2011 CSPG CSEG CWLS Convention

Automatic P-wave Arrival Time Picking Method for Seismic and Microseismic Data

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Summary

P-wave arrival time picking is very significant in the processing of seismic and microseismic data. The method presented here is based on the standard deviation in a moving time window that produces reasonably accurate results when tested on real microseismic dataset comprising of eight receivers with good and poor signal to noise ratio.

Introduction

P-wave arrival picking plays a significant role in the processing of exploration and earthquake seismological data. Microseismic methods have emerged as an important tool for hydraulic fracture monitoring (HFM) and other continuous monitoring applications at the mine or reservoir scale. The size of microseismic data is typically much greater than the other borehole recorded data (VSP and crosswell seismic). It is, therefore, more important to find an accurate time-picking method for efficient processing of microseismic data.

There are many automatic time picking methods available that are based on the correlation properties, on some statistical criteria or on artificial neural networks for both individual and group of traces. Several workers have utilized the standard deviation and variances for the automatic time picking. Gelchinsky and Shtivelman (1983) used the spatial correlation property of the signal to detect first arrivals. Boschetti et al (1996) and Jiao and Moon (2000) picked the arrival times using the fractal dimensions techniques. McCormack et al (1993) used the back projection neural network algorithm to detect the first arrivals. Chen et al (2005) presented a multi window algorithm for detecting first arrivals. The other techniques of short time average and long time average ratio (STA/LTA) and modified energy ratio are also well known (Wong et al, 2009; Munro, 2004 and Han et al, 2010). However, results of the picked arrival times using these methods vary in accuracy in datasets of different signal-to-noise ratio (SNR).

The technique presented here involves the computation of standard deviation of seismic trace in a moving window. This method appears to produce reasonable time picking results when tested on the datasets of different signal to noise ratio. It is understood that P-wave is not always the recorded fist arrival on the microseismic data. However, in this study, since only the vertical component of microseismic data is used, first arrival is assumed to be a P-wave.

Theory and/or Method

The concept of standard deviation in automatic first arrival picking is not new. The simple method used here is illustrated in Figure 1. It involves the computation of standard scores (z) of the microseismic trace (x) to convert it to a trace with mean value of zero and standard deviation of one. Standard deviation (δ) of z (containing N samples) is computed on a moving time window (w) using the following equation

$$\delta_j = \sqrt{\frac{1}{w}\sum_{i=j}^{w+j-1}(x_i - \mu)^2} \qquad \text{where } j = 1, 2, 3, 4, \ldots\ldots\ldots, N\text{-}w$$

First arrival times are then determined as the closest time to the maximum value of standard deviation in the minimum time direction where the standard deviation value equals Y times the mean value of z. The choice of Y value depends on the ratio of the maximum amplitude in the first few samples to the maximum amplitude of the microseismic trace.

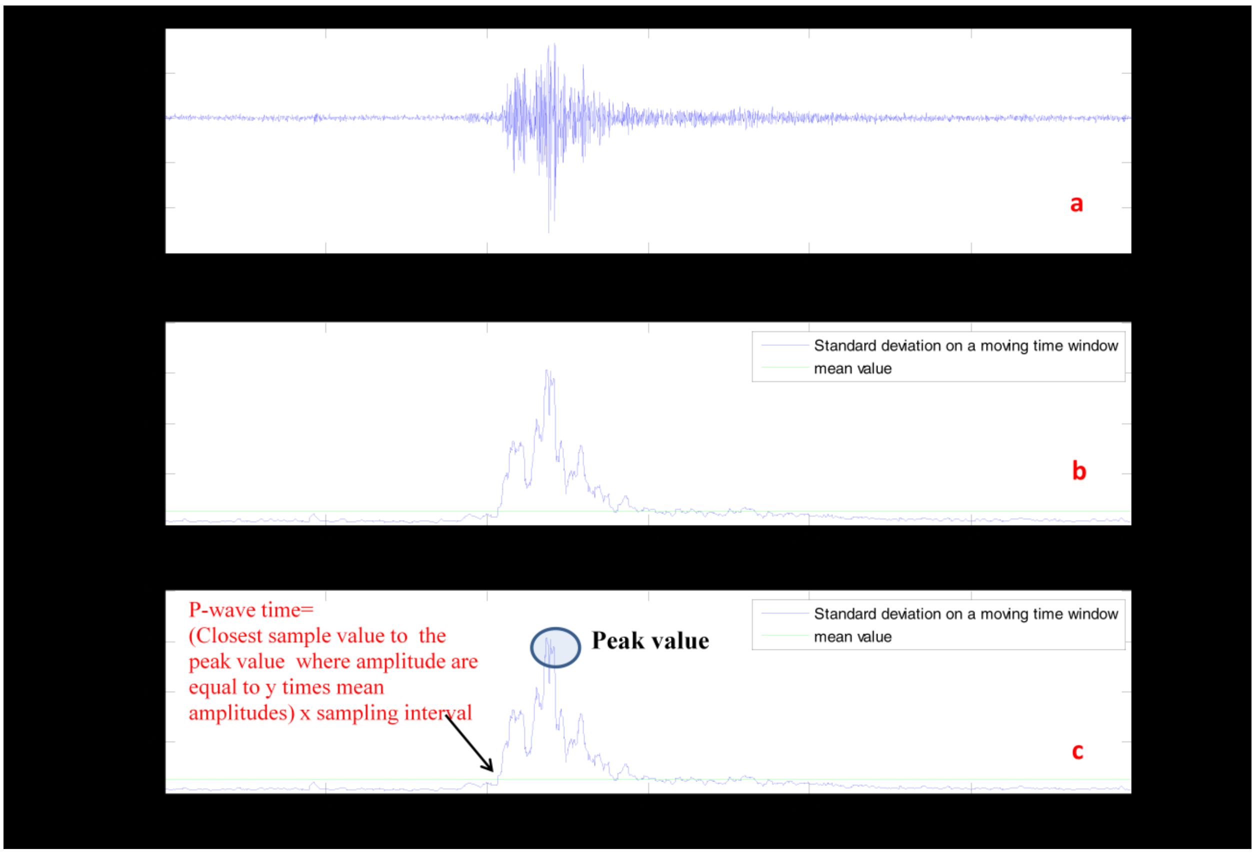

Figure 1: a) Input microseismic trace b) standard deviation on a moving time window of z c) P-wave arrival time estimation.

Examples

Figures 2 - 4 show the arrival time picked on microseismic traces with varying signal to noise ratio. Top window in the figures is the trace normalized microseismic traces with picked arrival times overlaid on them. The bottom window is the standard deviations of z computed in a time window. The quality of picked arrival times is reasonably good. In this method, the amount of noise present in the microseismic trace doesn't actually affect much the picked P-wave times. As long as the maximum amplitude of noise doesn't exceed the maximum amplitude of the signal, the arrival times are picked with reasonable accuracy even in the low signal to noise ratio microseismic events.

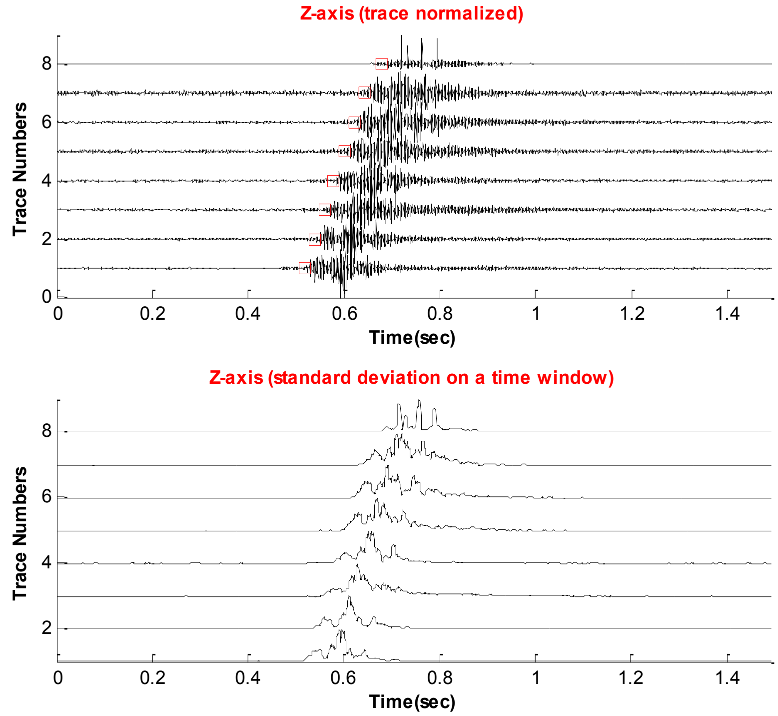

Figure 2: Microseismic traces with picked arrival times plotted as red squares. The bottom window represents the standard deviation of z in a moving window.

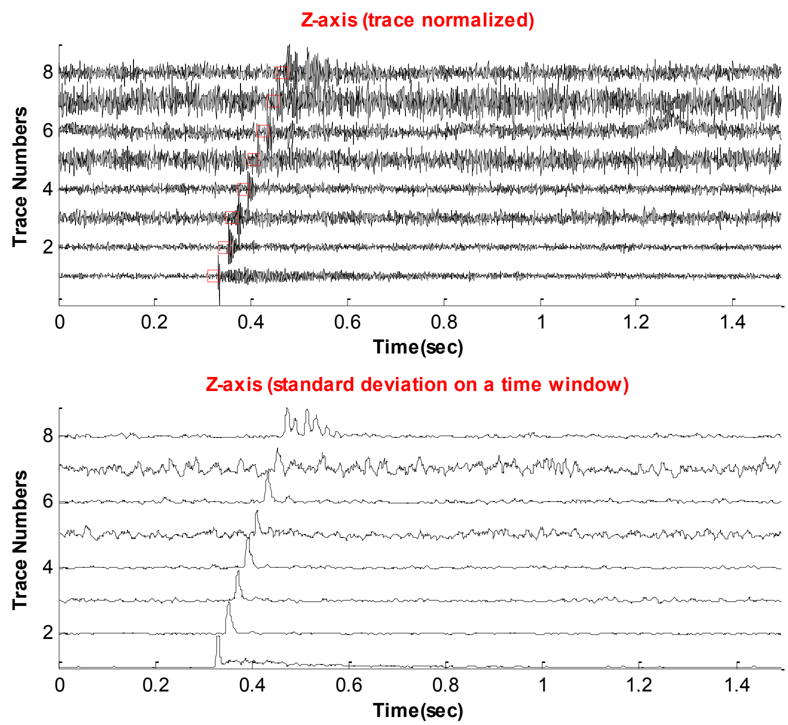

Figure 3: Microseismic traces with picked arrival times plotted as red squares. The bottom window represents the standard deviation of z in a moving window.

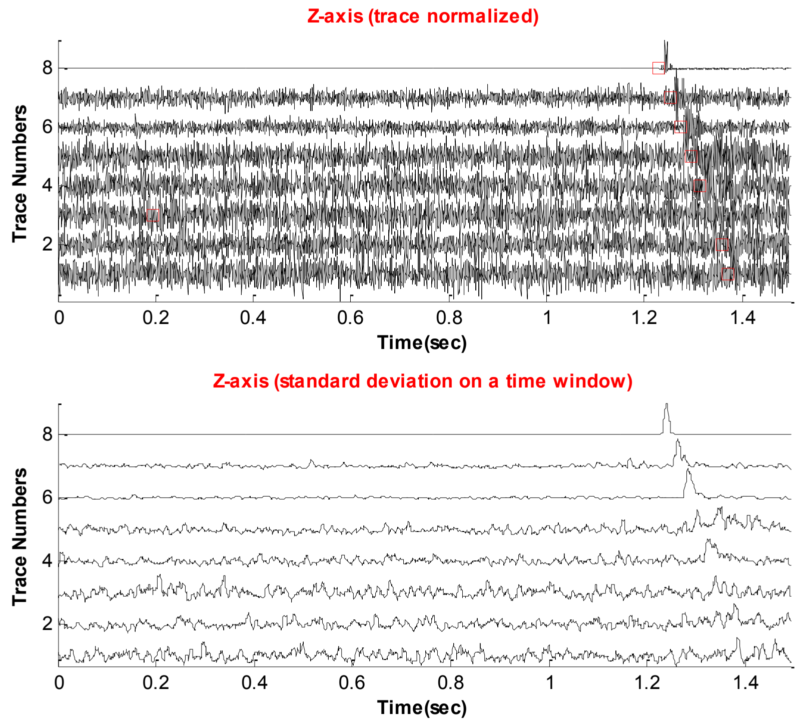

Figure 4: Microseismic traces with picked arrival times plotted as red squares. The bottom window represents the standard deviation of z in a moving window.

Conclusions

The method produces reliable first arrival time picking in microseismic data with high signal-to-noise ratio (SNR). The amount of noise in the microseismic data has relatively little effect on the accuracy of the picked P-wave arrival times. As long as the maximum amplitude of noise doesn't exceed the maximum amplitude of the signal, the P-wave arrival times are picked with reasonable accuracy even in the low SNR microseismic data. Since the other borehole seismic data (VSP) generally have higher signal to noise ratio than the microseismic data, this method can also be used to automatically pick the P-wave arrival time on VSP datasets.

Acknowledgements

Sponsors of the Microseismic Industry Consortium are sincerely thanked for their support of this initiative.

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