MACROSEIS: A TOOL FOR REAL-TIME COLLECTING AND QUERYING MACROSEISMIC DATA IN ROMANIA

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Earthquakes that are unambiguously sensed by humans or even destructive are often happening natural phenomena in Romania. The MACROSEIS application is an automated tool for collecting information from volunteers that felt the effects of an earthquake. Based on this interactive system, data can be collected and macroseismic maps can be obtained. The MACROSEIS application collects reports from volunteers that were sent via Internet shortly after an event is produced. Electronic reports are sent to the National Institute for Earth Physics. This information is further transformed in CII Community Internet Intensity Maps by means of a modified version of the Dengler and Dewey algorithm.

1. INTRODUCTION

The European Spatial Development Perspective and new EC Regional Policy regulations emphasize the need of a better spatial planning and require new tools for the impact assessment of regional developments on natural and technological risks [1]. Earthquakes risk management is a very important topic today [2] because earthquakes are a rapid on-set hazard (the strong shaking that causes damage during an earthquake usually lasts for less than one minute), although the effects can last for decades [3]. Earthquake intensity is used today all over the world in order to estimate the damages produced by earthquakes. The macroseismic intensity scales were developed long before the modern seismic devices and they represent a criteria to describe the complexity of the Earth movement. At the same time, these scales can be used for obtaining information regarding the extent and the nature of the damages produced by an earthquake. The Internet - the Information System that is used by an increasingly number of users - can be used for a quick collection of information regarding the earthquake’s intensity. The Internet can be also used to generate and
automatically broadcast the macroseismic maps.

The traditional method that was previously used in order to estimate an earthquake’s intensity consisted in sending printed forms by regular mail, to the authorities and volunteers in the affected areas. These forms contained different questions regarding the effects of the earthquake that were felt in one specific area. Therefore, obtaining a map of macroseismic intensity by traditional means is difficult, and time consuming, so that a map could have appeared much later (even after a few weeks) after the earthquake. Such a map had a limited use, even though the information it contains is very useful shortly after the earthquake is produced in order to estimate damages and manage first aid intervention activities.

In contrast to automatic sensor-based approaches, where sensor devices send data automatically, the role of the human users is significant in the architecture of community-based map generation, where the community-made maps are one approach within the concept of *Public Participation GIS (PPGIS)* [4]. In the context of earthquake intensity estimation, some approaches already exist for integrating human-sensed data into the research process of seismic events [5].

The use case implemented in the context of this work is to create a community-based earthquake intensity map for Romania. The estimation of earthquake intensity applied here is operationalized using the standardized MMI scale and the EMS-98 scale [6]. This article describes an automated tool implemented at the NIEP - the National Institute for Earth Physics site. The MACROSEIS tool avoids the time-, human resources-, and material-consuming traditional method of data collecting. MACROSEIS is an IT-based interactive system. The rapid generation of the macroseismic maps is possible by using special procedures for processing Internet available forms that are filled in by volunteers via Internet, shortly after an earthquake is produced. The volunteers have the possibility to access the dedicated NIEP website and fill in the standard electronic form available on this site. This information is automatically transformed into intensity values according to a modified version of the Dengler and Dewey algorithm [10]. The algorithm requires that the geographic position of the macroseismic effect is based on the GPS coordinates of the observer during the earthquake. While the information is recorded on the website by the volunteers it is processed by a dedicated software and a local map of the seismic intensity is generated on the Internet. On this map, every observation point is associated with a different colour, according to the seismic intensity in that location.

This automated generation process can be used for strong earthquakes and for weak earthquakes. The Information System that will generate the map allows improvements by acquiring new data received over the Internet from the volunteers. At the same time, it allows an infinite number of users to access the results over the Internet.
2. ARCHITECTURE AND OPERATION OF THE MACROSEIS APPLICATION

The MACROSEIS system architecture is presented in figure 1. External users can access the system through the Internet directly on the NIEP external web server that hosts only the external application. The internal web server hosts the full functionality application and it is not visible from the Internet. It can only be accessed from the internal network.

The primary database for the MACROSEIS project uses a RDBMS (Relational Database Management System) based solution from MySQL. The MySQL database holds the following information:

- earthquake identification data (latitude, longitude, region, magnitude, depth, time, hallmark, number of received responses, number of received photos);
- received answers from external users;
- identification data of the external users that fill in the required questionnaire (title, county, city, street, time when the photo was made and sent, name, contact data, hallmark);

Fig. 1 – The MACROSEIS architecture at macros.infp.ro
• results regarding the processing of the data filled in the questionnaire.

The operation of the MACROSEIS tool provides facilities for remote data sources management, macroseismic intensity maps generation, querying on seismic parameters of earthquakes, and data warehouse operations.

The remote data sources management operation mode allow customized access based on granted access rights. The system has two types of users (figure 2). Internal users from NIEP can access the internal component in order to manage and visualize querying data. Internal users have full access to the system functions. Non-authenticated external user can access the system through the Internet, from were they can upload new information through the electronic questionnaire or to visualize querying data. As can be seen in figure 3, external users can only fill in new electronic forms and launch a visualization command of the macroseismic map. Internal users can access all the functions of the system including reports and seismic event management activities.

The main responsibility of the information system available for the MACROSEIS application is the generation of the macroseismic intensity maps. This component of the application allows to collect rich information on earthquake event soon after it is produced, from the volunteers that felt it. These macroseismic intensity maps can be easily generated considering the growing number of the users of the Internet. Further information could be also available in order to update the initial generation of these maps.

In order to process the data sent by the volunteers over the Internet and collected through the electronic questionnaire, specific activities are to be fullfiled. The first step implies the assignment of numerical values to the answers in the questionnaire. Than for each location a volunteer is registered the Modified Mercalli Macroseismic Intensity and the EMS-98 are computed. Based on these data, a macroseismic intensity map is generated for the considered seismic event. On this map, the name of the location and the average intensity for the location can be displayed.

The macroseismic intensity map is generated within a few minutes time after the earthquake is produced when only the epicenter of the event is marked on the map. As long as the information becomes available based on the volunteers’ answers, the locations from were the answers are sent are marked with circles. The colour of the circles is related to the computed intensity for the corresponding location [7].

The model of the web interface (figure 4) displays the available functions for querying on seismic parameters of earthquakes, a default facility provided to the internal and the external users. Users can ask about epicenters of earthquakes in distance from location, the nearest epicenter with respect to a given point on the map, highly populated cities close to strong earthquakes.

Online historical earthquake data investigation is also available through the
data warehouse operations in the MACROSEIS application. This option allows a geographical representation and manipulation of data describing the macroseismic
effects of historical earthquakes. Due to the potentially huge amount of information related to earthquake phenomena, summary data views could equally address user needs. Implementing MACROSEIS as a data warehouse offers the possibility to store locally summary information only (e.g. number of shocks, average magnitude), at different levels of detail in space (area, country, etc) and/or temporal dimension (month, year, century).

3. THE MACROSEISMIC SITUATION IN ROMANIA

Romania is an European country having significant seismicity. The most active seismic zone is situated in Vrancea area, at the arch of the Carpathians Mountains. The seismicity of the Vrancea region in the SE-Carpathians Mountains is characterized by intermediate depth earthquakes in a narrow epicentral and hypocentral region. The epicentral area is confined to about 30 km x 70 km. Strong earthquakes occurred between 70 km and 180 km depth within an almost vertical column. The depth interval of the strong events is bounded by levels of low seismicity between 40 km and 60 km and beneath 180 km. According to the number of people lost in earthquakes dur-
ing the 20th century as well as in a single earthquake during the last century (March 4th, 1977, $M_w = 7.4$, 1574 dead people, including 1424 in Bucharest), Romania can be ranked the 3rd country in Europe after Italy and Turkey [8].

Figure 5 presents as an example the macroseismic intensity map for the $M_w$ 5.0 earthquake produced in Ukraine, on May 7th, 2008.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Intensity (MMI)</th>
<th>Weighted Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/05/2008</td>
<td>11:15</td>
<td>46.40</td>
<td>30.50</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

Fig. 5 – The Macroseismic Intensity Map for the $M_w$ 5.0 earthquake produced in Ukraine, May 7th, 2008.

The earthquake detection system available at the NIEP site uses the Antelope ver 4.10 program, and it generates the seismic report by sending on the Internet page the necessary parameters for opening the Internet earthquake report questionnaire for volunteers (see http://macros.infp.ro).

The corresponding Shakemap for this earthquake (figure 6) confirms the relation between the higher intensity area on the macroseismic intensity map and the instrumental measuring values recorded on site in the Republic of Moldova. The macroseismic intensity maps are a valuable tool that can be used to calibrate the Shakemap intensity algorithm for weak earthquakes, even in case of poor data.

Because very few data are recorded for areas with IV MMI earthquakes, low
Fig. 6 – The Shakemap for the $M_w$ 5.0 earthquake produced in Ukraine, May 7th, 2008.

intensities can not be assigned based on actual data [9]. Therefore, the collected data from community-based earthquake intensity maps available through Internet can be successfully used in order assign a limit for small intensities based on the modified version of the Dengler and Dewey algorithm [10]. The variables in the earthquake report form have been chosen in such a way that their relationship to the earthquake intensity is unambiguous. In a matching process, the most appropriate earthquake intensity class is chosen for each report submitted by combining the set of variables.

A comparison between the macroseismic intensity maps and Shakemap for recent earthquakes in Romania is presented in figure 7. Because they are obtained based on the earth movement, the figure shows how the recorded data relate to the macroseismic intensity maps. It was computed that the border between "felt" and "non-felt" is situated around the 0.2%g value, for weak-medium intensity seismic events [8]. These values could be updated after more data is received from the seismic recording stations.

These maps that are generated shortly after the earthquake is produced should be considered preliminary and of short-term valability. Further recorded date should improve their quality. It was observed that the approximation obtained for the MMI estimation on the macroseismic intensity maps is more accurate when the number of answers is greater than 5.
4. CONCLUSIONS

With the upcoming of the Internet and especially recently developed web services and service-oriented architectures, a technological basis is nowadays given for collecting data more efficiently than is currently the case in many scientific communities. The aim of this paper is to give insight into the concept of a community-based map creation process in Romania in the context of earthquake intensity estimation. On this account, our approach aims at establishing a more generic architecture for the integration of community-based earthquake intensity estimation data into the process of generating digital, interactive maps and reports for research and publication on the Internet.

Being that the seismic activity in Romania is extremely severe with a significant destructive potential, the topic proposed is of large importance. Setting up such an activity requires both fundamental research activities as well as application aspects. The MACROSEIS project is a first step toward an Information System that could be capable of supporting the whole spectrum of DEOs (Disaster and Emer-
ergency Operations), from large-scale national and cross-border crises, regional disasters down to local-scale incidents. In all cases, collaboration between a variety of different organizations and units is envisaged which may include Central Government at one end of the spectrum down to local people and support groups at the other end of the scale.

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REFERENCES


