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Anisotropic diffusion filter modified by adaptive neuro-fuzzy interference system (ANFIS) and its application to random noise attenuation in seismic data

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Extended Abstract

Summary

Anisotropic diffusion filtering (ADF) is widely used as an efficient method in random noise attenuation problems, and various modifications to its original version have been proposed. The main reason could be the thought that ADF preserves edge features with acceptable performance beside noise attenuation procedure. In seismic data processing, however, it should be noticed that using ADF could cause severe changes (artifacts) in the zones that are highly contaminated with random noise. In this paper, the optimum value is derived, by introducing an automatic framework based on two artificial intelligence (AI) algorithms, adaptive neuro-fuzzy inferences (ANFIS) and fuzzy c-mean clustering (FCM). The neuro-fuzzy network is trained using original data, successive ADF values are calculated for each data point, and FCM output is obtained in a weighted averaging manner adapted with estimated noise level. The trained network is, then, generalized to all data, and thus, the ANFIS optimized version of ADF, called here AOADF, is achieved. Comparison of the results of the ADF and AOADF experiments reveals that in synthetic common mid-point (CMP) gathers, the proposed method improves peak signal to noise ratio (PSNR) value, 40% higher than ADF (in the best case) and in real CMP and common offset sorted gathers, the performance of AOADF is considerably higher than ADF, in terms of random noise attenuation without adding unwanted artifacts and preserving continuity of coherence components.

Introduction

As an inevitable phenomenon in seismic data acquisition, random noise affects the processing and interpretation results of seismic reflection data. Although it is expected that random noise decreases dramatically by increasing the stack fold, observation of random noise at far offsets and later arrivals, especially in relatively deep acquisitions, could be considered as a common case.

This paper intends to enhance the signal to noise ratio (SNR) of the seismic reflection data by attenuating background random noise and preserving reflection data, utilizing powerful potential of the ANFIS and FCM in model discrimination and the ability of ADF in random noise attenuation. The proposed method mainly seeks to improve the ability of ADF in the zones when the input data is highly contaminated with random noise, and thus, ADF output usually severely cause unwanted artifacts. Achieving latter goal is mainly based on increasing the weight of FCM output value, in the averaging scheme designed for optimum output calculation.

Methodology and Approaches

In the interior of a segment in the input data, the nonlinear isotropic diffusion behaves almost like the linear diffusion filter, but one should consider that at edges, diffusion is inhibited. Therefore, noise at edges cannot be eliminated successfully by the mentioned process. As a solution to this problem, anisotropic models do not only take into account the modulus of the edge detector, but also its direction.

ANFIS, as a neural-fuzzy system, combines the learning capabilities of neural networks with the functionality of fuzzy inference system.

FCM is a robust method for analysis of data and construction of models, more natural than hard clustering, in almost all problems. Data on the boundaries between several classes are not forced to fully belong to one of the classes, but rather

are assigned membership degrees between 0 and 1 indicating their partial membership. In the method adapted in this research, at the very first stage, ADF with some different diffusion coefficients (5 to 80) are calculated for a small part of input data. At the next step, the standard deviations of ADF values are compared to each other. The point with higher standard deviation could be considered as noise related data point and vice versa. Hence, sorting, and then, selecting the first, let us say five percent of data, could relatively promise that we have selected one percent of dataset, which are less likely to be masked by random noise. Using the set of selected data and a weighted average of initial ADF values, original values of input data and output of FCM analysis, the training pairs for ANFIS network will be constructed. The AOADF output will be automatically achieved by generalizing the trained network to all data.

Results and Conclusions

Although ADF is a strong method for random noise attenuation in many problems, in seismic data processing, ADF could cause artifacts in the zones that are highly contaminated with random noise. In this research, as the comparison of the results of AOADF and ADF on synthetic and real seismic datasets indicates, the AOADF method considerably performs better in random noise attenuation and in preserving the continuity of the coherence events without adding significant artifacts.