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Automatic picking based on an AR-AIC-costfunction appraoach applied on tele-, regional- and induced seismic datasets

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A quick picking procedure is an important tool to process large datasets in seismology. Identifying phases and determining the precise onset times at seismological stations is essential not just for localization procedures but also for seismic body-wave tomography. The automated picking procedure should be fast, robust, precise and consistent. In manual processing the speed and consistency are not guaranteed and therefore unreproducible errors may be introduced, especially for large amounts of data.

In this work an offline P- and S-phase picker based on an autoregressive-prediction approach is optimized and applied to different data sets. The onset time can be described as the sum of the event source time, the theoretic travel time according to a reference velocity model and a deviation from the theoretic travel time due to lateral heterogeneity or errors in the source location. With this approach the onset time at each station can be found around the theoretical travel time within a time window smaller than the maximum lateral heterogeneity. Around the theoretic travel time an autoregressive prediction error is calculated from one or several components as characteristic function of the waveform. The minimum of the Akaike-Information-Criteria of the characteristic function identifies the phase. As was shown by Küperkoch et al. (2012), the Akaike-Information-Criteria has the tendency to be too late. Therefore, an additional processing step for precise picking is needed. In the vicinity of the minimum of the Akaike-Information-Criteria a cost function is defined and used to find the optimal estimate of the arrival time. The cost function is composed of the CF and three side conditions. The idea behind the use of a cost function is to find the phase pick in the last minimum before the CF rises due to the phase onset. The final onset time is picked in the minimum of the cost function.

The automatic picking procedure is applied on datasets recorded at stations of the GRSN and GEOFON network in Germany from 1990 to 2014. To show the functionality of the algorithm, different event-station-distances are taken into account. For the picking of teleseismic P-, PP- and S-phases event source times and locations are taken from the EHB catalogue. For the regional distances, Pg-, Sg- and Pn-Phases are picked of events from the BGR-catalgoue.

In addition to the arrival times, a quality is estimated. Altogether three picks are determined. The most likely pick is the minimum of the previously explained cost function. The latest possible pick is the AIC minimum. The earliest possible pick is found as the minimum of a cost function of the CF without the water level and the time penalty. The earliest- and latest possible pick provide an asymmetric error estimation for the most likely pick. Furthermore a quality estimation based on three criteria is assessed. The criteria are the signal to noise ratio of the waveform, of the CF and the steepness of the CF after the picked onset time.

For low quality picks the variance of the residual times to manual picks is much larger than for high quality picks. This confirms the applicability of the proposed quality measures.

The picking algorithm works fast, precisely and consistently. Thus, it fulfills the major requirements for a picking procedure. The application to tele- and regional seismic event datasets delivers a high number of first- and later-arriving phase picks with high quality. The comparison with manual P-, Pg-, and S-pick catalogs shows that the residual times between manual picks and automatic picks have a standard deviation of 0.7 seconds around a mean value of 0.08 seconds for teleseismic P-phases, a standard deviation of 4.5 seconds around a mean value of -0.1 seconds for tele seismic S-phases and 0.17 seconds around a mean value of -0.01 seconds for regional Pg-phases. The mean values indicate that the picker has no significant offset to the manual picks, while the standard deviations are significantly smaller than the standard deviation of the residual between theoretic travel times and manual picks.