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The Use of Classifiers in Image Analysis of Oil Wells Profiling Process and the Automatic Identification of Events

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***Abstract*—**Different strategies and tools are available at the oil and gas industry for detecting and analyzing tension and possible fractures in borehole walls. Most of these techniques are based on manual observation of the captured borehole images. While this strategy may be possible and convenient with small images and few data, it may become difficult and suitable to errors when big databases of images must be treated. While the patterns may differ among the image area, depending on many characteristics (drilling strategy, rock components, rock strength, etc.). In this work we propose the inclusion of data-mining classification strategies in order to create a knowledge database of the segmented curves. These classifiers allow that, after some time using and manually pointing parts of borehole images that correspond to tension regions and breakout areas, the system will indicate and suggest automatically new candidate regions, with higher accuracy. We suggest the use of different classifiers methods, in order to achieve different knowledge dataset configurations.

***Keywords*—**Brazil, classifiers, data-mining, Image Segmentation, oil well visualization, classifiers.

I. Introduction

BOREHOLE imaging is an extremely powerful tool that enables the log analyst, geologist, geophysicist and petroleum engineer to better evaluate reservoirs. Conventional log analysis has to join in each step of formation evaluation.

Sedimentary patterns, textural and bedding characteristics, displayed on borehole images permit built depositional environment histories and estimate petrophysics model for producing planning.

Natural fractures and drilling-induced wellbore failures (breakouts and induced fractures) provide critical constraints on the state of *in-situ* stress and the direct applicability to problems of reservoir production, hydrocarbon migration, and wellbore stability. Wellbore images provide the means to detect and characterize natural fracture systems and to distinguish them from induced wellbore failures [2].

Fractures are discontinuities in rocks, which appear as local breaks in the natural sequence of the rock's properties. Most geological formations in the upper part of the earth's crust are fractured to some extent. The fractures represent mechanical failures of the rock strength to natural geological stresses such as tectonic movement, lithostatic pressure changes, thermal stresses, high fluid pressure and drilling activity. Fractures with displacement of rock mass are called faults.

Fractures/faults play an important role in hydrocarbon reservoirs. They can impact permeability and porosity and thence reservoir performance. This is becoming more apparent with the advancement of technology and the shifting of frontiers to deeper and tighter reservoirs, in increasingly high temperature/high pressure environments. Therefore the need for fracture characterization is no longer limited to classical fractured reservoirs (in which fractures are the main source of permeability). Deep, tighter reservoirs rely on fractures as a source of porosity too. In addition, reservoirs with high matrix porosity and permeability can show negative symptoms related to un-wanted high permeability in fracture zone [1].

Reference [1] says that in both fractured and non-fractured reservoirs *in situ* stresses impact reservoirs properties (porosity and permeability) and reservoir performance. This accounts for the stress-sensitivity of reservoirs (*i.e.* the changes in reservoir petrophysics and performance as a function of *in situ* stress). In addition these stresses play an important role in issues of borehole stability, productivity and injectivity.

This study should guarantee the borehole stability, and to reach this objective it is necessary to evaluate the following factors: perforation fluid weight, rock strength, temperature variations, mechanical drilling trajectory inclination and orientation, tension and strength anisotropy, perforation column vibration and hole geometry.

When a borehole is drilled in a non-isotropic pre-stressed rock, we can note a failure, which is a result from the reorientation of the stress field and the stress concentration around the borehole wall.

Borehole breakouts are brittle enlargements of the hole diameter due to high stress concentrations around the wellbore. They are compressive failure structures, occurring if the tangential stress exceeds the compressive rock strength.

In this context, the stability of an oil reservoir is a challenge for specialists of the petroleum industry; therefore, a correct analysis of this question can reduce the perforation cost significantly.

It can be considering that 10 to 15% of the time expense to perforate a hole is related to the analysis of its stability, which means billions of dollars cost annually.

The study of boreholes stability requires, besides the causes understanding, its correct identification and modeling. In this

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context, the present work presents a computational tool to contribute in the evaluation and analysis of holes stability, to be used in petroleum industry. The data are collected from a mechanical tool (4-arm or 6-arm caliper) that is conducted inside the boreholes. This device uses electric sensors that measure and register the resistivity patterns in electrical borehole wall images.

Geologists can evaluate breakout in an image profile. The breakouts direction indicates the minimum horizontal strength direction. The study of boreholes stability requires, besides the causes understanding, its correct identification and modeling.

In this context, the present work proposes a consideration about the use of Classifiers for Enhancing the Process of Image Analysis for Finding Oil Drills and Tension Regions of Boreholes Images.

II. FRACTURES AND FAULTS IN BOREHOLES

Fractures are defined as all discontinuities that occur in rocks due to brittle/semi-brittle deformation. Faults are defined when can identify a rock displacement. Borehole images can be display fractures/fault by intercepting line of fracture/fault plane *vs*. wall borehole (Fig. 1), and faults are often recognized on borehole images of the offset of different rock types across the fault plane (Fig. 2). Fractures/faults play an important role in hydrocarbon reservoirs because they can impact permeability and porosity and thence reservoir performance (Fig. 3). Borehole imaging tools provide quantitative information on fracture attributes, such as fracture density, aperture size, porosity, and orientation. The density and orientation characteristics of the fracture system determine the connectivity of the fracture network, whereas the aperture and porosity of the fractures determine their potential transmissibility. Knowledge of these fracture attributes is critical to assess the fractured reservoirs, and it also aids in the exploration and exploitation of many petroleum reservoirs.

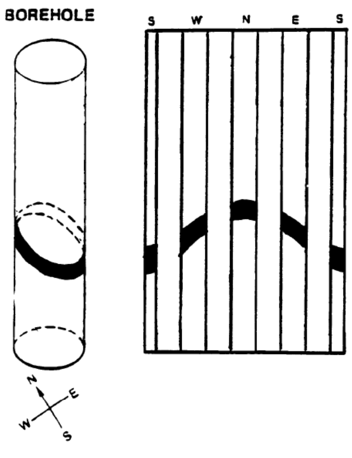

Fig. 1 Schematic of a fracture/fault plane crossing a wellbore [8]

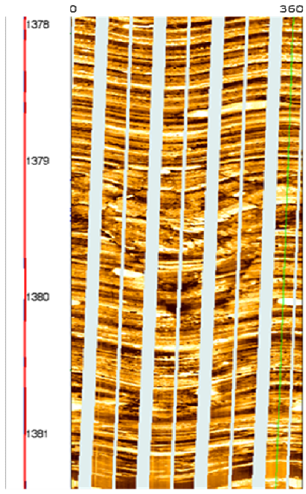

Fig. 2 Borehole image displays fractures/faults set

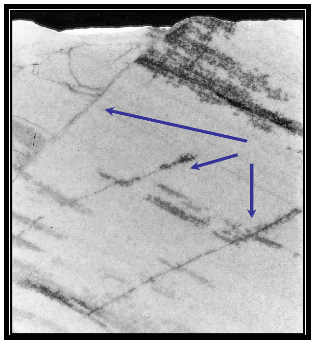

Fig. 3 Oil staining along open fractures in Nugget Ss [10]

For the identification of the main events that have similar aspects with the sinusoids, it is possible to use Hough Transformation, which is able to detach geometric forms in binary images from its parametric equations. Hough Transformation is a well-established and common method for Computer Vision problems [6], [7].

The method consists on applying the transformation to the image in such a way that all the pixels that are in the same curve can be mapped through one only point of a new parameterized space of the searched curve.

Depending on the geometric form, parameters must be defined previously. For instance, with the Hough transformation used for identifying circumferences in images it is fixed a circle radius, while at the sinusoid transformation is necessary to fix as parameters the curve amplitude.

In [7] we considered two groups of images obtained from Caliper tool: dynamic and static. Each one is generated with different hardware strategies. The purpose of this approach consists on identifying events with sinusoidal aspects from the borehole region, in order to be able to analyze in future works events that may turn these regions compromised.

Fig. 4 shows that we used the same methodology that was applied for the static images, being the results similar. This is due to a difference of observed contrasts. In the case of the dynamic image (FMI), where there is a better contrast, the results were more accurate, while at the static image, with low contrast, it is possible to see a blur region with dark points, which causes a high rank punctuation when the Hough Transformation is applied. This causes a highlight in a region that there is no event or fracture [7]

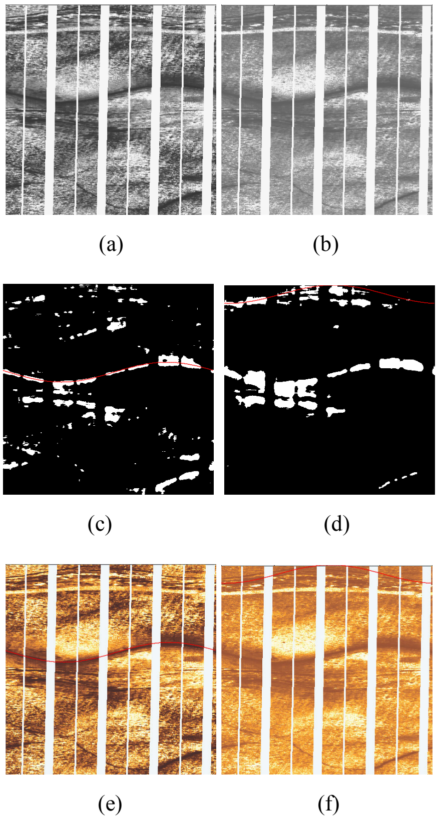

Fig. 4 Comparison between dynamic (a), (c), (e) and static (b), (d), (f) images: (a), (b) gray scale images; (c), (d) Hough transformation; (e), (f) Hough transformation inserted in the original image

III. Proposal

The automatic identification of events on oil borehole profiles requires the analysis of huge amounts of data and specialized knowledge, evidencing the need of a computational method to assist this identification. Due to the large amount of available data for processing, the need for automation is evident.

According to [3], to automatically identify the objects, classification is required after the segmentation. Classification techniques aim to automatically classify objects according to given decision criteria, grouping in classes the objects that are similar.

During the development of this paper, several applications and studies that involve the utilization of image classifiers were identified.

Reference [11] presents a paper that implements and integrates the main steps of the proposed method for the automatic recognition of "lithofacies" based on electrical profiles of boreholes on an oil field. The core of this method is based on neural networks, computational technique that has shown good results in several areas involving pattern matching. Presents tools developed for: conversion of the electrical profiles data into training data and test for the utilized neural simulator, graphical analysis of the borehole profiles, and the extraction of rules from a trained neural network.

Reference [5] utilizes a method based on artificial neural networks to identify the oil boreholes' "lithofacies". The paper focuses the importance of the automatic identification of the "lithofacies" and proposes a method for this application composed by the association of: profiles' data, data discretization, class grouping, neural network training, problematic patterns treatment and validation rules extraction.

Reference [4] draws a comparison between two digital image classifiers for the estimation of soil's vegetal covering. Describes in his work that one way to evaluate the accuracy of a classifier is mounting the error matrix or confusion, in which, starting from the validation sample, the classification results are organized in a square matrix of dimension equal to the number of classes.

Reference [9] presents a study on the use of degrees of confidence of the classes in Bayesian classifiers. The results indicate that there is no unique combination of degrees of confidence classes that maximize the result of a classifier.

Reference [12] uses the morphology for the detection of fractures on geophysical profile images of a borehole. The morphological base consists of extracting the geometry from an unknown image, through the utilization of the transformation of another image that is completely defined, called structuring. The choice of the structuring element is determinant for the quality of the highlighted features.

The proposed work, besides the exploration of algorithms for the evaluation of the classification/segmentation of these images, proposes the development of a new algorithm. The main objective is to develop a study of solutions for the automatic classification of images through an algorithm oriented to the classification of oil borehole profile images. From the study of some classifiers such as Decision Trees, Nearest Neighbors and based on regressions, a new classifier is proposed.

IV. Conclusion

The image profiles are similar to photographs of the borehole wall, based on resistive and acoustic characteristics of the formations. These data profiling generates information of great importance for reservoir characterization, such as tilting of layers, the occurrence of fractures and their inclinations, the occurrence of breakouts, stress management, lithology, thin layers, vugs and caves.

The process of identification and manual dialing of these events is very work-full, because it involves the analysis of large volumes of data and requires specialized knowledge highlighting the need to automate this process. This paper proposes a study of solutions for the automatic classification of images through an algorithm oriented classification of profile pictures of oil wells. The methodology proposed for this problem is compounded by the use of techniques of segmentation and classification of images using the automatic recognition of objects. The proposed work consists of the discretization of data, grouping of classes, training classifiers treating problematic patterns and extraction rules.

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