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A New Robust Approach Using a 1D-CNN Model for Predicting Compressional Wave Velocity and Density in Geophysical Well Logs from the Campos Basin

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Introduction

The characterization of geological materials in rock environments, particularly in sedimentary basins of petroleum interest, is fundamentally dependent on seismic wave velocity and rock density (Christensen & Mooney, 1995; Brocher, 2005). Accurate estimation of these properties, such as compressional sonic profile (DTCO) and density (RHOB), is crucial for reservoir characterization. However, the frequent absence of compressional wave velocity (Vp) profiles, coupled with the limitations of traditional empirical equations (e.g., Gardner's equation) to adapt to diverse geological environments, drives the search for more robust approaches, including machine learning (ML) algorithms. This work proposes a new approach to deal with well-log regression, considering the observations a time sequence.

Method and/or Theory

This study proposes and validates an approach based on one-dimensional convolutional neural networks (1D-CNN) to estimate DTCO and RHOB from conventional geophysical logs. Although ML methodologies are recognized for their effectiveness, precision challenges persist in real borehole data. To optimize model performance, a data preprocessing technique was developed that transforms inputs (gamma ray, resistivity, photoelectric effect, sonic and density) into tensors representing time series in depth.

The methodology was validated using a real dataset of 65 wells from the Campos Basin, provided by the National Agency of Petroleum (ANP). The performance of the 1D-CNN was compared with that of other regression techniques, including linear regression, XGBoost (XGB), and Multilayer Perceptron (MLP). The evaluation was performed using holdout cross-validation, with Mean Absolute Error (MAE), Mean Squared Error (MSE) and coefficient of determination (R^2) as metrics.

Results and Conclusions

Results indicate that while MLP and XGB generated reliable estimates, with XGBoost showing the best error metrics, these algorithms demonstrated susceptibility to overfitting and poor performance in regions with high frequency and spurious values, adjusting to geologically meaningless data. In contrast, the 1D-CNN, which benefits from the contextual approach provided by time series tensors, proved robust in these intervals, generating geologically coherent predicted curves with error metrics comparable to those of XGB without the peaks or high frequency observed in other approaches.

It is concluded that the 1D-CNN-based methodology offers significant advantages in terms of accuracy, efficiency, and cost compared to traditional methods and other machine learning (ML) techniques, facilitating a more comprehensive analysis and informed decisions in oil and gas exploration in the Campos Basin.