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QuakeUp: An advanced tool for a network-based Earthquake Early Warning system

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The currently developed and operational Earthquake Early warning, regional systems ground on the assumption of a point-like earthquake source model and 1-D ground motion prediction equations to estimate the earthquake impact. Here we propose a new network-based method which allows for issuing an alert based upon the real-time mapping of the Potential Damage Zone (PDZ), e.g. the epicentral area where the peak ground velocity is expected to exceed the damaging or strong shaking levels with no assumption about the earthquake rupture extent and spatial variability of ground motion.

The platform includes the most advanced techniques for a refined estimation of the main source parameters (earthquake location and magnitude) and for an accurate prediction of the expected ground shaking level. The new software platform (QuakeUp) is under development at the Seismological Laboratory (RISSC-Lab) of the Department of Physics at the University of Naples Federico II, in collaboration with the academic spin-off company RISS s.r.l., recently gemmated by the research group.

The system processes the 3-component, real-time ground acceleration and velocity data streams at each station. The signal quality is preliminary assessed by checking the signal-to-noise ratio both in acceleration, velocity and displacement and through dedicated filtering algorithms. For stations providing high quality data, the characteristic P-wave period (τ_c) and the P-wave displacement, velocity and acceleration amplitudes (P_d, P_v and P_a) are jointly measured on a progressively expanded P-wave time window.

The evolutionary measurements of the early P-wave amplitude and characteristic period at stations around the source allow to predict the geometry and extent of PDZ, but also of the lower shaking intensity regions at larger epicentral distances. This is done by correlating the measured P-wave amplitude with the Peak Ground Velocity (PGV) and Instrumental Intensity (I_MM) and by mapping the measured and predicted P-wave amplitude at a dense spatial grid, including the nodes of the accelerometer/velocimeter array deployed in the earthquake source area. Within times of the order of ten seconds from the earthquake origin, the information about the area where moderate to strong ground shaking is expected to occur, can be sent to inner and outer sites, allowing the activation of emergency measurements to protect people , secure industrial facilities and optimize the site resilience after the disaster.

Depending of the network density and spatial source coverage, this method naturally accounts for effects related to the earthquake rupture extent (e.g. source directivity) and spatial variability of strong ground motion related to crustal wave propagation and site amplification. In QuakeUp, the P-wave parameters are continuously measured, using progressively expanded P-wave time windows, and providing evolutionary and reliable estimates of the ground shaking distribution, especially in the case of very large events. Furthermore, to minimize the S-wave contamination on the P-wave signal portion, an efficient algorithm, based on the real-time polarization analysis of the three-component seismogram, for the automatic detection of the S-wave arrival time has been included. The final output of QuakeUp will be an automatic alert message that is transmitted to sites to be secured during the earthquake emergency. The message contains all relevant information about the expected potential damage at the site and the time available for security actions (lead-time) after the warning. A global view of the system performance during and after the event (in play-back mode) is obtained through an end-user visual display, where the most relevant pieces of information will be displayed and updated as soon as new data are available.

The software platform Quake-Up is essentially aimed at improving the reliability and the accuracy in terms of parameter estimation, minimizing the uncertainties in the real-time estimations without losing the essential requirements of speediness and robustness, which are needed to activate rapid emergency actions.