Application of three-dimensional digital image processing for dynamic pore structure characterization

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Abstract: In this study the effect of various image-processing techniques such on the detail visibility of core images are investigated. The three-dimensional spatial distribution of petrophysical properties are controlled by two geological processes, depositional and diagenetic. Although it is clear that the three-dimensional spatial distribution of petrophysical properties initially controlled by the spatial distribution of depositional textures. Here, the spatial domain refers to the image plane itself, and methods in this category are based on direct manipulation of pixels in scanning electron microscope (SEM) images by Matlab software. The first are point operations, or image processing operations that are applied to individual pixels only. Thus, interactions and dependencies between neighboring pixels are not considered, nor are operations that consider multiple pixels simultaneously to determine an output. Since spatial information, such as a pixels location and the values of its neighbors are not considered, point operations are defined as functions of pixel intensity only.

Key-Words: spatial distribution, petrophysical, image, pixel

1. Introduction

Complex pore configurations arise from the interaction of many factors in the geologic environment of the deposit. These factors included the packing and particle-size distribution of the framework fraction, The type cavities commonly found in limestones. Rocks having primary porosity are more uniform in their characteristics than rocks in which a large part of the porosity Is induced. For direct quantitative measurements of porosity, reliance must be placed on formation samples obtained by coring. In general, greater angularity tends to increase the porosity, while an increase in range of particle size tends to decrease the porosity.

of interstitial material and the type and degree of cementation[1]. The influence of these various factors may be evaluated as statistical trends. Primary porosity is typified by the intergranular porosity of sandstones and the intercrystalline and oolitic porosity of some shales and lime stones and the vugs of solution. The image logs can provide images of fractures, breccia, large vugs, and sedimentary structures useful for correlation and characterizing touching-vug pore systems[2]. Images of carbonates commonly appear as patchy patterns of black (low resistivity, high porosity) in a field of lighter browns (more resistive, lower porosity).
The size and shape of the pore space is controlled by the size and shape of the needles and grains, and the pore sizes are very small because the particle are very small. (Electron Photo-Micrographs of carbonate mud). The various techniques used to study size and shape distribution of particles can be categorized as indirect (sieving) and direct (manual or image analysis) methods [3].

The development of a fast and accurate image analysis method for determining the three-dimensional (3-D) size and shape of coarse particles would greatly benefit our ability to interpret the genesis and engineering properties of coarse grained sediments in core samples. With the advancement of digital image acquisition techniques, image analysis methods are developing with great variety. However the existing image analysis methods have limitations in acquiring particle images in the field, and are typically suited to laboratory-based analysis [4].

2. Spatial filtering

The spatial domain techniques operated directly on the pixels of an image [5]. The spatial domain processes discussed are denoted by g(x,y) = T[f(x,y)], where f(x,y) is the input image, g(x,y) is the output (processed) image, and T is operator on f, defined over a specified neighborhood about point (x,y). In addition T can operate on a set of images, such as performing the addition of K images for noise reduction. Although this equation is simple conceptually, it is computational implementation in MATLAB requires that careful attention be paid to data classes and value ranges [6]. The two principal terms used to identify this operation are neighborhood processing and spatial filtering, with the second term being more prevalent. If the computational performed on the pixels of the neighborhoods are linear, the operation is called linear spatial filtering, otherwise it is called nonlinear spatial filtering.

Fig. 1. SEM of a critical-point-dried sample from a typical Aux Vases reservoir (2,400-ft depth, Budmark 3 Burr Oak, Energy Field) shows porelining and -bridging diagenetic clay minerals (closely intergrown mixed-layered illite/smectite, chlorite, and illite) and no quartz overgrowth.
2.1. Linear spatial filtering

The concept of linear filtering has its roots in the use of Fourier transform for signal processing in the frequency domain. We are interested in filtering operations that are performed directly on pixels of an image. Use of the term linear spatial filtering differentiates this type of process from frequency domain filtering. The linear operations of interest consist of multiplying each pixel in the neighborhood by a corresponding coefficient and summing the results to obtain the response at each point (x,y). If the neighborhood is of size m*n, mn coefficients are required. The coefficients are arranged as a matrix, called a filter, mask, filter mask, kernel, template, or window, with the first three terms being the most prevalent.

Fig 1. Shows a core image in which pore bridges are covered by clay minerals and clarity of view is decreased. By using linear digital image filtering by Matlab we enhance the visibility and ease analyzing the images. The M-file generated via Matlab in linear spatial filtering:

```matlab
function createfigure(cdata1) %CREATEFIGURE(CDATA1)
% CDATA1: image cdata
%
% Auto-generated by MATLAB on 03-Feb-2013 08:32:50
% Create figure
figure 1 = figure;
% Create axes
axes 1 = axes('Visible','off','Parent',figure 1,'YDir','reverse',
'TickDir','out',
'Position',[0.1349 0.134 0.7298 0.7943],
'Layer','top',
'DataAspectRatio',[1 1 1]);
%
% Uncomment the following line to preserve the X-
% limits of the axes
```
2.2 Non-linear spatial filtering

Nonlinear spatial filtering is based on neighborhood operations also, and the mechanics of defining m*n neighborhood by sliding the center point through an image are the same as discussed in section2.1. However, whereas linear spatial filtering is based on computing the sum of products (which is a linear operation), nonlinear spatial filtering is based, as the name
implies on nonlinear operations involving the pixels of a neighborhood.

Fig. 1 is again treated via image filter processing. This time in non-linear type of Matlab coding. The M-file generated for image filtering in this section is:

```
function createfigure(cdata1)
    % CREATEFIGURE(CDATA1)
    % CDATA1: image cdata
    % Auto-generated by MATLAB on 03-Feb-2013 08:42:29
    % Create figure

M-file created for nonlinear spatial filtering
```

Fig. 3. gray-level intensity enhanced via non-linear spatial filtering
figure 1 = figure;
% Create axes
axes 1 =axes('Visible','off','Parent',figure1,'YDir','reverse',...
'TickDir','out',...
'Position',[0.1349 0.134 0.7298 0.7943],...
'Layer','top',...
'DataAspectRatio',[1 1 1]);
% Uncomment the following line to preserve the X-limits of the axes
% xlim([0.5 443.5]);
% Uncomment the following line to preserve the Y-limits of the axes
% ylim([0.5 332.5]);
box('on');
hold('all');
% Create image
image(cdata1,'Parent',axes1);

The image output shows an increment in gray scale intensity in which the pore bridge and grain structure is remarkably investigated through the clay minerals covering the core sample. Fig. 3 shows the output image resulting from non-linear filtering.

3. Conclusion

Images that occur in practical applications invariably suffer from random degradations that are collectively referred to as noise. If a large enough number of frames are averaged together, then the resulting image should be nearly noise-free, and hence should approximate the original image. In our job we get acceptable testing and experimentations based on Matlab filtering in progress of petroleum core image analysis. Generated M-files shows the varying gray scale intensity and its effect on the dynamic structure of the core image. This was a new methodology used in petroleum core analysis and help to be more precised about permeability scale existing in core samples.

References


