Horizon Extraction Via Hybrid Machine Learning And Optimization Framework

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Abstract

Objectives/Scope: Interpretation of seismic horizons in areas of stratigraphic or structural complexity can be challenging and time-consuming but is crucial for the characterization of the detailed geological structures and stratigraphic features that are increasingly becoming targets for exploration. Here we demonstrate how machine learning (ML) can be combined with an interactive optimization approach for horizon interpretation, allowing high-resolution and rapid characterization of the subsurface.

Methods, Procedures, Process: Interactive ML workflows that combine generically trained deep learning models with lightweight decoders that take sparse user input have shown their effectiveness in tasks such as image segmentation. In this way, predictions can be updated with user constraints without the need for computationally intensive retraining; this is useful for assisting in data labelling or interpretation tasks where the pre-trained algorithm may give sub-optimal results. Learning from these frameworks, we have designed a two-step workflow that accomplishes a similar process for seismic horizon interpretation. A convolutional neural network (CNN) is trained to produce useful seismic attributes for horizon interpretation. An optimization framework is then employed to combine the output of the CNN with sparse user input to derive an accurate seismic horizon interpretation. To refine the output horizon, no model retraining is needed, the user must simply add additional constraints to the horizon, the prediction is then updated in near-to-real time.

Results, Observations, Conclusions: To demonstrate this new method, we use an example from the Maui 3D seismic volume from the Taranaki Basin, offshore New Zealand. In data subset, a clinoform succession can clearly be seen despite the structure of the foresets having a low signal-to-noise ratio (SMR). Horizon interpretation via waveform or dip-based tracking procedures struggle in such intervals due to the geological complexity and low SNR. The pretrained CNN combined with a single constraint point can provide a good first pass approximation of the horizon surface across the volume. However, it can be quickly refined with just a few additional constraint points to produce a high-quality horizon interpretation.

Novel/Additive Information: Interpretation workflows will always require a level of interactivity to produce high quality results. The novelty of this methodology allows the prediction power of deep learning models to be combined with user interaction in near-to-real time without the need for model retraining.