3D City Modeling on Infrastructure Construction Using Digital Twin

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Abstract. With the acceleration of global informatization, digital twin (DT) technology is gradually infiltrating into all fields of urban infrastructure construction. Technologies based on CAD (Computer aided design) and VR (Virtual reality) provide strong support for DT cities, and provide new ideas for realizing sustainable development and intelligent governance of cities. Based on CAD and VR, this article discusses the implementation method and framework of infrastructure construction in DT cities. A 3D city modeling algorithm based on CAD and VR is proposed. Through the DT modeling and real-time monitoring of urban infrastructure, intelligent management and efficient operation of urban infrastructure can be realized, and the efficiency and safety of urban operation can be improved. The research shows that the accuracy of the proposed algorithm can reach about 95.61% under the condition of continuous iteration. Moreover, the F1-score of the algorithm can reach 95.99%. The results show that the algorithm in this article has certain reliability. Generally speaking, this research provides useful reference and enlightenment for the infrastructure construction of DT cities based on CAD and VR.

Keywords: Computer Aided Design; Virtual Reality; Digital Twin Cities; Urban Infrastructure Construction
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1 INTRODUCTION

With the acceleration of urbanization and the continuous growth of information technology, urban infrastructure construction is facing higher and higher requirements and challenges. Traditional urban infrastructure construction and management methods have been difficult to meet the needs of modern urban development. Brucherseifer et al. [1] analyzed the digital twin conceptual framework for high critical infrastructure resilience. Digital twins and automation technology play an important role in improving the resilience of critical infrastructure. By using digital twin technology to establish digital models for real-time monitoring and prediction of infrastructure, problems can be identified early and solutions can be developed. Automation technology can monitor and maintain infrastructure in real-time through intelligent devices and sensors, improving the reliability, availability, and security of the infrastructure. Key infrastructure is the pillar of national economic development and the foundation of social stability. With the increasingly severe global security situation, improving the resilience of critical infrastructure has become increasingly important. Digital twins and automation technology provide new ways to improve the resilience of critical infrastructure. Digital twins provide the possibility for preventive maintenance by establishing digital models for real-time monitoring and prediction of infrastructure. Automation technology, on the other hand, utilizes intelligent devices and sensors to monitor and maintain infrastructure in real-time, improving its reliability, availability, and security. In order to meet people's demand for urban infrastructure and the efficiency of urban operation, DT technology is gradually applied to the field of urban infrastructure construction. The essence of DT cities is to map the physical urban space to the virtual digital space one by one, forming a future urban development form of coexistence of reality and reality. Digital technology is the core of computational design, which can transform design data into building solutions and optimize them. In architectural design, digital technology can be applied to the thermal environment, helping architects analyze, process, and solve complex architectural problems more scientifically and reasonably. Chen et al. [2] analyzed a new creative approach to computational design. It organizes design data through algorithms, generates design solutions through rule logic, and optimizes their performance. Therefore, for beginners in computational design, it is very important to understand and master the basic concepts and methods of computational design. Computational designers can collaborate with designers from other fields, such as architects, structural engineers, mechanical engineers, etc., to complete architectural design projects together. By collaborating with other designers, one can learn from each other and exchange experiences, thereby enhancing their computational design abilities. At present, the infrastructure construction of DT cities has become a new urban development model, which can realize the intelligent management and efficient operation of urban infrastructure. DT cities are the key to improving infrastructure, accelerating the construction of hardware environment, improving operational efficiency and improving living standards. Moreover, the DT city is an important facility and basic ability to give the city wisdom, which will lead the smart city into a new stage of development. Digital twin is an integrated technology based on physical models, sensor updates, historical and real-time data, combining the physical world with digital models to provide real-time insights into assets and processes. Cheng et al. [3] analyzed the current application status, research achievements, limitations, and future development directions of digital twins in civil and infrastructure emergency management. With the rapid development of technology, traditional emergency management methods are no longer able to meet the needs of modern society for safety and reliability. The emergence of digital twin technology has brought new solutions to emergency management. Digital twin technology provides valuable time and data support for emergency response by establishing digital models of assets and processes, monitoring and predicting potential risks in real time. By establishing a digital twin model, real-time monitoring and prediction of civil facilities can be carried out, potential risks can be identified in a timely manner, and corresponding preventive measures can be taken. In terms of emergency rescue, digital twin technology can provide accurate navigation and decision-making support for rescue personnel by establishing a digital model of the affected area.

The combination of Digital Twin (DT) and Building Information Model (BIM) has great potential in the maintenance of intelligent buildings. By digitizing the various attributes and states of physical buildings, improvements can be achieved in various aspects such as real-time monitoring of building maintenance, predictive maintenance, and optimization of energy use. To achieve maintenance and improvement of BIM based digital twins, it is necessary to collect real-time data from various sensors and devices, and process and analyze these data in the first place. This places high demands on data processing hardware and software, while also addressing issues such as data noise and data loss. One important application of BIM based digital twins is predictive maintenance. By simulating and analyzing building systems, potential problems can be predicted and maintenance can be carried out in advance. However, to achieve this goal, it is necessary to address the issue of model prediction accuracy. This not only involves the complexity and accuracy of the model, but also needs to consider various uncertain factors in actual operation. Urban functional system consists of two systems, one is people and their social groups, and the other is economic subject and operating environment. The common breakthrough point of both is urban space. In the past, it relied more on material to build the environment, and the future development will rely on both digital space and material space. The basic connotation of digital city includes: the development and application of urban information resources; Urban information infrastructure construction; The growth of urban information technology and information industry; Formulation of standards, norms and regulations for urban informatization; Cultivation of information talents and popularization of information knowledge; Information application, etc. DT city infrastructure construction is a new urban development model, which can realize intelligent management and efficient operation of urban infrastructure. In addition to building a huge and complex DT platform to intelligently process massive data and information, how to build interactive application scenarios in physical space has become one of the key tasks in the construction of DT cities. In the future, the infrastructure construction of DT cities will be further improved and developed, involving more urban infrastructure fields, promoting more scientific and technological innovation and industrial upgrading, and bringing more economic and social benefits.

Augmented reality is a technology that combines virtual information with the real world. Through AR devices (such as smart glasses or mobile phones), users can see virtual objects superimposed by digital information on top of the real world. The advantage of this technology is that it can provide real-time information feedback and guidance in practical operations, thereby improving work efficiency and safety. Digital twin is a technology that simulates physical devices or processes in the digital world. By collecting various data from physical devices or processes, a digital twin model can be established, which can then be used for simulation, prediction, and optimization. Digital twins can monitor the status of devices in real-time, predict their maintenance needs, and even predict potential issues that may arise. Hasan et al. [4] constructed a new type of system by combining AR and DT technologies in construction machinery. This system can provide real-time and accurate information to help operators make better decisions. For example, when operating construction machinery, operators can see virtual information superimposed on the machinery through AR equipment, which can indicate how to proceed with the next step of operation or remind operators to pay attention to potential problems with the machinery. At the same time, using digital twin technology, the status of construction machinery can be monitored in real-time, the maintenance needs of equipment can be predicted, and even potential equipment problems can be predicted. The application of digital twins at the architectural and urban levels has enormous potential. Hu et al. [5] integrate Internet of Things (IoT) data with Building Information Modeling (BIM) to gain in-depth insights into building or urban operations, thereby achieving more effective management and operations. The application of this technology will help improve the efficiency of facility management, reduce energy consumption, enhance safety, and improve the living and working environment. In the future, the development of digital twins will change our way of life and work, and it will undoubtedly be an important technological innovation for the construction industry. Overall, the Internet of Things, Building Information Modeling (BIM), and digital twins are gradually changing our understanding and practice of infrastructure management. The combination of these technologies provides us with a new perspective and tools to understand and improve our living and working environment. Through continuous research and practice, we believe that digital twins will play an increasingly important role in future infrastructure management and operation.

As the explosion point and trillion-dollar market of the next wave of technological innovation recognized by the global scientific and technological community, VR is becoming the focus of competition in the industry. The infrastructure construction of DT cities is realized by DT technology based on CAD and VR. DT technology is a comprehensive technology integrating IOT, cloud computing, big data, machine learning and other technologies, which can realize DT modeling and real-time monitoring of physical equipment. DT cities are an important way to increase the value of urban space and an important means to share the construction and operation costs of smart cities. Through DT technology, we can realize DT modeling and real-time monitoring of urban infrastructure, and realize intelligent management and efficient operation of urban infrastructure. Create a real-life environment similar to a city through VR, add possible urban elements into it, and deduce according to the attributes of each element, so as to verify whether the expected goal of smart city construction is feasible. This article will discuss how to use CAD and VR to promote the infrastructure construction of DT cities. Its innovations are as follows:

① This article presents a 3D city modeling algorithm based on CAD and VR; Moreover, the infrastructure construction framework of DT cities based on CAD and VR is proposed.

② Based on the method of 3D modeling, this article analyzes the 3D visualization technology, and summarizes the key technologies involved in urban 3D visualization. Moreover, the k-d tree is used to effectively manage the obliquely matched point cloud, and it is applied to the multi-view grid model to realize the fast search of the nearest triangle patch of the point cloud, and improve the efficiency of obtaining the missing wall surface of the vertical grid model.

③ In this article, the related data processing methods are studied for the mismatch between terrain and objects in 3D virtual scene. For surface features, the method of embedding feature points and boundary feature line constraints is used to reconstruct the terrain triangulation locally to make the terrain adapt to the features. Moreover, the spatial overlap detection of multi-view grid model is carried out to eliminate overlapping redundant data, the inclined non-redundant points are horizontally projected, and the fine grid data of building facade are obtained by point density threshold segmentation.

Firstly, this article introduces the background and purpose of infrastructure construction in DT cities. The application of CAD technology in urban infrastructure design is discussed. Then, the article discusses the application of VR in urban infrastructure design and public participation. Then, the paper puts forward the infrastructure construction framework of DT cities based on CAD and VR. Finally, the paper summarizes the research results and puts forward some suggestions for future research.

2 RELATED WORK

Computer assisted sketching can be combined with parametric design to better control three-dimensional geometric design. Parametric design allows users to change the geometric shape of a 3D model by adjusting parameters. José et al. [6] used computer-aided sketching technology to parameterize the design of 3D models by drawing trajectories. This method can greatly reduce design time and improve design efficiency. Computer assisted sketching can be combined with constraint modeling to better control 3D geometric design. Constraint modeling refers to adding constraints that constrain the shape and position of a 3D model. By using computer-aided sketching techniques, constraints such as symmetry, tangency, and distance can be added to a 3D model. This method can greatly improve design accuracy and efficiency. Computer assisted sketching can also be combined with reverse engineering to convert existing physical objects into three-dimensional geometric models. Reverse engineering is a technique that converts existing physical objects into digital models. By using computer-aided sketching technology, the contours and shapes of physical objects can be transformed into three-dimensional models, thereby accelerating the product development process. In the 21st century, we are witnessing the rapid development of digital technology, and one of the most promising and challenging areas is Digital Twin. Digital twin technology is widely regarded as an important development direction for future infrastructure management. It collects real-world information, simulates and predicts its performance to achieve more effective, secure, and sustainable management and operations. Lu [7] analyzed the digital twin technologies developed at the architectural and urban levels. Building Information Model (BIM) is an important tool for achieving digital twins. BIM provides full lifecycle management for construction projects by creating three-dimensional models containing physical, functional, and economic information. By integrating Internet of Things (IoT) data into BIM models, we can achieve true digital twins. The Internet of Things technology provides powerful data collection and analysis capabilities for digital twins. Collect environmental data such as temperature, humidity, light, CO_2 concentration, etc. by deploying various sensors in buildings and central cities. By integrating these data with BIM models, we can gain a deeper understanding of building performance for more effective management and operation.

Lv et al. [8] digitize the driver's operational behavior, which can be evaluated, optimized, and trained in a virtual environment. For example, by analyzing the driving habits and operational characteristics of drivers, targeted training and guidance can be provided to help them improve their driving skills and habits, thereby reducing the risk of accidents. Digital twin technology can also be used for safety performance testing and verification of intelligent vehicles. For example, by simulating vehicle collision tests, the safety performance of the vehicle can be tested and the structure and components of the vehicle can be optimized to improve safety performance. After an accident occurs, digital twin technology can be used to reproduce and analyze the cause of the accident. For example, by replaying the vehicle status and driver actions during the accident process, the cause of the accident can be accurately analyzed, providing important basis for accident handling and responsibility determination. Digital Twins (DTs) technology is a cutting-edge technology that combines physical space with virtual space. Its technical elements include sensors, data processing, modeling and simulation, data integration and interoperability, etc. In urban construction, digital twin technology has a wide range of coupling effects and application value. Lv et al. [9] deploy sensors and monitoring systems to collect real-time data on urban infrastructure, environmental quality, traffic conditions, etc., and use digital twin technology for data analysis and processing to achieve real-time monitoring and optimization of urban construction. By utilizing digital twin technology, urban planning schemes can be digitally modeled and simulated, predicting the future development trend and potential problems of the city, and providing scientific basis for urban planning. Digital twin technology can provide intelligent decision-making support for urban construction, helping decision-makers make more scientific and reasonable decisions through data analysis and simulation prediction. The application of digital twin technology can simplify urban management processes, improve the efficiency and accuracy of urban management, and reduce the cost of urban management. Ma et al. [10] used the 3D modeling tools of Auto CAD to create various components in buildings, such as furniture, equipment, decorations, etc., and saved them as blocks or groups for reuse in the building. You can use the texture and color tools of Auto CAD to add appearances to buildings and their components, such as wallpaper, carpets, paint, etc., in order to better simulate buildings in the real world. In addition to the 3D view of the building, multiple different views can also be created, such as plan views, elevation views, and section views, in order to more comprehensively display the structure and functionality of the building. The intelligent marking and measurement tools of Auto CAD can automatically calculate the size and characteristics of buildings, such as area, perimeter, height, etc., in order to better describe and grasp the situation of the building. The secondary development tool of Auto CAD can integrate the above building design and measurement into the teaching system, so that students can operate and practice on computers, and better master architectural design and measurement skills. In summary, using Auto CAD to design a network architecture teaching system requires certain skills and experience, but through continuous learning and practice, a practical, efficient, and interactive architecture teaching system can be constructed.

The efficient and robust registration and model fitting of laser scanning point clouds for pipeline system completion modeling based on cylinders is a complex problem that requires the combination of multiple technologies and methods to achieve. Moritani et al. [11] preprocessed the raw point cloud data obtained from laser scanning to improve the accuracy and efficiency of registration and fitting. Pre-processing includes removing noise, filtering data, and removing outliers. Feature extraction is performed on the pre-processed point cloud data to identify the cylindrical features of the pipeline system. Point cloud processing software or algorithms such as PCA-Based algorithm, RANSAC algorithm, etc. can be used to extract cylindrical features. After feature extraction is completed, point cloud data needs to be registered to align scan data from different perspectives or time points. The registration algorithm can use point cloud registration methods or feature registration methods, such as ICP algorithm, NDT algorithm, SAC-IA algorithm, etc. To ensure the accuracy and robustness of registration, multiple algorithms can be combined for registration, and the registration results can be evaluated and screened. Digital twin refers to the digital model of objects, systems, or processes in physical space in virtual space. This digital model not only includes all the characteristics of physical objects, but also includes real-time data feedback based on the physical object's state. Digital twinning is a technology that has only begun to develop in recent years. Its goal is to achieve effective interaction between physical space and digital space through real-time data sharing and precise simulation, in order to optimize the decision-making process and improve the performance and efficiency of devices. Qian et al. [12] analyzed the digital twin - network replication of physical objects: architecture, applications, and future research directions. Nowadays, digital twins have been applied in many fields, such as industrial manufacturing, urban management, aerospace, etc. In the field of industrial manufacturing, digital twins can help enterprises achieve predictive maintenance of equipment, improve equipment operation efficiency, and reduce losses caused by equipment failures. In the field of urban management, digital twins can achieve real-time monitoring and optimization of urban infrastructure, improving the operational efficiency of cities. In the field of aerospace, digital twins can achieve real-time monitoring and optimization of aircraft, improving their performance and efficiency. The system can also perform spatial analysis, such as analyzing urban spatial structure and terrain through GIS technology. The combination of big data digital city technology and 5G virtual reality can help cities achieve intelligence, improve operational efficiency and management level. In summary, the immersive 5G virtual reality visualization display system based on big data digital city technology is an advanced technology that can provide users with a more intuitive, real-time, and interactive urban data display and analysis experience, providing strong support for the development and management of cities. Waqar et al. [13] analyzed the factors that affect the development of smart cities using advanced digital twin technologies. The core of digital twin technology lies in data. To achieve smart city construction, it is necessary to obtain and process massive amounts of data. The current problems include inconsistent multi-dimensional and multi-scale data collection, insufficient data transmission stability, insufficient data storage and processing capabilities, and imperfect data sharing and opening mechanisms. The application of digital twin technology requires data interconnection between different levels and the extraction of valuable information from the data. However, there are deficiencies in digitization, standardization, and platformization, which make it difficult to achieve efficient and accurate integration and fusion of data. At the same time, there are also issues with the lack of structure, inheritance, and planning in terms of the lifecycle. Yang [14] uses CAD software to sketch and design based on the preliminary interior design plan. During this process, basic information such as the basic layout of indoor space, the shape and size of furniture and decorations can be determined. After the sketch design is completed, the sketch is converted into a 3D model using 3D modeling software. During this process, detailed adjustments and modifications can be made to the model according to actual needs, including its shape, size, color, texture, etc. After the completion of the 3D model shaping, use specific lighting design software to perform virtual lighting design on the model. In this process, it is necessary to determine parameters such as the intensity, direction, and color of the main light, auxiliary light, and background light to simulate the lighting effect of the real environment. Finally, use specific rendering software such as Vray to render the model, and use image processing software such as PhotoShop for post-processing. During this process, adjustments can be made to the color, brightness, texture, and other aspects of the model to achieve a more realistic and aesthetically pleasing effect.

Urban Digital Twin (UDT) is a revolutionary technology that uses data-driven 3D city modeling to help planners make smarter decisions. UDT technology combines physical cities with digital models to simulate urban conditions in real-time, helping planners better understand the current state and development trends of cities. Yosse and Aharon [15] analyzed the social digital twin: the social shift in the field of smart cities. UDT technology uses a large amount of data to build city models, which can come from various sensors, maps, satellite images, etc. Through these data, UDT can provide real-time information about the operational status of cities, helping planners make more accurate and timely decisions. UDT technology can create realistic 3D city models that can be presented in various ways. UDT technology can simulate and predict urban models in real-time. By combining historical and real-time data, it can predict the future development trends and potential problems that cities may face. These predicted results can help planners develop more scientific and reasonable urban planning plans. With the popularization of the Internet of Things (IoT) and artificial intelligence (AI), digital twin technology can collect and analyze a large amount of data in real-time, providing more accurate guidance for disaster prevention and reduction. In addition, policy makers and the business community are increasingly valuing digital twin technology, promoting its widespread application in the field of intelligent disaster prevention and reduction in infrastructure. Yu and He [16] discussed in detail the progress, challenges, and opportunities of intelligent disaster prevention and reduction in infrastructure driven by digital twins, as well as the related content of natural disasters. UDT technology provides a new perspective and method for urban planning and management, helping planners make more scientific and reasonable decisions through data-driven urban modeling. With the rapid development of technology and the promotion of digital transformation, intelligent campuses have become a new development trend. In this context, the intelligent campus digital twin of sustainable comfort monitoring has attracted widespread attention. Digital twin is an integrated technology based on physical models, sensor updates, historical and real-time data, combining the physical world with digital models to provide real-time insights for assets and devices. In intelligent campuses, the application of digital twins helps to improve the efficiency, accuracy, and sustainability of campus management, providing teachers and students with a better learning and living environment. Zaballos et al. [17] analyzed the intelligent campus digital twin for sustainable comfort monitoring. Digital twin refers to the real-time simulation and monitoring of the physical world in a virtual environment through the integration of mathematical models, sensor data, and other information sources. Digital twins can present real-time status of the entire campus in a virtual environment, rather than just individual assets or devices. This helps to improve the overall efficiency and accuracy of campus management. Digital twins can monitor various changes in the campus in real time through sensors and data collection devices, including environment, facility status, pedestrian flow, etc., in order to promptly identify and handle problems. Digital twin is an integration based on physical models, sensor updates, historical and real-time data, combining the physical world with digital models to provide real-time insights into assets and processes. In the construction industry, the application of digital twins can be achieved through Building Information Modeling (BIM), which is a three-dimensional model used throughout the entire lifecycle of buildings from design to operation and maintenance. The existing Level of Detail (LoD) of BIM usually refers to the model accuracy and level of detail that needs to be met at different stages of design and construction. It models various parts of architectural design from rough to detailed levels to meet the needs of different stages. Zhang et al. [18] extended the framework of digital twins with the LoD concept of BIM to construction site management, which can achieve digitalization, intelligence, and visualization of site operations. Improve construction efficiency, reduce costs, enhance safety, and enhance asset management capabilities. In the future, this will be one of the important trends in the development of the construction industry. It can be found that most of the existing research focuses on concept elaboration and technical feasibility, and less on specific implementation strategies and challenges. Based on this, this article mainly discusses the related problems of DT city infrastructure construction based on CAD and VR, and puts forward the infrastructure construction framework of DT city based on CAD and VR.

3 INFRASTRUCTURE CONSTRUCTION OF DT CITIES

DT is a comprehensive application of new generation information technology in cities, and it is an important carrier to realize digital governance and develop digital economy. The virtual real urban space scene based on the DT basic space platform, with the help of intelligent large screen, stereo projection and other display forms, allows urban managers to have their own "urban cockpit", gain insight into the running situation of urban physical space in digital space, and can command and dispatch in real time. Specifically, the infrastructure construction of DT cities includes the following two aspects: ① Global smart facilities: by laying sensors in the sky, ground, underground, river and other aspects, urban roads, bridges, manhole covers, lamp covers, buildings and other infrastructure are digitally modeled. Moreover, we will promote multi-network collaborative high-speed and ubiquitous network access environment such as 5G, WLAN, eMTC, NB-IoT, LTE and their city private networks, and generate an integrated information network integrating the sky and the ground to meet the seamless access of urban data and adapt to different DT city application scenarios. ② High-precision urban information model: DT cities can predict the people and things in the city and realize the optimal operation of the city according to the adaptive changes of various subjects in the city. The core content of this "pre-judgment" technology is a high-precision, multi-coupling urban information model, that is, by loading all the global data, it will converge and fuse in the urban system to realize the identification of urban laws and provide effective guidance for improving and optimizing the urban system. The conceptual framework of DT cities is shown in Figure 1.

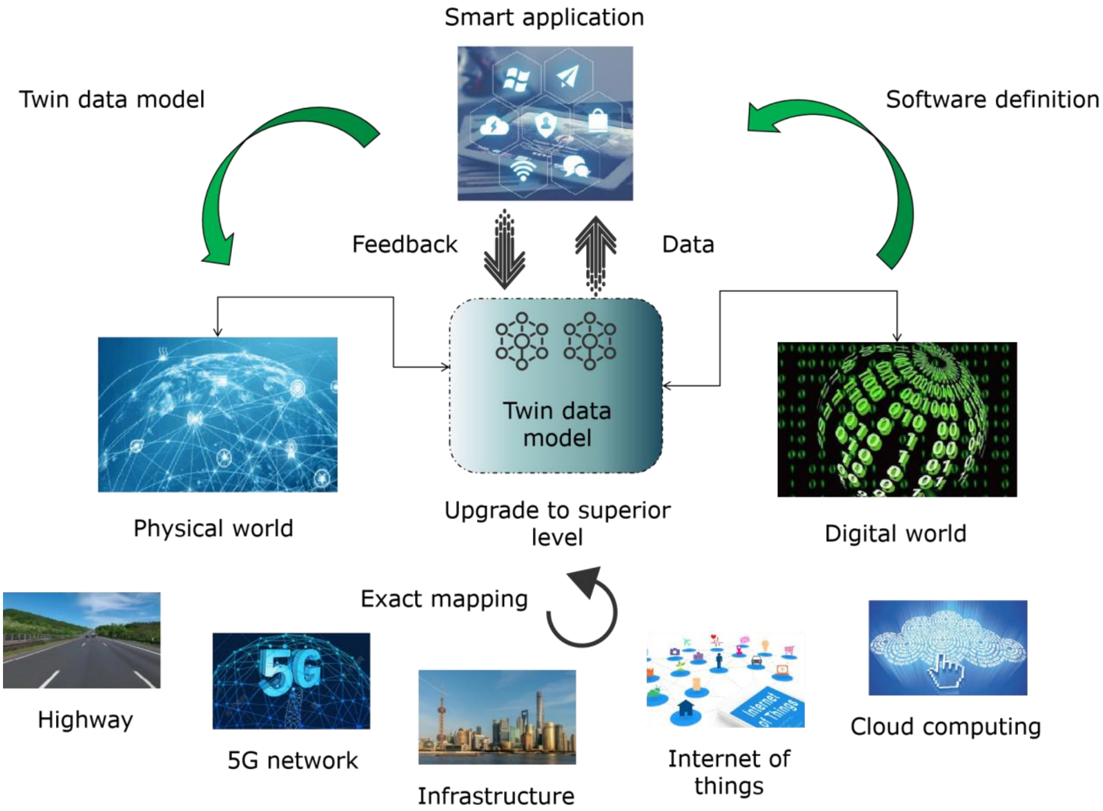

Figure 1: Conceptual framework of DT cities.

The specific process of infrastructure construction in DT cities includes establishing the infrastructure database of DT cities, realizing real-time monitoring and management of urban infrastructure through DT technology, and realizing public participation and transparent decision-making process through VR. Through the infrastructure construction of DT cities, we can realize the intelligent management and efficient operation of urban infrastructure and improve the efficiency and safety of urban operation. The new infrastructure provides the underlying technical support for the construction of DT cities. Through the construction and application of new infrastructure, technologies supporting DT cities, such as 5G, IOT, edge computing, cloud computing and artificial intelligence, will be more mature, and the integration of Internet technology and traditional infrastructure will be promoted to form an intelligent integrated infrastructure, which will promote the transformation of physical cities into digitalization, networking and intelligence. Urban spatial data infrastructure includes three aspects: spatial data benchmark and specification, spatial basic information database, information sharing technology and mechanism. In the past, urban planning was mostly an unchangeable "blueprint planning". However, under the smart planning decision-making mode, it is necessary to gather more refined business perception data and make an all-round dynamic and accurate evaluation of urban development and construction, so as to put forward a people-oriented fine layout scheme and a dynamic allocation scheme of various resources. This article summarizes the DT core into seven elements: physical space, digital space, data, model, control, interaction and service, that is, the interactive relationship between the model with data and the real space management business. Figure 2 shows the overall architecture of DT cities' full spatial data service.

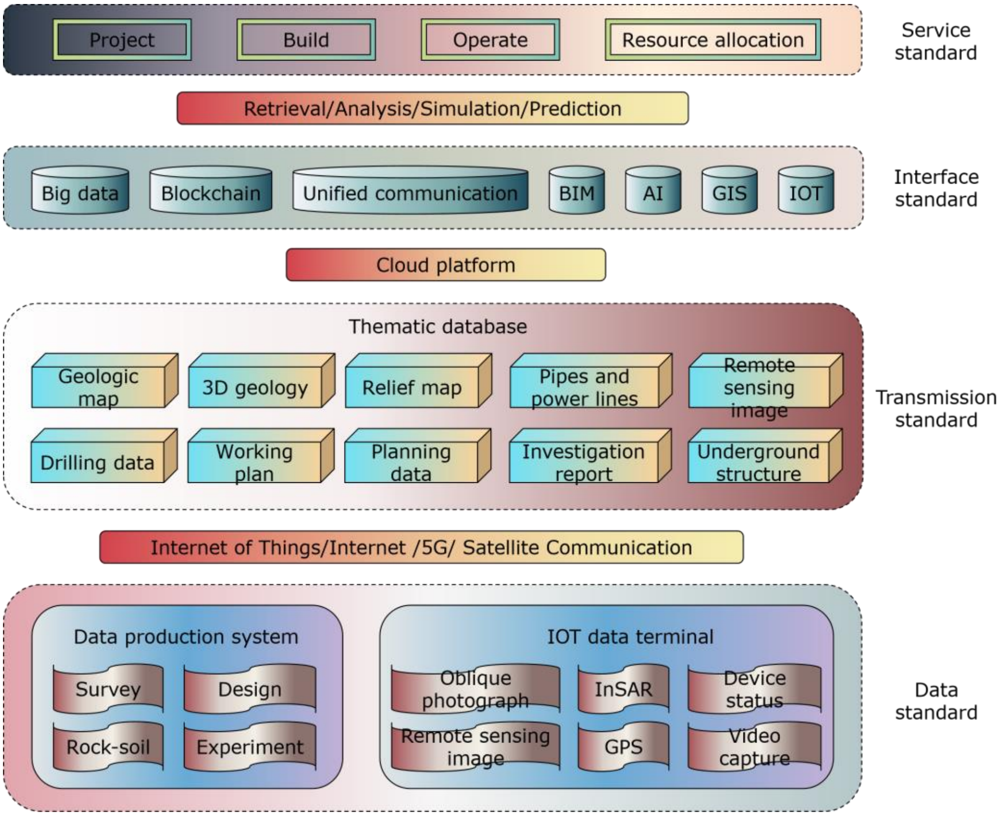

Figure 2: Overall architecture diagram of full spatial data service in DT cities.

The spatial data infrastructure of DT cities is a huge and complex system engineering, which involves the technical system of data collection, transmission and management, including data collection and processing technology, transmission technology and management technology. As the core of the basic layer of the framework, urban spatial data infrastructure provides basic spatial geographic data guarantee for DT cities. Its basic function includes three aspects: as the most basic information for studying and observing urban conditions; Become the public information needed by various urban application systems; As a positioning reference, it can be used by various users to add other thematic information related to spatial location. DT system is a real-time dynamic surreal mapping of physical entity system, so real-time data collection, transmission and update play a vital role in supporting DT. A large number of various types of high-precision sensors work in the front line of the whole twin system and play the most basic sensory role. As the information base of DT cities, the data service system refers to all spatial data objects, including urban spatial planning data, basic geographic data, building BIM data, IOT data and all data related to urban construction and development, such as economy, society and people's livelihood, which are generated in urban management.

4 3D CITY MODELING ALGORITHM BASED ON CAD AND VR

The realization of visualization can also be modeled by VRML of VR modeling language. 3D city visualization includes terrain visualization and ground object visualization. The framework of 3D visualization application system is mainly composed of data extraction and processing module, 3D city generation module and 3D city browsing module. In this article, the fine grid data of the inclined facade of the building obtained by segmentation is used to replace the missing wall surface of the vertical grid model, and the boundaries of the replaced wall surface and the original vertical grid model are automatically obtained, and the gaps between them are spatially patched and interpolated and optimized, so as to realize the seamless integration of the five-dimensional grid models and obtain a complete true 3D modeling of the city. Using the image coordinates of the ground control point and the ground coordinates of its homonym point, the coefficients in the polynomial are calculated by the adjustment principle, and then the image is corrected by this polynomial. The quadratic term correction transformation formula is:

$$x = a_0 + a_1 X + a_2 Y + a_3 X^2 + a_4 XY + a_5 Y^2 \tag{1}$$

$$y = b_0 + b_1 X + b_2 Y + b_3 X^2 + b_4 XY + b_5 Y^2 \tag{2}$$

Where x and y are the original image coordinates of a pixel; X and Y are the ground or map coordinates of pixels with the same name. The number of terms N of a polynomial has a fixed relationship with its order n:

$$N = \frac{(n+1)(n+2)}{2} \tag{3}$$

The coefficient $a_i b_j (i, j = 0,1,2,3,\ldots, N-1)$ of polynomial is solved by using the coordinate values of known control points according to the principle of least square.

In the 3D modeling of DT cities, the required data sources include 2D graphics, topography, surface information, 3D observation data and the texture of the model surface. The amount of data such as geometric models and textures involved in the construction of 3D DT cities is huge, so the performance of computer hardware and software is required. At present, for 3D scenes, the commonly used accelerated rendering algorithms mainly include visibility elimination, back elimination and level of detail method. The real degree of 3D model of ground objects mainly depends on the real degree of texture images pasted on its surface. Texture processing is the processing of texture naming, format, size and mapping method. Digital photogrammetry can provide various geometric and texture data for modeling, and can also provide various topological and semantic information. After obtaining texture data, it needs to be mapped to related buildings to make it authentic. Remote sensing data can provide high-resolution remote sensing images, enable 3D models of cities to obtain detailed and rich geometric and semantic information, generate orthographic images and DTM data, and synthetic aperture radar can provide detailed topographic and geomorphological data, data on the surface of the earth and data below the surface. In this article, the dense matching point cloud of oblique images has a high density and a large amount of data. It is proposed to use kd-tree to manage the scattered matching "point cloud" and improve its subsequent calculation and search efficiency. Compared with ordinary binary tree, kd-tree makes branching decisions according to the hyperplane formed by each layer of resolvers, and generates left and right child nodes, which can realize fast search and retrieval of multi-dimensional data points or multi-attribute data. The schematic diagram of two-dimensional kd-tree creation is shown in Figure 3.

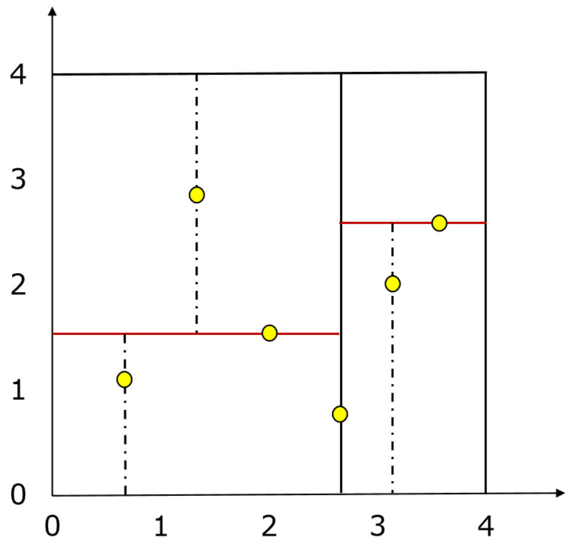

Figure 3: Schematic diagram of two-dimensional kd-tree creation.

A hyperplane H orthogonal to the d dimension divides the d dimension data into two left and right hyperplanes R_l and R_r , and the corresponding hyperplanes are recorded as:

$$H = \{x_d = h; x \in R^k\} \tag{4}$$

Where h is the position of the hyperplane on the axis corresponding to the first d dimension, and the super rectangles R_l and R_r are respectively recorded as:

$$R_l = \{x_d \le h; x \in R^k\} \tag{5}$$

$$R_r = \{x_d \le h; x \in R^k\} \tag{6}$$

To judge whether a vertex is in the visual volume, it is necessary to judge the positional relationship between the vertex and the six planes of the visual volume. This involves the determination of the positional relationship between a point and a plane. The plane in 3D space is expressed by the following equation:

$$Ax + By + Cz + d = 0 \tag{7}$$

Where (A, B, C) is the normal vector of the plane; d is the distance from the origin to the plane. If the position coordinates of a vertex satisfy the above formula, it means that the point is on the plane. If the following formula is satisfied, the point is located on both sides of the plane:

$$Ax + By + Cz + d > 0 \tag{8}$$

$$Ax + By + Cz + d < 0 \tag{9}$$

With this rule, the coordinates of a vertex in the scene can be substituted into six plane equations of the scene to judge whether the vertex is in the scene. As shown in Figure 4.

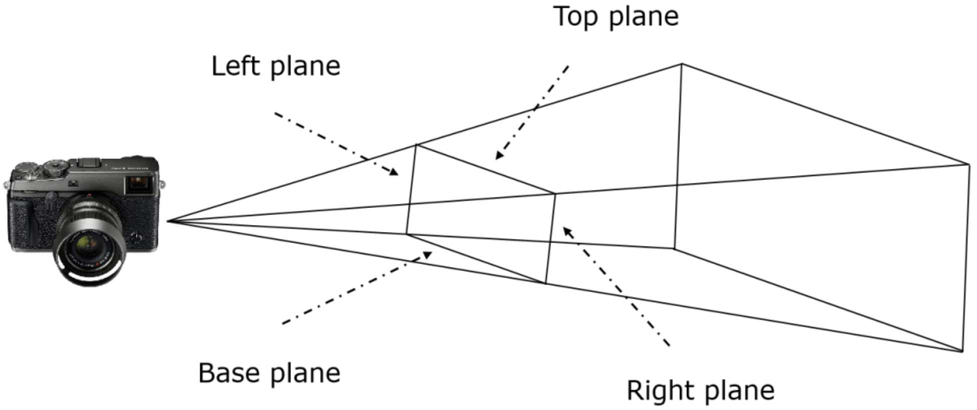

Figure 4: Visual body.

The level detail of the model is to determine the fineness of the model by the distance between the object and the viewpoint. Therefore, this article considers layering, and different levels of models use different surprise degrees, so that the staggered appearance will not cause data pressure, and at the same time, the expected effect can be achieved. Firstly, the two-dimensional vector data is processed, and then the data is imported into 3DMAX software. After the attribute data is entered, the attribute structure is defined on the database platform, and the connection between graphic elements and attribute records is realized, and the logical consistency is checked to establish an attribute database that meets the system requirements. Analyze the data and extract the outline of the building contained in it, then combine the field image and measurement data, import the floor number and elevation data into the software, and start to build a 3D model. After completing the model, import the processed surface texture picture, then map it and check the quality of the model. After passing the inspection, the model is optimized, and the model is optimized by rendering and baking. Finally, export the 3D model and save it.

In this article, the projected horizontal plane is divided into regular grids, and the number of points projected on the grid is taken as the point cloud projection density value on the grid. According to the point cloud projection density value, a normalized grid gray image is formed, and the gray value of its pixels is the normalized point cloud projection density. Because the density values of the ground and the roof are relatively small, the density values of the building facade points are large, so the non-building facade points can be eliminated by setting appropriate thresholds. Because there are few commonalities between complex buildings, most of them need to write rules separately, and the reusability of rules is relatively low. For the same type of buildings, rules can be associated with their own attribute information, just write a general rule and call it repeatedly.

In terrain scene drawing, the display speed is improved on the premise of ensuring the accuracy of terrain display, and DOM and DEM data with different resolutions are selected according to the height of the viewpoint from the terrain surface. The data size of each pyramid has an order of magnitude relationship with the data size of the original image, and its formula is as follows:

$$r(n)=\left[\frac{r(0)}{2^n}\right] \tag{10}$$

$$c(n)=\left[\frac{c(0)}{2^n}\right] \tag{11}$$

Where $r(0)$ is the line size of the original image at the bottom of the pyramid; $c(0)$ is the column size of the original image at the bottom of the pyramid. $r(n)$ is the line size of the n image in the tower; $c(n)$ is the column size of the n image in the tower.

As the interactive layer of urban spatial data, the core of information sharing and management platform is spatial database, which contains a lot of data, such as land use, topography, planning, satellite images and so on. The "coarse" extraction of the inclined point cloud building facade is completed by detecting the intersection of spatial triangles. In view of the inevitable actual error of the data, this article thinks that the existence of a small gap between the two grids is also part of the overlap, that is, the intersection is judged by judging whether the Euclidean distance d from the vertex of the inclined grid to the triangular patch of the vertical grid is within a given threshold range D.

5 EXPERIMENTAL STUDY ON DT 3D CITY MODELING ALGORITHM

Based on CAD and VR, this article discusses the implementation method and framework of infrastructure construction in DT cities. This article proposes a 3D city modeling algorithm based on CAD and VR. In this section, the DT 3D city modeling algorithm is analyzed experimentally. The oblique aerial images needed in this experiment were obtained by MIDAS in the Netherlands. The camera internal parameters of the system are known, the image frame size is 5600×3684 pixels, and the spatial resolution is about 0.15m, all of which have been corrected. The azimuth overlap of oblique images in all directions is about 65%, and the lateral overlap is about 20%. The external azimuth parameters of each oblique image are obtained by aerial triangulation of photogrammetry. The data of 3DGIS system in the study area is mainly composed of spatial data and attribute data. Among them, the spatial data are mainly DEM, image and 3D model. Spatial data is stored in Geodatabase database. The main data layers stored in Geodatabase are shown in Table 1.

Layer name	*Element type*	*Spatial type*	*Explain*
Ludeng	Point	Point	Street lamp position point
Shumu	Point	Point	Tree position point
RoadCenter	Polyline	Line	Road center line
Building	Polygon	Face	Building contour surface
Grass	Multi Patch	Polyhedron	Lawn model
Shumu	Multi Patch	Polyhedron	Trees in the pool area
ShapesBuilding	Multi Patch	Polyhedron	Building model
Tree	Multi Patch	Polyhedron	Independent tree model
Lamp	Multi Patch	Polyhedron	Street lamp model
Meshes	Multi Patch	Polyhedron	Stadium and lawn model
StreetNetwork	Multi Patch	Polyhedron	Road model
Image	Raster	Grid	Remote sensing image of study area
DEM	Raster	Grid	Digital elevation model

Table 1: Geodatabase storage data.

Data sharing technology is the inevitable result of establishing urban basic spatial data facilities. The platform for information sharing and management is managed by the Information Resource Management Center. According to authorization, various data application service platforms can directly access urban spatial basic data facilities, or extract the required data through the information center to form data packets and send them. The information platform can provide vector data, 3D geospatial data and attribute data, and can meet the browsing, analysis and decision-making needs of the government, enterprises and the public. By expanding its application, it can better support the functions of data editing and exchange, display, analysis, statistics, summary, output and maintenance.

In this article, k-d tree is used to manage point cloud data effectively, and it is applied to the spatial overlap detection of multi-view grid model to achieve the goal of searching the nearest triangular patch quickly, thus improving the efficiency of the algorithm. Moreover, redundant data are eliminated by detecting the spatial overlap of multi-view grid model, and the inclined non-redundant points are horizontally projected. The fine grid data of building facade is obtained by point density threshold segmentation method. Table 2 shows the index discrimination results of the algorithm.

Index	*Decision tree algorithm*	*NN algorithm*	*Algorithm in this article*
Recall rate	59.40%	76.71%	92.98%
Degree of accuracy	80.68%	89.48%	95.61%
F1-score	89.66%	89.88%	95.99%

Table 2: Index discrimination results of different algorithms.

In order to show the comparison results of various indexes of different algorithms more intuitively, this article draws the experimental results into a data graph. As shown in Figure 5, the comparison results of the recall rate of the algorithm are shown.

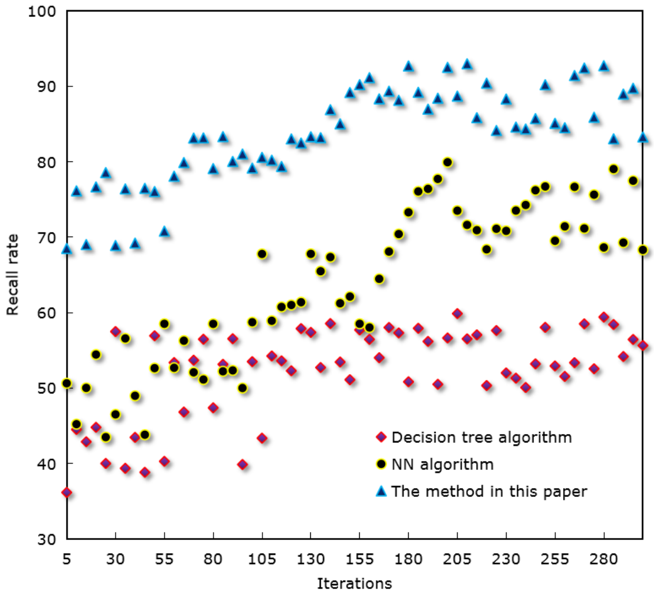

Figure 5: Recall rate of algorithm.

The precision comparison result of the algorithm is shown in Figure 6.

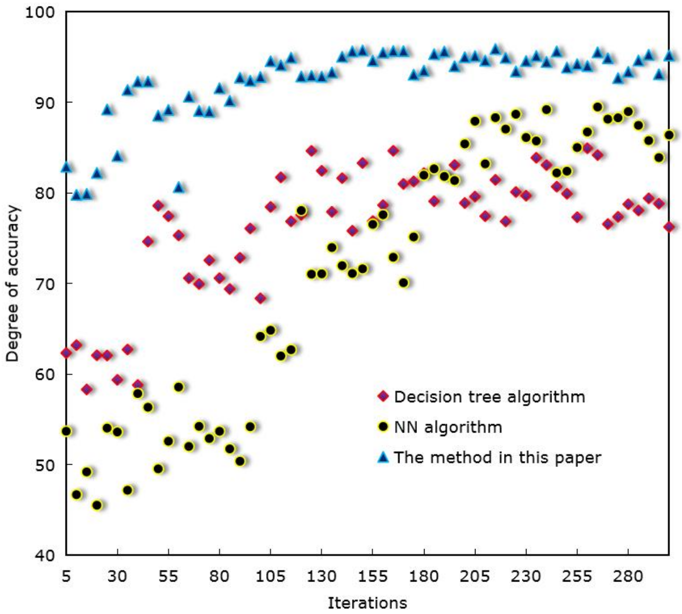

Figure 6: Accuracy of the algorithm.

The F1-score comparison result of the algorithm is shown in Figure 7.

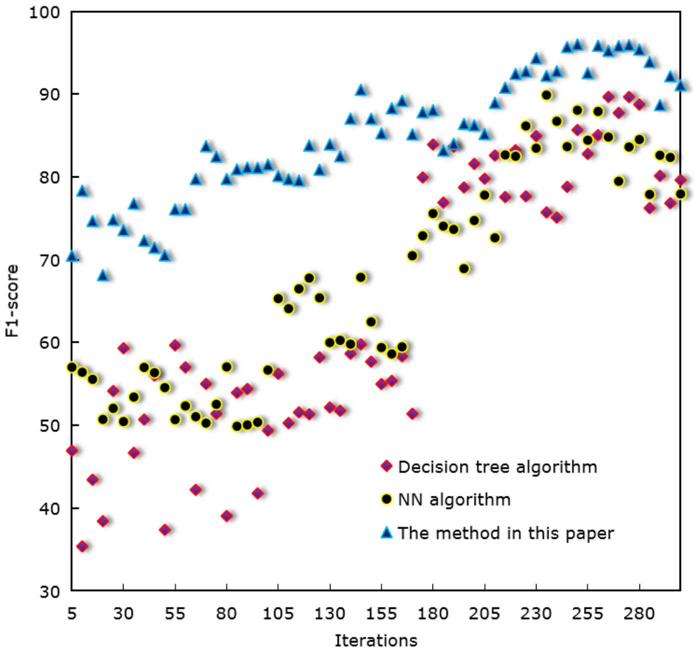

Figure 7: F1-score of the algorithm.

It can be seen that the recall rate of the algorithm can reach 92.98% under the condition of continuous iteration; The accuracy can reach about 95.61%; Moreover, the F1-score of the algorithm can reach 95.99%. All the above results show that the algorithm in this article has good performance.

After the 3D DT city is established, it can be roamed and browsed, that is, it can be observed from multiple perspectives, including zooming, expanding, rotating and pitching, or roamed on the formulated route. If conditions permit, you can also use stereo observation equipment for real roaming. The following is a visual rendering of the true 3D model of the DT city under the fused oblique grid, and the observation and comparative analysis of the viewpoint roaming to verify the effectiveness of the algorithm. Fig. 8 shows an overview of the true 3D model of DT cities using this method.

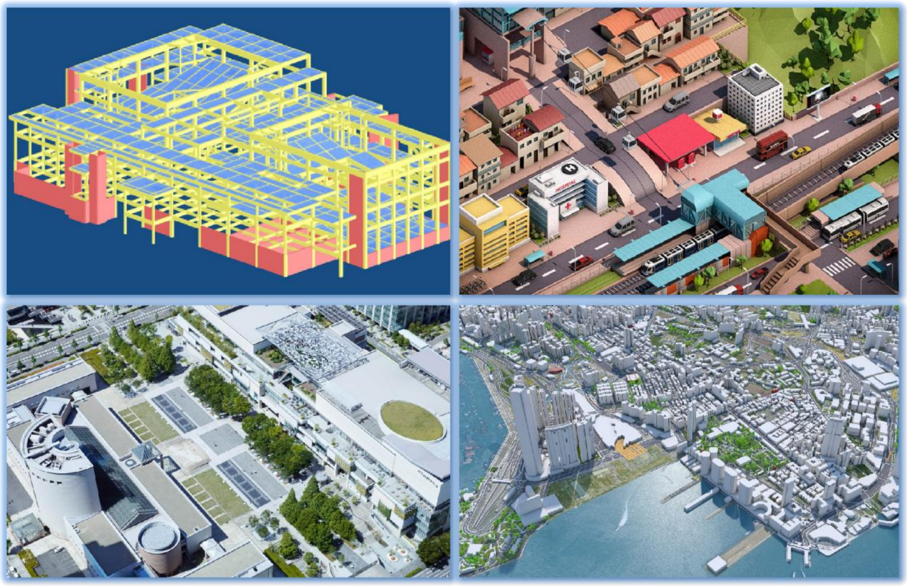

Figure 8: 3D modeling of DT cities.

In the 3D modeling visualization technology of DT cities, 3DMAX technology is used to model, and then database storage software is used to store data. The 3D model is visualized by using the DT city display platform, and it can provide functions such as display, positioning and query. In addition, after analysis, it is found that CAD and VR have played an important role in the infrastructure construction of DT cities. However, there are also some problems, such as inconsistent data standards, difficulty in real-time updating, and low public participation. In view of these problems, this article puts forward the following solutions: ① Establish a unified data standard to ensure that data from different sources can be integrated with each other. ② Develop real-time updating technology to ensure the dynamic and accuracy of DT cities. ③ Strengthen public participation and improve the effectiveness and sustainability of infrastructure construction in DT cities.

6 CONCLUSIONS

DT city endows the city government with the ability of overall planning and real-time governance, which enables public institutions to respond faster and conduct flexible governance. It is an advanced stage of DT city and a new height of smart city. This article analyzes the application of

CAD and VR in urban infrastructure construction in detail, and discusses its advantages and limitations. Based on this, a 3D city modeling algorithm based on CAD and VR is proposed. Moreover, the infrastructure construction framework of DT cities based on CAD and VR is proposed. The framework includes establishing the infrastructure database of DT cities, realizing real-time monitoring and management of urban infrastructure through DT technology, and realizing public participation and transparent decision-making process through VR. Finally, through experimental analysis, it is found that the recall rate of the algorithm can reach 92.98% under the condition of continuous iteration; The accuracy can reach about 95.61%; Moreover, the F1-score of the algorithm can reach 95.99%. All the above results show that the algorithm in this article has certain reliability.

The research in this article provides useful reference and enlightenment for the infrastructure construction of DT cities based on CAD and VR. It is of great significance to improve the efficiency and safety of urban infrastructure, promote public participation and transparent decision-making process. Generally speaking, the infrastructure construction of DT cities based on CAD and VR has great potential, but it still faces many challenges. In the future, we need to further deepen our research. Relevant personnel can verify and improve the infrastructure construction framework of DT cities in practical application, deeply study the influence of public participation and transparent decision-making process, and improve the security and privacy protection ability of DT technology. In order to explore more effective implementation strategies and promote the healthy growth of infrastructure construction in DT cities.

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