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Automatic Time-picking of Microseismic Data Combining STA/LTA and the Stationary Discrete Wavelet Transform

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Summary

A strategy for automatic time-picking using results from the stationary discrete wavelet transform (SDWT) as an input to the STA/LTA (short-term-average over long-term-average) filter is proposed. This strategy is compared against four other published methodologies using both synthetic and real data. The compared methodologies are the standard STA/LTA filter using energy as characteristic function (CF), STA/LTA filter using a CF that takes into account the derivative of the input trace, the modified energy ratio function, and the SDWT using the square of the first scale. The comparisons observed in this work suggest improved results when using methods based on the SDWT.

Introduction

Event location is an important step in the processing of microseismic data. For algorithms that determine location based on P- and S-wave arrival times, accurate time-picking becomes crucial. Different methodologies have been proposed to automate the time-picking process with the short-term-average over long-term average (STA/LTA) filter (Allen, 1978) being the most common. The STA/LTA filter acts over a characteristic function (CF), which is usually the energy of the seismic trace. Allen (1978) also uses a CF that takes into consideration the time derivative of the seismic trace, giving it a weight that depends on the signal-to-noise ratio (SNR). Another methodology for automatic time-picking is the modified energy ratio function (Wong et al., 2009). An important difference between the STA/LTA filter and the modified energy ratio function is that the former operates over windows that precede the sample of interest, while the latter combines windows that precede and follow the sample of interest. Hafez and Kohda (2009) present a completely different alternative that makes use of the stationary discrete wavelet transform (SDWT). In this method, the square of the first scale of the SDWT is used as an input to an automatic time picking algorithm. This strategy has proved to be helpful in identifying first arrivals in earthquake data. In this work, we combine the benefits of both the SDWT and the STA/LTA filter to propose a new automatic time-picking strategy. The newly described method is also compared against four other methods using synthetic and real data.

Theory and Method

Given a seismic trace **s** = [s_1, s_2, s_3, … s_n], the STA/LTA filter at the sample i is obtained through

$$\mathrm{STA}(i) = \frac{1}{\mathrm{ns}} \sum_{j=i-\mathrm{ns}}^{i} \mathrm{CF}_j, \qquad (1)$$

$$\mathrm{LTA}(i) = \frac{1}{\mathrm{nl}} \sum_{j=i-\mathrm{nl}}^{i} \mathrm{CF}_j, \qquad (2)$$

$$\mathrm{STA/LTA}(i)=\frac{\mathrm{STA}(i)}{\mathrm{LTA}(i)}, \qquad (3)$$

where ns and nl are the time windows in number of samples to compute the short-term-average and long-term-average, respectively. In the method proposed here, the CF selected after multiple tests is the square of the fourth scale of the SDWT of the seismic trace (see also Hafez and Kohda, 2009). The automatic time picker sets a time pick when the output of (3) is above a threshold value.

Examples

In the following figures the time picks are represented with bars whose color is the same as the trace with which the automatic time picker detected it. The methods used for comparison are: 1) STA/LTA using energy as CF (see e.g., Wong et al., 2009), 2) STA/LTA using energy and derivative of the input trace as CF (Allen, 1978), 3) the modified energy ratio function (Wong et al., 2009), 4) the pure SDWT (Hafez and Kohda, 2009) using the 4th scale and 5) the method combining SDWT and STA/LTA filtering.

Example 1. Synthetic data

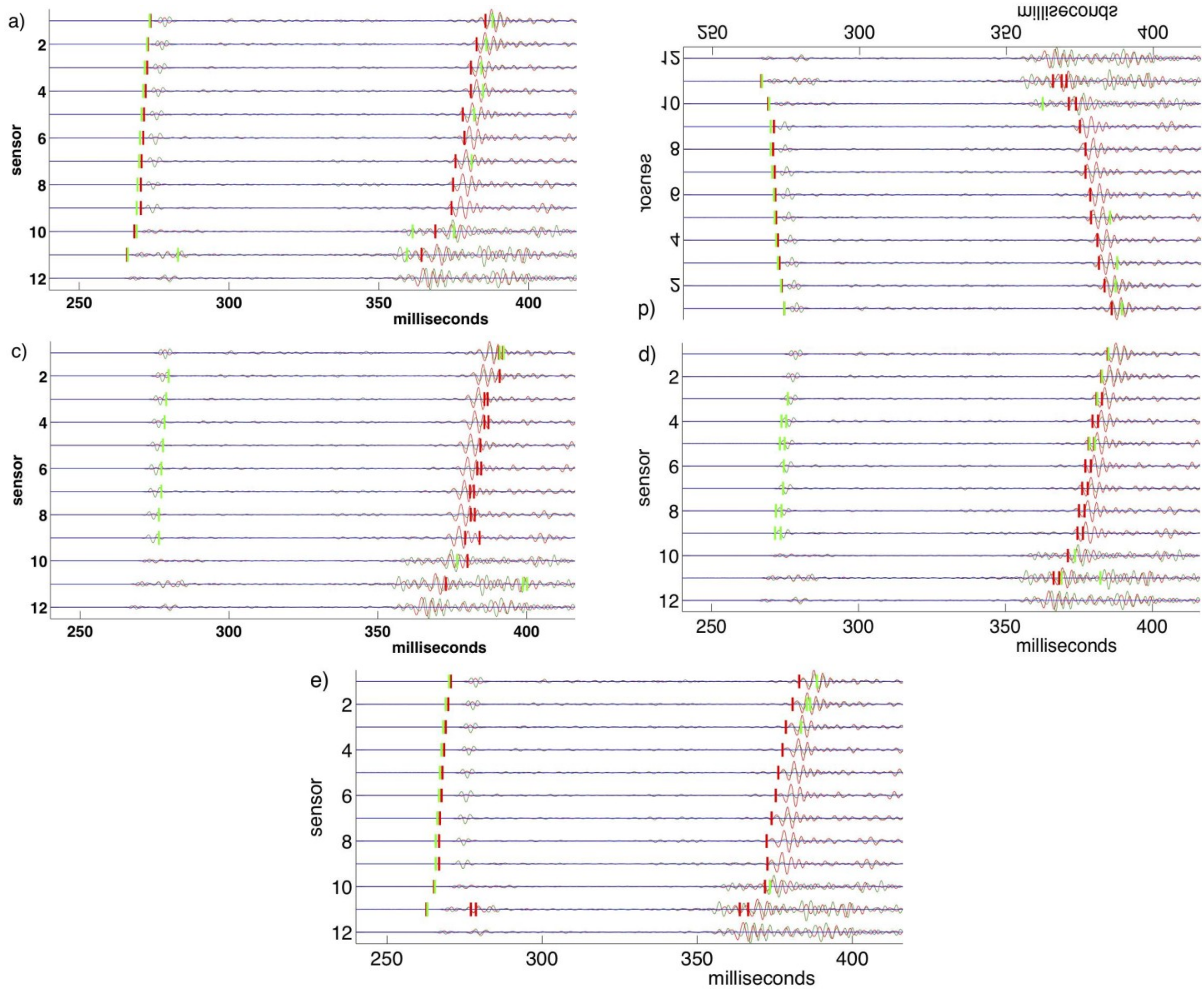

Figure 1: a) Method 1. b) Method 2. c) Method 3. d) Method 4. e) Method 5.

Example 2. Real data

Due to space constraints only 1 example with real data is presented here, however more data sets were investigated during this work.

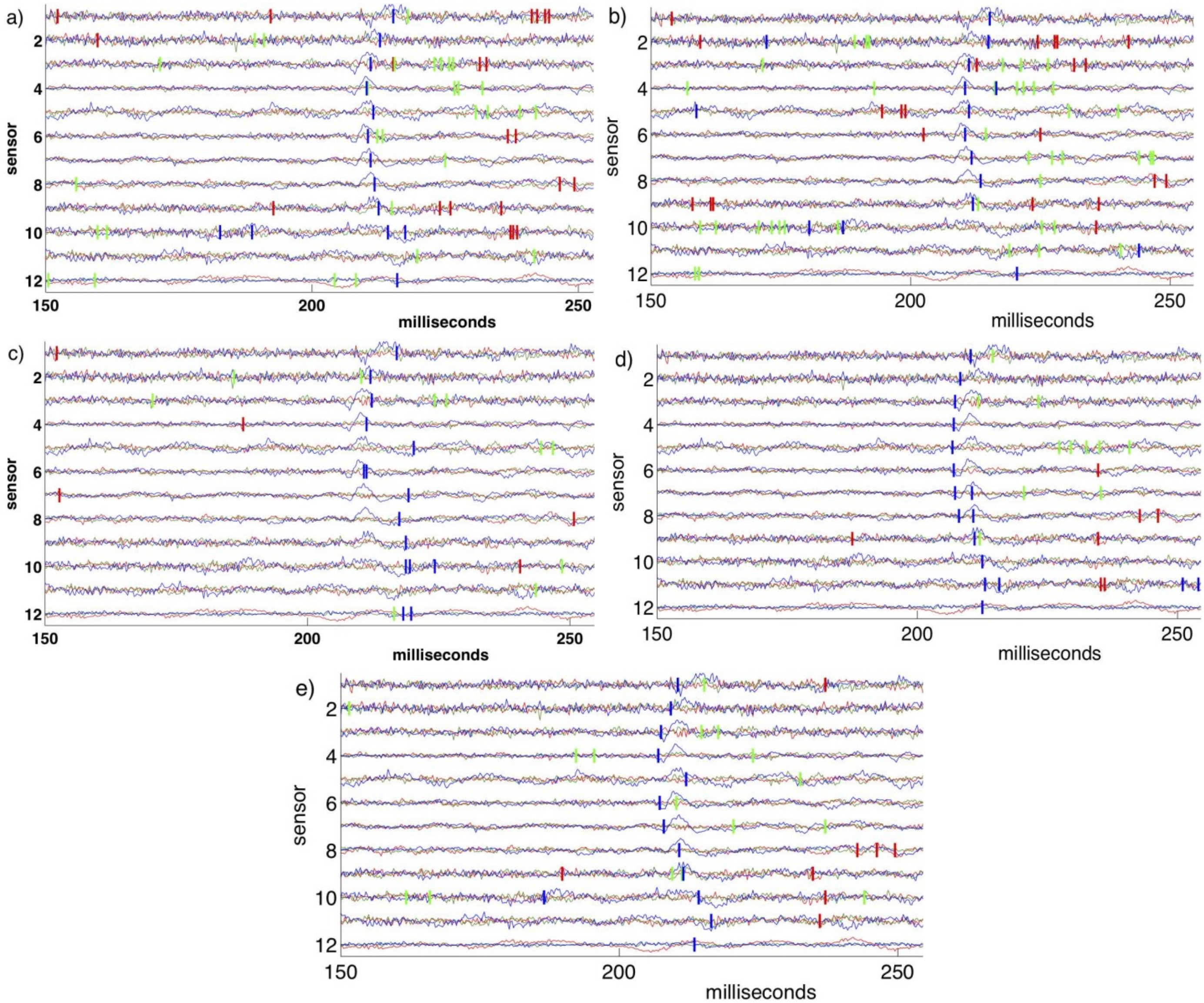

Figure 2: a) Method 1. b) Method 2. c) Method 3. d) Method 4. e) Method 5.

All methods perform well with synthetic data, although slightly better results can be observed with the pure STA/LTA filter (Figure 1-a and b). In this synthetic example, the modified energy ratio function located the time picks some time after the onset of the main arrivals (Figure 1-c). The pure SDWT performed almost as good as the STA/LTA methods except for a few missed arrivals (Figure 1-d). The same can be said of the combined SDWT – STA/LTA method, where the first arrival picks are located some time before the onset. With the real data set the best results are obtained with the methods that make use of the SDWT (Figure 2-d and e). In general, both the pure STA/LTA (Figure 2-a and b) and the SDWT based methods detect the arrivals located around 215ms, however, more time picks that can be considered "false alarms" are observed in the pure STA/LTA based methods. In addition, we notice that the time picks in the SDWT methods are closer to the onset. Similar results were observed when comparing the methods with other real data sets.

Conclusions

An alternative strategy for automatic time picking has been proposed. This strategy uses the square of the fourth scale of the SDWT as CF for a STA/LTA filter. The methodology proposed here shows better results in real data when compared with three other published methodologies not based upon the SDWT. When compared against another method based purely in the SDWT, the results from our strategy are similar or better in some cases. Two key advantages were observed with the SDWT-based methods. First, a smaller number of “false alarms” picks and, secondly, picks were located closer to the onset of the arrivals. Finally, it is important to stress that SDWT methods are particularly suitable to work in low signal-to-noise ratio environments.

Acknowledgements

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