Submission code: 8NRXGQ5RNK

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Time-lapse repeatability enhancement of depth-migrated images with neural networks: A case study on real data from the Brazilian pre-salt

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Introduction

Non-repeatability (NR) is the main technical challenge in oil and gas reservoir monitoring with time-lapse seismic. NR introduces data artifacts that can mask the production-related signals or be misunderstood as such, hindering the interpretation of reservoir changes. One important processing technique to mitigate NR is matched filtering (MF), which has known drawbacks such as strong dependence on the selection of calculation parameters.

Neural networks have recently been proposed as an alternative to MF, with promising results being reported. However, most works tend to use very complex networks that are prone to overfitting, which may result in distortion or removal of the reservoir signals. This over-matching effect is troublesome for regions with low 4D signal-to-noise, such as the Brazilian pre-salt.

In this study, we propose a novel methodology based on neural networks to enhance repeatability. A new neural network architecture is proposed, with regularization measures to minimize over-matching. Results show that the technique outperformed conventional MF in some aspects on real post-stack depth-migrated images from the Brazilian pre-salt.

Method

In the proposed method, a single neural network is trained to approximate the monitor to the baseline volume on a subset of the data, manually chosen by the user, in which the time-lapse differences are assumed to be caused primarily by non-repeatability. In the inference stage, the trained network is applied to the entire monitor, performing the corrections learned in training.

The method's first step is to perform a RMS amplitude AGC jointly on baseline and monitor. Then, several small rectangular regions of migrated amplitudes (patches) are extracted from both volumes. Patches extracted from monitor and baseline are respectively used as inputs and targets for training the network. A similar process is performed in the inference stage, where the many predicted patches are combined to reconstruct the processed volume.

We propose a new network architecture, based on the Temporal Convolutional Network, that performs 2D convolutions to exploit the spatial coherence of migrated events in xline and depth directions. Over-matching is mitigated with regularization measures including spatial dropout.

Results and Conclusions

We compared the proposed method with conventional trace-by-trace MF on real post-stack depth-migrated data from the Brazilian pre-salt. We worked on partially processed (fast-track) baseline and monitor volumes, still contaminated with significant noise.

Matching performance was evaluated calculating the NRMS metric and NdRMS 4D attribute in the reservoir, overburden and underburden depth windows. Results show that, compared to MF, the network achieved stronger noise suppression in the overburden, and also in the west and south regions, and better recovered reservoir signals around a key injection well.

These results demonstrate the potential of enhancing repeatability with neural networks. Due to their different nature, these methods can be used as a supplement to conventional techniques, giving interpreters more information for better uncertainty assessment of 4D signals.