

PAPER • OPEN ACCESS

## OpenGL based A 3D Visual Technology of Digital Core

To cite this article: Rui Huang *et al* 2019 *J. Phys.: Conf. Ser.* **1302** 022086

View the [article online](#) for updates and enhancements.

You may also like

- [Development of a machine tool auxiliary machining system based on android phone](#)  
C M Zhang, L S Zhang, T Zhang et al.
- [Frog: The fast & realistic OpenGL event displayer](#)  
Loïc Quertenmont
- [Visualization Research of STL Model Based on OpenGL Technology](#)  
Wei Xu and Hongwei Jia



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# OpenGL based A 3D Visual Technology of Digital Core

Rui Huang<sup>1,\*</sup>, Cheng Zan<sup>1,2</sup>, Wei Long<sup>1,2</sup>, Haoran Cheng<sup>1,2</sup>, Wei Li<sup>1</sup>,  
Guanqun Wang<sup>2</sup> and Bing Zhang<sup>1</sup>

<sup>1</sup> Research Institute of Tsinghua University in Shenzhen, A216, Nanshan Hi-new  
Technology and Industry Park, Shenzhen, China

<sup>2</sup> ICORE GROUP INC, A216, Nanshan Hi-new Technology and Industry Park,  
Shenzhen, China

Email: huangrui25@126.com

\*Corresponding Author

**Abstract.** OpenGL is widely used in many industrial application fields as a powerful 3D graphics library. Especially, it plays important roles in displaying the visualization emulation model of digital cores. In this paper, according to the practical demands of projects, we conduct a thorough research on displaying 3D visual models of the pore structure and the skeleton structure of digital cores using OpenGL application library. Actual applications indicate that the idea of this paper is feasible and it holds the keys to scientific research of digital cores.

## 1. Introduction

Recently, 3D visualization technology has been widely applied on many macroscopic fields of petroleum engineering such as the integration of seismic data processing and interpretation, 3D reservoir geological modelling techniques and reservoir simulation technology during oil field exploration and development, which is also one of the important subjects to solve in computer simulation and plays a very important role in enhancing oil recovery <sup>[1]</sup>. With the advent of technology and the increasing needs of oil production site for simulating the pore forms and the seepage condition of reservoir, 3D visualization technique is increasingly being used to solve the problem of digital core at the micro level.

First of all, through this research a simulation environment of the computer system is established by VS 2017 development platform and OpenGL graphics library. Secondly, according to the binary data obtained from micro CT, a digital core model is built which can display 3D virtual scenes on a computer screen. Meanwhile, many functions are implemented by this technique including zooming, panning, rotating, slicing and displaying the structure of the pore and skeleton <sup>[2]</sup>. It has provided the effective technical support for the construction of intelligent digital oil fields.

## 2. Building OpenGL Development Environment

### 2.1. Introduction to OpenGL Library of Visual Studio 2017

OpenGL as the most extensive and high-performance image processing standards, which can provide hundreds of standard functions for 3D image processing and modelling, can be used to build the shape of a model, to process the visual effects of a model and to render a model <sup>[3]</sup>. At present stage, there are three main development languages for developing the visualization techniques of Windows desktop applications based underlying technology, which are VB, C# and C++ <sup>[4]</sup>. With the improvement of computer visualization technology, in order to complete an object that includes the 3D visualization simulation and application of digital core, more and more tedious work has been eliminated by one of



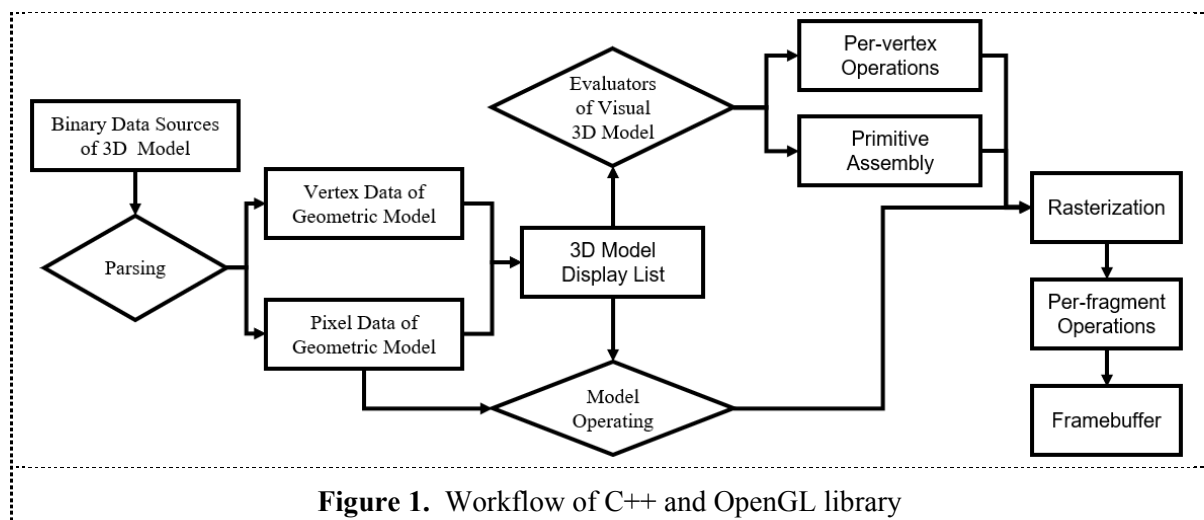
the programming languages mentioned above and OpenGL library, meanwhile the extensibility of the technology also can be improved widely<sup>[5]</sup>. Finally, using Visual Studio 2017 platform, the establishment of visual development environment is studied by a combination of C++ language and OpenGL library in this paper.

### 2.2. 3D OpenGL Library Environment Configuring Process

For establishing development conditions, five files will be used, including glut.dll, glut32.dll, glut.lib, glut32.lib and glut.h, which are based on 64-bit Windows system environment<sup>[7]</sup>. First of all, under the root installing directory of VS 2017, one creates a folder ("gl") in the specified path which is "...\\Microsoft Visual Studio\\2017\\Community\\VC\\Tools\\MSVC\\14.11.25503\\include", and copies the "glut.h" file into the "gl" folder. The next, one copies two files ("glut.lib" and "glut32.lib") into the path which is "...\\Microsoft Visual Studio\\2017\\Community\\VC\\Tools\\MSVC\\14.11.25503\\lib\\x86". Finally, one copies "glut.dll" and "glut32.dll" into the path which is "C:\\Windows\\SysWOW64", to complete the configuration of 3D OpenGL development environment.

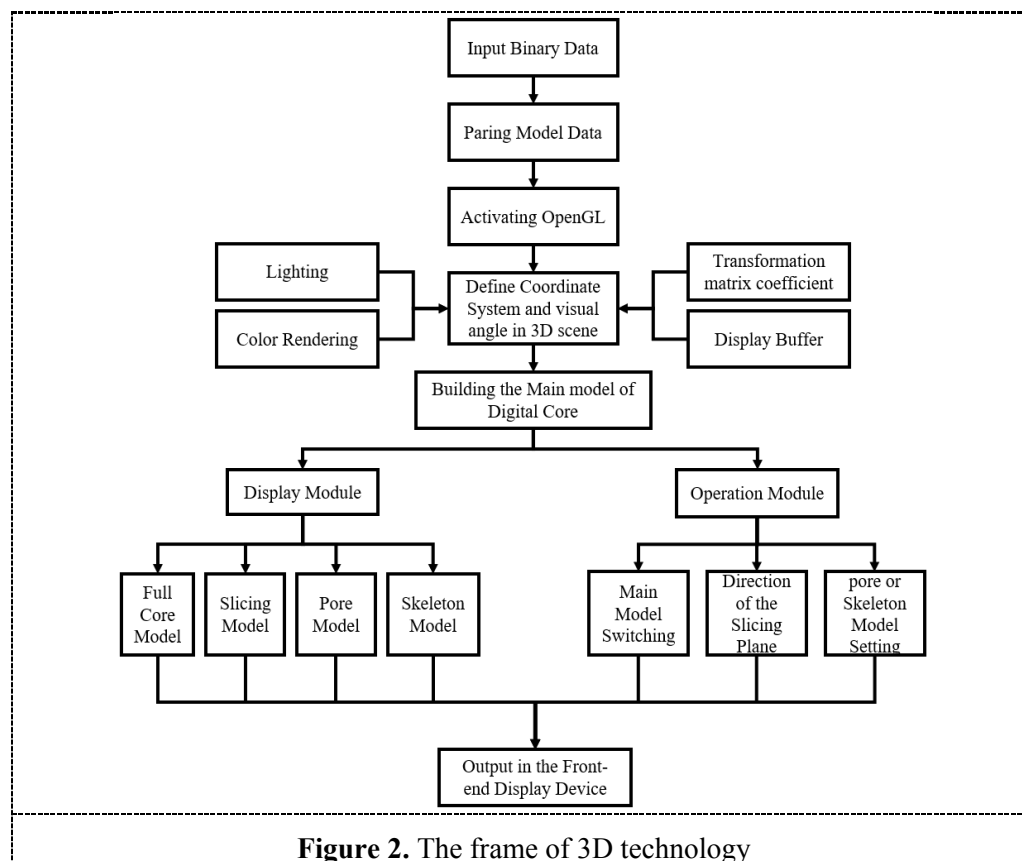
### 2.3. OpenGL 3D Graphics Establishing Workflow

The workflow to create a 3D graphics with C++ OpenGL library comprises the following steps<sup>[8]</sup>: reading and parsing the binary data sources of 3D model, initializing visual environment, establishing viewpoint and scene, building core model, visualizing the graphics. First, one needs a mathematical description of OpenGL, and the underlying mathematical methods to obtain the spatial location and color information of each element on the 3D surface, and then one needs to implement modeling operation, rasterization, per-fragment operations etc. Finally, delivering the data of core model to the frame buffer, the 3D core model can be displayed on a computer screen<sup>[9]</sup>. As shown in Figure 1



### 2.4. Technical Design for 3D Visualization of Digital Core

To get a better idea of how the 3D technology of digital core is working, a technical framework is designed by the following main steps: first, a technique of inputting and paring model data should be completed. Then, for building and displaying the main model of the digital core model, a 3D scene will be configured. Finally, the front-end display and operation models will be also completed, which includes but not limited to displaying full core model, sliced model, pore model and skeleton model shown in Figure.2.

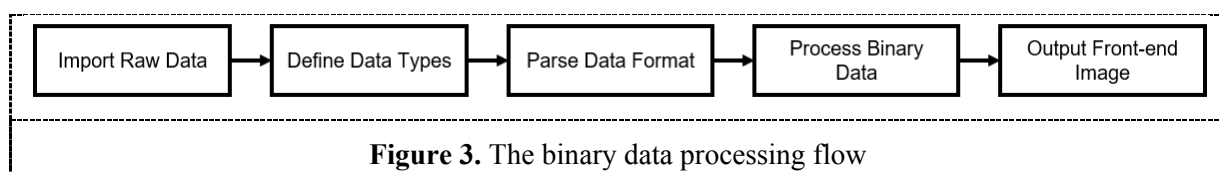


**Figure 2.** The frame of 3D technology

### 3. Technological Realization of 3D Visual Digital Core

#### 3.1. Binary Data Reading and Processing

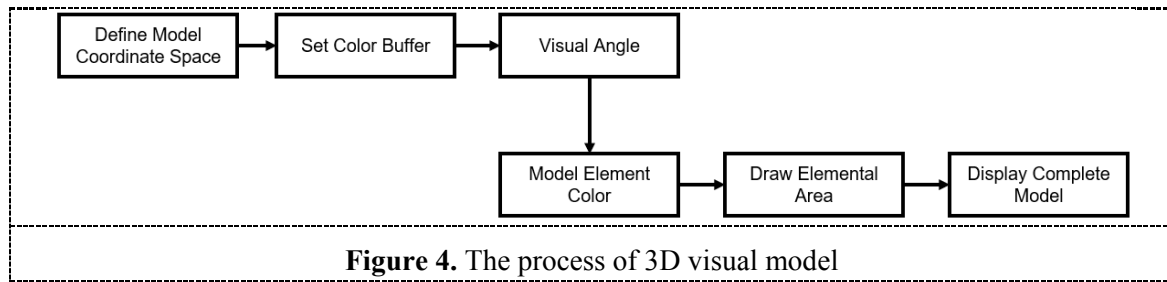
These raw data sources come from CT-scan of the core or rock debris, which will be stored and read in binary file formats. And in general, these data types include short int, integer, float, double, character and so on. The main process is shown in the following figure.



**Figure 3.** The binary data processing flow

#### 3.2. 3D Visual Digital Core Modeling

After the user finishes reading the binary data sources, a 3D coordinate system and visual angle should be established by using reasonable methods as follows, which can display the 3D visual model. The function "glOrtho (xleft, xright, ybottom, ytop, znear, zfar)" is used for an orthogonal projection, thus building and initializing effective range in space coordinate system. Meanwhile, these functions of glClearColor() and glClear() can set buffer by specified color and arbitrary polygon can be drawn by the function "glBegin(GL\_POLYGON)". And then the function "glColor3f ()" can render model color, the function "glVertex3f()" will be used in calibrating vertex coordinates of every model elements. The main process is shown in the following figure.



Each discrete point plane coordinates  $(x, y, z)$  of the model element is calculated by the Eq. (1)-(3).

$$\begin{cases} x_i = -0.5n + i - 1.5, & n \in \text{even} \\ x_i = -0.5n + i - 1, & n \in \text{uneven} \\ i = 1, 2, \dots, n+1 \end{cases} \quad (1)$$

$$\begin{cases} y_i = -0.5m + i - 1.5, & m \in \text{even} \\ y_i = -0.5m + i - 1, & m \in \text{uneven} \\ i = 1, 2, \dots, m+1 \end{cases} \quad (2)$$

$$\begin{cases} z_i = -0.5k + i - 1.5, & k \in \text{even} \\ z_i = -0.5k + i - 1, & k \in \text{uneven} \\ i = 1, 2, \dots, k+1 \end{cases} \quad (3)$$

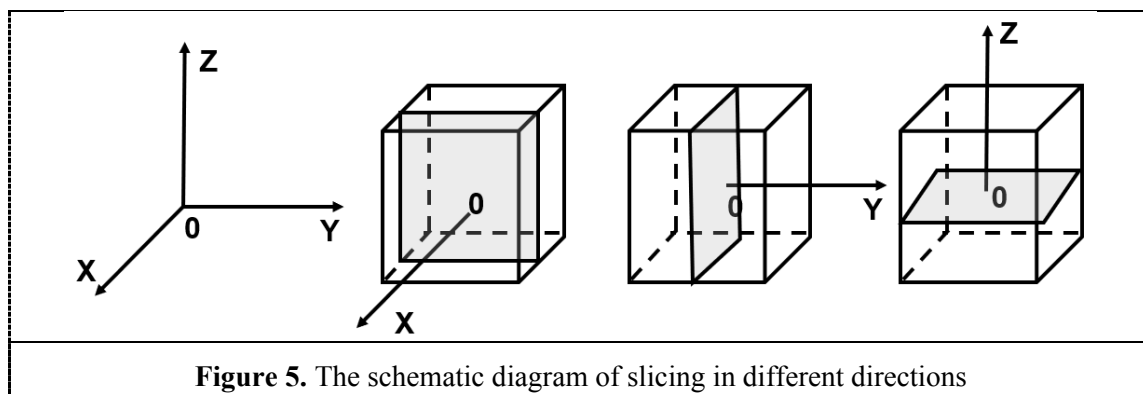
where  $n$  is the resolution of  $x$  direction,  $m$  is the resolution of  $y$  direction,  $k$  is the resolution of  $z$  direction.

### 3.3. 3D Model Geometric Transformation

In the 3D visual space, the lighting functions: “glLightfv()”, “glEnable(GL\_LIGHT0)” and “glEnable(GL\_LIGHTING)” can greatly improve the visual effects of core model. Besides, in order to display and observe models from different perspectives and sizes, functions such as “glTranslatef()”, “glScalef()” and “glRotatef()” could be used for translation, scaling and rotation of the images

### 3.4. 3D Model Slicing

Normally, in order to investigate the distribution of internal geophysical property, a digital core with a hexahedral profile, is cut by three sequences of planes perpendicular to the  $x$ -axis, the  $y$ -axis and the  $z$ -axis, respectively. As illustrated in Figure 5, the control function of the solid hexahedron centred at the origin is given in Eq. (4), the equations of cutting planes are shown in Eq. (5).



$$\begin{cases} -a \leq x \leq a \\ -b \leq y \leq b \\ -c \leq z \leq c \\ a > 0, b > 0, c > 0 \end{cases} \quad (4)$$

$$\begin{cases} x = a1, & -a \leq a1 \leq a \\ y = b1, & -b \leq b1 \leq b \\ z = c1, & -c \leq c1 \leq c \end{cases} \quad (5)$$

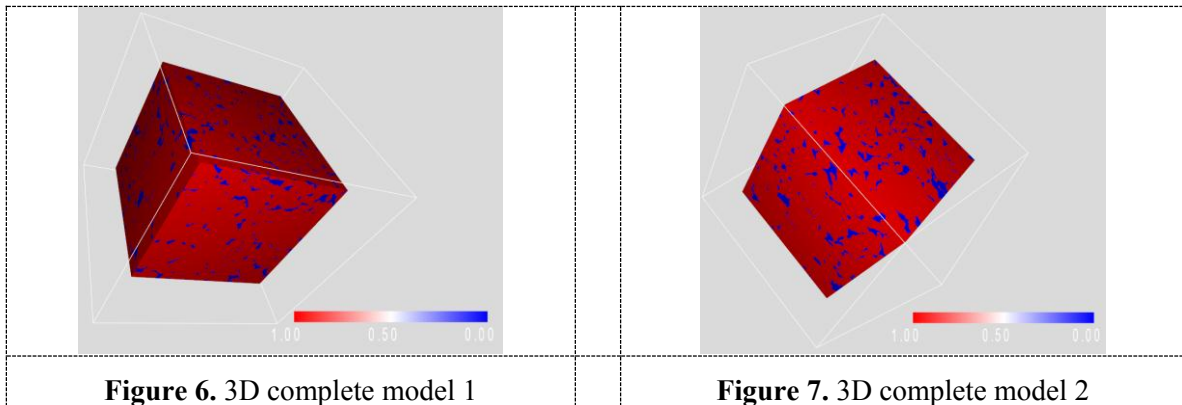
### 3.5. 3D Pore and Skeleton Modeling

A 3-D digital core is a 3-D image of a piece of rock, which reveals the microscopic structures of the rock at the pore-scale. Usually, the study on the distributions of the pores and the solid skeleton is of great importance during a 3-D visualization process. Considering the distribution of pores and throats and the distribution of skeleton as two distinct cases, the control function is simplified as:

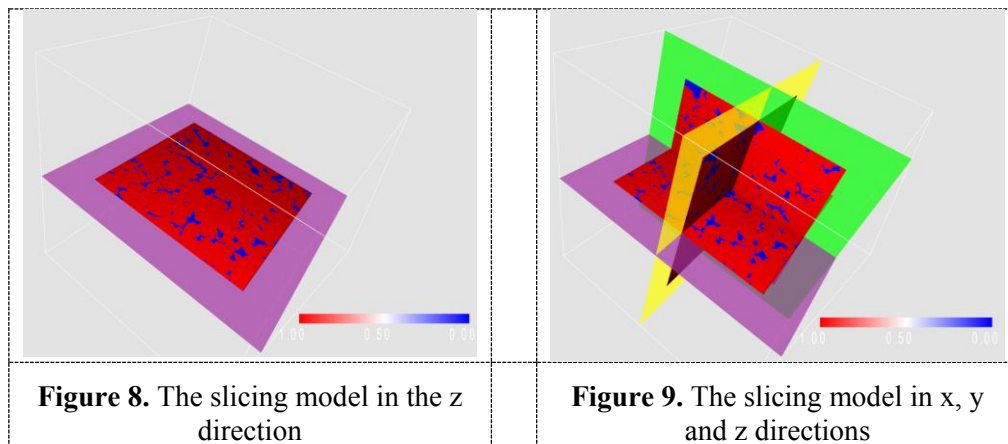
$$f(x) = \begin{cases} 0, & x \in \text{porous} \\ 1, & x \in \text{skeleton} \end{cases} \quad (6)$$

## 4. 3D Visual Application for Digital Core technology

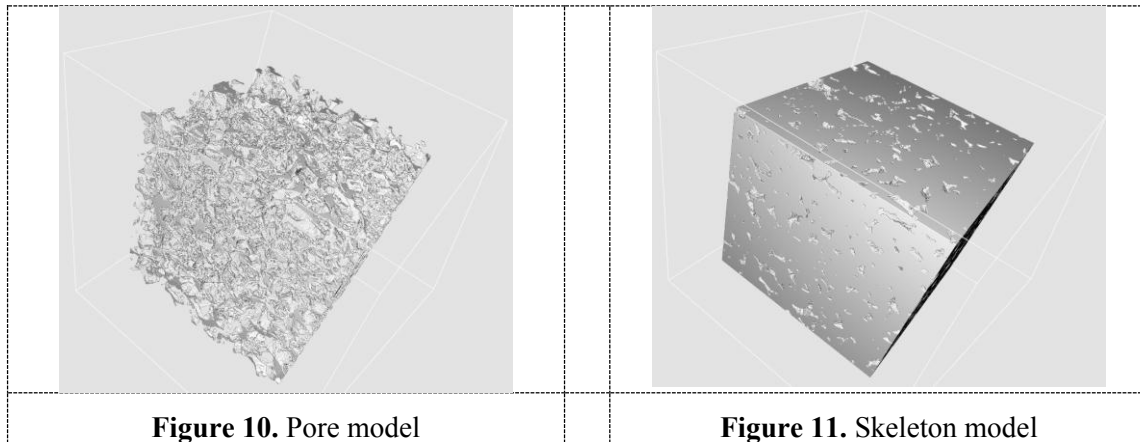
### 4.1. 3D Complete Models



### 4.2. 3D Slicing Models



#### 4.3. 3D Pore and Skeleton Models



#### 5. Conclusion

Based on VS2017 and OPENGGL platform, the paper mainly studies a three-dimensional simulation technology for core CT scanning data source. Based on the OpenGL graphics library, the visualization of three-dimensional core simulation model is implemented through directly reading binary data source. It has good expansibility, supports multi-mode display and implements the functions of rotation, zooming and slicing. The results show that the application of three-dimensional visualization of digital cores has achieved good results and is of great significance to the construction, exploration and development of intelligent oil and gas fields.

#### 6. Acknowledgments

This work is supported by the Program for Guangdong Introducing Innovative and Entrepreneurial Team (NO. 2017ZT07G264) and Shenzhen Peacock Plan (NO. KQTD2017033114582189).

#### 7. References

- [1] Kairong L, Juanni W, Kui Z and Jian Y 2012 *Physics Procedia*. **24** 1801
- [2] Bo C and Harry H 2005 *Computers & Graphics*. **29** 331
- [3] Dirk B, Michael M and Tobias H 1999 *Computers & Graphics*. **23** 667
- [4] Liu F and Liu X 2012 *AASRI Procedia*. **1** 177
- [5] Václav K, Zdeněk B and Tomáš B 2018 *IFAC-PapersOnLine*. **51** 190
- [6] Mafalda S and Paulo A 2014 *Neurocomputing*. **123** 372
- [7] Lin M, Takuma H and Shigeru O 2018 *Procedia Computer Science*. **129** 438
- [8] Stephan K, Ralf G, Alf P, Markus R and Clemens F 2015 *International Journal of Thermal Sciences*. **96** 354
- [9] Thomas M and Frank G 2010 *Computer Physics Communications*. **181** 413