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Community-made Earthquake Intensity Maps using Google's API

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INTRODUCTION

The availability of abundant reliable data is a constraint for successful scientific research. Research progress is often inhibited by the difficulties in collecting data in a reasonable time period due to missing infrastructures, cost and time issues.

With the upcoming of the Internet and especially the 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. In this context, the OGC develops standards for the exchange of sensor data over well-defined XML interfaces. While this approach seems feasible for machine-to-machine communication of sensor data, additional approaches seem necessary for making use of data "sensed" by human. The term sensor is here not understood solely as technical device measuring physical, chemical or biological parameters directly, but can also be people recognizing certain effects that can be linked to spatio-temporal phenomena. All participants of a data collection process can be seen as a community for that particular research topic. To make use of these "human sensors", a user-friendly interface to communicate their estimation of a sensed phenomenon using existing technical infrastructures should be provided instead of syntactically and semantically complex specifications.

The aim of this paper is to establish a concept for a community-based map creation process in the context of earthquake intensity estimation. The approach relies on established technologies and APIs, where Google Maps play a major role.

Community-made maps

The overall idea of integrating distributed users of a research community into data collection processes is to extend the data basis significantly and to save time and costs collecting these data sets by using nearly real-time collection methods. For spatio-temporal applications, the result of such a survey can be a map depicting the estimations of the community, a so-called community-made map. In this case, the spatial characteristic of a data set needs to be registered by providing address data, postal codes or coordinates.

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. User interfaces should be easily understandable while being unambiguous in terms of the semantics for parameters that need to be gathered.

Earthquake Intensity estimation

The use case realized in the context of this project is to create a community-based earthquake intensity map for Germany. The vast majority of the seismic epicentres in Germany are concentrated in three weak zones of the Earth's crust: (1) the Rhine area (2) the Swabian Jura and (3) Eastern Thuringia as well as Western Saxony with its swarm quake area ("Vogtländisches Schwarmbebengebiet") (Grünthal, 2003). Since earthquakes unambiguously sensed by humans or even destructive earthquakes are very rare natural phenomena in the country, the established architecture is intended to be generic so it can be used in other spatial contexts beyond the specified use case as well.

Workings on the systematic collection of ground motion effects triggered by earthquakes began in the 19th century. The degree of ground motion and its effects were classified in terms of intensity grades. The intensity scales developed for this purpose were improved and designed over the years to minimize effects caused by subjective errors.

In the context of earthquake intensity estimation, some approaches already exist for integrating human-sensed data into the research process of seismic events. The probably best-known system "Did you feel it?" has been developed by the U.S. Geological Survey (USGS, 2007). It relies on the web-based collection of intensity estimation data by the community and results in a contribution to a digital map integrated on a web page after collecting the record of each single user. The static map contains ZIP areas representing a single intensity value that is deduced from multiple intensity estimations by the community.

In other projects, community data has been integrated as well, although in a rather event-specific context. Such a project is the *Dumfries Earthquake Survey* (BGS, 2007), where a macroseismic survey was launched on the BGS 'Earthquakes' web site with a total of 301 responses.

INFORMATION ARCHITECTURE

This project 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. It is based on multiple technological components that are combined in a process chain in order to automatically generate maps from user input.

Earthquake Report Form

The estimation of earthquake intensity applied here is operationalized using the standardized EMS-98 scale (Grünthal, 1998). The macroseismic intensity I represents a classification of the magnitude of ground motion based on observed phenomena in a defined area, e.g. a town. Effects of ground motion on people, objects in houses as well as damages to buildings form the basis for the appraisal. Intensities are a robust measure of magnitude classification: I not felt, II scarcely felt, III weak, IV largely observed, V strong, VI slightly damaging, VII damaging, VIII heavily damaging, IX destructive, X very destructive, XI devastating, XII completely devastating.

Instead of querying the users directly for their intensity estimation, these values are deduced from recognized natural phenomena in a standardized way. As an example, by paraphrasing the different intensity classes with textual descriptions (e.g. "hanging objects swing heavily, small objects maybe shifted. Doors and windows swing open and close."), it is possible for users to integrate their local event-specific knowledge into the overall system without knowing the actual semantics of an intensity class. Instead, the descriptions collected in a web-based form are later on mapped to the corresponding class. Following this approach, non-experts are able to take part in a survey, such that the number of participants is large enough to gain significant results from the data.

The form used here contains among questions concerning the mentioned textual descriptions also variables for spatially referencing the event. The user is given the opportunity to either enter a postal code, an address, or a set of geographical coordinates. The latter two parameters are later on matched to an appropriate postal code for visualization in the map, but are additionally being kept for more specific localization of an event in other contexts.

Intensity Information Service

While the report form provides data entered by the user, the intensity information service processes this data by a) mapping the given form parameters to earthquake intensities, b) forward the spatial information to the geocoding process provided by external components, c) administrate the processes of data storage, map creation and web page response to the user.

The variables in the earthquake report form have been chosen in such a way that their relationship to 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.

On the basis of the provided spatial information, i.e. a postal code, an address or a geographic coordinate, the sensed earthquake intensity can be geocoded to the map resolution, which is in this case the combination of postal code areas (for large cities) and communities (for rural areas). The geocoding process itself is however not performed by the intensity information service itself, but rather by an external service provided by the Google Maps API (see below). The role of the former service is to parse the spatial variables from the submitted form and pass them to the external service. The resulting coordinates can eventually be transformed to postal codes with an internal spatial matching process based on the coordinate information of all German postal codes.

The remaining tasks of the intensity information service is to parse the other variables from the form, forward the data to the report database, setup scripts to create map layers with the summary of all earthquake intensity reports submitted so far and to return to the user with a web page containing the eventual map.

Earthquake Reports Database

The database keeps track of all earthquake reports submitted and stores additionally for each of them the most appropriate estimated earthquake intensity and the result of the geocoding process (at least geographic coordinates and postal codes). Due to its spatial content, the database is able to return all reports for a certain area, so queries to the database can be used to generate statistics on certain regions, which is the case for the resulting intensity map. For visualization in the map, the average intensity is calculated from all reports submitted for each area of interest.

Google Maps API

One central component in the architecture is the Google Maps API, which fulfills two roles in the system. With its powerful and efficient mechanism to geocode addresses (that even do not necessarily need to be complete) to coordinates, it upgrades the usability of the overall system by high performance while keeping error rates on a low level. By simply submitting the spatial parameters as strings to the Google Maps geocoding web service, the appropriate coordinates are returned to the client, which is in this case the intensity information service. Since Google Maps base data is available for most countries of the world, this approach fulfills the aim of being generic for transmitting the concept to other regions.

The second role of the the Google Maps component is to create maps based on two layers: the base layer provided by Google containing background information like topographic data or remote sensing images, and the actual information layer generated by the intensity reports of the community. The latter is generated based on spatial queries of the database and the subsequent statistical operation of averaging the single reports to a single value.

The Google Maps API provides a means to generate customized symbols to be drawn in the map. In the case of the earthquake intensity map, the standardized icons used in this context can therefore be created and used for classification in the resulting map.

Communication Architecture

The overall communication architecture combining the four base components is sketched in figure 1. Basically, the process chain performs the following activities.

1. The user gives an estimation of earthquake intensity by filling out and submitting the form on a web page.
2. Intensity information system generates intensity from parameters following EMS-98 standard.
3. Address data provided in report form is sent to Google Maps API in order to geocode it into geographic coordinates.
4. Google Maps API returns geographic coordinates.
5. The whole report (incl. Coordinates and estimated intensity) is saved in database for archiving and further processing.
6. The set of estimated intensity values for each location is sent to the intensity information system in form of a point list with attributes. The intensity information system generates average intensities for each area.
7. Average intensity estimations are sent to Google Maps API together with symbol information.
8. Google Maps API returns map with user-defined symbols showing average estimated intensity values.
9. Map is integrated into web page and returned to client synchronously.

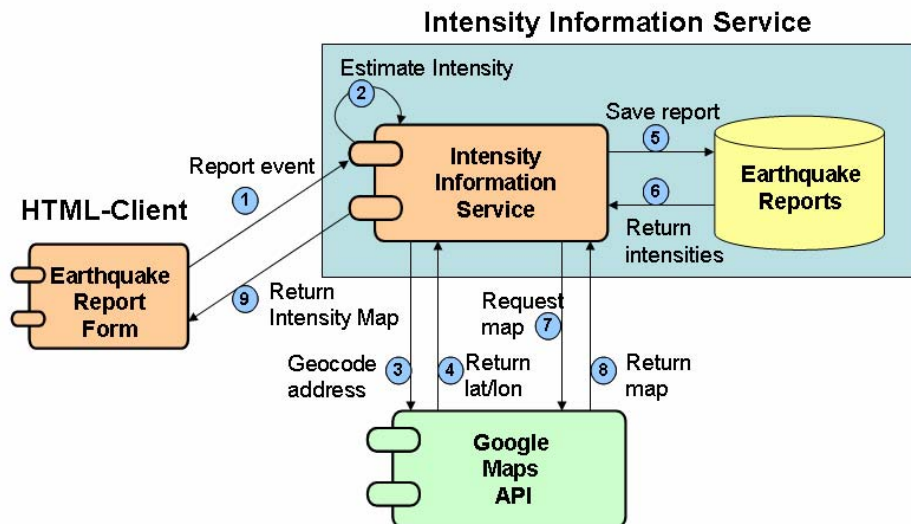


Figure 1: Conceptual communication architecture of the system.

Technical implementation

The whole system is based on the established technologies readily available and usable on the Internet. The form is integrated in a simple HTML page, which is served by an Apache HTTP Server. PHP scripts are used at the server side to manage database access, data storage and forwarding of requests. It is further used for communicating with JavaScripts, which play the key role in using the Google Maps API. A simple MySQL instance has been chosen as database, since coordinates for point measurements as well as postal codes can be stored easily without any spatial extension.

CONCLUSION AND OUTLOOK

The conceptual approach presented here aims at establishing a framework for integrating data “sensed” by a community for estimating earthquake intensity in Germany. The goals are to set up a generic system, that can be extended to other regions of the world, but also used in different thematic contexts that need to integrate community information. So far it has been developed as a conceptual first prototype and is intended to be developed as an operational system in a next step.

In order to optimize the participation of the community, it has been designed to be technically simple, easy-to-use and bring up results immediately after submitting the individual contribution in form of the report. Usability is further improved by founding the concept on the very fast interactive web client of Google Maps.

At the same time, the scientific value of the resulting map is given due to the fact that established methodologies like the EMS-98 are applied, standard symbols are used and statistical procedures in the background are transparent. However, in order to enhance the quality of the results, the reports provided by the users need to be evaluated in some way, which has to be considered when further developing the architecture for operational usage in the community.

From a technical point of view, the whole system is relatively straightforward to establish and use and therefore gives a good foundation for integrating community data into the scientific research. By using established technologies, it has the potential to significantly enhance cost and time issues in the data collection process.

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