

Research Article

Modeling of Residential Environment Artistic Design Based on Multisensor Data Fusion

Yang Yu 

Academy of Fine Arts, Weifang University, Weifang, 261061 Shandong, China

Correspondence should be addressed to Yang Yu; 20110898@wfu.edu.cn

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The development of a 3D city model is accompanied by the continuous progress of technical knowledge, the continuous increase of public interest in it, and the rapid progress of national knowledge. The use of a 3D city model has become the common concern of academia, enterprises, and most users. The article takes the community as an example to summarize the research overview and basic knowledge of the 3D model. From the aspects of 3D city location data collection technology, 3D city model technology, 3D exhibition, etc., the advanced technology in 3D city model, 3D GIS software system, and other issues are discussed and studied, and the current state-of-the-art technology development level is summarized and analyzed. The article first introduces the purpose and importance of the 3D town model and further analyzes the development context, research background, and research content at home and abroad. Secondly, the theoretical basis of the 3D data model, study location data characteristics, location data model configuration, location data survey structure, and location data model construction requirements were put forward. Then, 3DMax software was used to build a house model and finally find it in OpenGL software. The effective distance of the detector is 0.4–3.5 m, and the maximum resolution is 640×480 . It also introduces the realization of 3D architectural model storage and the visual expression of 3D city modeling. The article uses the Kinect depth sensor to recreate a simple static dimensional scene.

1. Introduction

In the process of modernization, 3D modeling of cities is an admirable and challenging task. Exploration and surveying are important measures to build the national economy and national security. In the process of social development, the geographical knowledge obtained through testing provides an important foundation to analyze, express, and explain global changes, and it is also an important platform and guarantee for urban modeling. Based on the analysis of different types of information on the subject, through the city's comprehensive system research, various types of data are exchanged and integrated. The city 3D model is a high-tech computer network model system. It can not only create a virtual computer city but also enable each city to allocate resources. Most importantly, it will encourage cities to support various industries, through digital procurement, integrated computer storage, and management. With the advancement of computer technology, the rapid development of remote sensing technology, photogrammetry tech-

nology, and related technologies can realize the rapid three-dimensional structure of spatial information [1].

Experts at home and abroad also have a lot of research on environmental art design modeling. Ziedan believes that the advancement of 3D mapping and the availability of 3D city models have promoted the development of new technologies for mitigating multipath. He proposed several algorithms that use all available multipath and non-line-of-sight signals to improve the accuracy of city positioning [2]. Meyer et al. proposed an algorithm to track an unknown number of targets based on the measured values provided by multiple sensors. The algorithm achieves scalability with low computational complexity by running propagation on a properly designed factor graph. The redundant formula of data association uncertainty and the "enhanced target state" including binary targets make it possible to use statistical independence to greatly reduce its complexity [3]. AHC believes that the main advantage of 3D is that it can alleviate the degradation problem when training a deep network, so that it can make full use of the performance improvement

obtained by increasing the network depth [4]. Singla and Padia feel that the virtual 3D city model is a digital representation of terrain surfaces, sites, buildings, roads, waterways, etc. Usually, these models are used to present, explore, and analyze urban areas. These models are also used in areas such as smart cities, virtual reality, infrastructure planning, telecommunications, disaster management, real estate services, education, tourism, and change detection [5]. Xie and Lu feel that 3D modeling algorithms include modules that preprocess point clouds, extract tunnel axes, perform coordinate transformation, perform noise reduction, and generate 3D models. The measurement results of TLS were compared with the results of total station and numerical simulation, which confirmed the reliability of TLS [6]. Peronato et al.'s 3D model-based method simulates the solar radiation on all building surfaces, while also taking into account mutual reflections. Therefore, the 3D model is discretized by calculating the solar sensor grid [7].

With the rapid development of science and technology today, nature and creative art must be able to fully meet the needs of the development of the digital age, and new technical forces are needed to enrich and expand the content and density of the environment. It opens up a new way of environmental design, and the 3D application research of art design has jumped out of ordinary horizontal, vertical, and cross-sections. The location and design were observed and tested from different angles to make the work more meticulous and perfect, thereby enhancing the designer's competitiveness. The use of modeling to participate in the display of the program can enrich the means of display, mobilize the enthusiasm of the visitors, increase the value of the design project, and bring prosperity to the related industries of environmental technology design [8].

2. Three-Dimensional Spatial Data Model Analysis and Point Cloud Data Acquisition and Preprocessing

2.1. Spatial Data Management. In the current three-dimensional GIS field, how to effectively manage three-dimensional spatial data is a difficult problem. Most of the 3D geographic information system data is still managed by design visualization. For the three-dimensional representation of spatial entities, a two-dimensional system is used, and only part of the model basically manages and expresses three-dimensional spatial data in a three-dimensional manner. Comprehensive comparison of the feasible data management methods of 3D GIS can be summarized as the following.

2.1.1. File Method. Texture image data and multimedia data, spatial data, attribute data, etc., are all stored in the file system. The file format is organized by custom developer data, such as Arc/Info, MapInfo, and other software stored in custom files. This management method is easier to understand and implement. If the amount of data is not very large and the data does not include simultaneous operations, etc., it can play an active role in a wide range of data. As the amount of data increases, new forms of data types and data

applications will release new functions to computers. This management method can no longer meet the requirements of spatial data management. It is difficult to integrate geometric data management, data attribution, image texture data, etc., which makes 3D GIS software unsuitable [9].

2.1.2. Relational Database. Even if the existing general commercial relational database is used to manage multiple types of spatial data, there are usually two ways to achieve it: using binary data types, such as BLOB. All geometric objects are considered to have points, and X , Y , and Z of each point are stored as a line. The collection of spatial data is a joint operation. No matter which method is adopted, users must modify the spatial data structure, construct, and manage the corresponding spatial index, and the operation is very complicated. At the same time, in terms of spatial data objects, there is still a big gap between binary and correlation tables [10].

2.1.3. Mixed Management. The original data is still controlled by the two-dimensional GIS, in which the geometric data is controlled by the file system, and the quality data is controlled by the business-related database system. In addition, image files are also included in the data. This control method is very common in 3D architectural images and is usually used to create simple simulated scenes. It is expressed with a new data structure from the two-dimensional geographic information system database, which gives the file a new data structure. The reconstruction method is most suitable for expressing images and data files and then using software to create landscape models. The main disadvantage of this method is the lack of effective integrated data management in 3D data management [11].

2.1.4. Object-Oriented Database. Most object-oriented models are the English expression and control of spatial data. It not only supports records of different lengths but also supports knowledge legacy and nesting. Compared with traditional relational databases, object-oriented spatial database management systems have many advantages, such as allowing users to define objects and the structure and operations of objects; increasing the ability to manage internal dynamic data, data connections, and so on; and supporting complex data types, language compatibility, etc. Other object-oriented library systems have been withdrawn and are not used in GIS. However, with the continuous advancement of its theory and technology, object-based databases can become the main management method of GIS spatial data [12]. The performance comparison of database systems is shown in Table 1.

2.2. Three-Dimensional Spatial Data Acquisition Method. Nowadays, three-dimensional geographic information systems are widely used, such as mountainous areas, oceans, mines, and other fields. This is not much different from a two-dimensional geographic information system. The workload of 3D geographic information system is relatively large, and the costly part is data collection, which is an important part of a smoothly running 3D geographic information system. The 3D city model includes many objects, such as

TABLE 1: To compare the performance of the database system.

Project	Oracle	Sybase	Infomix	DB2	MS SQL server
Ease of operation	Relatively high	High	Generally	Generally	High
Stability	High	High	High	High	Relatively high
Compatibility	High	High	Generally	Generally	High
Speed	Highest	High	High	High	Relatively high
Network performance	Good	Good	Difference	Generally	Good
Performance under massive data	The best	Good	Good	Good	Generally
Spatial database structure	Have	Without	Have	Without	Have
Spatial data indexing speed	High	Without	Generally	Without	Generally
Data security	High	High	Generally	Generally	High
Support three operating systems	Yes	Yes	Yes	Yes	Windows only
Support Chinese	Good	Generally	Good	Good	Good
Windows client	Have	Have	Have	Have	Have
Annotation data interface	ODBC, ADO, OLEDB	ODBC, ADO	ODBC	ODBC	ODBC, ADO, OLEDB

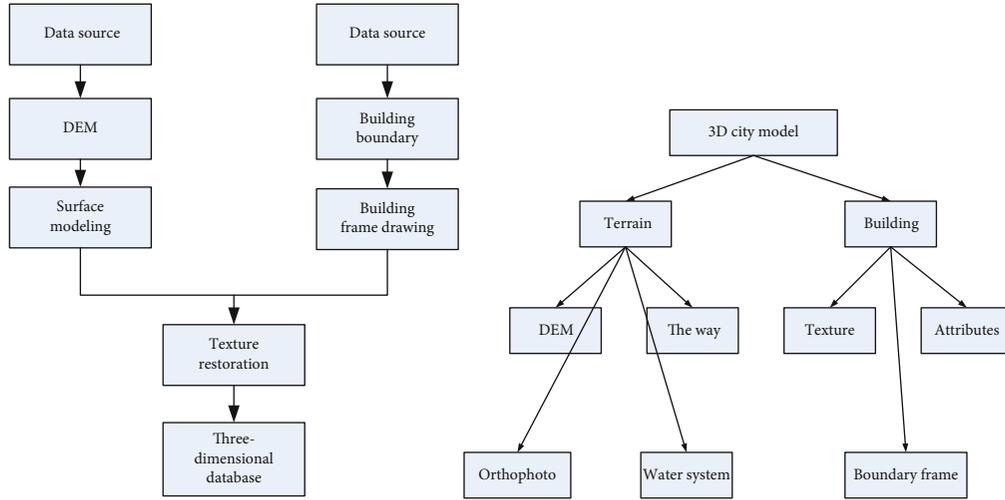


FIGURE 1: The 3D GIS data acquisition process and the 3D city model.

buildings, landscapes, water systems, roads, and plants, but there are two main types of 3D data collection: one is to control the underlying soil trend and soil moisture. Due to the need for in-depth urban management, digital elevation models are usually used to visualize the landscape in 3D GIS and provide users with ground elevation information. The other part is the most important part of the city, and it is often the building that people care about most. The collection methods of these two parts of spatial data are also different, as shown in Figure 1. Surface features such as roads are attached to the terrain DEM for display; shown in Figure 1 is a simple three-dimensional GIS data collection flowchart and three-dimensional city model [13].

2.3. Registration of Point Cloud Data. In the process of Kinect data collection, due to the limitations of the environment and the equipment itself, only the local depth information of the scene can be obtained from one angle. In order to obtain global point cloud data, it is necessary to collect data

on the surface of a certain object model from multiple angles. In order to obtain the complete model surface point cloud data, the point cloud data obtained from different angles should be unified to the camera coordinate system through matrix transformation. This process is called point cloud registration, and finally, these data are merged into one piece to generate the final point cloud model [14].

The relationship between the two sets of point cloud data in different coordinate systems can be represented by a conversion matrix. For a point $X = [x\ y\ z]$ in the point cloud, its homogeneous coordinates can be written as

$$X = [xyz]. \quad (1)$$

Given the transformation matrix H , the transformation relationship between the data point X and its corresponding point X' is as follows:

$$X' = HX. \quad (2)$$

Among them, the transformation matrix H can be written as follows:

$$H = \begin{bmatrix} a_{11} & a_{12} & a_{13} & t_x \\ a_{21} & a_{22} & a_{23} & t_y \\ a_{31} & a_{32} & a_{33} & t_z \\ v_x & v_y & v_z & s \end{bmatrix}. \quad (3)$$

H can be abbreviated as follows:

$$H = \begin{bmatrix} A & T \\ V & S \end{bmatrix}. \quad (4)$$

In formula (4),

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \quad (5)$$

is the rotation transformation matrix, $T = [t_x, t_y, t_z]^T$ is the translation vector, $V = [v_x, v_y, v_z]$, and S are the overall scale factor.

In the process of Kinect obtaining point cloud data, there will be rotation or translation transformations between point cloud data from different perspectives. The matrix transformation here refers to the rigid body transformation; that is, there is no deformation. The problem of point cloud registration is transformed into the point cloud data alignment with the help of translation or rotation transformation of the point cloud data under specific criteria. The Euclidean transformation matrix can be written in the following form:

$$R = \begin{bmatrix} \cos \beta \cos \gamma & \cos \beta \sin \gamma & \sin \beta \\ -\cos \alpha \sin \gamma - \sin \alpha \sin \beta \cos \gamma & \cos \alpha \cos \gamma - \sin \alpha \sin \beta \sin \gamma & \sin \alpha \cos \beta \\ \sin \alpha \sin \gamma - \cos \alpha \sin \beta \cos \gamma & -\sin \alpha \cos \gamma - \cos \alpha \sin \beta \sin \gamma & \cos \alpha \cos \beta \end{bmatrix}. \quad (10)$$

The article is mainly aimed at the registration of rigid objects, so after determining the Euclidean transformation, the above 6 parameters $\alpha, \beta, \gamma, t_x, t_y, t_z$ can be calculated.

2.4. Number of Control Points. According to the transformation formula of formula (2), if several groups of control points in the point cloud data can be found, then the parameters of the rotation matrix H can be calculated. From the formula of the transformation matrix of formula (3), it can be seen that there are 15 degrees of freedom in the formula, and 3 linear formulas can be obtained from a set of corresponding points of the point cloud data in accordance with formula (2):

$$H = \begin{bmatrix} A_{3 \times 3} & T_{3 \times 3} \\ 0_{1 \times 3} & 1 \end{bmatrix}. \quad (6)$$

In the above formula, $A_{3 \times 3}$ is the rotation transformation matrix. When the point cloud rotates by an angle α around the x axis, $Ax(\alpha)$ can be expressed as

$$Ax(\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \alpha & \sin \alpha \\ 0 & -\sin \alpha & \cos \alpha \end{bmatrix}. \quad (7)$$

When the angle of rotation around the y axis is β , the rotation matrix $Ay(\beta)$ is

$$Ay(\beta) = \begin{bmatrix} \cos \beta & 0 & \sin \beta \\ 0 & 1 & 0 \\ -\sin \beta & 0 & \cos \beta \end{bmatrix}. \quad (8)$$

When the angle of rotation around the z axis is γ , the rotation matrix $Az(\gamma)$ is

$$Az(\gamma) = \begin{bmatrix} \cos \gamma & \sin \gamma & 0 \\ -\sin \gamma & \cos \gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}. \quad (9)$$

If the point cloud rotates around the $x, y,$ and z axes in turn, the transformation matrix of the point cloud can be expressed as $R = A_x(\alpha)A_y(\beta)A_z(\gamma)$:

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & t_x \\ a_{21} & a_{22} & a_{23} & t_y \\ a_{31} & a_{32} & a_{33} & t_z \\ v_x & v_y & v_z & s \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}. \quad (11)$$

According to formula (11), to obtain 15 parameters of matrix H , at least 5 sets of corresponding points are needed. Because it is the registration of rigid objects, the coordinate transformation between point clouds is Euclidean transformation, and the transformation relationship is

$$X' = HX \begin{bmatrix} A_{3 \times 3} & T_{3 \times 1} \\ 0_{1 \times 3} & 1 \end{bmatrix}_{4 \times 4} X. \quad (12)$$

It can be seen from formula (12) that at least three sets of control points are needed to find the unique solution of the six parameters of matrix H , but the three sets of corresponding points must not be collinear. Therefore, in order to achieve the registration of point cloud data, it is necessary to find at least three pairs of corresponding points from the point clouds obtained from different angles, which is the key to obtaining the transformation matrix.

2.5. Transformation Matrix Solution. Changing the coordinate transformation of the point cloud data into a nonhomogeneous way, then formula (12) becomes

$$X' = R_{3 \times 3}X + T_{3 \times 1}. \quad (13)$$

In order to eliminate the influence of nonlinear formulas, it is necessary to transform the nonlinear formula system into a linear formula system; then, the Euclidean transformation relationship of the coordinates of the space point becomes

$$\begin{bmatrix} x'_i \\ y'_i \\ z'_i \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix}. \quad (14)$$

It can be seen from the above formula that to obtain the rotation matrix A and the translation vector T in the above formula, it is necessary to find at least 4 sets of corresponding points. If the angle of rotation between the two point clouds is small, then the matrix of its rotation around the x , y , and z axes can be written as

$$A_x(\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & \alpha \\ 0 & -\alpha & 0 \end{bmatrix} A_y(\beta) = \begin{bmatrix} 1 & 0 & \beta \\ 0 & 1 & 0 \\ -\beta & 0 & 1 \end{bmatrix} A_z(\gamma) = \begin{bmatrix} 1 & \gamma & 0 \\ -\gamma & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}. \quad (15)$$

Therefore, the rotation transformation formula of formula (10) can be changed to

$$R_{3 \times 3} = \begin{bmatrix} 1 & \gamma & \beta \\ -\gamma & 1 & \alpha \\ -\beta & -\alpha & 1 \end{bmatrix}. \quad (16)$$

Then, the Euclidean transformation relation of formula (13) can be written as

$$\begin{bmatrix} x'_i \\ y'_i \\ z'_i \end{bmatrix} = \begin{bmatrix} 1 & \gamma & \beta \\ -\gamma & 1 & \alpha \\ -\beta & -\alpha & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix}. \quad (17)$$

Therefore, the above formula can approximate the 6 parameters of the transformation matrix through 2 sets of control points: $\alpha, \beta, \gamma, t_x, t_y, t_z$. Since the corresponding points between the two-point cloud sets we get are not particularly accurate, there will be errors when the transformation matrix is solved by the least-point linear solution. In order to reduce this error, it is usually necessary to find as many control points as possible to limit this conversion relationship, so as to better solve the transformation matrix.

2.6. Objective Function. If N sets of corresponding point pairs are obtained from two sets of point cloud data obtained from different perspectives, the two sets of corresponding points are represented as $Q = \{Q_1, Q_2, Q_3, \dots, Q_N\}$. The transformation matrix between the point cloud data is solved by the relationship between the corresponding point sets, that is, the European transformation matrix H described above, so that the two sets of point sets undergo coordinate transformation, and the registration error between the point sets is minimized. Assuming that the mean square error between the two sets of corresponding points P and Q is $f(H)$, then the problem of solving the nonlinear formula system is transformed into solving the transformation matrix H that minimizes the value of the objective function $f(H)$.

$f(H)$ is what we call the objective function. The objective function has many forms. According to different error measurement requirements, the solution of $f(H)$ is also different. The common forms are as follows.

The distance from point to point and

$$f(H) = f(R, T) = \sum_{i=1}^N Q_i - RP_i - T_2. \quad (18)$$

The sum of squared distances from point to point:

$$f(H) = f(R, T) = \sum_{i=1}^N Q_i - RP_i - T_2^2. \quad (19)$$

Normalized sum of squared point-to-point distances:

$$f(H) = f(R, T) = \frac{1}{N} \sum_{i=1}^N Q_i - RP_i - T_2^2. \quad (20)$$

Point-to-surface distance and

$$f(H) = f(R, T) = \sum_{i=1}^N n_i^T (Q_i - RP_i - T)_2. \quad (21)$$

Among them, n_i represents the unit normal vector of Q_i surface.

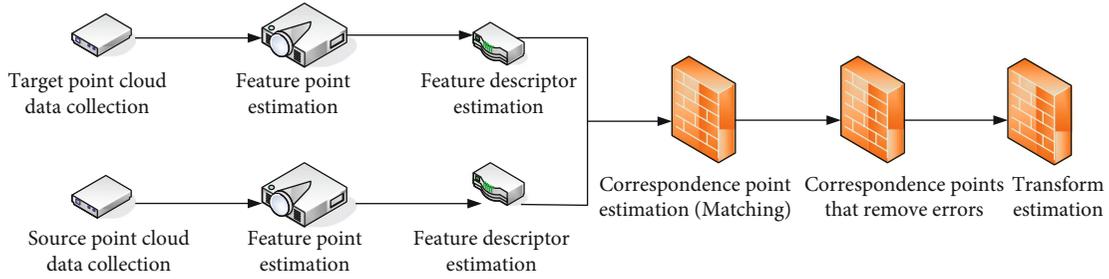


FIGURE 2: Block diagram of the point cloud data coarse registration process.

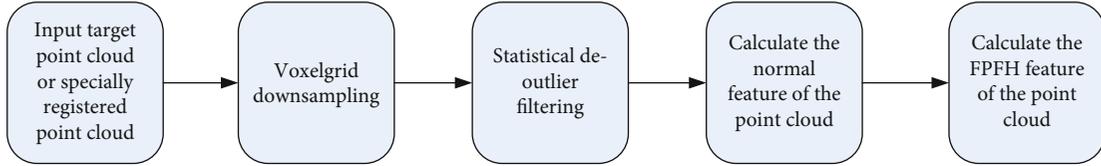


FIGURE 3: Schematic diagram of FPFH calculation process.

2.7. Initial Registration Based on Sampling Consensus Algorithm. The purpose of the initial registration is to estimate the initial transformation parameters between the point clouds under different viewing angles, make them initially aligned, and provide a good initial value for the ICP fine registration. In this paper, the sampling consistent initial registration algorithm (SAC-IA) is used. The main principle is to first calculate the normal of the surface and then estimate the fast point feature histogram (FPFH) descriptor of the surface. Then, according to the feature descriptors, the feature matching and the selection of matching points are performed, so that the transformation parameters between the point cloud data can be obtained quickly and more accurately. The initial registration process of point cloud data is shown in Figure 2.

To achieve SAC-IA registration, first, we need to estimate the fast point feature histogram (FPFH) of the point cloud surface. On the premise of not affecting the detailed features of the point cloud surface, in order to reduce the amount of calculation, the data needs to be processed by downsampling and filtering. Figure 3 shows the flow chart of extracting FPFH descriptors.

The normal vector is an important attribute of the geometric surface, and many operations on the point cloud data will use the normal vector information. For example, when lighting and rendering the surface of a point cloud model, the normal information of the point cloud surface is required to produce an effect that conforms to people's visual habits. The calculation methods of the surface normal of point cloud data are roughly divided into two types: the first one is to reconstruct the surface mesh of the collected point cloud data and then to solve the surface normal vector according to the reconstructed surface. Since the surface global meshing needs to be performed first, the solution of the normal vector will become more complicated; the second method does not need to perform surface meshing on the point cloud data but directly estimates its surface based on the point cloud data. For the normal vector, the latter

method is adopted here. The normal vector approximation of a certain point on the surface can be replaced by the normal of the tangent plane of the surface at this point, which becomes the problem of least squares plane fitting estimation. The least squares method is an optimization algorithm whose purpose is to minimize the mean squared error between the objective function and the data to be measured. Therefore, the normal vector of the estimated surface can be transformed into the eigenvectors and eigenvalues of the covariance matrix between a point on the surface and its neighboring points.

On the basis of Kinect-based 3D reconstruction research, using PCL point cloud library and OpenNI framework, programming in VC++, design a 3D reconstruction system. The system can realize the rapid reconstruction of simple, small-scale scenes. The system is divided into several functional modules. The main functional modules are shown in Figure 4.

The specific functions of each module are as follows:

- (1) *Image Information Acquisition Module.* After Kinect obtains the depth image, it is read into the computer memory through the OpenNI interface and then copied to the video memory.
- (2) *Preprocessing Module.* This module filters the original depth image. The calculation process of each point in the filtering process is independent of the calculation process of other points, and the GPU can be used for parallel calculation. The implementation code of preprocessing is written as a CUDA Kernel function, and each thread calls the Kernel function to process a pixel
- (3) *Point Cloud Computing Module.* First, the module calculates the three-dimensional coordinates of each point according to the depth image collected. The three-dimensional coordinate calculation process of each point has no dependence on the coordinate

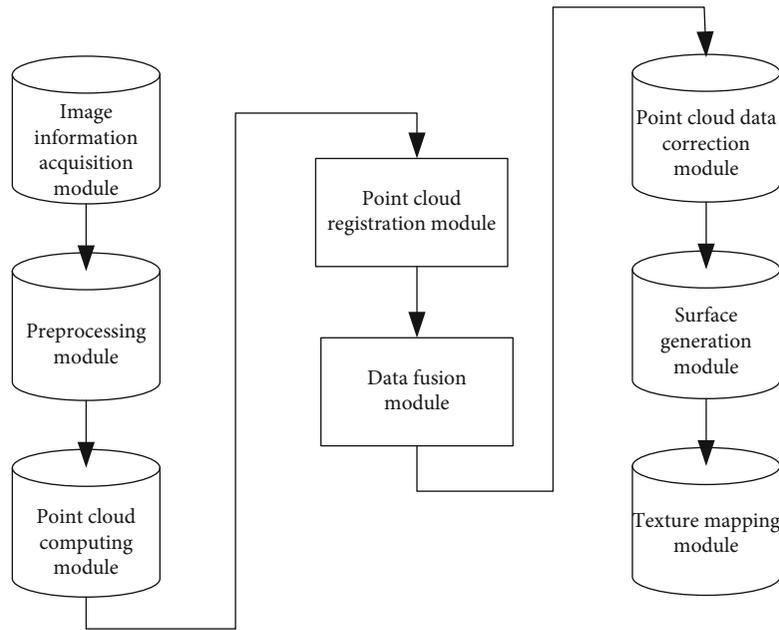


FIGURE 4: Function module diagram.

calculation results of other points, and the GPU can be used for parallel calculation. The code for calculating the coordinates is written into the Kernel function, and each thread calls the Kernel function to calculate the three-dimensional coordinates of a point. Then, the module calculates the normal vector of each point according to the coordinate data. The normal vector calculation process of each point does not depend on the normal vector calculation results of other points. The GPU can be used for parallel calculation, and the normal vector calculation code is written as a Kernel function. Each thread calls the Kernel function to calculate the normal vector of a point.

- (4) *Point Cloud Registration Module*. Firstly, find the corresponding point pair between the point cloud of the current frame and the point cloud of the previous frame, and construct the equation. In this step, GPU parallel computing can be used, and the code for finding corresponding points is written as a Kernel function, and each thread is responsible for finding the corresponding point of a point in the point cloud of the current frame in the point cloud of the previous frame. After constructing the equation, the coefficient matrix of the equation is copied back to the memory, and the transformation parameters are solved in the CPU.

The program module diagram of the 3D reconstruction system is shown in Figure 5.

As shown in Figure 5, the CPU is mainly responsible for the main process of executing the program and the serial calculation part, and the GPU is mainly responsible for parallel acceleration operations. In the process from point cloud pre-

processing to data correction, GPU participates. The parallel computing of GPU can increase the speed of data calculation, so as to meet the real-time requirements of model reconstruction.

3. Workflow of Residential Environment Art Design Modeling

The current mainstream development technology of 3D models has two categories, one is to model stereo images through high-precision aerial photography, and the other is to model stereo images based on low-altitude oblique photography. In order to save costs, considering the existing high-precision aerial photography and 1:500 topographic map data, the project adopts the first method [15]. The main workflow is shown in Figure 6.

The detailed workflow is shown in Figure 7.

3.1. Building Element Modeling. The three standard accuracies of low, medium, and high modeling accuracy of objects are 1 meter, 0.8 meters, and 0.5 meters, respectively.

In the process of community modeling, building model modeling is an indispensable part. The architectural model is between the plan view and the actual three-dimensional space, which closely connects the two to form a three-dimensional model. Building modeling can intuitively reflect the design intent for customers' reference and make up for the limitations of drawings in performance. It is not only a form of design but also a link in the designer's design process, and it is widely used in real estate development, urban construction, design bidding, commercial housing sales, and investment cooperation. The building element model includes the following:

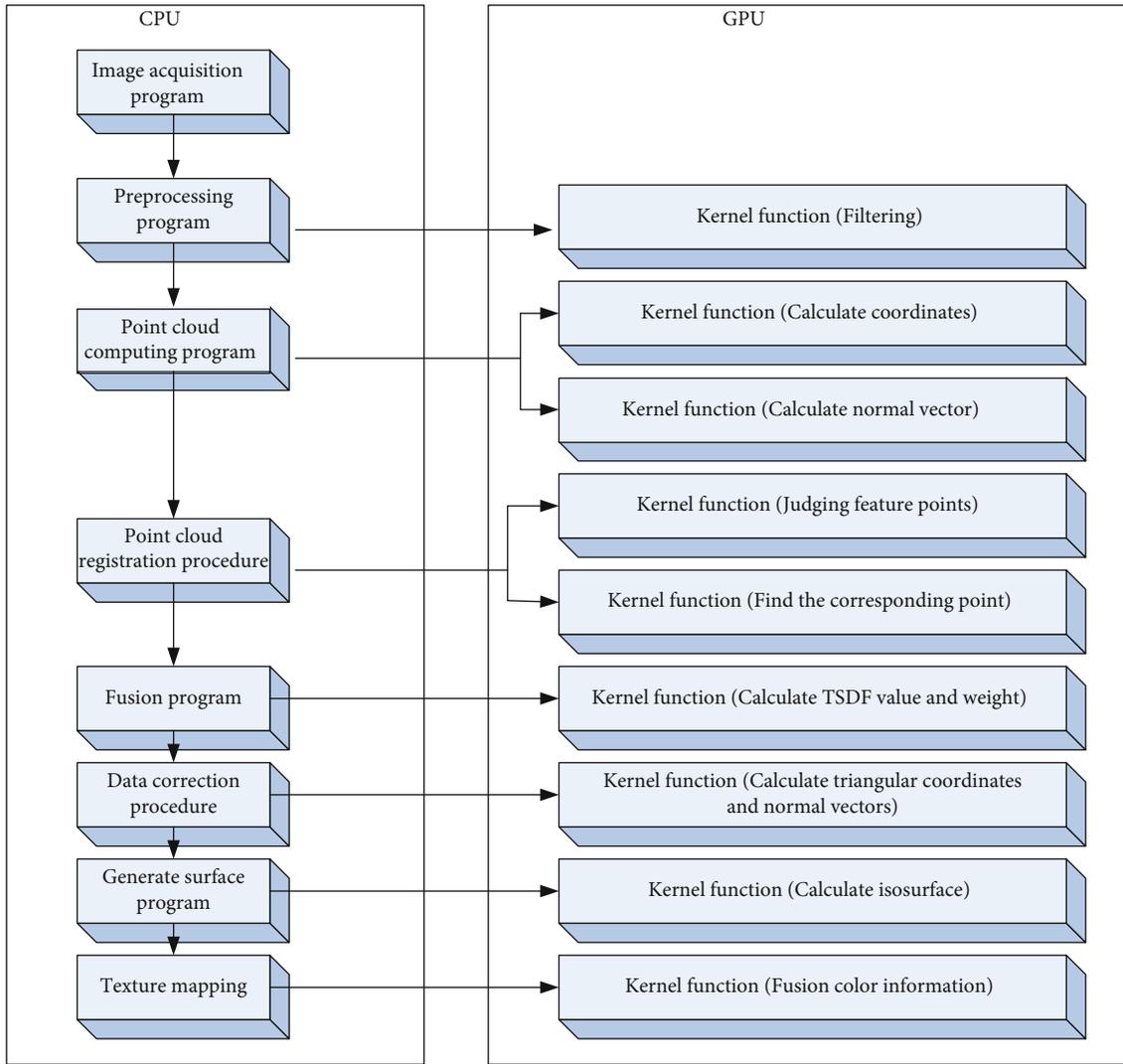


FIGURE 5: Program module.

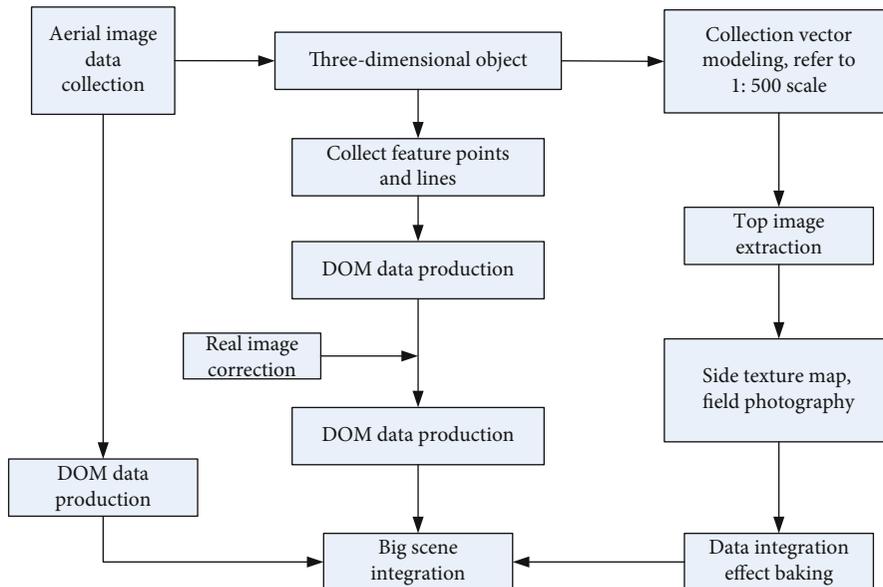


FIGURE 6: Workflow chart.

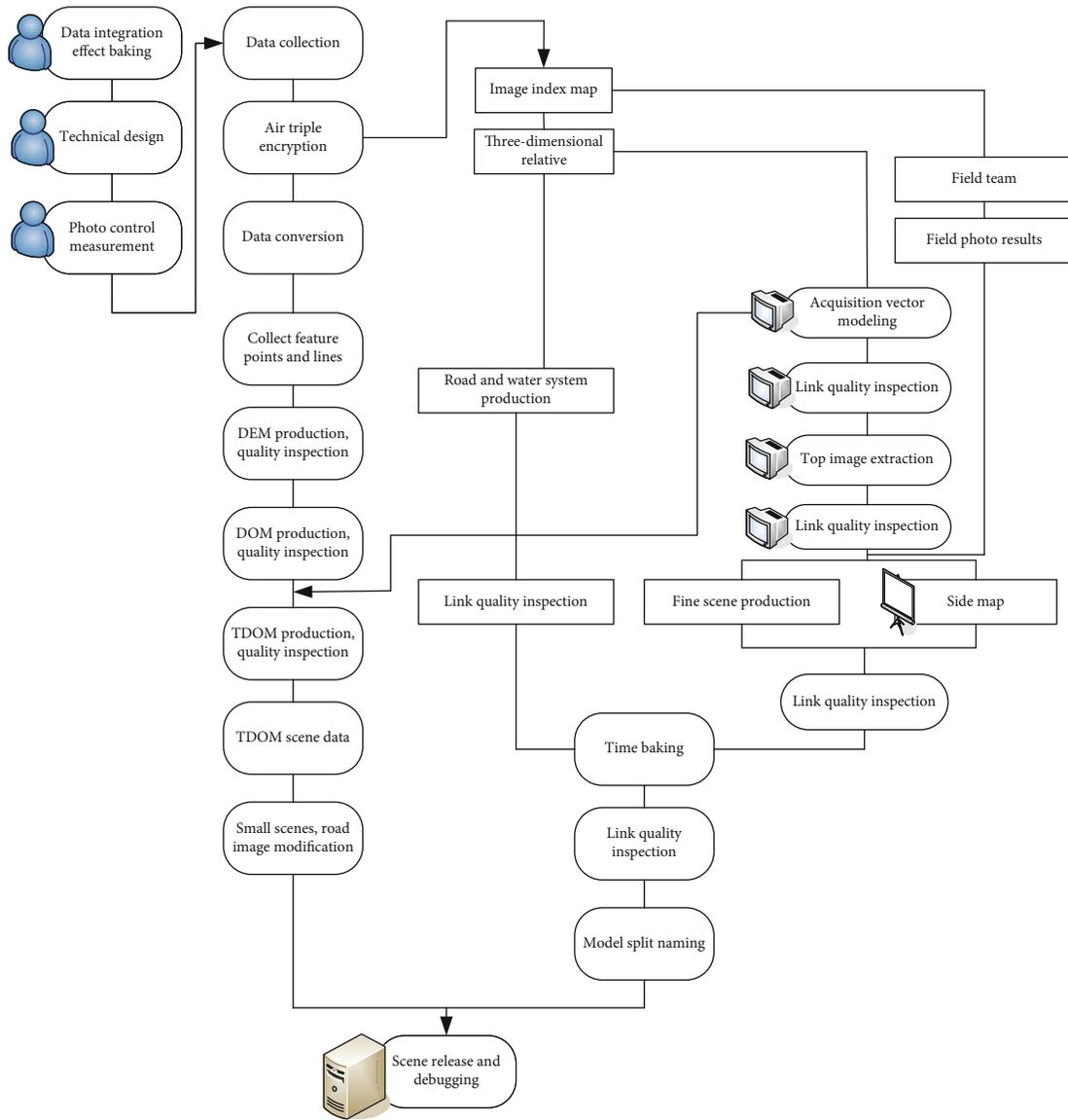


FIGURE 7: The detailed workflow chart.

Building: according to the complexity of the building, location distribution characteristics, and shape, it is divided into the following aspects:

- (1) Simple independent buildings
- (2) Multistorey buildings: this type of building is higher than all types of buildings
- (3) Auxiliary building: it must be determined that it is a building and that it is connected to the main building. There are two situations, one is that both sides are connected to other buildings, and the other is that one side is connected to the main building
- (4) Inner courtyard: it is divided into complex inner courtyard and simple inner courtyard. The complex inner courtyard refers to the open space enclosed by various eaves; the simple inner courtyard refers

to the open space in the flat roof house. Figure 8 shows the accuracy and quantity of buildings and roads

For the model that reflects the modeling object, any size changes such as length, width, height, and other details should not be less than 50 cm. Individual iconic antique buildings should reflect the size change details not less than 20 cm, such as changing the corners of the building's appearance, eaves shapes, door frame styles, windows and balconies, etc. The building model modeling method must meet the following requirements:

Building model production regulations: it is suitable to use technical means such as photogrammetry, laser scanning, or interactive CAD to obtain geometric information, add different types of geometric textures according to its modeling level, and then perform geometric modeling.

Building models must meet the following requirements:

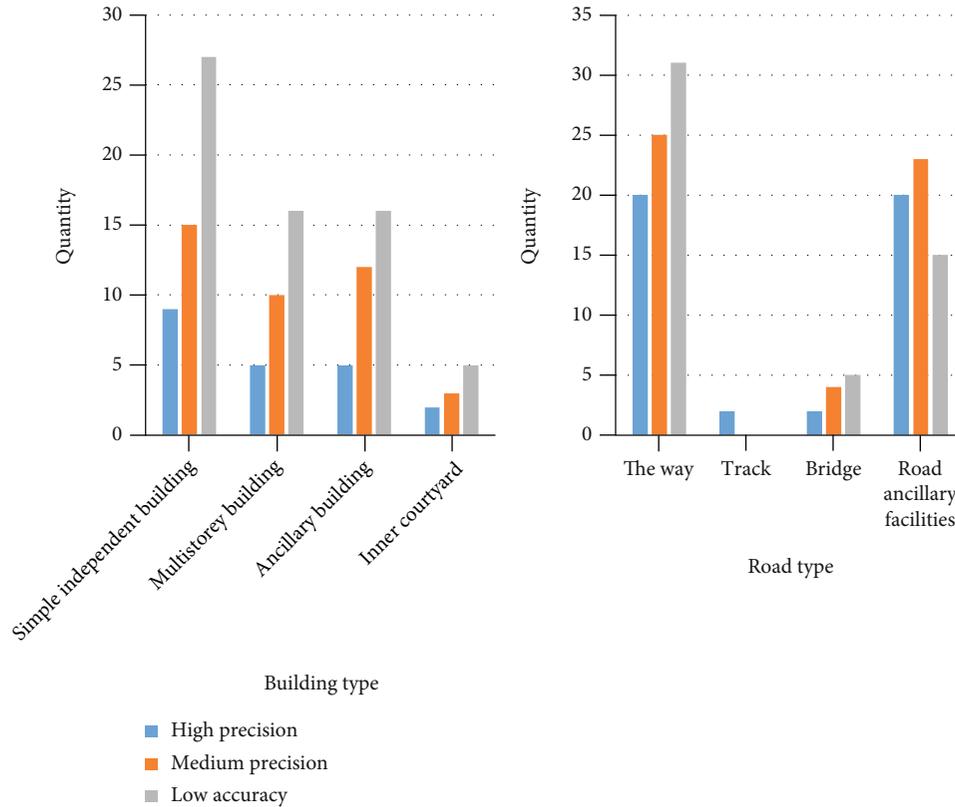


FIGURE 8: Accuracy and quantity of buildings and roads.

- (1) The model should be made according to the architectural design data or the measurement structure of fine instruments
- (2) The roof of the model should reflect details such as accessory equipment and roof structure
- (3) The height accuracy of the model should be better than 1 meter
- (4) The base of the model should be consistent with the topography and be on the same level as the topography
- (5) For more complex buildings whose main body includes a variety of other types of buildings, it can be divided into different types of buildings first and then modeling
- (6) The texture used in the model should be consistent with the appearance of the building; reflect the transparency, color, image, etc., that meet the actual situation; and distinguish the different textures of wood, glass, bricks, etc. Except for the objects modeled in the texture image, there should not be any objects. The changing details of the roof and the facade of the object should be clearly visible
- (7) The complex buildings, arcs, spheres, or folded surfaces whose main body contains a variety of geometric shapes should reflect the main geometric characteristics of the building
- (8) The model should truly reflect the appearance details of the model object. All types of accessory equipment, windows, balconies, and billboards must be clearly marked on the side, and the side contour line should reflect the details of the change on the model. When walking along the modeled object, it can clearly observe every detail of the modeled object, and the original object is consistent with the model [16]. The accuracy of the model in the construction elements should meet the requirements of Table 2

Under normal circumstances, the terrain planning is mostly a large area, which can be a large area of community or the terrain of schools, factories, and so on. Due to the large area of planning terrain, when creating the model, the strict modeling idea is first determined; otherwise, some structures will be missed in the modeling process. The general planning type of terrain contains many different structures, and the model is established according to a certain order of modeling, so as not to miss the actual needs of any structure in the production process. Here, from low to high, the height of the bottom of the model is created in order of space. These models include the underground garage, the surface (including the entrance to the underground cavity that needs to be reserved), the underground garage and the water surface, sidewalks and urban green space, roads and various shops, some steep slopes or steps that vary widely (including pavilions), equipment such as water dock areas, platforms and ramps in places, sports venues, and paving within the community. The modeling

TABLE 2: Model accuracy performance of building elements.

Content	First level	Level 2	Level 3	Level 4	Quantity
Roof	Subject modeling effect	Detailed modeling effect	Subject modeling effect	Subject modeling effect	55
Underwear structure	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	25
Eaves	Subject modeling effect	Detailed modeling effect	No need to show	No need to show	45
Parapet	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	14
Open balcony	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	88
Important roof decoration	Subject modeling effect	Detailed modeling effect	No need to show	No need to show	52
Building	Detailed modeling effect	Detailed modeling effect	Subject modeling effect	Subject modeling effect	75
Large steps	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	53
Eaves	More than 1 meter detailed modeling effect	More than 0.5 meters detailed modeling effect	No need to show	Subject modeling effect	78
Water tank	Symbolic effect	Subject modeling effect	No need to show	Symbolic effect	41
Queti	Symbolic effect	Subject modeling effect	No need to show	No need to show	14
Bottom quotient	Subject modeling effect	Detailed modeling effect	No need to show	No need to show	5
Porch	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	41
Ordinary steps	Subject modeling effect	Subject modeling effect	No need to show	No need to show	25
Launch tower	Symbolic effect	Subject modeling effect	No need to show	No need to show	25
Pillar (pier)	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	4
Facade protrusions or important decorations	More than 1 meter detailed modeling effect	More than 0.5 meters detailed modeling effect	No need to show	Subject modeling effect	75
Flagpole	Symbolic effect	Subject modeling effect	No need to show	No need to show	23
Skylight	Subject modeling effect	Subject modeling effect	No need to show	Subject modeling effect	53
Kiss beast	Symbolic effect	Subject modeling effect	No need to show	No need to show	69
Outdoor stairs	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	87
General population	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	53
Door decorations	Symbolic effect	Subject modeling effect	No need to show	No need to show	12
Chimney	Symbolic effect	Subject modeling effect	No need to show	No need to show	36
Hanging corridor	Subject modeling effect	Detailed modeling effect	No need to show	Subject modeling effect	58
Unit inscription	Symbolic effect	Subject modeling effect	No need to show	No need to show	78

method of the extrusion modifier is used to extract line segments using CAD drawings and add closed lines to make terrain models, which greatly improves the efficiency of use. The extraction of lines and closed lines requires care and patience to successfully complete the modeling of the cells.

Other special requirements: all buildings should be based on the height of the parapet wall. Sidewalks, small bridges, and barns do not need to be collected in the construction area. For the roof decoration, the geometric shape must be modeled on the highest side not less than 2 meters, or the projection surface is not less than 2 square meters. Collect basic houses with building height not less than 2 meters and not less than 2.5 square meters and houses higher than 2 meters and longer than 2.5 square meters. When the length of the structure is too large, it should be divided accordingly. The height of the building usually exceeds 60 meters. In the case of maintaining the appearance of the original house, the height difference shall not exceed 0.5 meters, and the horizontal angle and the house with a level of not more than 0.5 meters can be assembled appropriately according to the situation. Modeling areas of level 4 do not need to model fences and walls. Modeling areas above level 3 should model fences and walls. For shopping malls, enterprises and institutions, government schools, hospitals, high-end residential buildings, and other buildings along both sides of the street, where the height of the parapet wall is not less than 0.5 meters and the width is not less than 0.5 meters, it should be reflected separately. There are parapets on the roof, and in a residential area, the height of the parapets is the standard. For shopping malls, enterprises and institutions, government schools, hospitals, high-end residences, and industrial and mining buildings along both sides of the street, where the height of the parapet is not less than 1.5 meters, except for billboards, the parapet needs to be reflected separately. The parapet wall always needs to be in the form of the house on top of the house, except for the iron fence [17].

3.2. Modeling of Traffic Elements. The community adopts a loop-through road layout. Cars and pedestrians are unblocked, and the arterial roads are clearly demarcated. The road from east to west is a main road in the community, integrating landscape and arterial traffic. Other community-level roads are clearly divided into groups and connected to main roads. Community-level roads have various forms, some of which are responsible for greening or parking. Road modeling can make it more convenient and accurate for customers to see the internal structure of the community on the map, bringing more convenience to customers. Modeling of traffic elements includes the following main contents [18].

- (1) Roads, including urban roads, intercity highways, and rural roads
- (2) Rail transit on the ground, including light rail and railway
- (3) Bridges, including pedestrian bridges, vehicle bridges, and viaducts

- (4) Road ancillary facilities, including roadsides, road traffic signs and markings, fences and vegetation isolation belts, etc.

The modeling method of the traffic element model should meet the following requirements:

- (1) The base of the model should be on the same level as the terrain position and should be consistent with the terrain undulations
- (2) It should accurately reflect the structural characteristics of traffic facilities and auxiliary facilities. Structural features with any dimensional change of more than 1 meter should be 3D geometric modeling
- (3) The texture should have clear details and accurately reflect the material characteristics of the modeled object. The difference and separation between different materials or paving forms should be clearly reflected
- (4) The linear model of the road and its ancillary facilities should be drawn based on the road centerline in the topographical map and should be consistent with the road centerline. The curved line sections can be smoothly processed
- (5) The base contour line should be consistent with the topographical map or design drawing. The curved line can be smoothly processed, and the height of the model can be measured on-site or interpreted by on-site photos

The accuracy of the traffic element model should meet the requirements of Table 3.

3.3. Modeling of Vegetation Elements. Although flowers and trees are not the main buildings in the three-dimensional geographic information system of the community, they play an irreplaceable role in the simulation of the community. There are two types of vegetation models: one is lawn-like area vegetation; the other is flower, wood grain, and other point models. The vegetation element model includes the following main contents: street trees and green spaces planted in rows on both sides of the road and landscape plants grown in communities, parks, and courtyards [19]. Figure 9 shows the relationship between the calculation speed and the number of vegetation. When the number of calculation speeds of the point model is small, the calculation speed is 218 k/s, while the running speed of lawn-like vegetation is stable at 100-200 k/s. The relationship between the number of parts and the speed is mainly evaluated for water objects and buildings in the modeling software.

The modeling method of vegetation elements should meet the following requirements:

One or several methods of CAD, fractal, and other modeling techniques can be used to model.

For example, the process of CAD modeling is as follows:

- (1) Data processing, including field data collection, standard texture production, data distribution, etc.

TABLE 3: Traffic factor model precision performance grading.

Content	First level	Level 2	Level 3	Level 4	Quantity
Road barrier	Terrain effect or no performance	Subject modeling effect	Detailed modeling effect	Main body modeling effect or terrain effect	25
Roadbed	Terrain effect or no performance	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	42
Road noise barrier	No need to show	Subject modeling effect	Subject modeling effect	No need to show	42
Sidewalk	Terrain effect or no performance	Subject modeling effect	Detailed modeling effect	Subject modeling effect	52
Ground road	Main body modeling effect or terrain performance	Main body modeling effect or terrain performance	Detailed modeling effect or terrain effect	Main body modeling effect or terrain performance	34
Road traffic marking	No need to show	Main body modeling effect or terrain performance	Detailed modeling effect	Terrain effect or no performance	19
Road, railway tunnel	No need to show	Subject modeling effect	Detailed modeling effect	No need to show	25
Vehicle bridge	Symbolic effect	Subject modeling effect	Detailed modeling effect	Subject modeling effect	86
Bus station	No need to show	Symbolic effect	Detailed modeling effect	Terrain effect or no performance	38
Train platform	Terrain effect or no performance	Subject modeling effect	Detailed modeling effect	Main body modeling effect or terrain effect	72
Footbridge	Symbolic effect	Subject modeling effect	Detailed modeling effect	Subject modeling effect	25
Rail	Terrain effect or no performance	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	42
High-speed road	Symbolic effect	Subject modeling effect	Detailed modeling effect	Subject modeling effect	24
Overpass	Symbolic effect	Subject modeling effect	Detailed modeling effect	Subject modeling effect	53
Round the island	No need to show	Subject modeling effect	Subject modeling effect	Symbolic effect	25
Traffic barrier	No need to show	Subject modeling effect	Subject modeling effect	Subject modeling effect	42

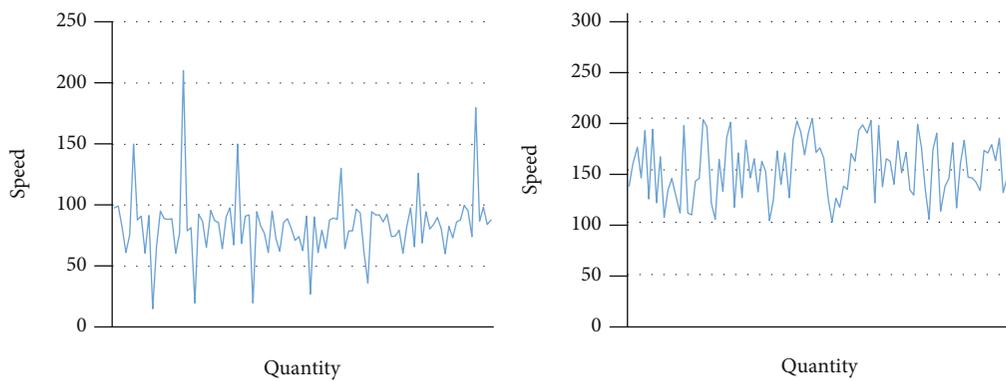


FIGURE 9: The relationship between computing speed and quantity.

- (2) Field research and data collection, collecting information such as shape, location, tree species, distribution, tree height, color, etc.
- (3) Optimization of plant element model data; according to performance and application requirements, the model

- is optimized by reducing the number of geometric faces in the model and reducing the texture resolution
- (4) The model is made to make the model equivalent to the level according to performance requirements and site survey conditions

TABLE 4: Vegetation factor model precision performance grading.

Content	First level	Level 2	Level 3	Level 4	Quantity
Greenbelt fence	Symbolic effect	Subject modeling effect	No need to show	No need to show	54
Flower garden	Main body modeling effect or terrain effect	Subject modeling effect	No need to show	Terrain effect or no performance	24
Hedgerow	Main body modeling effect or terrain effect	Subject modeling effect	No need to show	Terrain effect or no performance	14
Nursery	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	Terrain effect or no performance	Terrain effect or no performance	55
Grassland	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	Terrain effect or no performance	Main body modeling effect or terrain effect	35
Forest	Symbolic effect or terrain effect	Symbolic effect	No need to show	Terrain effect or no performance	85
Tree protection facilities	Symbolic effect	Subject modeling effect	No need to show	No need to show	54
Greenbelt fence	Symbolic effect	Subject modeling effect	No need to show	No need to show	42
Flower stand	Symbolic effect	Subject modeling effect	No need to show	No need to show	35
Striped greening tree	Symbolic effect	Subject modeling effect	No need to show	Terrain effect or no performance	23



FIGURE 10: Hydrological model.

The modeling plant element model must meet the following requirements:

- (1) The geographic location of plants should be based on topographic maps or DOMs at scales such as 1 : 500, 1 : 1000, and 1 : 2000
- (2) The texture must be true and accurate, can reflect the texture, pattern, and color of each component part of the plant and be clearly distinguishable
- (3) Realizing the fine modeling effects of specific modeling such as landscape plants, small landscapes, cultural relics, and tree species
- (4) It is suitable for the complete element modeling of branches, leaves, and trunks and the modeling of plant elements. It can use wooden models or can use fractal techniques in architecture
- (5) The collocation and positioning of landscape plants must conform to reality

The model accuracy of vegetation elements should meet the requirements of Table 4.

3.4. Water System Element Modeling. The water system is an important part of physical geography, and it is of great significance to hydrological research. Under natural conditions, water flows to low places; the initial distribution of the water system can be obtained from the water flow lines in digital topographic maps or other graphics. The water system component model mainly includes rivers, water surfaces, river banks, small bridges, and guardrails. The content is shown in Figure 10 [20].

The modeling method of the water system element model should meet the following requirements:

- (1) The water system element model can be made according to the centerline of the water system in the topographic map, and the curved water system can be smoothly processed. One or several other methods of CAD and other modeling techniques can also be used for modeling
- (2) The water system and its auxiliary facilities must have modeling performance
- (3) The water surface can be represented or modeled by terrain as required, and the water surface texture can

TABLE 5: Hydrological model precision performance grading.

Content	First level	Level 2	Level 3	Level 4	Quantity
Embankment	Main body modeling effect or terrain effect	Terrain effect or no performance	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	52
Bed	Main body modeling effect or terrain effect	No need to show	Main body modeling effect or terrain effect	The effect of the terrain or no performance	41
Reef	Symbolic effect	No need to show	Main body modeling effect or terrain effect	The effect of the terrain or no performance	25
Breakwater	Main body modeling effect or terrain effect	Terrain effect or no performance	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	36
Boiled terrier	The modeling effect of the subject	No need to show	The modeling effect of the subject	The modeling effect of the subject	29
Water surface	Main body modeling effect or terrain effect	Terrain effect or no performance	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	42
Guardrail	The modeling effect of the subject	No need to show	Detailed modeling effect	No need to show	53
Hydrophilic step	The modeling effect of the subject	Terrain effect or no performance	Detailed modeling effect	Terrain effect or no performance	25
Pier	Main body modeling effect or terrain effect	Terrain effect or no performance	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	45
Sluice	The modeling effect of the subject	Terrain effect or no performance	The modeling effect of the subject	Symbolic effect	39
Flood wall	The modeling effect of the subject	No need to show	The modeling effect of the subject	The modeling effect of the subject	42
Dam	The modeling effect of the subject	No need to show	The modeling effect of the subject	The modeling effect of the subject	32
Parking lot	Main body modeling effect or terrain effect	Terrain effect or no performance	Main body modeling effect or terrain effect	Main body modeling effect or terrain effect	53
Hydrophilic platform	The modeling effect of the subject	Terrain effect or no performance	Detailed modeling effect	Main body modeling effect or terrain effect	23
Tidal flat	Main body modeling effect or terrain effect	No need to show	Main body modeling effect or terrain effect	Terrain effect or no performance	11

be represented as dynamic, static animation effects, or translucent effects according to its specific needs

- (4) When modeling auxiliary facilities such as flood walls, guardrails, and river banks, in order to match the display effect of the three-dimensional scene, the DEM should be changed to match the three-dimensional model
- (5) The geographic location of the water system and its ancillary facilities should be based on a topographic map with a scale of 1:2000 or above and can also be determined based on the DOM. The water depth should be interpreted and extracted based on the DEM model, the images obtained by aerial photography, or on-site surveys [21]

The accuracy of the water system element model should meet the requirements of Table 5. Figure 11 shows the relationship between the number and accuracy of water system elements.

The category of visualization technology discussed in this article is to express the indicated cell in the form of a graph or image. In fact, for a large area of the cell model, if an image

is used to express, it is difficult to grasp the layout of tall buildings without specific houses, and if the community model is divided into small units, although it reflects the local topography, it is difficult to grasp the overall situation. A better solution is to use computer animation technology to enable people to swim in the real environment, so as to understand the community environment from both the whole and the local aspects. The so-called animation is actually to release a group of continuous images at a fast enough speed to give people a feeling of continuous movement. That is to say, to form an animation, it is necessary to generate a sequence of consecutive patterns in advance, play them continuously when needed, and store the pattern in the computer. At present, according to the difference between the storage and the hour of each frame, the animation technology is divided into two types: frame animation and graphic array animation. Each image is just a full-screen graphic of a box, saving more memory and getting faster runtime performance.

4. Discussion

The scope of the visualization technology discussed above is to express the cell that is about to be represented in the form

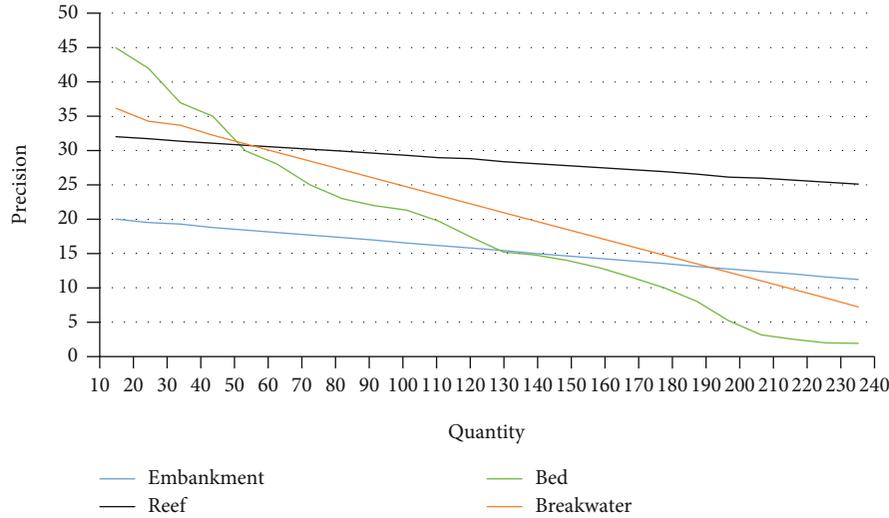


FIGURE 11: The relationship between quantity and accuracy.

of a graph or image. In fact, for a large-area cell model, if using an image to express, it can only see the high-rise buildings but not the specific houses, and it is difficult to grasp the layout. If the community model is divided into small units, it is difficult to grasp the overall situation although it reflects the local terrain. A better solution is to use computer animation technology to enable people to swim in the real environment, so as to understand the community environment from both the overall and the local aspects. The so-called animation is actually to release a group of continuous images at a fast enough speed to give people a feeling of continuous movement. That is to say, in order to form an animation, it is necessary to generate a set of continuous code sequences in advance, play them continuously when needed, and store the graphics in the computer. At present, according to the difference between the storage and the hour of each frame, the animation technology is divided into two types: frame animation and graphic array animation. Each picture is just a full-screen cuboid graphic, which saves more memory and can achieve faster runtime performance [22].

In particular, the constructed three-dimensional spatial data model should meet the following requirements as much as possible: as far as the real performance of the real world is concerned, the accuracy of the description is of course the highest. From the unilateral observation of the application as a whole, meeting actual needs is the most important. From the perspective of database management, the higher the level of detailed real-world description, the greater the amount of geometry and attribute data required and the greater the management difficulty [23]. The description ability of spatial relationship can express the mutual relationship between geographic objects. This is the characteristic of three-dimensional geographic information data model which is different from other data models. Complete and accurate description of spatial relationship is also the basic principle of spatial analysis. In order to make 3D GIS not only a demonstration tool but also a practical tool, the data model must include the description of the spatial relation-

ship. Three-dimensional GIS systems not only deal with some simple single objects but also cover all the characteristics of a given geographic area, and the amount of data is often very large. The speed of data retrieval, which is closely related to this, must also be considered at the same time, which also includes retrieval of geometric information and retrieval of attribute information [24].

Attribute description ability is a means to simulate and reproduce the real world as much as possible. The spatial three-dimensional data model should not only observe the characteristic attributes of things but also pay attention to other manifestations of geometric characteristics. Attributes can be divided into social attributes and physical attributes. The first refers to the inherent properties of the feature, such as ownership, name, and type; the latter refers to the external performance of the feature, such as material, texture, and color. Once this information is available at the same time, the 3D GIS system can satisfy the reproduction of the real world, as well as the repair and query needs in practical applications. The speed and difficulty of 3D imaging visualization are important applications that affect 3D spatial data models. The scale and data model of 3D display are closely related to aesthetics and data structure. For example, the display vector structure data model is better than the grid structure data model, and the effect is more beautiful. At the same time, as the amount of data in the display scene model increases, the 3D rendering speed will also decrease. Therefore, as far as possible, to speed up the effective speed of 3D model display and the degree of appearance, under certain hardware resource conditions, it is also one of the issues that must be considered when establishing a data model. In order to ensure the current nature of the data and serve other systems or projects, the data model has the ability to transform other systems' models, which can not only accept the transfer of other data but also realize the transfer of other data. And to ensure that, during this mutual conversion, the information loss should be reduced to a minimum, and there should be a higher degree of convenience [25].

5. Conclusion

Through the analysis of the development of 3D city modeling at home and abroad, the construction and visualization of the community 3D modeling have been researched, mainly analyzing the meaning and purpose of 3D city modeling; further study its background, combined with domestic and foreign development, to further understand the necessity of 3D city modeling. The theoretical basis of the three-dimensional spatial data model is explained, the nature and distribution of spatial data are studied, the acquisition of three-dimensional spatial data is studied, and the acquisition process and method are carefully summarized. Using 3DMax software to build a residential building model, import the 3ds file into OpenGL, and model the building; finally, use OpenGL software to visualize the model. Research on the theory and foundation of city 3D modeling and visualization, put forward the matters needing attention in the process of texture matching, explain the importance of viewport transformation in visualization, and finally realize the visualization of the district. In terms of three-dimensional data acquisition, although there are many methods to obtain three-dimensional information from the urban landscape, they cannot fully meet the requirements of speed and convenience. Most methods are inefficient and difficult to obtain, and accuracy cannot be guaranteed in engineering operations. From the perspective of landscape modeling, the current data model description items are mainly focused on geographic entities, and there is no general description of the urban landscape in terms of human thinking concepts, nature, and social semantics. In terms of 3D landscape visualization, in order to improve the speed of mass data roaming, landscape, and other aspects, further research is needed to establish a better realism and aesthetic database.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there is no conflict of interest with any financial organizations regarding the material reported in this manuscript.

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