Semi-automatic first arrival picking of micro-seismic events by using pixel-wise convolutional image segmentation method

Hao Wu[1], Bo Zhang[1], Fangyu Li[2]

[1]Department of Geological Sciences, University of Alabama, Tuscaloosa, AL, United States

[2]University of Georgia, College of Engineering

Summary

Micro-seismic imaging plays an important role in hydraulic fracture detection and the first arrival picking of micro-seismic events is the bedrock in micro-seismic imaging. Manually picking is the most reliable but also the most time consuming method for the detection of the first arrival of micro-seismic gathers. Accurate and efficient first arrival picking in the real noisy environment is a challenge for most of the automatic first arrival picking methods. We propose a novel workflow to automatically pick the first arrival of micro-seismic by using a state-of-art pixel-wise convolutional image segmentation method. Both the synthetic and field data examples demonstrate that our proposed method successfully identify the first arrivals. The predicted first arrival result that obtained by using our proposed method is superior to the result that obtained by using the traditional method of short-term average and long-term average (STA/LTA).

Method

Picking the first arrival of micro-seismic events is detecting the onset time of micro-seismic arrivals in the refracted signals that from the wellbore. Figure 1 shows a typical micro-seismogram recorded by geophone and the first arrival is indicated by the red arrow.

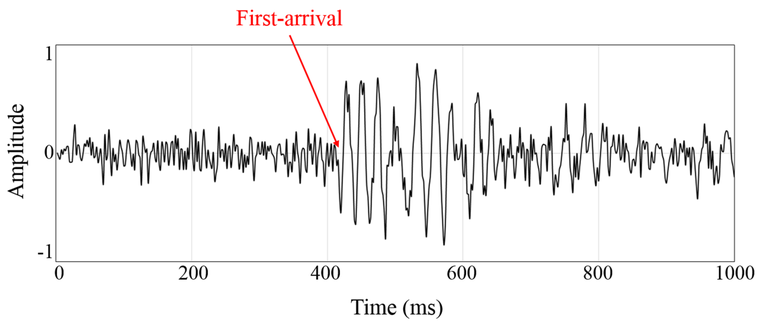

Figure 1. Micro-seismogram record. From this Micro-seismic trace, we can detect the first arrival that indicates by the red arrow.

We first convert the micro-seismic trace into 1D gray-scale image. We next segment the micro-seismic trace into two sequences according to the time index of manually picked first arrival. We then label the upper and lower sequences with 0 and 1, respectively.

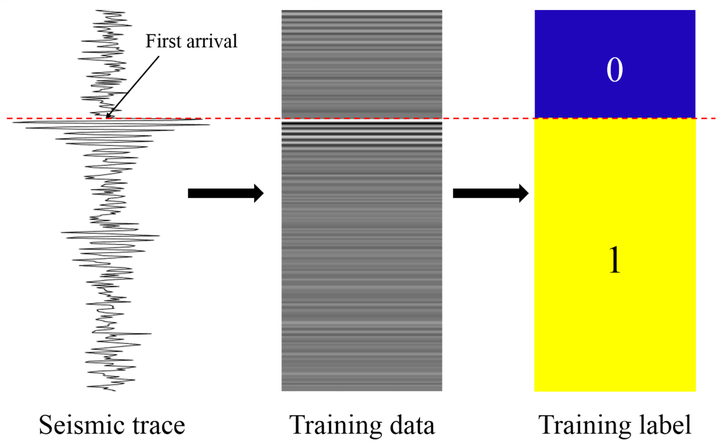

Figure 2. The basic workflow to build the train data and train label.

After preparing the input data, we need to build a deep convolutional encoder-decoder neural network. The architecture of deep convolutional neural network is a sequence of nonlinear processing layers (encoder and the corresponding decoder) and followed by a soft-max classification layer.

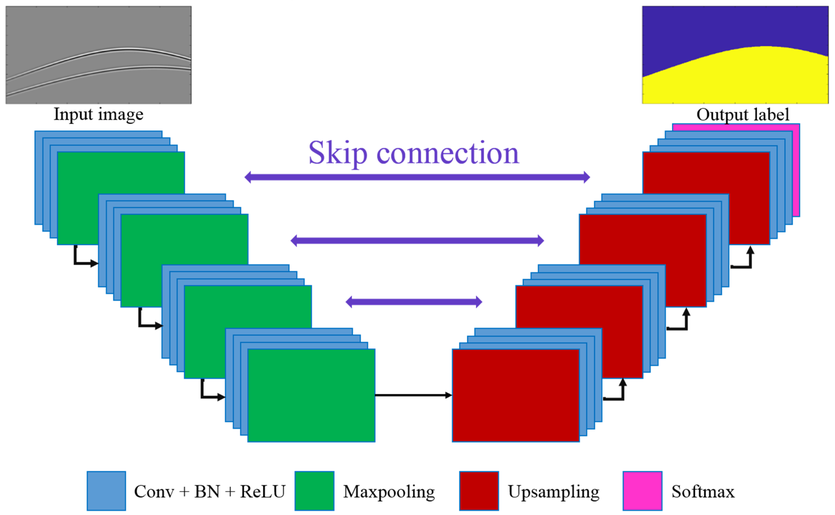

Figure 3. One representative architecture of deep convolutional neural network.

The training process will keep updating the parameters until the loss function or epoch time meet the user defined threshold. We finally apply the trained network on the rest of micro-seismic traces and extract the boundary as the predicted first arrival of micro-seismic events.

Application

We test on the synthetic model and field data examples and compare with the tradition method of STA/LTA.

There are 300 traces in our synthetic example and the time sampling interval is 1*ms*. The blue dots in Figure 4 are the manually picked first arrival of the micro-seismic gather and those manual interpretation function as the ground truth for validating our workflow. We randomly select 30 seismic traces (The seismic traces labelled by red color in Figure 4a) as the train data set. We next convert the selected micro-seismic traces into gray images and label the training traces (Figure 4b) according to the time index of manually picked first arrival.

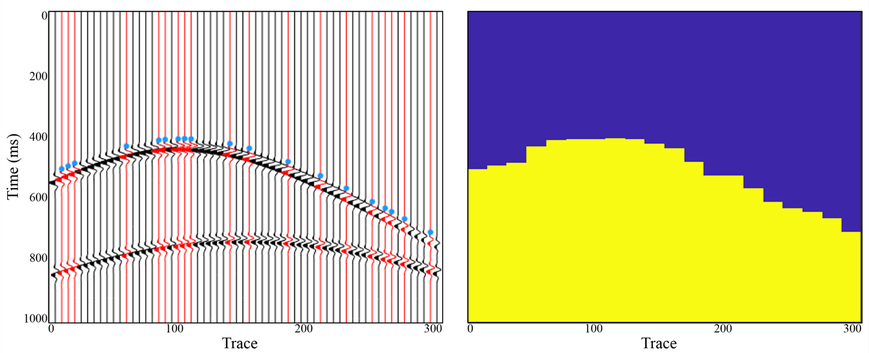

Figure 4. The input training data and the corresponding training label.

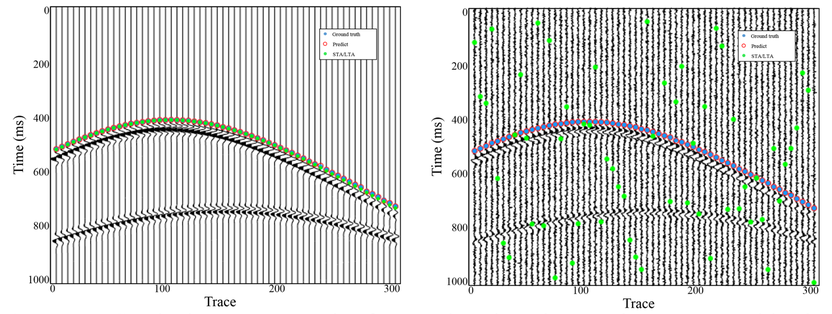

Figure 5. Synthetic test on noise-free and noisy data and compare with the conventional method of STA/LTA.

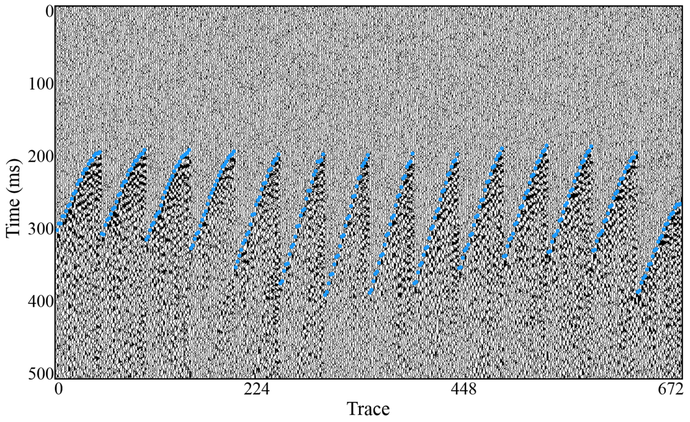

Figure 6. The field data example and the manually interpreted first arrivals (blue dots). We choose the first two gathers as our training data and rest as the test data.

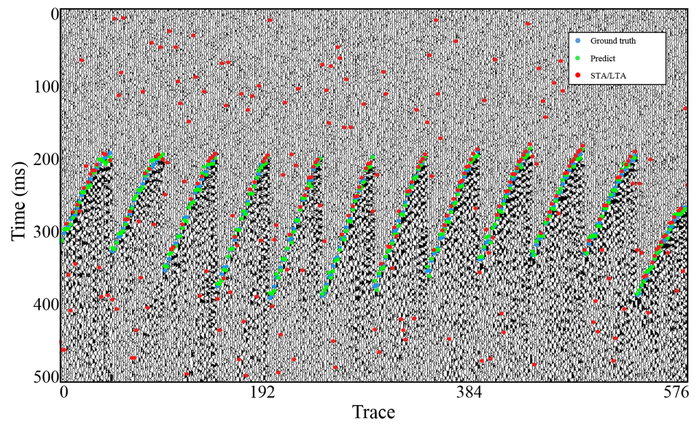

Figure 7. The results by using our proposed method (green dots) and STA/LTA (red dots) and the manually picked first arrival is indicated by blue dots.

Conclusion

We propose a novel micro-seismic first arrival picking method that is based on the pixel-wise convolutional image segmentation method. We modified the size of convolution kernel from constant to downward trend that obtained higher accuracy in the predicted result. Both synthetic and real data applications illustrate that our proposed method is superior to the traditional method of STA/LTA and can save huge labor work than manually interpretation.