Leveraging OpenStreetMap to support flood risk management in municipalities: A prototype decision support system

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ABSTRACT

Floods are considered the most common and devastating type of disasters world-wide. Therefore, flood management is a crucial task for municipalities- a task that requires dependable information to evaluate risks and to react accordingly in a disaster scenario. Acquiring and maintaining this information using official data however is not always feasible, especially for smaller municipalities. This issue could be approached by integrating the collaborative maps of OpenStreetMap (OSM). The OSM data is openly accessible, adaptable and continuously updated. Nonetheless, to make use of this data for effective decision support, the OSM data must

be first adapted to the needs of decision makers. In the pursuit of this goal, this paper presents the OpenFloodRiskMap (OFRM)- a prototype for a OSM based spatial decision-support system. OFRM builds an intuitive and practical interface upon existing OSM data and services to enable decision makers to utilize the open data for emergency planning and response.

Keywords

Decision support systems, OpenStreetMap, Volunteered Geographic Information, Critical Infrastructure

INTRODUCTION AND BACKGROUND

Floods are the most impacting type of disasters world-wide and are expected to cause increasing damage in the near future (Guha-Sapir, Hargitt, & Hoyois, 2004). This makes flood risk management an important responsibility for governments and municipalities. In this context, the European Community passed the *Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risk* (The European Parliament and the Council of the European Union, 2007). This directive determines that European municipalities must have created and published flood risk management plans by the end of 2015. Nonetheless, mostly due to a lack of general guidelines, available resources and suitable data, many municipalities are having problems to meet the requirements of the directive.

Dependable data on the potentially affected areas and especially on the impacted critical infrastructure (CI) is an indispensable resource not only for planning risk mitigation strategies, but also for responding to flood events. By definition, CI objects are of major public interest and/or may cause serious harm if they are damaged or destroyed. Therefore, they require specific attention and protection (International Federation of Red Cross and Red Crescent Societies (IFRC), 2014). However, acquiring and maintaining high-quality data about CI is a demanding task. As a consequence, official information about CI of municipalities can be outdated and thus not include all necessary objects and information that might be needed for flood risk management.

Within this context, Volunteered Geographic Information (VGI) from the collaborative of OpenStreetMap (OSM) emerged as a promising information source, being investigated by a growing body of research studies (Schelhorn, Herfort, Leiner, Zipf, & Porto de Albuquerque, 2014; Soden, Budhathoki, & Palen, 2014; Zook, Graham, Shelton, & Gorman, 2010). OSM data is collected and maintained by volunteers and, owing to the open data structure, every registered user can edit or add data as well as attributes, thereby helping to improve and update the open data base.

These characteristics made OSM become a popular data source that finds increasing use in applications like Wikipedia, Map Box, CartoDB and Foursquare (Sehra, Singh, & Rai, 2014). Moreover, the data has been recognized to be a valuable data source for disaster management and emergency planning (Horita, Degrossi, Assis, Zipf, & Porto de Albuquerque, 2013; Soden et al., 2014). The OSM data has already been utilized in various disaster scenarios, including the earthquake 2010 in Haiti (Neis, Singler, & Zipf, 2010), the flooding 2010 in Pakistan[1] and the earthquake 2015 in Nepal (Poinani, Rocha, Degrossi, & Porto de Albuquerque, 2015). Some projects, like Missing Maps[2], also emphasize the use of OSM for disaster preparedness. The objective of this project is to map vulnerable places in the world in OSM and to thereby make the map material available to prepare for and respond to disasters.

While the potential of OSM has been recognized, humanitarian aid organizations nonetheless still refrain from using the data. This is often due to the fact that the volunteered data is not expected to be of high quality. Furthermore, the official organizations are not yet familiar with the OSM structure and services and rather rely on familiar tools (Harvard Humanitarian Initiative, 2011; UN OCHA, 2012). While the OSM data in Germany is expected to be of a great level of quality and detail due to an active OSM mapping community (Neis, Zielstra, & Zipf, 2013), the second issue also emerges here. The OSM effective for improving decision-making in local governments is still challenging, as municipalities often lack the resources and knowledge to utilize OSM data for their tasks. The OSM services are mostly targeted to users with more advanced technical skills. Besides, municipalities often have difficulties in connecting the bottom-up, heterogeneous data structure of OSM with their information needs and flood risk management practices. Thus, if these issues could be overcome, OSM

[1] http://wiki.openstreetmap.org/wiki/2010_07_Pakistan_Floods 25.02.2016.

[2] http://www.missingmaps.org. 25.02.2016.

could however become a valuable data resource. Therefore our research objective is to assess, how OSM data and the services can be made available and utilizable for local decision makers in flood risk management.

In order to address this question, the OpenFloodRiskMap (OFRM) was developed. The OFRM is a prototype for a web-based spatial decision-support system aimed at assisting decision makers to leverage OSM as an information basis for tasks in flood risk management through the adjustment and combination of OSM services.

The paper starts out by describing the approach of the OFRM and the utilized OSM services. In the subsequent section the adjustments to the OSM services that were conducted to meet the requirements in flood risk management are presented. In the following, the OFRM user interface is displayed to show how the functions are provided to decision makers, before leading over to the discussion and outlook.

APPROACH

The objective of this paper is to present a prototype web application to assist decision makers in developing alarm and operation plans for flood risk management. The OFRM hereby provides support in accessing CI information in the OSM data base and to furthermore add this information to an emergency routing service.

In a disaster scenario decision makers need to be able to identify asset types of CI as these objects are of specific interest for the community and thus, deserve special attention. While there are various frameworks containing definitions and categorizations regarding this concept, these documents do not contain object type catalogues listing these infrastructures on an object level. For this purpose, a catalogue of asset types of CI was already developed by Herfort et al. (Herfort, Eckle, Porto de Albuquerque, & Zipf, 2015). In the OFRM, this catalogue serves as a preselection that enables identifying CI in OSM.

In a flood scenario, decision makers have to moreover navigate to the CI objects, e.g. for evacuation or to provide security measures, while considering flood related road conditions. This kind of information cannot be considered in a general navigation system, nor can these systems detect CI objects. In the OFRM, the core functionalities of two OSM-based services are adjusted and combined to meet these requirements in flood risk management.

OSM services for CI selection and Emergency Routing

There are various tools to select or export OSM data based on boundaries or defined areas, e.g. the Geofabrik[3] or the HOT export tool[4]. The latter was developed for the use in humanitarian aid, to enable accessing current humanitarian map data for GIS analysis and the use in GPS and mobile devices. Yet, none of these tools allow the user to select specific object types. A tool that is commonly used to run type-based queries in OSM is overpass turbo (Olbricht, 2015). This application allows for running queries based on user defined tags. These tags are used to identify object types which are then cross-referenced in the OSM database using the Nominatim tool[5], a search engine for OSM data.

In the case of a flood, decision makers need to furthermore be able to access and navigate to and from CI. While official data is not necessarily designed for routing and therefore not utilizable for routing applications, OSM data can contain all necessary information. Therefore OSM can be used for routing in countries with a sufficient level of detail and OSM data coverage (Schmitz, Zipf, & Neis, 2008).

Under normal circumstances, regular OSM routing service, e.g. OSMand[6] and YOURS[7], could be utilized to navigate to and from CIs, if CIs and their locations are known. However, these systems cannot and do not take into consideration emergency related information, e.g. flooded areas or impassable roads. When streets are flooded or blocked, customary routes cannot be utilized anymore. The OpenRouteServive (ORS) is an OSM based routing service that was specifically developed for the utilization in disaster situations (Weiser & Zipf, 2007). Since its first utilization in a real world disaster situation in Haiti 2008 after hurricane Ike (Schmitz et al., 2008), this emergency routing service was successfully utilized for disaster management support after the 2010

[3] http://download.geofabrik.de/ 26.01.2016.
[4] http://export.hotosm.org 26.01.2016.
[5] http://nominatim.openstreetmap.org/ 26.01.2016.
[6] http://osmand.net/ 26.02.2016.
[7] http://www.yournavigation.org/ 26.02.2016.

earthquake in Haiti (Neis, Singler, & Zipf, 2010) and recently for disaster response in Nepal 2015[8]. The ORS allows users to choose between route options, vehicle type and vehicle properties as well as special roads to be avoided. In the ORS applications that have been developed for disaster scenarios, users can moreover define bypass areas and avoid destroyed roads. Information about destruction and road conditions can be added by the OSM community. Additionally, ORS provides functionalities to calculate the accessibility of a location (Neis, Dietze, & Zipf, 2007).

IMPLEMENTATION OF OSM SERVICES

In the OFRM two OSM based services, the overpass turbo API and the ORS were combined to meet the requirements in flood risk management.

The overpass turbo application was recognized to meet the requirements of the OFRM regarding the selection of OSM objects. In contrast to the original application, in the OFRM the object type selection is based on the defined catalogue of potentially critical object types. Thus, users are already provided with a preselection containing all relevant critical object types from which they can choose those required at the situation at hand. While overpass turbo also allows users to draw bounding boxes to limit the search area, in the OFRM this area can be adjusted individually using a drawing tool, e. g to match flooded areas or bypass these areas. As the OFRM additionally allows registered users to display flood hazard maps, the areas of interest can be easily identified. The defined criteria, regarding object types and search area, are then added to a request send to the overpass turbo API. The results of this query contain all objects in the OSM data base that match the defined object types and criteria.

All objects that are listed in the results can be printed out for field use or may be directly added to the emergency routing service. Another supplementary feature in OFRM is a link to the OSM iD editor[9]. This feature allows registered OSM users to add or edit information for the selected object in the OSM database. An overview of all adjustments to the overpass turbo functionalities in the OFRM is provided in table 1.

<table>
<tr><th colspan="2"></th><th>OpenFloodRiskMap</th></tr>
<tr><td rowspan="3">Functionality</td><td>Find Critical Objects</td><td>Selection of object types from defined catalogue of asset types of critical infrastructures</td></tr>
<tr><td>Define search area</td><td>Individual area, specified by user with drawing tool</td></tr>
<tr><td>Results</td><td>- List of critical objects in OSM, sorted according to critical sector
- Print function for field use
- Direct transfer of critical objects to emergency routing query
- OSM Id editor link: editing of object in OSM data base
- Storage function for further use of query</td></tr>
</table>

Table 1. OpenFloodRiskMap Critical Object Query Functionalities

The emergency routing in the OFRM is carried out using core functionalities of the ORS. The ORS is utilized, on the one hand, to enable routing based on the current information in the OSM database and, on the other hand, to enable accessing the ORS emergency extensions. Likewise to the overpass turbo functionalities, the ORS functionalities were however adjusted to meet the requirements in flood risk management. While the original ORS application only allows users to define a start and end point by providing an address, for the OFRM this

8 http://www.openrouteservice.org/disaster-nepal/ 26.01.2016.

9 http://ideditor.com/ 26.01.2016.

functionality was expanded to enable better flexibility in an emergency situation. As explained in previous paragraph, objects listed in the results of a critical objects query can also be directly added as navigation destinations, moreover new destinations can also be added by setting a new mark into the map. Likewise to the original ORS functionality, users can add bypass areas, e.g. to avoid a flooded area. This will cause the service to automatically detect the obstacle and choose a route around the defined area. As registered users can display flood hazard maps in the OFRM, bypass areas and areas at risk can easily identified. An overview of all adjustments to the ORS functionalities in the OFRM is provided in table 2.

		OpenFloodRiskMap
Functionality	**Starting and end points**	- Full OSM data base - Selection of object types of critical object query - Setting of new navigation destination in map
	Define areas to avoid	- Individual area, specified by user with drawing tool - Integrated Flood Hazard Map layer to assist identifying bypass areas
	Results	- Print function for field use - Storage function for further use of query

Table 2. OpenFloodRiskMap Routing Query Functionalities

The result of the routing query is displayed with time of travel, routing distance and the route itself.

All queries can be stored, edited and are run in the current OSM database. Therefore users receive up-to-date information regarding CIs and routing conditions. An illustration of the OFRM system architecture is displayed in figure 1.

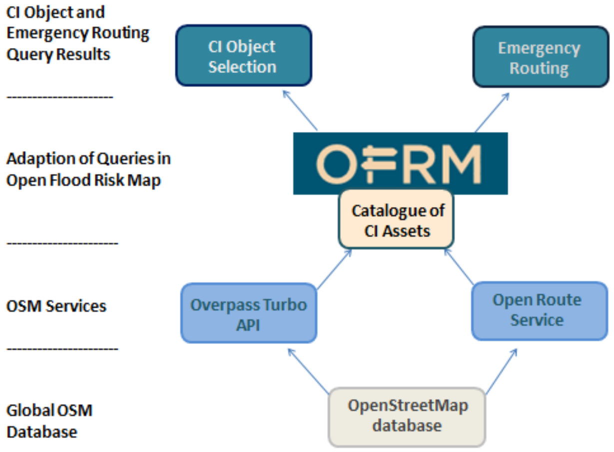

Figure 1. OpenFloodRiskMap System

OFRM USER INTERFACE

A prototype of the OFRM was implemented and is openly accessible at https://ofrm.de. The core functionalities of the application are publicly available which allows the public to test and provide feedback about the decision support system. The use of more sophisticated features, like display of flood hazard maps, as well as saving and loading queries, or the implementation of user-defined geographical objects, is restricted to professional users provided with appropriate login credentials. The following figures show all core functionalities of the professional version in use. Figure 2 displays the query functionalities which can be found on the left-hand side of the user interface, figure 3 moreover presents the map view in OFRM in which the defined critical object types and routes are displayed.

Figure 2. Critical Objects and Emergency Routing Query

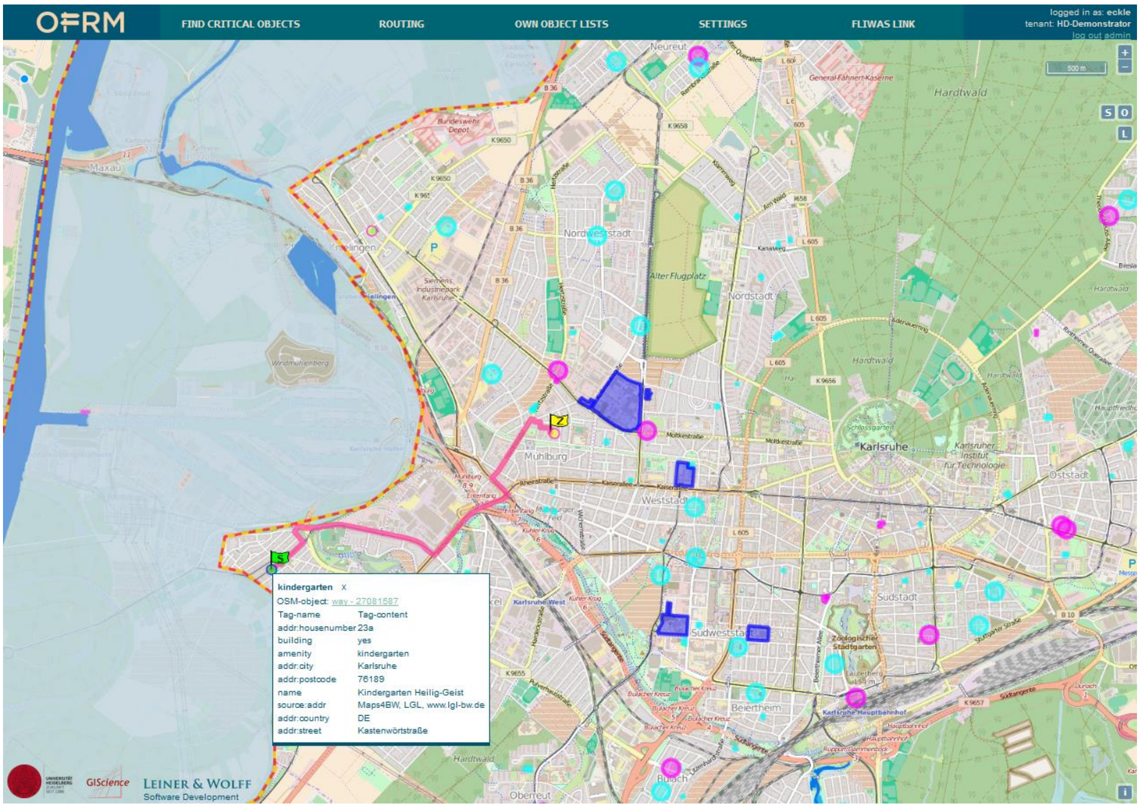

Figure 3. OpenFloodRiskMap Map View

DISCUSSION AND OUTLOOK

The OFRM allows decision makers to make use of the OSM data base in order to create emergency plans and to respond accordingly in the case of a disaster. This tool therefore provides an example on how to make OSM data and tools available for specific use cases by adjusting the already existing OSM services to the needs of users, in this case decision makers in flood risk management.

An additional advantage in the OFRM is the possible integration of supplementary data sources. Already in the prototype of the OFRM flood risk maps are integrated to enable easier identification of areas at risk. The integration of further data layers could help to furthermore improve the level of detail and quality.

The OFRM prototype is currently being evaluated with local decision makers in flood risk management in Baden-Württemberg (Germany) to assess the practicability of the application, possible extensions and limitations of the OFRM. With OSM being a crowdsourced map, the database is only as good as the contributions the OSM community provides. The quality of the information provided in OSM as well as the level of detail of the data therefore varies depending on the number of members and contributions (Neis & Zipf, 2012). This could cause some features to malfunction. If these issues are detected, the database can nevertheless always be improved and updated by the OSM community, including the local public and the decision makers- a possibility not given for official data.

OpenStreetMap is an online map data base of the world. Thus, there are in general no limitations regarding the use of the map data, and accordingly no limitations in OSM based applications like OFRM. Flood management is only one sector in which a lack of available data causes challenges for decision makers. This issue is however known in all fields of disaster management. The method presented in this paper should therefore be tested for other use cases and scenarios to enable more people to benefit from the open data base.

ACKNOWLEDGEMENTS

The authors are thankful to Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW) for providing funding for this research within the "Klimopass" program. The authors also thank Joachim Fritz of the technical construction department in Offenau and Frank Lamm of the technical construction department in Karlsruhe for their practical insights. J. P. Albuquerque is grateful for CAPES (grant no. 12065-13-7) and Heidelberg University (Excellence Initiative II / Action 7) for supporting his contribution to this research.

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