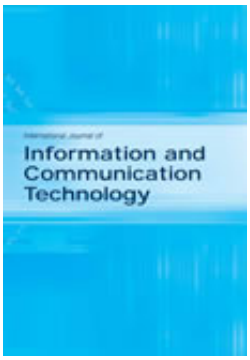

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Upgrading path of aging friendly functional layout in residential spaces based on biology and computer software engineering

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Abstract: With the acceleration of global population aging and the rising proportion of China's elderly population, the aging design of residential space is of great significance to improve the quality of life of the elderly. From a biological perspective, elderly people have special needs for living space due to physical decline, sensory degradation, and cognitive changes, while traditional living spaces have obvious deficiencies in spatial scale, functional zoning, and environmental adaptation. This study is based on the biological characteristics of elderly people, deeply integrating computer and software engineering technologies, and proposing optimisation strategies from three dimensions: spatial layout, furniture and facility configuration, and environmental creation to address the existing problems in traditional residential spaces. The research aims to improve the convenience of daily activities and indoor environment comfort for the elderly, effectively enhancing their living safety, convenience, and comfort.

Keywords: residential space; suitable for aging; computer and software engineering; spatial layout; biological characteristics.

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1 Introduction

With the acceleration of the global population aging process, the living environment of the elderly is increasingly concerned. According to the data of the seventh national census, the proportion of the population aged 60 and above in China has reached 18.70%, and the degree of population aging has been higher than the world average (Jiang and Jie, 2020). It is estimated that by 2050, China's elderly population over the age of 60 will be close to 500 million, accounting for one third of the total population (Jiang and Jie, 2023). In this context, the aging design of residential space is of great significance for improving the quality of life of the elderly and realising healthy aging.

From the biological point of view, the elderly have undergone significant changes in physical function, sensory ability and cognitive ability. These changes come from the physiological and pathological changes of human body in the process of aging, which puts forward special requirements for residential space (Anne et al., 2024). The decline of physical function makes the elderly have higher requirements for the safety, convenience and comfort of living space. The muscle strength and balance ability of the elderly are weakened, which is caused by biological factors such as muscle fiber atrophy and nervous system dysfunction (Oh, 2024). These changes make them prone to fall during walking, so the floor material, channel width and furniture layout of the living space need to take these physical changes into account to reduce the risk of accidents. The degradation of sensory ability, such as the decline of visual acuity and hearing, is closely related to the biological processes such as the decrease of lens elasticity and the decline of hair cell function in the inner ear. This puts forward special requirements for lighting, colour and sound environment of residential space. Changes in cognitive ability, such as memory loss and inattention, are related to biological mechanisms such as the decrease in the number of brain neurons and the imbalance of neurotransmitters (Kim and Kim, 2020). This requires that the layout of living space and the operation of facilities are simple and easy to understand, and convenient for the elderly.

Traditional residential spaces often fail to fully consider the special needs of the elderly in their design, and lack technical support from computer and software engineering, resulting in many inconveniences faced by the elderly in their daily lives. A survey shows that over 80% of residential bathrooms in old residential areas in Beijing have a net width of less than 1.2 meters, making it impossible to install basic elderly friendly facilities such as handrails and shower chairs. Many interviewed elderly people have reported falling in the bathroom due to limited space and slippery floors; In a residential area in a certain urban village in Guangzhou, the living room and bedroom are only separated by a wall and have not been soundproofed. The kitchen is adjacent to the bedroom window, and cooking noise and smoke smell seriously affect sleep (Golubchenko et al., 2023; Zhu and Li, 2024). Therefore, it is urgent to integrate computer and software engineering into the biological based aging functional layout upgrade of residential spaces. This study aims to create a safer, more comfortable, convenient, and healthy living environment for the elderly by analysing their biological

characteristics, behavioural habits, and psychological needs, combined with computer technology and design methods.

2 Contradiction between living space status and biological characteristics of the elderly

2.1 Mismatch between spatial scale and physical function

With the growth of age, the physical function of the elderly gradually declines, and the ability to move will also be affected to varying degrees. From a biological perspective, this is primarily attributed to the age-related decline in muscle mass and bone density, coupled with the progression of articular cartilage wear. These physiological changes in turn lead to shorter stride length, reduced walking speed, and impaired balance control, making the elderly feel cramped and unsafe when navigating narrow corridors. In many traditional residential settings, the corridor width is typically designed to only meet the basic mobility requirements of young and middle-aged adults. For the elderly, however, such inadequate width often forces them to adopt a cautious gait or even require side-stepping to pass, thereby significantly increasing their risk of falls. The corridor width of some residential buildings is less than 900 mm, which can not meet the needs of wheelchair access, which is undoubtedly a great inconvenience for the elderly who use wheelchairs, limiting their range of activities.

The unreasonable size of furniture is also an important manifestation of the mismatch between the spatial scale and the biological characteristics of the elderly. According to the 'Research Report on Ergonomic Dimensions of the Elderly' released by the China Aging Science Research Center, the height of sofa suitable for the body size of the elderly should be between 450 mm and 500 mm, and it should be shallower and narrower than ordinary sofas, with moderate armrest height, supported by cushions and auxiliary armrests suitable for the elderly (Xu et al., 2024). However, in real life, many sofa designs do not take these factors into account, which brings inconvenience to the use of the elderly.

2.2 Conflict between functional zoning and behaviour mode

Unreasonable dynamic and static zoning is a common problem in the conflict between functional zoning and behaviour patterns of the elderly. In some living spaces, dynamic areas such as living rooms and kitchens are too close to static areas such as bedrooms and study rooms, which are not effectively isolated. The sleep quality of elderly people is usually poor, which is related to biological factors such as reduced melatonin secretion and weakened biological clock regulation function, making them more sensitive to noise (Bo et al., 2023). Behavioural monitoring data shows that the noise level when watching TV in the living room is usually between 55–70 dB, while the noise level when cooking in the kitchen can reach 65–80 dB. The suitable sleep noise environment for elderly people's bedrooms should be below 35 dB (Zeng et al., 2024). Such unreasonable division of movement and stillness will seriously interfere with their rest and life, affecting their physical and mental health.

In daily life, the elderly need to move frequently between various functional areas. If the functional zoning is unreasonable, the activity route is too long or there are too many

turns and obstacles, it will increase the walking distance and difficulty of the elderly and bring inconvenience to their movement. The distance between the bathroom and bedroom of some residences is far, and the middle needs to pass through narrow corridors or steps, which is a great potential safety hazard for the elderly who need to wake up frequently at night. The elderly's vision at night is reduced, and their body function is in a semi awake state at night, with poor balance and reaction ability, which is easy to cause them to fall during walking.

2.3 Environmental factors contradict physiological needs

The elderly are highly sensitive to light. Adequate lighting can not only help them see the surrounding environment, reduce the risk of falling, but also promote the synthesis of vitamin D and enhance bone health (Wang, 2024). 7-dehydrocholesterol in the skin is converted into vitamin D under ultraviolet irradiation. Vitamin D helps the intestinal tract absorb calcium and maintain the normal metabolism of bones. However, in some residential spaces, due to unreasonable building orientation, small window area or being blocked, the indoor lighting is insufficient. In some old residential areas, the building spacing is too small, and it is difficult for some rooms to get enough sunshine during the day, which makes the elderly in a dark environment for a long time, prone to depression, anxiety and other negative emotions, affecting their mental health.

Poor ventilation is also an important problem that environmental factors contradict the physiological needs of the elderly. Good ventilation can keep indoor air fresh, reduce the degree of indoor air pollution and reduce the incidence of respiratory diseases. The elderly's respiratory mucosa atrophy and ciliary motor function weakened, resulting in the fragile respiratory system and higher requirements for air quality. However, in some residential spaces, poor indoor ventilation is caused by unreasonable house type design and imperfect ventilation equipment.

3 Optimisation strategy for residential space functional layout based on computer and software engineering

3.1 Spatial layout optimisation strategy

3.1.1 Reasonable planning of dynamic and static zoning

Dynamic and static zoning is an important principle in residential space design. For the living environment of the elderly, reasonable dynamic and static zoning planning is particularly critical. Quiet areas mainly include bedrooms, study, etc., which are places for the elderly to rest and have quiet activities, and need to maintain a quiet and private environment. As the core space for the elderly to sleep and rest, the bedroom should be as far away from the living room, kitchen and other moving areas as possible to avoid noise interference (Figure 1). A quiet environment can help improve the sleep quality of the elderly, reduce the secretion of stress hormones, and promote the recovery and repair of the body. In some traditional houses, the bedroom is close to the kitchen, and the noise generated during cooking in the kitchen will seriously affect the sleep quality of the elderly.

Figure 1 Dynamic and static zoning planning (see online version for colours)

Therefore, in the upgrading of aging friendly function layout, acoustic simulation software can be used to predict the noise propagation path, and combined with spatial planning to divide the sound insulation buffer area, ensuring that the bedroom is far away from the noise source and creating a quiet and comfortable rest environment for the elderly. The moving area includes the living room, kitchen, bathroom, etc., which are places where the elderly have more frequent daily activities, and the noise is relatively large. The living room is the centre of family activities and social activities. There are many people coming and going, and the activities are noisy. In the design, the spatial simulation software was used to simulate the daily activity trajectory of the elderly, and the living room should be set near the entrance door to facilitate the elderly to enter and receive guests. At the same time, reasonable furniture layout and space separation ensure that the activities of the living room will not interfere with other areas. The kitchen is a place for cooking and preparing food, which will produce lampblack, noise, etc. The kitchen should be separated from the bedroom, study and other quiet areas, and the closed or open design can be adopted. However, no matter which design, attention should be paid to the installation of effective range hoods and sound insulation facilities to reduce the impact of lampblack and noise on other areas. As an indispensable functional area in daily life, the bathroom is frequently used. In the dynamic and static zoning planning, the toilet should be set in a convenient location, while avoiding being directly adjacent to the bedroom, so as to reduce the impact of odour and noise on the bedroom. For the elderly with mobility difficulties, the toilet should be located as close to the bedroom as possible

to facilitate their use at night. A barrier free passage can be set between the bedroom and the bathroom to ensure that the elderly can travel safely and conveniently.

3.1.2 Barrier free access design

Barrier free access design needs to rely on computer and software engineering technology to improve scientificity and adaptability. Many elderly people's joint range of motion is reduced, and their muscle strength is insufficient, which makes it difficult to lift their legs, and the threshold is easy to cause them to trip. Therefore, in the upgrading of aging function layout, the threshold of indoor and outdoor should be eliminated as much as possible to keep the ground flat. At the entrance door, the doorless design can be used to level the indoor and outdoor ground to ensure that the elderly can easily access. For some cases where the threshold cannot be completely eliminated, a gentle slope transition can be adopted to reduce the height difference of the threshold and reduce the risk of tripping for the elderly. Appropriate ramps should be set at the entrance of the residence, stairs and other locations according to the use needs of the elderly. The gradient of the ramp shall comply with relevant standards, generally not more than 1:12, to ensure that the elderly can climb and descend the slope safely and easily (Liu et al., 2024). The width of the ramp shall also be sufficient, generally not less than 1,200 mm, to meet the traffic requirements of wheelchairs. Handrails shall be set on both sides of the ramp. The height and material of handrails shall conform to the usage habits of the elderly to provide them with stable support. Continuous handrails shall be installed in stairs, corridors, toilets and other places prone to falls. Generally, the height of stair handrail should be about 900 mm, and the diameter of handrail should be between 35 mm and 45 mm, so as to facilitate the elderly to grasp. The corridor handrail can be embedded or surface mounted, and the size of the concave area of the embedded handrail should be appropriate to avoid jamming the back of the hand or wrist joint; For surface mounted handrails, the appropriate type should be selected according to the physical condition of the elderly. For example, the circular handrail is suitable for the elderly with grip strength and pulling force, the wide flat handrail is suitable for the elderly who lack grip strength and need to be supported on the handrail with their palms, and the elbow support handrail is suitable for the elderly who cannot use grip strength and cannot be supported with their palms and can only be supported with their elbows (Figure 2).

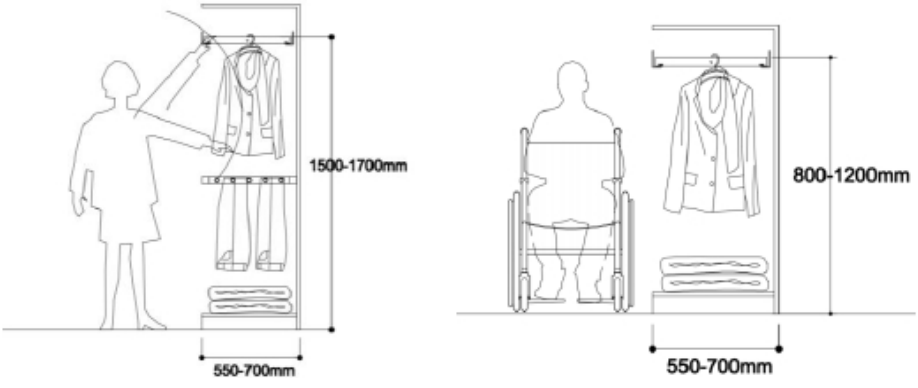
Figure 2 Stair and corridor handrails (see online version for colours)

3.2 Furniture and facility configuration strategy

3.2.1 Fit between furniture size and ergonomics

The body size and function of the elderly are significantly different from those of the young. Therefore, in furniture design, it is necessary to accurately determine the height, depth, width and other size standards of furniture according to the physical characteristics of the elderly, so as to achieve the perfect fit between furniture and ergonomics. In terms of height, the height of the sofa suitable for the body size of the elderly should be between 450 mm and 500 mm, which can ensure that the elderly do not need to use excessive force when sitting and getting up, and reduce the body burden. The height of the dining table is usually set between 750 mm and 800 mm, so that the elderly can place their arms naturally when eating, so as to avoid discomfort caused by improper height. The height of the bed is also crucial. After placing the mattress, the height of the bed should be between 450 mm and 50 mm to facilitate the elderly to get on and off the bed by themselves. The depth and width of furniture also need to fully consider the needs of the elderly. The depth of the wardrobe is generally controlled between 550 mm and 700 mm, which can not only ensure the vertical hanging of clothes, but also prevent the elderly from having difficulty accessing items due to too deep (Figure 3). For the elderly using wheelchairs, the hanging height of the wardrobe is set within the range of 800 mm to 1,200 mm to meet their needs of taking and placing clothes under the wheelchair. The width of the desk is appropriate between 800 mm and 1,200 mm, providing sufficient space for the elderly to place books, stationery and other necessities. In furniture design, we should also consider the physical comfort and safety of the elderly. For example, the edges and corners of furniture should be rounded and chamfered to avoid injuries to the elderly; the backrest and armrest of the chair shall be designed in accordance with the principle of ergonomics, providing good support and holding points for the elderly, so as to facilitate them to get up and sit down.

Figure 3 Size requirements for old wardrobe



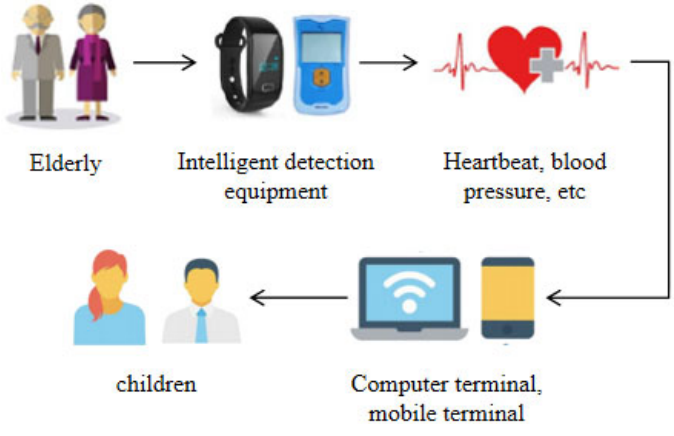
3.2.2 Application of intelligent facilities

With the rapid development of science and technology, intelligent facilities are more and more widely used in residential space, which has brought great convenience and security to the life of the elderly. The intelligent lighting system can automatically adjust the

brightness and colour temperature according to the ambient light and the activity needs of the elderly. In the daytime, the system can automatically reduce the brightness of lights, make full use of natural light and save energy; at night, when the elderly get up at night, the induction lamp will automatically light up to provide soft lighting and avoid the risk of falling due to too strong or too dark light. The intelligent lighting system can also set different scene modes, such as reading mode, leisure mode, sleep mode, etc., to meet the lighting needs of the elderly in different activities. The intelligent security system provides comprehensive protection for the living safety of the elderly. The smart door lock adopts fingerprint, password, face recognition and other unlocking methods, which is convenient for the elderly to enter and exit, and improves the security of the house. The intelligent camera can monitor the situation inside and outside the house in real time. Once any abnormality is found, the system will immediately send alarm information to the elderly and their families. The intelligent smoke detector and gas leakage alarm can detect fire and gas leakage and other dangerous situations in time, automatically trigger the alarm, and notify the relevant departments for treatment, effectively ensuring the life and property safety of the elderly.

Intelligent health monitoring facilities are of great significance for paying attention to the health status of the elderly. Smart bracelets, smart watches and other devices can monitor the elderly's heart rate, blood pressure, sleep quality and other physiological indicators in real time, and synchronise the data to the mobile phone or computer. When abnormal data is detected, the system will send an early warning in time to remind the elderly and their families to take corresponding measures (Figure 4).

Figure 4 Intelligent elderly care health system (see online version for colours)



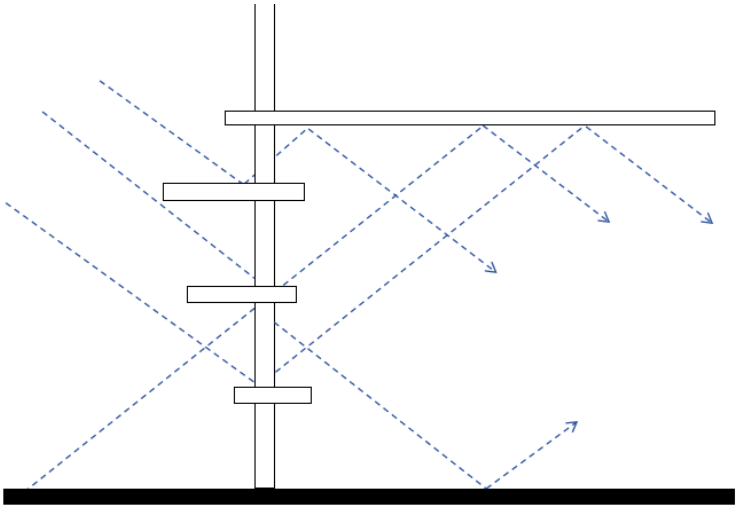
3.3 Environment creation strategy

3.3.1 Daylighting and lighting design

Natural lighting is an important factor in the current interior architectural design, which has a good role in energy conservation and environmental protection. Through the change of natural light, the interior space and the overall environment are decorated, providing a natural and comfortable light environment for residents, and realising the coordination and unity of indoor light environment design and natural environment. Good natural

lighting is essential for the physical and mental health of the elderly. It can not only provide sufficient light, make the elderly safer and more comfortable when they are indoors, but also promote the synthesis of vitamin D, contribute to the absorption of calcium, and enhance bone health (Xu et al., 2024).

Figure 5 Venetian blinds avoid glare



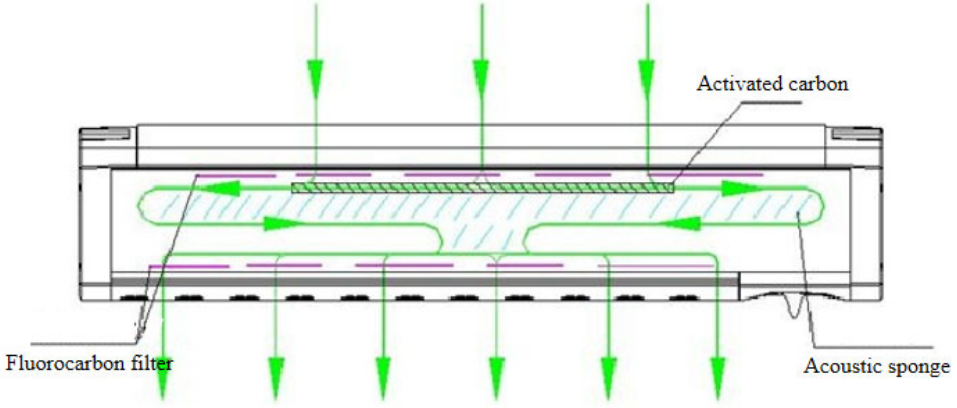
Therefore, in the design of residential space, building sunlight simulation software is used to analyse the angle of sunlight exposure in different seasons and time periods, combined with window position and area parameters, to calculate the uniformity of indoor lighting and avoid blind spots in lighting. Large area floor to ceiling windows or bay windows can be used to fully illuminate every corner of the room. In the design process of indoor natural lighting, due to the difference in the angle of sunlight exposure with the passage of time, especially in the case of indoor glare, in modern interior design, the effective application of sunshades and shutters (Figure 5) can make reasonable adjustment when the sun shines, so as to effectively avoid the discomfort caused by direct light.

3.3.2 Acoustic environment treatment

Noise will have a negative impact on the hearing, sleep and mood of the elderly. Long term exposure to noise may also lead to hearing loss, insomnia, anxiety and other problems in the elderly (Jaglarz, 2024). Therefore, in the design of residential space, effective measures should be taken to control noise and improve the sound insulation effect. In the design of building structure, wall materials and doors and windows with good sound insulation performance can be used, such as double-layer hollow glass doors and windows, sound insulation wallboard, etc., to reduce the introduction of external noise. The commonly used sound insulation doors and windows mainly include plastic steel sliding doors and so on. The effect of sound insulation mainly depends on whether the tightness of the window and the window frame meets the standard. Ordinary aluminum alloy doors and windows adopt the ‘hard touch’ push closing method, while plastic steel doors and windows adopt the rubber strip sealing method, so there is a significant difference in the sound insulation effect between the two. Generally speaking,

the sealing effect of plastic steel doors and windows is better, but it also has some disadvantages, which will lead to insufficient air circulation. In order to solve this problem, designers will install ventilators indoors (Figure 6), which can not only ensure the sound insulation effect, but also accelerate the exchange and circulation of indoor air. The sound insulation effect of the ventilator depends entirely on the sound insulation material. Because the sponge is installed between the partitions, it has both the effect of heat insulation and sound insulation, which can isolate the outdoor noise to the greatest extent.

Figure 6 Schematic diagram of ventilator (see online version for colours)

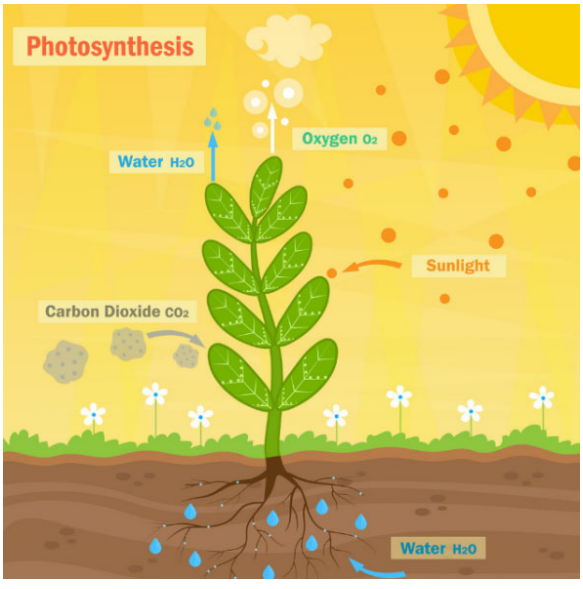


3.3.3 Air environment optimisation

The optimisation of air environment requires the integration of computer software to achieve intelligent regulation of ventilation and purification. Natural ventilation is the most economical and environmentally friendly ventilation mode. The position and opening mode of windows should be reasonably planned to form good ventilation and convection so that fresh air can fully enter the room. When designing windows, windows with large openable area, such as casement windows, sliding windows, etc., can be used to improve ventilation efficiency. The air pollution purification technology developed in recent years by biological purification technology has been gradually used and studied in indoor air purification. Many potted plants have the ability to purify air (Figure 7), but the effect is different. Placing green plants at a place 1.4 m away from the user is conducive to better health promotion. Some green plants that have adverse effects on human body cannot be placed inside the room. Compared with the indoor environment decorated with green plants, the indoor environment decorated with flowers is more attractive. Among the indoor plants of various sizes, colours and fragrance types, people are most satisfied with the small green plants with slight fragrance. Previous studies have confirmed that the introduction of plants into indoor space is beneficial to people's physical and mental health, and within a certain range, with the increase of the number of indoor plants, plants have a positive effect on people's health and well-being. However, the number of indoor plants is not the more the better. Excessive proportion of plants will have negative effects on the elderly, such as causing psychological pressure and affecting the effect of completing some cognitive tasks (Yamout et al., 2024). Therefore, the green

plants placed in the living room space for a long time should have the following three points at the same time: first, the cultivation method is simple, second, there is no public hazard, and finally there must be the effect of purifying the air.

Figure 7 Schematic diagram of blade air purification (see online version for colours)



4 Discussion

The life of the elderly needs meticulous care. In the process of aging adaptation, the professional level of aging adaptation needs to be continuously improved. Through aging adaptation, the self-care ability of the elderly can be improved, and the dignity of the elderly's personality and the establishment of spiritual independence can be maintained, showing a positive aging and healthy aging. From the perspective of biology, this study deeply analyses the internal relationship between the characteristics of physical function decline of the elderly and their housing needs, and puts forward the upgrading path of aging functional layout of residential space from the dimensions of spatial layout, facilities, intelligent application and so on. In terms of spatial layout, it follows the principles of dynamic and static separation and barrier free access design, reasonably plans various functional areas, and improves the accessibility and safety of the space; in terms of facilities, according to the physical function characteristics of the elderly, optimise the design of furniture, lighting, sanitary ware and other facilities to improve their comfort and ease of use; in the field of intelligent application, intelligent security, health management, environmental control and other systems are introduced to realise the comprehensive monitoring and care of the life of the elderly, and enhance the safety and convenience of the living space.

The upgrading of the aging function layout of residential space is of great significance for improving the quality of life of the elderly, promoting the harmonious development of society, promoting the progress of architectural design and improving the

pension security system (Liu and Qian, 2022). With the aggravation of the aging society, the number of the elderly population continues to grow, and the demand for living space suitable for aging is increasingly urgent. This paper hopes to explore the new context of aging adaptation from the perspective of indoor space, endow aging adaptation design with more humanistic care, establish a sustainable link between people and the space environment, and analyse the key points of space design in detail, in order to create a safe, comfortable and convenient living environment for the elderly.

At present, there are two main types of aging friendly design schemes in China: one is based on building codes for basic renovation, focusing on eliminating physical barriers. Its advantages lie in strong universality, low implementation cost, and suitability for large-scale renovation of old residential areas. However, the disadvantage is the lack of targeted consideration for the physical characteristics of the elderly, often resulting in standardised renovations that are 'one size fits all' and difficult to meet the personalised needs of elderly people with different health conditions. Another type is high-end intelligent elderly care community solutions, which introduce a large number of intelligent devices and have advanced hardware configurations. However, their core problem lies in excessive reliance on technology stacking, neglecting the cognitive ability and operating habits of the elderly. Some intelligent devices are complex to operate and difficult for the elderly to master, and the cost of the solution is high. It is only suitable for a few high-end elderly care projects and does not have universality. Compared with existing approaches, this research plan has the following advantages: firstly, it takes the biological characteristics of elderly people as the core logical starting point to achieve precise adaptation of the design. Secondly, establish a dual driving system of 'biology + computer software engineering' to enhance the scientific and operational nature of design. Thirdly, balance universality and personalisation, and strike a balance between cost and effectiveness. Fourthly, emphasise the integration of multidimensional systems to achieve maximum overall efficiency.

However, the coverage of the research sample needs to be expanded, and individual differences among the elderly have not been fully considered. In the future, we can expand the scope of research and strengthen regional adaptability research; Conduct personalised design research and construct a classification adaptation system. By combining knowledge from multiple disciplines such as psychology, sociology, and medicine, we will conduct in-depth research on the psychological and social needs of the elderly. We will integrate emotional care, social support, and other elements into residential space design, while exploring the application of new technologies such as artificial intelligence and the Internet of Things to further enhance the aging friendly level of residential spaces

Declarations

The data used to support the findings of this study are all in the manuscript.

All authors declare that they have no conflicts of interest.

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