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Geological target-driven volume rendering local enhance lighting design

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ABSTRACT

It is a conceptually simple process to compute illumination in many scenes. However, in seismic data processing, the researchers often encounter a lot of 3D discrete data. Compared with other areas of data, seismic data has the characteristics of big data volume and high discrete degree. As a result, the naive application of this methodology can lead to erroneous results which can't meet the requirements. Phong (1975) put forward an experience model used to calculate the brightness of specular reflection of a surface. The least number of experiments are committed to improve the basic model to make better effect or accelerate the speed while few people apply it to seismic data. The purpose of our study was to present a semi-automatic method that allows the user to manually design the interesting areas and change the coefficient of classical model to solve the problem of 3D seismic data imaging. Use the multi-resolution voxel management and acceleration arithmetic based on GPU which support seismic data of big volume.

Keywords: Phong illumination model; Seismic data processing; Geological data

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INTRODUCTION

As the graphics and image processing technology increasingly grown mature, volume rendering technique for 3D data visualization field[1] becomes the most important and the most rapid development in recent years in the field of technology. Scene performance depends heavily on accurate application of the illumination model. In 1975, Phong put forward an experience model used to calculate the brightness of specular reflection of a surface, namely the Phong model [2].Since 1988 the Phong illumination model used in the volume rendering [3] for the first time, it's widely used in all kinds of visualization tools.

In recent years, methods using local lights have been explored. In 1977 Blinn improved the reflected light part of phong illumination model calculation which reduced the computational complexity [4]. Then Cook and Torrance put forward a model of surface reflectance based on physical optics called Cook-Torrance model[5] in 1982, makes the model very close to the location and distribution of reflected light and practical but not establish contact with the surrounding objects leaded to the insufficient diffuse process. In the early 19th century, half Angle section [6] is put forward by Kniss. The method based on the slices make second rendering for each slice, one from the Angle of the observer and the other from the direction of the light source. The system allows illumination intensity attenuation arrived at each voxel which achieves the efficient shadow effect. Many models on implementation are limited by the processing capacity of CPU and GPU. Although improved effect of display, they don't have practical application value. With the improvement of GPU computing power, in 2010 Yunpeng Zou [7] improved reflection model based on the Phong model and its application in medical image visualization can satisfy the requirement of real-time rendering. In 2011, Michael Breu [8] discusses the contribution the specular reflection model made to graphics sense of reality on the basis of the Phong model. In the same year, the lighting model in recent years -- the Phong model, half Angle slice method and the global illumination model are summarized by Florian Lindemann and Timo Ropinsk [9]. The principle of model, image quality and time consumption compared to each other to find out the evolution of the relationship between models, making it possible to create a new visual lighting model. In 2013 the Phong model is applied to the 3D cartoon rendering by Shaohao Wang [10]. The improved cartoon rendering lighting model achieved an unique effect on the basis of generating a cartoon appearance.

In seismic data processing, the researchers often encounter a lot of 3D discrete data. Compared with other areas of data, seismic data has the characteristics of big data volume and high discrete degree: 3D geological exploration data often as big as dozens to hundreds GB; internal structure consists of sand body, river, etc.; the data is discontinuity and relevance between voxels is small. When people directly use the existing lighting model, they often cannot highlight the useful information in the data. Therefore, if automatically and intelligently adjust the lighting model parameters for the user according to the characteristics of the volume data, we can local enhance the interested part in geological data which plays an important role in improving the efficiency of volume rendering and helping users to rapidly and accurately understand the earthquake visualization data.

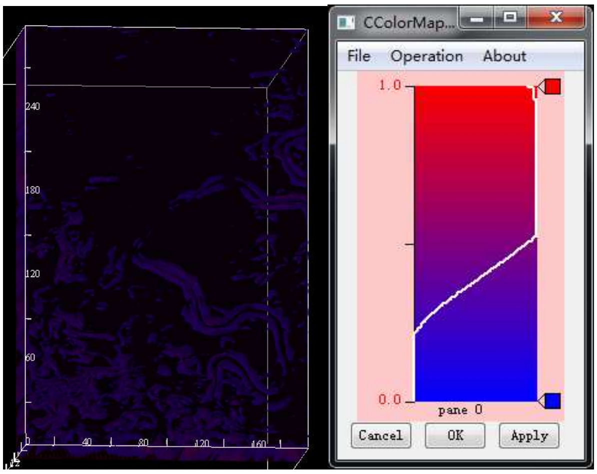


Fig. 1: Phong model and color table, set the color table as shown in Fig. 1(right), color gradual change from red to blue. A region of low transparency presents blue while high transparent part presents red. Select the channel seismic data, only using Phong model is shown in the Fig. 1(left)

GEOLOGICAL TARGET-DRIVEN VOLUME RENDERING LOCAL ENHANCE LIGHTING DESIGN

Phong illumination model is a kind of simple and efficient local illumination model based on physical observation experience with use of Diffuse Reflection and Specular Reflection to calculate the result of the light reflection. Environmental illumination model is also included in Phong model to simulate the light affect to the scene. Effect of ambient light is inherent in the environment which is the same for each point in the graphics. Diffuse light is casted from the light source to the surface of the object and intensity is equal for each reflection direction. Therefore diffuse light intensity is only relevant to the normal at the reflection point. Specular reflected light is light source through specular reflection. The light intensity is related to the normal of the reflection point and sight direction. As an example of point light, $\vec{L}_m$ presents the direction of the light source to the surface; $\vec{N}$ is normal vector; $\vec{R}_m$ presents the reflected light of m-th light; $\vec{V}$ is the direction vector from points to the observer. When using external light source, vector $\vec{L}_m$ is a constant vector which has nothing to do with the position of the point. So when the angle of volume rendering has determined, equation (1) can be written as an equation about the normal vector $\vec{L}_m$:

$$\vec{R}_m = 2(\overrightarrow{L_m} \cdot \vec{N})\vec{N} - \overrightarrow{L_m} \quad (1)$$

The light intensity *Ip* of each point on the surface using Phong illumination model can be calculated as (2):

$$I_p = K_a i_a + \sum_{m\in \text{light}s} \left(K_d (\overrightarrow{L_m} \cdot \vec{N}) i_{m,d} + K_s (\overrightarrow{R_m} \cdot \vec{V})^{\alpha} i_{m,s} \right) \quad (2)$$

In (2), i_s and *id* i_d respectively specular reflection and diffuse reflection light intensity of each light source while i_a is on behalf of the environment light intensity. K_s is specular reflection coefficient reflecting the incident light reflectivity; K_d is diffuse reflection expressing incident light intensity; K_a is on behalf of the ambient parameters. *a* is the light intensity coefficient of material. The bigger the number is, the smoother the surface is as well as more close to standard mirror plane. When the parameter is very large the specular highlights of the area is very small. When color is expressed in RGB mode, the equation (1) and (2) can be respectively used in R, G, B three channels, so it can allow different reflection coefficient, such as K_s and K_d can have different values in three channels.

Because the geological data have the characteristics mentioned above in introduction last paragraph. As shown in Fig 1, directly using the Phong illumination model often cannot highlight useful information in the data. So according to the characteristics of the data itself, choose user interests through artificial input interest in the position, semi-automatically and intelligently adjust the lighting model parameters for the user will classify the interest of sand bodies and river helping users rapidly and accurately understand the earthquake visualization As Phong illumination model is built on the principle of light reflection on the surface of the object, so if the Phong illumination model was applied to direct volume rendering, methods to determine the visual surface of object and its normal are required. In order to avoid the complex intermediate steps as well as to accelerate the speed of volume rendering, we usually use the gradient vector $\nabla f(\overrightarrow{x_i})$ to approximate the surface normal vector of x_i voxel. Above all, our methods can be divided into three steps:

- Voxel gradient are calculated by use of the central difference algorithm, for interpolating in the six directions of the current processing points in GPU namely up down before and after, according to the equation:

$$\vec{N}(x_i) \approx \frac{\nabla f(\overrightarrow{x_i})}{\|\nabla f(\overrightarrow{x_i})\|} \quad (3)$$

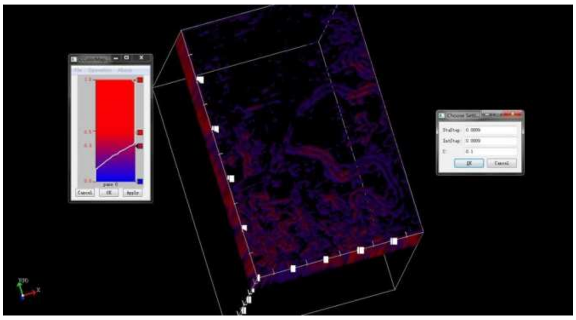
$$\nabla f(\overrightarrow{x_i}) \approx [f(x_{i-1}, y_j, z_k) - f i x_{i+k} y_j, z_k), f(x_i, y_{j-1}, z_k) - f(x_i, y_{j+1}, z_k),\ f(x_i, y_j, z_{k-1}) - f(x_i, y_j, z_{k+1})] \quad (4)$$

Calculate the gradient of all voxels, and thereby to approximate the normal of the voxels' surface.

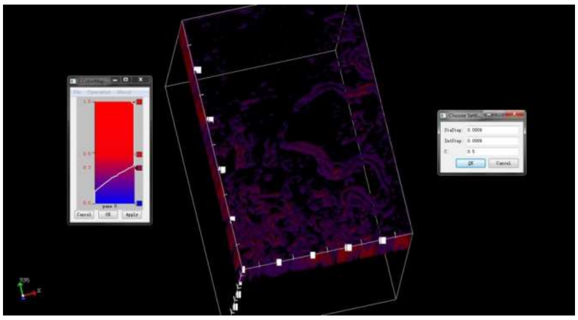
- Determine all illumination coefficients of voxels with use of type (2).
- Complete improved Phong model by adding alpha selection model to realize 3D seismic data display.

SIMULATION RESULTS AND ANALYSIS

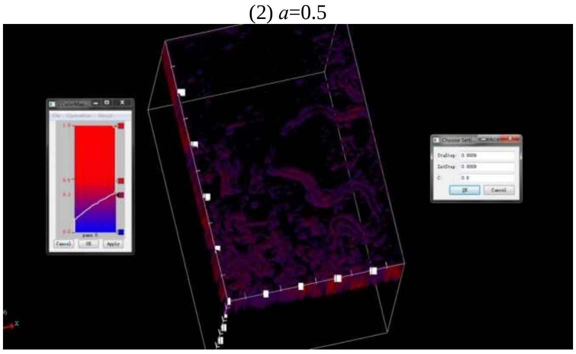
Test the simulation results by changing the thickness of anomalous body shell namely transparency threshold. Set the color table as shown in Fig. 1(right), color gradual change from red to blue. A region of low transparency presents blue while high transparent part presents red. Select the channel seismic data, only using Phong model is shown in Fig. 1.



(1) *a*=0.1



(2) *a*=0.5

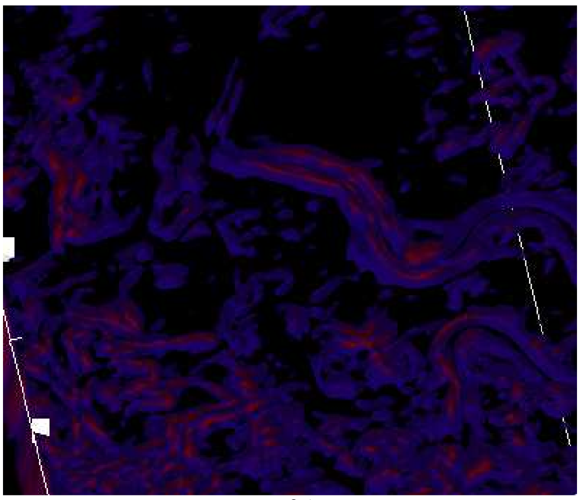


(3) *a*=0.8

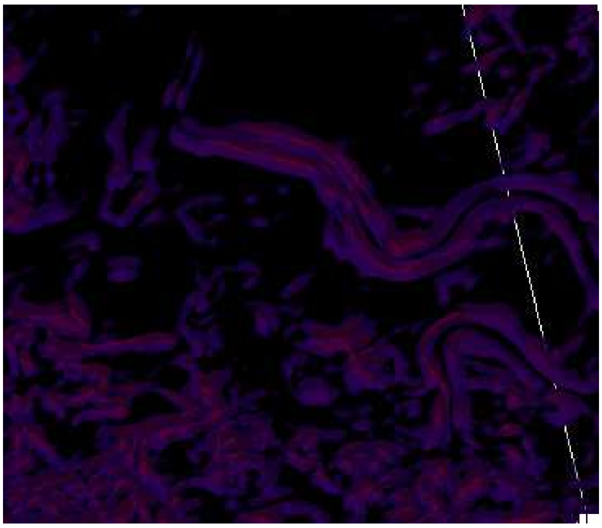
Fig.2: Channel data display effect

The channel data sections and sand body data can't distinguish very well only using traditional methods to solve the problem. In the space structure, abnormal body reflects the outer envelope for part of the space structure while at the data level, abnormal body are divided into groups by its connectivity in the space, each group is made up of multiple triangle triangulation. Transparency are not the same in abnormal body each layer. In the application processing, we usually need to display the various levels of the shell shape for further analysis. For example when only the middle of the river level process and effect are required, the original model can't meet the needs of the user. So we modify the Phong model according to ROI choice to distinguish the interest degree in order to choose according to the user to distinguish the shell thickness of river data which is convenient for the user to further observe the internal structure. When *a* is chosen respectively 0.1, 0.5, 0.8, results are shown in Fig. 2.

To strengthen local illumination, we blur the other parts of the sand body by manual input interest value after assigning the data value degree. Effective data will be given the high value degree while not required data given the low values. Contrast when *a* is 0.1 and 0.8:



a= 0.1



a=0.8

Fig. 3: Part of the channel display effect with diffirent *a*

Compared to the same part under the same color table selection, blue is the outermost part of the data while the red is on behalf of the center of the partial channel data. The blue part is thinning after threshold increased and part of the river channel is highlighted which has an effect on blur away the outer layer of the river. But our method still has defects which can be improved. First of all, on the choice of model we choose classic the phong model because the phong model is relatively simple in implementation and rapidly, in order to obtain better results for further study we can use other suitable improvement model; Moreover, we use the transparency to distinguish data value degree, although each piece in the seismic data has different attributes of the data will be divided into different transparency, but there are still the differences on the definition and the different effect. Further research could use the illumination intensity L to the division and integration of the degree.

CONCLUSION

By comparing the original algorithm and our algorithm simulation results it can be seen that our improved method can be applied to seismic data volume rendering lighting. We can get more clearly seismic anomaly body shell shape using these features combined with voxel rendering and selection. By semi-automatic input interest of transparency and value, the user can realize the purpose of local illumination enhancement, further research and analysis of characteristics of the data.

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