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A Study on Aging-Ready Retrofit of Intelligent Interior Design Based on Dynamic Planning in the Context of Age-Friendly Society

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Abstract Under the development trend of age-friendly society, the living needs of the elderly have gradually become a hot spot of concern. Among them, indoor space, as the main activity place for the elderly, has a crucial impact on the quality of life of the elderly. In this paper, the objective function is determined according to the task of optimal selection of indoor layout candidates, and the problem of solving model parameters is transformed into a structured regression problem to solve the parameter problem of the model, and the modeling method of indoor space layout estimation under the optimal selection of layout candidates is proposed. Meanwhile, for the conflicting needs between family members and the elderly in the ageing indoor space retrofit and the associated paths of different functional spaces, the basic idea of dynamic programming is used to solve the optimal paths. By combining the dynamic planning method and the layout estimation modeling method, a retrofit design method for aging-adapted indoor spaces is formed. Using this method to design a retrofit program for the aging space, the proportion of "very satisfactory" rating reached 41.98% in the satisfaction evaluation of the actual layout features, which can effectively adapt to the needs of the elderly.

Index Terms dynamic planning; layout estimation modeling, space remodeling design, aging needs

I. Introduction

With the aggravation of population aging, the welfare and social integration of the elderly are receiving more and more widespread attention [1], [2]. Building an age-friendly society has an important impact on the well-being and quality of life of the elderly [3]. An age-friendly society refers to a society that meets and protects the rights and needs of the elderly in political, economic, social, cultural, and environmental aspects [4], [5]. It emphasizes inclusive, equitable, and humane care for the elderly, as well as the provision of adequate opportunities and conditions for the elderly to actively participate in all aspects of social, economic, and cultural activities [6]-[8]. While indoor housing, as an important part of improving the quality of life of the elderly, its intelligent and age-adapted retrofitting is of great significance in improving the well-being of the elderly [9], [10].

Ageing-friendly renovation refers to the provision of a safe, comfortable and convenient living environment for the elderly through the renovation of the living environment, facilities and equipment, and furniture arrangement, in order to meet the special needs of the elderly life [11]-[13]. And with the application of artificial intelligence, intelligent interior design for ageing transformation has important application prospects and significance [14]. Intelligent design can provide higher convenience, better safety and security, and promote social and recreational activities for the elderly [15], [16]. However, the practice of intelligentization in ageing retrofit still needs to overcome the use barriers of the elderly and solve the safety problems, and the development of intelligent retrofit design for ageing residences has a certain degree of systematicity and complexity, especially in the current grim situation of rural pension, and there is a pressing need for innovation in the retrofit design of the new rural residential space in the information age [17]-[20]. With the continuous development and innovation of technology, intelligent interior design is expected to further promote the process of ageing-friendly renovation, so that the elderly can enjoy a smarter, more convenient and safer life [21]-[23].

This paper analyzes the characteristics of changes in the physiological and psychological states of the elderly in their daily behavior from the physiological and psychological perspectives. Based on the analyzed behavioral characteristics, we summarize and evaluate the behavioral patterns and corresponding needs of the elderly. Based on this theoretical foundation, the method of determining the objective function and the estimation modeling process under the candidate of optimal ageing-friendly indoor layout are discussed. Then, the basic idea of dynamic planning is elaborated in detail and applied to the design of ageing indoor living space, forming the design method of ageing indoor space renovation based on dynamic planning. Finally, in terms of the design effect, the spatial layout quality score, the subjective feeling test of the design style and the evaluation of the actual layout characteristics are carried out respectively. In the overall performance of the model, the convergence effect of similar methods is compared.

II. Behavioral Characterization of Older Adults

II. A.Physiological and psychological characterization

As they age, older persons undergo changes in their psychological and physiological states that directly affect their needs and ability to adapt to their living environment. Physically, older people often face challenges such as limited mobility, reduced perceptual ability and health problems, which seriously affect their quality of life. The physical conditions of the elderly should be assessed and categorized, so as to carry out corresponding space planning and the introduction of facilities, and realize multi-level and multi-faceted design to reflect humanistic care. In the design, consideration should be given to the provision of barrier-free facilities, optimized lighting and sound equipment, as well as functional layouts and furnishings that meet health needs, in order to provide the elderly with a safe, comfortable and convenient living environment. It should also focus on making the space more suitable to meet the independence of the elderly, that is, to provide them with the space environment facilities that can be used independently and on their own, so that the elderly can be comfortable, self-compatible, and enjoy themselves in the apartment, which is not only a respect for the independence of the elderly, but also a guarantee of the safety and functionality of the space.

From a psychological point of view, the elderly are generally characterized by cognitive decline, emotional fluctuations and self-identification needs, and changes in social roles and economic income, which can lead to a decline in the elderly's sense of spiritual and social belonging. Therefore, consideration should be given to how to help the elderly better adapt to the living environment and maintain a positive mindset and independent life through relatively simple and clear layouts, a warm and comfortable atmosphere, and recognizable design elements that are easier to understand. At the same time, it is necessary to pay attention to the cultural level, economic conditions, the surrounding environment and other objective factors of different elderly people, respect their subjective wishes, understand the actual differences, and carry out targeted spatial design and planning. Focus on the emotional needs of the elderly at the psychological level, such as the sense of helplessness and dependence on family members due to the decline of physical health. The loneliness caused by the lack of family companionship is likely to cause great pressure on their psychological level, which seriously affects their own mental health and may lead to doubts about their self-worth. These problems need to be considered by designers in the space design, but not without the participation of family members, and jointly bring the elderly a beautiful construction of the subjective and objective environment.

II. B.Behavioral patterns and needs assessment

Understanding the behavioral patterns and needs of the elderly is the basis for interior design of age-friendly housing, which requires an assessment of their daily behaviors and needs in order to meet their actual living needs and enhance their living experience. Evaluating the behavioral patterns of the elderly requires comprehensive consideration of their living habits and daily actions. By observing and recording the behavior of older people, designers can summarize their paths, common areas and possible barriers to action, thus providing valuable reference information for design. For example, in the study of the daily behavioral patterns of the elderly, attention should be paid to their living habits and range of activities, which will help to determine the functional areas that need to be focused on in the design, as well as how the space should be laid out and organized so that it is more in line with the living habits and actions of the elderly.

Attention should be paid to spatial needs, including functional needs, safety needs, and social needs, which cover a variety of aspects such as living functions, safety, and social interaction. Elderly people are particularly concerned about safety, which is limited by the declining health of the body, especially to prevent accidents such as falls and slips. Older people need furniture and equipment that is easier to use, as well as safe and reliable accessibility and crash prevention measures. At the same time, due to the reduced range of motion brought about by mobility problems, the social activities of the elderly are also greatly restricted, which is not conducive to the maintenance and development of mental health. By understanding the needs of the elderly, designers can provide targeted solutions to improve their quality of life and sense of well-being.

III. Interior space remodeling design based on dynamic planning

III. A. Layout estimation modeling for optimal selection of layout candidates

Given the generated indoor scene image layout candidates, the problem of estimating the scene layout is realized by transforming the problem of estimating the scene layout into a method of selecting the best layout candidate from a number of layout candidates to be labeled as the layout estimation result. Ideally, the best layout candidate has a layout labeling that is most similar to the baseline layout labeling of the corresponding image. Given a set of training data, which is composed of indoor scene images $\{x_1, x_2, x_3, \cdots, x_n\} \in X$ and the corresponding scene layout datum annotation $\{y_1, y_2, y_3, \cdots, y_n\} \in Y$, it is hoped that the mapping relationship between the input spatial domain X and the arbitrary discrete output spatial domain Y can be obtained by training pairwise data (x_i, y_i) to learn $f: X \to Y$. Given an input image x_i, each layout candidate in the generated layout candidates can be computed to obtain the corresponding score through the mapping function f, and candidates with higher similarity to the baseline layout annotation y_i should obtain higher scores. Based on the above assumptions the objective function of the scene layout estimation task can be obtained, and the specific mathematical expression is shown in Equation (1).

$$y^* = \arg\max_y f(x, y; w) \tag{1}$$

where w denotes the parameter vector, y^* denotes the final layout estimation result, and y denotes the possible layout cases. The function f can be viewed either as a compatibility function to measure the match between (x, y), or $-f$ can be viewed as a cost function parameterized by w.

Suppose that the input x and the output y can be represented as $\Psi(x, y)$ by some combination of features, in which case f is considered to be linear, as expressed in Equation (2).

$$f(x, y; w) = w^T \Psi(x, y) \tag{2}$$

where $\Psi(x, y)$ denotes the multidimensional feature vector extracted based on the image x and the random variable y. The elements in the feature vector, denoted as Ψ_r, are usually expressed as a sum of non-separable functions, each of which depends on the potentials of an arbitrary subset in y, whose base is the dimension of the domain in which it is located. Representing the relationship between the image x and the random variable y in terms of features can be viewed as a graphical model, and the structure of the model suggests that the state of each random variable cannot usually be predicted accurately on its own, and that it is often necessary to put the states of other neighboring random variables into consideration. Therefore, the above inference task is called structured prediction and is often solved using a structured learning model, which models the relationship between different outputs in the output domain, thus making better use of the known training dataset.

Based on the assumptions of Eq. (2), the problem of solving the mapping relation f is then transformed into the problem of solving the parameter w, which can be transformed into the following structured problem, which is expressed in Eq. (3).

$$\begin{aligned} &\min_{w,\xi} \frac{1}{2}\|w\|^2 + C\sum\nolimits_i \xi_i \\ &s.t.\ \forall i: \xi_i \ge 0,\ and \\ &\forall i, \forall y \in Y \setminus y_i : w^T\Psi(x_i, y_i) - w^T\Psi(x_i, y) \ge \Delta(y_i, y) - \xi_i \end{aligned} \tag{3}$$

where ξ_i denotes the slack variable, $\Delta(y_i, y)$ denotes the loss function, which is used to quantify the measure between the two layouts, C denotes the scale constant, and $\Psi(x_i, y_i)$ denotes the feature vector consisting of a set of features extracted from (x_i, y_i) according to the image layout. In the experiments of this paper, C takes the value of 1. The training data includes the original indoor scene images, the layout candidates after coarse selection, and the corresponding baseline layout annotations, and the solution of the above equations is trained on the constructed dataset, so as to learn the appropriate weight value w.

The loss function $\Delta(y_i, y)$ considers 3 main aspects: (1) The missingness of the region face. (2) Deviation of the center of mass of the region face. (3) The non-overlap of the pixel labeling of the region face. For an indoor scene image x, its benchmark layout labeling is expressed as equation (4):

$$F = \{F_1, F_2, F_3, F_4, F_5\} \tag{4}$$

where F_1 denotes the floor, F_2 denotes the center wall, F_3 denotes the right wall, F_4 denotes the left wall, and F_5 denotes the ceiling. The generated candidate for either layout is denoted as equation (5):

$$F = \{F_{i1}, F_{i2}, F_{i3}, F_{i4}, F_{i5}\} \tag{5}$$

Then the specific definition of the loss function is given by equation (6):

$$\Delta(y_i, y) = \Delta_t(y_i, y) + \Delta_c(y_i, y) + \Delta_p(y_i, y) \tag{6}$$

Δ_t is used to measure the difference in the proportion of the corresponding regional surface in the whole image, and $\Delta_t(y_i, y)$ is defined as shown in Equation (7):

$$\Delta_t(y_i, y) = \sum_{k=1}^{5} \begin{cases} 1 & \text{when } F_{ik}, F_k \text{ is missing on one side} \\ \dfrac{\| Area(F_{ik}) - Area(F_k) \|}{Area(image)} & \text{when } F_{ik}, F_k \text{ is present on both sides} \\ 0 & \text{when } F_{ik}, F_k \text{ is missing on both sides} \end{cases} \tag{7}$$

where F_{ik} and F_k denote the k th area face in the layout candidate and the baseline layout annotation, respectively, and $Area(\cdot)$ denotes the area of the specified area, which can be translated into calculating the total number of pixel points in the specified area. In the corresponding layout structure, when F_{ik} and F_k area surface if both missing, obviously Δ_t is 0. If both exist, then calculate the difference in the proportion of pixels occupied by both in the whole image. But if one side is present and one side is missing, a fixed loss value of 1 is assigned as a penalty for the presence of inconsistency in its regional face.

Δ_c is used to measure the offset difference of the center of mass of the corresponding regional face, and $\Delta_c(y_i, y)$ is defined as shown in equation (8):

$$\Delta_c(y_i, y) = \sum_{k=1}^{5} \begin{cases} 1 & \text{when } F_{ik}, F_k \text{ is missing on one side} \\ \| c_{ik} - c_k \| & \text{when } F_{ik}, F_k \text{ is present on both sides} \\ 0 & \text{when } F_{ik}, F_k \text{ is missing on both sides} \end{cases} \tag{8}$$

where c_{ik} and c_k denote the center-of-mass coordinates of the region faces F_{ik} and F_k, respectively, and since F_k consists of a collection of coordinate points enclosing the region face, calculating the center-of-mass coordinates can be transformed into finding the average value of the coordinate points. In the corresponding layout structure, when F_{ik} and F_k area surface if both missing, obviously Δ_c is 0. If both exist, then calculate the displacement difference between the two centers of mass, with the image diagonal length value of the normalization process. However, if one side is present and one side is missing, a fixed loss value of 1 is assigned as a penalty for the presence of inconsistency on its regional side.

Δ_p is used to measure the proportional difference in pixel point misclassification between regional faces, and $\Delta_p(y_i, y)$ is defined as in equation (9):

$$\Delta_p(y_i, y) = \sum_{k=1}^{5} \sum_{l=1}^{5} \begin{cases} 1 - \dfrac{Area(F_{il} \cap F_k)}{Area(F_{il} \cup F_k)} & when\ l = k \\ \dfrac{Area(F_{il} \cap F_k)}{Area(F_{il} \cup F_k)} & when\ l = k \end{cases} \tag{9}$$

The first two loss functions are solved for a specific $\{F_{ik}, F_k\}$ pair, and compute only the loss between the layout candidate and the k th region face in the baseline layout annotation, and do not take into account the loss between the l th region face in the layout candidate and the l th region in the baseline layout annotation (and $l \neq k$). the loss between them. Here Δ_p complements it.

Δ_p is divided into two cases; if $l = k$, it refers to the layout candidate and the k th region face in the benchmark layout annotation. Since the semantics of the region faces are the same, the proportion of pixel points that do not overlap between them is calculated as a loss. If $l \neq k$, it refers to the l th region face in the layout candidate and the k th region face in the baseline layout annotation. Since the semantics of the region faces are different, the proportion of pixel points overlapping between them is calculated as loss.

III. B. Basic Ideas of Dynamic Programming

(1) The key to the dynamic programming method is to correctly write the basic recurrence relations and appropriate boundary conditions (in short, the basic equations). To do this, the problem process must be divided into several interrelated stages, the appropriate selection of state variables and decision variables and the definition of the optimal value function, so that a large problem into a family of the same type of subproblems, and then solved one by one. That is, starting from the boundary conditions, recursive search for the optimal segment by segment, in the solution of each sub-problem, are used in its previous sub-problems of the optimization results, in turn, the optimal solution of the last sub-problem, is the optimal solution of the whole problem.

(2) In the multi-stage decision-making process, the dynamic programming method is an optimization method that separates the current segment from future segments and combines the current and future benefits. Therefore, the selection of decisions for each segment is considered from a global perspective and is generally different from the optimal choice of answer for that segment.

(3) In the search for the optimal strategy of the whole problem, because the initial state is known, and the decision of each segment is a function of the state of the segment, so the optimal strategy through the state of the segments can be transformed one by one to obtain, so as to determine the optimal route.

After clarifying the basic concepts and basic ideas of dynamic programming, we see that the following five points must be done when building a dynamic programming model for a real problem:

(1) Divide the process of the problem into appropriate stages.

(2) Choose the state variable s_k correctly so that it describes the evolution of the process while satisfying no posteriority.

(3) Determine the decision variable u_k and the set of allowed decisions $D_k(s_k)$ at each stage.

(4) Write the state transfer equation correctly.

(5) Correctly write the relationship of the indicator function $V_{k,n}$, which should satisfy the following three properties:

1) Be a quantitative function defined on the full process and all posterior subprocesses.

2) It should be separable and satisfy the recurrence relation. That is, equation (10):

$$V_{k,n}(s_k, u_k, s_{k+1}, \cdots, s_{n+1}) = \Psi_k[s_k, u_k, V_{k,n}(s_{k+1}, \cdots, s_{n+1})] \tag{10}$$

3) The function $\Psi_k(s_k, u_k, V_{k,n})$ should be strictly monotonic with respect to the variables $V_{k+1,n}$.

The above five points are the basis for constructing a dynamic programming model, and are essential for correctly writing the basic equations of dynamic programming.

And whether the dynamic programming model of a problem is correctly given, it is centrally reflected in the proper definition of the optimal value function and correctly write the recurrence relation equation and boundary conditions. In short, the basic equations of dynamic programming should be written correctly.

According to the dynamic planning method, there are reverse-order solution method and sequential solution method, so how should their basic equations of dynamic planning be expressed?

Let the indicator function be in the form of taking the sum of the indicators of each stage, i.e., equation (11):

$$V_{k,n}(s_k, u_k, s_{k+1}, \cdots, s_{n+1}) = \Psi_k[s_k, u_k, V_{k,n}(s_{k+1}, \cdots, s_{n+1})] \tag{11}$$

where $V_j(s_j, u_j)$ denotes the indicator of the j th segment. It obviously satisfies the three properties of the indicator function. So the above equation can be written as equation (12):

$$V_{k,n} = V_k(s_k, u_k) + V_{k+1,n}[s_{k+1}, \cdots, s_{n+1}] \tag{12}$$

When the initial state is given, the strategy of the process is determined, then the indicator function is determined. Thus, the indicator function is a function of the initial state and the strategy. It can be written as $V_{k,n}[s_k, p_{k,n}(s_k)]$.

Therefore, the above recurrence relation can be written again as equation (13):

$$V_{k,n}[s_k, p_{k,n}] = V_k(s_k, u_k) + V_{k+1,n}[s_{k+1}, p_{k+1,n}] \tag{13}$$

Its sub-strategy $p_{k,n}(s_k)$ can be viewed as a combination of decisions $u_k(s_k)$ and $p_{k+1,n}(s_{k+1})$. That is, equation (14):

$$p_{k,n} = \left\{u_k(s_k), p_{k+1,n}(s_{k+1})\right\} \tag{14}$$

If $p^*_{k,n}(s_k)$ is used to denote the optimal sub-strategy among all sub-strategies of the posterior sub-process with an initial state of s_k, then the optimal value function is equation (15):

$$f_k(s_k) = V_{k,n}\left[s_k, p^*_{k,n}(s_k)\right] = \underset{p_{k,n}}{opt}\, V_{k,n}\left[s_k, p_{k,n}(s_k)\right] \tag{15}$$

And equation (16):

$$\begin{aligned} \underset{p_{k,n}}{opt}\, V_{k,n}\left(s_k, p_{k,n}\right) &= \underset{\{u_k, p_{k+1,n}\}}{opt} \left\{V_k(s_k, u_k) + V_{k+1,n}(s_{k+1}, p_{k+1,n})\right\} \\ &= \underset{u_k}{opt} \left\{u_k(s_k, u_k) + \underset{p_{k+1,n}}{opt}\, V_{k+1,n}\right\} \end{aligned} \tag{16}$$

But equation (17):

$$f_{k+1}(s_{k+1}) = \text{opt}\, V_{k+1,n}(s_{k+1}, p_{k+1,n}) \tag{17}$$

Hence equation (18):

$$f_k(s_k) = \underset{u_k \in D_k(s_k)}{opt} [V_k(s_k, u_k) + f_{k+1}(s_{k+1})] \quad k = n, n-1, \cdots; 1 \tag{18}$$

The boundary condition is Eq. (19):

$$f_{n+1}(s_{n+1}) = 0 \tag{19}$$

The above dynamic planning ideas are applied to the design of ageing-adapted indoor space layout to solve the optimal path between family members, the whole family and the needs of the elderly, so as to realize the optimal design of indoor space renovation.

IV. Application of retrofit design for ageing-friendly indoor spaces

As can be seen from the above, this paper proposes a layout estimation modeling method based on global characteristics of indoor spaces in combination with dynamic planning. In this chapter, the method is used to construct a layout estimation model for the ageing indoor space, and to carry out the scoring of the quality of the indoor space layout as well as the subjective feeling test of the main design style. At the same time, the overall performance of the constructed model is simulated in the form of comparing similar methods. Finally, the evaluation and analysis of indoor space characteristics are carried out.

IV. A. Spatial layout quality score and analysis

The comparison methods chosen in this section are (B1) genetic algorithm-based retrofitting method, (B2) particle swarm optimization-based retrofitting method, (B3) ant colony algorithm-based optimization method, and (B4) the method in this paper.

Under the condition of parallel layout of the overall indoor space, the layout quality under different methods is counted separately. Considering that the design space is oriented to the group of the elderly, combined with the evaluation standard of space suitability for the elderly, the specific design effect is rated from the perspective of activity accessibility, practicality and safety respectively. The evaluation indexes selected are: (A1) comprehensive volume ratio, (A2) bedroom lighting, (A3) living room lighting, (A4) bedroom noise control, (A5) living room noise control, (A6) kitchen and bathroom ventilation, (A7) accessibility index, (A8) fire prevention composite index, (A9) accessibility design index, and (A10) balcony window composite safety index.

The statistics of the layout quality scores of the elderly-friendly indoor environments with different methods are shown in Table 1. Comparison of the test results shows that the layout effects of different indoor spaces under different layout methods exhibit certain differences. In the test results of (B1) method, the effects of (A2) bedroom lighting (0.49) and (A6) kitchen and bathroom ventilation (0.46) are low, which affect the living experience of the elderly to a certain extent, and the indexes of (A5) noise control in living room and (A9) barrier-free design are 0.73 and 0.76, respectively, which have the room for further improvement. In the test results of (B2) method, (A6) kitchen and bathroom ventilation is underperforming, with an evaluation result of only 0.41, and in (A7) accessibility index, (A1) comprehensive floor area ratio and (A3) living room lighting, the corresponding evaluation results are between 0.7 and 0.8, which need to be further improved. In the test results of (B3) method, the performance is insufficient in (A4) bedroom and (A7) accessibility index and (A8) fire prevention composite index, with corresponding evaluation results of 0.62, 0.59 and 0.66 respectively, while the evaluation results of the remaining indicators are relatively high. In contrast, in (B4) the test results of this paper's method, the corresponding results of each evaluation index are above 0.80, of which (A3) living room lighting is 0.82 and (A2) bedroom lighting is 0.99, which can effectively meet the needs of the elderly living. The results show that (B4) the method of this paper can realize the reasonable layout of the indoor space, and the feedback of the data results is good.

Table 1: Statistics on the quality score of indoor environmental layout

Evaluation index	B1	B2	B3	B4
A1	0.82	0.76	0.85	0.88
A2	0.49	0.82	0.87	0.99
A3	0.93	0.76	0.79	0.82
A4	0.82	0.85	0.62	0.93
A5	0.73	0.88	0.76	0.89
A6	0.46	0.41	0.78	0.87
A7	0.87	0.73	0.59	0.97
A8	0.79	0.79	0.66	0.92
A9	0.76	0.98	0.89	0.86
A10	0.88	0.87	0.88	0.95

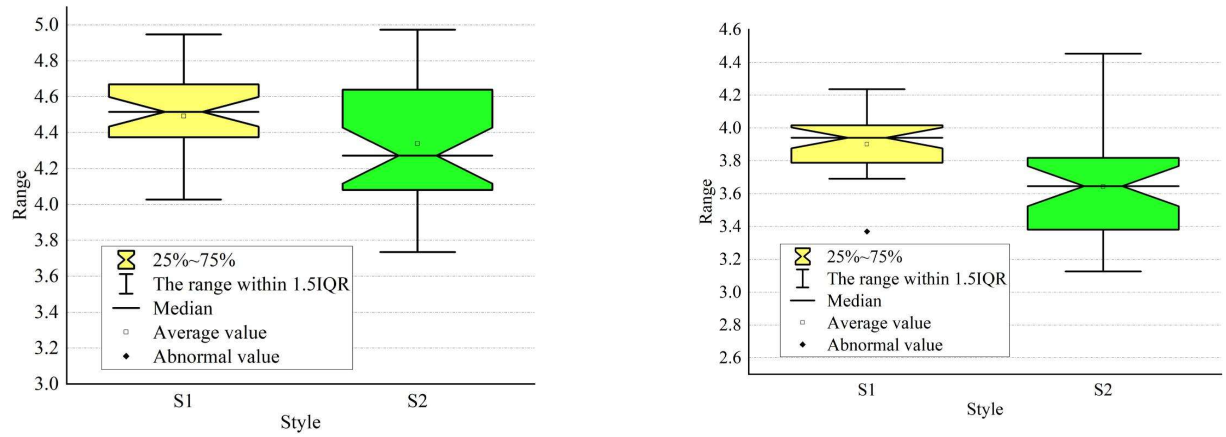
IV. B. Subjective perception test of design style

In the collection of opinions on ageing-friendly layout space renovation solutions, 800 sample models were randomly generated and divided into 8 equal parts, 8 testers were selected and each of them was allocated 100 sample models, and they were asked to evaluate their respective 100 samples according to the two styles of (S1) Comfort and (S2) Sophistication (the range is from 0 to 10), and then based on the scores, 5 samples were selected from each group each respectively to represent the (S1) Comfort and (S2) Sophistication styles were modeled as reference standards for each tester's own preferences. Next, the 8 testers were iterated to find the optimal solution according to the two styles using the models constructed in this paper, and the search was limited to 50 generations.After 50 generations, the testers selected the individuals that most closely matched their preferences from the last generation of the population, compared them one by one with the previously developed criteria, and scored their similarity (ranging from 0 to 5). Finally, the results were statistically analyzed, and Figure 1 shows the level of satisfaction of the testers presented at 92% and 97% reliability, respectively.

Under 92% confidence interval, the tester scores 4.51 for the comparison results obtained for (S1) comfort style objective and 4.29 for (S2) sophistication style objective, which shows that the final solution generated by this paper's method meets the tester's preference needs. Under the 97% confidence interval, the testers rated the obtained comparison results of (S1) comfort style objective as 3.94 and (S2) sophistication style objective as 3.62. Meanwhile, the (S1) comfort style objective consistently has a narrower confidence interval and a higher satisfaction level than the (S2) sophistication style objective. It can be concluded that the method proposed in this paper can satisfy users' layout needs without the involvement of professional designers.

IV. C. Simulation testing of model performance

This section unfolds a comparison of the overall performance of the models constructed by the designed layout estimation modeling methods. Taking the assumed target vector $O(O_1, O_2, \cdots O_D)$ as the reference value, Fig. 2 shows the variation of the average convergence curves of the three methods (B2, B3, and B4) for finding the target value in 10 simulation experiments. The experimental results show that when t = 20, there is no significant difference between the three algorithms in the initial stage of iteration. When t=60, (B4) the convergence speed and convergence accuracy of the method in this paper are significantly better than the other two algorithms.



(a) Satisfaction distribution under the 92% confidence interval

(b) Satisfaction distribution under the 97% confidence interval

Figure 1: Mean satisfaction

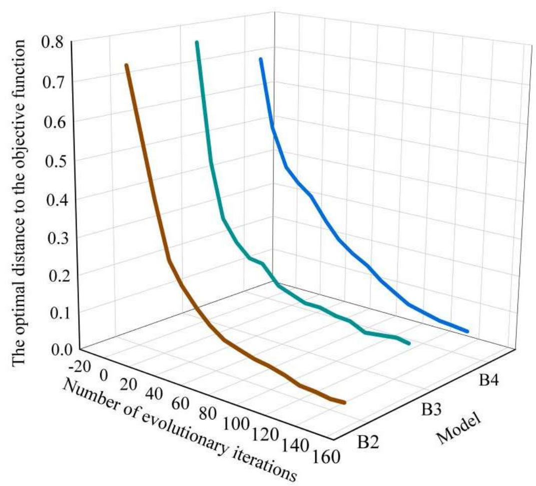


Figure 2: Simulation evaluation results

IV. D. Evaluation of physical layout characteristics

This section carries out the evaluation of a number of features of the designed elderly-friendly space layout, the evaluation of space features of the elderly-friendly layout is studied by questionnaire survey method, and 200 elderly people are randomly selected to carry out the questionnaire survey, the questionnaire consists of two parts, the first part is the survey of physical and mental characteristics of the elderly, mainly on the health degree, logical ability to carry out the statistics. The second part is the courtyard space characteristics satisfaction survey, combined with the above analysis content of this part of the selected characteristics of the index are: (A1) comprehensive volume ratio, (A2) bedroom lighting, (A3) living room lighting, (A4) bedroom noise control, (A7) accessibility index, (A8) fire prevention composite index, (A9) accessibility design index, (A10) balcony window composite safety index. For each index, the satisfaction evaluation level was categorized as (H1) very satisfied, (H2) relatively satisfied, (H3) average, (H4) relatively dissatisfied, and (H5) very dissatisfied.

The evaluation results of the layout features of the suitable space for the elderly are shown in Fig. 3, which shows that the 200 elderly people are generally more satisfied with the actual features presented by the layout design scheme. The distribution of satisfaction of the eight evaluated features mainly focuses on (H1) very satisfied, (H2) quite satisfied, (H3) average, with the proportion of 20.00%-30.00%. In the evaluation index (A3) living room lighting, the proportion of (H1) very satisfied rating reached 41.98%.

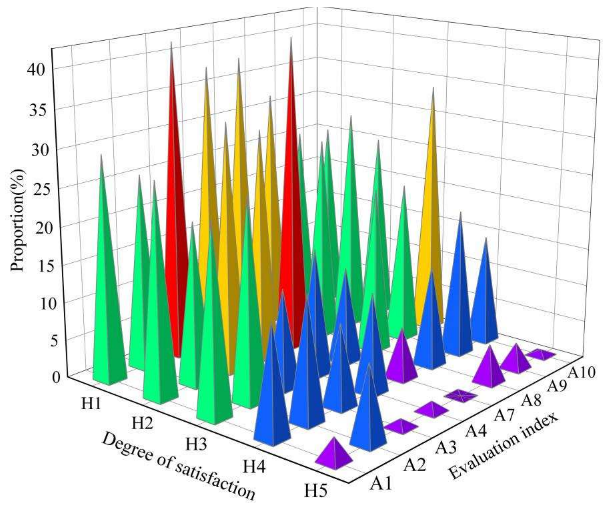


Figure 3: Satisfaction with the characteristics of living space

The correlation analysis of satisfaction among the eight features is shown in Table 2, and the correlation of satisfaction for a number of indicators is 0.800 and above, showing significant positive correlation. It indicates that the introduction of dynamic planning methods can effectively assist in the optimal layout and remodeling design by fully considering the association between different functional spaces and the overall needs of the family.

Table 2: The correlation of satisfaction with the characteristics of living space

		A1	A2	A3	A4	A7	A8	A9	A10
A1	Pearson correlation	1	0.562	0.956*	0.865*	0.936*	0.925*	0.946*	0.977*
	Sig. (Double Tail)		0.026	0.049	0.002	0.012	0.025	0.007	0.001
	N	8	8	8	8	8	8	8	8
A2	Pearson correlation	0.562*	1	0.977*	0.985*	0.847*	0.526	0.866*	0.903*
	Sig. (Double Tail)	0.026		0.005	0.026	0.011	0.038	0.121	0.005
	N	8	8	8	8	8	8	8	8
A3	Pearson correlation	0.956*	0.977*	1	0.856*	0.906*	0.914*	0.932*	0.966*
	Sig. (Double Tail)	0.049	0.005		0.023	0.011	0.113	0.007	0.017
	N	8	8	8	8	8	8	8	8
A4	Pearson correlation	0.865*	0.985*	0.856*	1	0.874*	0.562	0.888*	0.832*
	Sig. (Double Tail)	0.002	0.026	0.023		0.008	0.012	0.006	0.022
	N	8	8	8	8	8	8	8	8
A7	Pearson correlation	0.936*	0.847*	0.906*	0.874*	1	0.632	0.521	0.879*
	Sig. (Double Tail)	0.012	0.011	0.011	0.008		0.023	0.016	0.009
	N	8	8	8	8	8	8	8	8
A8	Pearson correlation	0.925*	0.526	0.906*	0.562	0.632	1	0.986*	0.932*
	Sig. (Double Tail)	0.025	0.038	0.011	0.012	0.023		0.011	0.007
	N	8	8	8	8	8	8	8	8
A9	Pearson correlation	0.946*	0.866*	0.906*	0.888*	0.521	0.986*	1	0.874*
	Sig. (Double Tail)	0.007	0.121	0.011	0.006	0.016	0.011		0.021
	N	8	8	8	8	8	8	8	8
A10	Pearson correlation	0.977*	0.903*	0.966*	0.832*	0.879*	0.932*	0.874*	1
	Sig. (Double Tail)	0.001	0.005	0.017	0.022	0.009	0.007	0.021	
	N	8	8	8	8	8	8	8	8

V. Conclusion

Based on the behavioral characteristics and life needs of the elderly, this paper proposes a modeling method for estimating the layout of aging-adapted living space under the optimal selection of layout candidates, and borrows the basic idea of dynamic programming to solve the optimal path between different functional spaces and the life needs of different members.

In terms of spatial layout quality scoring, the results of this paper's method in 10 evaluation index pairs are all above 0.80, including 0.82 for living room lighting and 0.99 for bedroom lighting.In terms of design style subjective feeling test, this paper's method always has narrower confidence intervals and higher satisfaction on the design scheme of the comfort style target, and obtains a higher score of 4.51 under the 92% confidence interval. In the evaluation of the actual layout features of the remodeling scheme, the distribution of the testers' satisfaction with a total of eight features mainly focuses on very satisfied, relatively satisfied, and generally satisfied, with a proportion of 20.00%-30.00%, and the correlation of satisfaction with a number of indexes is 0.800 and above, which shows a significant positive correlation.

By using the dynamic planning method to assist in the design of ageing-adapted retrofitting programs for indoor spaces, not only does it give full consideration to the needs of the elderly in their old age, but it can also effectively coordinate a variety of retrofitting needs and give the optimal solution, which is in line with the development trend of an age-friendly society.

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