Journal of Natural Gas Science and Engineering 35 (2016) 944–955

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

journal homepage: www.elsevier.com/locate/jngse

Two intelligent pattern recognition models for automatic identification of textural and pore space characteristics of the carbonate reservoir rocks using thin section images

Omid Borazjani*, Javad Ghiasi-Freez, Amir Hatampour

Department of Electrical Engineering, Dashtestan Branch, Islamic Azad University, Borazjan, Iran

ARTICLE INFO

Article history:
Received 25 April 2016
Received in revised form
14 September 2016
Accepted 16 September 2016
Available online 17 September 2016

Keywords:
Textural characteristics
Dunham classification
Porosity analyzer
Pore space identification
Carbonate rocks
Pattern recognition models

ABSTRACT

Over the last two decades pattern recognition approaches have attracted engineers to solve real world problems more accurately through the development of computational technology. In the present research, the capabilities of intelligent systems are employed to develop two algorithms for identification of textural and pore space characteristics of carbonate rocks from thin section images. The texture identifier model classifies the images based on Dunham classification, while the porosity analyzer model determines the percentage of each type of pore spaces in the image. The texture identifier model extracts thirteen features to recognize texture type and the porosity analyzer determines percentage of each type of porosity based on eleven features extracting from the thin section image. Finally, two confusion matrixes are used to evaluate the performance of the developed models. The results show that the models perform reliably from the perspective of petroleum geology for studying carbonate reservoir rocks.

1. Introduction

Accurate knowledge about the history of a sedimentary basin plays an important role in hydrocarbon exploration. Preparation of thin sections from outcrops of sedimentary formations is the first step to acquire this knowledge. Mostly thin sections are studied under the optical microscope. Qualitative and quantitative data such as pore space distribution, type and amount of cement, textural characteristics, grain size distribution, type of fossils as well as type of minerals can be extracted in such study. Extraction of aforementioned parameters is a time consuming process. Ehrlich et al. (1991) can be considered as the pioneers in employment of thin section images for studying carbonate rocks. They discussed the fundamentals of image preparation from thin sections and also they developed a simple model for classification of porosity based on images. After that various researchers have focused on this topic.

Development of computers helps us to solve the engineering problems and make them easier. First, we take a look at some of these researches which are used computer technology for solving geological problems. Anselmetti et al. (1998) characterized carbonate pore spaces using image analysis of thin sections. Van den Berg et al. (2003) tried to assess textural variations in laminated sandstones through image analysis of thin sections. Perring et al. (2004) introduced an automated image analysis model to acquire size, shape and modal data for olivine-phyric basalts. Their model could be adapted to various petrographic problems and was not restricted to the study of igneous rocks. Weller et al. (2005) extracted morphological and textural discriminatory features through image analysis techniques to present a semi-automated classifier of sedimentary organic matter in palynological preparations. Their results showed that such model is able to classify the organic matter with accuracy of 87%.

Al-Bazzaz and Al-Mehanna (2007) extracted morphological characteristics of both pore spaces and grains from images captured under polarized and scanning electron microscope. Kuncheva et al. (2008) developed an intelligent classifier to identify macerals from slide images of kerogen. Peternell and Kruhl (2009) studied the possibility of accurate quantification of automatically digitized mineral-phase distribution patterns in igneous rocks. They concluded that box-counting measurement of recorded mineral distribution patterns leads to three important outcomes including

* Corresponding author.
E-mail address: omid.bor62@gmail.com (O. Borazjani).

http://dx.doi.org/10.1016/j.jngse.2016.09.048
1875-5100/

accurate pattern quantification, phase distribution patterns (in micro to macro scales), and receiving information on pattern-forming processes.

Al Ibrahim et al. (2012) introduced an automatic model to evaluate pore spaces and distribution of pore-throat size using image analysis. They finally simulated capillary pressure curves based of the results of image analysis. Ishikawa and Gulick (2013) extended the application of image analysis to mineral characterization in igneous rocks. Lai and Krevor (2014) studied the impact of pore heterogeneity in chemical transport through micro-CT images and thin sections. Aprile et al. (2014) integrated neural network and image analysis to classify mineral inclusions and pores in archaeological potsherds. Berrezueta et al. (2015) studied the evolution of rock pore network subjected to super critical CO_2-injection through the advantage of image identification techniques. A quick-look at all previous literature shows that combination of image analysis and intelligent systems could be a potential tool for development of pattern recognition systems, which help for characterization of rocks.

In the present article, an automated image analysis technique is introduced, in which pore space and textural characteristics of carbonate rocks are simultaneously studied by computer. The proposed model takes the advantages of images analysis to study thin section images and introduces percentage of different parts of rock and finally evaluates the potential of the rock to be a reservoir rock. Such model presents a valuable view of the rock for future investigations in a short time and more importantly with low cost.

2. Methodology

2.1. What is a pattern recognition problem?

Image analysis and pattern recognition are potential techniques expanded due to recent advances in software programming and hardware in computers. Image analysis is a systematic process employed for identification and quantification of various features of an image, which can be divided to two main types including RGB and gray scale (Martinez et al., 2007). The present article employed the advantages of pattern recognition to solve two problems for reservoir zonation petrophysicaly. Such studies can be divided into two steps. First step is feature extraction, in which special features of images are extracted. In the second step, the extracted features are classified by an intelligent classifier. The extracted parameters are introduced to a classifier as inputs. The corresponding output of each set of inputs is also introduced to the classifier; this step can be called model training. Selection of most related parameters to the desired output leads to a better interpretation and consequently to better classification by the intelligent model. In simple words, better training better results in test step. Fig. 1 represents a flow-chart of a pattern recognition problem. Before discussing the feature extraction step, a brief explanation about image preparation is presented below.

2.2. Image preparation

A gray scale and RGB digital image is a 2D or 3D matrix of real numbers, respectively. Each element of this matrix is called pixel.

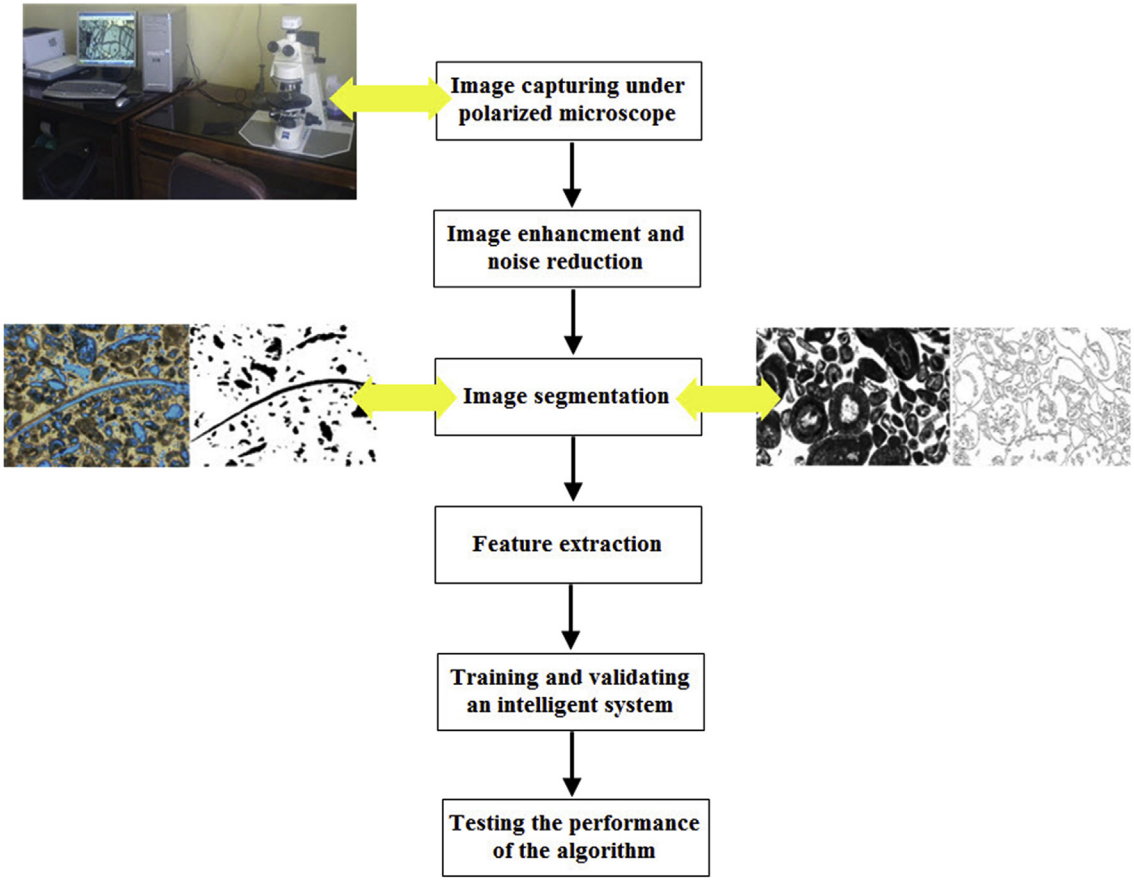

Fig. 1. A schematic flowchart of a pattern recognition algorithm for porosity identification and texture characterization.