Methodology for the Automatic Estimation of Seismic Source Parameters and Updating Corrections for Path Effect

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The dense, local seismic network produces a large volume of seismic data, which has to be processed immediately to assess current rock mass conditions. Mining activity in the Witwatersrand region of South Africa has led to induced seismicity, with dozens of events per day with magnitudes ranging from 1 to 4.

Seismic source parameters are estimated in offline and near real time regimes. The offline approach has several well established methods for estimating spectral parameters of a large group of earthquakes. These methods of inversion usually handle different trade-offs between seismic source parameters and the medium well, such as trade-offs between the corner frequency, quality factor, Q(f), and near surface attenuation, kappa. The task is not easy. A simultaneous inversion for the source, path and kappa must attempt to avoid a bias in the source parameter calculations. However, in the near real time processing approach the inversion is performed for a single earthquake with a fixed path effect and near surface attenuation. There is no room for improvement of the trade-off between attenuation and corner frequency.

This work presents developments towards a reduction in the uncertainty of the seismic source estimation for near real time processing. Observed ground motion generated by induced earthquakes is affected by the seismic source, travel path, and local site conditions. Attenuation of the P- and S-waves is estimated using the coda normalization method. The method was chosen because the estimation of $Q(f) = Qo\ f^n$ is not effected by seismic source parameters or site effects. The coda normalization method was extended to include optimal parameters of geometrical spreading with piecewise segments. To be able to estimate spectral parameters automatically and in a robust way, the observed spectra, after correcting for the path and site effects, are processed using the Andrews integrals of each event spectrum. After recording a new seismic event, corrections for the path effect parameters are estimated using an interaction algorithm. The values of 'Qo' and 'n' are estimated using a linear regression method. Once new data are available, updating the regression model is made possible by adding a row to the matrix of observations. New regression coefficients are calculated without starting from the beginning through the use of QR-factorization. The QR-factorization was already done for the older data. The effect of the new observations is evaluated using Cook's distance.

The program calculates the following parameters of the seismic source: scalar seismic moment, M_w magnitude, radiated seismic energy, corner frequency, source radius, apparent stress and static stress drop. Results of routine processing indicate that a reliable estimation of the source parameters of various earthquakes can be achieved for seismic source-to-station distances of less than 80 km. A catalogue of almost 500 earthquakes induced by mining activity was created and spectral parameters of the events were estimated. Scalar seismic moment varied from 10^{10} to 10^{14} Nm. SV-wave energy ranges from 10^3 to 10^9 J. The static stress drops calculated from S-waves vary between 0.02 and 35 MPa. The relationships between stress drop and scalar seismic moment undoubtedly show that the stress drop increases with seismic moment. Nevertheless, the scattering of the static stress drop or apparent stress drop around a fixed seismic moment spans roughly 1.5-2.0 orders of magnitude.