THE EMSC TOOLS USED TO DETECT AND DIAGNOSE THE IMPACT OF GLOBAL EARTHQUAKES FROM DIRECT AND INDIRECT EYEWITNESSES' CONTRIBUTIONS

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ABSTRACT

This paper presents the strategy and operational tools developed and implemented at the Euro-Mediterranean Seismological Centre (EMSC) to detect and diagnose the impact of global earthquakes within minutes by combining « flashsourcing » (real time monitoring of website traffic) with social media monitoring and crowdsourcing.

This approach serves both the seismological community and the public and can contribute to improved earthquake response. It collects seismological observations, improves situation awareness from a few tens of seconds to a couple of hours after earthquake occurrence and is the basis of innovative targeted real time public information services.

We also show that graphical input methods can improve crowdsourcing tools both for the increasing use of mobile devices and to erase language barriers. Finally we show how social network harvesting could provide information on indirect earthquake effects such as triggered landslides and fires, which are difficult to predict and monitor through existing geophysical networks.

Keywords

Situation awareness, social media, crowdsourcing, flashsourcing, citizen science

INTRODUCTION

Seismology has always valued reports of felt experiences by laypersons because they are often the only evidence of pre-instrumental period earthquakes. This probably explains why seismology has been amongst the pioneers in citizen science and crowdsourcing. For example, the « Did you feel it » system developed by the US Geological Survey to massively collect felt experiences through online questionnaires has been in operation since 1999 (Wald et al., 1999) before the term « crowdsourcing » was even coined.

Today one of the main benefits for seismologists that result from the collection of these eyewitnesses' observations is to provide in-situ constraints to the intrinsically uncertain earthquake damage scenario and improve situation awareness (Bossu et al., 2015). We will also show through the different tools developed and implemented at the EMSC that it also benefits the public since the best way to optimize collection of in-situ observations is first to ensure a massive and immediate convergence of eyewitnesses to the collection tools by associating them with real time information services that meet eyewitnesses' expectations immediately after an earthquake occurrence. This efficient engagement strategy is achieved by speeding up our information services, by focusing them on felt and damaging earthquakes (the only ones that matter for the public) and, by digesting user-generated information and compiling it into a more comprehensive information service which covers both earthquake parameters (location, magnitude, time) and descriptions of their effects (shaking level, pictures of damage). We will illustrate these points by summarizing the main functions and performances of LastQuake which is the name of our smartphone application, a Twitterbot -in this case, it is also called a QuakeBot, i.e. a program that produces automatic tweets on earthquakes- and web browser add-ons.

In this article, we show how the crowdsourced information (testimonies, comments and geo-located pictures and videos) can be enhanced by 2 complementary indirect data contributions derived from the monitoring of activity on Twitter and from traffic analysis of EMSC website (www.emsc-csem.org, our popular website dedicated to global earthquake information). We then present how social network harvesting is being tested to detect indirect effects of earthquakes such as triggered landslides and fires and how such an integrated approach can contribute to improved situation awareness after an earthquake.

MONITORING PUBLIC REACTIONS TO DETECT AND DIAGNOSE EARTHQUAKE IMPACT

Up until the 1990's, seismologists knew that an earthquake had been felt when suddenly the different laboratory phones started to ring together. Today, eyewitnesses are mostly turning to the Internet for searching for earthquake information or for sharing their experiences after the shaking. The Internet acts as a digital nervous system of our planet whose pulses offer a way to detect felt earthquakes independently from seismic monitoring networks, and from earthquake magnitude.

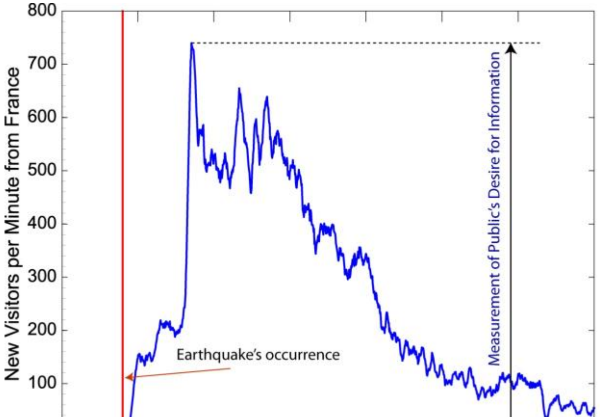


Figure 1. Example of a flashcrowd observed on the EMSC website and caused by a M 4.9 earthquake in SE France. It was automatically detected 96s after the earthquake occurred.

The EMSC uses 2 complementary approaches, Twitter earthquake detection TED (Earle et al., 2010, 2011), performed by the US Geological Survey, and flashsourcing (Bossu et al., 2008, 2011a, 2011b), developed and operated at EMSC. TED monitors the publication of 140-characters Twitter messages (tweets) and applies place, time, and key word filtering to detect felt earthquakes through the surge in published tweets related to shaking experiences (Earle et al., 2010, 2011). TED data is shared in real time with the EMSC, which automatically associates them with seismic locations through time and spatial analysis using the geocoded tweets (Earle et al., 2010).

Flashsourcing is based on flashcrowds, i.e. rapid and massive traffic increases (Jung et al., 2002, Marnerides et al., 2008) generated by the natural convergence of eyewitnesses looking for earthquake information on EMSC website immediately after the shaking (Figure 1). The convergence is extremely rapid: it was shown for the 2011 Mineral, Virginia earthquake that the arrivals times of visitors on the website followed the seismic wave propagation, allowing one to determine the epicentral location with a 30 km accuracy from only 2 minutes of EMSC website traffic (Bossu et al., 2014). This demonstrates that the initial flashcrowd is actually caused by eyewitnesses rather than referred visitors. In turn, it implies, as discussed later, that providing a recognized rapid public information strategy is an efficient strategy for engagement with earthquake eyewitnesses.

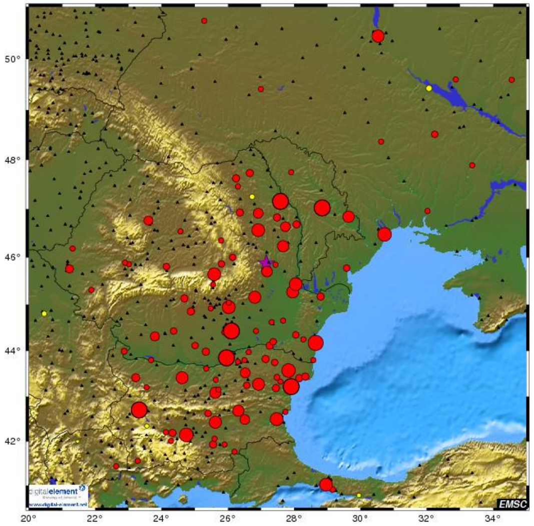


Figure 2: Geographical origins (determined from IP locations) of the website visitors within 5 min of the occurrence of the Nov. 22 2014 M 5.6 earthquake in Romania. Red dots represent geographical origins of statistically significant increased traffic (for more details see text). Yellow circles represent the geographical origins of website traffic with no significant variations. Black triangles represent the geographical origins of website visitors over the previous 12 months. Circle size is function of the difference between the expected and observed number of unique IPs (more details in Bossu et al (2011a)

Detections of felt earthquakes are typically within 2 minutes of earthquake occurrence for both methods and they precede seismic locations in the vast majority of cases (more than 90%) (Bossu et al. 2011a, Earle et al., 2011). They are fully complementary, as only 10% of the detected earthquakes in 2014 were detected by both TED and flashsourcing (45 over a total of 429).

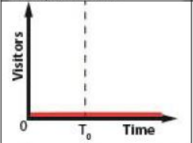
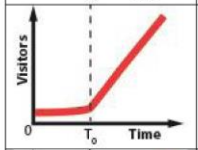
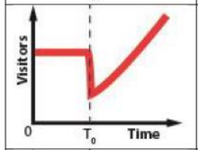
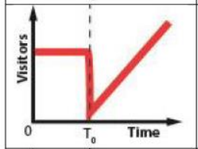
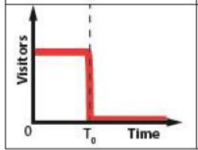
Time evolution of the number of visitors after an earthquake at T 0	Interpretations/Inferences (The cases' various conclusions are non-exclusive)	Remarks
	Not felt, or severe loss of Internet connectivity, or significant widespread damage, or severe perception of danger	Only valid in areas where the website is well known & Interpretations based on a cluster of IP locations
	Felt and no significant loss of Internet connectivity and no significant damage	
	Felt and, local or temporary, loss of Internet connectivity, or, locally significant damage or, locally severe perception of danger	Capacity to discriminate between local or widespread depends on the statistical significance of the number of website visitors before the earthquake
	Felt and, local or temporary, loss of Internet connectivity, or, locally or widespread significant damage or, locally or widespread severe perception of danger	
	Significant loss of Internet connectivity, or significant damage, or severe perception of danger.	

Figure 3: Interpretations of the different possible time evolutions of the number of Internet sessions following an earthquake occurrence at T_0. When the perception of danger is significant, eyewitnesses are more likely first to flee to safety rather than immediately browsing the Internet for information

Beyond the detection of felt earthquakes, flashsourcing also provides rapid information on the local effects of earthquakes (Bossu et al., 2011a, 2014). For instance, the area where shaking was felt can be automatically located by plotting the geographical locations of statistically significant increases in traffic (Figure 2) (Bossu et al., 2011b). More importantly, it can detect and map damaged areas in certain cases through the concomitant loss of Internet sessions due to damaged networks (Figure 3) (Bossu et al., 2015). This automatic damage detection system was implemented in late 2014 although it has so far not produced definitive results as only electricity black-outs have been observed and mapped so far.

THE IMPORTANCE OF CROWDSOURCED INFORMATION

EMSC collects testimonies, comments and geo-located pictures of earthquake damage. In 2014, it received at least 3 testimonies (our criteria to confirm an earthquake as being felt) for 507 earthquakes which had not been detected by TED or flashsourcing; further supporting the hypothesis that a single method is unlikely to detect all the events of interest.

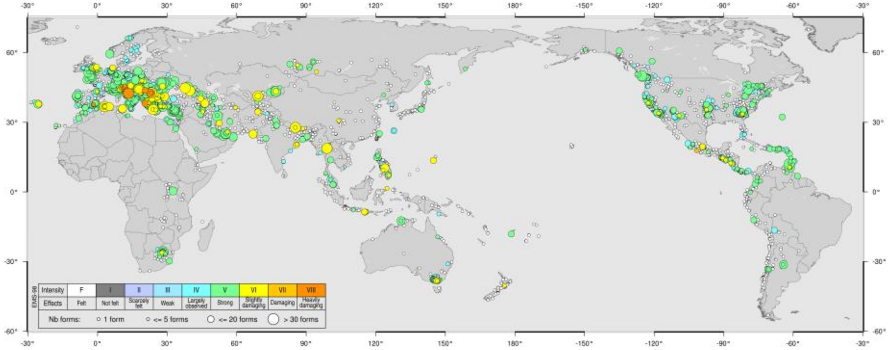


Figure 4: Composite macroseismic maps from testimonies collected by EMSC. The pace of collection has been increasing fast: 30% of the 58 000 questionnaires which collection started in 2008 were collected in 2014, and 60% of the 16 000 thumbnails, which collection started in 2011.

Testimonies are collected through online questionnaires available in 32 languages. They are automatically converted in macroseismic maps depicting the local shaking level (Figure 4) and made available online. Macroseismic data is more detailed than flashsourced information but the latter is collected faster as it generally takes a few tens of minutes to collect a significant number of questionnaires. The conversion of testimonies to shaking level uses a statistical approach excluding outliers due to error or misuses.

Geo-located pictures are essential for describing local damage and documenting transient effects (Figure 5). They are manually validated by our seismologist on call before being made available on the website. The seismologist checks their pertinence and coherency with date, location and the local expected shaking level.

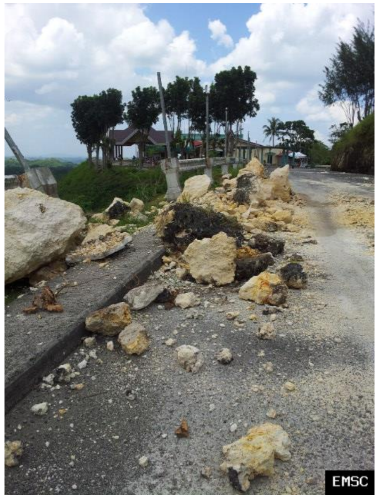


Figure 5: Crowdsourced picture of the 2013 Bohol (Philippines) earthquake

CROWDSOURCING TOOLS IN A MOBILE WORLD

Mobile devices (smartphones, tablets) have significantly changed the way people access information at EMSC. In 3 years, from 2011 to 2014, the average number of unique daily visitors to EMSC mobile website experienced a 3-fold increase while, during the same period, accesses to the classical website decreased by 10%. The change is even more dramatic when it comes to information access immediately after a widely felt earthquake: in the first 30 minutes following the Aug. 24th 2014, M 6 Napa (California) earthquake, 2/3 of the visitors within 300km of the epicenter accessed information with a mobile device (3656 over a total of 5579 individual visitors) and were automatically directed to our mobile website (Figure 6).

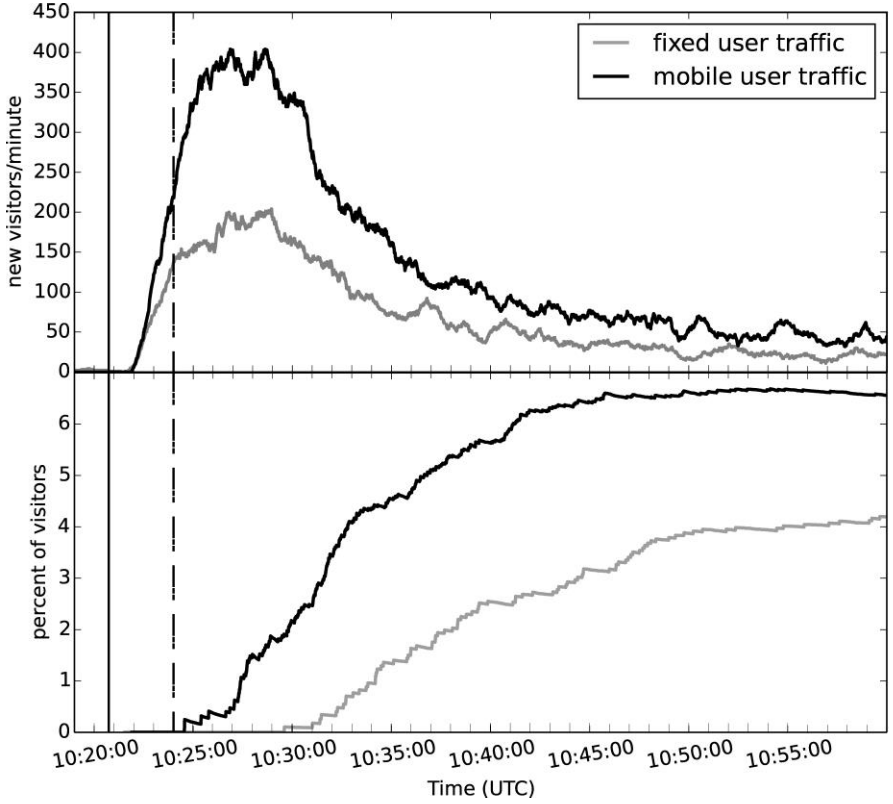


Figure 6: Traffic on EMSC websites in the minutes following the Napa earthquakes (above) and percentage of visitors providing their testimonies (below). The continuous line represents earthquake occurrence, the dashed one the publication of the first information on EMSC website.

Such behavior is not unexpected, especially for an earthquake striking in the middle of the night, when desktops are less likely to be on and mobile devices offer a faster Internet access. In order to take into account this change and the difficulty to fill questionnaires on a small screen, the online questionnaire used to collect testimonies has been replaced on the website for mobile devices by thumbnails depicting the 12 levels of the EMS98 macroseismic scale (Grunthal, 1998) (Figure 7). The ease of use of thumbnails, and the removal of language hurdles are the likely cause of the significant increase in the percentage of visitors offering their testimonies from about 4% to more than 6% (Figure 6). This ease of use compared to the couple of minutes required to fill the online questionnaire, may explain why the first thumbnails were collected 5 minutes before the first questionnaires (Figure 6) whereas both fixed and mobile users hit their respective website with the same swiftness. It may also be worth noting that the first testimonies were only collected once preliminary information was made available on EMSC websites. This may indicate the importance of meeting visitors' expectations first to initiate engagement and efficient crowdsourcing.

Figure 7: Example of thumbnail used by EMSC to collect testimonies on mobile devices

Thumbnails were also implemented in the LastQuake application presented below. With the same idea of meeting users' expectations, users can share their comments not only with EMSC but also on their Facebook and Twitter accounts. The LastQuake application proved efficient for collecting geo-located pictures: since its launch, all our collected pictures come from LastQuake. It is much more convenient to share a picture taken by a smartphone using the app and this also increases the number of GPS determined locations. Please note that page layout may change slightly depending upon the printer you have specified

LASTQUAKE INFORMATION TOOLS

LastQuake is the name of a set of information tools developed by EMSC, smartphone applications (iOS, Android), a twitter robot (or QuakeBot) and web-browser add-ons which are all based on the same principle: providing rapid information for the only earthquakes which matter to the public i.e. felt and damaging earthquakes. It aims at broadening the EMSC service portfolio to serve a wider community.

LastQuake is based on the automatic discrimination of felt earthquakes by merging different sources of information, mainly information collected directly or indirectly from eyewitnesses described above (Figure 8). The full description of the algorithm is beyond the scope of this article. It should however be underlined that discriminating felt earthquakes, especially the low magnitude ones, is challenging from seismological data only: variations of 1 or 2 km (i.e. well within uncertainties of real time locations estimates) in relation to centres of population can lead to a M 3 earthquake either being widely felt or only picked up by instruments. The aim is not to locate all earthquakes, this is the role of monitoring networks, but to identify the ones of societal importance because they affect the population in one way or another. By focusing on the few thousands of widely felt earthquakes a year, LastQuake prioritizes earthquake information aimed at public and authorities and optimizes crowdsourcing of in-situ observations at little cost (Bossu et al., 2015).

LastQuake is the prolongation of our engagement strategy with eyewitnesses through additional channels. It creates a virtuous circle where collected data is integrated in LastQuake information services to offer improved information on both the earthquake itself and its consequences (macroseismic maps, pictures of damage, comments from eyewitnesses…) which in turn should increase the volume of collected data.

Since its launch in July 2014, the smartphone application has been downloaded approximately 20 000 times.. There are 6 300 followers to the LastQuake Twitter account which currently generates up to 40 different tweets that are automatically published from 1 to 90 minutes of an earthquake occurrence. They include the automatic detection of flashcrowds, epicentral and macroseismic maps and their updates, the possible associated tsunami warning or alerts or links to additional resources. New tweets are regularly implemented to cover additional cases, like sequences of earthquakes, i.e. a number of earthquakes affecting the same area in a short period of times.

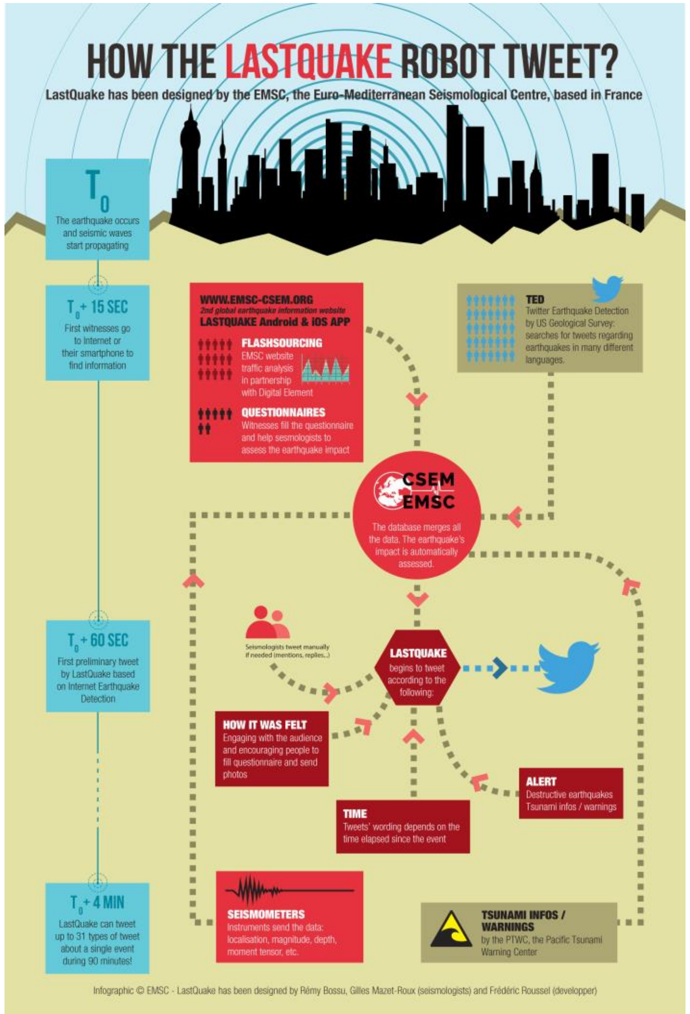


Figure 8: Schematic description of LastQuake QuakeBot

Web browser add-ons allow ‘pushed’ information like for the smartphone notifications. It is less popular than the smartphone application or Twitter but it contributes to increased damage detection capabilities through concomitant loss of web sessions by increasing the baseline traffic (Figure 3). The add-on for the Chrome browser has been released in January 2015. During the working hours there are around 1 200 sessions generated by website visitors and 300 by the add-on increasing damage detection capabilities by 25%.

CONCLUSION AND OUTLOOK

This paper focuses on the strategy and tools developed and implemented at the EMSC to collect direct and indirect data contributions on global earthquake effects from eyewitnesses for improved situation awareness and improve rapid public earthquake information. It does not intend to review the use of Twitter or other social tools to create earthquake detection or mapping system but to share our specific experience with researchers and practitioners and present future developments.

The engagement with eyewitnesses is based on targeted real time public information services intending to meet their needs in the immediate aftermath of the earthquake occurrence. Attracting more eyewitnesses increases the volume of collected data which is then integrated to further improve the information services, creating a virtuous circle.

Traditional online questionnaires have been replaced by a series of thumbnails to fit the screen size of mobile devices, improve convenience and erase language hurdles. Indirect data contributions are performed by 2 complementary methods based respectively on the analysis of the use of Twitter and of the EMSC website, one of the most popular rapid global earthquake information sources. They both take advantage of the rapid onset nature of the earthquake phenomena; so they are unlikely to be easily adapted to phenomenon with a slower dynamic.

There are currently several on-going or planned developments beyond the constant evolution and improvements of the different components of our information system. EMSC has been promoting and coordinating the deployment of citizen operated seismological networks in the Euro-Med region in coordination with the Quake Catcher Network (QCN) initiative (Cochran et al., 2009) and ensures data collection on its own servers. Two prototype networks are in operations in Patrai and Thessaloniki (Greece). The aim is to augment seismological data to better map the spatial variations of the shaking level in urban environment during an earthquake, a key parameter for damage scenarios. We plan to test within a year in the same regions a smartphone application that records earthquakes with the phone’s internal motion sensors. Another development for the smartphone applications is to exploit the teachable moment immediately after a felt earthquake by providing users with preparedness tips and security guidelines for the ones subjected to damaging shaking levels. Social network harvesting is a promising technique to identify possible indirect earthquake effects such as triggered landslides and fires, which are difficult to predict and monitor through global networks; a test of the Artificial Intelligence for Disaster Response (AIDR) (Imran et al., 2014) platform is to begin to evaluate the possibility of detecting weak signals associated to this phenomena.

In conclusion, our strategy has fully demonstrated its advantages for improved public earthquake information and collecting information on earthquake effects at little cost for the benefit of seismologists. The ultimate objective is to fully demonstrate its operational benefit for improved earthquake response by developing a fully functional, time evolving situation map integrating all available data and sharing its results with first responders.

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