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Abstract (800 English Words)

Reliable ground motions are needed in the near-field of large earthquakes for several important purposes including tsunami prediction, estimation of ground strain, design of lifelines, and design of structures and deep foundations. Recovering displacement and permanent rotation from acceleration records is interesting because of the large number of accelerometers deployed and the variety of places where they are installed. This is, however, a challenging task: displacement time histories can theoretically be obtained by double integration of accelerograms recorded by strong-motion seismometers, but they usually show drifts larger than expected for the true ground displacement.

The recent installation of high-quality strong-motion seismometers with low internal noise provides records with high signal-to-noise ratio, which offers the possibility for retrieving accurate information up to long periods. We performed a comprehensive study of a modern strong-motion accelerometer, and quantitatively evaluated the different sources of noise which collectively contribute to the noise in the digital acceleration data. Strong-motions recorded by the accelerometers' horizontal components contain records of the translational accelerations (what they are made for) together with the rotation/tilt of the instruments. During the recording process, both are modified by the response of the instrument, which is the sum of its theoretical response and 1/f electronic noise at low frequencies. Original in this work, the long-period content of acceleration records is investigated in the frequency domain instead of the time domain. This requires a detailed visualization of the records' low frequency content. To obtain it, long zero pads are added to the acceleration records. This forces the computer to calculate the records' Discrete Fourier Spectra at frequencies so close that the Discrete-Time Fourier Transform, best possible visual display of the records' Fourier transform, are obtained. Very detailed visualizations of the records' Fourier content, including at low frequencies, are at this point available for further analysis.

In the near-field of large earthquakes and after the main shaking, the permanent residual tilt of the instruments is recorded as a small constant acceleration but of long duration. The Fourier transform of that rectangular function is a cardinal sine (sinc) function. If the residual tilt is large enough, the sinc function dominates the record's low frequency content, and the amplitude and duration of the permanent rotation may therefore be estimated by the analysis of its specific shape. The comparison with external rotation measurements at Kasho dam, a well instrumented site during the 2000 Western Tottori earthquake (Japan), confirms that the method may provide accurate rotation angles.
Simultaneously, reliable translational accelerations may be obtained by subtracting the permanent rotations from the accelerations recorded by modern strong-motion seismometers. By double integration, reliable displacements, including permanent ones, are obtained. We analyze several earthquakes, including the 2004 and 2007 Niigata-ken Chuetsu earthquakes (Japan). The displacement obtained by double integration of reliable translational accelerations have good similitude to closely spaced 1-Hz GPS data, over duration of engineering interest, for both the oscillatory and permanent parts of the displacements.

Among the potential applications, we focused on civil engineering ones. The evaluation of near-field ground displacements and permanent rotations from strong-motion accelerograms may contribute to improve the design of large structures. Especially, they might be used as direct input for time-domain analysis or to derive reliable displacement response spectra up to very long periods.

Limitations of this original methodology are reached in several circumstances, especially in case of record within a single accelerogram, of motions from more than one event, or from late pulses. Such records cannot indeed at present be processed successfully, because they contain multiple baseline offsets that cannot be distinguished.

Another important limitation occurs when the permanent rotation angle is small and the low frequency content of the acceleration record is dominated by the 1/f semiconductor noise. This instrumental issue is currently being solved by the development and installation of strong-motion seismometers with always smaller 1/f noise, which shall greatly ease the recovery of displacement time-histories and permanent rotation, including of very small rotation angles, from strong-motion records.

This methodology will no doubt gain in efficiency with the continuous development of new strong-motion seismometers, which will enlarge the number of situations where it may be applied, and broaden its range of applications.