

# Determination of the earthquake epicenter from the Geographic Profiling of the digital footprints left by eyewitnesses



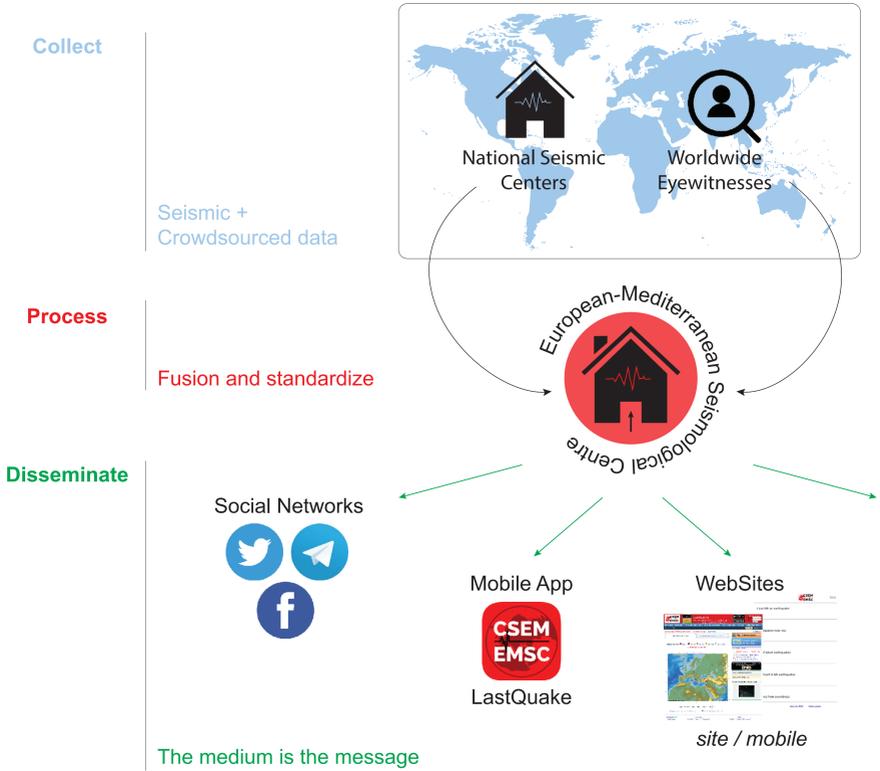
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When an earthquake is felt, eyewitnesses digitally manifest themselves thanks to the various collect methods developed by the European-Mediterranean Seismological Centre. Those observations are mostly collected through the websites traffic analysis (site and mobile), a Twitter earthquake detection bot (TED), the Lastquake mobile application and a dedicated questionnaire... The idea developed here consists in considering the pattern printed by the entirety of these observations (which can be considered the digital footprint left by the eyewitnesses) as being the signature of an earthquake. Through several examples, a method for fusing and combining all eyewitness observations collected is presented. Especially, in the framework of the statistical method of the Geographic Profiling (GP), this approach leads to fast determination of a seismic epicenter. And, because the propagation of the information on the Internet network is faster than the propagation of the seismic waves, this approach leads also to compare the GP solution to that obtained from conventional geophysical procedures (detection / location of the seismic waves).

## 1 - EMSC data Centre



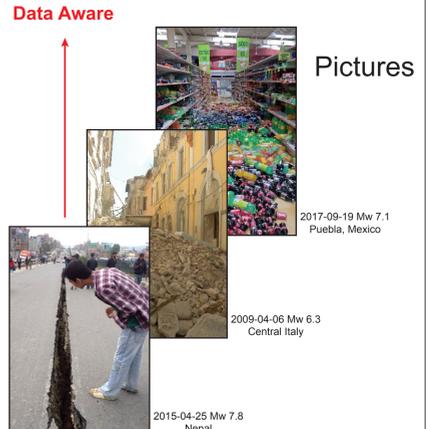
SCHEMA 1 - Overview of EMSC data Centre activities: Collect, Process and Disseminate data.

## 2 - Crowdsourced Data

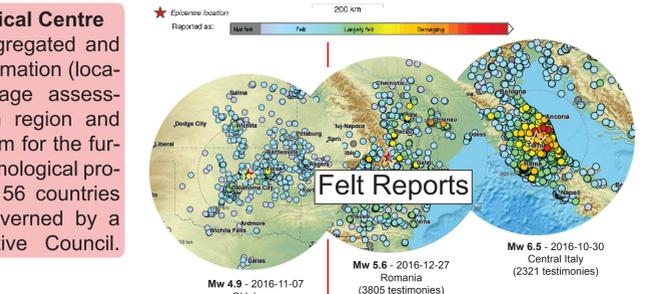
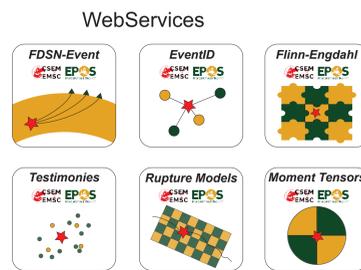
Evolution of Technology



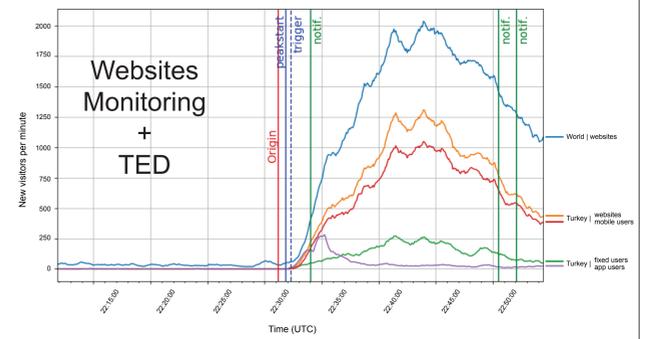
- Comments**
- 2017-07-20 - Mw 6.6 Dodecanese-Turkey Border Region: Felt it in the hotel room. The electricity went out. All the hotel lodgers woke up. We are still on the street.
  - 2017-11-12 - Mw 7.3 Iran-Iraq Border Region: I'm a Structural Engineer (MSc). I think these kind of earthquakes will not cause any serious damages to the nowadays buildings. But unfortunately most of our buildings in Iran, especially in this region are obsolete and masonry. Hope I could help.
  - 2017-09-08 - Mw 8.1 Offshore Chiapas, Mexico: I am 72 years old and it was my strongest quake. It lasted much more than a minute.



**European-Mediterranean Seismological Centre** was established in 1975 to provide aggregated and authoritative parametric earthquake information (location, magnitude, moment-tensor, damage assessment) for the European-Mediterranean region and serves as European coordination platform for the further development and integration of seismological products. 85 seismological agencies from 56 countries contribute data to EMSC, which is governed by a Coordination Bureau and an Executive Council.



**SCHEMA 2 - Overview of EMSC's Crowdsourced data:** EMSC uses Citizen as primary source of information. Internet traffic of EMSC web sites are transcribed as earthquake detectors. Gather earthquake responses from eyewitnesses (comments, felt intensities, pictures, ...).



## 3 - Geographic Profiling (GP)

### a. Physical case studies

Euclidean distance

Decay-functions

$$f(d) = \begin{cases} \frac{k}{d^h} & \text{if } d > B \quad (1) \\ \frac{kB^{g-h}}{(2B-d)^g} & \text{if } d \leq B \quad (2) \end{cases}$$

the constants  $k$ ,  $g$ ,  $h$  and  $B$  are calibrated against earthquake data

The epicenter is located in a region with a high «hit score».

The hit score,  $S(y)$ , has the form:

$$S(y) = \sum_{i=1}^n f(d(y, x_i)) = f(d(y, x_1)) + f(d(y, x_2)) + \dots + f(d(y, x_n))$$

where  $x_i$  are the observations (digital footprints),  $f$  is a decay-function and  $d$  is a distance.

Special cases: If  $B \neq 0$ , take into account of the "Doughnut effect" (Bossu et al., 2017), If  $B = 0$  and  $h = 2$ : "Geometrical spreading" of the seismic waves.

### b. Fusion of Observations

An observation ( $X$ ) is a vector of dimension 4 composed of: a latitude, longitude, an origin time and an attribute (intensity).

Felt reports → Intensity reported  
Other data type → Assume unity value } EMS 1998 scale

### c. Alternative models

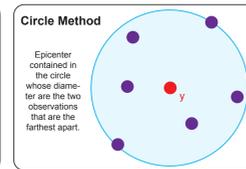
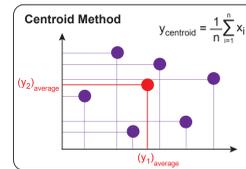
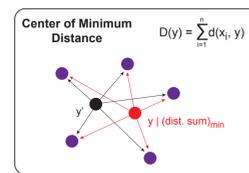


FIG 2 - Probability distance strategies.

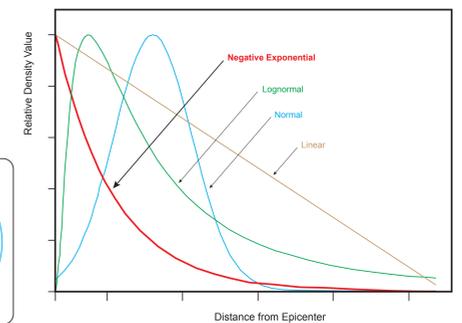


FIG 1 - Spatial distributions strategies.

## 4 - Applying the GP method on an Mw 4.9 earthquake in Greece on 2016-11-18 23:23:48

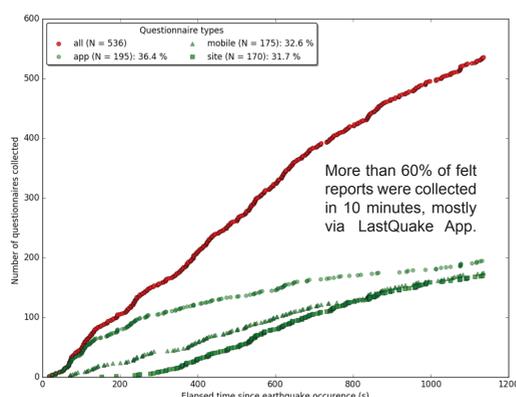


FIG 3 - Number of felt reports collected as function of time elapsed since earthquake occurrence.

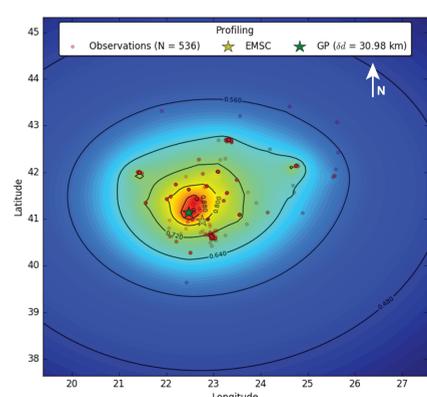


FIG 4 - Geographical Profiling of observations and comparison with EMSC seismic location.

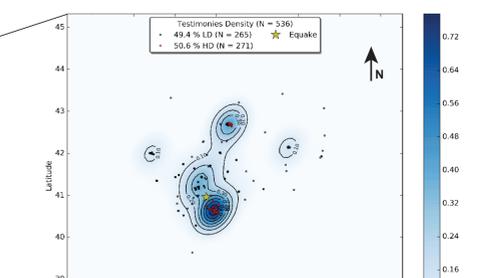


FIG 5 - Observations are pondered according to their inherent densities in order to take into account of highly crowd concentration in cities.

## 5 - Acknowledgement

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