3D Reservoir Modeling Based on Mobile Platform and OpenGL ES

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Abstract. This paper discusses 3D petroleum reservoir modeling based on android platform and development of relavite graphical software system for reservoir models on the mobile terminal. Using OpenGL ES graphical library to perform graphics processing and realize 3D rendering of the mobile reservoir models. Making use of the Kriging algorithm and Choleskly method to accomplish the interpolation calculation, it is the core of all grid vertxes algorithm and cutting operation for the reservoir models. On the basis of 3D reservoir modeling, complete several 3D reservoir geological model maps, and a serial of functional maps such as rotation, translation, scaling and grid displays, peeling, axis slicing, arbitrary slicing, well connected section, etc. The software system successfully passed the tests of some oil field data. The 3D reservoir modeling based on mobile platform enables the professional persons to analyse the reservoir distribution and direct the oil well drilling feasibly and easily, which will bring great convenience for technical exchanges of oil and gas exploration.

1. Introduction
Through the oil and gas field exploration and well-logging, a series of geophysical parameters such as porosity, permeability and oil saturation with the coordinate values of the test points for the petroleum reservoir[1][3][7][9] are obtained. It is necessary to demonstrate the reservoir geological data model and reproduce its layer structures[3][4][5][6] on our everday use mobile platform according to the actual fluctuation reservoir surfaces. The 3D reservoir models are drawn by surface rendering technology[1][3][4][5], and they are interactively operated and processed to facilitate the exploration and technical exchanges of oilfield geological personnel.

The system uses the OpenGL ES graphics library to create and draw a 3D reservoir model on the Android mobile platform. OpenGL ES (for Embedded Systems) is a subset of the OpenGL 3D graphics API[10][3][11] tailored for embedded devices such as mobile phones and PDAs. The basic graphics supported by OpenGL ES are Points, Lines and Triangles. Other complex graphics are combined by these basic geometrical structures. After the drawing instructions are issued, the specified coordinate transformation and illumination processing are performed on the vertices array. After the vertex processing is completed, the pixel information Fragments are generated by the Rasterizer. Then by the Texture Processing, Color Sum, Fog and other processing methods, the final results are stored in the memory FrameBuffer.

2. Design of system functional modules
2.1. Read in the original reservoir data
The original reservoir data required are the coordinates of a series of spatial points measured in the oilfield formation and corresponding geophysical parameters of these points, the data used is numerous, and the method of dynamically allocating arrays is adopted. When the data files are selected, the program automatically allocates the size of the required parameter arrays and reads the data from the data files, which are stored in the dynamically allocated arrays. After the dynamic arrays are used up, the dynamically allocated memory should be freed.

2.2. Reservoir data preprocessing

The original reservoir data read from the data file is the measurement data. Due to various deviations and human factors in the measurement, there may be some errors or unreasonable data. Therefore, after the data is read in, it is necessary to check the validity of the data, and the unreasonable data should be converted to reasonable data. In addition, the actual original reservoir data of the oil field is read, the amount of data is quite large. In order to facilitate the calculation and drawing, the grid data volume (which is also called data body) of reservoir should be coarsened or scaled to reduce the data range used by the reservoir model.

2.3. Creation of 3D reservoir model

After a series of data preprocessing, the processed reservoir data can be used for mapping or drawing of the reservoir model. The key step in achieving 3D reservoir mapping is the modeling of reservoir data body or data volume. According to the analysis of the arrangement structure and distribution characteristics of the original reservoir data, the petroleum reservoir data body constitutes a spatial hexahedral layer, and the two faces in the vertical direction (Z direction) have ups and downs or fluctuation on surfaces, and the remaining four faces are parallel to the plane of the ZOY or ZOX surface. As shown in Figure 1 below.

![Figure 1 Schematic diagram of a 3D reservoir model](image)

Observing the 3D reservoir model, only the six outside faces of the spatial data body can be seen, namely the bottom surface, the top surface, the left surface, the right surface, the front surface, and the back surface. Therefore, the vertex data of the six surfaces is extracted, and the depth test\(^3\)\(^\text{[10][11]}\) of the OpenGL ES is used to perform invisible surface hidden processing, and the three-dimensional reservoir model can be created by using the drawing functions\(^3\)\(^\text{[10][11]}\) of OpenGL ES to color each surface of reservoir model according to vertex parameters on the surface.

2.4. Free rotation and controlled rotation of reservoir model

In order to view the geophysical distribution of each face of the reservoir model, the object model should be able to rotate at an angle on the X, Y, and Z axes. The rotation of the 3D reservoir model can be achieved using OpenGL ES's double buffer refresh technology\(^3\)\(^\text{[10][11]}\).

The interactive manipulation of the reservoir model is more important. The user touches the screen with a finger to slide the model in a certain direction, and the model rotates at an angle in the direction about an axis perpendicular to the direction, so that the user can observe each surface of the reservoir model arbitrarily.
2.5. Magnification, reduction, restoring, translation of reservoir model
When performing detailed reservoir geological analysis on the drawn 3D model, it is often necessary to move a part to the center for enlarged display. Therefore, the operation of the model should have functions such as zooming in, zooming out, restoring, and panning. The interactive operation of reservoir model is done by graphical matrix transforming of OpenGL ES.

3. Development implementation of the reservoir modeling system

3.1. Model construction and reservoir mapping
The 3D reservoir model data body is displayed in a cube frame. As shown in Figure 1 above, the six faces of the data volume are drawn, and the three-dimensional graphics space of reservoir data body is obtained. Drawing of any face of the data body can be achieved by drawing a number of quadrilateral facets. According to the distribution features of the reservoir geophysical data, the loop statement is used to read and process original reservoir data, calculate the color values corresponding to the geophysical parameters of each vertex, and put the interactive graphics operations into the cube model framework by using the translation, scaling and rotation functions of OpenGL ES, the three-dimensional model drawing and manipulation of the reservoir data body can be realized.

The modeling system draws reservoir maps using the original reservoir data loaded by the user, and the plotted 3D model maps can display the grid lines and the coordinates of the x, y, and z axes. The color index table and its corresponding parameter values are given to help the user to understand the geophysical distribution of the reservoir data. As shown in Figure 2 below. According to the specific requirements of reservoir geological evaluation and analysis, parameter values and color editing can also be performed on the reservoir model.

![Figure 2 Loading original reservoir data and drawing the model maps](image)

3.2. Layer stripping display of reservoir model
In order to better observe the internal details of the reservoir data body, the reservoir layer stripping display function is realized, which can display the arbitrary layer stripping of the petroleum reservoir, and the user can conveniently observe each specific layer of the reservoir data model. According to the user's requirements, input the specific layer parameters, the event response function automatically generates the corresponding specific layer index, and the modeling system draws the corresponding specific layer graphic according to the index. As shown in Figure 3 below.
3.3. Reservoir model sectioning and continuous well profile

The reservoir model section is obtained by slicing the model data body. That is, cutting the data body along the coordinate axis or arbitrarily model cutting to obtain a three-dimensional graphic of the model sectioning surface. The corresponding index is calculated according to the cut position coordinates touched by the user's finger, and relavite interpolation points and their color values of the sectioning surface are calculated, and then the modeling system draws the model sectioning surface according to the index. The sectioning index and the parameter or color of any vertex of the section plane could be obtained by color interpolation of the given vertices nearby this vertex, which can be realized by the Kriging algorithm and the Cholesky method [2][6][7][8][9].

With the well connected section or continuous well profile, the distribution of reservoirs near each well location can be observed. Determine the well location coordinates according to user interactive input or finger touch, the data automatically extracted by the response function to finish interpolated calculation for the joint profile index and the color of each vertex of the profile. Thus the modeling system can draw the well profile according to the index, and then cross-sections of each well are unfolded. As shown in Figure 4 below.

Figure 3 Layer stripping display of reservoir model

Figure 4 Reservoir model sectioning and continuous well profile
4. Software system deployment
The reservoir modeling software system is developed and run on the Android mobile platform, and the original reservoir data is written into the SDCard of the mobile device using the UltraISO tool. In actual deployment, the Android system configuration requires sdk level 8 (Android 3.2) and above. Copy the reservoir data to the SDCard, and install finished apk file in the project bin directory to the mobile phone to run the system.

5. Conclusions
Based on the reservoir modeling algorithm and combining the characteristics of OpenGL ES, various 3D reservoir models generation algorithms based on surface patches and cut-off indexes are designed. According to the diverse needs of the user, a corresponding index array is generated, and the interpolation calculation process is performed according to the input of the user. Then spatial coordinate of the interpolation point and the corresponding color value are calculated according to the geophysical parameters of the adjacent points in the reservoir model space.

The model construction of this system is fundamental. Only the creation and drawing of the 3D reservoir model are completed, the rotation, stripping, slicing and connected well profile of the model data body can be implemented. Through these operations, the user will learn the detailed information of the geological structure and internal geophysical parameters of the 3D reservoir data model.

About the author
Kaidong Zheng received his Master degree from Shanghai Jiaotong University in 1988. He is now an associate professor in School of Computer Science, Xi’an Shiyou University. His current research interests include Computer Graphics, Computing Visualization, and Virtual Reality.
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