

New Developments on Automatic Macroseismic Evaluation Based on Internet Questionnaires at I.M., I. P.

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SUMMARY:

One of the most critical moments in an operational centre for seismology occurs when an earthquake is felt and there is an urgent need to provide seismic information to civil protection authorities. It was developed an automated process for preliminary evaluation of seismic intensities in different locations, based on responses to on-line web-questionnaires. The reported effects are analysed, filtered and converted into degrees of seismic intensity. The integration of the initial results in the first statements to be sent to the authorities, in a semi-automatic manner, was an underlying purpose in order to minimize the intervention of the operational on duty. This program, called Webmint, and our institutional implementation of USGS-ShakeMap software are intended to interact deeply. ShakeMap results helps us to constrain our results. Further integration is being tested. Some results are presented in this work. The method application and implications with related programs and procedures are here discussed.

Keywords: Macroseismic Intensity, Web-questionnaires, automatic evaluation.

1. INTRODUCTION

One of the most critical moments in the Operational Centre of Seismology (COS – Portuguese acronym) in the Portuguese Institute of Meteorology (IM) is when occurs an earthquake that is felt or likely to be felt by the population. The first concern is to determine the basic parameters of earthquake and release them as soon as possible to the national authorities with responsibilities on civil protection.

Subsequently, a number of other processes must occur and that includes: publish and disseminate first report to international seismological agencies and to the media, the publication of preliminary information on the IM's website and the macroseismic data collection and analysis. Usually two statements are publish, one with basic parametric and preliminary information, which may include results of the program ShakeMap (Marreiros et al., 2009 and Wald et al. 2005), and another with the seismic information reviewed with first results on macroseismic data, which confirms or not the results provided by ShakeMap Portuguese implementation.

The process of gathering and analysis of macroseismic information has been particularly complex and time consuming. Until recently it was performed manually and implied a certain number of phone calls, in order to have a comprehensive picture of the effects of the event. Also, and understandably, there are numerous people and institutions that try to contact the operational centre in order to request information, making it impossible to respond to most of them.

In 2006 it was possible to implement at IM a new method of collecting macroseismic information based on voluntary collaboration over the internet. For this purpose a questionnaire was made, available on the website of IM that was based on Macroseismic European Scale 1998 - EMS-98 (Grünthal, 1998).

Now, few hours after an event with an appreciable impact on the population, it is possible to receive a few thousands of responses to the questionnaire. These answers are received as an e-mail at COS. However this information can not be analysed in time by operators in duty once there are at most two, but usually only one.

This led to the necessity to develop an automatic process of preliminary assessment of macroseismic intensities at different locations, based on responses to the questionnaires. The reported effects are analysed, filtered and converted into degrees of seismic intensity.

It was an underlying purpose of this work the integration of macroseismic data, in a semi-automatic form, in the first statement to be submitted to the authorities. Also it was necessary to minimize the intervention of the operational on duty.

This tool, called Webmint, acronym for WEB Macroseismic INTensity, is still in a pre-operational phase in COS at IM, mainly because there was not a considerable event since December of 2009.

2. HISTORY

Up to the nineties macroseismic assessment was made based on information that was collected on field trips few days after the event and also from information obtained from questionnaires mailed by some external volunteers. After the middle nineties macroseismic information was obtained mainly by phone contacts made to the police and fire department. General public were also contributing by phone calls. Since 2003, it was made possible for general public to send macroseismic information by e-mail. For instance, after the occurrence of the earthquake of December 13, 2004 (SW CS Vicente, ML = 5.4) there were received 301 e-mails. The following figure (1) is an example of an e-mail received at COS.

“Good morning! On the 13th at 14h18, sharp time, I was in Carregado on the 10th floor when I felt a slight oscillation, which made a desk creaking slightly, and a Chinese artifact (metallic pieces with a pendulum hanging in the middle) play.
The oscillation did last at least 20 sec but, probably, almost 30 sec.”

Figure 1 - Example of an e-mail received after the occurrence of the earthquake of December 13, 2004 (SW CS Vicente, ML = 5.4).

In 2004 a new questionnaire was designed based on EMS-98 scale for field work (Alves, 2004). In 2006 a new version of the questionnaire was developed which can be filled out voluntarily on the IM's website and internally sent by e-mail to the operators. For instance, just after the occurrence of February 12, 2007 earthquake (Horseshoe Abyssal Plain, ML = 6.0) 565 responses were received and after the occurrence of December 17, 2009 earthquake (SW CS Vicente, ML = 6.0) 3667 responses were available in few hours.

In 2010 began the process of automatic analysis of responses. Testing phase still ongoing (pre-operational phase).

3. QUESTIONNAIRE ON THE IM'S WEBSITE

The macroseismic questionnaire found on the web-page of IM, is called "Did you feel an Earthquake?". It is aimed at any direct observer of an earthquake and can be accessed by the link: <http://www.meteo.pt/pt/sismologia/informe/>.

The aim of the questionnaire is to assess the presence of macroseismic effects as they were felt by the

observer, in accordance with the description of a EMS-98 macroseismic scale. An important element is the information on the geographical location of the observer. This questionnaire consists on simple questions, most with multiple choice answers. The questionnaire is divided into four main thematic sections after a first block which includes only the personal information.

The first section is related to the geographic location of the person and time of observation. The second section is a succession of questions about effects on people. Examples of such questions are: "Did you felt the earthquake?", "Where were you?", "What did you felt?", "Was it difficult to stand?", "Was you frightened?", etc. The third section deals with questions about effects on objects and nature. These are issues related to effects on suspended objects, glassware and glasses, doors and windows, furniture, animals, etc. The questionnaire ends with a section where the observer can report any other observed effects.

It is observed a high participation of users of the web-page of the IM to the new method of collecting macroseismic information. In fact, in most of the days some inquiries are received.

In the Figure 2 it is exemplified a questionnaire response, among few thousands, just after December 17, 2009 event (SW CS Vicente, ML = 5.4). This amount of answers led to the need to solve the problem of automatic processing of the information obtained from the macroseismic questionnaire in the IM's web-page.

PROFILE

Name: "name"

Phone: "phone"

e-mail: "e-mail"

EARTHQUAKE DATA

Date / local time: 2009-12-17 01:37

Zone: Mainland Portugal

District: Faro

County: Lagos

Parich: Santa Maria

C.P.: 8600 - 571 Lagos

Local name: Lagos

EFFECTS ON PEOPLE

Did you feel an earthquake?

Yes

Where were you?

I was sleeping

If you where in a building, which was the type of its structure?

Masonry

On which floor was you (0 equal to ground-floor)?

2

How did you feel it?

Strong shaking or rocking of the whole building, room, furniture.

Did you have any difficulty remaining stand?

No

Did you got frightened?

Yes

Did you run outdoors?

No

EFFECTS ON OBJECTS AND NATURE

Hanging objects?

Not observed

Glassware and glasses?

Clinked

Doors and windows?
Quivered and produced some noise

Objects?
Unobserved

Liquids?
Unobserved

Furniture?
Visibly trembled

Animals?
They were frightened even outdoors

Did the wood structure creaked?
Yes

Damages in the buildings (eg, fissures, cracks, falling plaster, damage on chimneys, displaced tiles, falling tiles, etc.)?
There may be small cracks (not confirmed).

COMMENTS
The earthquake last long. It was accompanied by a strong noise. The structure of the building (3 floors) strongly shook. At home we are three and in two separate rooms, we all awakened. The dogs barked in the street, on the moments that followed the earthquake.

Figure 2 - Example of one e-mail received at COS with the questionnaire responses of the IM's website.

4. ESTIMATION OF SEISMIC INTENSITY

In order to automate the evaluation process to determine macroseismic intensities at different locations, based on analysis of responses to the web-questionnaire it was developed a computer application.

The algorithm analyses the responses of each macroseismic inquiry and converts these responses to a degree of seismic intensity (number). After this all surveys are grouped according to the district, county and parish (DCF – Portuguese acronym for regions terminology) where they are coming from. It is used in this work the English term “county” as equivalent to Portuguese term “concelho” and the English term parish as equivalent to Portuguese term “freguesia”.

According to the results obtained in each group is assigned a single degree of intensity to each parish. In Figure 4 it is shown the algorithm for macroseismic evaluation. The algorithm was implemented in C programming language (Kernighan, 1998).

Considering that the observation of one effect is an indicator of a degree of seismic intensity, for the effect described is assigned a number representing the degree of their intensity. Figure 3 shows an example of one programming cycle.

```
if(EPrefixoDe("Não",usr[j].pessoa_assustou)==1) usr[j].num.pessoa_assustou_num = 0;
elseif(EPrefixoDe("Sim",usr[j].pessoa_assustou)==1) usr[j].num.pessoa_assustou_num = 5;
```

Figure 3 - Example of some programming lines of the algorithm.
If observer answered that he was frightened, then it returns 5;
if he was not frightened it returns 0.

In the process described by the algorithm several steps can be considered: 1) reading and filtering data,

2) conversion to numbers, 3) analysis by inquiry, 4) summary by DCF, 5) writing results.

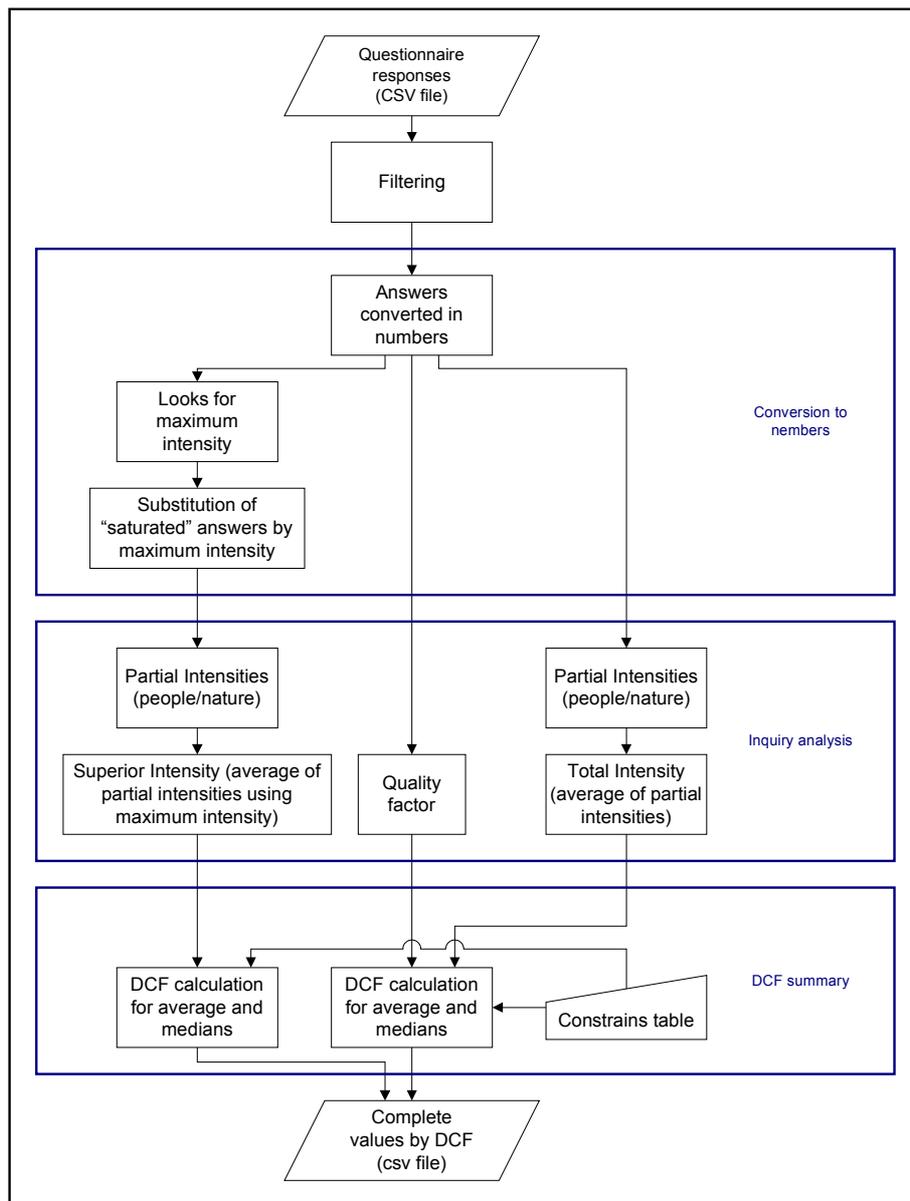


Figure 4 - Schematic representation of the algorithm for automatic macroseismic evaluation.

The program was designed to read input data in CSV format (comma separated value) with the questionnaire responses. This file is generated by the program W_Emap (Carrilho, 2005) – a local software package used at COS. Each line of this file gives the data received in an e-mail, regarding: 1) date and time of e-mail arrival, 2) observer - the person's name, phone and e-mail, 3) association with an earthquake and the geographic location of the observer – observation time of the earthquake, zone, district, county, parish, zip code, site, 4) description of the effects on people - responses to the effects on people (was it felt, where he was, what he felt, balance, fright, escape, panic), 5) description of the effects on objects - responses to the effects on nature and objects (hanging objects, glassware and glass, doors and windows, objects, liquids, furniture, animals, wood structure), 6) additional information - comments on the buildings, other comments, 7) extra questionnaire information, added by W_Emap program - theoretical intensity, latitude, longitude, ratio between distance to the epicentre and distance to a place of theoretical intensity II.

Still in the first part of the process, the questionnaire responses are filtered, in order to identify: 1) repeated responses (when there are multiple responses sent by the same person only the last one is considered), 2) non-compliant, 3) observations on the 6th floor or upper.

In the second part, each answer of the questionnaire is converted into a number that represents the intensity value that is associated with this response. Another path is also processed in parallel. In this case the algorithm searches for the higher intensity value of each inquiry (maximum intensity). If the inquiry contains responses there are "saturated" (responses that correspond to the highest value set to a question) and that have less value than the higher intensity reported in another question, these saturated responses will be replaced by maximum intensity observed. This is necessary since the direct application of the algorithm for higher intensities never would return these values because many indicators "saturate" at lower intensities.

In the third part of the algorithm, the analysis is carried out by inquiry. For each survey, two intensity values are calculated resulting from: 1) weighted average of the values attributed to effects on people and objects and effects in nature (total intensity), 2) weighted average of the values attributed to effects on people and effects on objects and nature, with answers "saturated" being replaced by maximum intensity values (superior intensity). It is also calculated for each inquiry, a quality factor (FQ) related to the percentage of survey questions that were answered.

In the fourth part, are determined by each DCF, the average value and medians of: 1) total intensities, 2) superior intensities, 3) quality factors. It can be applied a set of configurable constraints, allowing to exclude certain inquiries during the process of calculation. For example, inquiries which result points to an unreliable intensity, with values much higher than expected. The excluded inquiry is assigned by a special code indicating the reason for their exclusion.

Finally, in the last part, the program writes a CSV file that contains the summary of results by DCF (resumo.out): average intensity, average for superior intensity, codes (number and letter) that indicates the quality factor (average quality factors of all the inquiries associated with a given DCF), average of maximum intensity, median intensity, average for superior median codes (number and letter) that indicate the quality factor (quality factor of the inquiry or the average of two surveys that are used to calculate the median), total number of inquiries, number of valid inquiries, district, county, parish, latitude, longitude. If there are no inquiries considered valid for a given DCF, this region is assigned with a zero and the code "E" is used to express the quality factor. Figure 5 shows an example of resumo.out file.

5. ANALYSIS AND COMPARISON OF RESULTS

The automatic macroseismic evaluation process was applied to the responses of the questionnaire received in COS after the occurrence of the earthquake of December 17, 2009 (SW CS Vicente, ML = 6.0). This was the event with more responses, after the beginning of availability of the questionnaire on IM's web-page.

To test and validate the evaluation method developed at IM, the results obtained were compared for some DCF, with obtained results from other methods and sources, which are: 1) manual assessment of macroseismic intensity; 2) map of instrumental intensity distribution of seismic intensity generated by the ShakeMap based on instrumental measurements and 3) system "USGS Did You Feel It" (USGS-Dyfi) from the U.S. Geological Survey (USGS). The results from this last method are published on the website: (<http://earthquake.usgs.gov/earthquakes/dyfi/events/us/2009qhac/us/index.html>).

Although the evaluation of the macroseismic intensity by manual methods, USGS-ShakeMap and USGS-Dyfi has been performed based on the Modified Mercalli Intensity scale (MMI), and the questionnaire on IM's web-page was based on the EMS-98 scale, it is considered that the two scales are equivalent, according to Musson et al. (2009) work.

W_Emap software), resulting from the automatic evaluation applied to inquiries received in the COS, only one hour after the occurrence of the earthquake. These inquiries were used to determine values of seismic intensity for 197 DCF's. The data represented on the map clearly allows the identification of the most affected area of this earthquake.

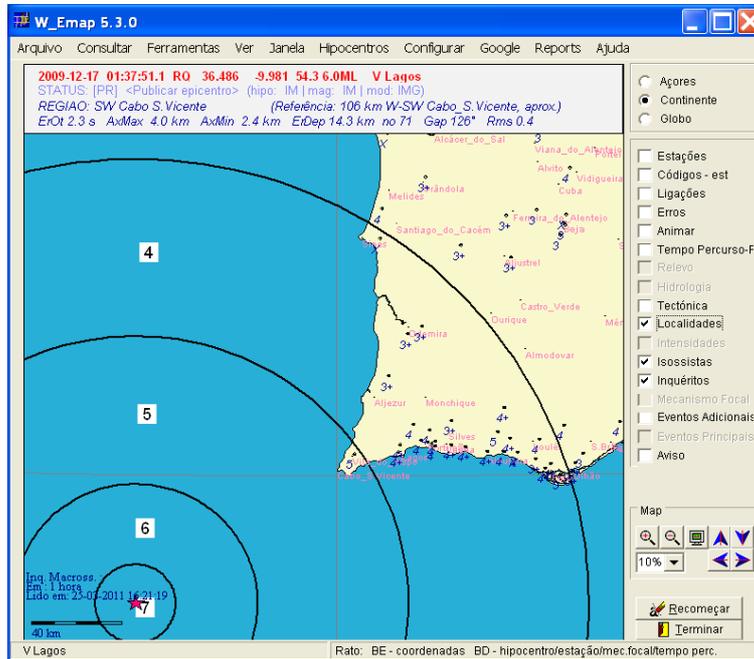


Figure 6 – Seismic intensity distribution, as result from automatic evaluation of the inquiries received during the first hour after the December 17, 2009 (SW C.S. Vicente, ML=6.0). Black circle represent theoretical isoseismal lines. Symbols: 1) red star – earthquake epicentre; 2) blue numbers – local intensity value; 3) “+” after a number – intensity is between this number and the next; 4) “X” - there is some information but it was excluded by constrains imposed.

In figure 7 is shown the distribution of seismic intensity, which results from the automatic evaluation of the 3667 responses to the questionnaire received after the event. The program took about 1 minute to process all responses and consistent results were obtained for 659 DCF's. This figure also shows a zoom that allows seeing in more detail the distribution of macroseismic intensity obtained for the southern region of Portugal mainland, where the earthquake had bigger impact.

Lastly, theoretical tests for intensities 6 to 8 were done and their results were consistent, but in the absence of true answers in this range of intensities, no definitive conclusions should be expressed.

6. FINAL CONSIDERATIONS

In a first approximation the results obtained through the macroseismic evaluation process developed at IM are consistent with the results obtained from other sources (manual assessment, USGS-ShakeMap and USGS-Dyfi).

After application of the automatic method of analysis it is concluded by comparison with manual analysis that:

- 1) Manual analysis has the advantages to include more information and it is widely used, but has the disadvantage to be very slow and more subjective,
- 2) Automatic analysis is much faster, more objective and allows dealing with a huge amount of data, but has also some disadvantages such as being restricted to the parameters used and is still undergoing testing in several agencies.

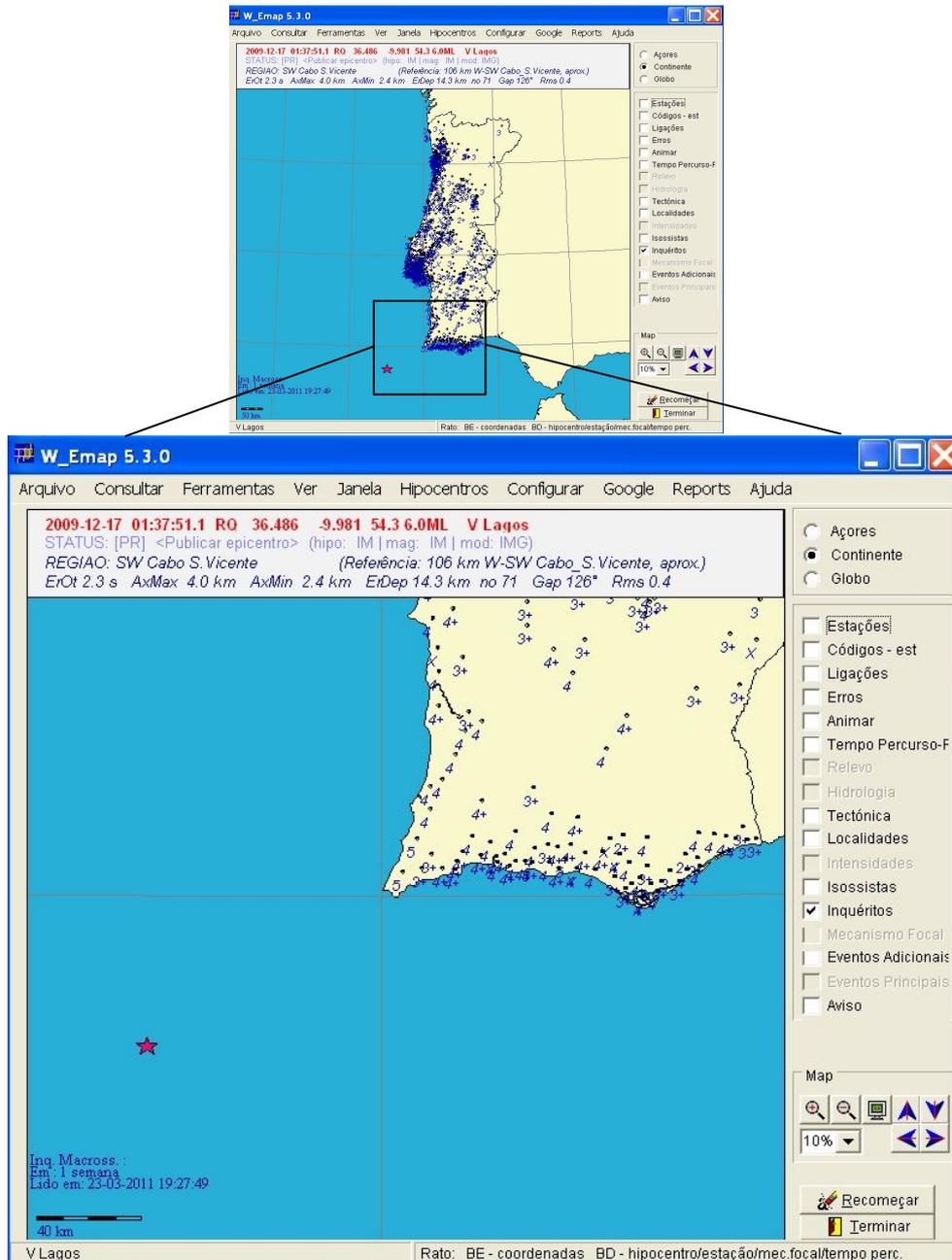


Figure 7 – Seismic intensity distribution, as result from automatic evaluation of the 3667 inquiries received after the December 17, 2009 (SW C.S. Vicente, ML=6.0). For symbols explanation, see figure 6.

However, it is necessary to take into consideration that the macroseismic intensity is always the result of a complex set of parameters that are related to seismic source (more or less source complexity, seismic ray directivity), with the path of the seismic waves (geometric attenuation and absorption), with the observation site (topography, geology, surface conditions of the observer in the environment, hour of the day, day of week, etc...; exterior / interior; low floor / high floor, design, position, materials, maintenance of the buildings, etc...; resonance phenomena, etc...).

Another important aspect is the fact that it is possible to test this method with very few earthquakes, but, it's not yet possible to test greater intensities, just because there is no data for these intensities. There is an awareness that an upcoming event with a considerable impact could have a massive

response from visitors of the IM's web-page, probably reaching several tens of thousands of individual responses. Not only IM's website is one of the ten most visited sites in Portugal, but also IM are directly inviting teachers and other professionals with earthquake related jobs to join us as volunteers to complete the questionnaire. It is admitted that these questionnaires made by these special volunteers are considered more reliable. In a near future, when this network is stabilized in terms of organization, it is believed that it can be given to this group a different weighing in the intensity evaluation process.

The use of this information in the first report to authorities, in general, can not be possible, once the first responses start to arrive at the same time the report is published (usually less than 3 minutes after waves pass through the 3 first mainland stations). Typically 2 or 3 minutes after it is possible to have a glimpse about real impact.

In terms of future work regarding the automatic macroseismic evaluation, it is necessary to tune some details, deepen further investigations inside statistical analysis, produce more integration with the operating system of seismic monitoring, deepen integration with USGS-ShakeMap and with reports to the national authorities. Moreover, it is important to establish a broader range of developers and collaborators and work on a more reliable and dynamic web-engine dedicated to the questionnaires in the background of IM's main web-service. The problem of taking in consideration damages on buildings in order to increase a bigger range of intensities is an urgent topic to work about. Some alternative ideas were already being developed, once direct applications of EMS-98 is difficult in practical terms because it requires a careful *in situ survey*. Another detail is the possibility to go further than DCF, using Google Maps® facilities.

So all this approach is still in a pre-mature stage, but nevertheless, it is believed that a significant step was done in the IM's methodology of macroseismic evaluation.

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