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Research Article

5G Virtual Reality in the Design and Dissemination of Contemporary Urban Image System under the Background of Big Data

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As an important part of the soft power of urban culture, the importance of city image has received widespread attention from academic circles and society. The study of city image communication has become one of the important research directions in the field of communication in recent years. This research mainly discusses the application of 5G virtual reality in the design and dissemination of a contemporary urban image system under the background of big data. This research designs and develops a city image system that models and simulates virtual cities in a three-dimensional scene. The system consists of several different modules, including a data acquisition module, scene construction, and roaming module. The most important data resource formats used by this system are the DXF format and 3DS format, which can be created and acquired using digital stereo images in the data acquisition module. The data import and export module can convert the models in DXF format and 3DS format into Openfligt format models. The model editing and reconstruction module can visually edit and reconstruct the converted model, so that the space and attribute information of the recreated model is stored in the data storage and management system. Finally, a scene roaming module is created, and models are selected from the database to create a 3D city scene and provide interactive roaming information extraction. After the implementation of virtual reality technology, the per capita awareness of urban humanities reached 63.2%. The test results show that because the system integrates the respective advantages of the geographic information system, virtual reality, and database technology, it can better realize the modeling and simulation of digital cities under the conditions of three-dimensional visualization, which is conducive to the spread of urban image.

1. Introduction

As the cultural industry has become a new growth point for the global economy, cities with developed urban cultural industries and distinctive cultural images will have greater advantages in future international competition, which overturns the previous competition based on economic strength. Therefore, it integrates the cultural history of the city and the education industry that has a high degree of relevance to the cultural industry, thereby forming a cultural system of the city image and reintegrating and connecting the city's image communication from the perspective of the system theory. The impact of economic globalization and the advent of the era of high-speed information have put all urban resources in a high degree of competition. The shaping of the image city requires the dissemination of media. 5G virtual reality technology is the fastest communication medium for obtaining information in today's society. It plays a pivotal role in the process of information dissemination and has also become a beneficial tool for people's search engines. The 21st century is the internet era and the era of big data. "Big data" requires a new processing mode to have stronger decision-making power, insight, discovery power, and process optimization ability to adapt to massive, high growth rate, and diversified information assets. In this context, we study the application of 5g virtual reality technology.

Although with the transformation of urban functions and the development of mass media, cities at all levels have realized the importance and urgency of urban image communication. However, the existing relevant theories are relatively lagging, which is detrimental to the urban image in the current environment. The communication operation is not conducive to the integrity of the urban marketing theory. Therefore, this study studies the city image from the perspective of city image communication, conducts a more comprehensive and in-depth theoretical discussion on the dissemination of 5G virtual reality city image, makes up for the shortcomings of China's current urban image dissemination theory, improves urban marketing theory, and promotes the development of China's urban image dissemination field.

Recently, the concept of wireless augmented and virtual reality (AR/VR) has swept the entire 5G ecosystem, causing unprecedented interest in academia, industry, and others. Bastug *E* believes that the success of immersive VR experiences depends on solving numerous challenges across multiple disciplines. He used storage/memory, fog/edge computing, computer vision, and artificial intelligence for research [1]. Virtual reality immersion (VRI) is an advanced computer-generated technology that reduces the subjective reports of pain in procedural medicine. Vera *L* believes that VRI reduces brain activity related to pain as measured by functional magnetic resonance imaging [2]. Freeman *D* believes that with virtual reality (VR) and computer-generated interactive environments, individuals can repeatedly experience their problematic situations and learn how to overcome difficulties through evidence-based psychotherapy [3]. Daniel Freeman believes that the use of virtual reality can promote new learning. He evaluated the delusions and pain of 30 patients with compulsive delusions. The patients were then randomly assigned to virtual reality cognitive therapy or virtual reality, and both were performed in a hierarchical virtual reality social environment for 30 minutes. Then, it reassessed the delusional beliefs and real-world troubles. His research experiment data is insufficient [4].

Based on the theory of a three-dimensional simulation system and 5G virtual reality technology and based on the theoretical technology of urban three-dimensional simulation system construction, this research proposes a technical process plan for the construction of an urban three-dimensional simulation system, which specifically includes urban three-dimensional modeling technology process and simulation system. The technical design of the engine and the technical process of the construction of the urban 3D simulation system have three parts. Among them, the technical process of urban 3D simulation system construction is the overall technical process, which specifically includes the technical process of urban 3D modeling and the technical design of the simulation system engine [5, 6]. Use the OpenFlight data organization format as the standard format for database model management in this project. Finally, based on TerraVista and Creator modeling software, the city's topography, landforms, buildings, and other artificial features are modeled, and the key technology scene segmentation, level of detail technology, instantiation technology, and texture mapping technology in the modeling process are carried out.

2. City Image

2.1. City Image Communication. The lag in the creativeness of urban image communication in the social is mainly manifested in the homogeneity of communication forms and contents. Although governments and communication experts at all levels have actively explored the form and content of urban image communication, the convergence of urban image communication modes at the national level is still common, which is not only contrary to the original intention of urban image communication but also not conducive to urban competition. Regarding the homogeneity of urban image communication in China, many media workers and communication experts in China have made severe criticisms and pointed out that the image of some cities in China should have brand image construction convergence, lack of innovation and personality, and lack of disadvantages, such as clear market positioning and market segmentation [7]. The reason is that, on the one hand, it is closely related to the convergence of the image positioning of some cities in the social, and on the other hand, it is directly related to the lack of urban image communication theory in the social [8, 9]. 5 g is a general technology, which will affect the lifestyle of future cities in all aspects. It can help build cities and spread city images. For example, its combination with virtual reality technology can help builders build cities more conveniently and accurately.

The application of virtual reality technology in construction projects allows the architectural design process to be expressed in a visual way: architects seem to be in the construction site to be built, and they can modify the color scheme of the building's facade at will and change the floor height of the building. The design results are clear at a glance [10]. The use of virtual reality technology can make designers easily detect the defects in the urban planning stage, effectively reduce the irreversible losses and regrets caused by unscientific planning, thereby greatly improving the quality of project evaluation [11, 12].

2.2. 5G Virtual Reality

2.2.1. 5G virtual Reality Technology. 5G virtual reality (VR) is a very active technology field in recent years [13]. It is specific to the urban virtual reality technology, which is to realize the virtual operation of the city beyond space by the construction of the virtual city so that the manipulator can roam all corners of the city, vividly reproduce the real environment of the city, and realize the network and digitalization of city management [14, 15]. From the above introduction, the rise of "digital cities" puts forward the requirements for the realization of three-dimensional urban simulation: the rapid development of remote sensing technology provides geographic coordinates describing urban spatial information and image data describing surface cities, which solves the problem of expressing urban three-dimensional cities. Digital photogrammetry technology provides rapid processing methods, such as geometric precision correction of remote sensing image data and information extraction, which solves the problem of extracting urban spatial information: realistic image generation technology realizes the geometric simulation of urban spatial information and the virtual reality technology solves the problem of urban three-dimensional urban reproduction [16]. The solution of the above problems has created excellent conditions for the establishment of urban three-dimensional cities and the realization of virtual roaming, and it has laid a good foundation for the construction of "digital city" spatial information infrastructure. For this reason, it is necessary to normalize the realistic graphics with gray values $\xi(k)$ [17]. Because of the different color and brightness of each point of the image, each point on the black-and-white photo taken or the black-and-white image reproduced by the TV receiver presents different degrees of gray. The relationship between white and black is divided into several levels according to the logarithm, which is called the "gray level." Using the gray value to normalize the image is conducive to a more realistic scene construction.

$$\xi(k) = \frac{\rho \min\left|C_k^m - C\right| + \rho \max\left|C_k^m - C\right|}{\left|C_k^m - C\right| + \rho \max\left|C_k^m - C\right|}. \quad (1)$$

Among them, C_k^m and C are graph databases. The use of virtual reality technology for urban construction, management, and development is a new technical attempt [18, 19].

To improve the calculation efficiency in the axisymmetric enclosing body, the intersection check process becomes a set of simple unit axis overlap checks. Verify whether an axisymmetric enclosure defined by the three-dimensional vectors A and B and another axisymmetric enclosure defined by the three-dimensional vectors I and J meet the intersecting condition, and obtain the following:

$$G = (A_x > J_x) \vee (I_x > B_x) \vee (A_y > J_y) \vee (I_y > B_y), \quad (2)$$

$$G(A, B) = (A_x B_x)(I_x J_x)(A_y B_y)(I_y J_y). \quad (3)$$

For the convenience of calculation, MBR is also projected to a coordinate axis. If the side length D is centered on R, then the projection along the N axis is obtained as follows:

$$c = 0.2D_x \times \left|B_x\right| + 0.2D_y \times \left|B_y\right|, \quad (4)$$

$$M = R_x B_x + R_y B_y + R_z B_z. \quad (5)$$

Among them, A and B are the minimum and maximum values, respectively.

When the resolution of a certain layer of spatial data is $O \times P$, the identification code covered by the calculated spatial entity H can be calculated by the hash function, which is defined as follows:

$$G(x, y) = \begin{cases} x = \dfrac{Hx}{o} * \dfrac{Hy}{p}, \\ \\ y = \dfrac{HxHy}{op}. \end{cases} \quad (6)$$

The result of the hash function is usually smaller than the original data to realize data compression. At the same time, the calculation process through the hash function is irreversible, i.e., the original data cannot be deduced according to the hash value. Hence, the hash function is widely used in the application scenarios that need to generate data summary or realize data encryption.

For the spatial query algorithm, it is mainly used to quickly obtain the spatial data within the specified range and its intersection. For any three-dimensional spatial range, the query algorithm is as follows:

$$U_{\min} = U\left[\log_2 \frac{A}{2} - 1\right] \times \log_{A/2}\left(\frac{B}{A/2 - 1}\right), \quad (7)$$

$$U_{\max} = U\left[\log_2 \frac{A}{2} \times \left(\log_{A/2} B - 1\right)\right], \quad (8)$$

$$U_{ave} = U\left[\log_2 \frac{B}{2}\right] - U[S]. \quad (9)$$

The variable U represents the time complexity. It can be seen that the worst performance of the search is polynomial level, and the average complexity of the entire algorithm is also polynomial level, which has high performance and stability.

$$ROW = \left[\frac{(AU + BU)}{2}\right], \quad (10)$$

$$\text{COLUMN} = \left[\frac{\log_2 (AU + BU - 1)}{2}\right]. \quad (11)$$

It can be seen from the formula that the calculation process of ROW is to average the sum of Au and Bu, while the COLUMN is to calculate the logarithm first and then divide.

The grid can be simplified while satisfying the visual effect. The cost of a multifolding is defined as follows:

$$cust(a, b) = |a - b| \times \max_{s \in R\ D}, \quad (12)$$

$$cust(r, d) = \min_{n \in AB}\left\{\frac{(1 - A_{\text{normal}} * B_{\text{normal}})}{2}\right\}. \quad (13)$$

Among them, a and b are the two vertices of the folded edge, and A is the point to be deleted. A_{normal} and B_{normal} correspond to the unit normal vector of the triangle, respectively. The formula can be equivalent to the following:

$$\cos t(a, b) = [a - b] \times \max_{x \in R\ D}\left\{\min_{y \in R\ D} \sin^2 \frac{a}{2}\right\}. \quad (14)$$

When calculating, choose a sequence with lower computational complexity, higher compression effect, and better data recovery. Table 1 is a comparison table of computational complexity. From the table, it can be seen that the computational complexity of each sequence is in multiple dimensions, and it can be seen that the calculation complexities of 5/3 and 2/6 are the lowest.

2.2.2. Construction of Virtual Reality City Model. To create a virtual reality city model, firstly, extract the road data, including the length, width, and texture of the road, subdivide and filter these data to obtain the real size of the road data, and subdivide and calculate the complete vector of width and angle.

Knowing the measurement angle μ, which is the sum of the angles μ_1�μ_2, as well as the length h and the width w, we can get,

$$\frac{w_1}{\cos \mu_1} = \frac{w_2}{\cos \mu_2} = ||s||, \tag{15}$$

$$\mu = \mu_1 + \mu_2. \tag{16}$$

Equation (15) shows that the sine of the angle corresponding to the half-width length of the two roads is used as a link, and a relationship can be established between the half-width length itself and the translation vector length. After combining the two equations together, one can get another simplified version of the equation, which is as follows:

$$\frac{w_1}{w_2} = \frac{\cos(\mu - \mu_2)}{\cos \mu_2} \frac{w_1}{w_2} = \frac{\cos(\mu - \mu_1)}{\cos \mu_1}. \tag{17}$$

Then, the length of the vector s can also be obtained. Combining the solved angle with the vector s, the vector s itself can be further obtained as follows:

$$\mu_2 = \arctan \frac{\cos \mu}{w_1/w_2 + \sin \mu}, \tag{18}$$

$$\mu_1 = \arctan \frac{\sin \mu_2}{w_1/w_2 + \cos \mu + \ \cos_2}. \tag{19}$$

Finally, connect these translated target points according to the previous sequence to get the contracted block.

However, they have exactly the same form, and there are differences in some constants. The general boundary equation can be written as follows:

$$w_{\text{limit}} = w_{\min} + (w_{\max} - w_{\min}). \tag{20}$$

The contracted block is instantiated and used in distributed simulation to reduce the amount of data transmission. The geometric transformation matrix D of the object in the three-dimensional space is obtained. The translation, rotation, and scaling can be expressed as a unified matrix multiplication form, which is as follows:

$$D = \begin{bmatrix} b_1 & b_2 & b_3 & b_4 \\ b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \end{bmatrix} \tag{21}$$

The matrix D is divided into four submatrices from the change function to generate geometric transformations, such as proportional rotation, which can be deduced as follows:

$$[a', b', c', f] = [a, b, c, f] \left| a + D_a b + D_b c + D_c f \right|. \tag{22}$$

In the right-hand coordinate system, the transformation formula for rotating the origin of the coordinate system around the coordinate axis by μ angle is as follows:

$$[a', b', c', f] = [a, b, c, f] \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos \mu & \sin \mu & 0 \\ 0 & -\sin \mu & \cos \mu & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \tag{23}$$

Instancing is because that the collection position of the object is obtained through a geometric transformation. Hence, when the number of instance objects increases, the number of objects and the number of geometric transformations should be considered, as shown in Table 2.

In addition, VR is used very frequently in urban modeling. Many commands in VR can be realized using the buttons on the toolbar, such as moving, selecting, rotating, and mirroring. Only when the resolution of the current screen is 1280×1024, the toolbar will be fully displayed, and in the case of commonly used resolutions of 1024×768 or lower, can it be displayed incompletely. If one wants to combine the entire scene with other scenes, one can also use this command [20]. The network architecture of the virtual reality city system is shown in Figure 1.

2.3. Big Data. With the rapid development of information technology, various industries in society pay more attention to big data. In this context, the sharing of big data resources has gradually become a hot spot in the development of big data [21–23]. The rapid increase in the demand for the rapid flow of information in the big data environment has promoted the rapid development of information technology, making the exchange of information more frequent and faster [24]. Therefore, the requirements for data distribution technology are getting higher. In distance-based clustering methods, the distance between data objects is often used when measuring the similarity between the data objects [25, 26]. Here are some distances that are often used in Euclidean space.

$$\begin{aligned} d(x, y) &= \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \cdots + (x_n - y_n)^2} \\ &= \sqrt{\sum_{i=1}^{n} (x_i - y_2)^2} \end{aligned}, \tag{24}$$

$$d(x, y) = \sqrt{\frac{\sum_{i=1}^{n} (x_i - y_i)^2 (x_j - y_j)^2}{(x_n - \ y_m)^2}}. \tag{25}$$

Table 1: Computational complexity.

MBR	Addition operation	Shift operation	Multiplication	Total amount of calculation
5/3	5	2	0	7
2/6	5	2	0	7
SPB	7(8)	2(3)	1(o)	12(11)
9/7-M	8(9)	2(3)	1(o)	11(12)
2/10	7(10)	2(6)	2(0)	11(16)
5/11-c	10	0	0	13
6/14	10(11)	3(5)	1(o)	14(16)
SPC	8(10)	4(5)	2(0)	14(15)
9/7-F	12(26)	4(18)	4(0)	20(44)

Table 2: Instantiate test results.

Model	*a*	*b*	*C*	*f*
Number of vertices	2648	2487	5416	279
Number of triangles	4576	5484	1547	527
Simplify efficiency	15.43%	46.77%	68.17%	86.25%

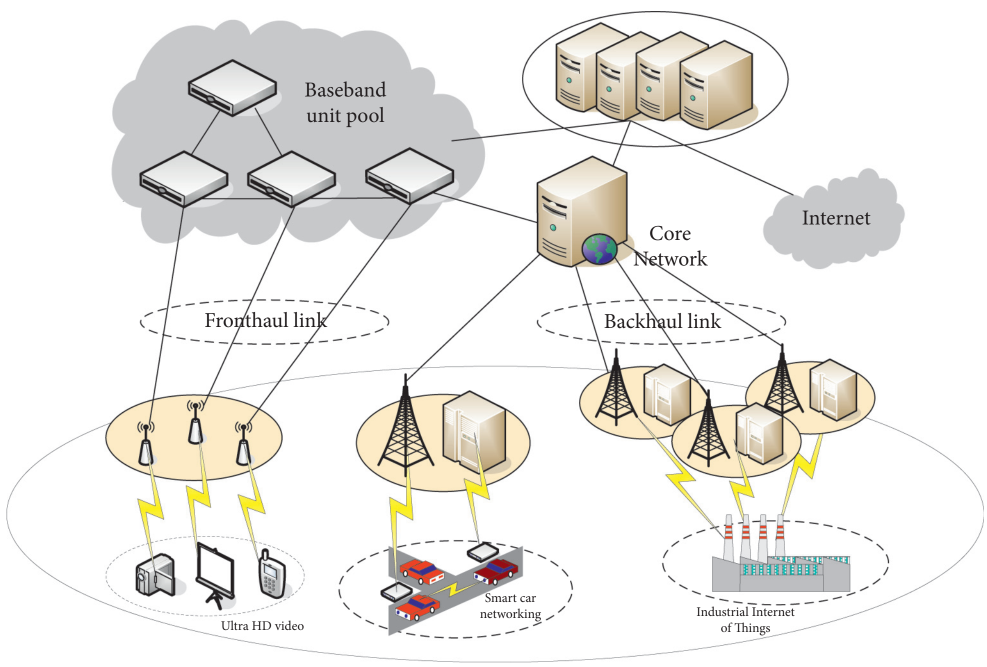

Figure 1: Network architecture of virtual reality city system.

Among them, x_n and y_n are the coordinates of the corresponding points. The detection effect for a single attribute is better, however, for two-dimensional and above attributes, the detection effect is not ideal [27]. The main reason is that different detection models have different mechanisms for generating outliers, and the explanation of isolation is insufficient. There are many elements of the spatial structure and layout of urban planning, including buildings, squares, roads, and waterscape greening. It also involves related planning technical and economic indicators, such as residential type, apartment type, building area, number of floors, floor area ratio, greening rate, spacing, and so on. There are other related pieces of information, such as building height, materials, colors, and the relationship between the plan and the general map [28, 29]. Therefore, the designer needs to constantly adjust the elements and the relationship between the elements in the planning process, which needs to be completed with the help of virtual reality technology and big data. The industrial combination of big data technology and virtual reality technology will become a new development trend in all walks of life.

3. Urban Image System Design Experiment

3.1. System Function Design. The three-dimensional urban planning image system developed is composed of a two-dimensional geographic information system (GIS) and three-dimensional virtual reality (VR) systems. The main functions include two-dimensional GIS functions, virtual reality (VR) functions, and urban planning program simulation functions. The virtual reality functions include three-dimensional scene roaming functions and two-dimensional and three-dimensional scene interactive operation functions. The GIS function is implemented in a two-dimensional form, and the supporting data is a two-dimensional raster and vector data: the virtual reality (VR) function mainly expresses city information in the form of three-dimensional visualization and realizes the connection between the two-dimensional and three-dimensional by synchronizing with two-dimensional GIS. Powerful interactive functions provide users with a three-dimensional platform on which users can freely simulate urban planning and design, preview the planning effects in two-dimensional and three-dimensional scenes at the same time, and change the planning scheme and adjust the planning element objects in real-time.

3.2. System Framework Design. The actual system of comprehensive application is written by VC++6.0, and on the basis of Vega runtime library and Arcinfo components, it adopts a loosely coupled structure composed of the GIS module and VR module. In the system, when the GIS module loads the two-dimensional terrain data in the database using the interactive graphics engine ArcSDE, the instructions and data are transferred to the virtual reality module (3D module) through the instruction interface and the data interface, and the Vega runtime library is called through the scene manager. Load the building model from the model library, and display it in the virtual reality window (3D window) in a visual form for simulation roaming. At the same time, the system also receives instructions entered by the user at any time and responds accordingly according to the type of event. The system also provides an interface with other MIS systems, which can conveniently call other applications. The contemporary city image system designed in this paper is implemented using the client and server architecture, as shown in Figure 2. The data is stored on the server. The server is mainly responsible for the storage of data and the realization of some analysis functions. The client sends a request to the server. The server obtains data from the database and returns it to the client, and the data is processed, analyzed, and applied to the client. This system architecture is mainly composed of these three parts, which complement each other to form a complete urban image system.

The virtual city-oriented three-dimensional spatial data engine uses spatial data indexing and fast access technology to realize the high-speed access service of multiple data sources, multiresolution, and massive spatial data of the virtual city. It realizes the drive-based data access, which can be based on the virtual city spatial data. Each feature constructs different access drivers, realizes the dynamic scalability of data services, and forms a consistent access service platform for multisource spatial data. The overall framework of the virtual reality city image system design is shown in Figure 3.

3.3. Design of System Database. In the digital city management information system, the development of a large number of applications is based on the database. Therefore, the design and management of the database is a very critical process in the system development process. If the database design is unreasonable, it will not only increase the number of clients, but also make the programming and maintenance of server-side programs more difficult and it will affect the performance of the system. On the contrary, a good database design can maximize the processing performance and scalability of the system. The reported information is shown in Table 3.

Store system information used to display the user interface and save the directory hierarchy information of the user interface. The field names and meanings are shown in Table 4.

Attribute data is stored in different data tables according to the division of functional modules. To provide an interactive query, attribute information records associated with model combinations are associated with model combinations by the model Id field in the table design. The field design description is shown in Table 5.

Planned land control table: the planned land control table stores information, such as the scale and proportion of different planned land, and it is a hierarchical tree structure. To reflect the tree structure, the parent node id is stored in the child node, and the design description of the field is shown in Table 6.

3.4. Creation of 3D Scene. After the building is modeled, because there are a lot of details on the surface of the real building, there is still a certain gap between the realism of the model and the actual building. Therefore, the simulation of the texture details of the building surface plays an important role in the realism of the virtual city system. The simulation of the surface texture details of the model is usually called texture mapping technology, which is an effective method to simulate the surface details of objects. Using texture mapping technology can achieve the simulation of the rich texture details of the surface of the real scene and improve the realism of the model.

3.5. Model Integration. The data obtained in the data collection stage is converted into the virtual reality modeling software, MultiGen, according to the terrain data, cultural feature data, and building data. When organizing the scene database, the file naming, storage path, and production method should be unified. It is stipulated that the scene production shall be completed in strict accordance with the production process.

3.6. Virtual Interaction Design. After completing the urban scene modeling, design the interactive function between the user and the urban scene. The overall interaction of the system is achieved using the control of the keyboard and mouse. Its function can be summarized into two aspects: direct interaction by viewpoint control and indirect

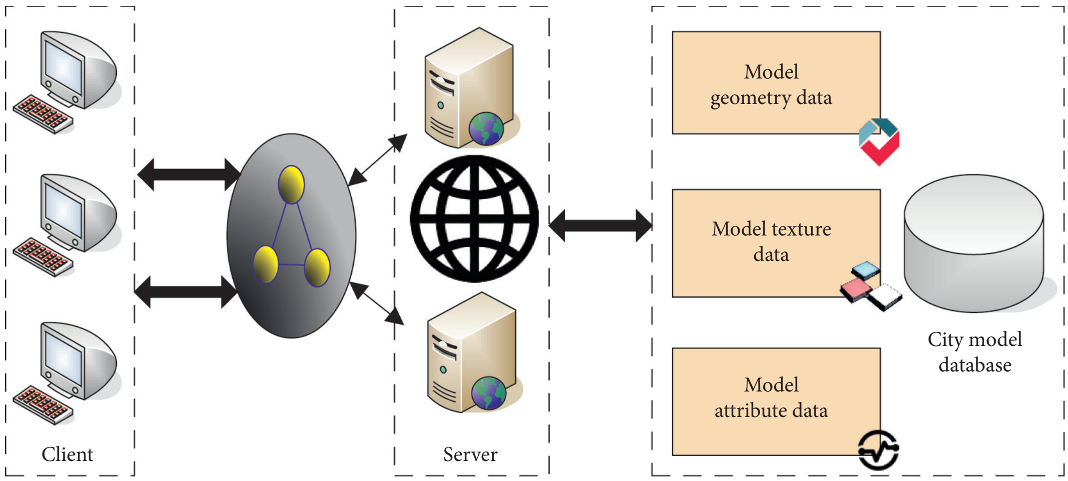

Figure 2: City image system network.

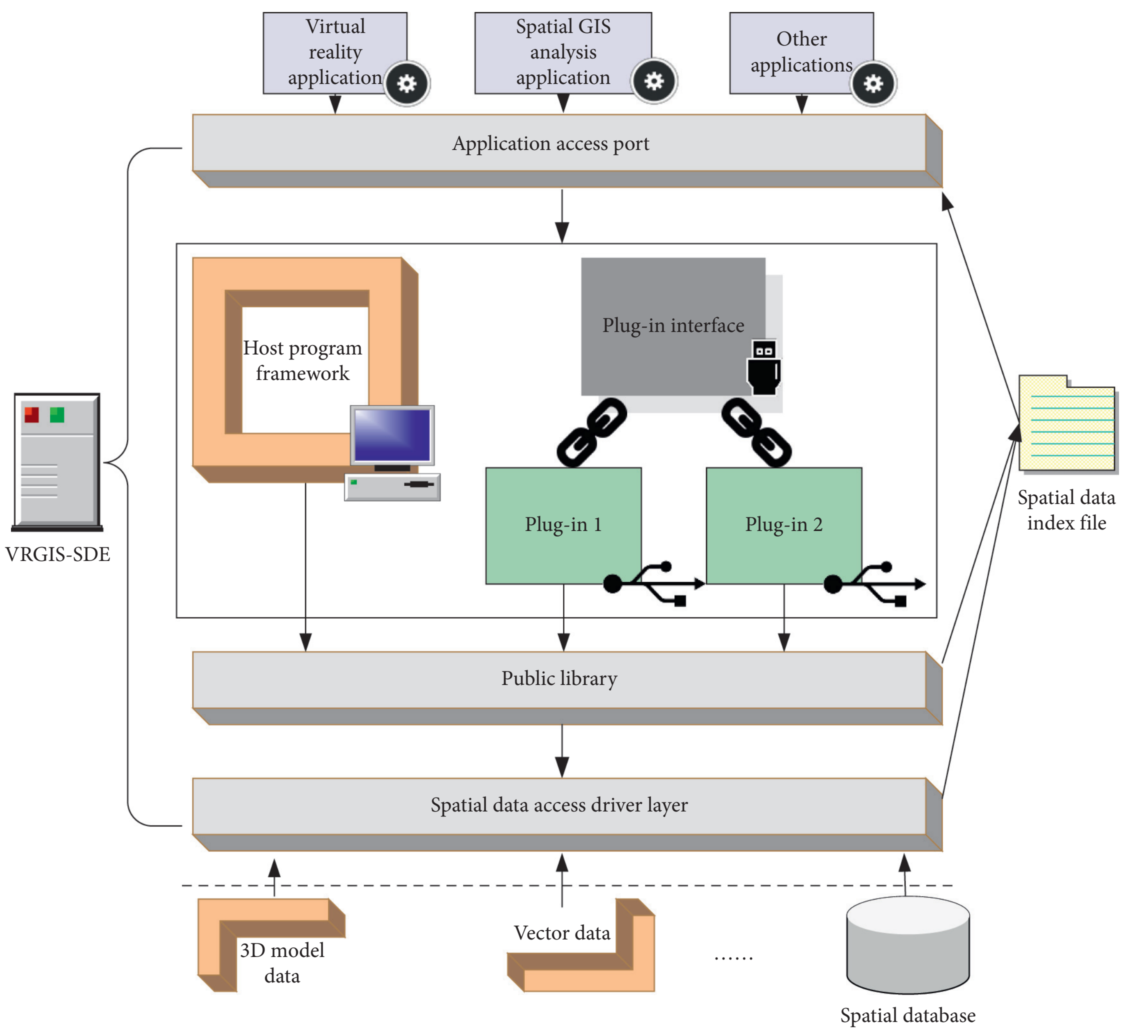

Figure 3: The overall framework of virtual reality city image system design.

interaction by software interface. The software used in this experiment is a three-dimensional scene editor. The users of the system control the system using a computer and software.

3.7. System Application Realization. The system interface is developed based on the VC++ application framework (MFC). The main interface of the application is divided into three parts, namely the main control toolbar,

Table 3: Information reported.

Field name	Types	Description
ID	INT	Uniquely identifies
Case ID	INT	Number of identified case
Report information category	CHAR	Indicates which category the reported information belongs to, such as supervisor reporting
Name of reporting personnel	CHAR	Identifies the name of the reporter
Report information status	CHAR	Identifies the status of the reported information

Table 4: Directory structure table.

Field	Type	Describe
Id	Int	Null
Pld	Int	Null
Sortd	Int	Null
name	nvarchar(50)	Null
showName	nvarchar(200)	Null
Layer	Int	Null
Scene	nvarchar(50)	Null

Table 5: Current city building information sheet.

Field	Type	Describe
Id	Int	Not null
bdName	nvarchar(50)	Not null
bdType	nvarchar(50)	Not null
bdQual	nvarchar(50)	Not null
bdFloors	Int	Null
bdArea	Int	Null
bdStyle	nvarchar(200)	Null
bdMaterial	nvarchar(200)	Null
bdImg	nvarchar(200)	Not null
Modelld	Int	Not null

Table 6: Planned land control table.

Field	Type	Describe
Id	Int	Not null
Pld	Int	Not null
fieldNo	Int	Not null
fieldCode	nvarchar(50)	Null
fieldUse	nvarchar(200)	Not null
fieldArea	Real	Null
fieldPer	Real	Not null
Modelld	Int	Not null

two-dimensional window, and three-dimensional window. The interface item is the main control toolbar, and the main functions include the virtual simulation of ADF file browsing, opening of two-dimensional windows, three-dimensional windows, office automation system call interface, and other application and system interfaces. The left part below is a three-dimensional window, which displays the three-dimensional scene and simulation roaming of the planning plan, and the right part is a two-dimensional window, which displays the plane and GIS information of the planning plan. The two-dimensional and three-dimensional windows have their own menus and toolbars, which are easy to operate. System users are divided into three levels of permissions according to their functional requirements, namely, administrator permissions, operator user permissions, and browsing user permissions. The administrator user has the highest level of authority, can manage and set the database, model library and the number of users, and can have all the operation rights of other users. The operation user refers to the creator of the planning scheme and other operations that have the authority to modify the scheme personnel. They can edit, modify, operate, delete, and perform other operations on the plan and browse users who belong to the third level of authority. They are the viewers of the roaming results of the planning plan, including all the expert leaders and planning plans who participate in the review of the planning plan for the general public. They can only browse and roam the existing planning schemes, however, they cannot edit and modify them.

To sum up, this experiment completely designs the system function, system framework, 3D scene creation, system database, and virtual interaction and forms a complete urban image system.

4. Urban Image System Analysis

4.1. Analysis of System Test Results. As the system is still under further development and improvement, we only tested certain indicators of the system. The running results under each running environment are shown in Table 7. The original scene tested is a model composed of 260,000 vertices, 140 triangle sets, and 87,000 triangle faces. We process the scene as follows: (1) copy 12 copies of the original scene to form a model with more than 3.13 million vertices, 1680 triangle sets, and 1.04 million triangle faces. ② Convert the triangle set node of the original scene into a triangle fan set node. The created scene has 150,000 vertices, 140 triangle fan sets, 35,000 triangle fans, and 87,000 triangle faces. ③ Copy 12 copies of the scene processed by ② to form a model with 1.88 million vertices, 1680 triangle fan sets, 420,000 triangle fans, and 1.04 million triangle faces. Then, test the system's real-time performance improvement in node data structure and frustum removal. It can be seen from Table 7 that the node data structure has a significant impact on the operating performance of the system. The triangle data organization method removes many shared redundant vertices without changing the total number of rendered triangles, effectively reducing the number of vertices entering the rendering pass and greatly reducing the load on the graphics pipeline conversion stage. From the data measured in scene ① and scene ③ in Table 7 with the frustum culling off, the system

Table 7: Run results under each operating environment.

Frustum culling	Original scene	Scene①	Scene ②	Scene ③
Close 1	40.50/40.50	2.97/2.95	52.86/ 54.25	5.55/5.65
Open 1	40/50	2.88/5.12	54/67	5.60/7.68
Close 2	52.60/52.60	10.45/ 10.45	64.84/ 64.95	18.62/ 18.67
Open 2	52.60/64.95	10.47/ 15.40	65.15/ 86.05	18.48/ 44.01

performance basically has an inverse relationship with the number of vertices entering the rendering channel. It is based on the technical basis of the scene graph. The above frustum culling technology effectively improves the real-time roaming performance of the system, however, it basically has no negative impact on the whole city inspection. It is suitable for designing the frustum culling algorithms with the hierarchical inheritance structure of the scene graph. Relationship: the operating environment ② is the current mainstream PC configuration. From the test results, with the improvement of CPU performance, the system bottleneck problem is significantly reduced. As a comparison, the operating environment ① because of the existence of the host bottleneck, the operating performance of the system is severely limited. The original scene used in the test is a scene database under extreme conditions. Its node granularity is too small, and the average length of the triangular fan set generated is 2.97. If the nodes of the scene can be reorganized and the granularity of the nodes can be increased, it is expected to further improve the real-time rendering speed of the system. Because of the limitation of conditions, this test cannot make a more comprehensive test of the system. However, judging from the results of several tests carried out, it is basically consistent with the expected results, indicating that the optimization strategies and some optimization measures adopted for the design of the scene database and the system are correct.

Assuming that a set of test cases has the same value on the random seed and the virtual world scale, according to the single variable principle, the only remaining variable is the processing amount of the generated entity in each frame. According to each different stage, the generated entity can refer to roads and intersections, road models, blocks and its subdivisions, and building models. In addition, the judging standard for the system is the total number of generated entities and the time consumption in this stage. The detailed results are shown in Table 8.

The test results of block generation and building generation are shown in Table 9.

The number of generated entities in the road map generation stage is composed of two parts, which are divided by backslashes. The front represents the number of roads, and the back represents the number of intersections. The infinite symbol in the processing volume of each frame represents that the system will try its best. All generated entities are processed within one frame.

Set up a different number of points. Under the same leaf node upper limit, the modeling time and searching for different areas are counted, as shown in Table 10.

The statistical results of modeling time-consuming are shown in Figure 4. It can be seen from the figure that when the modeling time-consuming index exceeds a certain value, it will be controlled within a certain range, indicating that the modeling efficiency also tends to be flat.

4.2. Road Planning Simulation Analysis. The results of the road planning simulation analysis are shown in Figures 5 and 6. The entire design takes a long time, and the main focus is on the construction of 3D. The more abundant the early stage collection, the more convenient the later production. In the cooperation between 3D and Sketchup, Sketchup reflects the powerful modeling ability, and the operation is very simple and straightforward. Its unique operation mode greatly reduces the cumbersome modeling. Although it still cannot solve the problem of reducing the number of facets, its calculation method to quickly realize the design intent is worthy of further study. Figure 5 contains 27 road sections and 14 nodes. The evaluation of the degree and weight of each node mainly considers the level of all road sections and the number of road sections connected to the node. The road section level evaluation is in the order of road level, elevated, and urban main road. The city streets are 10, 8, and 5, respectively. The number of road sections connected to the node is set to 10 for more than 5 (including 5 roads), 8 for connecting 4 roads, 6 for connecting 3 roads, and 40 for connecting 2 roads. Take node 1 as an example. The degree of 1 is 4, which means that the number of road sections connected to node 1 is 4, and the value of the degree of the node is 8. The road sections connected to node 1 are all urban arterial roads, and the value of the weight of node 1 is 32. Then, the total value of the degree and weight of node 1 is 40. When the user is currently using a certain project, the two-dimensional allows to create a new road planning scheme or open an existing planning scheme. To open an existing planning scheme, click add road layer in the road planning toolbar. The existing road planning schemes under the project will be displayed in a pop-up dialog box as a list, and the road planning scheme can be loaded optionally. The loaded planning scheme is displayed in the layer display column of the workspace like other layers. If one wants to create a new plan, one may click on the road plan in the menu. It will create a GeoDatabase named by the user and directly add the road data to it, which can be edited. When GeoDatabase is created, other fields include BUILDID, road width, road model, model name, and whether the Z value is set to true. Hence, all straight roads must be assigned z values when they are created. There are three road shapes that users can create: straight, arc, and bezel. It is relatively easy to create a straight line, which is similar to creating a walk-through path. The creation of an arc is determined by the user's selection of two endpoints and a point outside the endpoints, while the besai curve is realized by the two endpoints and two endpoints accidentally selected by the user. When sending these detailed pieces of information to

Table 8: Number of test entities and time-consuming results.

Stage	Road map generation	Road model generation	Total time (ms)
Processing capacity per frame	100	100	
Generated entity volume	1748	1256	1243
Time (ms)	581	662	

Table 9: Block generation and building generation test entity number and time-consuming results.

Stage	Road map generation	Road model generation	Total time (ms)
Processing capacity per frame	200	200	
Generated entity volume	2246	2173	1420
Time (ms)	752	668	

Table 10: Time-consuming comparison of modeling and searching.

Points	Modeling time (s)	Time-consuming to search across the territory (s)	Time consuming for 1/2 environment search (s)	1/4 search time (s)
5000	0.3166577	0.0005462	0.0003653	0.0002036
10000	1.3979071	0.0012484	0.0006729	0.0003256
15000	3.1140531	0.0022874	0.0010817	0.0006336
20000	5.6907177	0.0023428	0.0011845	0.0009681
30000	11.648522	0.0041006	0.0019706	0.0011541

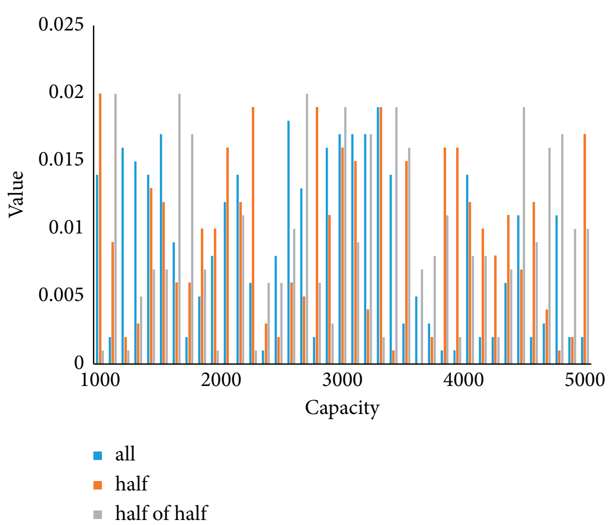

Figure 4: Time-consuming comparison.

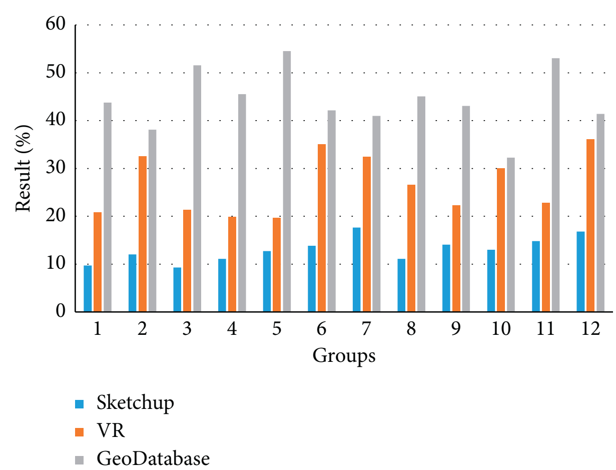

Figure 5: Road planning simulation analysis results.

3D, both the arc and the curve need to be split into small straight lines according to a certain algorithm before being transferred to 3D.

As can be seen from Figure 6, the value of SketchUp is less than 0.5 at different times. The value of VR is not less than 0.5, and the value of Geodatabase is not less than 0.8.

4.3. Rationality of Virtual City Planning. Most of the existing GIS software is two-dimensional or 2.5-dimensional, while the 3-dimensional GIS software is not very mature and complete, whether it is a data model or a practical system. Most of the three-dimensional modeling software focuses on the construction of spatial models, however, for attribute data, the management and query of the virtual reality are not paid much attention. The existing virtual reality VR software mostly focuses on the display and management of the real scene, or it mainly focuses on the management of spatial data, however, it cannot realize the lack of spatial data and attribute the data in the 3D scene. The construction of the urban digital virtual design database platform serves the majority of designers. Therefore, in the construction of the database platform, we must pay attention to the logic of the database platform construction, the simplicity, and convenience of information extraction, and the audience can find the required information quickly and conveniently. In addition, the database platform information should be comprehensive, three-dimensional, and accurate. The rationality

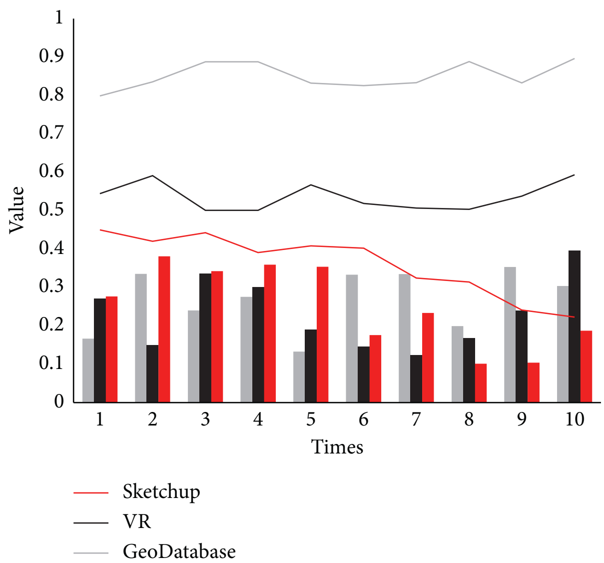

Figure 6: Road planning simulation index analysis.

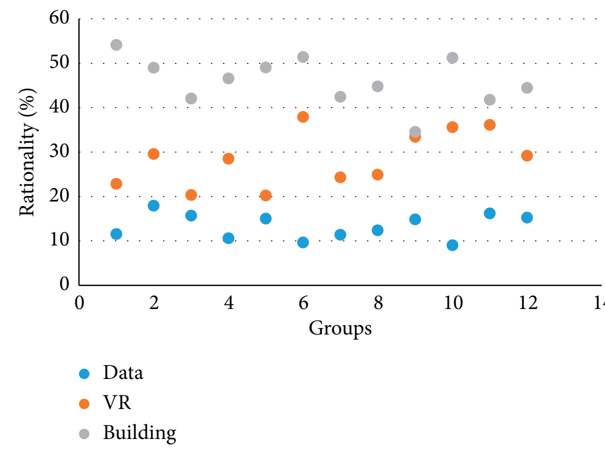

Figure 7: The rationality of virtual city design.

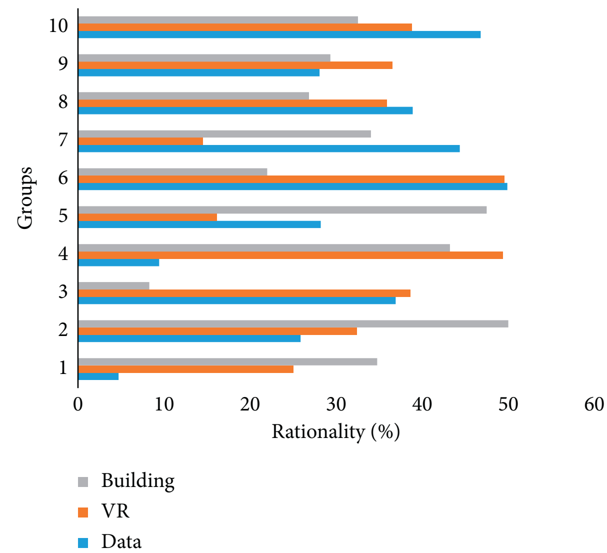

Figure 8: The importance of virtual city design.

of the virtual city design is shown in Figures 7 and 8. Therefore, by the classification and sorting of the modules and textures used in urban design, the overall design idea of the digital database platform is that the information is classified by modules, and the information is distributed from the whole to the part. Virtual reality technology is different from the prerendered 3D animation, which can interactively change the input parameters and observe the changed results in real-time. For example, as long as we enter the date and time, we can observe the shadow changes of any building. Using virtual reality technology, users can locate the viewpoint using the mouse or keyboard in real-time and observe the urban design city from a specific angle (such as the outline of the city skyline, the commanding height, the city's sight corridor, the main road, etc.); and can watch and adjust programs from any angle and scale, quickly select various feasible programs, and give full play to the innovative ability of professionals.

It can be seen from the figure that the building VR and data are of high importance, in which the highest value of data is 40.366%, the highest value of VR is 49.011%, and the highest value of building is 49.472%.

4.4. Optimization Analysis of Collision Detection in Virtual City System. Collision detection technology is one of the important technologies to realize the fidelity of solid simulation in a virtual environment. People require to obtain a visual experience similar to the real world in the virtual world so the touch of objects in the city should be natural and real. The basic idea of system design is to initially establish a PC-based 3D visual simulation software platform by integrating a 3D scene database, real-time visualization system, scene integration function, and 3D scene interaction technology. Because of the limitations of objective conditions in our plan, we did not choose ready-made commercial simulation software products for secondary development. Instead, we used 3D graphics development tools OpenGL and scene graph development kits and combined our optimization in the scene database, some algorithms and technologies accumulated in 3D interaction and visualization are realized in the Visual C++ development environment, a desktop virtual reality application system that integrates scene management and roaming. It provides multiple interactive methods and faces the expression of three-dimensional cities. When designing the system, considering that some GIS software and 3D modeling (modeling) software developed in the market are quite mature (such as ArcGIS series, 3DSMax, Maya, SoftImage, AutoCAD, etc.), there is no need to redevelop 3D for this system. The modeling module should make full use of these software tools to build virtual scenes and import the data into the scene database using the design conversion interface. The collision detection result of the virtual city system is shown in Figure 9. If there are too many objects with collision properties in the scene, it will greatly affect the running speed of the scene. Therefore, the main work of collision detection optimization is to reduce the number of models

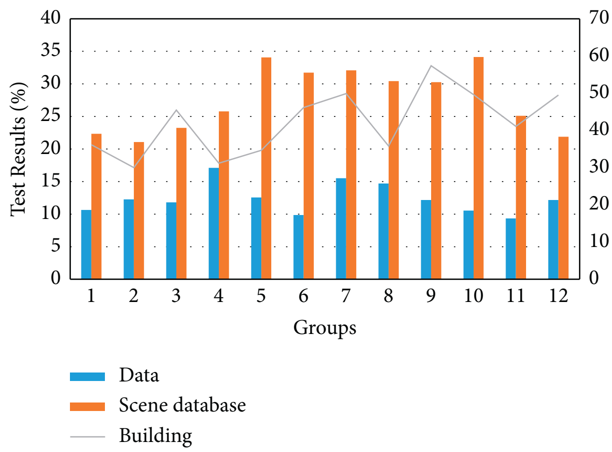

Figure 9: Collision detection result of virtual city system.

and faces of collision detection in the scene as much as possible under the conditions that meet the real situation to optimize the calculation amount of collision detection. The optimization principle is as follows: some surfaces that are impossible to encounter when roaming do not need to be added to the collision, such as the indoor ceiling: a model with complex shapes needs to make a simplified invisible collision body to improve the collision efficiency. In addition to the function of creating urban scenes, this module can also be used to build roaming scenes, such as walking, flying, jumping, providing multiple cruise modes, making people feel that they are in this virtual city and are roaming this place from their own perspective. In the city, it can also be recorded and played back in movie mode during the cruise. At the same time, the information of various things in this scene can be easily inquired. In this system, there are many interesting and practical small tools, such as some useful tools in distance measurement and so on. After adding a building, the building is visually displayed in front of us, and every facade can be clearly displayed. At the same time, we can use the mouse to easily adjust the position of the building. For example, we can show the building in different positions, and the direction can also be adjusted. In this way, in future urban planning, we can intuitively understand the situation of the building in the urban space and plan it effectively.

4.5. City Image Analysis. The digital city management information system realizes the integration of various social economy, resource environment, urban management, and public facilities information in a unified geographic reference frame and realizes the basic data exchange and sharing of various departments. The communication effect of the city image system is shown in Figure 10. This system can provide 3D model construction, management, and roaming. Realize the seamless connection between the spatial data of the 3D model and the attribute data, and realize the “map and number mutual check” under the condition of 3D scene roaming. The system can also realize the import of DFX and 3DS data to the 3D model, provide a visual 3D model reconstruction platform, realize the management, scheduling,

Figure 10: City image system communication effect.

and roaming of the 3D scene, and realize the mutual check of the number of figures between the spatial data and the attribute data in the 3D scene environment. To reduce the influence of subjective assignment method on index weight calculation, this research also no longer chooses the Delphi method to establish the index weight but chooses the entropy weight method to calculate the weight of each index. At the same time, because of the comprehensiveness of the image system and the subjectivity of the satisfaction survey, this research no longer uses the AHP analytic method commonly used in the traditional empirical research on urban image communication; however, it choose the gray comprehensive evaluation model to measure the relationship between the satisfaction of individual audience and the satisfaction of the ideal object, so as to judge the satisfaction of the group to the urban cultural system, and finally, form an index evaluation system for urban image system satisfaction. It is hoped that by this evaluation system, the overall satisfaction of the city image system and the satisfaction of various cultural elements can be quantitatively investigated to provide a basis for decision-making to optimize the city image system in the future. After the implementation of virtual reality technology, the per capita awareness ratio of each element cultural carrier has performed well on the whole, reaching more than 40%, reflecting that the audience has a high degree of awareness of the cultural carrier of urban cultural elements. The venues are all familiar. Historical and cultural carriers have the highest awareness, with an average awareness rate of 63.2%. Urban image communication is essentially a subjective process in which various aspects of urban development are selected according to the established standards, integrated, and spread within a certain range in a perceivable form. It is a subjective process. Correspondingly, the urban culture in urban communication has gone through the process of screening by the communication subject according to the standards. Therefore, the urban culture in urban communication has gone through two aspects: historical choice and social choice, which also endows the unique and visible characteristics of urban culture in urban communication.

In this part, we analyze the test results of the system, road planning simulation, the rationality of urban planning, the optimization of system collision detection and urban image, and verify the excellent performance of the urban image construction system based on virtual reality technology.

5. Conclusion

The effect of city image communication discussed in this article mainly refers to the function and role of city image communication. The effect of city image communication is an audience-oriented study of communication effect. Consistent with the demand analysis results of the system, this digital city simulation model platform is divided into several different components according to different special demand conditions. Firstly, get the data for this city. Then, design an input and output model to convert the acquired digital model. Convert different formats into Openflight format, or convert the output Openflight model into other different formats. It is an inevitable trend of modern information technology development to apply 3D visual simulation technology to the fields of urban construction and management.

Data conversion from different types cannot be completely consistent compared to this data model and the data structure on our platform. Hence, it requires a tool to edit and reset them. Model editing and restructuring models (MERM) were designed to make this platform more complete. Finally, a scene creation and roaming system (SCCM) was designed to construct the entire city scene and provide a simulation of the entire city to extract the information and scene roaming of the entire city. Each subsystem can run independently. Through the data structure and data model of the platform, all the subsystems are completely integrated.

This research, firstly, introduces the research status and development trend of virtual reality in modern urban design. Then, based on the actual needs of virtual reality, the virtual process is analyzed in detail using the actual application of various collaborative software. Then, it is described in detail how to achieve the comprehensive analysis of technologies, such as virtual results. We believe that the development of virtual reality technology will upgrade the urban planning and management methods from the original traditional technology to a new digital technology stage and solve the long-term problem that the performance and evaluation of urban construction projects by traditional technical methods are not intuitive, true, and realistic. Moreover, the new generation of virtual reality technology has further improved the professionalism, practicability, and cost-effectiveness of digital city technology, so that this originally relatively high-end technology can be more widely popularized and applied.

Data Availability

This article does not cover data research. No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] E. Bastug, M. Bennis, M. Medard, and M. Debbah, "Toward interconnected virtual reality: opportunities, challenges, and enablers," *IEEE Communications Magazine*, vol. 55, no. 6, pp. 110–117, 2017.

[2] L. Vera, M. Florella, and C. Sarale, "Effects of virtual reality immersion and audiovisual distraction techniques for patients with pruritus," *Pain Research and Management*, vol. 14, no. 4, pp. 283–286, 2016.

[3] D. Freeman, S. Reeve, and A. Robinson, "Virtual reality in the assessment, understanding, and treatment of mental health disorders[J]," *Psychological Medicine*, vol. 47, no. 14, pp. 1–8, 2017.

[4] D. Freeman, J. Bradley, A. Antley et al., "Virtual reality in the treatment of persecutory delusions: randomised controlled experimental study testing how to reduce delusional conviction," *British Journal of Psychiatry*, vol. 209, no. 1, pp. 62–67, 2016.

[5] Z. Lv, X. Li, W. Wang, B. Zhang, J. Hu, and S. Feng, "Government affairs service platform for smart city," *Future Generation Computer Systems*, vol. 81, pp. 443–451, 2018.

[6] Y. Tang and M. Elhoseny, "Computer network security evaluation simulation model based on neural network," *Journal of Intelligent and Fuzzy Systems*, vol. 37, no. 3, pp. 3197–3204, 2019.

[7] G. Xiao and Z. Wang, "Empirical study on bikesharing brand selection in China in the post-sharing era," *Sustainability*, vol. 12, no. 8, p. 3125, 2020.

[8] M. S. Elbamby, C. Perfecto, M. Bennis, and K. Doppler, "Toward low-latency and ultra-reliable virtual reality," *IEEE Network*, vol. 32, no. 2, pp. 78–84, 2018.

[9] S. Serino, E. Pedroli, A. Keizer et al., "Virtual reality body swapping: a tool for modifying the allocentric memory of the body," *Cyberpsychology, Behavior, and Social Networking*, vol. 19, no. 2, pp. 127–133, 2016.

[10] G. Saposnik, L. G. Cohen, M. Mamdani et al., "Efficacy and safety of non-immersive virtual reality exercising in stroke rehabilitation (EVREST): a randomised, multicentre, single-blind, controlled trial," *The Lancet Neurology*, vol. 15, no. 10, pp. 1019–1027, 2016.

[11] N. Didehbani, T. Allen, M. Kandalaft, D. Krawczyk, and S. Chapman, "Virtual reality social cognition training for children with high functioning autism," *Computers in Human Behavior*, vol. 62, pp. 703–711, 2016.

[12] C. J. Falconer, A. Rovira, J. A. King et al., "Embodying self-compassion within virtual reality and its effects on patients with depression," *Bjpsych Open*, vol. 2, no. 1, pp. 74–80, 2016.

[13] L. P. Berg and J. M. Vance, "Industry use of virtual reality in product design and manufacturing: a survey," *Virtual Reality*, vol. 21, no. 1, pp. 1–17, 2017.

[14] E. Ronchi, D. Nilsson, S. Kojić et al., "A virtual reality experiment on flashing lights at emergency exit portals for road tunnel evacuation," *Fire Technology*, vol. 52, no. 3, pp. 623–647, 2016.

[15] D. C. Schwebel, T. Combs, D. Rodriguez, J. Severson, and V. Sisiopiku, "Community-based pedestrian safety training in virtual reality: a pragmatic trial," *Accident Analysis & Prevention*, vol. 86, pp. 9–15, 2016.

[16] J. Dascal, M. Reid, and W. W. IsHak, "Virtual reality and medical inpatients: a systematic review of randomized, controlled trials," *Innov Clin Neuro*, vol. 14, no. 1-2, pp. 14–21, 2017.

[17] J. Munafo, M. Diedrick, and T. A. Stoffregen, "The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects," *Experimental Brain Research*, vol. 235, no. 3, pp. 889–901, 2017.

[18] A. Vankipuram, P. Khanal, and A. Ashby, "Design and development of a virtual reality simulator for advanced cardiac life support training," *IEEE Journal of Biomedical & Health Informatics*, vol. 18, no. 4, pp. 1478–1484, 2017.

[19] J. Gutiérrez-Maldonado, B. K. Wiederhold, and G. Riva, "Future directions: how virtual reality can further improve the assessment and treatment of eating disorders and obesity," *Cyberpsychology, Behavior, and Social Networking*, vol. 19, no. 2, pp. 148–153, 2016.

[20] Z. Lv, T. Yin, X. Zhang, H. Song, and G. Chen, "Virtual reality smart city based on WebVRGIS," *IEEE Internet of Things Journal*, vol. 3, no. 6, pp. 1015–1024, 2016.

[21] M. C. Howard, "A meta-analysis and systematic literature review of virtual reality rehabilitation programs," *Computers in Human Behavior*, vol. 70, pp. 317–327, 2017.

[22] S. A. W. Andersen, S. Foghsgaard, L. Konge, P. Cayé-Thomasen, and M. S. Sørensen, "The effect of self-directed virtual reality simulation on dissection training performance in mastoidectomy," *The Laryngoscope*, vol. 126, no. 8, pp. 1883–1888, 2016.

[23] Y. Sun, H. Song, A. J. Jara, and R. Bie, "Internet of things and big data analytics for smart and connected communities," *IEEE Access*, vol. 4, pp. 766–773, 2016.

[24] S. A. W. Andersen, P. T. Mikkelsen, L. Konge, P. Cayé-Thomasen, and M. S. Sørensen, "Cognitive load in distributed and massed practice in virtual reality mastoidectomy simulation," *The Laryngoscope*, vol. 126, no. 2, pp. E74–E79, 2016.

[25] B. S. P. Viñas-Diz a, "Virtual reality for therapeutic purposes in stroke: a systematic review," *Neurologia*, vol. 31, no. 4, pp. 255–277, 2016.

[26] R. J. Menzies, S. J. Rogers, A. M. Phillips et al., "An objective measure for the visual fidelity of virtual reality and the risks of falls in a virtual environment," *Virtual Reality*, vol. 20, no. 3, pp. 173–181, 2016.

[27] T. Jones, T. Moore, H. Rose, and J. Choo, "(512) the impact of virtual reality on chronic pain," *The Journal of Pain*, vol. 17, no. 4, pp. S102–S103, 2016.

[28] P. Rosedale, "Virtual Reality: the Next Disruptor: a new kind of worldwide communication," *IEEE Consumer Electronics Magazine*, vol. 6, no. 1, pp. 48–50, 2017.

[29] T. D. Parsons and A. R. Carlew, "Bimodal virtual reality stroop for assessing distractor inhibition in autism spectrum disorders," *Journal of Autism and Developmental Disorders*, vol. 46, no. 4, pp. 1255–1267, 2016.