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Automatic detection of diffraction-apex using fully convolutional networks

Thamiris Coelho*, Lucas de M. Araújo, Tiago A. Coimbra, Martin Tygel, Sandra Avila and Edson Borin

Abstract
Diffractions play a significant role in seismic processing and imaging since they can image structures smaller than the seismic wavelength, such as discontinuities, faults, and pinch-outs. The traveltime of a non-migrated stacked diffraction event typically has a hyperbolic shape around its apex, which collapses after a migration procedure. In this work, we introduce a Fully Convolutional Network (namely, LeNet-5 FCN) to automatic detect diffraction apexes on real seismic data. To deal with the low amount of annotated data, we propose to use data augmentation and ensemble strategies. By combining our LeNet-5 FCN with those strategies, we reached 91.2% average accuracy on three land seismic datasets.

Key words:
Machine learning, geophysics, fully convolutional network

Introduction

We consider a D-section, which predominantly contains diffraction information, constructed by a double-square-root (DSR) stacking operator. The method provides, besides the stacked diffraction events (in the shape of approximate hyperbolas), also the stacking velocity section. In seismic approaches it is of valuable to find the apex position of diffraction events in the D-section, these being obtained by manual picking. However, manual picking turns out to be a time-consuming and error-prone task. In fact, even for 2D-acquisition datasets, there are hundreds of diffraction events with ambiguous regions, thus making picking a difficult endeavor.

In this work, we propose a Deep-Learning based approach to devise an automatic tool to detect the apex of diffractions in seismic, real D-sections. More specifically, we introduce an FCN for apex detection. Our proposed FCN is implemented on the LeNet-5 architecture, giving rise of what we called a LeNet-5 FCN. By combining LeNet-5 FCN data augmentation and ensemble strategies, we reached, for three illustrative land seismic datasets, an average accuracy of 91.2%.

Results and Discussion

We performed four experiments using: 1) pure training set; 2) augmented training set; 3) models trained on pure training set; 4) models trained on the augmented training set. We run the experiments 1 and 2 nine times to reduce the effects of randomness. Experiments 3 and 4 were executed only one time since variability is already built into the ensemble.

Due to the increase in volume of data obtained with augmentation, we got a training set seven times larger. This contributed to a faster model converging and presenting greater stability on training and validation.

Figure 1 shows the results for all experiments. We obtained an average accuracy of 91.6% for experiment 1, 93.7% for experiment 2, 93.4% for experiment 3 and 98.6% for experiment 4. The ensemble with augmentation strategy yielded the best result, with an error reduction of over 83%.

For our final analysis of this automatic apex detection tool, we evaluated the performance of the best model, from experiment 4, over the test set. The average test set accuracy is 91.2%. This drop between validation and test accuracy is expected since the final model never had contact with this data during training or validation.

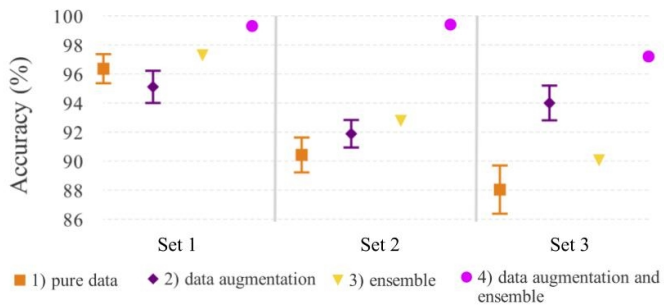

Image 1. Validation accuracy for all experiments: 1, 2, 3 and 4.

Conclusions

We presented a LeNet-5 FCN to automatic detect diffraction apexes on D-sections. We trained and tested the network using only real data from land basins. To deal with the relative scarcity of annotated data, we proposed to use data augmentation and ensemble strategies. Results indicated that augmentation and ensemble contributed independently to the final improvement. Our experiments show the viability of employing an FCN architecture to the diffraction apex detection problem, yielding an attractive accuracy even from a modest amount of annotated data.

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