Implicit Neural Representations for Unsupervised Seismic Data Processing

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Abstract

The unique characteristic of Implicit Neural Representation (INR) can effectively mitigate coherent and incoherent noise in seismic data. Furthermore, the capacity to represent signals continuously facilitates the interpolation of seismic signals on irregular grids. Based on these, we proposed an unsupervised seismic processing method here.

Introduction

This paper proposes an exploration of the efficacy of INR, specifically leveraging Sinusoidal Representation Networks (SIREN), in addressing seismic data processing challenges. Our approach employs Implicit Neural Representations with Periodic Activation Functions and demonstrates its effectiveness in seismic noise denoising, encompassing both coherent and incoherent noise. Additionally, we apply the network for interpolating missing seismic data.

Methods

Similar to the Deep Image Prior, the INR approach also effectively suppresses noise during early training iterations and prioritizes the extraction of self-similar features. This unique characteristic allows INR to reconstruct coherent seismic data before addressing incoherent noise. For the denoising of incoherent noise, the loss function is defined simply as:

$$\min_{\theta} \|f_\theta(r) - x_0\|_2^2. \quad (1)$$

For interpolation, we can add a sampling operator S into the loss function:

$$\min_{\theta} \|Sf_\theta(c) - x_0\|_2^2. \quad (2)$$

The network also tends to extract horizontal events before the dip one, which can be used to remove the ground roll. We perform Normal Moveout (NMO) correction to flatten reflections. Then, applying the network yields immediate reconstruction of the flattened events within the initial few hundred epochs. After that, we apply inverse NMO to restore the original reflections.

Examples

Figure 1 shows the finite difference synthetic example with erratic noise.

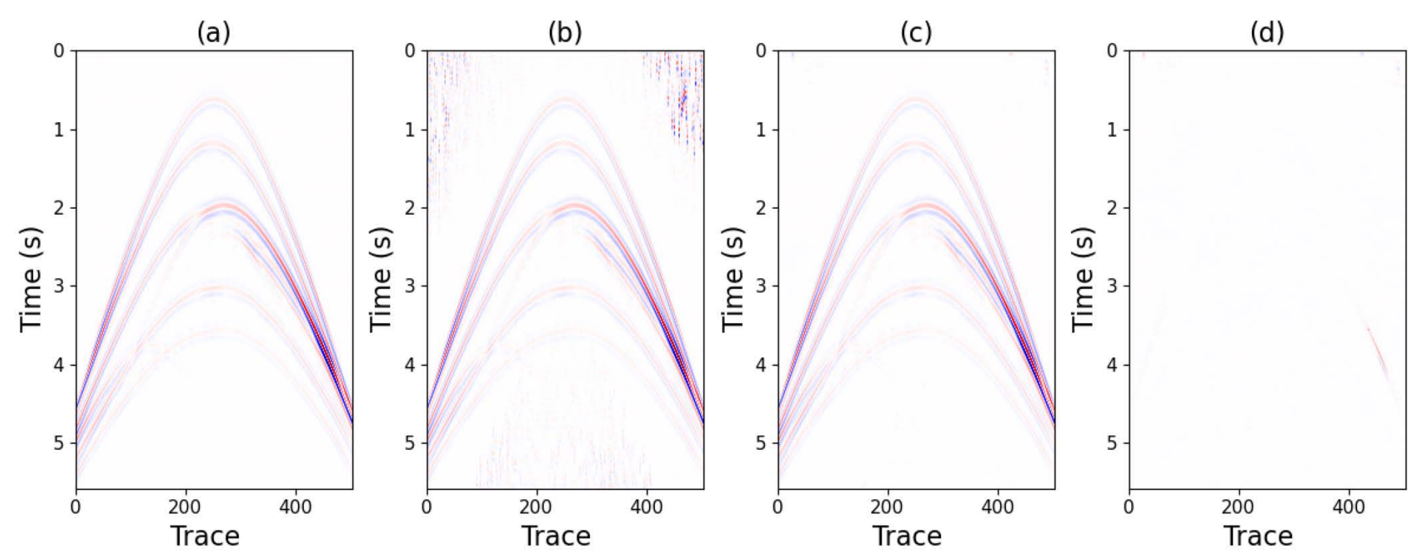

Figure 1: Erratic noise attenuation example.

Figure 2 shows the seismic data interpolation example.

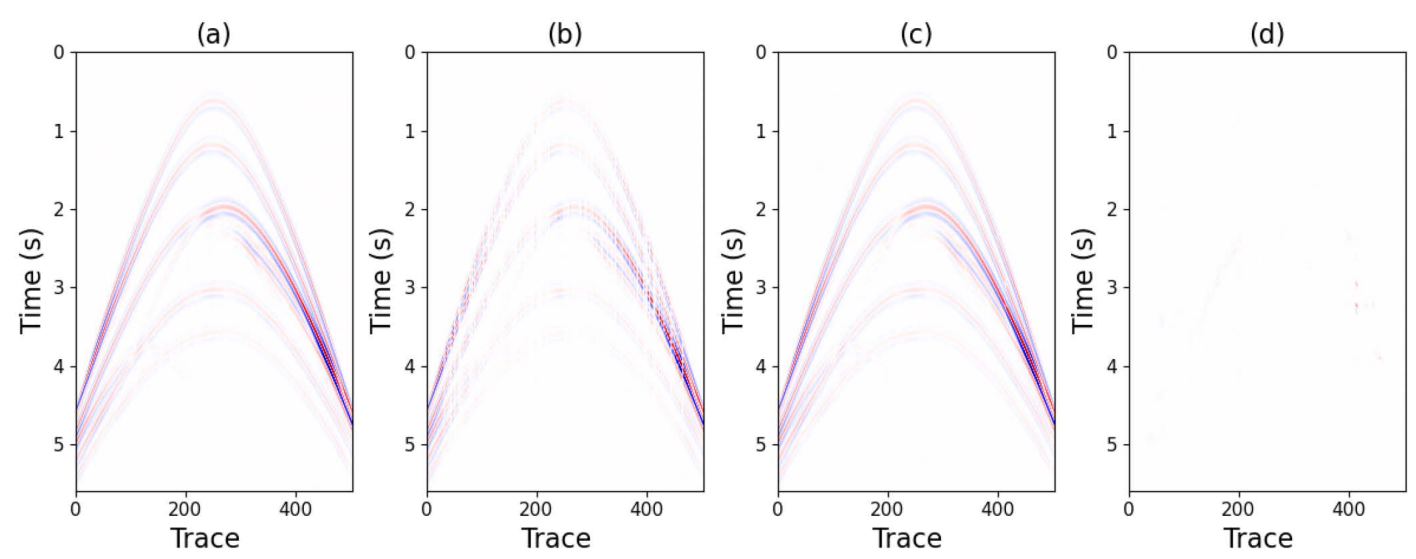

Figure 2: Seismic data interpolation.

Figure 3 shows real data example with ground roll.

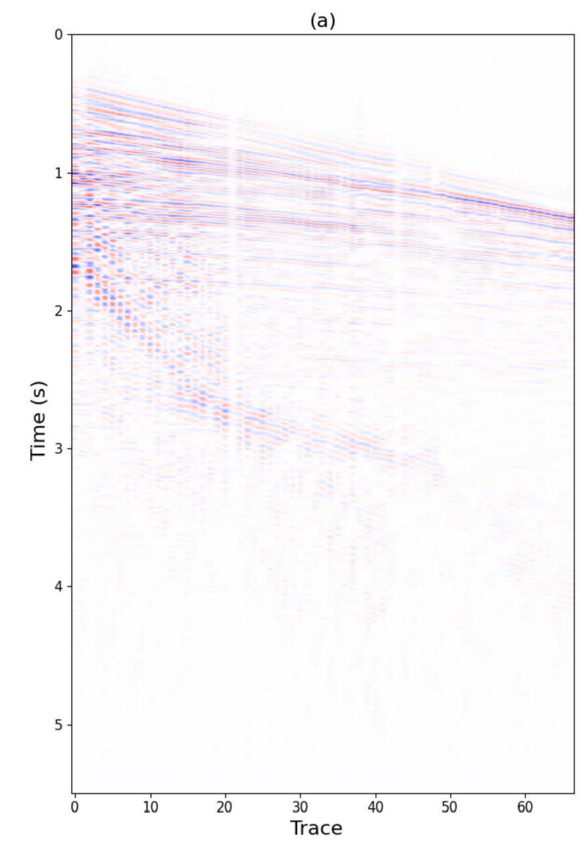

Figure 3: Real data example with ground roll.

Figure 4 shows the corresponding ground roll attenuation result.

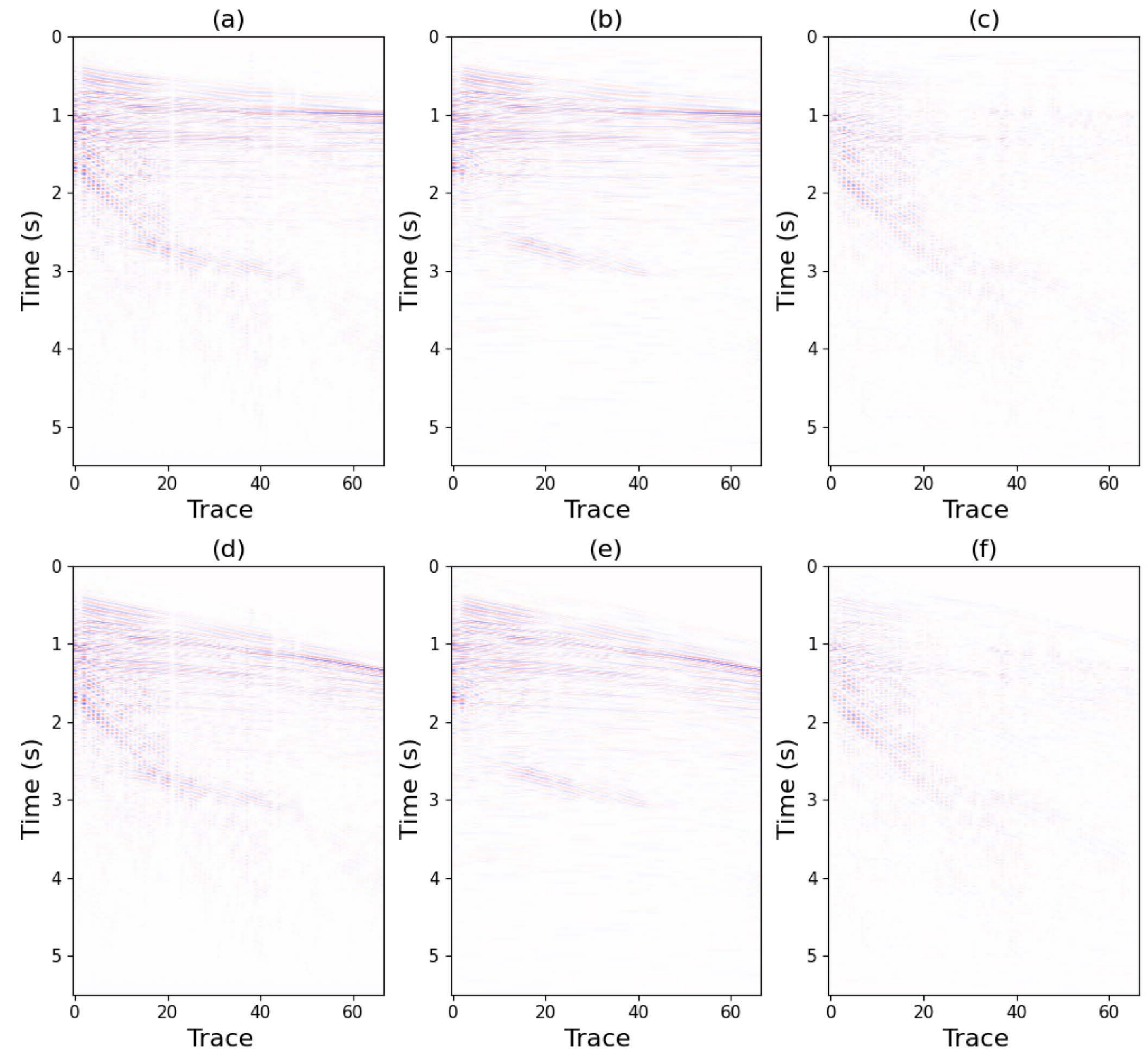

Figure 4: Ground roll attenuation result.

Conclusions

We applied the INR for seismic data processing like seismic data denoising, interpolation, and ground roll attenuation. Remarkably, the INR network exhibited the capacity to address various seismic data processing challenges without necessitating additional training data.

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