GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

Prediction of stratigraphic units from spectral co-occurance coefficients of well logs

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Summary

Well logging is the process of making physical measurements down bore holes in order to characterize geological and structural properties. Logs are visually interpreted and correlated to classify regions that are similar in structure, a process that can be modelled with machine learning. This project applies supervised learning methods to labelled well logs from the Trenton Black River dataset in order to classify major stratigraphic units. Spectral co-occurance coefficients were used for feature extraction, and a k-nearest-neighbours approach was used for classification. This novel approach was applied to real field data in a high-impact domain, yielding promising results for future research.

Introduction

Structures in nature exhibit fractal geometry, where a complex irregular structure reoccurs at every scale[1]. This fractal nature of the Earth's stratigraphic layers is contained in the well log data. Analysis of fractals by Mandelbrot[1] demonstrated that seemingly complex geometries could be represented by a very simple recursive relationship. This formulation has been exploited by the special effects industry, where realistic landscapes are synthesized with a simple parameterization. A desert or a mountain landscape can be rendered based on differing fractal relationships, an insight that motivates the use of fractals for classifying geological groups.

Machine learning from well log data is an active field of research, yet remains relatively sparse in scientific literature. Work by Salehi and Honarvar[2] demonstrated success predicting photoelectric adsorption from other measurements, but this type of numerical prediction is not as novel as predicting a geologists interpretation. This project instead follows an approach similar to [3] where Holder exponents of wavelets were used as inputs into an artificial neural network. Holder exponents are used to analyze fractal properties of signals[4], which make them an intuitive discriminating feature. The approach was ineffective at predicting thin bed lithologies, as the wavelet transform removed much of the high-resolution geological features. Wavelet transforms may be better suited for stratigraphic analysis, where thin beds are grouped into larger geological units.

Higher-order wavelet transforms, such as the scattering transform[5], use a neural network of cascading wavelet transforms to characterize signals. The spectral co-occurance coefficients (SCOC) output by the scattering transform contain multi-scale information about the signal, making them a promising basis for characterizing fractal relationships. The scattering transform has demonstrated success in classifying audio signals into genres of music[6], which is a problem of predicting human interpretation of a 1D signal. The fractal nature of the scattering transform and its prior success with classifying human interpreted data makes SCOCs a promising feature basis for well log learning.

Theory/Method

A supervised learning approach was applied to gamma-ray measurements with labelled stratigraphic units. A scattering transform was used to extract SCOCs as features from gamma-ray measurements, which were input into a KNN classifier.

Well logs are not uniform measurements, as each log will have different start and stop depths and contain multiple stratigraphic labels. This type of data does not fit directly into a classification scheme, so an extraction to a new feature basis was required. The scattering transform was used to transform well logs into spectral co-occurance coefficients. The scattering transform takes on the structure of a trained neural network(Figure 1) where each stage is a wavelet transform resulting in multi-scale measurements of signals, making them well-suited for the fractal structure of well logs. The MATLAB code ScatNet [8] was used for calculating SCOCs.

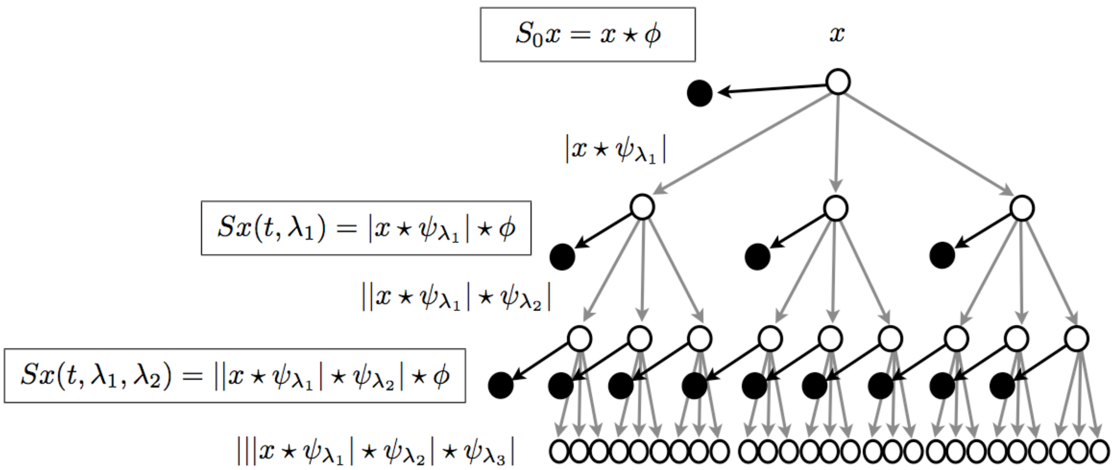

Figure 1: Diagram of the scattering transform, originally from [5].

The labelled dataset was split into training and testing datasets. A classification was made by calculating the euclidean distance between each testing and training vector and choosing the mode of the k closest neighbours. Cross-validation was used to determine a value of 14 for k.

Examples

In the early 2000s, the Trenton Black River carbonates experienced renewed interest due to speculation among geologists of potential producing reservoirs. A basin wide collaboration to study the region resulted in many data products, including well logs with corresponding stratigraphic analysis. The dataset contained 80 gamma-ray logs with corresponding stratigraphic labels, and an additional 70 unlabelled logs. An example of a labelled log is shown in Figure 2. The dataset can be downloaded at [7].

Table 2 shows the classification accuracy for each stratigraphic group. The total classification accuracy was 36% with the highest accuracy (67%) occurring in the Black River group. Referring to Table 1 and Figure 2 there is direct correlation between the relative size of the stratigraphic unit and the classification accuracy. This could indicate that the scattering transform is better applied for characterizing larger groups, but could also be a statistical artifact related sample sizes.

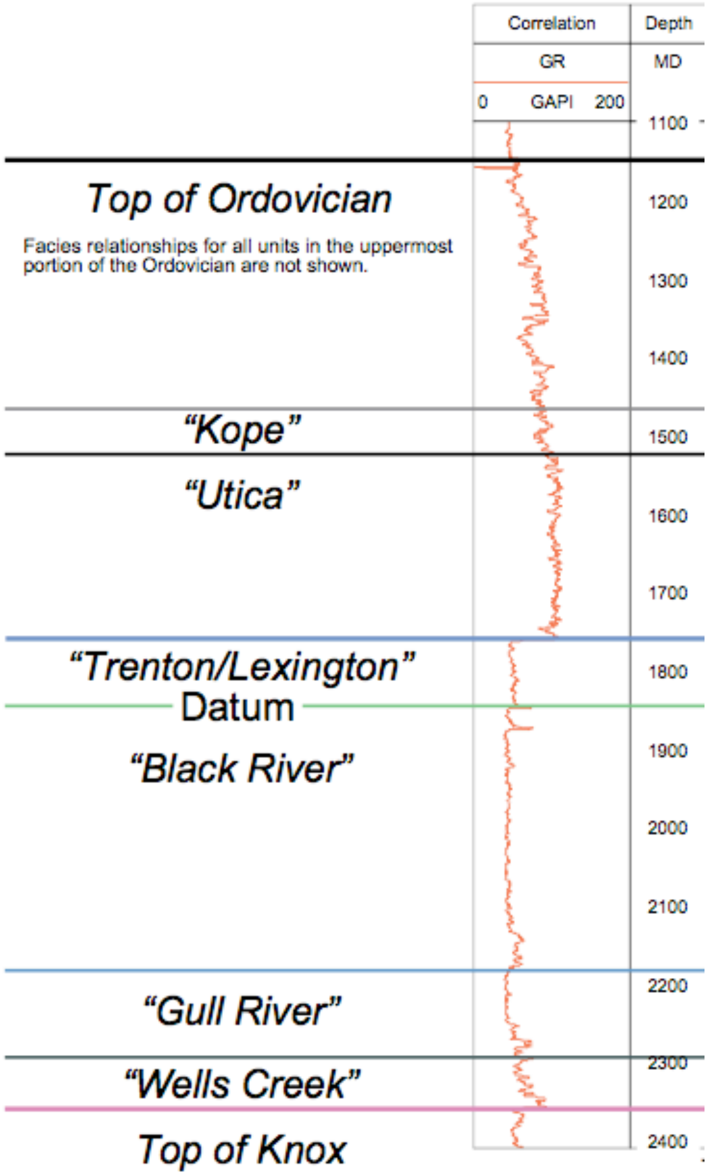

Figure 2: Well log image with stratigraphic labels, originally from [7].

Table 1
Summary of stratigraphy units

Unit	Feature Count	Classification Accuracy
Ordovician	671	0.5
Kope	369	0.2
Utica	241	0.12
Point Pleasant	119	0.03
Trenton/Lexington	165	0.04
Black River	567	0.67
Gull River	101	0.0
Wells Creek	57	0.0

Conclusions

Geological analysis is often about visual interpretations of patterns across large multidimensional datasets; a workflow that can be targeted by machine learning techniques.

A supervised machine learning approach was applied to stratigraphic unit prediction from well log data. Early results show initial promise, and the motivation and method opens the door for future research.

This project suggests a connection between fractal patterns observed in nature and a neural network based multi-scale wavelet transform. The method was demonstrated on geological field data with disparate human interpretations. Initial results from a simple classifier show promise for future research.

References

[1] Mandelbrot, B.B. (1982) The fractal geometry of nature. Ed. W. H. Freeman, San Francisco.

[2]Salehi, S.M. & Honarvar (2014) Automatic Identification of Formation lithology from Well Log Data: A machine Learning Approach. *Journal of Petroleum Science Research* 3(2):73-82.

[3]Leila Aliouane, Sid-Ali Ouadfeul and Amar Boudella (2012). Well-Logs Data Processing Using the Fractal Analysis and Neural Network, Fractal Analysis and Chaos in Geosciences, Dr. Sid-Ali Ouadfeul (Ed.), ISBN: 978-953-51-0729-3, InTech, DOI: 10.5772/51875. Available from: http://www.intechopen.com/books/fractal- analysis-and-chaos-in-geosciences/well-logs-data-processing-using-the-fractal-analysis-and-neural-network

[4]Herrmann, F.J. (1997) A scaling medium representation, a discussion on well-logs, fractals and waves, Phd thesis Delft University of Technology, Delft, The Netherlands

[5]Deep Scattering Spectrum, Andn J. and Mallat. S., Submitted to IEEE Transactions on Signal Processing, 2011.]

[6]Salehi, S.M. & Honarvar (2014) Automatic Identification of Formation lithology from Well Log Data: A machine Learning

Approach. *Journal of Petroleum Science Research* 3(2):73-82.

[7]Trenton Black River Project (2006), http://www.wvgs.wvnet.edu/www/tbr/

[8] ScatNet MATLAB package, http://www.di.ens.fr/data/software/scatnet/