Virtual Reality Modelling of Garden Geography and Geology Based on 3D Modelling Technology

Qiumin Zhang
Jiangxi University of Applied Science, Nanchang, Jiangxi 330100, China
qiuminzhang@jxcsedu.com

Abstract. The work of 3D garden ge-geological modelling is very tedious and complicated, in order to reduce the labour intensity of the operators and improve the visualization effect of the model. This article proposes a method for 3D stratum visualization based on the combination of limited Delaunay triangulation and OpenGL. We can use the limited triangulation algorithm to generate stratum surface triangulations with any boundary shape, any size, or with multiple holes. At the same time, the paper uses OpenGL’s object picking mechanism to realize the visualization management of drilling data and human-computer interaction stratum modelling. Finally, we applied the model to garden geology, and the results showed that the system can quickly and accurately construct a three-dimensional model of the stratum. At the same time, the model realizes the three-dimensional visualization processing of garden geology.

Keywords: 3D modelling, garden geology, virtual reality, Delaunay triangulation algorithm.

1. Introduction
From the perspective of system development, this paper combines the limited Delaunay triangulation algorithm with OpenGL 3D graphics display technology, and uses the limited Delaunay triangulation algorithm to quickly generate high-quality stratum surface triangle meshes [1]. Through the development of OpenGL 3D programs, the drill can be realized. Visualized management of hole data, real-time interactive creation and visualization of 3D geological models. Finally, taking the drilling data obtained from a 3D geological survey project in a certain area as an example, the functions of the system were tested, and good modelling and visualization results were achieved.

2. Mathematical model of engineering geology

2.1. Basic ideas
The layer (curved) surface model constructed by discrete data fitting interpolation is a mathematical abstract description of the distribution of geological information in complex geological bodies, and provides an important method basis for drawing and displaying the spatial distribution of geological information. The interpolation and fitting functions of geological information should be established based on actual survey data [2]. The richer and more accurate the actual survey data, the more
accurately the geological model obtained can truly depict the spatial distribution of this information. In addition, due to the particularity of geological information data, many constraints and related geological principles must be considered when performing spatial data interpolation. For geological information with different characteristics, different fitting functions are needed to form an accurate and reliable model. Because the drawn compaction curve must pass through the points corresponding to the measured geological information and the corresponding dry density, turning this into a mathematical problem is an interpolation problem. That is, given the function value of \( f(x) \) at \( n \) nodes, find the general expression of function \( f(x) \) and the extreme value problem of function \( f(x) \).

2.2. Interpolation polynomial

The basic principle of the interpolation method in the numerical analysis method is to use a simple interpolation polynomial \( P(x) \) to approximate a very complicated function \( F(x) \) that can only be represented by a data table [3]. For example, it is known that the corresponding relationship between \( f(x) \) and \( X \) is that \( X_n \) corresponds to \( f(x_n) \). The problem of studying the complex function \( f(x) \) is transformed into the problem of studying the simple function \( P(x) \) through the interpolation polynomial \( P(x) \), and finally an approximate value that meets the accuracy requirements is obtained. If \( n + 1 \) nodes and their corresponding function values are known, the \( n \) order interpolation polynomial that satisfies the known conditions can be approximated as a function expression. According to the above principle, the water content and dry density values of group \( n + 1 \) measured in the compaction test are calculated using Newton interpolation method to obtain an interpolation polynomial of degree \( n \). This polynomial curve passes through the known \( n + 1 \) nodes and is the only one that satisfies the test the degree polynomial of the data, the \( n \) degree polynomial is approximated as the function expression of the compaction curve.

2.2.1. Bad Quotient. Suppose that the function values \( f(x_0), f(x_1), \ldots, f(x_n) \) of function \( f(x) \) on \( n + 1 \) different nodes \( x_0, x_1, \ldots, x_n \) are known, and \( [f(x_j) - f(x_i)]/(x_j - x_i) \) is called the first-order difference quotient of \( f(x) \) with respect to nodes \( x_i \) and \( x_j \), denoted as \( f[x_i, x_j] \) generally, the difference quotient of the \( (k - 1) \) order difference quotient is called the \( k \) order difference quotient, namely:

\[
f[x_0, x_1, \ldots, x_{k-1}, x_k] = \frac{f[x_0, x_1, \ldots, x_{k-1}, x_k] - f[x_0, x_1, \ldots, x_{k-2}, x_{k-1}]}{x_k - x_0}
\]

(1)

From the definition of the difference quotient, it is known that if the function value of \( f(x) \) on \( n + 1 \) nodes is given, the difference quotient of each order up to the \( n \) order can be obtained.

2.2.2. Newton interpolation polynomial. The difference quotient has the following main properties: \( k \) order difference quotient \( f[x_0, x_1, \ldots, x_k] \) is formed by the linear combination of function values \( f(x_0), f(x_1), \ldots f(x_k) \) namely:

\[
f[x_0, x_1, \ldots, x_{k-1}, x_k] = \sum_{m=0}^{k} \frac{f(x_m)}{(x_m - x_i)} (i = 0, i \neq m)
\]

(2)
Using the above principles, you can write a polynomial of degree $n$ of several sets of data measured through experiments, and use this polynomial to approximate the function $f(x)$ as the functional expression of the compaction curve.

2.2.3. **Polynomial extreme value conditions.** To obtain the maximum dry density and optimal water content, it is necessary to find the peak value of the curve, which is transformed into a mathematical problem to find the extreme value point $x^*$ of function $f(x)$ and its function value $f(x^*)$. Because $x^*$ is the extreme value point, there is $f'(x^*) = 0$ ( $f(x)$ of First Derivative). Suppose $G(x) = f'(x)$, then $G(x^*) = 0$ is satisfied, so finding the extreme point $x^*$ can be transformed into finding the solution of $G(x) = 0$.

2.2.4. **Extremum-Newton iteration method.** The basic idea of iterative method is a method of successive approximation, among which Newton method is a method of linearizing nonlinear equations. Let $X_k$ be an approximate root of the original equation $G(x) = 0$, then $X_{k+1} = X_k - \frac{f(X_k)\cdot f'(X_k)}{f'(X_k)^2}(k = 0, 1, 2, \ldots)$ is the Newton iteration format, and iterate repeatedly until the root $X_k$ that meets the accuracy requirements is obtained [4]. You can first determine the approximate range of the optimal water content based on experience. Choose an approximate value within this range, and iteratively solve the problem, you can find the root $x^*$ of $f'(x) = G(x) = 0$ that meets the accuracy requirements, that is, the optimal water content, and the value of $f(x^*)$ is the maximum dry density.

3. **System development**

3.1. **Modelling and visualization process**

The drilling data is read through the program, and the three-dimensional model of the drilling is selected by human-computer interaction to generate the modelling area boundary. Secondly, the original drilling data is encrypted by calling the interpolation algorithm to generate virtual drilling inside the modelling area. Secondly, the limited Delaunay triangulation algorithm is used to generate the surface triangulation of each layer; then, the boundary surface of each layer is closed to form a three-dimensional volume model of the stratum [5]. Finally, call OpenGL drawing commands to realize the real-time display of the model, and the modelling and visualization process is shown in Figure 1.

![Figure 1. 3D geological modelling process.](image-url)
3.2. Functional design
In order to simplify the operation process of the system as much as possible, and facilitate users to learn and master, the system functions are divided into two main function modules: data management and geological modelling.

![Diagram of system functions](image)

**Figure 2.** The main functions of the system.

3.3. Establishment of spatial scattered data
In order to facilitate processing, the selected area needs to be meshed, that is, random points \((X_i, Y_i, Z_i, i=1, 2, 3,...,n)\) mentioned in the geography profession are used as vertices to divide the selected area. It is a collection of geometric grid-like elements very similar to the solid. It is mainly divided into two types: rectangle and triangle [6]. Although the gridding unit processing is convenient, because of insufficient accuracy, further interpolation processing is required. There are many interpolation methods in simulated information geography, such as polynomial interpolation, spline interpolation, etc. After fitting by computer simulation interpolation technology, the basic graphics are formed. The next step is to process the visual effects of three-dimensional geographic objects. It is hoped that the three-dimensional image can be expressed on the two-dimensional interface of the computer monitor, and a projection transformation of the three-dimensional image is required. According to specific requirements, you can choose perspective projection or parallel projection. If you choose perspective projection, you must collect data from multiple perspectives, and then achieve a better adjustment of the visual effect of the virtual geographic landscape. When processing the geographic perspective effect display, the processing of the bright and dark effects of the geographic virtual landscape is equally important. Usually there are two methods for the shading of three-dimensional graphics: 1. Under natural light, the shading and dark effects produced by the three-dimensional display of digital models and images. 2. Set up a light source, under which the shading effect is formed. An example of geographic landscape is shown in Figure 3. The picture on the left is a grid demonstration, and the picture on the right is an example of a geographical and geological landscape demonstration based on the left picture.
3.4. Profile creation
The side map of the hexahedron is a key step in the establishment of a 3D geological model. It is actually a geological section with the four sides of the quadrilateral on the top of the hexahedron as the section lines. The basic drilling information (see Table 1) and the drilling rock formation information (see Table 2) are stored in different database tables [7].

Table 1. Basic drilling information.

| Numbering | Orifice elevation/m | Groundwater level/m | Construction time/year and month |
|-----------|----------------------|----------------------|----------------------------------|
| MW141     | -2.35                | -4.53                | 200303                           |
| MW121     | -3.52                | -4.47                | 200307                           |

Table 2. Drilled rock formation information.

| Drilling number | Rock formation number | Floor top elevation/m | Elevation of bottom layer/m | Legend number |
|-----------------|-----------------------|-----------------------|------------------------------|---------------|
| MW141           | 1-3                   | -2.34                 | -3.44                        | L1011         |
| MW141           | 2-4                   | -3.44                 | -8.34                        | L1013         |
| MW141           | 2-4                   | -8.34                 | -14.46                       | L1044         |
| MW141           | 3-1                   | -14.46                | -24.46                       | L1048         |
| MW121           | 1-3                   | -3.42                 | -4.38                        | L1041         |

4. Application case analysis
In order to verify the operability and reliability of the modelling and visualization of the system, the actual modelling operation was carried out with the drilling data obtained by the geological survey of a 3D geological survey project in a certain area, and the system was constructed by the method of multi-view 3D model design familiar to users. The three-dimensional model of the stratum, the system interface is shown in Figure 4.
5. Conclusion
The paper adopts a three-dimensional garden geographic stratum visualization method that combines the limited Delaunay triangulation algorithm and the OpenGL 3D graphics platform, which gives full play to the limited Delaunay triangulation algorithm’s meshing capabilities, and can significantly improve the quality of the stratum grid and the visualization of the model effect. At the same time, the system adopts a multi-view human-computer interaction modelling interface to realize the visualization management of drilling data and real-time interactive modelling, which is an enrichment and perfection of the existing 3D garden geo-geological modelling methods.

Acknowledgments
This work was financially supported by Teaching Reform Project of Jiangxi Institute of Applied Science and Technology: Study on Cultivation of Application Oriented Talents in Private Higher Vocational Garden Engineering (JXYKJG-19-15).
This work was financially supported by Science and Technology Research Project of Jiangxi Provincial Department of Education: Research on Carbon Emission of Building Decoration Engineering Based on BIM Technology (GJJ203009).

References
[1] Zhang, T. F., Tilke, P., Dupont, E., Zhu, L. C., Liang, L., & Bailey, W. Generating geologically realistic 3D reservoir facies models using deep learning of sedimentary architecture with generative adversarial networks. Petroleum Science, 16 (3) (2019) 541-549.
[2] Wellmann, J. F., De La Varga, M., Murdie, R. E., Gessner, K., & Jessell, M. Uncertainty estimation for a geological model of the Sandstone greenstone belt, Western Australia–insights from integrated geological and geophysical inversion in a Bayesian inference framework. Geological Society, London, Special Publications, 453 (1) (2018) 41-56.
[3] Varga, M. D. L., Schaaf, A., & Wellmann, F. GemPy 1.0: open-source stochastic geological modelling and inversion. Geoscientific Model Development, 12 (1) (2019) 1-32.
[4] Olierook, H. K., Scalzo, R., Kohn, D., Chandra, R., Farahbakhsh, E., Clark, C., ... & Müller, R. D. Bayesian geological and geophysical data fusion for the construction and uncertainty quantification of 3D geological models. Geoscience Frontiers, 12 (1) (2021) 479-493.
[5] Quesnel, B., de Veslud, C. L. C., Boulvais, P., Gautier, P., Cathelineau, M., & Drouillet, M. 3D...
modelling of the laterites on top of the Koniambo Massif, New Caledonia: refinement of the per descensum lateritic model for nickel mineralization. Mineralium Deposita, 52 (7) (2017) 961-978.

[6] Krietsch, H., Doetsch, J., Dutler, N., Jalali, M., Gischig, V., Loew, S., & Amann, F. Comprehensive geological dataset describing a crystalline rock mass for hydraulic stimulation experiments. Scientific data, 5 (1) (2018) 1-12.

[7] Wang, H., Wellmann, J. F., Li, Z., Wang, X., & Liang, R. Y. A segmentation approach for stochastic geological modelling using hidden Markov random fields. Mathematical Geosciences, 49 (2) (2017) 145-177.