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A STUDY OF VOLUNTEERED GEOGRAPHIC INFORMATION (VGI) ASSESSMENT METHODS FOR FLOOD HAZARD MAPPING: A REVIEW

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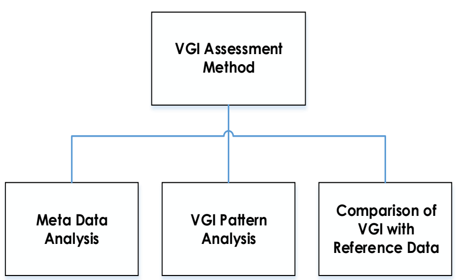
Graphical abstract



Abstract

Floods are known as frequent and destructive global events that are caused by natural and human factors. Beside traditional methods, flood hazard mapping has been empowered by spatially enabled cell phones and web mapping technology which are feed by user generated data. This user generated information or Volunteered Geographic Information (VGI), becomes the first point of response during any natural disaster. Since this information is created by volunteers, its reliability and credibility issues bring restriction on use of them as main source of information. The available methods of VGI credibility assessment mainly focus on meta data analysis, VGI spatial pattern analysis and comparison of VGI data with reference data. This paper thoroughly discusses recent development in these three groups of VGI assessment methods. At the end we highlighted several research gaps and potentials of combining and improving these methods to support flood hazard mapping.

Keywords: Volunteered Geographic Information (VGI), Web 2.0, Flood Hazard Mapping

Abstrak

Banjir merupakan kejadian kemusnahan global yang sering berlaku disebabkan oleh faktor-faktor semulajadi dan manusia. Di samping kaedah tradisional, pemetaan bencana banjir telah diperkasakan oleh telefon pintar dengan keupayaan maklumat ruang dan teknologi pemetaan web menggunakan data yang dibekalkan oleh pengguna. Maklumat terbitan pengguna ini atau Maklumat Geografi secara Sukarela (VGI) merupakan data tindakbalas pertama semasa bencana banjir. Oleh kerana maklumat ini dicipta oleh sukarelawan, isu kebolehpercayaan dan kredibilitinya membawa sekatan ke atas penggunaan maklumat ini sebagai sumber utama. Kaedah-kaedah sedia ada bagi penilaian kredibiliti VGI telah memberi tumpuan terutamanya kepada analisis metadata, analisa corak spatial data VGI dan perbandingan data VGI dengan data rujukan. Kertas kerja ini membincangkan dengan teliti pembangunan terbaru dalam ketiga-tiga kumpulan kaedah penilaian VGI. Pada akhirnya kita menekankan beberapa jurang penyelidikan dan potensi menggabungkan dan meningkatkan kaedah ini untuk menyokong pemetaan bahaya banjir.

Kata kunci: Maklumat Geografi secara Sukarela (VGI), Web 2.0, Pemetaan Bahaya Banjir

1.0 INTRODUCTION

Disasters such as hurricanes, earthquakes and flood often leave widespread damages and data is crucial part for managing disaster and relief operations. In disasters data can be supplied in variety of ways such as remote sensing, interviews, photos, videos or via social media. GIS can be used in different phases of the disaster management. Most efforts related for using GIS in disaster management are focused on identifying hazards, rather than analyzing social patterns that describe vulnerability. Understanding the physical hazard is one thing, but if people cannot remove themselves from harm on time, disaster management could be in vain.

The introduction of Web 2.0 provided valuable tool to achieve public knowledge of new disasters and has provided the public to participate to create content and give opinions in social networks. Volunteered Geographic Information (VGI) can help since the volunteers are in scene, which inform rescuers isolated from the scene to find those who are in most urgent need. For VGI assessment this paper covers data mining technique, VGI comparison with its own data method and VGI similarity with authoritative data. A table itemizing the techniques covered in this paper is presented in section 3. The rest of the survey is organized as follows. Section 2 examines flood hazard management background. Section 3 listed VGI credibility issues and discusses VGI assessment methods.

2.0 FLOOD HAZARD MANAGEMENT STRATEGIES

In a two-component gel, it is easy to modify the molecular structure of either of the two components. Unfortunately, flooding can't be prevented entirely, but we can manage flood risk and reduce its impact. Urbanization accelerate flooding, changes in the urban area and inadequate drainage capacity cause runoff and flood [1]. Small streams in urban areas can also rise quickly after heavy rain due to higher generated runoff and less concentration time as depicted in Figure 1.

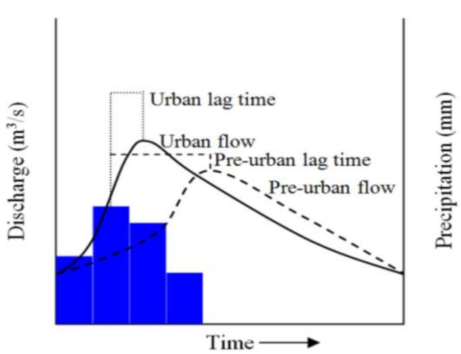


Figure 1 Typical hydrograph of urban and non-urban area [2]

We can adapt a more sustainable approach to manage flood by looking at the whole catchment area and parameters that impact and affect flood risk directly or indirectly. Flood management strategies divide in two main categories of hard and soft engineering [3]. Table 1 shows a summary of hard and soft engineering approaches for flood hazard management.

Table 1 Summary of hard and soft engineering approaches for flood hazard management

Hard Engineering	Soft Engineering
Dams & Reservoirs	Land Use Zoning
Flood Walls	Forestation
Rip Rap	Flood Prediction
Embankments	Warning System

2.1 Flood Hazard Mapping

Floods are known as frequent and the most devastating events worldwide. Maps become the common element for identification of flood prone areas, preparation of emergency response, and design of flood protection and flood proofing measures. People are first line of defense against flooding. The main purposes of a flood hazard map is to show the extent of flooding under a given scenario and provide information for smooth evacuation, it can also be used as a basis for integrated flood risk assessment as well as resources management. Flood hazard maps are one main part of soft engineering in flood hazard management and are necessary for emergency response and for long term flood disaster management. Flood hazard maps are detailed flood plain maps complemented with type of flood, its extent and depth and flow velocity [4]. The existing flood hazard mapping techniques are based on flood plain modeling, hydrological analysis and satellite data [5].

Flood hazard maps usually are created by morphological approaches, remote sensing data and simulation methods. For disadvantages of these approaches we can point to lack of common methodology to model flood as every location has its own geomorphological and environmental characteristics. The U.S. Geological Survey has developed three methods to make maps of floods for long stretches of a river near forecast points [6].

The first one is using LiDAR technology, second is a computer program that can simulate flood flows all across the floodplain; the third one is using GIS. The current approaches of mapping flood hazard using DEM and satellite images has its own drawbacks, such as being expensive, radar images are hard to interpret, optical remote sensing can be obscured by clouds, simulation techniques are time consuming and always complete long after flood hits a place. Flood hazard mapping is a challenging task, not only because there is no common methodology on how to model and map flood, but because of the fact that updating flood hazard map requires constant review and updating of spatial data. The conventional approaches of mapping flood hazard using high resolution DEM or satellite images for flood vulnerability of an area are too costly especially for developing or least developed countries. As flood data collection and processing for making flood map relies on expensive technology and professional experts, to measure flooding, the authorities must check data from fixed measuring sites that have been set up throughout the country. In addition, the traditional methods of map-making by government agencies, are constantly subject to funding constraints [7]. There are some limitations that agencies usually face in making flood hazard maps, such as the fixed orbit pattern of satellites, revisit time span that may cause data collected long after a flood has receded and limited spatial resolution of satellite data that may be too coarse for identifying small flooded areas [8].

Remote sensing would not be so useful in cloudy weather. Many types of geographic information are not suitable for remote sensing like population density and street names. Remote sensing acquisitions usually carry out a few days after the event, as the floods recede quickly and often, after major events, bad weather conditions hinder the successful acquisition of optical satellite or aerial photogrammetric data [9].

GIS software's are crucial part of plotting the flood data but geographic information usually produces either by large public organizations or by commercial data providers. In hazard management e.g. flood cases, different parameters such as water levels or water contamination are measured by sensor networks or installed instrument. The recent web developments and its availability have made collection of information from the public easier and faster, and make it possible to collect information from volunteers on a large scale to make flood hazard maps.

The introduction of social media, GPS tools especially and the use of geo-data leads to achieve a better situational awareness during disasters and pave the way for getting geospatial data from volunteers. The creation of flood hazard map based on user-generated spatial data will allow users to easily identify critical elements and infrastructure in their local environment. By employing volunteers in a constructive way, a process model as well as a technical implementation can be developed to combine official flood hazard maps and free geo-data by crowdsourcing.

2.2 VGI for Flood Hazard Mapping

One of the main applications of VGI is to show flood affected area and provide facilities for monitoring the places that is hit by flood. Accurate and timely flood assessments are critical during all phases of a flood disaster. The need for regular monitoring and evaluation as well as social security systems for flood mitigation are necessary. By means of new computational systems, flood hazard maps can be generated publish in real time to benefit residents of risky area. However due to the lack of awareness, resources and suitable approach, flood hazard maps couldn't be generated frequently even in developed countries [10]. In case of a disaster, there is an immediate need for maps since emergency responders have to know where they are located and how to get relief to them. Large parts of society especially in developing countries lack updated and related maps to cover area of incident.

Social media provide a portal for the public to disseminate information quickly. It helps public to link to external data sources such as Twitter, YouTube and Flicker. Twitter is one such service that allows users to broadcast short textual messages, or tweets by using web or mobile based platforms. An important characteristic of twitter is its real time nature, users frequently post what they are doing and thinking about and the information is updated by users [11]. Twitter can be used as a tool to better understand the big picture during critical situations, and make the best, most informed decisions possible for deploying aid, rescue, and recovery operations [11]. Twitter enhances user information updates related to real world events including natural disasters such as earthquakes and flood. OpenStreetMap (OSM) project is a prominent example of Web 2.0 style mapping, which increased the ability for volunteers to assist in disaster response situations via mapping and other spatial analysis [12]. The same researchers also listed out the benefits of Web 2.0 in disaster response, they state the greatest benefit to this form of distributed mapping is that a greater number of maps can be produced in a shorter period of time, and the second important benefit of Web 2.0 and disaster mapping is the ability to allow individuals to report on local and specific conditions. The integration of social media with local government increases citizen participation e.g. urban planning, management and crisis mapping.

The development of Web 2.0 and the availability of geolocated mobile devices such as GPS units have introduced new age of geography that named neogeography. Neogeography is defined as the complicated ways in which people interact with geography, that is not merely the production of information, but also includes map creation, personal analysis and reading and understanding of geographic information [13]. In neogegraphy the data can be from volunteers or from professionals, which may be open or closed source. VGI is information from potentially untrained volunteers that can be used for knowledge sharing about incidents and suggest government to use these technologies in emergency management. The reliability and liability of citizen generated information for disaster management is controversial and this survey seeks methods and opportunities to utilize this technique in disaster management. The term VGI was coined by Goodchild to describe user generated geographic information [14]. VGI is harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals. GIS is designed on the base of static map, that's there is need for online flood hazard map and its automatic updates. In case of disaster, people from surrounding areas can provide nearly real-time observations about disaster scenes. The different type of volunteered information brings different concept of data quality and pose new challenges, while this growing can be useful in data quality.

3.0 VGI DATA CREDIBILITY ASSESSMENT

VGI can be a useful source in disaster management. However, we need a framework to ensure its quality and reliability. There are concerns for using VGI as a data source as we are not sure for its credibility and reliability. Data collection by volunteers is sensitive by the issue of data quality and accessibility. One of the major concerns of using VGI as a source of input to authoritative databases is how to assess the credibility of contributors and the reliability of their contributions. However, what becomes a great challenge, is the chaotic nature of VGI, with little in the way of formal structures [15]. Information is constantly being created and cross-referenced, and flows in all directions. In other definition [16] stated lack of integrated interfaces and variety of data format main problems facing using VGI for emergency management.

So to make use of the humans potential and make their report of the affected population usable for disaster management and loss estimation, it is essential to systematically and in an automated or semi-automated manner assess the quality and reliability of this kind of information. In the 1980s discussions over a potential geospatial data standard for the US Federal Government led to a consensus on five fundamental dimensions: positional accuracy, attribute accuracy, logical consistency, completeness, and lineage [17]. More recent literature has suggested the addition of further elements, including temporal accuracy and semantic accuracy. Several studies have evaluated the accuracy of VGI against reference sources.

The main limitations of data collected from the affected population, are as follow [18]:

- Affected people in incidents are not like physical sensors.
- Humans cannot adopt completely with standards.
- The extent of disaster can have impact on their emotions and have exaggeration on their posts.
- It is unknown, how much and from where information will be supplied and local agencies or rescuers cannot rely completely on updated information.

3.1 Analysis on spatial pattern of VGI data

The first law of geography according to Tobler tells that all things are related, but nearby things are more related than distant things, that describes spatial dependence, and suggests a location should be consistent with what is already known about the location's vicinity [Tobler, 1970, as cited in 19]. A report of a flood, for example, is more likely to be true if the torrential rain has already reported nearby. Some studies in GIScience have used locational information to quickly detect and locate disaster [17, 20-23]. several studies show VGI during crisis events, and have found "intrinsic value" for rescue teams, relief workers and humanitarian assistance coordinators, as well as the affected population [16].

According to Linus's Law; given enough eyes, all bugs are shallow, crowdsourcing brings the ability to reach the truth. Some studies check the function of Linus's law for VGI, as an example in Wikimapia project that is one successful examples of VGI, which accustom with some of the procedures that used in the creation of the Wikipedia. the effectiveness of this mechanism in the case of Wikipedia is documented [24]. It is tempting to think that Linus's Law can be applied to quality assurance for VGI. Several factors may have contributed to the failure of Linus's Law in this instance. First, Wikimapia may attract people with a greater interest in contributing than in editing. Second, the number of eyes with sufficient local knowledge may be very small. Finally, the architecture of the site may make it too difficult to correct or delete errors [17]. OSM is currently the most extensive and widely-used example of VGI available on the Internet. OSM is a project to create a set of map data that are free to use, editable and licensed under new copyright schemes, it can be edited online through a wiki-like interface where, once a user has created an account, the underlying map data can be viewed and edited [25].

A group of researchers defined and measured the different quality elements associated with crowdsourced data, and introduced means for dynamically assessing; they argued that the required quality assurance and quality control is dependent on the studied domain, the style of crowdsourcing and the goals of the study [26]. A new method for weighting VGI to identify elements at risk from OSM to validate their approach in the case of flood hazard presented to show that the conceptual match between elements at risk and VGI results in a generally applicable framework for the identification of elements at risk. The framework can add value in the process of evaluating the exposure of assets to potential hazardous events [27].

The procedures to enhance the quality, during the acquisition and compilation steps into the crowd sourcing and social approaches [17]. The social approaches rely on a hierarchy of trusted individuals who act as moderators or gatekeepers. Most of the researchers have used the spatial and temporal characteristics of VGI for its analysis. Spatio-temporal proximity and social distance were practiced to confirm the quality of VGI [28]. Their method is based on reciprocal confirmation of reports by other reports. One problem with their approach is that there must be always experts available for verification process that takes too long. Some researchers try to use fuzzy set to evaluate VGI quality that formulate and validate VGI by applying fuzzy rules in the database [29]. An architecture for harnessing social media for emergency awareness was introduced that is based on streaming Twitter during natural disasters and building statistical classifiers to identify automatically relevant tweets [11]. For classification they used two machine learning methods naive Bayes and support vector machines, after that they applied online clustering for topic discovery.

3.2 Meta Data Analysis

The metadata of VGI can be structured or unstructured and there is a fuzzy area between structured and unstructured. For extracting the metadata of VGI through web sites data mining methods is needed. Data mining the task of finding frequent pattern in large databases is very important and has been studied in large scale in the past few years. By data, mining one can browse to the websites of interest to locate and capture information. Classification, regression and clustering are the three main types of data mining applications.

Metadata of Web resources provide information about the web resources and enable us to use these resources in a better way.

The quality assurance provided by traditional mapping agencies has two parts: procedures designed to control quality during the acquisition and compilation of geospatial data, and procedures that document quality by taking samples of compiled data and comparing them to reference sources. The latter procedures are typically documented, and the results are attached to the data in the form of metadata. Some degree of generalization is inevitable, since it is impractical to check every item of data [17]. Volunteers who create data can also create Metadata for what they have added or updated in the open maps e.g. OSM.

In efforts to provide a better way to find proper resources on the WWW, research has been undertaken to analyze Web resource content and to create metadata automatically of a quality equal to that generated by humans but without the cost and scalability problems [30]. There have been two main approaches in automatic generation of metadata: harvesting and extraction. Harvesting draws information from existing metadata in the resources such as Metatags in HTML. Extraction generates information automatically using an algorithm based on the attributes or content of the resources. Information extraction and natural language processing techniques are used for extraction.

3.3 Comparison of VGI with Reference Data

A great number of researchers have focused on comparison of VGI with authoritative data to estimate the certainty of VGI. Some of the researchers use image and video interpreting techniques to make maps, they gathered VGI in form of amateur images and uses them as the main source of data to delineate the extent of the flood, next they compared the resulted map with the flood map from satellite images [9]. For getting VGI in the form of images, they used a public call for volunteered contributions and a web search for useful images. Some other researchers used VGI such as photographs and videos to assist in mapping the flood extents in regions where there was little or no mapping available [8]. But their methods failed to give on time map of flood.

Through the integration of volunteered information with existing geographic information, hydrological data and local knowledge, flood extents can be re-constructed and mapped. A methodology that uses non-authoritative data to develop flood extent mapping proposed that geolocated photos, twitter, cameras and OSM as four sources of non-authoritative data were used for identifying the presence of water to make flood hazard map in case of limited remote sensing data [31]. The impact of Twitter reports on the situational awareness during natural hazards within the field of crisis informatics was analyzed [32]. In that study, the presence of location references as well as situational updates like warnings and preparatory activities within topic related tweets were investigated by concerning two different catastrophes: the Oklahoma Grassfires of April 2009 and the Red River Floods in March and April 2009.

There are some successful examples of VGI for mapping disaster such as the interactive Gulf of Mexico Oil Spill map as a mapping disaster application of VGI that created in April 2010 after the Deepwater Horizon oil rig explosion, shows VGI related to the massive oil spill posted by citizens via Twitter, YouTube, Flickr, and Ushahidi [33]. The application provides context to the VGI data by including map data supplied by authoritative sources and the 2011 floods in Queensland, Australia. A prototype system presented that was designed to retrieve, process, analyze and evaluate social media content on forest fire, producing relevant, credible and actionable VGI usable for crisis events. The novelty of his approach lies in the enrichment of the content with additional geographic context information, and use of spatio-temporal clustering [16].

The quality of OSM has compared with data from the Ordnance Survey of Great Britain, the national mapping agency that resulted an average positional displacement of 6 m, but a substantial geographic variation in both positional accuracy and completeness [34]. Such studies give useful insights into the accuracy of VGI, but only indirectly help to identify mechanisms for assuring and improving quality. In one research geographically weighted kernels was used to estimate surfaces of volunteered land cover information accuracy and then to develop spatially distributed correspondences between the volunteer land cover class and land cover from 3 contemporary global datasets (GLC-2000, GlobCover and MODIS v.5) [23]. The methods suggest that some of the concerns about the quality of VGI can be addressed through careful data collection, the use of control points to evaluate volunteer performance and spatially explicit analyses.

Some researchers examine the application of VGI in real cases and explore its advantages in crisis and catastrophes. They investigated through the use of VGI in undeveloped country like Haiti and outline some of the ways that IT was used in relief efforts [12]. They focused on CrisisCamp Haiti, OSM, Ushahidi, and GeoCommons to demonstrate that IT was a key mean through which individuals could make a definite difference in the work of relief and aid agencies without actually being physically present in Haiti. In another study reverse viewshed analysis was used to assess the location correctness of visually generated VGI [35]. They have used metadata of Flickr as data source to assess the location correctness and thereby the credibility of Flickr contributors. Their approach after categorizing photos by their location they did the label correctness of photos manually. Table 2 summarizes the recent studies for VGI credibility assessment methods.

The problem of mapping user-generated data of Haiti earthquake as the duplication of efforts and barriers to combining data sets generated within different software packages that resulted by lack of compatibility between OSM and another leading means for crowdsourced street maps, Google's Map Maker [12]. In conclusion the recent methods of VGI assessment give more reliable results as there is some comparison with reliable data. The three approaches are summarized in Table 2.

4.0 CONCLUSION

According to Linus's Law, the more people that are involved and engaged in a community or in a project, the more we are able to identify and eliminate any error. from the perspective of sustainability and scalability there is no guarantee that for a given event there is a sufficient volunteer force, but in emergencies time is important when traditional methods are too slow [16]. A bit unreliable information in early moment of any incident is more valuable in saving lives than precise information later. In disasters geographic information need only be good enough to assist recovery workers to use the updated maps and it can be even more useful if the public contributions can be incorporated and distributed in near real time [12].

In case of flood, flood hazard maps are fundamental tools for community based flood management. In order to prepare flood hazard map of any area, data including hydrological, hydraulic, base maps are essential. These sorts of data are not easily available in every scale and location and is time consuming. However, getting information from the crowd has its own problems. Quality perhaps is the first issue when we want use VGI. Traditional methods of map-making by government agencies, which require expert are led to delays in the updating of maps because of expense and limitations. It is not certain whether VGI contributors are trained adequately to produce high quality geographic information and why they contribute their time and energy to produce and share geographic information. In emergencies accuracy of VGI is important a fully rely on VGI maps can be problematic and is not prudent that can leads to delay to respond to an actual hazard. Therefore there must be a balance for our judgment about VGI. Researchers followed three methods for validation of VGI; they used data mining approaches which use data mining techniques to filter VGI, such as reputation analysis, the group of researchers used VGI data to filter out VGI by using different type of geostatistical analysis. The last one has focused on cross validation of VGI by authoritative data to estimate the reliability of VGI. All the studies failed to reach fully automated method to filter out VGI in timely manner.

Table 2 VGI credibility assessment methods

VGI Assessment Approaches	Description of the Methods	Advantages & Disadvantages	Authors
Metadata Analysis	Presenting 4 classes of descriptive elements for designing an automated metadata generation system. In another study after getting Flickr photos they conducted reverse viewshed analysis to determine the photos lie within the area of visibility of the observer points.	Better data harvesting algorithms would create by these 4 classes. There is possibility of unintentionally errors due to user lack of sufficient knowledge.	[30], [35]
VGI Pattern Analysis	Several methods have tested such as Building statistical classifiers to identify automatically relevant tweets. Development of a prototype to retrieve, store and analyze VGI by cluster analysis and verification of results by cross validation. Using Geographically weighted kernels were used to estimate surfaces of volunteered land cover information accuracy. Spatio-temporal Proximity and Social Distance to confirm the quality of VGI Getting photographs and videos to assist In mapping the flood extents. Validating VGI by applying fuzzy rules in the database	Two types of clustering usually were applied that, automatically grouped tweets into topic and validated results by means of correlation. The researches mostly focus on using location to filter and verify VGI. In some parts the tweets were manually classified. Analyses of the videos and photos have been done days after flood event and can be used as a supplementary map. It utilized non-authoritative data by interpolation to make flood assessment. One problem with their approach is that there must be always expert available for verification process	[36], [8], [11], [37], [16], [23], [28], [29]
Comparison of VGI with Reference data	Using amateur images as the main source of data compare the resulted map with satellite images. Comparing the quality of OpenStreetMap with data from the Ordnance Survey of Great Britain. Applying reverse viewshed analysis to assess the location correctness of VGI. Then compare dependency relationship between the locations.	The satellite maps were based on satellite images taken days after flood. Using public call for volunteered images means it takes time to prepare map. Describe different concept of information quality credibility. Using Flicker as data source after categorizing by their location, label correction of photos were done manually. That means the results would not in real time.	[9], [34], [18], [35],

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