Model Design of Computer-Aided Public Space: An Urban Space Design Approach Based on Virtual Reality Technology

Wei Li[1] and Xian Xu[2]

[1]School of Art & Design, Zhengzhou University of Aeronautics, Zhengzhou 450000, China, leeway@zua.edu.cn
[2]School of Art & Design, Huanghe Science And Technology University, Zhengzhou 450000, China, xuxian@hhstu.edu.cn

Corresponding author: Wei Li, leeway@zua.edu.cn

Abstract. This paper presents an in-depth study and analysis of the design model of public space through computer-aided virtual reality technology, and discusses the urban space design method. This paper constructs a research method based on virtual reality technology for urban design of building interfaces along streets and proposes urban design refinements about building interfaces along streets. This method solves two problems, firstly, it solves how to integrate the bottom-up public demand feedback mechanism into the urban design system, and form the public's perceptions of the building interface along the street into guidance for urban design, providing ideas and methods for the refinement of urban design, and forming a supplement to the "top-down" urban design preparation system. The second is to propose how to use virtual reality as a tool for urban design. Secondly, we propose a working method to apply virtual reality technology to urban design. The spatial simulation of virtual reality technology is very important for urban design research, but there is little research on the application of virtual reality technology in urban design preparation, and this method fills the gap of virtual reality technology application research. In the study, the relationship between objective indicators and evaluation factors as well as street satisfaction is clarified, and the design points of the building interface along the high-satisfaction living street in this urban design are obtained, which are applied to the urban design of the future city, and the urban design indicators of the building interface along the street are refined. Finally, the feasibility of the research method based on virtual reality technology for the urban design of the building interface along the street is confirmed.

Keywords: computer-aided; public space; pattern design; virtual reality technology; urban space design
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1 INTRODUCTION

As urbanization advances and the scale of cities expands, people find that the urban building interface is broken, the street space lacks a sense of enclosure, the urban public space lacks characteristics, and the built space is far from the planning goal. Urban design is mainly a single "top-down" design idea, to take over the planning contents and objectives of the general plan and control plan, explaining in depth the general plan and control plan, explaining in detail how to achieve the planning objectives in the future, forming specific urban construction guidance and evaluation, and promoting the granting of urban construction land and design. Therefore, the overall objectives of the area are focused on in the design, but the details of urban design are easily ignored, which leads to the general objectives not being implemented into the underlying design, and the design requirements at the bottom are detached from the overall planning objectives [1]. Street space is closely related to people's lives and is the most frequently contacted urban public place in people's daily activities. The design and quality of urban streets greatly affect the public's impression of the city, and excellent streets can bring people a sense of comfort and pleasure, and can fully demonstrate the inner spirit of a city. The urban street space is enclosed by the building interface and road interface on both sides of the street, and the existing research proves that the form of the building interface along the street has a great influence on the quality of the street space, and the urban design puts forward mandatory requirements on the building height and the building sticker rate and puts forward guiding requirements on the architectural style. However, in the process of urban space construction practice, the new urban space does not achieve the expected effect, but on the contrary, there are many problems, such as an excessive scale of urban street space, lack of humanized design, and lack of continuity.

Virtual Reality (VR) technology enables participants to build, experience, and even interact with the environment with computer simulation technology. The technology uses various program algorithms within the computer to simulate the real world and enables the user to create a realistic spatial sensation through output devices. The user can feel the 3D dynamic virtual environment and even manipulate objects to get realistic feedback of the virtual environment [2]. The immersive human-computer interaction brought about by virtual reality technology is a significant change for the architecture and planning industry. The architecture and planning industry originally used a combination of graphic representation and model presentation in their designs. With the continuous development of computer technology, the architecture, and planning industry gradually began to introduce the virtual model of the computer display, and the way to use static pictures gradually developed to the dynamic video presentation. Pictures and videos often use a combination of human perspective and bird's eye view to show the viewer information about the site. The viewer can only passively receive the site information through the viewpoint or viewing path set in advance, lacking human-environment interaction. The emergence of virtual reality technology, on the other hand, realizes the interaction between the experiencer and the model of the site. The experience can choose what to watch and the path to walk through the headset and handle, which makes the 3D dynamic display scene more realistic, enhances the scale cognition of the model space and enables the experience to feel the space form more accurately. Therefore, virtual reality technology has sufficient content worthy of study in urban design.

By combining the knowledge and achievements in the fields of design and computer-aided design, the latest technologies and achievements are integrated into the field of residential planning and design, and computer-aided design software and methods are used to improve the efficiency of residential planning and design and to help make up and improve the specific details of residential planning and design schemes. In this paper, computer-aided design software and methods are integrated into each stage of residential planning and design, and the specific applications of computer-aided design methods are studied and analyzed in depth in each design stage so that the advantages and application scope of each software and method can be obtained and the optimal computer-aided design method can be found by comparing the traditional methods.

2 RELATED STUDIES

Dubey et al. [3] proposed a corresponding idea of stratified development of underground space based on the actual situation of underground space in Japan and developed a specific scheme for functional stratification of underground space. Shan et al. [4] proposed the development of deep underground space in the face of the shortage of land resources in Japan and placed the functional and recycling space originally on the surface into the deep underground space to improve the efficiency of material recycling and resource utilization. Jezernik and Hren [5] explored various functions and characteristics of underground space and proposed a vertical underground space layout model applicable to a variety of functional facilities, and the scheme has strong guiding significance in the construction of urban underground space. In the underground space, the spatial scale greatly affects people's experiences and feelings. This requires designers to explore and create a comfortable underground space scale environment from the perspective of humanization. The scale-space of underground commercial street is composed of three scale elements, namely length, width, and height, which are used as the basis to form one-dimensional scale combination, two-dimensional scale combination, and three-dimensional scale combination. Although many studies have been conducted on the scale elements and proportions of surface streets based on spatial cognitive relationships, there is less exploration of the relationship between scale combinations and the influence of architectural space, and the urban underground space environment is quite different from the surface environment, so it is not rigorous enough to guide the design of underground space directly by the design experience of urban surface scale exploration. Therefore, a scientific approach is needed to conduct targeted research on the correlation between the scale combination and spatial perception of underground commercial streets. This study uses the virtual reality method, guided by the theory of spatial cognition and design, and takes the underground commercial street as the main research object, and explores the appropriate scale combination of the underground commercial street through the virtual simulation experiment of underground commercial street.

In the study of computer-aided landscape ecological planning and design, Whyte et al. [6] analyzed the role of computer-aided design in the landscape ecological planning and design strategy and the influence in the planning and design of residential areas. In the analysis of computer-aided design software and its application, Ma et al. elaborated on the scope and field of its role and the way each software is applied in the planning and design of residential areas [7]. Expressways and traffic arterials assume the main traffic function of the city and are the main arteries of urban traffic, so ensuring the smooth traffic flow of these roads is the main design content in urban design. The landscape arterial road aims at shaping the scenic road landscape, emphasizing the shaping of landscape interface on both sides of the road, and the proportion of architectural interface is less. Living arterials, commercial as well as living secondary arterials, and feeder roads are the street spaces in the city mainly oriented to the residents' walking.

Computer-aided design techniques and methods have been better applied and developed in various professional fields, and at the same time have opened broad development prospects for the study of residential planning and design. For planners, it not only provides them with the tools and means for production but also puts forward new requirements for them to learn the content of knowledge in other fields, prompting their comprehensive development. At present, the development of computer-aided design techniques and methods in China is still in its infancy, and although new computer-aided design techniques have been developed rapidly in recent years, there are fewer applications and studies in the field of planning and design, which also provides a direction for us to engage in research in this area. The research in this paper focuses on the integration and application of computer-aided design methods in the planning and design of residential areas, for research in this paper focuses on the integration and application of computer-aided design methods in residential planning and design, and provides reference and reference for planners and researchers engaged in the planning and design field.

3 ANALYSIS OF COMPUTER-AIDED VIRTUAL REALITY TECHNOLOGY FOR URBAN SPACE DESIGN

3.1 Computer-Aided Virtual Reality Technology Design

Virtual reality technology is a comprehensive use of graphic rendering technology, simulation technology, multimedia technology, parallel processing technology, screen technology, and positioning technology to generate a 3D interactive immersive environment with a realistic simulation of reality [8]. It emphasizes the audience's experience and immersion and helps planners break through traditional thinking to build an emotional experience space for interaction from the audience's perspective. This technology not only allows the audience to experience and feel the planner's design from the first perspective, but also effectively connects the audience's emotion, the planner's emotion, and the residential planning and design plan, and finally presents a more perfect design. With the in-depth research and development of computer-aided design-related technologies, increasingly new technologies are widely used in residential planning and design, which also promote the planner's design thinking more diversified. The application of new technologies promotes the integration of multiple disciplines, enriches the connotation of residential planning and design, and promotes the continuous development of planning and design disciplines.

The preliminary planning plan is to transform the single enclosed organization form of the current community and form three community organization forms, namely, residential, and commercial community organization mode, residential community organization mode, and commercial and residential community organization mode, as shown in Figure 1. It aims to solve the phenomenon of a thin green space system and insufficient sunlight in the current community, and forms a multi-level and multi-layout green space system, as well as a central green space with concentrated sunlight. This kind of neighborhood with an enclosed courtyard layout returns to the layout pattern of architectural interface enclosing the street, and the design of the architectural interface on both sides of the street has an important influence on the shaping of the street space.

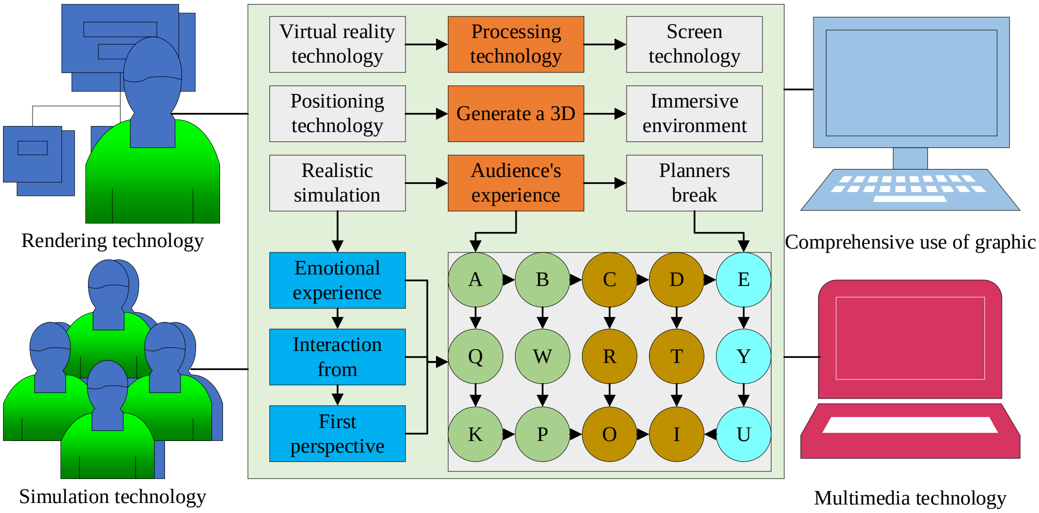

Figure 1: Framework of computer-aided virtual reality technology.

For the identification of key areas, certain principles need to be followed. Taking street urban design as an example, the focus of attention should be on-street space and street plots, so in the identification, firstly, different land types and plot boundary lines are sorted out according to land use planning, and then combined with the development mode and function of each plot in the planning scheme, the main pedestrian activity areas in each plot are determined. If both sides of the street are residential land, the area from the curb to the boundary line of the street building covering the sidewalk will be designated as the key area. In addition to residential land, the land with the intensive pedestrian flow, such as land for public administration and public service facilities, commercial service facilities, green areas, and squares, if the land is occupied independently, the area around the curb as the boundary is designated as the key area, and the rest of the case will be the curb and the boundary line of the land encompassed by the scope of the key area. East-west street north side of the street if the main public building, pedestrian activity area is generally in the south side of the building, as the north side of the building is mostly landscape-based green space less pedestrian flow into, so in the key area division should be the building after the boundary to the south and the surrounding curb area as the key area, as shown in Figure 2.

During the implementation of specific waterfront space projects, many problems have emerged such as uncoordinated spatial distribution of waterfront space, lack of connection with urban functions, and neglect of users' needs. In this situation, domestic scholars began to study a lot of successful experiences abroad and make theoretical summaries from practice. Field studies of public transportation systems in central cities show that although the topography of urban areas is relatively flat and the built-up scale of central cities is relatively small, the number of people walking or bicycling to their destinations in the cities is still low. The reason for this is that the planning and design of the urban road network did not target slow traffic planning for walkers or bicyclists, and now there is a lack of systematic slow traffic paths in both the central city and the surrounding tourist attractions, which brings a poor traffic experience to those tourists who choose to visit the city on foot or other slow traffic methods.

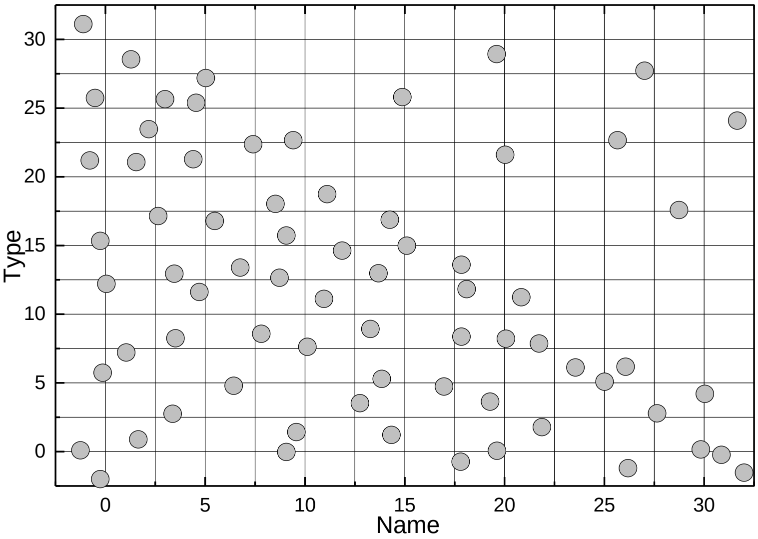

Figure 2: Analysis of co-occurrence matrix.

3.2 Analysis of Urban Public Space Design

In the process of optimization and adjustment of the scheme, it should be noted that the optimization of individual buildings and building groups should not differ significantly from the volume ratio of the corresponding plot of land determined in the original scheme, and the adjustment of the height and location of individual buildings should also be within the allowable variation range based on GIS [9]. In the actual operation process, for the spaces with physical environment problems, the spatial form, and auxiliary optimization measures are adjusted to make each physical environment meet the respective standards and improve on this basis. In the program, the plaza space is adjacent to the east-west road in the north and the building cluster in the south. Through the simulation evaluation of the site, it is found that the wind environment in summer is poor and does not reach the comfort standard, while the sunshine and noise environment are at a slightly higher level than the standard, and there is room for optimization. However, through analysis, the area urgently needs to solve the stuffy body feeling caused by low wind speed in summer, so it is necessary to strengthen ventilation, by increasing the spacing between the building walls on the south side of the site and reducing the building footprint, increasing the building height to ensure that the plot volume ratio does not become at the same time to increase the "wind permeability", but the optimization of space based on wind environment may lead to. However, the spatial optimization based on the wind environment may lead to the change of the internal noise environment of the south side of the plot, and it is necessary to ensure that the sound environment does not deteriorate at this time, which can be optimized through auxiliary measures such as greening and being a sound barrier, as shown in Figure 3.

By summarizing the coupling relationship between each physical environment and spatial form and the means of optimization between physical environments, and studying the comprehensive evaluation and optimization of physical environments, it was finally determined that the optimization of street space based on physical environment comfort should be based on the comprehensive evaluation of the physical environment of the program. The final result is that more than 90% of the area is subject to greater noise interference, with sound pressure level exceeding 60dB and poorer sound environment; area 3 is a secondary school, and due to the low continuity of street buildings, there is less shielding of noise from the road, so about 50% of the internal area has sound pressure level exceeding 60dB, and due to its internal playground adjacent to Futing Street, the lack of building and other auxiliary measures to shield the noise, resulting in 50% of the playground. The sound pressure level of about 50% of the playground area exceeds 60dB.

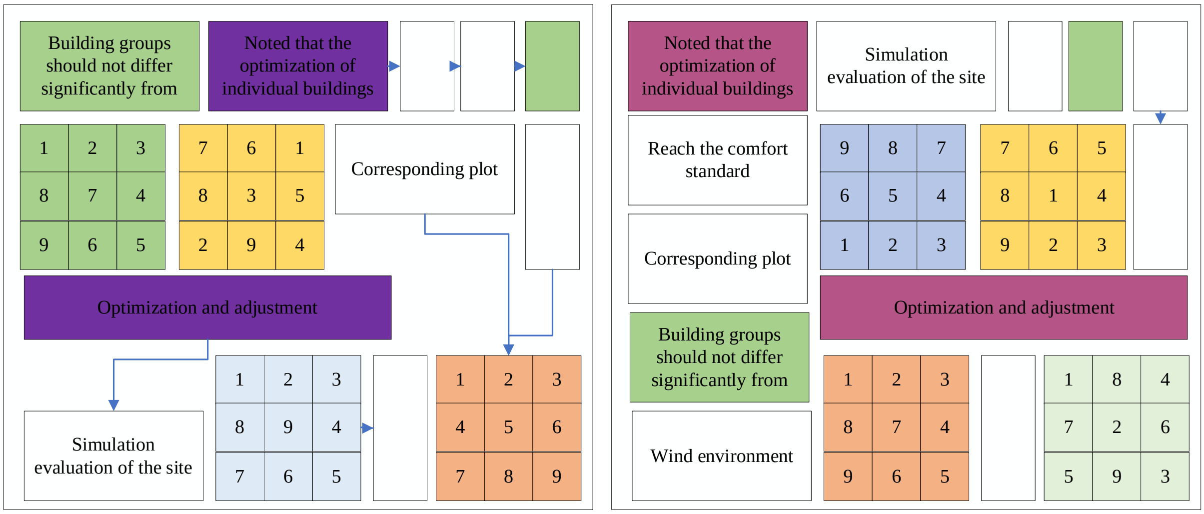

Figure 3: Schematic diagram of spatial optimization.

Area 6 is surrounded by three main roads, resulting in its internal sound pressure level exceeding 60 dB; due to the lack of buildings to shield the noise, while the space is more open, resulting in area 7 sound pressure level exceeds the standard, most of the area is above 60 dB; although Youyi Road is the main road and a light rail line is planned, but because the buildings on both sides are higher and the spatial pattern organization plays a better role in shielding the noise, so even if the internal sound pressure level of Youyi Road street Even though the sound pressure level inside the space is above 60 dB, the noise environment inside the street is better, and the sound pressure level can be kept below 60 dB, as shown in Figure 4.

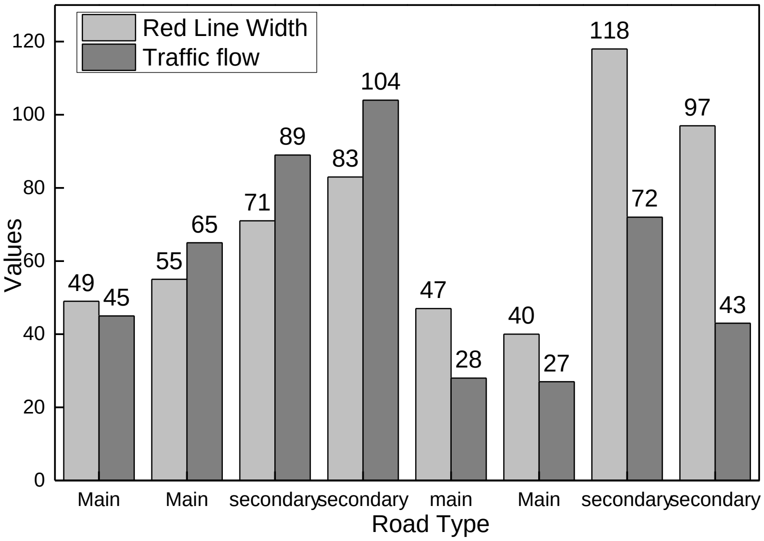

Figure 4: Statistics of road data parameters in the study area.

To better investigate the suitable scale combination of the main space of the underground commercial street and exclude the interference of other spatial scales, the underground commercial street will be simplified into a scale model containing the main street space to further improve the accuracy of the experiment. In the model space, the form of the space will adopt the linear shape that appears a lot in the research, the street material will adopt white plaster, and the light intensity will adopt the universal suitable value of 700 for the underground street.

Through the physical environment simulation of the initial scheme of street space, the wind, sunlight, and noise environment status of the initial scheme is obtained [10]. According to the comprehensive optimization process, the physical environment evaluation of the scheme should be conducted at the overall level and key areas first, to check whether the comprehensive physical environment of the scheme meets the standards through quantitative means, and to lay the foundation for the later urban design scheme optimization while making the scheme optimization more targeted. The comprehensive evaluation of the physical environment is not just a single evaluation of the scheme, but a dynamic cycle of the evaluation process and the comprehensive evaluation should be conducted for each round of adjusted schemes until the scheme meets the corresponding standards at the overall level and in the key areas. Therefore, a comprehensive evaluation of the physical environment should be carried out first for the initial scheme of the street space, but in practice, since the comprehensive evaluation of the physical environment is carried out step by step with the optimization hierarchy, a comprehensive evaluation of the physical environment at all levels is carried out first for the initial scheme to facilitate comparison with the final optimized scheme at a later stage.

4 ANALYSIS OF RESULTS

The computer-aided design approach is the most advantageous in terms of the efficiency and performance of the planning and design scheme, and its emergence has freed planners from traditional drafting work. In the early days, a residential planning and design scheme took manual drafting, which required a lot of time and effort for the planner to draw the plans, and mistakes in the drawing process could lead to the delay or failure of the whole project. Moreover, manual drafting requires a high level of art skills of the planner, so the drawings drawn will have uneven levels and the recognition of the planning and design scheme is poor. The computer-aided design approach has a complete set of design specifications, and the design software provides precise design tools to avoid errors caused by the planner's manual measurement, as shown in Figure 5.

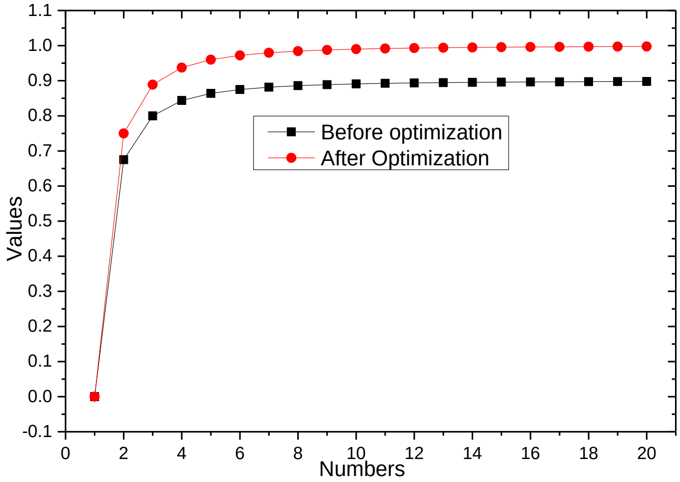

Figure 5: Comparison before and after optimization of the overall hierarchical wind environment.

The final optimized scheme is calculated by taking the area ratio of each physical environment to meet the standard into the overall hierarchical evaluation formula, which shows that in the wind environment winter condition, the optimized physical environment comprehensive attainment rate is 65.0%, which meets the standard requirements. In the case of wind environment in summer, the optimized physical environment compliance rate is 60.7%, which meets the standard requirements. By comparing with the overall physical environment compliance rate of the initial scheme, the overall physical environment compliance rate of the initial scheme is 53.9% under the wind environment in winter. The overall physical environment compliance rate is 48.2% in the windy summer season. Therefore, the final optimized solution has a significantly higher overall physical environment compliance rate than the initial solution in both winter and summer.

Computer-aided design software does not require planners to have hand-drawing skills, it is easy to understand in operation and can effectively solve the problems encountered by planners. Computer-aided design software can present the design plan in two-dimensional and three-dimensional ways and even immerse and experience the design plan from the audience's perspective through virtual reality and other technologies. In summary, computer-aided design and traditional drawing have their advantages. Traditional drawing can help planners find inspiration, while computer-aided design can better help planners improve efficiency and present design solutions so that the audience can feel the planner's design concepts and ideas. Therefore, I believe that the two approaches should take their respective advantages and complement each other, but focus more on the application of computer-aided design techniques and methods in the design conceptualization stage of planning and design solutions, which can quickly realize the planner's design ideas, and at the same time can design a variety of solutions based on different human needs, thus providing the audience with a variety of options, as shown in Figure 6.

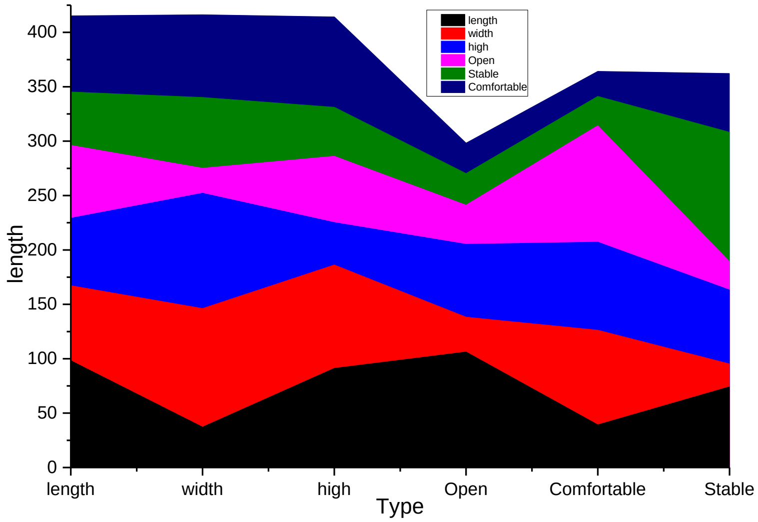

Figure 6: Correlation between the combined variables and cognitive evaluation.

To side interface the degree of influence of proportions on spatial perception, the possible proportions were correlated with the quantified spatial perception data in SPSS, as shown in Figure 7. In the positive field of view, P4 correlates higher with overall cognition relative to P1, the ratio proposed in the literature to measure the spatial quality of suitable streets, and both reach significant correlation. This indicates that the proportion of side interfaces within the 60° range of binocular comfort field of view has a greater influence on the perception of commercial street space in underground commercial streets. Although the correlation coefficient between P4 and overall perception is greater than that of P1, the absolute value of the correlation coefficient is within (0.5,0.8] and cannot reach a high correlation. It indicates that the proportion of side interface with possibility explored in this paper is not highly correlated to spatial cognition and cannot have a high impact on spatial cognition.

In the current urban design, the design indexes related to the urban interface are the posting rate and interface density. Many scholars have studied the interface density, which is not only related to the buildings on both sides of the road but also closely related to the density of urban road networks and road width. Therefore, the interface density will be different for different building heights, different streets, and different types of land. The way of calculating the discount rate determines that it is not affected by the density of road network and road width, but only related to the layout of buildings along the street. The design of the discount rate can indirectly influence the interface density. Increasing the discount rate of the building interface can increase the density of the street interface to a certain extent, therefore, only the discount rate is included in the detailed design of the urban interface in this planning. The basic logic of the urban interface refinement design is based on the nature of the site and the type of roads adjacent to the site. For example, the building density of commercial and business sites is high, and the sticker rate is generally high; the upper and lower limits of the sticker rate for residential sites vary widely, and the design standards for the sticker rate vary according to the type of road they are bordered by, while it is meaningless to specify the building sticker rate for utility sites.

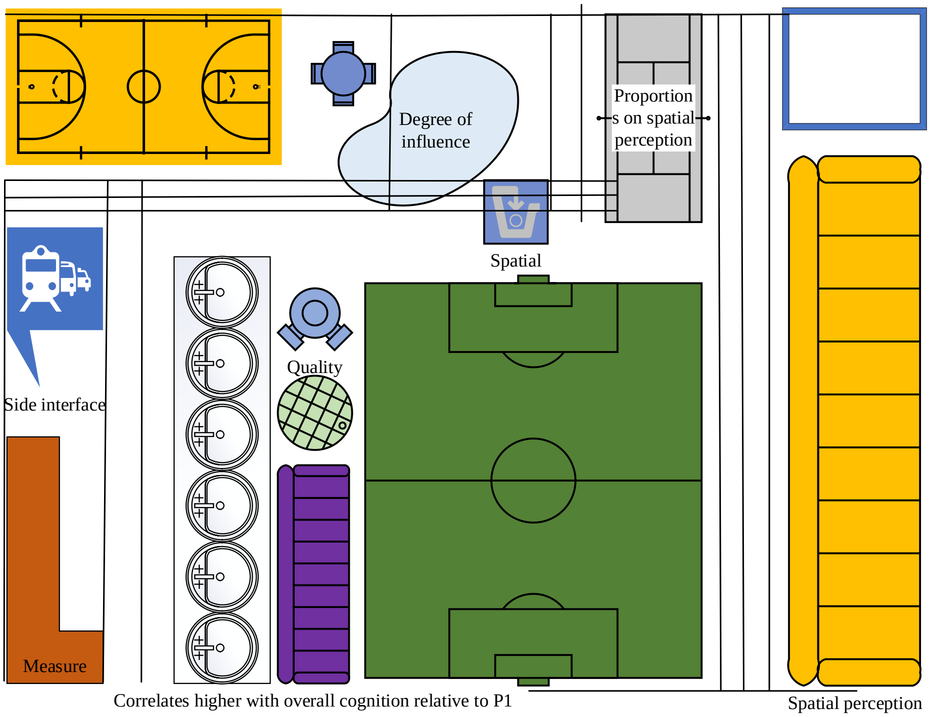

Figure 7: Post-refinement development model diagram.

5 CONCLUSION

The experimental model of multiple high-frequency scale combinations is constructed by using virtual reality technology, and the experiment of scale combinations of underground commercial streets is guided by the theory related to spatial cognition. The scale combinations of three dimensions are analyzed through virtual simulation experiments to understand the role relationship between scale combinations and overall spatial cognition, and to obtain the important scale combinations affecting the spatial cognition of underground commercial streets and their appropriate ranges and change laws. The relationship between objective indicators and evaluation factors as well as street satisfaction is clarified in the study of its building interface along the street. Through the correlation analysis of evaluation factors and street satisfaction, the correlation analysis of evaluation factors and objective indicators, and the analysis of critical values of objective indicators, the design requirements of high-satisfaction living street space are finally obtained and applied to the urban design of this case, which confirms the feasibility of the design method proposed in this paper.

Wei Li, https://orcid.org/0000-0001-9180-0422
Xian Xu, https://orcid.org/0000-0002-1898-7726

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