Seismic Resolution Enhancement Via Denoising Diffusion Probabilistic Model

B. Sun, Saudi Aramco

Abstract

Objectives/Scope: Seismic image resolution enhancement is important because the clarity of seismic images has a great impact on the results of seismic data interpretation. High-resolution seismic images can help with delineation of thin layers and provide finer geological information for reservoir characterization and well-placement. The objective of this study is to develop a seismic resolution enhancement method using machine learning, especially with the introduction of generative model, i.e., the denoising diffusion probabilistic model.

Methods, Procedures, Process: In this study, we propose a machine learning based end-to-end approach for mapping a low-resolution post-stack seismic image to a corresponding high resolution one. Based on the denoising diffusion probabilistic model, the neural network is designed to be a modified 3D Unet, the training processed is formulated by adding and removing noise from the low-resolution input. The dataset for training is sampled from the reflectivity distribution extracted from the well-log. After training, the resulting model can predict a high-resolution seismic profile given a statistically approximated seismic wavelet.

Results, Observations, Conclusions: Leveraging the power of the deep neural network as well as the diffusion probabilistic model, we addressed the two major limitations of conventional resolution enhancement method: 1) Considering the correlation between different traces: The training datasets are carefully prepared by realistic reflectivity sampling from well-log. Due to intrinsic features of a generative model, the diffusion probabilistic model will fuse the structure and latent level information of the seismic signal and thus can improve the stability of the resolution enhancement; 2) Uncertainty analysis: As its name implies, the diffusion probabilistic model is a probabilistic neural network with embedded randomness. With multiple runs, the same input can lead to different results. Thus, such probabilistic model serves as an implicit ensemble model and is an ideal model for uncertainty analysis. Besides, by fusion and retrieving the useful information from different outputs, we can improve the robustness of its prediction and enhance the SNR further.

Novel/Additive Information: The novelty of this study is the introduction of the diffusion probabilistic model into the task of seismic resolution enhancement. The structure and latent information embedded in the generative model leads to more robust and stable resolution enhancement. The ability to perform uncertainty analysis of the result is an extra bonus provide by the generative model.