The Research of the Digital Core Construction Based on Marching Cubes

To cite this article: Ling Zhao et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 394 042065

View the article online for updates and enhancements.

You may also like

- Three-dimensional image reconstruction for electrical impedance tomography
  F Kleinermann, N J Avis, S K Judah et al.

- Fabrication of Three-Dimensional Cu/CNT Composite Film By Electrodeposition
  Masaya Ozawa and Susumu Arai

- The World in Eleven Dimensions
  Dileep Jatkar
The Research of the Digital Core Construction Based on Marching Cubes

Ling Zhao1,3,*, Xue Shi2 and Huifen Xia1,2

1State Key Laboratory of Enhanced Oil&Gas Recovery of Ministry of Education, Northeast Petroleum University, Daqing 163318, China
2College of Petroleum Engineering, Northeast Petroleum University, Daqing 163318, China
3College of College of computer and information technology, Northeast Petroleum University, Daqing 163318, China

*Corresponding author e-mail: submit_article@yeah.net

Abstract. Digital core technology as a new numerical simulation method, through the core sample reflection of the real core of the complex internal structure, from the micro level in the theory study of core pore structure and residual oil and to improve oil recovery, to provide technical guidance for the production. In order to realize the core of the pore structure in three-dimensional space, this article will Micro - CT image and the Marching Cubes algorithm effectively, realize the three-dimensional reconstruction of digital core. First by using Micro - CT acquisition core section in CT scan images of different time, using the improved Marching Cubes algorithm, gives the method of constructing digital core, will the constructed three-dimensional digital imaging cores and realize the visualization of core pore structure model. The results show that the method presented in this paper the three dimensional data weight building, reconstruction results with complete data volume has the very good consistency, to verify the effectiveness of the new method and advanced.

1. Introduction

Digital cores started in the 1960s to 1970s, with the development of computing and instrumentation and the emergence of MICRO-CT, scanning electron microscope and other scanning equipment, the simple core type has been developed to show the real pore-skeleton structure of the accurate core model [1].

The fundamental to accomplish the enhanced oil recovery technology greatly is to complete the micro-seepage theory, the digital core plays a very important role in the research of micro-seepage theory [2]. The first CT machine cause a sensation in the scientific and technological circles in 1972, and then in the 1980s, Jim Elliott developed the first micron-level CT machine which improved by Dunsmuir[3] in 1991 and applied to the field of petroleum geology for the first time, not just for the field of medical any more. Subsequently, Joshi [4] applied the Gauss method to establish the digital core of the two-dimensional model for the first time, and then, after the development of computer, Quiblier improved the Joshi algorithm ten years later and get the first real sense of the three-dimensional digital model [5]. Since then to the 1990s, Joannidis [6] and the other scholars had
applied Fourier transform to Gauss method to improve the modeling efficiency of digital cores. In the 1990s, Fredrich [7] and other scholars put forward a focused scanning imaging method, which used dyed epoxy resin to the laser intensity response of different properties, injected the dyed epoxy resin into the sample pores of core and get the digital core of the three-dimensional image by laser. It was seldom used in practice because of the high requirement of injecting cores.

The sequential imaging method, CT scanning imaging, focused scanning imaging method above were all used different experimental instruments to directly image the rock samples to construct the digital cores. It is found that the CT scanning imaging is the best technology to build digital cores by comparison.

2. Micro-CT imaging

The paper uses this method to establish digital cores, focusing on the X-ray CT scanning method, introducing the basic principle of MC algorithm, and establishes the digital core of two sandstone samples by it.

The CT imaging technology has been widely used in various hospitals to carry out a variety of pathological fluoroscopic examination of the human body as a top imaging technology. CT is a powerful tool which main function is to study the permeability and physical state of liquids, the deformation of rocks and to analyze faults and fracture. The contents of the study include the density of rock-soil, porosity, water content, pore size and fissure width, the fluid state in porous media is also monitored and quantified [8]. In general, CT can be used to observe the changes of pore structure which can not be observed by the naked eye, it is a practical, powerful and noninvasive method to observe and analyze rock geology engineering.

![Micro-CT real graph](image)

**Figure 1.** Micro-CT real graph

The research of Chinese scholars in the field of CT scanning and imaging began later in the early 1990s, but the late progress was rapidly improved. The advantages of using CT to observe the change process of the inner structure of core specimen are as follow:

Firstly, non-destructive. The new style is always in a state of undisturbed in the test process.

Secondly, sustainability. The internal structure evolution of cores can be observed simply and continuously by using CT technique.

Thirdly, CT technique can show the three-dimensional morphological characteristics of core specimen, and can also project the image of any section.

Fourthly, CT images can be used to analyze various properties of cores through other chemical and physical properties of cores, such as granularity, infiltration of oil and water, lithology composition, pore size distribution and diffusion coefficients.

With the CT scanning imaging technique apply to the study of pore structure of reservoir cores, the three-dimensional gray image of rock can be obtained by it, different gray values in image show the difference of ingredients of rocks. A certain algorithm can be used to divide the three-dimensional gray image into core framework and core pores, and use corresponding numerical values to represent
the corresponding parts can get the digital rock, which is the digital core. The image obtained by CT Scanning imaging technique is a description of density of core. CT equipment does nondestructive testing to samples with high precision, and the scanning time is far shorter than other methods, therefore, digital core research in oil and gas exploration, geophysics and other fields take an important position based on this method [9].

3. The establishment of digital core by MC algorithm
This paper uses Marching Cubes algorithm to reconstruct the digital core of core CT tomographic images. Marching Cubes (MC) algorithm is one of the most popular surface display algorithms so far.

3.1. The principle of establishing digital core by MC algorithm
The principle of Marching Cubes is to regard a group of two-dimensional CT images as a stereo database, voxel can selected by it with two consecutive layers of 8 points of the same size three-dimensional graph, angular point is one of the vertex of voxel [10]. Which principle is to construct the cube in space and find its contact surface, which is the cube of entity’s body surface, and then to fit the equivalent surface by using the triangular section within the cube, the entity can be represented by a triangular cross-section through traversing cube finally.

3.2. An improved scheme for extracting equivalent surface
(1) Traditional MC algorithm for ISO surface extraction
   By comparing the size of eight angular points value and thresholds value, we can know the positive and negative conditions of them, which is whether the angular point is the equivalent surface or the equivalent surface. The distribution of equivalent surface can be obtained by the distribution of eight angular points, the MC algorithm achieves the goal of three-dimensional reconstruction by fitting the equivalent surface with triangular cross-section. It establishes 256 kinds of LUT about triangular cross-section distributions. In the process of the traverse cube, we know the positive and negative condition of the cube so we can find the distribution of the Triangle section. The vertex position of triangular section can be obtained by using the angular point value and the principle of linear interpolation.

(2) An improved MC algorithm for ISO surface extraction
   Because the problem of ambiguity has been solved, there is only one isoline on each individual cube’s surface. This conclusion can be easily reached through exhaustivity. There is only one isoline on each surface or even no isoline. All Isoline must be connected end to end, that is to say, any boundary cube can get a spatial polygon. Any spatial polygon can be filled by triangular section, so the transformation of the spatial polygon to the triangular section can be realized by simple algorithm. The vertices of any spatial polygon can be obtained by means of linear interpolation. This method can be used to get the distribution of triangular sections without establishing a look-up table. Because only if the boundary cube is more subdivided, the operation time and memory space that increased can be accepted, and the reconstruction is finer.

4. An example of 3D digital core reconstruction
The partial procedure of reconstruction of 3d digital core by MATLAB is as follows:
/*marchingcubes*/
while (1){
    while (1){
        flag_index = 0;
        // Obtain gray value
        // **********
        for (i = 0; i < 8; i++){
5. Conclusion
The three-dimensional digital core reconstruction experiment shows that these methods mentioned in this article can be used to reconstruct the rock slices more efficient with less time-consuming and higher precision. For the situation in three-dimensional reconstruction with MC algorithm, an improved scheme is proposed, which requires subdivide the boundary cube and then can get the distribution of triangular cross-section without establishing a lookup table. It is found that this scheme is based on the retention time advantage through many experiments, comparing with the reconstruct pore distribution by improved algorithm mentioned before classic MC algorithm, it has quiet advantages and is more elaborate.

![Figure 2. Program flowchart of constructing digital core by MC algorithm](image)

References
[1] Yao J, Zhao X C. Yi Y J, et al. The current situation and prospect on digital core technology [J]. Petroleum Geology and Recovery Efficiency (in Chinese), 2005, 12 (6): 52-54.
[2] Dvorkin J, Fang Q, Derzhi N. Etudes in computational rock physics; alterations and benchmarking [J]. Geophysics, 2012, 77 (3): D45-D52.
[3] Mavko G, Mukerji T. What's new in rock physics [J]. Geohorizons, 2007, 42 (1): 1.
[4] Lmeropoulos, D.P., Payatakes, A.C. Derivation of topological, geometrical and correlational properties of porous media from pore-chart analysis of serial section data [J]. Journal of Colloid and Interface Science, 1992, 150 (1): 61-80.
[5] Tomutsa L., Radmilovic V Focused ion beam assisted three-dimensional rock imaging at submicron-scale [C]. Proceedings of International Symposium of the Society of Core Analysts, 2003, Pau, France.
[6] Cai M F. Rock mechanics and engineering [M]. Science and Technology Press (in Chinese), 2002.

[7] Ceng Z, Dong F H. MATLAB to realize the three-dimensional reconstruction of CT tomography [J]. CT Theory and Application Research, 2004, 13 (2): 24-29.

[8] Manwart C, Torquato S, Hilfer R. Stochastic reconstruction of sandstones. Physical Review E, 2000, 62: 893-899.

[9] Li B, Ling Q C, Bao Z Y, et al. Determination of rock property by digital image analysis [J]. Xinjiang Petroleum Geology, 2008, 29 (2): 253-255.

[10] Liao M G, Li S L, Fu X W. Establishment of reservoir rock permeability estimation model [J]. Natural Gas Industry, 2001, 21 (4): 45-48.