An Earthworm based prototype of an EEWS for SW Iberia: first results

1. Introduction and objectives
2. Alert-es system prototype
3. Results
4. Conclusions
5. Ongoing research lines
The main objective of Alert-Es project is to study the feasibility of an Earthquake Early Warning System (EEWS) in front of potentially destructive earthquakes occurring in the area of Cape San Vicente - Gulf of Cadiz.

In this study, we show the main functionalities and the first results obtained from a prototype based on Earthworm developed in Institut Geològic de Catalunya (IGC).
In order to develop a feasible Early Warning System, some requirements were taken into account:

- Efficient reception of waveforms of seismic stations on the study area
- Optimization of the procedures of picking, event declaration and location to minimize the Warning Time while an acceptable location is being calculated
- Quick computation of the proxies needed to estimate the magnitude

Besides those terms, other functionalities were pursuit:

- Monitoring of the evolution of the detection of an event (parameters and Lead Times for selected targets)
- Storage of the information related to the events with the purpose of process them off-line
The complete Alert-Es system prototype is composed of several blocks, most of them developed from the system currently in operation in IGC:

- **Real-time system** has the functionalities to acquire data from a Seedlink server, automatic data processing (DAS: picking, event declaration, location, magnitude estimation) and alert monitoring (VISOR)

- **Database**: stores waveforms, arrival times readings, locations and magnitudes from the detected events in an Oracle database

- **Interactive system** handles the information kept in the DB to post-process (POSIDÓ) or browse and query (SISWEB)
Real-time processing system (or DAS) is performed by Earthworm tools (USGS). It is a modification of the system held in IGC in order to fit the requirements demanded by Alert-Es project.

Modules can be classified depending on their functionality:
- **processing modules**: `pick_eew`, `binder_ew` and `ewpublish`.
- **database storage modules**: `ora_trace_save` and `orareport`.
- **auxiliary modules** for archiving, status report, data source …
2. ALERT-ES SYSTEM PROTOTYPE: processing modules from DAS

**PICK_EEW**
- Picks automatic arrival times of the P waves to seismic stations
- Calculates the Pd and τc parameters, necessary for the estimation of the magnitude of an earthquake in window τ0 whose length depends on the epicentral distance of the channel being processed (new feature)

**BINDER_EW**
- Automatically declares events from the association of certain arrival time readings of the P waves
- Supplies a rough and quick hypocentral location of the event
- Updates the location for every new arrival-time received

**EWPUBLISH (new module)**
- Estimates the earthquake's magnitude from a weighted average of the magnitudes related to all Pd & τc stored parameters for each location received
- Publishes the complete and updated location and magnitude
VISOR is the last stage of the Real-time system and monitors the last event detected by DAS:

- Represents detailed earthquake parameters (location, arrival times, magnitude)
- Shows the Warning Time and computes the Lead Times at the targets
- Displays a map that combines geographical data of epicenter and stations with the progress of the S wave
2. ALERT-ES SYSTEM PROTOTYPE: real-time monitoring system (VISOR)
**SISWEB** is a web application to browse or query specific seismic activity such as earthquakes by time, depth, magnitude and location (**webevents**) or instrument data from the seismic stations of the network (**webinfra**)
POSIDÓ is an interactive data processing package for extracting and locating, among others features, and organizing digital seismograph data from DAS databases and files of different formats. This software application lets view and filter the registers of the events and compare the different locations of the RT system.
3. RESULTS: REAL-TIME SYSTEM

- **Main parameters of configuration:**
  - Event will be declared after the reception of **6 phases**
  - IGN velocity model for crust
  - BB stations from IM, IGN and WM networks in three different states: configured, testing, disabled
  - $P_d$ magnitude estimation

- **Operation of the RT system**
  - Period of **6 months**: 23/07/2013 - 23/01/2014
  - Foremost issues: no reception of data, inoperative system
3. RESULTS: automatic determination per type

- Only regional earthquakes are detected (no teleseisms, no noises, …)
- Most of them are useful: 9 SV and 17 GC
- 18 other regionals, coming from the surrounding area (mostly Portugal) are detected inside the grid
3. RESULTS: automatic detection per region and magnitude

**Magnitude ≥ 4.0**

- **SV**: 3 earthquakes in IGN catalog
  - 2 earthquakes lost (Mag’s 4.5, 4.6) by the Automatic System because of different issues (no data period; inoperative system)

**3 eqs automatically detected**

(24/07, Mag:4.4; 23/09, Mag:4.3; 16/12, Mag:4.9)

- **GC**: 2 earthquakes in IGN catalog
3. RESULTS: ORIGIN TIME ERROR (s) and DISTANCE BETWEEN EPICENTERS (km)

Comparison of average errors between Simulation of 6 historical earthquakes and the RT system:

<table>
<thead>
<tr>
<th>Region</th>
<th>Average of Origin time error (s)</th>
<th>Simulation of 6 historical earthquakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV</td>
<td>5.6 (✓)</td>
<td>6.3</td>
</tr>
<tr>
<td>GC</td>
<td>1.2 (✓)</td>
<td>-0.2</td>
</tr>
<tr>
<td>Others</td>
<td>8.1 (~)</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>Average of Distance between epicenters (km)</th>
<th>Simulation of 6 historical earthquakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV</td>
<td>39 (✓)</td>
<td>47</td>
</tr>
<tr>
<td>GC</td>
<td>25 (✓)</td>
<td>22</td>
</tr>
<tr>
<td>Others</td>
<td>126 (✗)</td>
<td>-</td>
</tr>
</tbody>
</table>
3. RESULTS: WARNING TIME and LEAD TIME to targets: Cadiz, Sevilla and Lisboa (averages)

Comparison of average errors between Simulation of 6 historical earthquakes and the RT system:

<table>
<thead>
<tr>
<th>Region</th>
<th>Average of Warning time, Tw (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Automatic Determination</td>
</tr>
<tr>
<td>SV</td>
<td>53 ✓</td>
</tr>
<tr>
<td>GC</td>
<td>44 ~</td>
</tr>
</tbody>
</table>
3. RESULTS: displacement signals @0.075Hz for 2 detected earthquakes

2013/12/16 GC  Mag$_{\text{IGN}}$= 4.9

2013/09/23 SV  Mag$_{\text{IGN}}$= 4.3

3 SIGNAL

Displacement = NOISE
3. RESULTS: Pd MAGNITUDE estimation vs IGN magnitude

- Estimated Pd magnitude is always >3.5
  - \(\text{displacement} \equiv \text{NOISE}\) for IGN magnitudes <4.5
- Good SNR in the displacement of the only earthquake with IGN magnitude >4.5
  - 2013/12/16 07:06:37 GC   IGN Mag = 4.9
Continuous and real-time waveforms from 25 stations from IM, IGN and WM networks are being received since April 2013 in IGC

An EEWS prototype has been developed based on Earthworm tools currently in operation in IGC

The whole Alert-Es system prototype has been completed with:

- Oracle database,
- real-time monitoring program
- interactive processing system and
- web applications

The system is fully operational since 23rd July 2013

First results show:

- Obtained average parameters values are very similar to the results of the simulations
- The resulting lead times are useful for all the Southwest Spain and South Portugal, apart from some parts of shoreline which depend on the earthquake epicentre area
It is necessary:

- Establish a strategy to avoid the magnitude estimation for earthquakes of magnitudes <3.5
  - SNR threshold for the displacement signal
- Evaluate the behaviour of the stations under test
- Study the consequences of the detection of other regional earthquakes
- Analyse the τc magnitude
- Carry on the period of testing to collect more data