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Opinion

Combining Structural Health Monitoring and Earthquake Early Warning Techniques for an Enhanced Monitoring System

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Opinion

Earthquakes, as one of the most catastrophic natural disasters worldwide, often caused destructive damages including large-scale loss of human lives, public/private properties, and so on. To mitigate such damages, structural health monitoring (SHM) techniques are expected to be continuous and autonomous during seismic events so that the SHM systems can provide timely warnings. In this regard, real-time or online structural analysis can be used to identify the state of the structure, track the modal parameters, provide warning messages about damage, and help post-earthquake reconnaissance and rehabilitation [1,2].

The SHM systems of engineering structures, such as bridges and buildings, observe any changes to the material and geometric properties [3-6]. Most of those systems in the world provide real-time warnings simply by setting warning and action levels to some specific measurement. The values of these levels as well as the channels of the measurement can be pre-assigned through a lot of sophisticated analysis based on tons of assumptions to cover the uncertainties. These limitations are the main reason for false alarms which are unacceptable for most managers. On the other hand, real-time or online structural analysis, for example, system identification (SI), damage detection, system evaluation techniques, and so on, can release real-time warning messages once the SHM systems have embedded the corresponding algorithms under the earthquakes [7-9]. It's quite challenging because the engineering structures are undergoing a non-stationary excitation under seismic events, compared to the ambient condition. The difficulties of offering real-time information are located in the processing framework, the computation effort, and, most importantly, the starting point of the non-stationary process (earthquakes) took place. Fortunately, considering that earthquake early warning (EEW) techniques flourishes in the past decades [10-13], a continuous and autonomous SHM technique can be preliminarily achieved by fusing the information provided by the EEW systems.

The concept of EEW was first proposed by J.D. Cooper in 1868 and gained intensive attention since the 1990s. Several systems have real-time sent alerts to the public, as shown in Figure 1. Plenty of algorithms have been developed and applied; however, the most popular algorithm for triggering, called phase picker, is the short-time average over long-time average (STA/LTA) proposed by R Allen [14,15]. The advantage of STA/LTA approach is easy and effective so most EEW systems worldwide are based on it, including the Earthworm used by the United States Geological Survey (USGS), the SAC2000 used by the Incorporated Research Institutions for Seismology (IRIS), and the Taiwan Rapid Earthquake Information Release System (TREIRS) used by the Central Weather Bureau (CWB). Hence, in order to provide timely warnings during seismic events, the SHM systems can incorporate with the EEW systems and the structural analysis can be immediately performed.

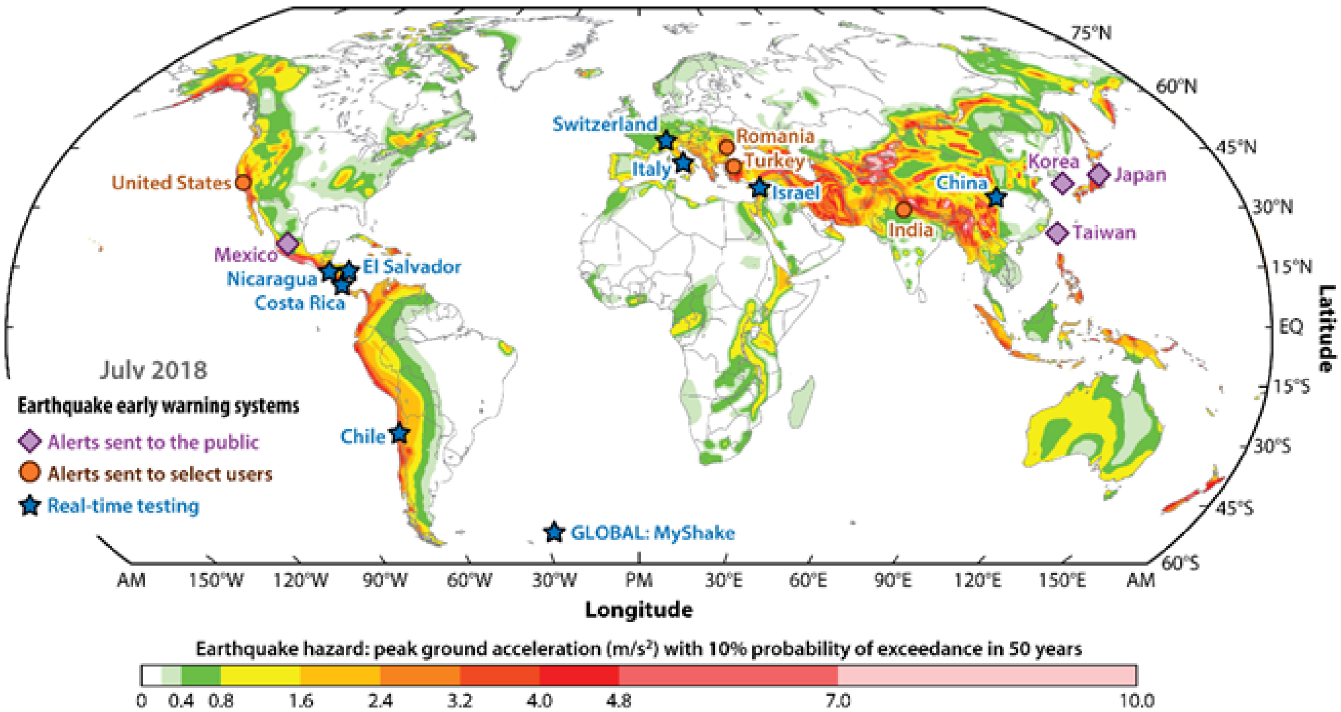

Figure 1: Status of earthquake early warning systems in different regions of the globe [12].

Generally, the warning messages generated by the EEW systems include two parts: the detection of seismic events and the prediction of earthquake parameters. The detection automatizes SHM systems and, the prediction, i.e., seismic intensity, earthquake magnitude, dominant period, and so on, is also useful for the SHM techniques. It can provide prior knowledge regarding seismic events, reduce the uncertainties of structural behavior, and improve the performance of the algorithms. Furthermore, real-time or online structural analysis can generate more accurate results about the state of the structure and give more comprehensive information about the seismically-excited structures and enhance the quality of the post-earthquake reconnaissance and rehabilitation.

In conclusion, the combination of the SHM and EEW systems can be effective and efficient to monitor defects in the material and geometric properties of engineering structures under earthquakes. Researchers have tried to investigate the possibility of fusing the information from SHM and EEW techniques. For example, relative conference papers have been presented in the 16th World Conference on Earthquake Engineering (WCEE) in 2017, a corresponding parallel session has been held in the 8th Asia Conference on Earthquake Engineering in 2022, and a special issue on EEW and SHM has even been pressed by Journal of the Chinese Institute of Civil and Hydraulic Engineering in 2022. The usage of the SHM systems can be broadened and improved by joining with EEW systems and development can be expected in the near future.

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