

# Seismic Fault Detection by Denoising Diffusion Probabilistic Model

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## Abstract

Seismic fault detection and interpretation play an important role in reservoir characterization and well placement. The conventional methods for fault detection rely on the computation of attributes (such as the semblance, coherence and variance) from seismic images. With the progress in machine learning and artificial intelligence, fault detection by attributes computation has been replaced by end-to-end neural network prediction. Wu et al. (2019) developed an end-to-end fault detection method based on machine learning using 3D Convolutional Neural Network. His method proposes a simplified U-net with reduced channel and layers and takes input of seismic images as patches and outputs the corresponding pixel-wise fault attribute. His method trains on synthetic data sets and can be generalized to field data-set with fairly good accuracy. With an improved neural network with attention mechanisms and adversarial training, his method can be further improved. In this example, we proposed a fault detection method based on the diffusion probabilistic model (specially, the denoising diffusion probabilistic model by Ho et al., 2020) and address two major limitations of the conventional deterministic fault detection methods by machine learning: 1) unawareness of geological prior information for the fault structure; 2) inability for uncertainty analysis. The diffusion probabilistic model is a kind of generative model and it improves the image iteratively and produces an image with quality better than any other types of generative models, such as the VAE, GAN, and FLOW. A diffusion probabilistic model is parameterized by the Markov chain and composed of the forward and reverse processes. In the forward process, the Gaussian noise is added according to a predefined procedure. By variational inference, a loss function based on KL divergence was formulated by fitting and prediction of the added noise. Conditioning the diffusion model on the input seismic image, we can train a diffusion model for robust fault detection. The trained neural network incorporates the geological prior information and thus produce more robust prediction of the fault attributes. Besides, due to the inherent probabilistic nature of the generative model, we can perform an uncertainty analysis of the detected fault by running multiple times of prediction and analyzing its statistics (such as mean and variance). The variance map which is unique to a probabilistic fault detection methodology can assist the interpreter in evaluating the reliability of the detected faults.