Seismic reconstruction using noise-assisted network

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Summary

We present a new framework of convolutional neural network called noise-assisted network (noise-net) for seismic data reconstruction. There have three main contributions in our proposed method. The first one is that we developed a new objective function for CNN-based denoising methods based on the assumption that the added white noise can simulate the feature of original noise contaminated in the seismic traces. This improvement has successfully made our method handle the task of noise attenuation without the "clean" data. The second one is that we build a new architecture for the denoise convolutional neural network (DnCNN), which make our method can not only attenuate the noise, but also interpolate the missing traces. The third one is that we use the context-encoder as the training data generator and integrated with our new framework CNN. The synthetic and field data examples have illustrated that our method successfully reconstruct the missing traces with large gaps and attenuate the noise. The recovering results also demonstrate that our method can remove the unnatural artifact and overcome the problem of unstable training in GAN.

Theory

Recovery of missing or noisy seismic data is very important for seismic interpretation and many related approaches have been proposed. However, it is difficult to apply conventional interpolation techniques into very complex topographic scenarios with large gaps. Generative adversarial network (GAN) is an unsupervised learning algorithm and has been applied to address the problem of image interpolation, while the training process is unstable and the interpolated result usually have some unnatural artifacts. Many CNN based methods have been used to handle the task of noise attenuation. However, those methods need the clean data and corresponding noisy data in the process of training, which is unfeasible in seismic exploration.

Objective function

We first proposed a new objective function for DnCNN:

$$\theta = \arg\min_{\theta} \frac{1}{N} \sum_{i=1}^{N} \left\| R_\theta(y_i) - (y_i' - y_i) \right\|^2$$

$$\theta = \arg\min_{\theta} \frac{1}{N} \sum_{i=1}^{N} \left\| R_\theta(y_i) - n_i' \right\|^2$$

where $\boldsymbol{y}$ is the original seismic data, to generate the new noisy seismic data $\boldsymbol{y}'$ denotes the new noisy data with additive noise $\boldsymbol{n}'$.

Framework

We next developed a new framework of CNN named noise-assisted network. This network integrated the GAN-based network of context encoder with DnCNN. Since the training process of GAN is unstable, our method treat the GAN part as the training data generator rather than the final objective. We proposed to use the additive white noise to simulate the feature of original white noise and attenuate the original white noise. We also add a convolution layer with large kernel size into the proposed network that make noise-assisted network can not only attenuate the white noise but also interpolate the missing traces.

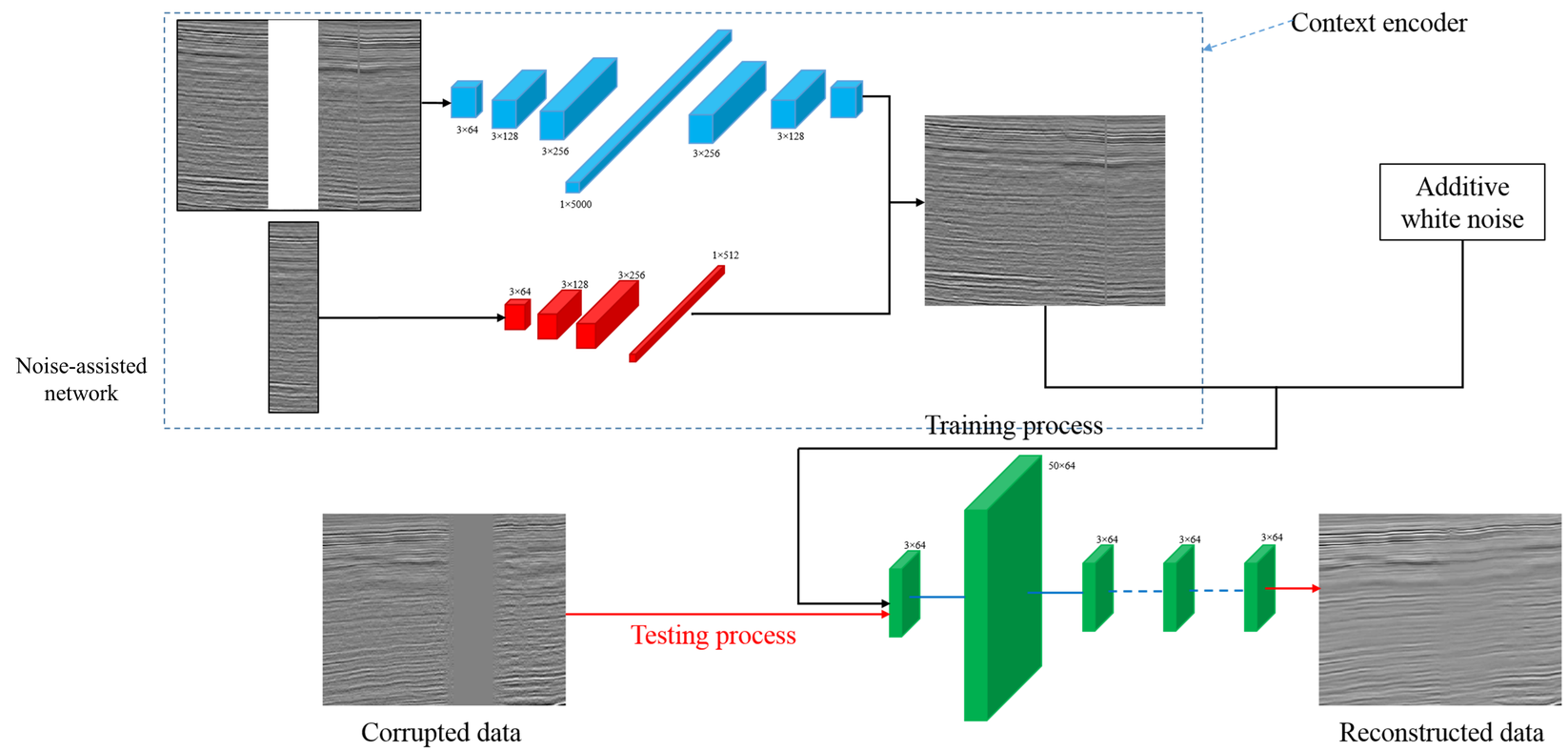

Figure 1. The framework of noise-assisted network

Field data example

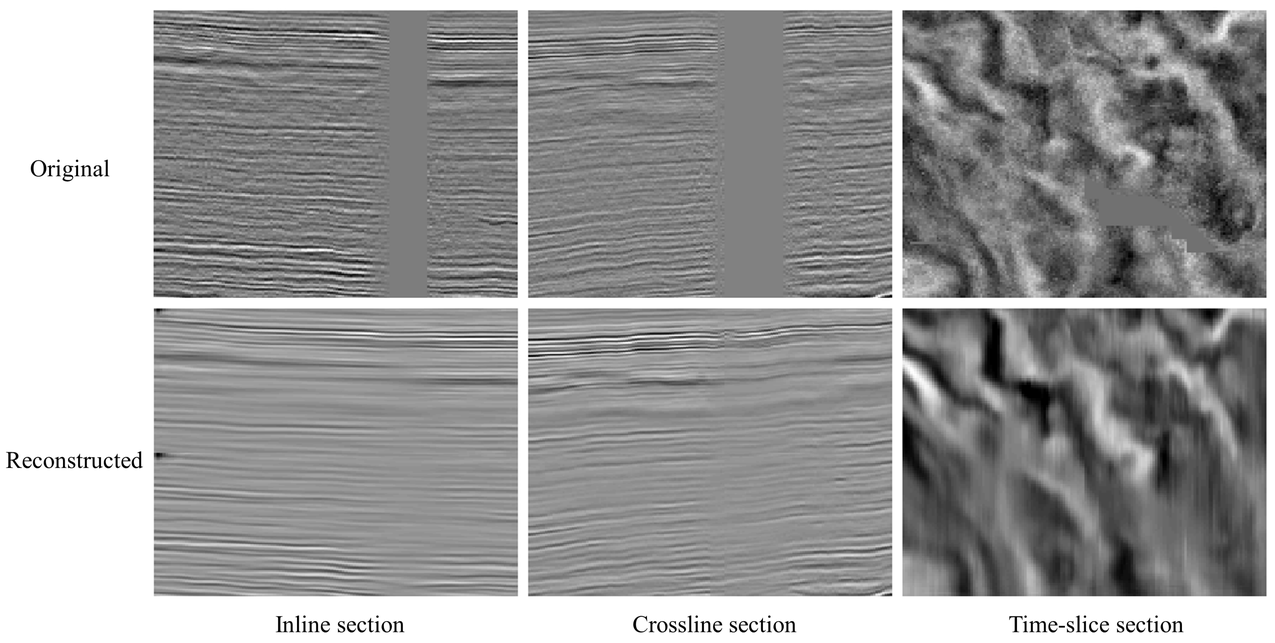

Figure 2. A reconstruction test on a field data by using our proposed noise-assisted network.

Conclusion

We present a new framework of convolutional neural network called noise-assisted network (noise-net) for seismic data reconstruction. The proposed method can attenuate the seismic noise and reconstruct the missing traces simultaneously. Our proposed method do not require the clean seismic data as the "label". Based on the statistical properties of white noise, we propose to use the additive white noise to simulate the feature of original white noise. We add a convolution layer with large kernel size into the proposed network that make noise-assisted network can interpolate the missing traces with large gaps. The field data example illustrate the effectiveness and robustness of noise-assisted network.