Predicting Shear Sonic Velocity Integrating the Concepts of Time Series Clustering and Ensemble Class-Based Machine Learning

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ABSTRACT

Shear sonic velocity is important in estimating elastic properties of rocks, such as Poisson's ratio and rigidity modulus, which are critical to delineating the suitable targets for landing lateral wells and hydraulic stimulation. However, such data are often absent from boreholes. Existing empirical models estimate shear wave velocity using compressional wave velocities using linear equations, which are often insufficient to predict the nonlinear behavior of velocity. Recently, machine learning (ML) algorithms have been used using conventional wireline logs with limited success. Although such ML models showed overall high performance in predicting velocity for the full borehole section, detailed observation shows sections where the velocity is either highly overpredicted or underpredicted. This happens especially across high- and low-velocity layers. Most ML algorithms consider the input attributes to the models independent of each other, which is hardly true in the case of wireline logs. This study tackles this fundamental challenge by using a novel multivariate unsupervised time series clustering algorithm (modified Toeplitz Inverse Covariance-based Clustering with adaptive windows) that assumes the existence of interdependence among wireline logs. The clusters are a function of the combined effects of mineralogy, texture, fracture, and in-situ stress gradient. After clustering, several ML–based regressor models, including deep learning, such as Random Forest and Bi-directional Long-Short Term Memory, etc., are trained and optimized for each cluster, and the results are aggregated together. The final ensemble class-based ML model results show that we can predict shear wave velocity in the Wolfcamp Formation with high accuracy (92–98%) across multiple wells with high consistency in a large study area in the Permian Basin. No individual clusters overpredict or underpredict shear sonic velocities.

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