Toward Automating Seismic Trace Editing Using Deep Convolutional Neural Networks

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Summary

One of the key steps in seismic processing is trace editing. Traditional trace editing methods are time-consuming, and prone to human error. This study proposes an automated seismic trace editing method using a robust, accurate, and efficient Artificial Intelligence (AI) algorithm called Point Rendering (PointRend). Using PointRend, we improve the accuracy of this time-consuming and lower its computational cost. In addition to bad trace detection in shot records, our proposed method also estimates the uncertainty in the predicted mask. We provide examples that demonstrate the efficiency enhancement achieved by our method in automating the seismic trace editing process.

Theory and Method

A good pre-processing workflow is key to having reliable data for imaging and interpretation. A part of this pre-processing phase is trace editing, which is a time-consuming task. Also, current approaches require skilled human interaction which is costly, particularly for large 3D datasets. Especially for land datasets, trace editing can be more tedious because the data are often poorer quality. To address this issue there have been many attempts to automate trace editing. Chen et al., (1991) developed a tool based on energy attenuation and frequency component of seismic signals. Later, McCormack (1993) tried to use one of the very first tools in the Machine Learning (ML) subfield, called Backpropagation Neural Networks (BNN), to detect noisy and bad traces in raw field data. Huang and Hu (1994) proposed fuzzy function-link network, which is a higher-order network to designate bad traces. Several authors have attempted to employ DL for seismic trace editing in the last few years. Shen et al. (2018) used ML to automate the trace editing process by employing Convolutional Neural Networks (CNN) in a computer vision-based algorithm.

In this paper, we propose a fast and efficient workflow based on one of the powerful and recently developed Deep Learning (DL) algorithms called PointRend (Kirillov et al., 2020). Unlike the mentioned AI methods, PointRend works based on irregular grids. This gives PointRend the ability to capture high frequency information (fine details) of objects in input images. This stops PointRend from producing smooth and "blurry" masks for each detected object in images. Here we trained the network to get maximum accuracy in bad trace segmentation. Results demonstrate that the proposed algorithm is accurate and cost effective for automatic seismic noisy signal detection using deep CNNs.

Results and Observations

We use a total of 15 shot records (in the form of images). We use 12 shots for training and 3 for testing. We trained the PointRend module for 1500 epochs in almost 1 h using a RTX Quadro

4000 GPU. Note that we ensure that all types of noise we wish to remove are in the training dataset. Equation 1 shows the total loss function Φ in this study

$$\Phi = \Phi_{Class} + \Phi_{BBox-reg} + \Phi_{Mask-reg} \quad (1)$$

Where Φ_{Class} calculates the loss function for assigning a class (e.g., valuable and defective) to seismic traces, $\Phi_{BBox-reg}$ calculates the loss values for creating and locating the bounding box for each group of seismic signals in the same class, and $\Phi_{Mask-reg}$ calculates the loss between creating and locating the assigned mask (attribute) to each group of signal types (e.g., valuable and defective). Figure 1 shows the loss component curves of the training phase.

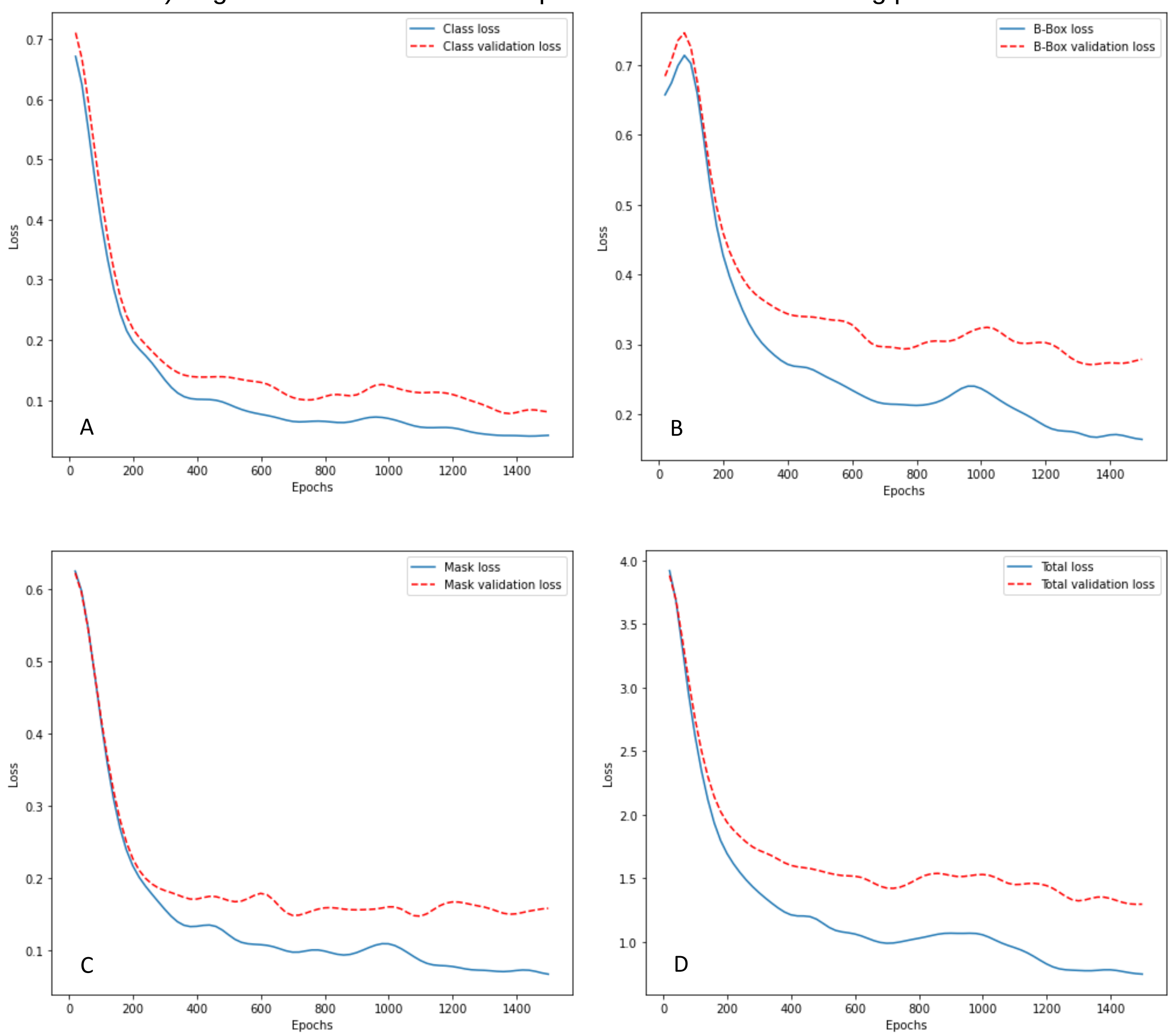

Figure 1: Loss and validation plots during the training phase of the PointRend module. (A) shows the classification loss curves, (B) shows the loss function values in creating and locating the bounding box, (C) shows the loss function values in creating and locating the mask, and (D) shows the total loss and validation function values during the training phase.

After the training phase, for testing the algorithm, we feed the unseen three shot records to the trained network for defective trace detection. A visual inspection of the results in Figure 2 shows that the algorithm is able to identify bad traces. In both shot records, all traces are identified and put into categories (e.g., valuable and defective traces). The red arrow in Figure 2 shows a defective trace in the shot record, which is detected very well by the algorithm. This illustrates the detection level of the algorithm and its accuracy. We used an Intel i7-11700 CPU for the testing phase with 32 GB memory. The algorithm detected defective signals in shot records in less than one second per image.

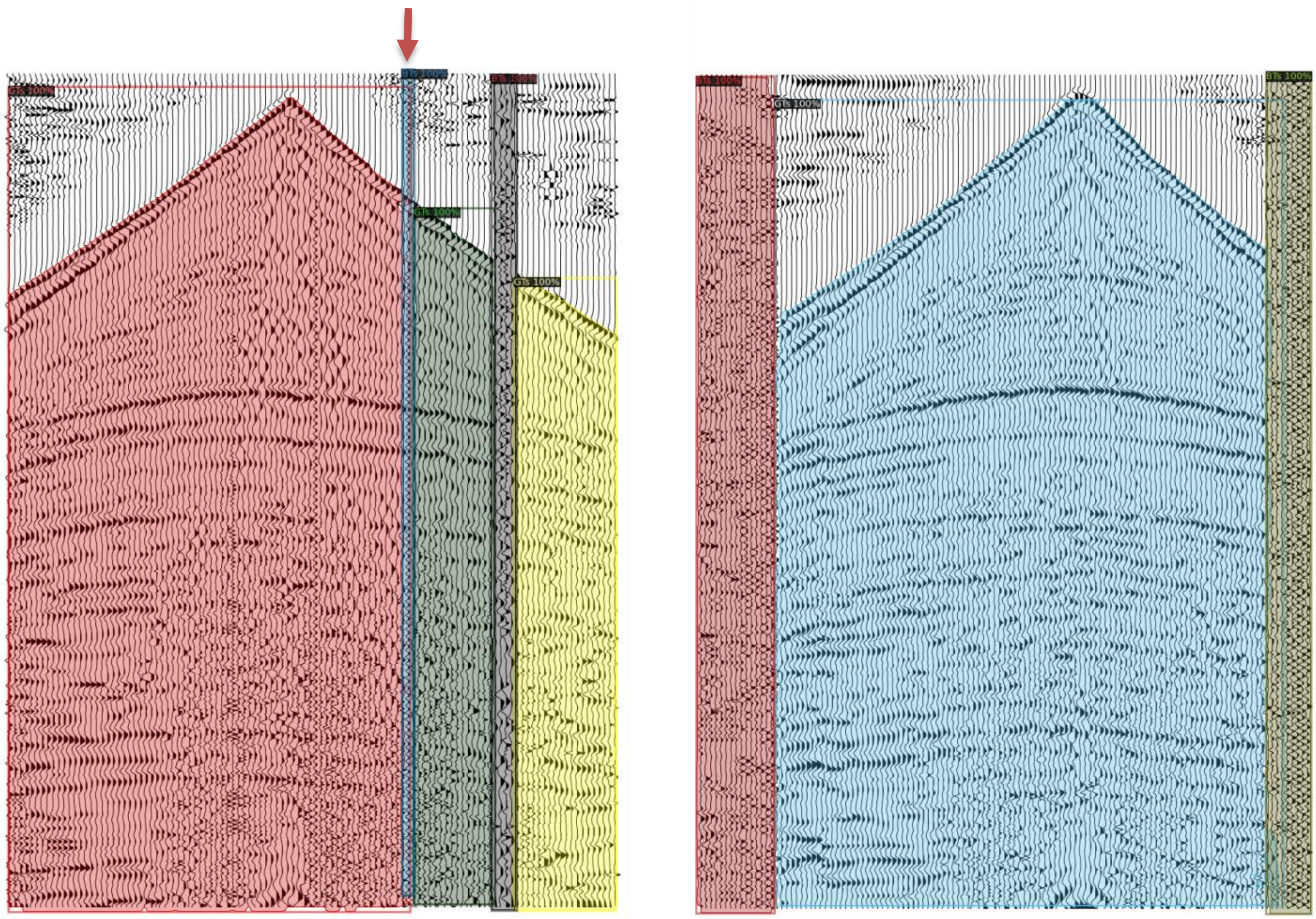

Figure 2: Valuable and defective traces detected using PointRend in two different shot records. Colors are randomly chosen for representing different types of signals (e.g., valuable and defective) in the images detected by the algorithm. An uncertainty in classification is given to each class. The red arrow shows a noisy signal successfully detected by the algorithm. The boxes with "GT" indicate useful traces and the boxes with "BT" indicate sections of the shot record made up defective traces.

Conclusion

We investigated a recently developed Neural Network (NN) module called PointRend to address seismic noisy signal detection. Our results show that the algorithm performed reasonably well in seismic noisy and defective signal detection and in addition it provides the classification certainty of each type of signal in shot records. Based on its performance, this method shows promise for automating the seismic trace editing task.

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