

Design and Implementation of GIS Territorial Space Planning Auxiliary System Based on Real-Scene 3D

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Abstract: The urban three-dimensional geographic information system is an important part of the smart city, and it has become a research hotspot in the field of surveying and mapping geographic information. From the perspective of constructing a three-dimensional urban geographic information system, this paper determines the technology and method for establishing a three-dimensional urban geographic information system. Based on aerial photographs, oblique photographic models and vector data, a three-dimensional urban scene model is established, which combines the traditional land. The spatial planning model is transformed into a modern planning model that takes into account the overall situation and provides reliable three-dimensional geographic data support for territorial and spatial planning and management.

Keywords: Three-dimensional GIS; smart city; urban planning; three-dimensional visualization

Online publication: May 26, 2025

1. Introduction

Compared with two-dimensional GIS, three-dimensional GIS has a stronger spatial description ability and can more clearly represent the urban building structure and urban spatial information^[1]. China's urban construction has entered a stage of accelerated development. Traditional urban planning methods cannot meet the requirements of refined urban management. 3D GIS technology can achieve comprehensive perception and management of cities^[2-3].

Liu Ting et al.^[4] utilized their self-developed 3D GIS software to integrate BIM models and two-dimensional data onto a three-dimensional visualization platform for urban rail transit planning. Lu Jian et al.^[5] combined 3D GIS with the Internet of Things and utilized SketchUp and ArcGIS technologies to achieve virtual reality and management of the farmland environment in the precise corn operation area. Zheng Weihao et al.^[6] utilized CityEngine software to model facilities such as traffic routes and, in combination with specific GIS technologies, implemented a digital twin system for traffic infrastructure. Lou Shurong et al.^[7] used professional software such as 3DsMAX to conduct 3D modeling of underground pipelines, buildings, etc., achieving unified management of various specialized planning contents of underground space.

In the field of territorial space planning, Zhang Chunmin et al.^[8] developed a three-dimensional auxiliary approval

system for urban planning in Changzhou City based on an open platform, achieving three-dimensional integration of above-ground, ground-level and underground Spaces. However, no three-dimensional database was established and the system operation was rather complex. Zhou Xiaobo et al.^[9] developed a three-dimensional planning approval system for Xuzhou City, unifying two-dimensional and three-dimensional data into a spherical space and achieving an organic combination of two-dimensional and three-dimensional data. However, the development cycle was relatively long. Gong Jing et al.^[10] developed the three-dimensional urban and rural planning auxiliary approval system of Zengcheng City using the Skyline TerraSuite platform software, which realized the display and review of planning results, as well as the query and analysis and evaluation of planning information. However, its three-dimensional spatial analysis function is somewhat lacking, and further research is needed in the aspect of the three-dimensional GIS visualization territorial space planning platform.

Starting from the requirements of territorial space planning, this paper selects Skyline as the basic platform for development and uses real-scene 3D data as the underlying data source to design and implement a 3D territorial space planning system. This system can carry out some tasks of territorial space planning from a three-dimensional perspective, manage various types of data more efficiently, improve planning efficiency, and better express the planning effect.

2. Overall system design

The system, guided by the national spatial planning, realizes functions such as 3D scene display of the city, information query, and spatial analysis, assisting urban planning. When designing the system, a multi-layer structure model was formed by using rich COM components, and the design was carried out in layers using the Skyline interface. Based on the specific content of the requirements, design and refine in stages. During the design process, the following aspects are mainly considered:

- (1) In accordance with the application requirements of assisting territorial space planning, design is carried out in a hierarchical manner based on specific requirements to ensure that the functions and documents at the lower level can be directly used by the upper-level functions.
- (2) On the basis of ensuring functional integrity and robustness, integrate the same processing flow in the same stage.
- (3) Make full use of the functional components and auxiliary development interfaces in Skyline to implement and optimize system functions, and improve the working efficiency and reliability of the system.
- (4) Each functional component should be developed as a separate module to ensure the system's scalability and facilitate further expansion of functional modules and in-depth development in the future.

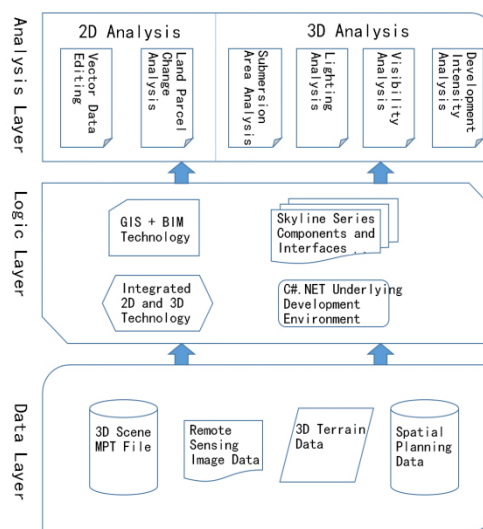


Figure 1. Overall design structure of the system

The overall design structure of the system is shown in **Figure 1**, mainly consisting of three layers: the data layer, the logic layer and the analysis layer.

2.1. Data layer

Data serves as the foundation for the operation of programs. The main data in this system include: urban land use data, urban 3D model data, historical planning data, 3D scene MPT data, etc.

2.2. Logical layer

As an important structure connecting the data layer and the analysis layer, the logic layer contains the system. The NET underlying environment framework and the Skyline secondary development platform. The secondary development interface reserved by Skyline provides a research and development approach for system development. The TerraExplorerPro software is applied to combine urban 3D data, 3D terrain data, vector data, etc. to form an MPT file of the urban 3D scene. By using the existing analysis tools and data processing modules of the Skyline series software, their interfaces are called to create the required analysis tools and expand the system functions.

2.3. Analysis layer

The analysis layer, based on the logic layer, realizes the display of the three-dimensional urban scene. Some analysis tool controls are based on the Skyline component and combine 2D and 3D data to perform basic operations such as viewing, browsing, and analyzing planning data. In accordance with the requirements of assisting territorial space planning, application software development components and interfaces have been applied to realize functions such as light analysis, visible analysis, inundation area analysis, and development intensity analysis, thereby adapting to the increasingly strict urban planning demands and providing different auxiliary decision-making for various requirements.

The analysis layer serves as the channel for communication between the program and the outside world. Interface function buttons enable the invocation of the logical layer, respond to user operations through function buttons, allowing the system to understand user requirements and return the results of the system's execution of user requirements^[11].

3. Detailed system design

The main function of the system is to assist in decision-making for territorial space planning. When evaluating urban planning schemes, it compares the coordination between each scheme and the surrounding environment, thereby selecting the best one. The system takes each demand point as a business development unit and mainly realizes functions such as vector data management, creation of urban 3D models, creation of urban 3D scenes, 3D scene roaming, 3D space query and measurement, vector data analysis, auxiliary planning analysis, and 3D space data analysis, as shown in **Figure 2**.

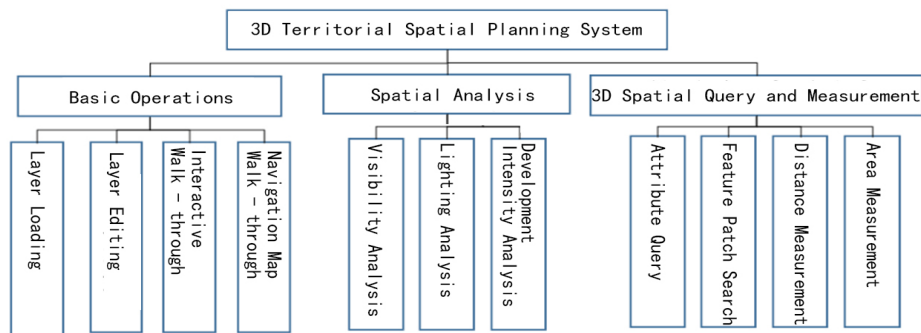


Figure 2. System Functions

3.1. Basic Operations

The basic operations of the system are mainly divided into two modules: vector data management and 3D scene roaming. Vector data management mainly involves viewing, querying and operating vector data. 3D scene roaming can be used to view and roam the 3D scenes of the city.

The specific functions are as follows:

Vector data management mainly involves managing commonly used planning maps in the past, such as urban plot category maps, urban building information maps, cadastral maps, and control detailed planning maps, etc. Vector layers can be loaded and operations such as moving, zooming in, zooming out, hiding, and deleting the layers can be performed.

The three-scene roaming feature offers a free and interactive roaming browsing method. When needed, it can quickly jump to the corresponding layer area, enabling multi-directional and multi-angle viewing of 3D models.

3.2. Three-dimensional Space Query Measurement

The system can query and measure objects in a three-dimensional scene. Attribute query can query and edit the attribute information of the corresponding spatial entity. Spot search can search for spots in vector layers as needed. By entering coordinates, users can directly locate the desired position. It can measure the distance and area between 3D models and other data.

3.3. Spatial Analysis

The spatial analysis module provides auxiliary planning and analysis functions, such as: visibility analysis, lighting analysis, inundation area analysis, development intensity analysis, etc.

The spatial analysis functions mainly include:

Line-of-sight analysis can take a certain point as the observation point to study the line-of-sight situation at another point or in a certain area, including: point-to-point line-of-sight analysis and regional line-of-sight analysis.

Light analysis can examine the changes in the shadows of buildings or terrains after they are exposed to sunlight within a certain period of the day, and visually display the shading effect of buildings on sunlight.

The inundation area analysis function can estimate the situation where a certain area is submerged by floodwaters when the water level reaches a certain height if it is threatened by floods.

Development intensity analysis can estimate the development intensity of a region and present it in a three-dimensional way. This function can help the management department determine more quickly which areas can still be developed and which areas have been overdeveloped.

4. System function modules

The system mainly uses Skyline's TerraDeveloper development controls to load and integrate them. Software development began after the NET environment^[12]. TerraExplorer has a rich set of secondary development interfaces, including the secondary development library of TerraDeveloper, which enables users to independently develop the 3D functions they need^[13]. The system mainly includes the following functions:

4.1. Light Analysis

Lighting analysis is to analyze the sunlight exposure of a building at a set time. In the system, it mainly displays the shadow blocking effect formed by the building on surrounding buildings. The program can drag the slider to view the lighting conditions of buildings at different time periods. The display effect is shown in **Figure 3**.



Figure 3. Sunlight analysis function

The following is the specific implementation method of the sunlight analysis function:

4.1.1. Obtain the shadow of the building

The 3D architectural models in the system are divided into two types: models imported by users and models generated by the system. Among them, the models imported by users are divided into batch import and individual import. In Skyline, the code for 3D buildings imported in batches is IFeature, and the code for individual imports is ITerrainModel. The code of the 3D building model generated by the system is ITerrainBuilding. Among the three models, ITerrainModel and ITerrainBuilding come with the CreateShadow method to generate shadows, while IFeature needs to call the SetProperty function of the feature group IFeatureGroup it belongs to to generate shadows. The code is pFeaGroup.SetProperty("Shadow",1).

4.1.2. Dynamic changes in shadows

The above code can only generate the static shadow, generate dynamic shadows need call interface IPresentation CreatePlayTimeAnimationCustomStep methods of interface, the method can be generated according to the dynamic change one day the sun path, The shadows of buildings will also change with the movement of the sun, creating dynamic effects.

4.2. Visual analysis

Line-of-sight analysis takes a certain point as the observation point to study the line-of-sight situation in a certain area. There are generally two situations in line-of-sight analysis: ① Judging the visibility between two points in arbitrary space; ② Calculate the visible area of the viewpoint^[14]. Visual analysis has a wide range of application backgrounds, such as laying communication lines and building TV station transmission stations, etc^[15].

After setting the observation point and the target point in **Figure 4**, it can be intuitively seen whether the area between the two points is visible. The green area is the visible range, and the red area is the invisible range.

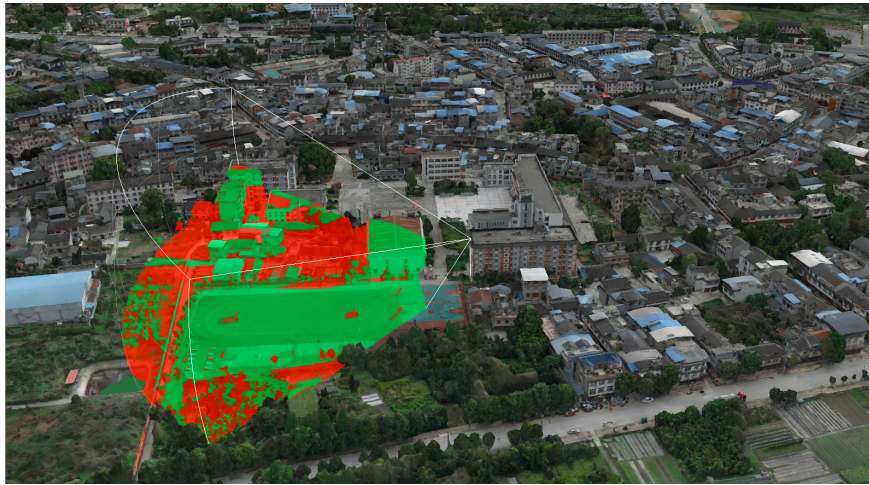


Figure 4. Visual analysis function

The following is the specific implementation method of the visual analysis function:

4.2.1. Set up observation points

When the user clicks, the program acquires the observation point position `IPosition` and calls the `Create3DViewshed` method in the analysis tool interface `IAnalysis`. This method can create a three-dimensional visible area based on a given viewpoint. Then call the `CreateLineOfSight` method in `IAnalysis`. This method will mark the visible range as green and the invisible range as red.

4.2.2. Field of view animation effect

The field of view obtained from the analysis varies according to the distance the user drags the mouse. After clicking the mouse, the program will bind the `OnFrame` rendering event and dynamically set the parameters of the `Create3DViewshed` method based on the Distance dragged by the mouse: the field of view analysis length distance starting from the observation point.

4.3. Inundation Area Analysis

This function can estimate the situation where a certain area is submerged by floodwaters when the water level reaches a certain height when it is threatened by floods. The blue covered area in **Figure 5** is the estimated flood-submerged area. This function can help the management department to more reasonably arrange various infrastructure within the area.

The following is the specific implementation method of the inundation area analysis function:

4.3.1. Set the location of the flood source

Analysis tool interface `IAnalysis` `CreateFloodSingleWaterRise` event allows users to set the flood in the source position `TotalWaterLevelRaise` `IPosition` and initial water level, the program will create a set of polygons showed flooded area. The program result will generate a deep blue three-dimensional area and cover some buildings in the city according to the height of the flood, as shown in **Figure 5**.

4.3.2. Animation effect of rising water level

`IAnalysis` `CreateFloodContinuousWaterRise` events can display in a certain period of time when the water at a constant rate (user setting rate of rise and rise interval set) continues to grow, to create a set of polygons showed flooded areas. When the rate of `WaterRiseRate` and the time interval are set, the flood will rise at the set parameters and inundate buildings.



Figure 5. Inundation area analysis function

4.4. Development Intensity Analysis

The program reflects the development intensity of the area by calculating the area occupied by the building patches in each patch and presents it in a three-dimensional way. The higher the development intensity of the area, the higher the bar chart and the darker the color. The program roughly divides the development intensity of regions into three levels. Red represents high-intensity development areas, yellow represents medium-intensity development areas, and green represents low-intensity development areas, with potential for further development. This function can help the management department quickly determine which areas can still be developed and which areas have been overdeveloped. The analysis results are shown in **Figure 6**.

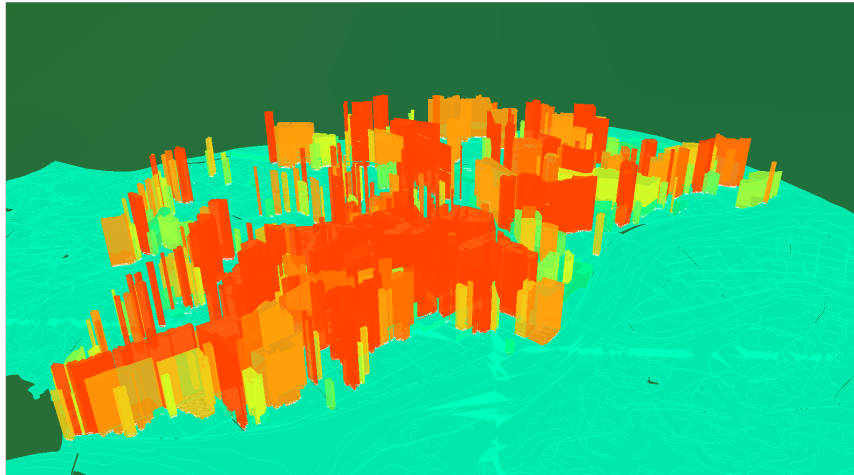


Figure 6. Development intensity analysis function

The following is the specific implementation method for the analysis function of the development intensity analysis area:

First, read the urban plot and building information Feature layer IFeatureLayer from the map. Then, traverse each Feature in the IFeatureLayer to find the surface Feature in the building layer that intersects with the urban plot surface feature. And calculate the intersection Area through the area field of the Feature, calculate the proportion of the intersection area in the total area, and write it into the BuildingPr field of the urban plot Feature. Finally, set the height and color according to the proportion.

5. Conclusion

Based on the characteristics of the 3D GIS system and in combination with the requirements of planning, this paper

analyzes the overall functions of the 3D GIS-assisted territorial space planning system. Based on the mastery of 3D visualization software and development environment, a technical route corresponding to the development platform was formulated, and the core technologies in 3D visualization were studied. The system has achieved the linkage of two-dimensional and three-dimensional data, fully leveraging the advantages of two-dimensional and three-dimensional integration to assist in territorial space planning, making the planning more efficient and the results more intuitive.

Disclosure statement

The author declares no conflict of interest.

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