Improvement of Earthquake Early Warning via Machine Learning applied to physics-based numerical simulations

Filippo Gatti, Fernando Lopez-Caballero, Cécile Gracianne, Nicolas Taillefer

MSSMat UMR CNRS 8579, CentraleSupélec - BRGM

Abstract

Early warning and seismic risk mitigation in Europe must face varied tectonic contexts with limited amount of records of major events (unlikely California or Japan). Hence machine-learning approaches must be conditioned by prior knowledge provided by now-available ab-initio numerical simulations reproducing the main physical phenomena at stake during an earthquake. Provided with physics-based pre- conditioning (accounting for local source-path-site features), learning processes extend to huge amounts of worldwide seismic data. The goal of the proposal is to craft a surrogate model for fast-computing realistic earthquake scenarios at regional scale, to integrate/improve current early warning procedures [1]. The methodology consists in: (1) constructing/calibrating a high-fidelity numerical model of the region of interest, including active faults, geological features, hot-spot areas/structures, based on geographic/geological information systems, seismic databases, site-specific characterizations; (2) training a surrogate model on real or virtual realistic scenarios, using fore-, main-, aftershock sequences and teaching the model to infer the conditional probability of an event to occur, synthesizing the information on the P-wave first arrivals [2] (e.g. estimation of hypocenter and magnitude) and other earthquake footprints extracted from seismic signals; (3) surrogate estimation of the ground shaking scenario, feeding the meta-model with seismic records in continuous real time acquisition, to provide warning before the S- wave arrival (i.e. the strong shaking causing most of the damage) and predicting seismic wave-field in mainly affected areas. The proposed machine-learning approach improves operational earthquake forecast, supported by numerical modeling, providing fast estimation of seismic response in densely populated areas and at critical structures. As side product, different scenarios are virtually explored improving risk mitigation measures in earthquake-prone areas.

Keywords: Earthquake Early Warning, Artificial Intelligence