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Inversion of Refracted Wave's Travel Times Using Linear Ensemble Combination of Single Artificial Neural Networks

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Extended Abstract

Summary

In this study, a new inversion framework based on artificial intelligence is presented for inversion of travel times of seismic refracted waves. The proposed inversion algorithm is comprised of three individual neural networks. The output results of the networks are combined by averaging method. The results show that in both test models and actual dataset, the proposed algorithm is capable of estimating the model parameters. Furthermore, a comparison between the proposed neural network inversion algorithm and tomography inversion method, shows that the introduced neural network inversion algorithm is a reliable and powerful method for automatic inversion of seismic datasets.

Introduction

Seismic methods are common techniques that are used in the fields of engineering and exploration. In seismic refraction method the aim is to measure travel times of P-waves from the shot point to the geophones, which are located at known points on the surface. In this method, the first wave arrivals are used to produce time-distance plots, which are then used in the calculation of the depths of refracting interfaces and compressional wave velocity with respect to depth. After gathering and preprocessing of seismic data, the inversion stage is performed to estimate model parameters. Similar to other kind of geophysical data, the inversion of seismic data is also faced to non-uniqueness challenge. In this study to tackle the non-uniqueness of seismic data inversion, a method based on artificial intelligence is proposed. Creating a neural network with the highest possible performance and decreasing the risk and level of error is a major goal in this regard. A large amount of effort is usually spent on fine tuning the network to make sure it provides the best results. However, a single classification or regression model can hardly produce the best results for every sub-section of a complex problem space. Creating multiple neural networks (or any other machine learning model) and combining the results of those networks could potentially improve the performance and decrease the risk and level of error.

Methodology and Approaches

In order to perform the inversion of travel times of seismic refracted waves using artificial neural networks, different synthetic models having different thicknesses and P-wave velocities were produced for the purpose of training the neural networks. Moreover, 20% of generated data (synthetic models) were considered as test (unseen) data for evaluation of the proposed inversion method. Many networks with different structures were tested using cross-correlation method (i.e. K-fold method). Then, networks with better performance or lower prediction error were selected. This is equal to assigning larger weights to better performing networks while assigning very small weights to those with large errors. Then, the output results of the individual networks were combined using linear averaging method. Finally, the proposed inversion algorithm was run on an actual dataset. In order to further investigate the proposed neural network based inversion algorithm, the actual dataset was additionally inverted using tomography method. The results of the two methods were then compared.

Results and Conclusions

In this study, a new inversion algorithm based on artificial intelligence is introduced. Then, the capability of the proposed inversion algorithm was evaluated using a test data and an actual dataset. The results show that the applied method is a fast and powerful technique in automatic inversion of seismic refraction data. Furthermore, the performance of the applied inversion algorithm was compared with tomography inversion method. The results show that the introduced inversion algorithm, which is based on neural networks, is capable of automatically estimating model parameters, including the number of layers, thicknesses and P-wave velocities of the layers without having auxiliary data. Furthermore, the inversion of the experimental data using the proposed inversion algorithm resulted in a two-layer model, which had a good correlation with the geological and seismic evidence of the study area.

The models produced from the inversion of the synthetic MT data and the Bushli MT field data set using the adaptive regularization, MGCV, and ACB methods are almost similar. The constructed model from using adaptive regularization is slightly better than the model obtained from MGCV and ACB methods. therefore, with respect to the results obtained from 2D inversion of the synthetic MT data and the Bushli (Nir) MT field data, the adaptive regularization method provides a more accurate solution especially in estimating the conductive layer and reservoir boundaries. In addition, this method, compared to the MGCV and ACB methods, is faster and requires less memory in the inversion process. Hence, this method can be considered as the most reliable method for selection of the optimal regularization parameter in the inversion of large 2D and 3D magnetotelluric data sets.