THE ENGINEERING STRONG MOTION DATABASE: WEB PORTAL AND WEBSERVICES FOR ENGINEERING SEISMOLOGISTS

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ABSTRACT

The Engineering Strong Motion database (ESM) is one of the infrastructures of the EU project EPOS, for the distribution of accelerometric waveforms. It combines the expertise and datasets acquired within several European projects (FP4 to FP7), the European Integrated Data Archive and national databases. ESM is centralized and distributes strong-motion recordings available from about 50 European networks, operating since 1969 in and outside Europe. It takes advantage of modern seismological services that provide rapid access to strong motion data and allow to populate the database automatically. Nevertheless, a manual interaction is still required as the waveforms are manually processed and quality checked before being distributed. Unprocessed and processed acceleration time histories are distributed together with velocity and displacement time histories and acceleration and displacement response spectra (5% damping). Webservices are under test for the distribution of waveforms and spectra in Advanced Scientific Data Format (ASDF). In the perspective of engineering use, an additional webservice has been developed for the distribution of waveform metadata, such as different distance metrics, ground-motion parameters (e.g. peak values, spectral ordinates) and site metadata (Vs,30 or proxies). Two tools are built on top of the database: a) data processing service, which is an online software that allows registered users to process waveforms contained in the ESM database; b) RexeLite, a service for the selection of accelerograms compatible with code spectra (e.g. Eurocode 8).

Keywords: strong-motion; waveforms; database; data processing.

1. INTRODUCTION

Building a unified engineering strong-motion database in Europe is of primary importance, due to the increasing demand of strong-motion data, that are one of the primary sources of information used by engineering seismologists and earthquake engineers to predict ground shaking and perform structural seismic analysis. Several attempts have been made during the past 30 years, starting from the European Strong-motion Database (ESD). Unfortunately, the previous databases were project related and their compilation stopped at the end of the specific project.

In order to avoid discontinuity, the Engineering Strong-Motion database (ESM, http://esm.mi.ingv.it) has a continuous support by the European project EPOS, the European Plate Observing System (www.epos-europe.org), a long-term plan for the integration of national and transnational Research Infrastructures for solid Earth science in Europe, to provide seamless access to data, services and facilities.

ESM is designed to enable users to fully exploit quality-checked, uniformly processed pan-European strong-motion data recorded since 1969, relative to events with magnitude larger than or equal to 4.

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The database has been designed for a large variety of stakeholders (expert seismologists, earthquake engineers, but also students and professional) and for this reason the web interface is friendly and straightforward. In addition, expert users may benefit from specific tools for data processing and data selection. An extensive description of the database is available at Luzi et al. (2016).

2. CONTENT OF THE DATABASE

ESM is a collection of several existing databases and online archives:

- Unified HEllenic Accelerogram Database (HEAD), released in 2004 and containing Greek waveforms and metadata from 1973 to 1999 (Theodulidis et al. 2004);
- ITalian ACcelerometric Archive (ITACA), the database of Italian strong-motion data from 1972 to 2015 (Luzi et al. 2008; Pacor et al. 2011a);
- Strong-motion database of Turkey (TR-NSMN), containing the Turkish data set from 1976 to 2007 (Akkar et al. 2010);
- Part of the strong Motion database of Iran (BHRC), limited to the waveforms of events with magnitude $\geq 6.0$;
- Pan-European data from 1972 to 2008, not included in regional databases, are extracted from the European Strong-motion Database (ESD);
- Data available at the European Integrated Data Archive (EIDA), from about 40 networks;
- European data available at Incorporated Research Institutions for Seismology (IRIS).

The waveforms contained in the database are processed manually following the procedure described in Paolucci et al. (2011), that allows the compatibility of acceleration, velocity and displacement by integrating once or twice the processed acceleration time-history.

Event and station metadata contained in the database are periodically revised. The event information collected from earthquake-specific literature studies are always ranked as the primary reference for large seismic events. For moderate to small events the sources of information are regional catalogues (e.g. the INGV Bulletin) or the Bulletin of the International Seismological Centre, ISC, in case regional catalogues are unavailable. The ISC bulletin relies on the contributions from worldwide seismological agencies and is typically 24 months behind real-time. Different magnitudes (e.g. Mw, Ml, Mb, Ms) are reported in the database as well as moment tensor solutions from different agencies. Information on the geometries of the seismic sources comes from regional or international catalogues (e.g. Ambraseys et al. 2004 for several European events; DISS for Italy; GREDASS for Greece; SRCMOD for large events occurred worldwide) or from specific source-model studies.

Station metadata are periodically updated, after specific studies are published in the literature or after the results of national and international projects. The station information actually contained in ESM is obtained from regional databases (ITACA, TR-NSMN, HEAD) or specific literature studies (e.g. Zare et al. 1999; Régnier et al. 2010; Michel et al. 2014).

The ESM database contains 51,200 three-component waveforms (last access 13 December 2017). About 60% of them are manually processed, 15% are automatically processed and need manual revision, whereas 25% are judged of bad quality. Bad quality data are preserved in the database, since intensity measures such as PGA can be used with a good confidence. Waveforms are relevant to about 6800 seismic events ($M\geq4.0$), recorded by 3340 sites. Figures 1 show the magnitude-distance distribution of records, the frequency distribution of event depths, style of faulting and site classes, assuming the EC8 categorization, based on Vs,30 intervals.
3. DATA ACCESS

The ESM database can be explored through a web site where the information is organized in three main blocks, relevant to waveforms, recording stations and seismic events. User can select earthquakes, stations and waveforms specifying 13, 14 or 35 key parameters, respectively.

Waveforms are accessed with the aid of a visualization tool (Figure 2), that allows zooming and exporting the time-series as images. Upon user registration, time-series can be downloaded in ASCII format, as unprocessed acceleration time series, processed acceleration, velocity and displacement time series, or acceleration, pseudo-velocity and displacement response spectra (5% damping) calculated at 105 periods (0.01s - 10s). A client, written in Python language, can be downloaded from the ESM home page in order to convert ASCII files in standard seismological formats (e.g. sac or mseed).
Figure 2. Example of unprocessed (top) and processed (bottom) acceleration time histories (component E of the second mainshock of the Emilia sequence, recorded at station MRN, Mirandola).

Each waveform can be tracked, since the metadata that reproduce the complete path, from the original data source to the processed data, are available. A license, provided by network operators, is associated to waveforms. It follows the Creative Commons standards, in order to enable the sharing and use of data through free legal tools and guarantee visibility to the original author.

Data and metadata in the Engineering Strong Motion database (ESM) are also available in the form of a flat-file (http://esm.mi.ingv.it/flatfile-2017/flatfile.php), a parametric table containing metadata and intensity measures relevant to the waveforms.

4. DATABASE TOOLS

4.1 Waveform processing

A waveform processing web front-end is available at http://esm.mi.ingv.it/processing, providing access to all waveforms in the ESM database (Puglia et al, 2018). The processing engine adopts the scheme described in Paolucci et al. (2011) and Pacor at al. (2011), originally designed to process the Italian strong-motion dataset (ITACA, http://itaca.mi.ingv.it/processing/). The reliability of the of the processing procedure has been tested by Boore et al. (2012) against padded and filtered time series and the procedure adopted by Pacific Earthquake Engineering Research Center, for the Next Generation Attenuation project (Power et al., 2008).

A user friendly web front-end allows to select uncorrected accelerograms according to 7 parameters: event ID, event start time, event end time, magnitude threshold, distance threshold, network code and station code. Registered users can process the waveforms according to their needs and derive processed acceleration, velocity and displacement time series, and acceleration and displacement response spectra. The results of the user-defined processing can be saved locally.

Figure 3 shows a screenshot representing the processing web front-end of the three components of the ground motion recorded at station Antikythera Island (ANKY, Greece), managed by the Observatory of Athens, on 2013-10-12 at 13:11:54 GMT (Mw = 6.76).
4.2 Rexelite

The ESM database is coupled with the REXELite application, which is the online version of the computer program REXEL (Iervolino et al. 2009; 2011), for the selection of ground motion suites for code-based seismic structural analyses. REXELite allows searching for combinations of seven 1- or 2-components strong-motion records, compatible, in average, with a target code spectrum. More specifically, REXELite: i) automatically builds code spectra for any limit state according to Eurocode 8 (EC8, ENV 1998) and ii) finds the set of seven records whose average matches the target spectrum, in a user-specified period range and with a desired tolerance. The records are pre-selected by the user from the database according to specific features, such as magnitude and source-to-site distance, style of faulting and site conditions. The resulting set of accelerograms may include unscaled (original) or amplitude-scaled records and may be used for code-compliant non-linear time history analyses of structures.

5. CONCLUSIONS

The Engineering Strong-Motion database (ESM) is an up-to-date collection of pan-European strong-motion data recorded since 1969, relative to events with magnitude larger than or equal to 4. The database has been designed for a large variety of stakeholders (expert seismologists, earthquake engineers, but also students and professional) and for this reason the web interface is friendly and straightforward. In addition, expert users may benefit from specific tools for data processing and data selection.

The core of ESM has been built from existing regional databases (~30% of the actual waveforms) and it is constantly growing thanks to the continuous supply of waveforms gathered from the European Integrated Data Archive (EIDA) or offline archives of several European and middle-East providers. The rate of growth of the database is about 3,000 waveforms per year, if we exclude seismic sequences that could substantially increase the estimated rate (e.g. the 2016 Central Italy data set consists in more than 10,000 waveforms).

ESM is not only the result of a project, but it is also part of a long-term vision for the distribution of
strong-motion data in Europe. To this aim, ESM has been selected as one of the infrastructures of EPOS, the European Plate Observing System (www.epos-eu.org), a long-term plan for the integration of national and transnational Research Infrastructures for solid Earth science in Europe, to provide seamless access to data, services and facilities.

7. REFERENCES


