Assessing Volunteered Geographic Information for Rapid Flood Damage Estimation

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ABSTRACT

For disaster management, a broad overview of the situation, resulting impairments and damages is required. For this overview, information from many different sources has to be acquired and integrated. Observations from the affected population can be an important source of information. New Internet technologies facilitate fast and easy data collection from the public. A major obstacle for using this information is its unknown quality. The aim of this research is to develop methods to assess the quality of observations from the affected population for rapid loss estimation after flood events. In a first step, data about flood events and associated losses collected in telephone interviews are assessed for their reliability and fitness for use for flood loss modelling. First results show that water level can be estimated by observers with a similar accuracy as it can be modelled by hydraulic models. Flow velocity, however, is very difficult to estimate and the estimates differ significantly from modelled values. The results of this analysis will be used in a second step to develop an automated procedure for quality assessment of observations from the public to be used in a prototypical implementation of web-based data collection for flood events.

1. INTRODUCTION - HUMANS AS SENSORS: OPPORTUNITIES AND CHALLENGES

For disaster management and rapid loss estimation after disasters, a broad overview of the situation, resulting impairments and damages is required. For this overview, information from many different sources has to be acquired and integrated, including data from different sensors, aerial and satellite images and observations of the emergency forces. As recent large-scale disasters such as Hurricane Katrina have shown, observations from the affected population can be an important source of information for disaster management.

Humans observe their environment and can act as intelligent sensors that can synthesize and interpret local information (Goodchild, 2007). For flood disasters, they can observe different phenomena such as water levels, or water contamination to supplement sensor networks, and even some parameters that cannot or are usually not measured by any sensors such as flow velocity, or damage levels.

Until recently, collecting information from the public by telephone, mail, or personal meetings was tedious and costly, and the organizational effort for such surveys usually caused delays. New Internet technologies and the widespread availability of broadband Internet connections have made this task easier and faster, thus making it possible to collect information from volunteers operationally on a large scale.

So far, however, information provided by the affected population has only rarely been taken into account systematically for disaster management or event and damage assessment. A notable exception are the community Internet intensity maps that the US Geological Survey produces based on information collected from the public via a web interface called “Did you feel it?” (Wald et al., 1999). Within this project, the affected people report on hundreds of earthquakes per year; depending on the location and intensity of the earthquake, up to tens of thousands of reports are filled for a single event.

The main limitations of data collected from the affected population that impede their use are:

- Availability: It is unknown, how much and which and from where information will be supplied. Unlike a sensor network, information collection from the public cannot be planned in advance so as to yield an optimal configuration of observations for the phenomenon of interest. Therefore, for vital information, volunteered information should only be supplementary to other data sources.
- Data quality: Unlike physical sensors, humans cannot be calibrated and do not comply with standards. Mostly, they are not trained for specific observations. When affected by a disaster, humans can be very emotional which may impair their judgment and they may intendedly or unintendedly provide false information.

To tap the potential of humans as sensors and make observations from the affected population usable for disaster management and rapid loss estimation, it is essential to systematically assess the opportunities and limitations of this kind of information. In particular, the quality of data that anonymous and untrained people supply via the Internet needs to be assessed and methods need to be developed to support quality control in on-line information systems using these data.

Using rapid loss estimation after flood events as an example, this research aims at developing methods to assess the quality of information from the affected population. The main questions that will be addressed are:

- Which required information can be supplied by the affected population with sufficient quality? How can this information be collected?
- How can the quality of this information be assessed and controlled?

Based on statistical and geostatistical analyses of the data quality and a fitness-for-use analysis for flood loss modelling, an automated procedure for quality control for use in web-based data acquisition will be developed.

2. METHODOLOGY FOR ASSESSING THE QUALITY OF DATA PROVIDED BY THE AFFECTED POPULATION

The research for assessing the quality of data provided by the affected population comprises two parts (see Figure 1). In the first part, the quality of observations from the public for flood events will be assessed using existing data from telephone interviews in comparison with results from hydraulic models and measured water levels. This assessment will result in a fitness-for-use analysis of these data for flood loss modelling. The results of this study will be used in the second part of the research to develop an automated procedure for the assessment of observations from the public using only data available operationally. This procedure will be prototypically implemented for the web-based data collection on flood events.

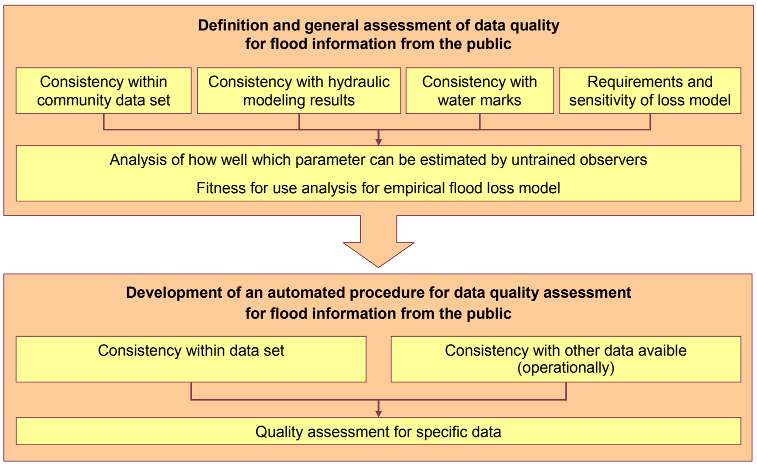

Figure 1: Overview of the research approach.

Available data

Information from the affected population is available from telephone interviews after the flood in the Elbe and Danube River catchments in 2002 (Thieken et al., 2007). In this survey, almost 1700 people affected by the flood were asked to provide information on flood parameters, preventive measures they undertook and damage that were caused by the flood at their home. As flow velocity is difficult to observe directly, several indicators such as a verbal description and the type of debris transported were used in the telephone interviews to get an estimate of the flow velocity. Of these, data on flood parameters (water level and flow velocity) are used in this study. These observations are compared with results of hydraulic models for selected sections of the Elbe River (Apel et al., 2008) and its tributaries, as well as with measured water levels from water marks at buildings (Schwarz et al., 2005).

Operationalization of data quality

Data quality has many aspects, and a number of different approaches to assess quality of (spatial) information exist. The general definition of quality as "the totality of characteristics of a product that bear on its ability to satisfy stated and implied needs" (ISO, 2002) needs to be broken down into more detailed quality elements in order to be useful.

Usually quality assessments for spatial data focus on internal data quality, i.e. the level of similarity between the data produced and the data that should have been produced according to the data model, if no errors were made (Devillers and Jeansoulin, 2006). For these analyses, ISO 19113 proposes the following data quality elements (ISO, 2002):

- Completeness
- Logical consistency
- Positional accuracy
- Temporal accuracy
- Thematic accuracy

These elements of internal data quality pertain to the data themselves and are independent of their possible use. A complementary concept is external data quality or "fitness for use" which assesses the fitness of certain data for a specific task in a specific area (Devillers and Jeansoulin, 2006). This concept implies that data quality is not absolute, but dependent on the intended use and the expectations of the user.

A completely different concept of data quality is often applied in the Web 2.0 context where large amounts of user-generated content pose new challenges: credibility assessment (Flanagin and Metzger, 2008). This concept focuses on the provider of information and rates his or her trustworthiness based on ratings by other users. This concept is particularly useful when individual perceptions are aimed at rather than objective properties. This concept can only be applied if there is a community of users who collaboratively provide information and rate each other's contributions.

Although this study focuses on user-generated content, the traditional approach of internal and external data quality will be used, since the information required consists of objective properties. Also, as the users are supposed to be people affected by floods, there will not be a community of regular users whose credibility can be assessed but rather different anonymous contributors for each flood event. The main focus will be on attribute accuracy for water level and flow velocity observations from the public as well as fitness for use of these data for empirical flood loss modeling.

Assessment of accuracy of information provided by the affected population

The assessment of the data on water level and flow velocity provided by affected people consists of three parts:

- <u>Consistency within dataset</u>: To approximate flow velocity, three questions were asked in the questionnaire. These were (1) a verbal description of flow velocity on a scale from "calm" to "torrential", (2) a question about debris transported by the water and (3) the question whether an average man could still stand. As these three questions are all on an ordinal scale with respect to flow velocity, they were compared using bar charts. Also, the answers to the third question were compared with the estimated water levels.
- <u>Comparison with data from hydraulic modelling</u>: For several communities within the Mulde River (a tributary of the Elbe) catchment, inundation of the 2002 flood was modeled by Apel et al. (2008) using a full two-dimensional hydraulic model. From the raster of inundation depth and flow velocity, values were extracted at the locations where data from telephone interviews were available and these values were compared using descriptive statistics.
- <u>Comparison with measured water levels</u>: Schwarz et al. (2005) measured water levels based on water marks on 400 buildings in the community of Eilenburg (Mulde River catchment) in the aftermath of the 2002 flood. As these measurements do not coincide with the locations of estimated water levels, interpolation of the water surface by kriging was performed in order to compare these data (see Figure 2).

First results of this assessment are provided in Section 3.

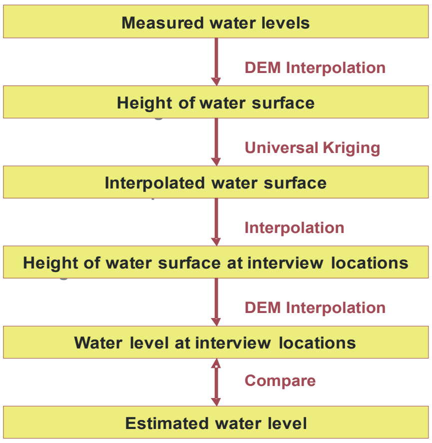

Figure 2: Comparison of measured and estimated water levels by geostatistical analysis.

Fitness-for-use analysis

After assessing the accuracy of the observations, the fitness for use of these data for empirical damage modelling will be assessed using the model FLEMOps (Büchele et al., 2006; Thieken et al., submitted). For this, a sensitivity analysis of the damage model with respect to the input parameters that are observed by the public will be performed and these results will be combined with the accuracy of the data to judge fitness for use.

Development of an automated procedure

The results of the quality assessment of existing data will be used to develop an automated procedure for the assessment of information of the affected population after flood events to be used in realtime. The challenge is that only very little data is available operationally and in near-realtime to aid the assessment.

3. FIRST RESULTS OF THE QUALITY ASSESSMENT

Consistency within dataset: The qualitative evaluation of consistency within the questionnaires aimed at the assessment of flow velocity. Overall it can be concluded that the answers to the three questions aiming at flow velocity in the questionnaires are largely consistent with each other (Figure 3). However, the description of flow velocity is much better correlated to the answers of the question if a man could still stand upright in comparison with the information about the largest particles deposited. As it is expected, the number of answers that “a man can stand easily” is significantly reduced from more than 50 answers in the description class “calm” down to no such answer in the description class “torrential”. The number of answers that “a man can’t stand upright” increases significantly from no such answer in the description class “calm” to about 30 such answers in the description class “torrential”. The answer that “a man can only stand upright with effort” is nicely in between, as it should be. The information about the largest particles deposited also show the right trend, however, this indicator seems not so suitable for a flow velocity differentiation. The answer “mud or sand” was similarly often given in the description classes “2” to “6 – torrential”, and the answer “boulders” was also similarly often represented in the description classes “3” to “6 – torrential”.

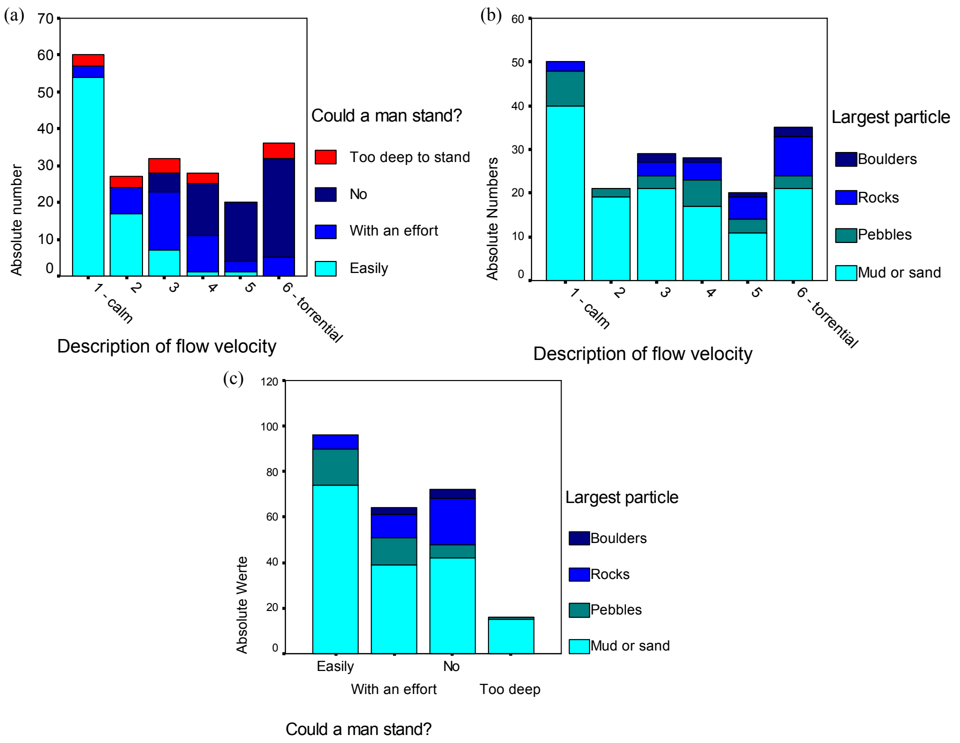

Figure 3: Comparison of the answers to the three questions aiming at flow velocity.

Comparison with data from hydraulic modelling: Estimates of both water level and flow velocity were compared with results from the hydraulic model using descriptive statistics. For water level, correlations and error measures were calculated (see Table 1, first data row). Although these deviations are relatively high, they are in a similar dimension as the deviations of the modelled data from measured data (Apel, 2008, see next section). Since the flood loss model FLEMOps uses classified water levels as input, the data were also compared after classification into the classes used by the model. As can be seen in Figure 4, more than 30% of the values are in the same class and more than 60% are within a difference of one class (which can easily happen when the values are close to the class borders).

	Mean of modelled data	**MAE of estimated data**	**Bias of estimated data**	**Correlation coefficient**
Water level	1.72 m	0.71 m	0.82 m	0.56
Flow velocity	1.79 m/s	1.62 m/s	1.42 m/s	0.03

Table 1: Descriptive statistics of estimated versus modelled data (MAE – Mean Absolute Error).

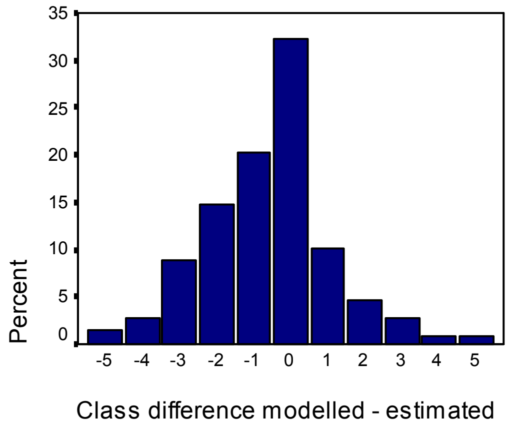

Figure 4: Deviations of classified modelled and estimated water level data.

For flow velocity, first rank correlations between the modelled data (ratio scale) and the estimated data (ordinal scale) were calculated. The values for the three questions were 0.217 for the verbal description, -0.040 for the type of debris transported and 0.255 for the question if an average man could still stand up, which confirms the finding from the indicator comparison (Figure 3) that the deposited debris seem to be the least suitable indicator for a differentiation/classification of flow velocities. Nevertheless, based on the question about debris transported, numeric values for flow velocity were calculated and these were compared with the measured values (see Table 1, second data row). The very low correlation and the large deviations of these data discourage the further use of the estimated flow velocity data, although it should be noted that the accuracy of the modelled data is unknown. At best, it can be concluded that the accuracy of the estimated data cannot be judged.

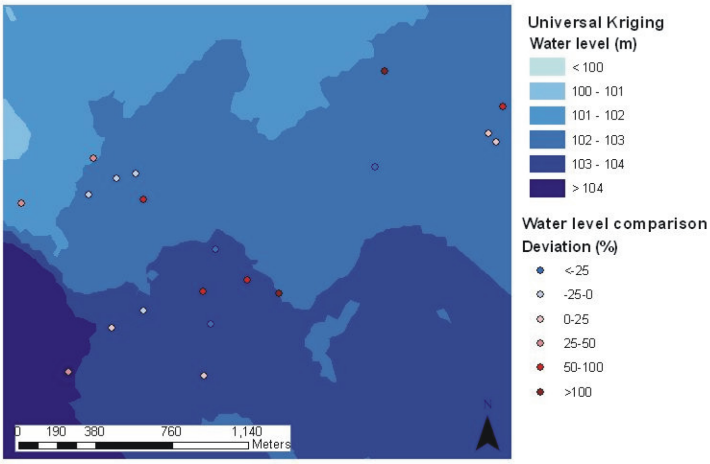

Figure 5: Modelled water surface with deviation of estimated water levels.

Comparison with measured water levels: For water level, the comparison with measured data yielded a Mean Absolute Error (MAE) of 0.70m and a bias of 0.37m (see Figure 5). Although these values may seem high, they correspond quite closely to the accuracy achieved by hydraulic modelling for the same flood event in the same area. Depending on the model used, hydraulic modelling yielded a MAE of 0.63-0.80m and a bias of -0.07- -0.62m, and still these data proved to be useful for damage estimation (Apel et al., 2008).

Summary of the results: From these results it can be concluded that the observations of water levels can be assessed using the given data and that they are accurate enough to be useful for empirical flood loss modelling. Their actual fitness-for-use will be assessed in the next step. For flow velocity, it can be concluded that the affected people give a consistent estimate of how fast the water flowed and that asking several different questions that aim at flow velocity helps to get a clearer approximation. However, these data cannot be validated using the given data. Since most flood loss models, including FLEMOps do not use flow velocity as an input parameter, the subsequent analyses will concentrate on water level only.

4. DISCUSSION AND OUTLOOK

New web technologies enable the general public to create geographic information. As some recent disaster have shown, this information can potentially be useful for disaster management and event and loss analysis. For this information to be useful, in particular for scientific or operational use, the assessment of its quality is pivotal. First results of this study show that water level can be estimated by observers with a similar accuracy as it can be modelled by hydraulic models and can be used for empirical flood loss modelling. The next challenge is to develop methods for automated quality assessment to be used operationally in web-based data acquisition where only a very limited amount of data is available operationally. This exemplary study of the fitness for use of observations of the water level by the affected population for flood loss estimation will hopefully contribute to an overall effort to evaluate the usefulness of humans as sensors for disaster management.

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