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Application of 3D visualization concept layer model for coal-bed methane index system

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Abstract

In the information times, comprehending and monitoring the development of science and technology are one of the most important activities. But the fast increasing in technologic information of the network makes people lose their way who finds that it is difficult to comprehend and master the trend of the technologic development. Visualization technology and its open source tools provide a new vision for people to understand the complex structural and unstructured information. In this paper a method of 3D modeling and visualization of coal bed methane index system is proposed. This method integrates basic coal-bed methane index data, borehole discharging data and interpretation section data of geophysical exploration from a view of multi-source data fusion. The 3D spatial data field model is established by using the spatial interpolation technique and drawing technique of the 3D texture hardware assisted volume rendering direct volume is used to realize the volume visualization, and then the spatial distribution characteristics and inner attribute of strata structures are reflected by true 3D model. The method which uses direct volume rendering techniques in 3D modeling of coal bed methane structure can more accurately reflect the coal gas structures and rapidly establish the data field, thus, it possesses good applied prospects. It also stresses the visualization tools used in dynamic monitoring and analyzing the scientific and technologic hot spot of coal bed methane and monitoring the science data of important coal bed methane research based on network database.

Keywords: 3D visualization; 3D space data field; volume rendering; coal bed methane; index system; software development toolkit; scientific data monitoring

1. Application of 3D visualization in scientific data processing

Due to the rapid development of science and technology, no matter there are the structured and unstructured scientific data, there are data of huge ies. Especially for scientific research institutions, it is difficult to have a direct reflection to monitor the scientific data relying on traditional methods of science and technology. The development of technology brings opportunities for science and technology monitoring. The integration of cutting-edge technology, such as knowledge discovery, knowledge extraction, data mining, and scientific visualization analysis, can help researchers carry out scientific data on high-density monitoring and timely follow-up new development in scientific research, and can help scientists study the new trends and advances in technology context. Visualization technology in scientific and technological monitoring is one of the key technologies [1], which provide a window for interaction with the data. Through a variety of technologies the data overloading will become a new opportunity. 3D visualization technology will convert a large number of complex abstract scientific data into visual information, such as graphic images and so on.
(colour, shape, texture, density, transparency, etc.), visually displayed on the screen, or visible, so that people accept and understand fully the data contained in the useful information in a short time. With the development of multimedia technology, network technology and virtual reality technology, the data visualization and information visualization is proposed based on the original 3D visualization in scientific computing. Visual analysis technology has become a useful tool to analysis natural phenomenon and the development of socio-economic situation, and to understand the nature of objective things and changing regulation [2].

Through a large number of scientific data collection, use of 3D visualization tools can be used to display a number of underground and surface characteristics of geological Phenomenon related to the underground coal-bed methane. 3D visualization is a mean to depict and understand the model, and is a form of expression as for data volume. Using a large amount of data, it can be used to check the continuity of data and find the abnormal phenomenon, which provides a useful tool to understand and repeat data. Visualization tools can be applied in web monitoring due to web-based database technology in coal-bed methane-domain analysis of dynamic monitoring of hot spots and important coal-bed methane research institutions.

2. Index system structure of coal-bed methane

In order to realize 3D visualization, the first is to establish standards of the index system structure of coal-bed methane. Research institutions have established their evaluation criteria in the preferred target area, and combined with these evaluation criteria, from the geological background, reserve factors, resource factors and the development of the basic attributes of four aspects, indicators and evaluation system can be formed. At the same time, the coal rank, depth, permeability, coal seam thickness, gas-bearing area, gas content, ground conditions, market demand and other parameters are selected as specific indicators of coal-bed methane in the target area (Fig. 1). Using a combination of subjective and objective to determine the level of the structure, it can be divided into 4 layers.

![Index system of coal-bed methane](image)

Fig. 1. Index system of coal-bed methane

Four-layer structure of coal-bed methane index system is as follows:

Geological factors include cap-rocks conditions (lithology roof, roof thickness, roof structures) and roof properties (topography, hydro-geological conditions).

Coal reserve factors include reserve geometry conditions (coal structure, coal seam size, burial depth) and the conditions of reserve properties (permeability, ratio of temporary reserve pressure, robustness coefficient);
Resources factors include gas-bearing conditions (abundance of resources, resources including gas-bearing area, gas content);
The factor of development basis is the market demand.

3. 3D modeling and visualization methods

The main features of existing geographic information system (GIS) are that it only is limited in surface expression of two-dimensional graphics and attribute information. There is a big gap with geological information system including 3D underground geological structure. In a large-scale gas project there is often the accumulation of a large amount of geological data, using 3D model of graphic images to express, reflect a realistic picture of the main geological structure and explain, it is a more effective way than relying solely on traditional means of drawings, information database and chart. The establishment of 3D model for geological body of gas storage and to deal with the interface relationship between the surface of rock composition and structure will provide a new means of research and research methods [3].

When using the 3D visualization software, the basic steps for explaining scientific data include
(1) Browsing 3D data volume;
(2) Selecting the target area (data outside target area of the main body will be removed);
(3) Transparency displaying the target areas;
(4) Stratified analyzing the displaying results;
(5) Drawing the index system map combined with analysis of scientific data;
(6) Realizing the hot technology domain of dynamic monitoring.

3.1. Approach of multi-source data fusion

Development of 3D geological modelling and visualization research is faster. 3D modelling and analysis software are needed mostly to determine gas reserve and distribution and level of change, and to calculate the gas pool reserves through processing of sampling of discrete points, sampling of exploration drilling, resulting in profiles, such as block and surface model. Software will show the distribution of drill holes through data of drilling, point, polygon, etc. by using graphics editing and generation tools. Triangulated irregular network is used to establish the use of surface and solid model, and the coil closure strata and the ore body border also are used to carry out analysis of gas reserves and grade, which provides a cross-function and allows users to outline the geological model according to their own experience and expertise [4]. It will achieve realization of arbitrary profile cutting, arbitrary angles, entities and the entity or entities and the surface of the intersection with the Boolean operation and so on. Related software can meet the needs of the storage layer resource exploration and evaluation of resource management as well as production management.

3.2. Application of spatial interpolation technology

A variety of geological information in gas reserve layer of complex geological body, including surface topography, groundwater level, interface formation, faults, joints, distribution of weathering zone, intrusion and a variety of geophysics, geochemistry, rock and soil physical and mechanical parameters and the indicators shown in Fig. 1, can be seen as the functions of 3D space. Their fitting function may be founded according to the actual investigation data. The more abundant the measured data, the more able to depict the true spatial distribution law of the information. Generation of single-valued surface generated graphics, such as measurements of surface topography, measurement of deep underground gas-bit information, can be attributed to two-variable discrete data interpolation and fitting, and multi-valued surface, such as overturned fold and space equal-value surface and so on, should use multi-parameter variable interpolation and other methods of some more complex measures. The function of space curved surface interpolation has the following structure methods, such as inverse distance weighting, radial basis function interpolation, interpolation of plane elasticity theory, etc. They are also suitable to use in single continuous strategy graphic interface, geophysical data and geochemical exploration data, as well as physical and mechanical parameters of rock and soil in spatial distribution of geological bodies.

3.3. Index system structure of coal-bed methane in true 3D simulation region
Geological body of gas storage is generally an irregular shape. In computer graphics, the curves and the curved surfaces are always a small straight line through a lot of tiny and small triangular surface approximation to simulate the rock borderline and curved surface of strata, that is, the interface (surface curve, surface of underground water level and other geological aspects) and curved surface of strata are a collection of small triangular face and many small straight lines respectively. The 3D data structure of gas storage is the basis of 3D modelling of gas storage and visualization. This requires that stratification must have an effective 3D data structure which can ensure the realization of the human–computer interaction and inquiry.

4. 3D modeling for index system of coal-bed methane using volume rendering technology

Volume rendering technology is a visualization technology of two-dimensional image directly generated by the 3D spatial data field on the screen. Direct volume rendering technology directly can draw pictures according to the refining and processing of data to generate two-dimensional image [4]. This technology can produce 3D data field as a whole image, including every detail, and the image quality is high and easy to parallel processing, etc. 3D modelling of the index system by using direct volume rendering techniques can reflect the structure of the gas layer and the internal characteristics of the spatial distribution of attribute information from the perspective of geological studies. Aimed at a big amount of index data, the clutter characteristic value distribution, there is no clear and smooth interface, but it reflects the overall law of changes of gas storage layer. The use of spatial interpolation algorithm and ray-casting algorithm will make direct volume rendering techniques apply to visualization research of gas storage layer, and reflect the gas storage layer and its internal physical and chemical properties, so that it gives solution ideas from the borehole data to build 3D data field to volume rendering using volume rendering algorithm.

5. Application of visualization tool in analysis and data monitoring of coal-bed methane

The dynamic monitoring of scientific hot spots in coal-bed methane uses the newly emerging knowledge and technology (text analysis, knowledge extraction, knowledge discovery, data mining, etc.) to discover and excavate the massive scientific and technical information resources, depict the internal structure and evolution course of disciplines and follow up important research activities of research institutions and experts [5].

Primarily through the acquisition of resources to get web data, RSS data, news data and OAI data, the science research object database, object-relational databases and terminology database are formed by integrated extraction of data. Based on deep analysis of such data, an information monitoring model can be established concerning research institutes, researchers, scientific activities, research areas, so as to timely monitor new developments of various research institutions and to achieve tracking, monitoring and insight into scientific research activities of various research institutions. The main application of visualization tools is information extraction in an important scientific and technological information network monitoring. After the establishment of object relations, it can carry out the visualization analysis of massive data, especially of web data, RSS data, news data and OAI data. It can detect hot spots and potential inter-linkages between hot spots, and detect development and changes of discipline areas combined with word-frequency statistical method.

Recently, the websites are mainly used to get the scientific and technology data. Directional collecting web page and data extraction may clean out the scientific terms data to conduct the monitoring analysis. The main analysis methods are word-frequency analysis, co-occurrence analysis, clustering analysis methods [6].

To select experimental data from the field of artificial intelligence, through web acquisitioning, the coal-bed methane term and coal-bed methane document are extracted, through the sequence of word-frequency statistics, the above high-frequency terms are collected, and then it can generate the object of co-occurrence relations using co-occurrence principle. Thus the clustering method is used to generate a two-tier clustering, each clustering is divided initially into 10 categories, at the same time the high frequency term in the categories is selected as category label. Results of clustering analysis can be shown by using the visualization toolbox.

6. Conclusions

In application of the scientific monitoring of visualization practice for coal-bed methane index system, the use of visualization tools has such advantages as easy-to-use, good transparency, lower cost, opening interfaces, good package performance and sustainable developing extended features etc. It gives researcher an abundant form to
carry out the visual analysis, statistical analysis and interactive graphical display. However, there are some shortcomings in science and technology monitoring still. The major role of visualization in science and technology monitoring is visual analysis. Although there are so many algorithms of data mining and analysis, the application of visualization in science and technology monitoring are not enough rich and in-depth. Of course, the applicability of algorithm is relative to the characteristics of data applications and the form of visual display. However, excavation and development of automatic analysis of the algorithms can reveal areas of science and technology development and the details of the dynamic changes clearly and completely. Hence, it need for further study and technology related to algorithms. The visual analysis map should be built to adapt to the user’s awareness and to improve user’s understanding of the scientific and technological development and the insight.

Although the open source visualization tool provides a good display mode, but the technology monitoring is based on the continuing research of massive data. Therefore, in the process of development and use, an attention should be paid to the choice of open source visualization tool, whether it meets the needs. And the loading mechanism of massive data displayed by visualization tools, the clarity and interactivity should be improved, because the data processing speed impacts directly on displaying speed of the massive data and interactive response time. In the process of interactive visualization of massive data, it should think about whether it includes zoom, parallel displacement, overview, focusing, adjustment of visual parameters, so as to display the details and profile data.

Although the visualization technology and visualization tools are rather mature, however, the practice of scientific monitoring technology is not yet mature [7]. The development from information visualization to the visualization of knowledge integrates with a variety of data mining, visual analysis of the analyzing algorithms again; all bring the more opportunities in the face of increasing in web scientific and technical information for researchers. It also provides a more in-depth insight for researchers to grasp the scientific and technological development and monitoring technology.

References