DEVELOPMENT OF A SEGMENTATION METHOD FOR ANALISYS OF CAMPOS BASIN TYPICAL RESERVOIR ROCKS

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Abstract. *This paper represents a master thesis proposal in Exploration and Reservoir Engineering that have the objective to development a specific segmentation method for digital images of reservoir rocks, which produce better results than the global methods available in the bibliography for the determination of rocks physical properties as porosity and permeability.*

Keywords*: Reservoir Rocks, Image Analysis, Segmentation.*

1. INTRODUCTION

Nowadays, are many research's in alternative energy source such as ethanol, bio-fuel and wind energy, however, the hydrocarbon reservoir still represent the main source of energy with even large investments in development of new technologies for oil/gas production.

One of the needs of the petroleum exploration and production industry is the determination of reservoir rocks physical properties. Normally these properties are determinate using laboratory experiments, consuming a considerable amount of time and money.

With the technology gain, computational analyses can be done in drill cuttings or core using several techniques of image analyses aligned to microscopic analyses of thin section, being possible, for example, estimate values of porosity and permeability of reservoir rocks.

The image segmentation or binary segmentation is an image processing techniques which consist in a conversion of a gray scale image in a binary image, which means, the pixels can assume only two values (0 or 1, black or white) separating the object of analyses from the background. Has the objective of reduce the data complexity for computational analyses, simplifying the procedures for objects recognition and classification.

The segmentation methods can be manual or automatic, nowadays in the bibliography, there are many methods of segmentation. As a manual method the grey-levels histogram, where the operator judges the point of cut which produces the better result. The automatic methods fonded in the bibliography are not universals, therefore, they do not produce satisfactory results for all kinds of images. Digital images of petrographics lamina of reservoir rocks have specific characteristics and properties to be analyzed.

With in the several automatic methods presented in the bibliography is any dealing specifically digital images of reservoir rocks, thus leading to dependency on human evaluation to acquire good results. If an image has not the process of segmentation successful, it may lead to erroneous interpretation in determining their properties.

Thus, this study is to develop a method of segmentation of digital images that will produce better results in the determination of attributes such as permeability and porosity of reservoir rocks typical of the Campos Basin. The development of this method will be held at the Laboratory of Scientific Software Development (LDSC) using algorithms and modern libraries, with the use of parallel processing.

It is expected to develop an efficient algorithm, which bring good results for the field of analysis of images of reservoir rocks. The results obtained with the method being developed will be compared with standard methods of bibliography.

2. BIBLIOGRAPHY REVIEW

2.1. Image Analyses

The study of images is an area of knowledge that has had a significant growth in recent years in terms of cost savings in the assembly of a laboratory for images analysis (Bueno, 2006). In light of this, the study of images has been applied in various knowledge fields, can be highlighted: Engineering Industrial - robots and computer vision, visual inspection for quality control; Weather - interpretation of satellite images; Technical register - analysis of Satellite images and aerial photographs of cities and urban areas, in control of areas cleared and burned; Materials Engineering - analysis of the materials and their physical properties (Bueno, 1994), (Bueno, 2001), (Fernandes *et al.* , 2002); Medicine - CT scan, X-ray, ultrasound; Biology - counting of cultures, identification of cell structures, identification of DNA (in tests of paternity); Defense public - installation of digital cameras for monitoring the movement of people in cities and public places, in identifying suspects through portraits spoken, automatic identification system for vehicles (Coelho de

Souza and Susin, 2000); Processing documents - in libraries, scan, archive and print books and historical documents, character recognition (OCR), recognition of electronic checks (Dias, 2006); Introduction to analysis of images in space exploration - images of telescopes (Hublle); Study of images - with the increased interest in the study area of images, there is a feedback, which involves the emergence of new research groups, new courses, new methods and new equipment.

2.2. Image Processing System

In general, the overall method of study using images involves one or more steps, among them are: Image Acquisition - get the image to be studied; Pre-Processing - the overall purpose of the pre-processing is to improve the image quality for a specific purpose; Segmentation - separating themselves the objects of the image; Characterization - this stage the objective is to extract information of interest, describing the characteristics of objects and classify them, apart from obtaining quantitative information; Recognition and Interpretation - involves the recognition of patterns and interpretation of objects, assign meanings to objects. These steps acquire a specific and detailed according to the study being conducted (Bueno, 2006).

Figure 1 shows the basic stages of digital image processing, adapted to studies of lamina's of porous materials. Among the advantages of using the analysis of images to determine the physical properties of rocks stand out the possibility of examining large amount of samples at a reduced cost and the use of damaged drill cuttings or damaged core.

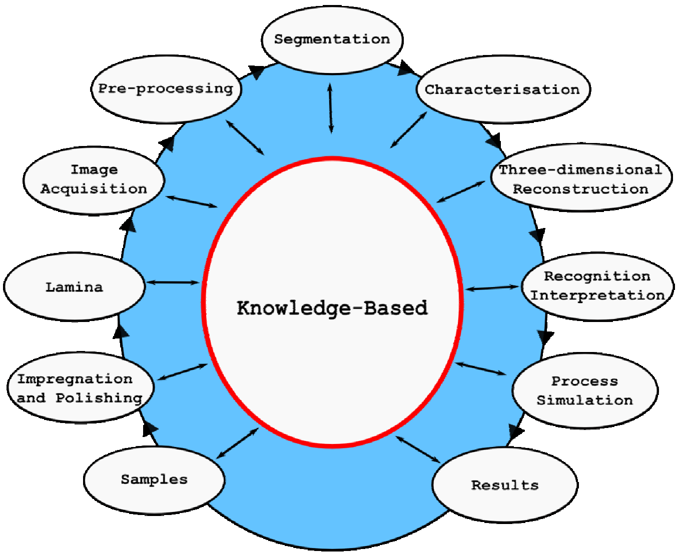

Figure 1. Fundamental steps to process digital images, applied to the study of lamina's of porous materials (Bueno, 2006).

2.2. Reservoir Rocks

Known reservoir rock with have appropriate permeability and porosity to the accumulation of oil. Most of the known reserves is in the sandstones and carbonate rocks, although accumulations of oil also occur in shales, or even conglomerates, igneous and metamorphic rocks (PGT, 2007).

The porosity ϕ is defined as being the relationship between the volume of empty rock and a total volume of the same (Rosa *et al*. 2006). In most reservoirs the porosity ranging from 10 to 20%. The porosity is the absolute total volume of empty, while the porosity effective only refers to pore connected to each other. The quantity, size, geometry and degree of connectivity pore directly control the productivity of the reservoir. Measure directly, in core samples, or indirectly through electric profiles, the porosity of a rock can be classified as small (0-5%), poor (5-10%), regular (10-15%), good (15-20%), or very good (> 20%).

The permeability k of a porous environment, is a measure of their ability to make it through by fluids (Rosa *et al*., 2006) and is expressed in Darcy's (D) or milidarcy's (md). Controlled mainly by the quantity, geometry and degree of connectivity pore, the permeability of a rock is measured directly, in core samples, and can be classified as low (<1md), regular (1-10md), good (10-100md), very good (100-1000md) and excellent (> 1000md). Most of the reservoirs has permeabilities of 5 to 500md.

In general, permeability and porosity are directly proportional to the degree of selection and size of grains and inversely proportional to sphericity. But variations of lateral and vertical permeability / porosity are heavily controlled by the characteristics of the depositional environment.

2.3. Lamina's Preparation and Images Acquisition

For the preparation of lamina's must first be obtained rocks samples, according to statistical criteria such as representativeness, the sample should represent, or attempt to represent the porous environment to be studied (Bueno, 2006). Samples of rocks can be: Core - cylinders complete removal of the well by a special drill, this type of sample is preferred because it brings many details of the rock being, very costly; Sidewall sample - acquired through shoot a well, in the form of cylinder (approximately one inch in diameter) the wall of the well; Drill Cuttings - crushed rock that comes through the surface of drilling fluid.

The sample of rock is to undergo a process of cleaning with organic solvents, for the hydrocarbons removal. Then it holds impregnation using a special resin that fills the empty spaces of the sample. The objective of this procedure is to make more clear the pores of the same when observed under the microscope, thus resulting in a wafer cylinder. Then it holds polishing of silicon carbide and cleaning with ultrasound for removal of abrasives. The sample then undergoes a process of polishing and cleaning using the diamonds folders. At the end of the process, the lamina has about 30 µm.

After all the procedures for obtaining and preparing rock samples, they finally are ready to have their images generated so we can analyze and calculate properties such as: relative porosity, effective porosity, permeability, etc.

3. SEGMENTATION METHODS

This chapter describes the concepts of some segmentation methods, manual and automatic, its algorithms and results, using for this purpose, a digital image of a sample of Berea sandstone, provided by CENPES/PETROBRAS.

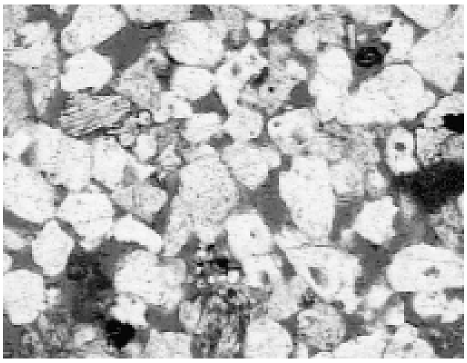

Figure 2. Digital grey-levels image sandstone of Berea.

Method of Grey-level Histograms – the manual method of grey-level histograms is the simplest way to image segmentation. The segmentation can be held, whichever is a grey-level as a cutoff point T_h *(threshold)* in the histogram in order to better separate image in the regions to be examined. Mathematically, from a function *Im(i,j)*, the binary image $Im_{bin}(i,j)$ will be given by Eq. (1).

$$\mathrm{Im}_{bin}(i,j)=\left\{\frac{0, I(i,j)\leq T_h}{255, I(i,j)>T_h}\right\} \quad (1)$$

Mean Value – the method of mean is to go the image *I(i,j)* and for each point *(i, j)* accumulate the value returned by *I(i, j)*, determining the sum total of grey-levels (Parker, 1997). Then determines the tone of gray average, this total is divided by the total number of *pixels* of the image, Eq. (2).

$$T_h=\frac{\sum_{i=0}^{N_x-1}\sum_{j=0}^{N_y-1} I(i,j)}{N_x N_y} \quad (2)$$

Method Two Peaks - the method Two Peaks scans the histogram grey-levels, provides the first peak (greater value). The second peak is determined by multiplying up the values of the histogram *h(k)* by the square of the distance of the first peak, Eq. (4).

$$p_1 = \max(h(k)) \tag{3}$$

$$T_h = \max\{(k - p_1)^2 h(k) \mid 0 \le k \le 255\} \tag{4}$$

p_1 is the position of the first peak, $h(k)$ the occurrence probability of the level k and T_h. Recommended when the histogram has two separate peaks and therefore are not always chosen the greatest peaks.

Method of Johannsen Entropy - the automatic method of Johannsen is based on entropy, or the division of gray levels of the image into two parts to minimize the interdependence between them. The entropy is a measure of information content, where entropy of a symbol x is given by Eq. (5):

$$E(x) = -x\log(x) \tag{5}$$

An image can be thought of as a source of symbols, or grey-levels. The Johannsen algorithm (Parker, 1997) propose to divide the grey-levels into one black part and one white part. The entropy associated, for a picture with 256 grey-levels, segmented using *threshold* T_h, is given by $S_b(T_h)$:

$$S_b(T_h) = \log\left(\sum_{i=0}^{T_h} pi\right) + \frac{1}{\sum_{i=0}^{T_h} pi}\left[E(p_{T_h}) + E\left(\sum_{i=0}^{T_h-1} pi\right)\right] \tag{6}$$

The same way, the entropy of white pixels is given by $S_w(T_h)$:

$$S_w(T_h) = \log\left(\sum_{i=T_h}^{255} pi\right) + \frac{1}{\sum_{i=T_h}^{255} pi}\left[E(p_{T_h}) + E\left(\sum_{i=T_h+1}^{255} pi\right)\right] \tag{7}$$

According to the Johannsen algorithm, the best *threshold* is the value of T_h that minimizes the sum $S_b(T_h) + S_w(T_h)$.

Method of Thrussel Iterative– iterative selection is a process in which a initial guess at a *threshold* is refined by consecutive passes through the image (Thrussel, 1979) apud (Parker, 1997). It instead *thresholds* the image into object an background classes repeatedly, using the levels in each class to improve the *threshold*.

The initial guess at the *threshold* is simply the mean grey-level. This *threshold* is then used to collect statistics on the black and white regions obtained, the mean grey-level for all pixels below the threshold is found and called T_b, and the mean level of the pixels greater than or equal the initial *threshold* is called T_o . Now a new estimative of the *threshold* is computed as $(T_b + T_o)/2$, or the average of the mean levels in each pixel class, and the process is repeated using this *threshold*. When no change in *threshold* is found in two consecutive passes through the image, the process stop.

Starting with the initial estimate of the threshold T_o, the estimate of threshold is Eq. (8):

$$T_h = \frac{\sum_{i=0}^{T_{h-1}} i.h[i]}{2\sum_{i=0}^{T_{h-1}} h[i]} + \frac{\sum_{j=T_{h-1}+1}^{N} j.h[j]}{2\sum_{j=T_{h-1}+1}^{N} h[j]} \tag{8}$$

where h is the histogram of the grey-levels in the image. Again, where $T_h = T_h + 1$ then T_h is the proper *threshold*.

Method of Otsu Variance – automatic method of *threshold* based on selecting the low point between two histogram peaks use the concept that object pixels and background pixels have different mean levels, and are random numbers drawn form one of two normal distributions. These distributions also have their own standard deviations and variances, where variance is the square of the standard deviation.

If there are two groups of pixels in the image, then it is a simple matter to compute the overall, or total, variance of the grey-level values in the image, denoted by σ_{Th}^2. For any given *threshold Th*, it is also possible to separately compute the variance of the object pixels and of the background pixels, these represent the *within-class* variance values, denoted by σ_w^2.

Finally, the variation of the mean values for each class from the overall mean of all pixels defines a *between-class* variance, which will be denoted by σ_b^2. This is the beginning of a method in statistics called *analysis of variance*. The important issue is that an optimal threshold can be found by minimizing the ratio of the between-class variance to the total variance (Otsu, 1979) apud (Parker, 1997), in other words:

$$\eta(T_h) = \frac{\sigma_b^2}{\sigma_{Th}^2} \tag{9}$$

defines the needed ratio, and the value of *Th* that gives the smallest value for η is the best threshold. Since σ_{Th}^2 is the overall variance it is easy to calculate from the image, as is the overall mean μ_T. The between-class variance is calculated by Eq. (10):

$$\sigma_b^2 = \omega_0 \omega_1 (\mu_0 \mu_1)^2 \tag{10}$$

where:

$$\omega_0 = \sum_{i=0}^{Th} p_i \tag{11}$$

$$\omega_1 = 1 - \omega_0 \tag{12}$$

and p_i is probability of grey-level i, or the histogram value at i divided by the total numbers of pixels. Also:

$$\mu_0 = \frac{\mu_{Th}}{\omega_0} \tag{13}$$

$$\mu_1 = \frac{\mu_T - \mu_{Th}}{1 - \omega_0} \tag{14}$$

$$\mu_{Th} = \sum_{i=0}^{Th} i.p_i \tag{15}$$

All of these values are quite easy to calculate from the histogram of the image. Then $\eta(T_h)$ is computed for all possible values of T_h, and the T_h that gives the smallest η is the optimal threshold.

3.1. Results

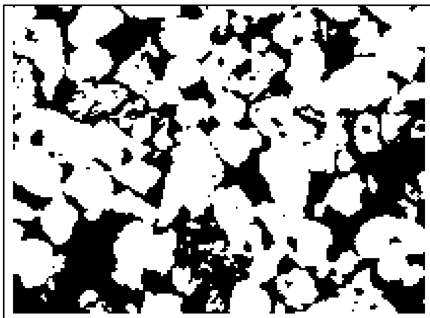

Figure 3. Manual Grey-Level Histograms.

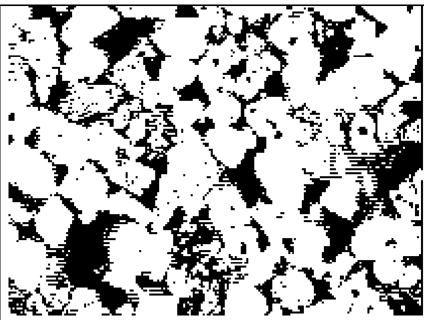

Figure 4. Mean Value.

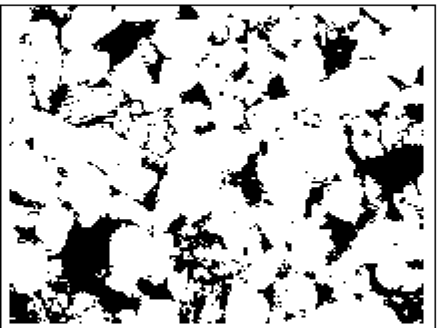

Figure 5. Two Peaks.

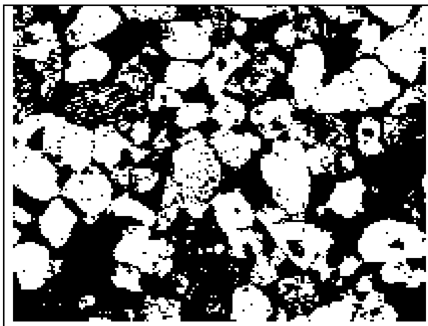	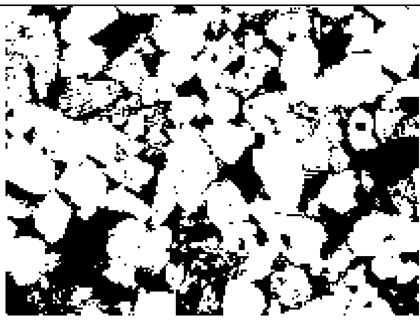	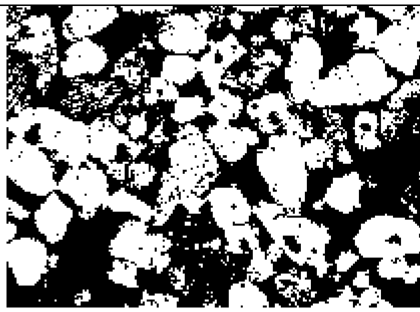
Figure 6. Johannsen Entropy.	Figure 7. Thrussel Iterative.	Figure 8. Otsu Variance.

Table 1. Result for the image of Berea sandstone applying the methods of automatic segmentation**.**

4. METHODOLOGY

The first step in this work is the bibliography review, which includes the study of methods of manual and automated segmentation, its concepts, algorithms and results. The automated methods to be studied are: Mean; Two Peaks; Johannsen Entropy; Thrussel Iterative; Otsu Variance.

This work will use as data, images of reservoir rocks acquired at the Laboratory of Scientific Software Development (LDSC) - LENEP / UENF and CENPES / PETROBRAS, the equipment used for the development of activities is already available in LDSC. These images will be classified into groups that best represent the different types of reservoir rocks.

The LIB_LDSC library, developed by LDSC, will be used as a parameter for the implementation of the study on the images to be analyzed, because the algorithms of bibliography has already implemented. The future results will be compared to results obtained with the model being developed.

The method being developed will be based in the bibliography using existing systems and multi-platform programming language, C++, stressing that there are many advantages for the development of scientific software, using a pure language in an environment of free software, among them you can highlight the re usability and portability.

The testing determined by the method of software development will be made so that this algorithm can be validated and then be added to LIB_LDSC library.

The results will be compared with findings in the study of existing methods, it is expected that this new method, specific to the analysis of groups of images of reservoir rocks typical of the Campos Basin, produce better results for the processing of digital images in the study of layers of porous materials.

5. CONCLUSION

In the study of methods of manual and automated segmentation, it was concluded that the manual method is what produces better results for images of reservoir rocks but depends on human evaluation, while the automation methods perform less than expected. Thus, the study and development of a method to deal specifically images of reservoir rocks will bring many benefits to the digital processing of images of reservoir rocks in the determination of the same physical properties.

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