New directions in real-time earthquake characterization, loss and structural damage assessment

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Rapid urbanisation, the interconnection of economies and growing dependence on technology make modern society increasingly vulnerable to natural disasters.
In case of earthquakes, the mitigation of seismic risk in urban and industrial area can be effectively accomplished by Earthquake Early Warning systems (EEWS), which performs real-time event detection and characterization, issues rapid alerts, and thus, allow both to protect the population and reduce the vulnerability of civil and industrial structures, as well as industrial machineries, by starting automatic security procedures.
This work provides an overview of some significant advancement achieved during the last years in the research field of EEWS. In particular, we cover an ideal path from large scale seismological towards site-specific structural-engineering EEWS applications.

The first part is dedicated to PRESTo (PRobabilistic and Evolutionary early warning SysTem), a highly configurable and easily portable platform for Earthquake Early Warning developed by the RISSC-Lab of the Department of Physics at the University of Naples 'Federico II'. The system processes the real-time accelerometric data streams from the stations of a seismic network to promptly provide the probabilistic and evolutionary estimates of location and magnitude of detected earthquakes while they are occurring, as well as shaking and intensity prediction at the regional scale. Alarm messages can thus reach target sites before the destructive S- and surface waves, enabling automatic safety procedures.

The system consists of a regional and an on-site component. The regional approach exploits an evolutionary, probabilistic approach for the earthquake location, and a Bayesian approach on peak displacement (Pd) measured on short 2-4 second windows of P- and S-waves signal for magnitude estimation. Finally, by means of GMPEs, an estimation of the Potential Damaged Zone (PDZ), where the highest intensity levels are expected is provided. The on-site component of PRESTO uses both the characteristic P-waves period (τ_c) and the peak displacement (Pd) measured on the initial P-wave signal at each station. These parameters are then compared with threshold values previously established through an empirical regression analysis, and an alert level at each station correlated with the expected local damage. Integrating the measured on-site parameters at stations (Pd, τ_c) and the estimated regional parameters (hypocenter), PRESTo can identify the damage area in a few seconds after the event origin with a good matching with the instrumental intensity maps produced much later. PRESTO is currently under evaluation at the ISNET network (Italy), as well as other international site (e.g. South Korea, Spain, Romania).

The second part of the work aims at presenting a first attempt to design an early warning and rapid response procedure for real-time risk assessment. In particular, the procedure uses the typical real-time information (i.e. P-wave time arrivals and early waveforms) coming from a regional seismic network for locating and evaluating the size of an occurring seismic event, information which in turn is exploited for extracting a map of losses from a datasets of predicted scenario compiled for the target city. A feasibility study of the procedure for the city of Bishkek, capital of the Kyrgyz Republic, that is surrounded by the Kyrgyz seismic network (KNET, Vernon 1992, 1994) is provided.

Finally, moving in the direction of EEWS for specific structures, we present an innovative on-site earthquake early warning procedure for buildings, which is based on the use of early P-waves recordings collected by an accelerometer at the base level and one at the top level of a structure. In particular, the early earthquake signals are exploited to obtain a first estimation of both the incoming event size, as well as of the structure impulse response function. Then, these latter pieces of information are in turn convolved to obtain a real-time estimation of the acceleration and response spectra at the top level of the structure, which could be profitably used to provide early warning alarms, or for example, to modify the characteristics of semi-active seismic security devices before the larger shaking of the incoming event hits the structure. Hence, an application of the procedure using the recordings of three aftershocks of the L'Aquila sequence 2009 that have been collected at the Navelli's city hall is shown.