Evaluation of an Interactive Deep Learning Tool for Multilayer and Fault Interpretation in 3D Seismic Data

Débora Barretto (IesBrazil Technology & Innovation)
Carlos Saraiva (IesBrazil)
Neida Ilana (IesBrazil Technology & Innovation)
Juliana Fernandes (IesBrazil Technology & Innovation)
Vanessa Lira (IesBrazil Technology & Innovation)
Breatriz Gripp (IesBrazil Technology & Innovation)

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Abstract

Three-dimensional seismic is a fundamental in geophysical exploration, particularly within the oil and gas industry. It enables detailed visualization of subsurface structures, facilitating the identification and characterization of geological formations and hydrocarbon reservoirs. Traditionally, seismic interpretation has relied on manual or semi-automated analysis of seismic images to detect geological features such as stratigraphic layers, faults, and reservoir geometries. However, with the increasing volume, complexity, and resolution of seismic datasets, deep learning (DL) methods have emerged as promising tools to enhance interpretation workflows by offering automation, computational efficiency, and improved accuracy. Contemporary DL tools for seismic interpretation are predominantly based on pretrained convolutional neural networks (CNNs) that utilize transfer learning to apply generalized feature recognition to new datasets. These models leverage extensive training on large seismic datasets to infer patterns and classify input data with minimal manual input. Alternatively, interactive deep learning (IDL) approaches enable interpreters to iteratively guide the model by providing labeled examples, allowing the network to adapt its predictions according to the interpreter's geological understanding. This technique offers increased reliability and interpretive control, especially in complex geological settings. This study investigates the performance of an interactive deep learning platform applied to 3D seismic interpretation, focusing on multilayer delineation and fault detection across geologically diverse regions. The primary objective was to assess the tool's effectiveness in mapping key stratigraphic units, including the water column, post-salt, salt, and pre-salt layers, as well as in identifying fault networks with varying structural characteristics. A single multiclass network was employed for simultaneous classification of all four stratigraphic layers. While the network generally performed well, improved accuracy was observed for complex units—such as the salt layer—when interpreted using dedicated single-class networks, due to their heterogeneous morphology and variable seismic expression. For fault interpretation, separate networks were required for distinct fault types. Attempts to classify multiple faults sets within a single model resulted in prediction overlap and lower accuracy, indicating the necessity of fault-specific models to reduce misclassification. The number of interpreter-provided labels was found to directly influence model performance, particularly in geologically complex areas. However, selection of suitable neural architectures and cost functions significantly improved learning efficiency, reducing the need for extensive manual labeling. Furthermore, interpretation results varied depending on the individual interpreter's input, reflecting the subjectivity inherent in manual labeling and its impact on training outcomes. Despite this variability, the overall results were satisfactory, with the IDL tool substantially reducing interpretation time while maintaining geological consistency. Makes it possible to conclude that integration of interactive deep learning tools into seismic interpretation workflows, particularly in complex structural settings where interpreter expertise can be combined with machine learning efficiency to achieve more reliable and expedited results.