Orfeus

ESM - Engineering Strong-Motion database

within EPOS

The ESM (http://esm.mi.ingv.it) database structure is built upon the ITACA architecture (http://itaca.mi.ingv.it; Luzi et al., 2008; Pacor et al., 2011), a well established system to host accelerometric waveforms and information on seismic events and recording stations used to store and distribute Italian data.

The relational database is centralized, with a core formed by about 80 tables, with a web interface and several tools to search data from online archives and catalogues, automatically populate the database, perform data quality check and processing.

The bulk of ESM data is formed by accelerograms available through European Integrated Data Archive (EIDA http://www.orfeus-eu.org/eida/eida.html). EIDA is promoted by the Observatories and Research Facilities for European Seismology (ORFEUS, http://www.orfeus-eu.org/) and represents a distributed data centre to securely archive seismic waveforms and related metadata, gathered by European research infrastructures. European data centres act as EIDA nodes, collecting and archiving continuous data from seismic networks deploying broad-band sensors, short period sensors, accelerometers, infrasound sensors and other geophysical instruments. Networks contributing to EIDA are listed in http://www.orfeus-eu.org/eida/eida_network_lists.html. Data within the distributed archives are accessible via the ArcLink protocol (http://www.seiscomp3.org/wiki/doc/applications/arclink), although more advanced protocols are under test.

Despite the efforts by international organizations (e.g. ORFEUS or International Federation of Digital Seismograph Networks, FDSN http://www.fdsn.org) to promote data standards and open access, still many network operators hardly follow the globalization process.

As a consequence ESM is designed to automatically download continuous data, but also host single waveform files, including offline recordings from providers that do not distribute data through international organizations. In addition, there is an existing patrimony of "historical" data, mainly recorded by analogue instruments (mainly before 2000), that needs to be preserved.

Therefore, the collection of waveforms is carried out in two ways: i) automatic upload from EIDA after an event alert; and ii) manually upload of offline data.

The procedure from a new earthquake occurrence to the record publishing consists in four steps.

Step 1: data upload after an event alert

After any event with magnitude larger than or equal to 4, reported in the ESMC webservice (http://www.seismicportal.eu/fdsnws/event/1/), records available through ORFEUS or IRIS are downloaded, using an automatic procedure for signal cutting, and uploaded into the database. At this stage only preliminary location parameters are assigned to the earthquake. Offline data are then searched in several repositories and uploaded after the network operators make them available.

Step 2: data processing

Bad quality records (e.g. records containing spikes or having low signal to noise ratio) are not processed, but made available to users in the unprocessed version.

Records of good quality are manually processed using the procedure proposed by Paolucci et al (2011) and processed acceleration, velocity and displacement time series are obtained together with acceleration and displacement response spectra at 5% damping.

Step 3: data release

All records manually processed are released in a time interval ranging from few hours (relevant events) to few days with the preliminary earthquake information.

Step 4: database revision

Station and event metadata are periodically revised. The Bulletin of the International Seismological Centre, ISC (http://www.isc.ac.uk/iscbulletin/) is the authoritative source of information for worldwide events, as it relies on contributions from seismological agencies around the world. It is typically 24 months behind real-time, therefore events are generally revised with one year delay. The prime (preferred) hypocentre for an event is selected. Reliable regional providers (e.g. the INGV webservice (http://webservices.rm.ingv.it/fdsnws/event/1/ for Italy) are also used to revise events. Station information are periodically uploaded after they become

available by network operators or specific studies are published in the literature (e.g. Michel et al 2014 for Swiss stations).

"Historical" strong-motion data have been obtained from different sources. The following regional databases are preferred to pan-European compilations:

- HEAD, the Unified HEllenic Accelerogram Database, released in 2004 and containing Greek data from 1973 to 1999 (Theodulidis et al., 2004);
- The ITalian ACcelerometric Archive (ITACA), containing Italian data from 1972 to 2014 (Luzi et al. 2008; Pacor et al. 2011);
- The strong motion database of Turkey from 1976 to 2007 (http://kyhdata.deprem.gov.tr).

Only waveforms missing in regional databases were integrated with waveforms contained in ISESD (http://www.isesd.hi.is).

To make existing and new data fully compatible, waveforms have been named following the SEED convention (www.iris.edu/manuals/SEEDManual_V2.4.pdf), developed by FDSN, and unique network codes have been assigned to all providers, included the ones no longer operating (e.g. networks of former Yugoslavia).

Data access

Seismic events can be retrieved entering the page "Events" of the portal. User can select 13 parameters including date and time, magnitude range, hypocentral coordinates or style of faulting. Each event is associated to event ids of major catalogues in order to provide additional information to the users. Several magnitude determinations are attributed from international agencies and focal mechanism solution and style of faulting are also provided. In case the fault geometry is available, the four vertices of the surface projection are provided.

Station information can be accessed entering the page "Stations", where recording stations can be retrieved according to 14 parameters including station coordinates, network and station codes, but also parameters related to the soil characterization, such as the average velocity in the uppermost 30 m (Vs_{30}). When available, the

stratigraphic profile and the Vs/Vp profile are also included, as well as the Nspt profile or Cu profile. The information related to each station is also provided in the form of a report containing detailed information, such as site stratigraphy, geophysical logs or horizontal to vertical spectral ratio from noise measurements.

Station information can be accessed entering the page "Waveforms", where single waveforms can be retrieved specifying up to 35 parameters related to stations, events, or strong-motion parameters.

Waveforms can be explored through a visualization tool, that allows to zoom and export the time-series as figures.

Data can be downloaded from the web site as unprocessed or processed acceleration, velocity, displacement, pseudo-acceleration and displacement response spectra (5% damping) for 105 period (0.01 - 10s) in ASCII format. A client software (dyna-convert.py, written in python language) can be downloaded from the ESM home page in order to convert ASCII files in popular seismological formats (e.g. sac, mseed, etc.)

Data license

Each waveform can be tracked, as the entire process from the original data author to data distribution is documented, including eventual data mediators used to obtain the records. A license is provided for single waveforms, according to creative commons standards (http://creativecommons.org), in order to enable the sharing and use of data and knowledge through free legal tools and guarantee visibility to data providers.

Data processing

A data processing web front-end is available at http://esm.mi.ingv.it/processing. The service provides access to all waveforms included in the ESM database. Registered users can select waveforms, do their own processing and save the results on their personal computer. The workflow implemented in this software is based on the procedure by Paolucci et al. (2001).

Rexelite

REXELite is a simplified online version of the computer program REXEL (Iervolino et al., 2009), for the selection of ground motion suites for code-based seismic structural analyses. REXELite is an application that allows to search for combinations of seven 1- or 2-components strong motion records, compatible in average with a specified code spectrum.

More specifically, REXELite: i) automatically builds code spectra for any limit state according to Eurocode 8 (CEN 2003) and the new Italian building code (CS.LL.PP. 2008, 2009); ii) finds the set of seven records having the most similar spectral shape with respect to that of the code, and whose average also matches the target spectrum in a user-specified period range and with the desired tolerance.

The records are pre-selected by the user according to specific features, such as magnitude, source to site distance, style of faulting and soil conditions. The set of accelerograms of the combination may include unscaled (original) or amplitude-scaled records and may be used for code-compliant non-linear time history analyses of structures.

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