Design and Implementation of Real Time 3D Visual Landscape Design System for Expressway

Qiu Jing 1,*

1. School of Architecture, Chang'an University, Xi'an, China

Abstract: Based on the research of DEM modeling theory and TIN triangulation theory, the general design and detailed design of the system are described in detail, and the method of 3D visual modeling is introduced. System in aerial topographic data graphics and indoor design software generated road data base, the realization of the real terrain landscape three dimensional road engineering modeling, and rapid modeling bridges, tunnels, roads and other ancillary facilities construction creation can be achieved by using the methods of parameter design and modeling. In this paper are discussed in detail terrain, roads, tunnels, bridges, traffic facilities and scenery model structure modeling method and process for the creation, discussed how to use digital elevation model establishment of the terrain model, for a wide range of complex terrain, when the data volume is huge, given the terrain simplification technology. Through the establishment of the terrain library, the texture image is mapped to the established model, so as to realize the highway 3D visual landscape design. According to the research target, the laboratory developed highway real-time 3D visualization of the landscape design system, of highway 3D visual modeling method of demonstration system, realized the 3D terrain model of rapid construction, seamless splicing of terrain model and road model and the whole road 3D scene visualization. The successful development of the system enables the designers to feel the quality and rationality of the design scheme, and can truly reflect the results of road design. The practical engineering application of the system shows the correctness and feasibility of the modeling method and theory discussed in this paper.

Keywords: expressway; 3D visualization; landscape design; 3D rendering; system design

1. Introduction

As an important part of Highway Survey and design, highway CAD technology has been widely used in various stages of highway engineering design in our country. At present, domestic most design institute are still using the traditional highway design method, that is, through the horizontal, vertical and horizontal design and earthwork calculation steps to complete the overall design of the route, the benefits of this approach is the designer of the design can meet the line of code for design of. However, the shortcomings of this kind of system is lack of the whole route 3D display link, designers rely on the imagination to grasp the design scheme in the 3-D effect after the combination of the flat, vertical, horizontal, is not conducive to the alignment results timely feedback and objective evaluation. To this end, the Design Institute of the conventional approach is the design after the completion of the road flat[1], vertical and transverse data, through professional 3D graphics software (such as 3D Max) to form a road model, and then pass to keep adding digital terrain model and landscape to achieve three-dimensional display of the road alignment. Although in this way can eventually get a good three-dimensional effect, but this process often need professional 3D graphics operator to complete, and in the production process need after the very fine manual, time-consuming and laborious.

2. System development platform and key technology

2.1. Object oriented programming technology

Traditional programming technology is to the algorithm as the core, the process oriented design method, this method to process data and is divided into two separate parts, data representation of spatial object, the program for processing these data. The data and procedures as the separation of two independent individuals, reflecting the characteristics of the computer operation, because the internal data in the computer and the program is stored separately. However, there are two kinds of traditional design methods, namely, using the wrong data to call the correct program module, or use the correct data but call the wrong program module. When the cooperative division of a large software system development, in order to make the operation data and consistent [2], the programmer must repeatedly debugging, if responsible for data structure design of the half-way change a data structure and did not promptly notify the other developers in the Qing, may occur many errors in the, the serious may lead to the whole system can not run. The emergence of object-oriented programming technology to solve this problem provides a convenient, object-oriented programming technology to the object (Object) as the core, the software system developed by this technology by the object. Object is the basic part of object oriented development model, each object can be defined by its own set of attributes and a set of operations that it can perform. Objects communicate with each other by passing messages in order to simulate the relationship between things in the real world. The advantages of object oriented programming technology are strong stability, strong reusability and extensibility, and its main characteristics are embodied in the three mechanisms of encapsulation, inheritance and polymorphism. The schematic diagram of the object oriented programming technology is shown in figure 1:

![Object Oriented Programming](image)

Figure 1. Sketch of object oriented programming technology.

2.2. Delaunay triangular mesh

Abstract:

© 2016 DEStech Publications, Inc.
This system based on Delaunay and constraint Delaunay triangulation theory, proposed and implemented for large-scale TIN the triangulation rapid overall construction algorithm of terrain. The algorithm USES the whole meshing technology, in view of the massive terrain data, no advanced block processing, can build whole continuous seamless belt once triangulation, avoid the block processing issues. Referenced by the ideas of TIN model of cutting algorithm, the application of constraint Delaunay triangle theory and algorithm first delivered construct good split line embedded in the original model of TIN terrain makes it a TIN of constraints, and using the algorithm of "triangle" virus "eat" away surrounded by intersecting line area of the triangle[3]. But cutting algorithm of TIN model only considering the joining together of convex polygon models to TIN terrain model, if need splicing model is a concave polygon, the above algorithm is applied for incomplete, need to take into account the many exceptions: multiple suspension problem, embedded constraints, while error problem, etc. In order to improve the stitching speed, system emphatically from the lookup the insertion point in the triangle algorithm, an improved embedded polygon algorithm and delete constraints polygon triangle within three aspects to optimize algorithm. Levels of Detail model LOD (Level of Detail), the environment is displayed according to the object model of nodes in the position and important degree, decided to object rendered the allocation of resources, reduce the important object in front of the number and the degree of Detail. Displayed according to certain judgment conditions, proper select a level of detail model for display. LOD technology allows on the premise of not affect image quality, to express the same 3 d models with different details, and combined with the location of the observation point determines the selection of the model details, in order to reduce the complexity of the graphics processing, improve the efficiency of pattern formation, meet the requirements of real-time dynamic rendering. Domestic research based on quadtree LOD algorithm, this algorithm does not apply to TIN terrain model, Garland, Hope and others had proposed some polygon simplification algorithms, but slow on large scale TIN terrain simplification, efficiency is not high, nor is it suitable for large-scale TIN model. Therefore, this paper presents a new large-scale TIN terrain simplification algorithm based on vertex degree elevation of the weighted average LOD algorithm. A model for the TIN, as shown in figure 2:

![Figure 2. Schematic diagram of TIN model.](image)

2.3. System development language

VC++ is a powerful programming language, VC++ with the characteristics of flexible and efficient by programmers today. The bottom of the general development of the system, the need to have excellent compatibility and stability, the first choice is VC++. At the same time, VC++ is the main development tool to develop Windows application, which can be used as a resource. VC++ is more than just a compiler. It is a comprehensive application development environment, make full use of the object-oriented characteristics of C++, can develop a professional level of Windows application. VC++, as a programming language, is also an integrated development tool, which provides the automatic generation of software code and visual resource editing function. The framework adopted by MFC is VS+++. MFC is not only a common understanding of a class library, select the MFC, it is equal to the choice of a program structure, a programming style. MFC is a powerful, extended C++ class hierarchy, which makes it easier and easier to develop Windows applications [4]. MFC in the entire Windows family are compatible, whether it is XP Windows, Windows2000 or NT Windows, the use of MFC are compatible. Whenever the new Windows version appears, MFC will also be modified so that the old compiler and the code can work as usual in the new system. Updates to the operating system version of the MFC will also be extended, adding new features, so that the establishment of the application becomes easier. The biggest advantage of using MFC is that it can do all the most difficult things for you. MFC contains thousands of lines on the correct, optimized and powerful Windows code library. As long as you call the rich member function to complete the work you may be difficult to complete. From this point of view, MFC greatly accelerated the pace of development of the program, but also convenient and efficient. Due to the MFC programming method makes full use of the advantages of oriented object technology, it makes the programming we rarely need to care about the implementation details of a method object. At the same time, the strong function of the various objects in the class library to complete most of the programs we function, which makes the program, the programmer need amount of code written is greatly reduced, effectively ensure the program good debugging. MFC provides to all properties and methods of the object is after careful preparation and strict test, high reliability. This ensures that the use of MFC libraries do not affect program correctness and reliability. In summary, the execution efficiency of VC + + is all advanced visual programming language in the highest, for the high demand of real time 3D visualization system, due to a large number of image processing operations. Therefore, using VC + + language is the most appropriate [5]. VC++ schematic diagram shown in figure 3:
2.4. The seamless splicing algorithm based on the TIN model

Reference TIN model clipping algorithm thinking, application of the constrained Delaunay triangle theory and algorithm, first to construct good merged intersection lines embedded to the original tin terrain model the become constrained edge in tin, by "delta virus" algorithm "swallowed" off line enclosed within the area of a triangle. But clipping algorithm of tin model only considering the convex polygon model spliced into tin terrain model, if needed stitching model is concave polygon, the above algorithm is not fully applicable, need to take into account the many anomalies: multiple suspension problems, inserting constrained edge error problems. In order to improve the stitching speed, the system focuses on the three aspects of the triangle algorithm, the improved embedded constraint polygon algorithm, and the algorithm of removing the constraints within the triangle. This paper introduces including road model, model of bridge, tunnel model, traffic safety facilities model and landscape design model of creating and rendering method, the method of reference for other engineering road 3D solid modelling [6]. Design a simple and practical 3D rendering engine, each independent model construct engine, to pipeline like cycle real-time rendering 3D model part, shading on the beams of the 3D graphics shading method based on rendering state will have the same rendering state model to join the same group, reduce the overhead due to frequent switching of the rendering state, as far as possible to ensure that a second to reach more than 25 frames of graphics rendering frame rate, without delay or micro latency real-time rendering many model group, ensure real-time continuous visual sense. Landscape design is the core part of Expressway real-time 3D visualization of the landscape design of the system, in the terrain, road model is created by the roads surrounding landscape design, simulate the proposed road scene overall effect, not only can check the design results of the rationality the roads were built after the environmental impact of prior estimates, is conducive to the construction project environmental impact assessment. In today's society, more and more environmental protection, landscape design will become a major feature of the system and highlights. This chapter mainly introduces the expressway real-time 3D visualization of the landscape design of the system related to the development of technology, first introduced the features of the oriented object programming technology, by analyzing the requirement of highway 3D visualization technology, according to the technical characteristics and the actual situation, select the Net platform of VC++ language as a system development platform and development language, and then described in detail the system in modeling and 3D visualization solving the key technical problem [7].

3. System requirements analysis and general design

3.1. System functional requirements

Highway 3D visual landscape design system is in aerial topographic data processing to construct terrain model, terrain model in construction based on the success of the loading path design software to generate the road, bridge and tunnel data, interactive and parameterized design of the basic parameters of the model set by generating bridge and tunnel model and rendering, then the seamless splicing of the road model and terrain model, and then the door bar, signs, central separation belt model to construct and render. Engineering management module is the design of the project management of all information. Due to the three-dimensional modeling of the expressway is the terrain model based on the new, so consider the matching relationship between terrain and road, road design program of the project file system used to store different, each project is according to the steps one by one to complete, each storage engineering engineering engineering state of the corresponding. System engineering management enables users to midway to save the state of a project, when opened again next time, simply call the corresponding project file, the system can record to a project status, continue to the engineering design, without due to withdraw from midway and re design, to avoid duplication of work, improve work efficiency. Because of the terrain tin powder the massive data points and sexual promiscuity, after data collection, in order to reduce the storage unit, save the memory must be to preprocess the original data, this treatment mainly for data sorting and organizing management to subsequent rapid retrieval and in lay a good foundation. The data preprocessing includes two aspects: the pretreatment of the terrain data and the preprocessing of the road design data. (1) topographic data preprocessing. Topographic data sources through aerial acquisition of 3D terrain vertices file, each terrain contains 3D coordinate values (x, y, z). Due to the sampled data of the original vertex density and the number will inevitably lead to some error and singular points. Therefore, it is necessary to preprocess, system in ensuring the premise of a terrain feature detail using inverse distance height weighted average method, for tin terrain scatter LOD simplification to reduce the number of powder to follow-up data for fast retrieval and in a good foundation. (2) road data preprocessing. Road model data is derived from the Road I road design software derived from the road cross section data. Each section of the data to the point of the pile is divided into about two lines, one line is the left side of the road width of the point of the coordinates of the point, the other line is the road to the right side of the cross section of the point of the characteristics of point coordinates [8]. After the analysis of the system, the necessary feature points are extracted to construct the road model. These essential features of point feature of line of the road to the roadside to is as follows: the pile point, the center divider with, lane, the hard shoulder, soil shoulder point, side ditch and slope. In the road data of pretreatment often encountered two cases: a adjacent sections of the same structure, namely, the width of the road ipsilateral excavation or filling, another is adjacent sections of different structures, namely ipsilateral adjacent sections of a excavation (fill), and another fill (excavation). For the treatment of the former is relatively simple, for as long as the same type structure can be; for the latter, as it involves to the excavation to fill and embankment to the excavation of transition
system for this thought is: the "elevation interpolation method in excavation and filling (fill and excavation) change, through the auxiliary point and the original section fitting out new cross-sectional data.

3.2. Terrain construction module

This module mainly completes the function of two parts of TIN terrain mesh and terrain mesh block management. (1) terrain construction. On the basis of the data preprocessing of TIN terrain scattered points, the Delauny triangular mesh. After the pretreatment of terrain data, the system will simplify the generation of new terrain scatter files, compared to the file and the original data file has removed the those mistakes and singular points and eliminate some non topographic feature points, in number than the original data file a lot less. Data preprocessing also generates a new vertex file for the source file of the triangle file. As long as the two data files are loaded, the system uses the Delauny triangle construction principle to complete the Delauny triangular mesh based on TIN. (2) terrain mesh block management. In order to facilitate the LOD viewpoint control and eliminate the narrow triangle features and fracture line system for the entire terrain according to the user through the interface parameters setting the size of the grid division, through the grid line terrain block processing. The boundary between adjacent grids is very regular, and there is no triangle, and each triangle belongs to a fixed grid. System through the terrain mesh is divided into blocks, can be more effective to terrain data to query and management, browse for the back of the system model of collision detection and vegetation system module block to create a play based, i.e., the user can in the terrain model implantation is not the same as the vegetation. The schematic diagram of this module is shown in Figure 4:

![Figure 4. Schematic diagram of this module.](image)

3.3. Road model building module

After the road data is pre processed, the system is in accordance with the direction of the road in the road, in order to take two adjacent cross section data to construct the road model. The system according to the order from left to right in turn will take the same road characteristic points of the adjacent cross section as the vertex of the triangle. Construction after the completion of the network, the road is divided into the central separation belt, road surface, the hard shoulder, soil shoulder, side ditch slope and six basic components. On this basis, can also have to travel lane dividing line, the lane edge line data; road model was constructed successfully, for the road ancillary facilities, bridges and tunnels and traffic safety facilities (signs and markings, fence) model construction, according to the road model of fault location, the road pile number to the anchor point and in the position corresponding to build or inserted into the corresponding model can be. In the 3D visualization system of highway[9], in order to make the scene to have continuous 3D overall effect, must will road model and terrain model of collision of good, improve the three-dimensional scene visual sense. But the difficulties of road model and terrain model of splicing is that of road model and terrain model are surface model that is composed of a plurality of triangular mesh, the traces of the splicing process prone to crack boundary, the model will appear to break in, which in a certain extent influence the overall effect of the 3D visualization. In order to solve this problem, the system uses a seamless mosaic algorithm of road model and terrain model. The basic idea is: first from the terrain data find the road boundary point where triangle, then boundary line embedded into terrain triangular mesh, boundary line become one side of a terrain triangular shaped, and then delete the boundary line within the terrain triangular mesh, which can achieve seamless splicing of road model and terrain model. The stitching process mainly includes four aspects: the organization of the terrain data, the triangle of finding the boundary points, the embedding of the constraint polygons and the triangles in the triangulation mesh.

3.4. Graphics engine module

Graphics engine is the core module of the 3D visualization system, which is used to visualize the 3D model. The system uses the XML file format to save the render parameters of the scene, and the system runs through the file to import the state of the rendering engine. Due to the 3-D highway system is involved in ground of like style and miscellaneous, including highways, bridges, tunnels and other infrastructure, including housing, agricultural land, vegetation and non infrastructure, texture information of these objects of each are not identical. This is 3D rendering of the difficulty. In order to improve the rendering speed, the system has the structure that the same type of rendering state as a group, for example, has a structure of the same type of structure and material as a group and in rendering the group structure of just a rendering parameters setting, again after rendering of the same type can directly call the rendering parameters, avoid re-design, thereby reducing the caused by frequent switching of the rendering state system resources consumption[10], and solves the problem of real-time rendering in 3D system. Landscape design refers to the terrain model and the road model to create a good future, the road to the landscape facilities for visual design. The landscape design module includes three sub modules, including terrain vegetation model creation, the central separation belt greenbel model creation and sky scene model. According to the information of the road model, landscape design mainly in central separate belt greenbel design system according to the needs of the user in creating the road model has been constructed with good separation model in the region, according to the principle of random distribution insert prefabricated the flowers and trees "block", the central green belt design. According to the model of terrain information system within the scope of the terrain or the specified terrain block planting vegetation, on the roads surrounding landscape greening, beautify the road outside of the terrain; for the sky as the king of attemperering and rendering, can according to need to add different texture rendering images to achieve different effects of the sky.
background. Landscape design is the most important part of the expressway real-time 3D visualization of the landscape design system, in the terrain, road model is created by the roads surrounding landscape design, simulate the proposed road scene overall effect, not only can check the design results of the rationality the roads were built after the environmental impact of prior estimates, is conducive to the construction project environmental impact assessment. In today's society, more and more environmental protection, landscape design will become a major feature of the system and highlights.

4. Implementation and testing of the system

4.1. Real time 3D visualization design of highway

The main interface of the system is divided into three parts: menu bar, toolbar and information display. Menu bar includes project management, project operation and scene setting three parts; toolbar is related to the operating system some of the shortcuts, such as new construction, open the project, save engineering; information display board is used to display 3D visualization rendering. The operation process of the system in the third chapter has made a detailed introduction, this is not in the repeat. Mainly related to scatter terrain simplification, terrain block processing, massive data organization and management of three parts, focused on solving the problem of massive data scatter correction, simplified and effective organization and management; terrain as the main data source in aerial survey data acquisition and in general are irregular scatter, not only to consider the correction of aerial survey error may arise the point of elevation error, also because the data volume is too large, need to think of a way to simplify and especially the massive data management and organization structure is adopted, with minimal system resources to get the fastest geometric querying and processing speed [11].

4.2. Building protection fence model

As the auxiliary facilities of the road, the establishment of the protective fence model is built on the basis of the completion of the road model building. System for the protection of the building model of the current consideration of the wave type barrier and concrete protective fence two types, including the concrete fence is divided into L type concrete fence and I type concrete protection fence system. System in the fence built bar modeling considering the column width, height and thickness are main factors, and the width of the baffle, the height and the inclination of factors, for the door bar rendering, the system provides a color metal, cement concrete color texture color quality for users to choose [12].

5. Conclusion

The subject completed the discrete points on tin simplification, tin powder delauny fast triangulation, terrain, roads, bridges, tunnels and various traffic safety accessory model generation and 3D real-time rendering, discusses the model and model in a seamless mosaic algorithm, an overview of the model of theoretical research, on the basis of the developed highway real-time 3D visualization of the landscape design software system. Through full and rigorous testing and practical engineering application, the correctness and feasibility of the theoretical model is verified, and the reliability and practicability of the software system are verified. Rendering engine design and application in project management model, designed and developed a practical and efficient 3D rendering engine, independent model for each of the 3D model part of real-time rendering loop, realize many model group without delay or micro delay real-time rendering, ensure in massive terrain and road data model based on 3D dynamic real-time rendering efficiency. The centralized and unified management functions of the model group, which can effectively avoid the repeated construction of the model, and the engineering management of the road 3D landscape design process.

Conflict of interest

The author(s) confirm that this article content has no conflicts of interest.

References