Geological spatial database and visualization modelling methods for mining groundwater

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Abstract

It is one of the research hotspot and difficult of the mining groundwater three-dimensional information and visualization for hydroinformatics, to solve the problem of groundwater hydrology geological spatial database and visualization of 3D geological modelling, proposed a three-dimensional geological modelling method based on finite difference method, and the mine hydrogeological spatial database, the groundwater survey information database,3D geological modelling based on GIS, groundwater spatial visualization of 3D data model and key algorithms are created. Simulation results show that can realize the hydrogeological space in Yulin area database and 3D visualization of geologic model and spatial hydrological data processing method provides a unified data model, the analysis of hydrological data support a large space, and lays the foundation for the dynamic control model refinement.

Keywords: three-dimensional visualization, groundwater, hydrogeological spatial database, modelling methods

1 Introduction

It is a major problem facing all countries in the world of water resources shortage, the dynamic regulation of water resources is the effective way to alleviate the problem of [1]. Groundwater as an important part of water resources, while ensuring the safety of drinking water, to support social and economic development and maintaining ecological balance has played an invaluable role. Through the interference natural evolution and long-term human activities, groundwater and the socio-economic and ecological environment interactions, interrelated and together constitute an extremely complex interaction of complex systems changes, and with the passage of time, the complexity of the system will continue to increase. Dynamic regulation of groundwater resources is very complex system engineering, and integrated studies involving cross between different disciplines [2]. Along with Yulin economic development, irrational exploitation of coal resources of groundwater resources caused tremendous damage and ground subsidence, damage to the environment of organic links - Water - coal resources system, a serious threat to sustainable development in the region. But so far, the mining area has been transferred to large-scale exploitation of coal resources, but related systems in-depth fundamental research is not enough, the lack of groundwater recharge in the area, runoff, drainage and temporal variation evolution of groundwater recharge, coal - the relationship between groundwater space combination research model and other basic scientific issues, urgent breakthrough in basic theory related aspects.

Effectively achieved dynamic regulation of groundwater resources is first to establish the refinement of the dynamic control model. However, due to the high complexity of nonlinear processes of groundwater ecosystems, nonlinear and temporal specificity of variation within the region and groundwater aquifer recharge and discharge structures [3]. Methods and theoretical system of regulation of groundwater resources, the internal mechanism and the role of system dynamics process of change has not yet been fully aware of such uncertainty aquatic ecosystem dynamics model based on the assumption of a simple mechanism or traditional limited. Therefore, an urgent need to design an ability to dynamically monitor and reveal the evolution of groundwater resources and dynamic regulatory model of coal mining conditions and changes in the region linked to the water cycle. Groundwater and groundwater regulation mechanism of evolution study provides a theoretical basis. With the rapid increase in the amount of groundwater monitoring data, including remote sensing, soft computing, cloud computing, networking, and big data, such as a new generation of IT has begun to be applied to the monitoring and numerical simulation of the ecological environment in groundwater to compensate for groundwater dynamic monitoring data relative lack of deficiencies.

In this paper in order to improve groundwater, measurement, collection management and computer-aided design quality and efficiency of basic objectives, the use of computer graphics theory, theory of three-dimensional modelling and Mineral Resources, MIS systems development theory, 3D visualization technology, intelligent recognition technology and GMS technology,

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mine groundwater underlying problem mining and visualization of critical technical information system development study, aims to achieve three-dimensional visualization of groundwater modelling methods.

2 Groundwater spatial information database collection and management

2.1 GROUNDWATER SURVEY INFORMATION DATABASE

All aspects of the field are measured to obtain information, processing, and interpretation and application process. How to effectively store, manage and exchange information in order to make full use of groundwater space is an issue the majority of the measured workers of common concern. Obviously, by using the technology of computer to establish the database system, for the land data were analysed by effective management, is the best way is the most economical and reasonable [4].

Groundwater database is based on the original database, according to the applied research topics purpose computing through space conversion, data extraction and classification established. These data can be classified catalogue data, grade data, geophysical data, geochemical data, rock alteration data, terrain data, exploration line position and the middle horizontal position data and geological characteristics of the expression of points, lines, polygons and attribute feature data.

According to the application target, through data integration and fusion technology, geology and mineral resources from the original database to extract the necessary data resources, the establishment of special databases, and the development of thematic applications on this basis. System data flow as shown in Figure 1. Thematic data is the original graphic data and attribute data sources, applications based on the thematic objectives through space and generate transform computing and data integration and fusion technologies.

2.2 ANALYSIS OF 3D GEOLOGICAL MODELLING BASED ON GIS

Construction of three-dimensional geological model, it needs to build a mathematical model of a real problem, need to be screened, to abandon a secondary factor, highlighting the main factors, and make the appropriate abstraction and simplification. General description of the whole process is divided into solving, interpretation, verification of each stage, and complete mathematical model from the real object to these stages, then yeah from the mathematical model to the real object of the cycle. Mineral three-dimensional modelling process is as shown in Figure 2.

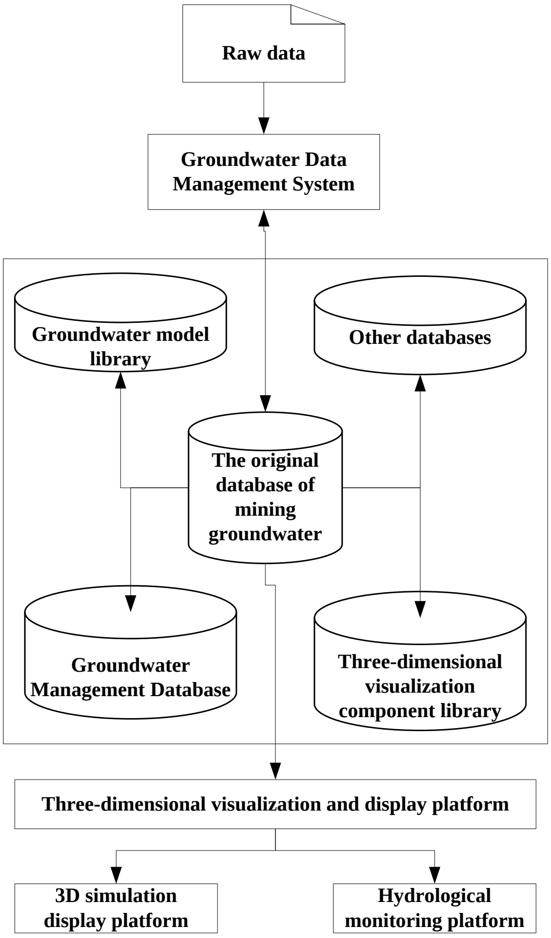

FIGURE 1 Three-dimensional groundwater flow chart of geological data management

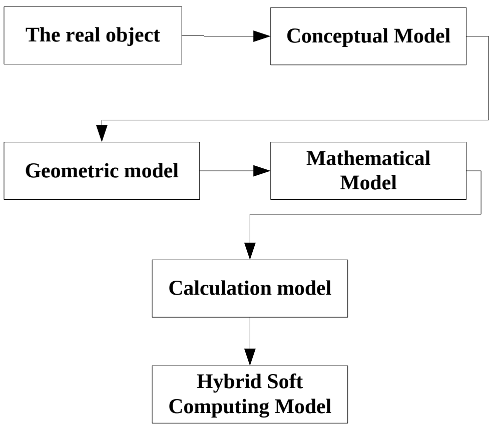

FIGURE 2 Mineral three-dimensional modelling process

According to the process of establishing mathematical model, you can put GIS based modelling process for the conversion of two-dimensional to three-dimensional mine modelling process.

3 Groundwater spatial visualization of 3D data model and key algorithms

Digital Elevation Model (DEM) is a set of values in the form of an ordered array represents an entity ground elevation of the ground model, it is a branch of a digital terrain model (DTM). DTM is generally considered to describe a variety of landforms, including elevation, including factors such as slope, aspect, slope and other factors [5], including the rate of change of linear and non-linear combination of spatial distribution, Which DEM is a simple zero-order single digital topography model, others such as slope, aspect and slope rate changes and other geomorphic characteristics can be derived on the basis of the DEM. The other two branch of DTM is a digital model in matrix form of various non-geomorphic characteristics, including natural geographical factors and the related social and economic and cultural factors, such as soil type, land use type, depth, land price, commercial advantage area etc. [6]. In fact, DTM is a raster data model. It is the image of the grid representation is the main difference: a dot image is representative of the pixel attribute, while in DTM, the point grid represents only attribute points, between points can be achieved by the interpolation calculation to obtain.

Due to the complexity of the three-dimensional spatial data description, making most of the three-dimensional simulation to learn about the research results are also based on certain limited areas, but are still scattered and incomplete. Currently, three-dimensional modelling of groundwater is mainly confined to the expression of visualization and visual aspects of the surface, and important operational functions and three-dimensional analysis is still limited, there are many problems to be solved, Theoretically mainly in the three-dimensional spatial data model and data structures, three-dimensional data acquisition methods, storage and management of large volumes of data, three-dimensional object modelling and analysis, and visualization techniques, where the core is including three-dimensional data model and data structures.

3.1 THE 3D DATA FIELD

Different scholars from different fields to non-hook data field are three-dimensional modelling problems similar studies [7]. It can be roughly summarized in the following two categories, and extended kriging method based on the first category, geological mining sector researchers geostatistical method called theoretical, The second class engineering force academia preclude SW finite element method, the second Sim who study mathematics hypersurface mining methods.

In calculating the elevation interpolation points, to be estimated power is inversely proportional to the distance between p and elevation points to be estimated and measured point of d. Far less impact from the interpolation points measured point, the value is also small; that is away from the actual point of impact interpolation points near the large, value is also large [8]. It is generally believed that when the terrain is inserted calculated using inverse distance squared interpolation method seeking, often achieve better results. The formula is:

$$H = \sum_{i=1}^{N} \lambda_i . h_i \,, \tag{1}$$

$$\lambda_i = \frac{1/d_i^p}{\sum_{i=1}^{N} (1/d_i)^p} \,, \tag{2}$$

where

H : represents elevation interpolation points;

h_i : represents the i-th measured value points;

p : represents power of inverse distance method;

N : represents the number of measured points in the specified range.

The interpolation points and the measured point distance formula is given by

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \,, \tag{3}$$

where (x_i, y_i) an i-th measured point coordinates; (x_j, y_j) coordinate of the j-th interpolation point.

Each measurement point has a certain influence its scope, during the interpolation; you must first determine the maximum radius of influence measurement points.

3.2 THE KEY METHOD OF THREE-DIMENSIONAL GEOLOGICAL MODELLING

In the 3D spatial data points to construct the discrete surface, it will need to use the surface interpolation method. Surface interpolation methods are widely used in the modelling process. In the following proposed three-dimensional geological modelling method, the use of surface interpolation method can love you discrete data control point interpolation into a smooth surface, and then use triangulation technology will be built in the delicate and smooth three-dimensional geological model.

(1) Inversely proportional to the distance weighting method.

This method was originally proposed by geologists, later called the staff D Sheppard method [9]. The basic principle is that the interpolation function $F(x, y)$ is defined as a function of each data point value of f_k weighted average, which is

$$F(x,y) = \frac{\sum_{i=1}^{n} \frac{f_i}{[d_i(x,y)]^u}}{\sum_{i=1}^{n} \frac{1}{[d_k(x,y)]^u}} \,, \tag{4}$$

where $d_i(x,y)=\sqrt{(x-x_i)^2+(y-y_i)^2}$ represents the distance from (x,y) to (x_i,y_i); μ value is generally the value is 2, different μ values have a certain influence on the surface morphology. If derivative Equation (4), the following can be concluded:

1) If $1<\mu\le 1$, then (x_i,y_i) does not exist one order partial derivative. That is to say a corner point or point at point (x_i,y_i).

2) If $\mu>1$, then (x_i,y_i) partial derivatives to zero. Thus the point of the tangent plane is parallel to the (x,y), thereby forming platform effect. Due to the increase, delete or change one of the control points, the surface will be recalculated, so this algorithm is a global interpolation algorithm. If you want to improve the interpolation rate, you need to control points divided by block, when this control point where the distance is greater than a given value, once you make the right value is 0, so it can speed up the interpolation speed. While the control points to be interpolated pitch far had little effect on the overall results, and thus the method is a commonly used surface interpolation methods.

(2) The radial basis function interpolation.

For radial basis function interpolation method used Multiquadri [10] method, Multiquadri method is the first to be presented and the most successful application of a radial basis function interpolation method. Its interpolation basis functions as follows:

$$F(x,y)=\sum_{i=1}^{n}a_i[(x-x_i)^2]+(y-y_i)^2+\Delta^2]^{1/2}. \quad (5)$$

In the Equation (5), Δ is used for any constant smooth degree of control surfaces, wherein Δ larger surface more smooth. But the in practice, the value of Δ should not be too big, because if Δ is too large will cause the error coefficient matrix affect us solve.

For a set of primitive known data points $(p_1,p_2,...,p_n)$, set each data point corresponds to the coordinates (x_i,y_i,z_i) into the Equation (5) can be obtained by n coefficient of $(a_1,a_2,...,a_n)$ system of linear Equations (6). Numerical solution using the numerical algorithm n coefficients can be obtained. So that when calculating at some unknown point (x,y) elevation coordinates z, just the unknown point (x,y) into the above interpolation basis functions.

$$z=\sum_{i=1}^{n}a_i[(x-x_i)^2]+(y-y_i)^2+\Delta^2]^{1/2}. \quad (6)$$

4 Three-dimensional geological modelling method based on finite difference method

Finite difference method is to simulate groundwater flow and migration issues most commonly used method. The concept is simple and easy to understand, and to solve the finite difference equations and has developed a series of algorithms. Finite difference model in saturated and unsaturated flow, transient and stable sources of pollution have great development. The basic idea of the finite difference method is: space will be divided into many small grids; the time is divided into a plurality of time Δt, the unknown variables in each grid central point as the average value of the grid. And then use difference approximation instead of derivative, the partial differential equation describing the change of the unknown variables continuous distributed throughout the study area into a finite algebraic equation to describe the unknown variables in the study area of discrete distribution. Solving algebraic equations, so to get the results of unknown variables each grid point of the Δt on the end of time. So Δt solved forward. We put these in space and time distribution of discrete variables has been obtained as a continuous function approximation value in each grid point.

For the finite difference method, we can use the function represented on discrete points

$$u(x_r)=u(rh)=u_r, \quad (7)$$

where r represents the position along the x coordinates of a node, h represents a step along the x direction.

For two-dimensional groundwater model can be expressed by the Equation (8)

$$u(x_r,y_s)=u(rh,sk)=u_{r,s}, \quad (8)$$

where $(r=0,\ 1,\ 2,\ \cdots;\ s=0,\ 1,\ 2,\ \cdots)$, the adjacent node is given by

$$\begin{cases} u_{r\pm1,s}=u\left[\left(r\pm1\right)h,sk\right] \\ u_{r,s\pm1}=u\left[rh,\left(s\pm1\right)k\right] \end{cases}.$$

Its two-dimensional coordinates as shown in Figure 3.

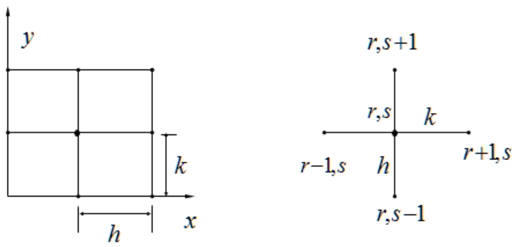

FIGURE 3 Two-dimensional coordinates

For the three-dimensional geological model, can be used the Equation (9).

$$u(x_r,y_s,z_t)=u(rh,sk,tl)=u_{r,s,t}, \quad (9)$$

where $(r=0,\ 1,\ 2,\ \cdots;\ s=0,\ 1,\ 2,\ \cdots t=0,\ 1,\ 2,\ \cdots)$

Its three-dimensional coordinates as shown in Figure 4.

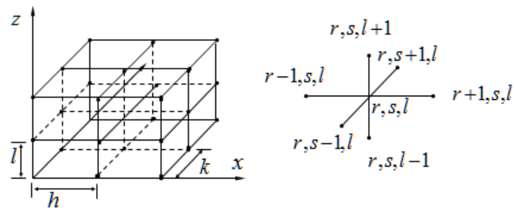

FIGURE 4 Three-dimensional coordinates

5 Experiment and analysis

This paper using Groundwater Model System (GMS) to simulate groundwater three-dimensional geological model, GMS is a laboratory environment model of Brigham Yong University and USA military Waterways Experiment Station cooperation development.

GMS is built and the numerical simulation model of groundwater environment with powerful graphical interface, integrated software package. GMS pre-treatment according to the model (modelling, initial and boundary conditions given), numerical simulation, and post-processing (data processing, calculation results display graphics and animation, etc.) structural design.

In addition to hydrogeological parameters can be set to different fluid properties can also be set outside the parameters in this model; according to solving problems, the choice of the three pyramids, triangular prism, hexahedral elements.

The module boundary conditions given convenient, accurate, and bins for element nodes for a given level and flux conditions can be simulated well flow and a given point Huainan, flow channels can be analysed; under the module can be saturated and non-saturated groundwater flow under the transport and tracking analysis;

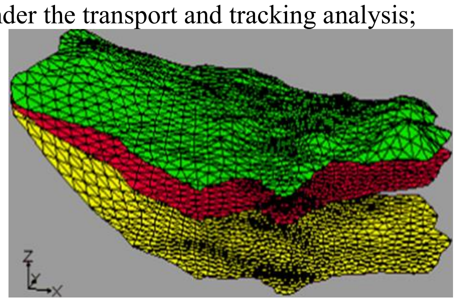

FIGURE 5 Hydrogeological 3D geological model of Yulin city

Simulation results can be used or given cutting surface contour, colour layer map displayed on the finite element mesh. GSM systems for the analysis of groundwater resources is a more comprehensive and applicable, easy to use software system; The GMS used in Yulin City mine groundwater; through the practice of specific applications, and improve understanding of the function of the GMS, According to the hydro geological characteristics of Yulin, and the saturated unsaturated state division parallel numerical model used in the calculation domain and calculation; Hydrogeological 3D geological model of Yulin city as shown in Figure 5.

Three-dimensional model of Yulin City mine groundwater shown in Figure 6.

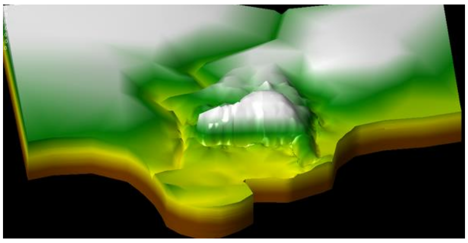

FIGURE 6 Three-dimensional model of Yulin City mine groundwater

6 Conclusions

In this paper combined with the characteristics of the underground geological bodies, application of three-dimensional visualization technology, realize the 3D visualization of geological body based on the surface model. Describes the basic technology of 3D visualization, and combined with the characteristics of data distribution with a control algorithm to interpolation of the geological spatial data.

In three dimensions model based on the theory, finite element analysis and surface interpolation method based on profiles were studied to achieve a known three-dimensional visualization of data fields, irregular three-dimensional geological structure, to achieve a three-dimensional geological model based on surface interpolation.

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