the population, which often indicates the optimal solution.

5.3. Results of the Practical Case

This study examines the results selected by the Average of Fitness Ranks method, identifying both the optimal solution and a set of better solutions. The optimal solution (Table **8**) appeared 9 times in the overall population, with a cumulative rank value of 3 for all objectives. Overall, this solution has a good spatial distribution, minimal Feng Shui deductions, and only scored the second-highest rank in objectives 5 and 6 for spatial adjacency. The actual spatial layout is shown in Fig. (**8**).

Next, we consider three second-best solutions, each with a cumulative rank of 4. In terms of spatial layout, second-best solution a (Fig. **9**) and second-best solution b (Fig. **10**) employ different strategies. However, they achieve identical ranks across all objectives (Table **9**-**10**). Both solutions are two ranks lower than the optimal solution in terms of Feng Shui deductions but achieve better results in objective 6 regarding connectivity. Finally, the spatial layout of second-best solution c can be seen in Fig. (**11**). In terms of objectives, it performs worse in Feng Shui deductions with a rank of 3, but achieves the best results in objectives 3, 4, and 5, with only objective 6 scoring rank 1 (Table **11**). These four selected results demonstrate that the parameterized process combined with the Evolutionary Algorithm can produce different configuration strategies through trade-offs among three different objectives.

For users purchasing real estate or planning interior layouts, the generated results can be evaluated based on the objective values to determine the performance of the schemes. Users can choose the most suitable layout from the optimal solutions as the basis for their purchase decision or the initial floor plan design. If the optimal solutions do not meet the user's satisfaction, initial input parameters, random values, mutation rates, and crossover rates can be adjusted to alter the computation results. Additional connectivity rules can also be added to the framework. The algorithm will try to place the rooms in the appropriate directions based on the personal conditions and find the optimal solutions that satisfy spatial connectivity and distribution rationality.

Table 8: Fitness objective values of the optimal solution.

Sol	Objective	Name	Value	Rank
Optimal Solution	FO1	Distribution Scoring	36.6667	Rank0
	FO2	Feng Shui Scoring	6	Rank1
	FO3	Spatial Connectivity a	100	Rank0
	FO4	Spatial Connectivity b	200	Rank0
	FO5	Spatial Connectivity c	241	Rank1
	FO6	Spatial Connectivity d	241	Rank1

Figure 8: Spatial layout of the optimal solution.

Table 9: Fitness objective values of the second-best solution a.

Sol	Objective	Name	Value	Rank
second-best solution a	FO1	Distribution Scoring	36.6667	Rank0
	FO2	Feng Shui Scoring	8	Rank3
	FO3	Spatial Connectivity a	100	Rank0
	FO4	Spatial Connectivity b	200	Rank0
	FO5	Spatial Connectivity c	241	Rank1
	FO6	Spatial Connectivity d	200	Rank0

Figure 9: Spatial Layout of the second-best solution a.

Table 10: Fitness objective values of the second-best solution b.

Sol	Objective	Name	Value	Rank
second-best solution b	FO1	Distribution Scoring	36.6667	Rank0
	FO2	Feng Shui Scoring	8	Rank3
	FO3	Spatial Connectivity a	100	Rank0
	FO4	Spatial Connectivity b	200	Rank0
	FO5	Spatial Connectivity c	241	Rank1
	FO6	Spatial Connectivity d	200	Rank0

Figure 10: Spatial Layout of the second-best solution b.

Table 11: Fitness objective values of the second-best solution c.

Sol	Objective	Name	Value	Rank
second-best solution c	FO1	Distribution Scoring	36.6667	Rank0
	FO2	Feng Shui Scoring	8	Rank3
	FO3	Spatial Connectivity a	100	Rank0
	FO4	Spatial Connectivity b	200	Rank0
	FO5	Spatial Connectivity c	200	Rank0
	FO6	Spatial Connectivity d	241	Rank1

Figure 11: Spatial layout of the second-best solution c.

5.4. Design Developed based on the Optimal Solution

The system developed in this study can primarily be applied to the pre-sale housing system [48], which is a very common sales model in Asian markets [49] This build-to-order model allows homebuyers to modify the interior layout to some extent according to their needs before construction begins, adapting the space to meet specific design requirements [43] Another scenario that requires reconfiguration is the complete interior renovation, where functional spaces are rearranged.

This study uses a presale housing in Taiwan as an example, with housing information sourced from https://www.leju.com.tw. The system applies layout suggestions calculated based on Feng Shui principles. The apartment shown in Fig. (**12**) consists of four units per floor, and according to the comparative results, homebuyers are advised to prioritize the selection of Unit B, as shown in Fig. (**13**), which fits best with the optimal solution shown in Fig. (**8**). It is important to note that although interior partitions can be modified in presale housing, certain elements, such as bathrooms, kitchens, and entrances, are more difficult, even cannot be relocated. Therefore, pre-purchase simulations are essential to develop an effective purchasing strategy.

In this study, we developed a practical design solution for an actual residential building unit, based on the spatial dimensions and orientation relationships generated by the EA's best solution, as shown in Fig. (**14**).

5.5. Discussion

The framework proposed in this study addresses how homebuyers' culturally driven needs can be accommodated within modern design processes. In Taiwan, it is common for individuals to consult Feng Shui experts when purchasing a property [50, 51] and to make interior layout decisions on their advice [39]. However, many elements in contemporary dwelling units cannot be easily altered, such as openings or pipelines. Even in presale housing, which offers customization services, these elements are difficult to modify.

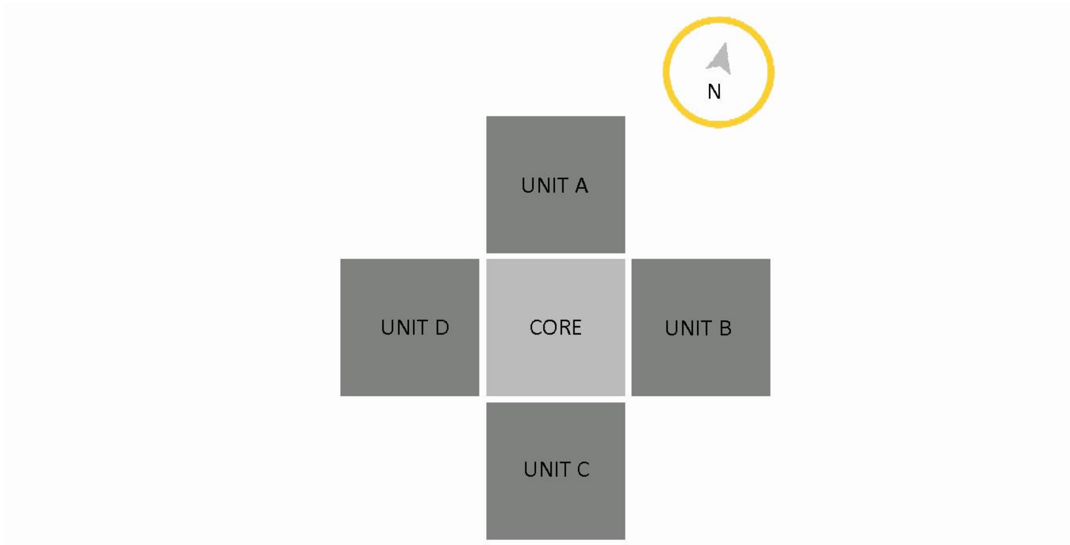

Figure 12: Pre-sale dwelling project in Taiwan.

Figure 13: Suitable unit (UNIT B) according to Feng Shui calculation results.

This situation can lead to two main issues:

1. After purchasing the property, the homebuyer may find that factors such as building's direction, openings, or pipelines do not align with their cultural or Feng Shui beliefs, preventing the design from meeting their expectations.
2. The expertise of Feng Shui consultants and designers differs, and their work often constrains one another, requiring extensive communication to achieve a satisfactory design outcome.

Figure 14: Customized interior floor plan based on optimal solution (Fig. **8**).

The operational process proposed in this study effectively resolves these issues. Firstly, before purchasing a property, consumers can simulate suitable layouts based on their birth time and spatial requirements. Then, they can filter available properties on the market according to spatial direction layouts, excluding options that are not compatible with their needs.

Secondly, if there are no perfectly suitable properties on the market, consumers can work with designers to select homes where fixed elements—such as entrances, bathrooms, and kitchens—are positioned in appropriate directions. The remaining requirements can be met by adjusting interior partitions as much as possible. Designers can directly refer to the Feng Shui calculation result generated by this study to adjust the layout, reducing the need for repeated communication and recalculation with Feng Shui experts.

Lastly, in cases where an existing property is being renovated, and certain spaces are fixed in specific directions, or in case the layout is not a perfect rectangle, the input parameters in Phase 1 can be restricted to maintain the shape with multiple directions missing, or lock specific functions into certain directions. The EA can then perform optimization based on these constraints. This approach ensures that the tool developed in this study is highly adaptable to projects with varying conditions.

6. Conclusions

This study explores the application of Feng Shui Compass School rules in interior layouts using multi-objective evolutionary algorithms and successfully establishes a parameterized decision model. The model can automatically generate optimal layout schemes that consider Feng Shui rules, spatial connectivity, and spatial uniform distribution based on user conditions and requirements. Case studies demonstrate that the proposed process can quickly identify multiple feasible solutions and select the optimal one among them. These solutions meet the auspicious and inauspicious direction requirements of Feng Shui while achieving better rationality in space usage efficiency and functional configuration.

Specifically, the main contributions of this study include the following three points:

Firstly, establishing a Feng Shui layout optimization model based on a multi-objective evolutionary algorithm, which can simultaneously consider multiple objectives and find a balance among them. Secondly, validating the model's practicality through empirical case studies, demonstrating its feasibility and effectiveness in real-world applications. Lastly, proposing strategies to balance Feng Shui rules with modern spatial layout requirements, providing valuable references for designers and decision-makers.

Future research can further expand the application scope of this study, such as exploring Feng Shui layout rules for different types of buildings, evaluating outdoor environments, or integrating other optimization algorithms to enhance the model's performance.

Conflict of Interest

The authors declare that they have no competing interest.

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