New algorithm for automatic determination of first arrival times using stationary analysis from KM2O-Langevin equation

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algorithms using AR model are widely employed in automatic measurement methods of a first arrival phase in a seismic wave. In these methods, it is assumed that a seismic wave just after P-wave arrival satisfies local stationarity as well as before P-wave arrival. However, this assumption is not confirmed and we can not check stationarity of seismic waves using AR model. Therefore, we apply a stationary analysis method based on the theory of KM2O-Langevin equation to detect arrival phases in seismic waves, and propose a new algorithm for automatic measurement of first P-wave arrival time.

Let us consider a certain time series X(n). Then we could statisticaly check the local stationarity of X(n) by using the theory of KM2O-Langevin equation. We apply this method to a certain divided part of a seismogram with fixed length time window, and shifts the window along time. To do this, we can check how the stationarity of the time series change when the last one data of the part added. If the background noise are stational, we can anticipate that stationarity of the part will be broken when the part includes the first one data of the arrival of initial P-wave. This seems useful to detect the arrival of P-wave. Note that we can know whether the background noise is truly staional and whether the part will become truly nonstational by using the theory of KM2O-Langevin equation, instead of the theory of AR model. So we can confirm to the correctness of this anticipation.

By applying the stationary analysis to seismic records, we got the result that the stationarity is usually satisfied in the background noises. So, we can use the assumption discribed above to the method of automatic determination for P-wave arrival. Besides, if we take the part after the first arrival, the time series apparently become nonstational.

The application of this determination method to some seismic records made a good result. When the background noise is stational, we could detect the arrivals so clearly even if the amplitudes of background noises are large.

The automatic measurement of first arrival times presented here results that this method detects the arrival of P-wave almost equally as the AR-model method. The application for seismograms with large background noise shows that this method is superior to the method of AR-model. A future study will focus on the determination of S-wave. But as we see above, time series become nonstational after the arrival of P-wave and S-wave detection may execute on the nonstational state. Then, the detection needs more complicated idea besides the stationary analysis.