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On 3D Geo-visualization of a Mine Surface Plant and Mine Roadway

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Abstract Constructing the 3D virtual scene of a coal mine is the objective requirement for modernizing and processing information on coal mining production. It is also the key technology to establish a “digital mine”. By exploring current worldwide research, software and hardware tools and application demands, combined with the case study site (the Dazhuang mine of Pingdingshan coal group), an approach for 3D geo-visualization of a mine surface plant and mine roadway is deeply discussed. In this study, the rapid modeling method for a large range virtual scene based on Arc/Info and SiteBuilder3D is studied, and automatic generation of a 3D scene from a 2D scene is realized. Such an automatic method which can convert mine roadway systems from 2D to 3D is realized for the Dazhuang mine. Some relevant application questions are studied, including attribute query, coordinate query, distance measure, collision detection and the dynamic interaction between 2D and 3D virtual scenes in the virtual scene of a mine surface plant and mine roadway. A prototype system is designed and developed.

Keywords coal mine; mine surface plant; 3D geo-visualization; virtual reality; geographical information system

CLC number P208; TD175.7

Introduction

Any mine can be considered as a specific geographic body that not only includes faculty buildings and mine roadways, but also ambiance, aquatic environment, underground terrane, geographic space and local community. Moreover, such a body has extremely spatio-temporal complexities due to the geographic processes involved in mining. Obviously, one of the most important key questions for mine surveying researchers is to represent mining structures, roadways and underground terrane and their relations in accurate, multi-dimensional and appreciated formats. Hence, employing spatial information technologies such as a geographical information system (GIS) and virtual reality to model mines in 3D is in high demand for effective, safe and green mining. Such a development will be a milestone for bringing the traditional mining industry into the digital era. This study will explore the key technologies and knowledge for the development of mining information. Contributions on both theory and practice are significant[1-3].

Typically, a mining 3D geo-visualization includes the mine surface plant, underground roadways, equipment, terrane and so on. To build up such a model that presents a large number of objects and their complicated spatial and temporal relations, a significant workload on data collection and 3D geo-visualization is involved. This study demonstrates a reliable approach for modelling mine surface plants and underground roadways with the example of the Dazhuang coal mine of the Pingdingshan coal

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group. A system has been developed for this mine.

1 System development

The development process of modelling mine surface plants and roadways includes data preparation, modelling and rendering.

In the stage of data preparation, 2D data will be collected and pre-processed for generating a 3D model, which will then be generated and rendered in the second and third stages. The software system was developed in the MS Visual C++ development environment with Custom API, Vega Prime API and MapObjects[4-6]. A comprehensive information navigation and analysis system prototype was developed.

2 Modelling a mine surface plant

A mine surface plant is similar to a portion of an urban area. A typical plant covers a large area that leads to a big workload to build its visual 3D model. To take advantage of the existing GIS database, a method based on the manual model building method in Creator for rapidly modelling large areas was developed using Arc/Info and SiteBuilder3D. This method is based on a mainstream GIS framework. Advantages of such a method are close integration between the mainstream GIS environment and visual reality and automatic 3D model generation from 2D data using existing datasets and effective model building. Fig.1 illustrates the typical process of generating 3D models from existing GIS databases and sampling datasets. SiteBuilder3D is a 3D GIS software development package from MultiGen-Paradigm Co. It is an extension of ArcView GIS v3 and ArcGIS Desktop v8 that provides a module that can generate a 3D model from 2D ArcGIS data and represent a 3D model in real-time. First, 2D datasets are prepared in Arc/Info(ArcView). These datasets include geographic features, cantor data and images. Second, these datasets are projected on to the terrain surface layer by using model replacement and conversion. The model replacement method replaces 2D features with pre-designed 3D feature models, while model conversion generates the 3D model by computing images and sampled attribute datasets. Generally, point features are replaced by model replacement, while line and polygon features are transformed by using model conversion.

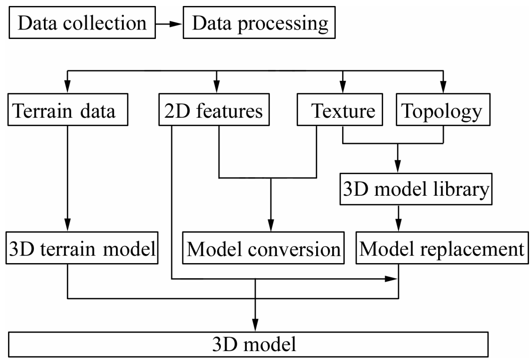

Fig.1 Process of model building

In the second half of this section, the modelling approach will be explored with a study case of the Dazhuang mine plant.

The overall site surface is flat and a coal mining waste dump is located south of plant. There are a number of buildings located in the study site, including a primary roadway, secondary roadway, food center, hotel, union house and office buildings.

Terrain data is scanned from 1:1 000 terrain map and imported into Arc/Info. After image coordinate projection, some basic information can be generated, including elevation points, contour lines, building structures, road structures, rivers, trees and fences. Additionally, the attributes of these features were recorded with these GIS datasets.

For box-type buildings, the structure is simple and can be treated as a roof polygon and straight walls. The 3D models of these features can be easily generated by model conversion. However, model replacement has to be used to generate buildings with more complex structures (office buildings and union house). In ModelBuilder3D, the road network is modeled as a series of polygons with defined weights. To properly attach a road network on the surface of a terrain, elevation information is required to place the road segments. Similarly, the river network is modeled by the same process and method. Modeling some surrounding features such as trees and fences is significant to improve the performance of visual reality scenes. These features can be properly modeled by texture projection with attribute information such as height and elevation.

The background terrain map was generated directly in SiteBuilder3D with maximum error 0.3 m. Images were corrected in Arc/Info for sound geographic texture projection. For complex objects such as buildings, tress and telegraph poles and plant squares, model replacement was used to structure 3D models by some built-in functions in the siteBuilder3D model library and newly designed models. An example of a 3D model is shown in Fig.2.

Fig.2 Buildings

3 Modelling roadways

In the first exploration of the Dazhuang mine plant case, mine roadways were modelled as 3D multiple line sections with attribute elevations in Creator. AutoCAD software then was used to rebuild 3D underground mine roadways. The authors found that such a method is not suitable in the environment that covers large areas with highly complicated 3D structures. The process of modelling was time-consuming and lacked control. Hence, a new method that can convert 2D roadway maps into 3D models automatically was carried out by the authors.

By considering their shape, all roadways can be classified into three classes: as even cylindrical roadways, uneven cylindrical roadways and non-cylindrical even roadways. Cylindrical roadways feature a circular profile with the same diameters, while those with circular profiles but with different diameters are uneven cylindrical roadways. Clearly, non-cylindrical even roadways are non–circular, but have the same shape and size profiles. For even cylindrical and non-cylindrical even roadways, their locations can be identified with the central lines of roadways and their size can be computed by profiles. Obviously, the locations of uneven roadways have to be described by a series of outlines on roadway profiles.

In coal mines, most roadways are evenly shaped. Their structure is not complicated and can be easily modelled by computer systems. This paper will only address modelling issues on this kind of even roadway.

For evenly shaped roadways, their 3D models can be computed with coordinates of their central lines and profile attributes. There are three methods to build roadway models: manual input, input from files and using 2D GIS maps. The last method was used to model 3D roadways automatically from exiting 2D GIS maps. The brief process is that the central lines' coordinates and profiles information are read from 2D GIS databases. With the information, 3D roadway models were computed directly and effectively.

A number of approaches can be used to obtain information from 2D GIS maps. One is to read datasets directly from GIS exchange formats (e.g. E00, shapefile and mif). The other is to acquire information by GIS development interfaces in an integrated developing environment. In this project, the latter one was used.

First, 2D GIS roadway relevant datasets were prepared in Arc/Info. A module was then developed by VC++ with ArcObjects COM library to gain 2D attributes. Based on these attributes information, a 3D model was generated by using Openflight API. Finally, Vege Prime was used to render these 3D models. Fig.3 is the system interface and Fig.4 illustrates the automatically generated models in this system.

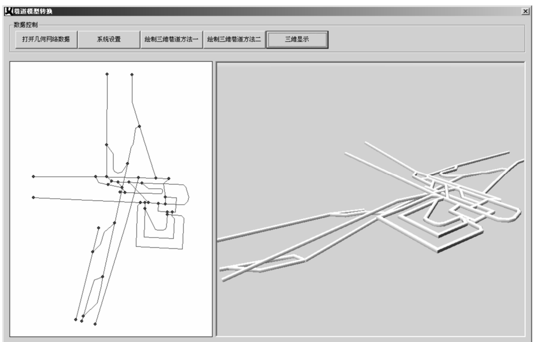

Fig.3 Interface of system

4 Query and quantity calculation

One of the purposes of building a 3D mine visual

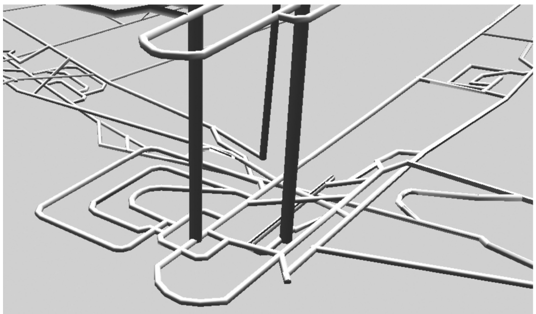

Fig.4 Generated roadway models in Dazhuang mine plant

reality model is to give the comprehensive picture of mining production relevant objects and their spatial relations, especially those underground. More importantly, such a model brings us reliable and important capabilities to employ spatial analysis functions on the models. This enables significant decision making in mining production. Some query functions such as locations queries by attributes and attributes queries by locations are extremely important for mining management and can be fundamental to high quality decision-making.

The key technique in the location-attribute query is to identify the specific spatial objects in the 3D environment via operations on a 2D computer screen. The ID and attributes of right target objects can then be recognized.

Owing to the nature of a computer screen's 2D surface, techniques that find the right spatial objects on the screen are important and basic to other advanced functions. In particular, after many rotations, pan and project transition operations, identifying a correct spatial object is difficult in practice. In OpenGL, such operations are supported. Within the selected model, drawing information is sent to the application system, not to catches in the rendering model, to ensure users select the correct object from the operating window. Although Vega Prime v1.2.2 is an extension of OpenGL, its selection function does not directly provide the correct object, and an alternative method had to be developed.

Crossing vector class (vpIsectorLOS) tests sections by a line with *Y* axis direction. The length of the line is calculated by Void setSegmentRange (double range) method and its coordinates are (0, 0, 0) and (0, +range, 0).

Vega Prime introduces a crossing test messenger, application subscriber event messenger and conducts operations based on the messengers. Variable Event is defined in vpIsector for describing a collision event. Messenger subscriber will receive vpIsector: EVENT_HIT messenger. By the end of collision, subscriber receives vpIsector::EVENT_CLEAR_HIT.

The traversal method for crossing test needs to be set up before implementing vpIsectorLOS; it affects traversal behaviours. There are some decision points to use vsTraversalIsect on scenes, including what information needs to be collected along the traversal path, which LOD child pints should go through. Some defined rules are used, but they can be reset by using void setMode (unsigned int *f*) method. The absolute class vpIsect provides many rules which are defined in enumerable variables. MODE_ISECT_GEOM_ PRIM mode in vpIsectorLOS means that the system conducts crossing test on the basic map elements when vsGeometryBase is accessed.

To process the crossing test results, vpIsect function virtual bool getHit() const can be used to identify collisions. Function virtual vsNode* getHitNode (const char * name=NULL, int occurrence = 0) const returns the collision nodes (vsNode), the type of node will be returned if the name variable is NULL.

Vega Prime does not offer coordinates query and measurement classes, but they can be achieved by testing collisions.

A virtual function virtual int getHitPoint (vuVec3 <double>* point) const, function of vpIsectorLOS class's based class vpIsector, returns coordinates of collisions. With mePicker class, coordinates of collisions can be easily obtained.

Distance measurement requires at least two coordinates. By clicking points using the mouse, the distance between two or more points can be calculated.

5 Moving in roadways

Underground roadways have an extremely complicated structure. To achieve a "real" walk through environment, collisions between user and roadway structure should be identified and represented in real-time. A simulation of collision can help avoid some unreasonable and unexpected scenarios such as crossing the walls.

The basic method to identify collision is to employ a line crossing test, but it requires an additional thread for each testing. In this project, the author developed an effective method by using vpIsectorBump class. In vpIsectorBump class, six line sections are defined along x, y and z axis in both negative and positive directions. The x, y and z axis and lengths of sections are according to the instance of vpIsectorBump class (Fig.5). The coordinates of objMan can be corrected by dx, dy (Fig.5). Hence, objMan will be ensured within the roadway models. The performance of simulation with collision effects and comparison with non collision can be seen in Fig.6.

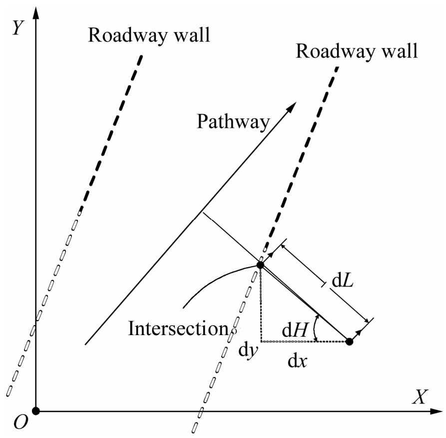

Fig.5 Collision method

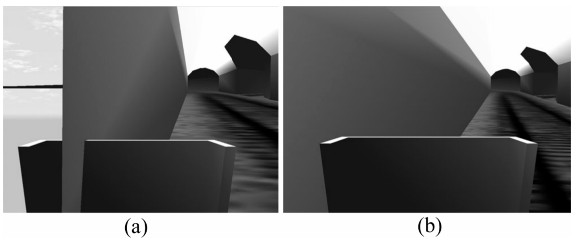

Fig.6 Examples with (left) and without (right) collision effect

6 Interactive with model

It is important to trace users' locations in both 3D models and 2D maps at the same time. Flexible switching between 3D models and 2D maps are required, since a loss of directions is common in 3D models and map-based systems. Consequently, a study on such switching functions is important.

Interactions between 3D models and 2D maps were accomplished not only in exploration mode, but also in query mode. In 3D exploration mode, the view section can be traced in the 2D map. In 2D map exploration mode, the view point will be placed at the point in the 3D model. For location query, attributes of objects will be presented as records while these objects are highlighted. For attribute query, the location will be highlighted in both 3D mode and 2D map.

This interaction method was realized by GIS MapObject COM and Vega Prime platform. In this application, GIS COM is integrated into a simulation platform. MapObjects offers objects of dynamic database operation. The function of CMoTrackingLayer is to organize and manage dynamic databases in MapObjects; it can be considered as a dynamic data layer. Contents will be drawn in CMoMaplayer and CMoImageLayer and re-drawing them is independent. CMoGeoEvent object is a dynamic objective or datasets, named as dynamic objects that attached with CMoTrackingLayer. In 3D exploration mode, the instance of vpObserver class represent observer. Virtual function virtual int setTranslate (double x, double y, double z, bool incr=false) change the observers' locations. Virtual function virtual int getTranslate (double * x, double * y, double * z) const, belong to vpObserver class, returns observers' locations.

An attribute query in 2D maps is a basic function in GIS systems that is easy to achieve by MapObjects. By using function SearchShape (geometricObject, searchMethod, Expression), function of CMoMapLayer class, keyword attributes can be gained. Similarly, attribute querying in a 3D model can be realized by querying attached attribute database, particularly scenes Access database and related 2D GIS attribute databases. From querying results, nodes in the 3D model and objects in 2D maps can be identified. Their interaction can be achieved if there is a relation between the nodes.

7 Prototype system

As shown in Fig.7, the main application window is divided into three sections. The larger section on the left is the 3D render window, which is host to representing 3D scene at the current view and also functions to receive user inputs. The sub-window top right is the 2D navigation window for 2D visualization and interactive operations between the 3D model and 2D maps. Finally, the right bottom window is an information board which presents system condition and query results, is also control pan of layers and map query.

Fig.7 System interface

In 3D exploration mode, the mouse and keyboard are used to navigate movements. As default in the system, applications will justify the moving behaviours by considering location of the mouse pointer in the window. Such a function was driven by its complexity. Some functions were designed to boost operations, such as a 3D window backing to default when pressing down the mouse three times. The left and right buttons of the mouse can increase and reduce the speed of movement respectively; the middle one is to stop movement. Moreover, hot keys were designed to boost observers' operations such as eye-view move up/down, accelerate forward/backward, eye-view move right/left, fog effect on/off, texture on/off, transparency on/off and animation on/off.

Most functions can be accessed by icons in toolbars, for example a window layout change, window focus change, querying in 3D models, coordinates query, distance measurement, basic map operations (zoom in/out, pan and full extent) in 2D maps, visualization method I II in 3D model and attributes query in 2D GIS databases. Visualization method I means that a camera view moves by object movement. Visualization method II refers to when an object is always in the center of the window but the map pans.

For better representation, a 3D sub-window is maximized and occupies the whole system window area in representing mode instead of sharing space with two others. Additionally, only an active sub-window responds to keyboard inputs.

The typical steps of the operation are: navigating the 3D scene by clicking on the 2D navigation map, the user then explores in the 3D scene while the location of observer can be traced in the 2D map, attribute-location interactive query can be implemented in both 3D scenes and 2D map.

8 Conclusions

Beyond the 3D model, attribute, coordinate and distance querying in 3D model; collision identifying in 3D exploration mode; interaction between 3D model and 2D map and many other functions were designed. The performance of the prototype is very reasonable and satisfactory in real application. More advanced GIS functions, such as spatial operations, spatial analysis modules and better interactive functions between 3D model and 2D map should be developed for better applications.

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