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Fast quantitative estimation method of fracture cavity porosity based on convolution depth neural network

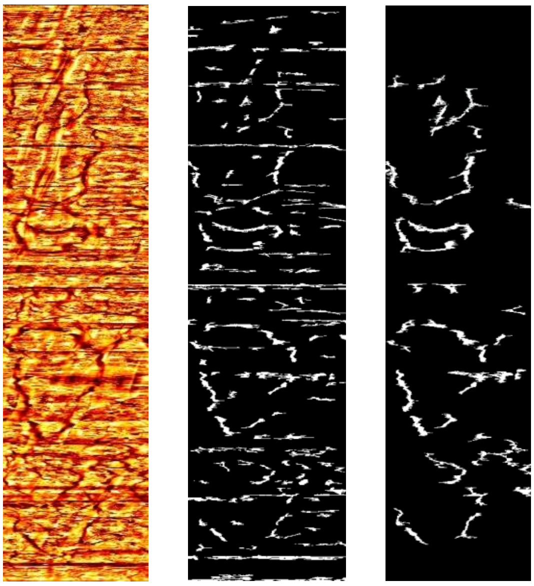
Introduction

Traditional interpretation on imaging logging data requires to manually import considerable types of data before commutating the porosity of fracture in targeting area due to the lack of gas and oil information from raw data. Such interpretation process could be time-consuming especially when raw data is not ideal. In this study, we propose a fast estimation method of fracture porosity that reduce manual work and increase the process efficiency within proper error limit.

Our estimation method is based on path morphology and convolution neural network in the extraction of fracture and cavity parameters. Firstly, related path morphology method is applied to obtain inclined fractures. Second, rotation jamming algorithm is utilized to obtain rectangular with minimum area in each cavity. Responsible parameters of horizontal fractures, vertical fractures and cavities are finally used to estimate the porosity together with the angle of the rectangle and length of the short and long sides.

Method

Original imaging logging conductivity is shown in Figure 1. Inclined fractures require to be distinguished from other fractures due to the consideration of inclination and tendency during extraction procedure. However, traditional binarization and denoising cannot be applied directly since cavities on basic binary images are black (Figure 1(b)). Therefore, certain curves need to be extract from original conductivity images by path morphology algorithm (Figure 1(c)).



(a) (b) (c)

Figure 1 *This is an example about comparison of different treatment methods for extracting cracks. (a) Original conductivity image. (b) Binary denoising image. (c) Path morphology extraction image.*

On the other hand, convolutional neural network (CNN) is required for the identification of the shape of restored cracks due to the affection of cavities on traditional mathematical fitting process. Convolution neural network is commonly used in recognition of concrete information such as image and sound. Main difference between convolution neural network and traditional fully connected neural network (DNN) refers to the fact that convolution layer and pooling layer are added to extract the characteristics of targets.

LeNet and AlexNet are most representative among various convolutional neural network algorithms. Generally, Alexnet follows LeNet on construction while the former applies ReLU activation function which greatly improves the training speed and avoids the loss of gratitude during derivation. In this study, we improve and apply AlexNet to the classification of conductivity image components. The configuration of modified AlexNet is shown in:

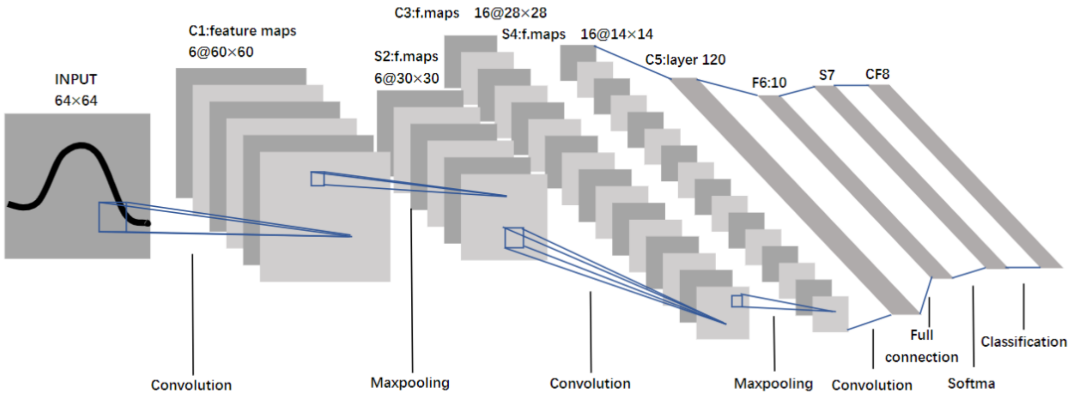


Figure 2 *The basic structure of the improved AlexNet convolutional neural network.*

The modified AlexNet algorithm adopt the maximum pooling method to obtain the maximum value in the target area. In the output layer, Softmax function is then used to reduce the complexity of training and improve the possibility of convergence. The learning process of adopts Adam optimizer to improve efficiency and reduce memory occupation.

Related parameters of cavities, horizontal fractures and vertical fractures are then calculated by the rotation jamming algorithm after the extraction of inclined fractures. Note that the cavities on conductivity images are exhibited as small irregular ellipses. Taken the fact that traditional Hough transform is considered time-consuming with low efficient on evaluation of large number of cavities, here we turn to use an alternative approach by obtaining circumscribed rectangles with minimum area in connected domain. The essence of that method is to treat the long side and short side of rectangles as the major axis and minor axis of ellipses.

A disadvantage of traditional ways of finding circumscribed rectangles with minimum area refers to low efficiency due to their algorithm. The rotation jamming algorithm, however, improves the computation speed by focusing its targets on directions coincide with long side of polygons.

The rotation jamming algorithm was proposed by Shamos and Toussaint (A simple linear algorithm for intersecting convex polygons) and it is widely used in calculation of the diameter, circumscribed rectangles and triangulation of polygons. For any convex n-gon as shown in Figure 6(a), the first step is drawing line on random side and then taking a parallel line across the point on the n-gon which shares the longest distance to the original line. Next, we take two parallel lines on each side of the n-gon which are normal the original line and then move both lines to the n-gon. When those two lines are tangent to the n-gon, the cross points of all four lines are treated as vertex of the circumscribed rectangles. Repeat the above steps after rotate the original line until it coincides with certain side of n-gon. After n times of iteration, a circumscribed rectangle with minimum area is obtained.

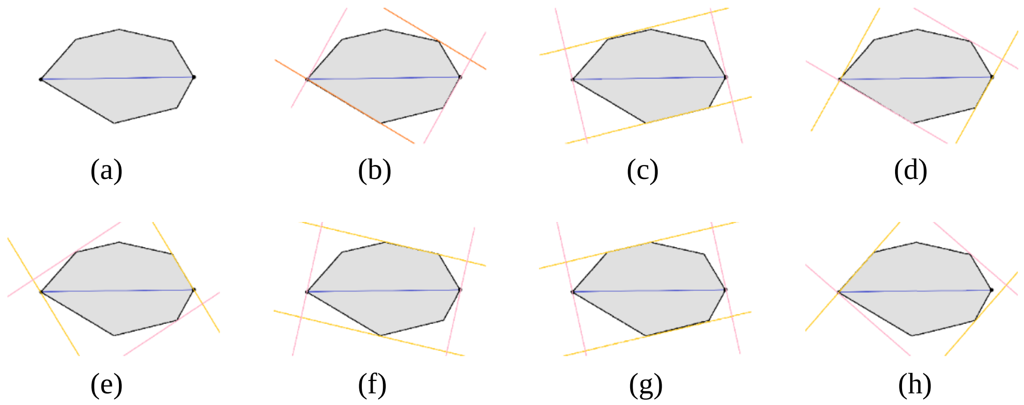


Figure 3 *Steps of the rotation jamming algorithm*

In a conductivity image, cavities always contain both convex and concave closure simultaneously. That requires to fill the concave ones to convex before using the rotation jamming algorithm. Finally, the parameters of effective porosity could be obtained by above programs.

Examples

For better demonstration of method used in this study, we pick certain range of well with low quality imaging log results. The diameter of well selected is 0.38 meter and depth range used in this study is 20 meters. The conductivity log exported from a logging software is shown in Figure 4(a). Binarization and path morphology are processed at the same time. Note that it is assumed that the results of path morphology are all inclined fractures and entire area is treated as connected. Hence, the next step refers to define the values in those connected area as 0 for the purpose of eliminating all inclined fractures. After that, the binary image contains only horizontal fractures, vertical fractures and cavities. Windows with single inclined fracture are then selected manually from the results of path morphology and they are used as training samples. According to the result (Figure 4(b)), 5 are classified correctly among all the 6 fractures. Figure 4(c) shows the fitting circumscribed rectangles after the rotation jamming processing, in which blue is the dissolution hole, red is the horizontal fracture, and there is no vertical fracture in this well section.. Finally, the estimation of effective porosity, cavity size ratio and cavity imaging ratio are shown in Figure 4(d,e,f).

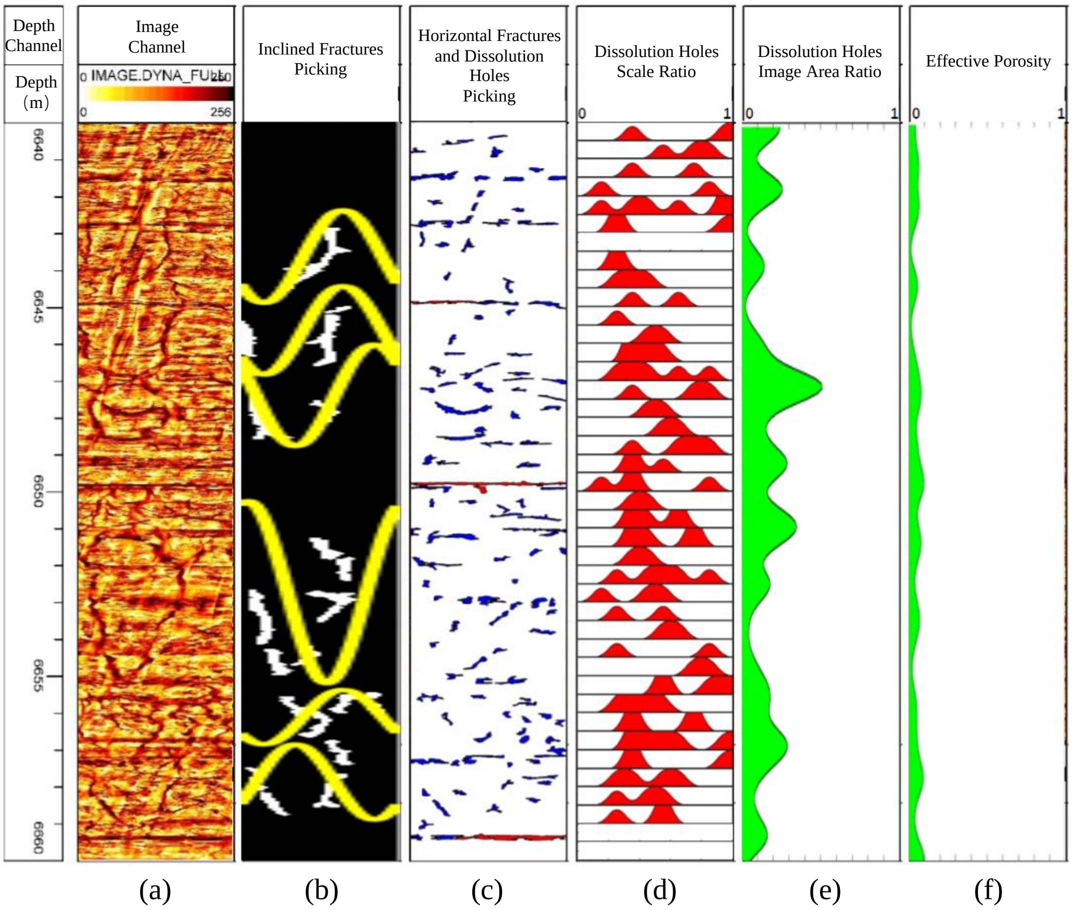


Figure 4 *This is an example of quantitative estimation results of dissolution hole scale ratio, dissolution hole image proportion and effective porosity.*

Conclusions

In this study we propose an estimation method of porosity of cavity by conductivity logging and deep neural network algorithm. The most prominent advantage of this method refers to its high efficieny and degree of automation. It is able to extract different type of fractures together with cavities within acceptable error limit. Meanwhile, it can quantitatively estimate the trend of porosity of cavity, which provides information for geologists in evaluation of high-value targets.

References

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