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Flooding and inundation collaborative mapping – use of the Crowdmap/Ushahidi platform in the city of Sao Paulo, Brazil

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Abstract

The trend of using volunteered and collaborative data in the context of natural disasters has been increasing. This fact, together with floods and inundations, which occur in the city of Sao Paulo, makes it possible to explore the volunteered and collaborative way of generating and transmitting geographic data dynamically. This can be done by using technologies affordable to the population, such as the Internet, the global positioning system and other monitoring systems embedded in mobiles. This article aims to present the proposal of a conceptual scheme for a dynamic and collaborative mapping system of flooding points, whose data source comes from people equipped with mobile devices that allow identify their locations. The results correspond to the conceptual scheme of the system as well as the prototype 'Flooding Points' – a map available on the web showing the flooding points in the city, which were provided at the time of the event by ordinary people. The prototype was developed by using the free and open source Crowdmap/Ushahidi platform. The system was assessed by a questionnaire answered by the users, who gave their opinion about its feasibility, as well as the adjustments which must be made for the population's effective use. It was found that the application of system for subjects of inundation and flooding is complex in relation for other types of events due to its temporal dynamics characteristics. The results of the questionnaire, applied to evaluate the system, demonstrated the public utility of the application and the interest of the population for a dynamic system that enables the exchange of information on the problem of inundation and flooding in near real time in the city of Sao Paulo.

Introduction

Floods are natural phenomena which are part of the human history. However, the number of occurrences and the number of affected people have significantly increased in recent years, a fact which can be explained by anthropic changes in the environment such as deforestation, unplanned urbanisation and occupation of risk areas (Goerl and Kobiyama 2005).

Furthermore, inundations and floods may also be considered natural disasters when they correspond to situations or events of great damage, destruction and human suffering, which exceed the local capacity to manage them and require national or international support (Guha-Sapir *et al.*, 2011).

The city of Sao Paulo has been experiencing situations of inundations and flooding since the beginning of its occupation. The constant process of inundation and flooding occur throughout the Metropolitan Region of Sao Paulo and cause significant social and economic damage to the population (DAEE, 2015).

The number of flooding occurrences in the summer months in Sao Paulo is significant. The rainwater accumulation causes strong impacts mainly in traffic and transportation systems, and consequently, the whole city dynamic is affected.

Furthermore, technology provides a means for more direct involvement of people in relation to the problems faced by them in daily life. According to Goodchild (2007), the Internet allows the users' participation as information providers, rather than just receivers. To Boulos *et al.* (2011), social media are effective means of communication used to report events when they occur. During a natural event, citizens can contribute data in near real time, as the description of the extent and intensity of the event, and the results and status of response activities (Poser and Dransch, 2010; van Herk *et al*., 2011; Lorenz, 2013).

The integration of information through various sources for a flood event can minimise the damage and increase the resilience of cities, as communication becomes easier, faster and more efficient among stakeholders and population (Toubin *et al*., 2014).

Thus, in view of the inundation and flooding scenario in the city of Sao Paulo and the current technological trends and information dissemination and sharing on the Web, it is valid to analyse how such events have been managed by the society in general.

Goodchild (2007) analyses the issue of cooperation of society in sharing information about natural phenomena, especially in disaster situations. According to the author, the popularity of global positioning system, coupled with the availability of Geographic Information System (GIS) tools freely and free of charge, allows citizens greater participation in the production of geographic information, as well as the sharing of information on how the map and making it available on the Internet. This process of data generation by unqualified persons (ordinary users) is known as volunteered geographic information (VGI), named by Goodchild (2007).

The action of mapping natural phenomena through volunteered information has several aspects which require further study, including the issues related to time, metadata and data quality, according to Sui and Goodchild (2011).

In this article, some examples of projects with VGI of various areas of application are analysed in order to see how the issues related to temporal dimensions, metadata and data quality are treated. The projects analysed are: OakMapper.org (Connors *et al*., 2011), QLD Flood Crisis Map (McDougall, 2011), OpenStreetMap (Mooney and Corcoran, 2014), Interactive Mapping Tool Injury Hotspot (Cinnamon and Schuurman, 2013), eBird (Ferster and Coops, 2013), Jesusita Fire (Goodchild and Glennon, 2010), TrackSource Project (Lima *et al*., 2010), Ushahidi Christchurch Recovery Map (McDougall, 2012), Sinsai.info (McDougall, 2012) and AbandonedDevelopments.com (Werts *et al*., 2012).

So, assuming that VGI can be used in situations of flooding in Sao Paulo, this article aims to present and discuss a conceptual scheme for a dynamic and collaborative mapping system of flooding points. In the proposed scheme data transmission is made through the location of the mobile phone system, whose application allows data to be automatically loaded into the map.

A concept test was developed – the prototype 'Flooding Points' (https://pontosdealagamento.crowdmap.com/) through the free and open source platform – Crowdmap (USHAHIDI, 2015). In this prototype, the flooding points were mapped in Sao Paulo with data obtained through the voluntary contributions of individuals in order to test the feasibility of the proposal.

For the such a system, the term 'geographic data' corresponds to the flooding points collected by users at the time of the event, while the term 'geographic information' corresponds to the content generated by the system and made available as a map on the web. These terms were defined according to their citations on recent studies about the concept of VGI, as it can be seen in Sui and Goodchild (2011); Elwood *et al*. (2012) and Hardy *et al*. (2012), among others.

Besides this introduction (first section), the article is divided into three more sections. The second section presents an analysis about the time issue, metadata and quality data that use VGI system. The third section presents the method used to build the conceptual scheme. The fourth presents the conceptual scheme for a dynamic and collaborative system of flooding in Sao Paulo. Finally, the fifth presents the conclusions.

Analysis of the temporal issue, data quality and metadata in projects with VGI analysed

Identification of volunteered geographic data time patterns of inundations and flooding

The temporal characteristics of spatial data vary according to the phenomenon represented. Thus, natural phenomena such as floods, forest fires, and earthquakes require different treatment in relation to phenomena that have defined and punctual duration time, given their dynamic temporal aspect.

From Table 1 it is possible to verify the different classifications of the temporal characteristics for each VGI project. Each object representation was classified according to its behaviour over time. Afterwards, the different objects of study of VGI projects will be compared to the flooding phenomenon and analysed from the time perspective.

Order

According to Edelweiss (1998) and Dias *et al*. (2005), the time can be represented by an axis, where the points are distributed consecutively. This distribution may be linear or branched. The linear time corresponds to a complete ordering between any two points. On the other hand, for branched time, there is no need of linear sequence, thus, two different points may be direct predecessors or successors of a same point. There is also the circular ordering time, which can be used to represent recurring phenomena.

Table 1 Examples of how the time issue is addressed in different VGI projects

Project	Description	Local	Time	Phenomenon recurrence	Time representation of the data in the system
Flooding Points	System that informs the flooding points volunteered and collaborative	Sao Paulo/SP	1 Order: circular 2 Variation: Continuous 3 Granularity: interval (hours)	Everyday	Not cumulative
OakMapper.org (Connors *et al*., 2011)	Web site created to monitor diseases in trees (oaks).	Western United States	1 Order: branched 2 Variation: discreet 3 Granularity: period (years)	Permanent	Cumulative
QLD Flood Crisis Map (McDougall, 2011)	Collaborative map of flooding	Queensland/Australia	1 Order : branched 2 Variation: Continuous 3 Granularity: interval (weeks)	Sporadic	Not cumulative
OpenStreetMap (Mooney and Corcoran, 2014)	Free editable map of the whole world	Global	1 Order: Linear 2 Variation: discreet 3 Granularity: period (years)	Permanent	cumulative
Interactive Injury Hotspot Mapping Tool (Cinnamon and Schuurman, 2013)	Locations of accidents by means of interviewing the emergency medical service	Cape Town (South Africa)	1 Order: branched 2 Variation: discreet 3 Granularity: time (hours)	Everyday	Cumulative
eBird (Ferster and Coops, 2013)	Data from observations of birds. The system reports in real-time notifications submitted on the day.	USA	1-Order 1: branched Variation 2: discreet 3 Granularity: period (years)	Permanent	Cumulative
Jesusita Fire (Goodchild and Glennon, 2010)	Map of fires outbreak	Santa Bárbara – California/ USA	1 Order: branched or cyclic 2 Variation: Continuous 3 Granularity: interval (days)	Sporadic	Not cumulative
Project Tracksource (Lima *et al*., 2010)	Road maps	Itajubá, MG, Brazil	1 Order: Linear 2 Variation: discreet 3 Granularity: period (years)	Permanent	Cumulative
Ushahidi Christchurch Recovery Map (McDougall, 2012)	Map with the location of services such as food, water, toilets, fuel, ATMs and post-disaster medical care	Australia	1 Order: Linear 2 Variation: discreet 3 Granularity: period (years)	Sporadic	Cumulative
Sinsai.info (McDougall, 2012)	Location of areas at risk of earthquakes, food and water	Japan	1 Order: Linear 2 Variation: discreet 3 Granularity: period (years)	Sporadic	Cumulative
AbandonedDevelopments.com (Werts *et al*., 2012)	Collection and dissemination of data relating to the beds of abandoned or unfinished residential construction and their potential for sediment pollution.	South Carolina, USA	1 Order: Linear 2 Variation: discrete 3 Granularity: period (years)	Permanent	Cumulative

The Table 1 shows that the time order to represent the volunteered geographic information may vary according to the mapped object. In situations of natural disasters or dynamic geographic phenomena, the order of time can be represented as branched or cyclic.

The representation of the time order in situations of disaster or natural geographic phenomena, such as inundations, forest fires and floods can also occur cyclically. In this case, it is understood that events like floods may be related to the seasons, so the flood will have a high likelihood of occurrence in the months of the year with more rainfall, as those corresponding to the summer in the city of Sao Paulo. Thereby, the circular time order can be applied to projects QLD Flood Crisis Map, Jesusita Fire and Christchurch Recovery Map, besides the prototype Flooding Points. Regarding to the mapping of geographical entities, such as the Open Street Map project and Track Source Abandoned Developments, the time order can be represented linearly, whose entry matches the consecutive distribution of data over time, even if the data are collectively obtained (Edelweiss, 1998; Dias *et al.*, 2005).

Variation

The time can vary in a continuous or discrete way. According to Edelweiss (1998) and Dias *et al.* (2005), the time variation is considered continuous by nature, but in some cases it can also be considered discreet. It is understood that the continuous variation can be interpolated by intermediate values, since the nature of the phenomenon can have intermediate states. However, in the discrete variation, the datum remains at a fixed value for a chronon.

From the analysis of Table 1, it was possible to verify that projects with dynamic mapping objects such as the floods in Queensland, Australia (QLD Flood Crisis Map), the forest fires in California, USA (Jesusita Fire) and the prototype Flooding Points had their temporal variations classified as continuous, while the temporal variation of the other projects was classified as discreet.

Granularity

According to Edelweiss (1998), the temporal granularity of a system is related to the duration of a chronon, which may vary in minutes, days or years in the same application, depending on the proposed objective.

The analysis of Table 1 reveals that the projects in which the granularity is the period (year), the recurrence of the phenomenon is sporadic (Christchurch Recovery Map and Sinsai.info) or permanent (Oak Mapper, Open Street Map, eBird, Project and Track Source Abandoned Developments), and data are cumulative in the system.

The proposed application for the flooding phenomenon is complex and differs from the other applications in Table 1 by the different characteristics of order, variation and granularity, besides the event recurrence time and the data representation time in the system. Given its representation of circular order due to the occurrence of floods in the summer months in the city of Sao Paulo, the event recurrence time is short, which makes it an everyday phenomenon in the lives of people every year, in the months of more rainfall.

Furthermore, because it is a dynamic project and in near real time, the data are not cumulative in the system. The data history exists, but it should not be visible to the user on the application homepage. The data of flooding points are only visible at the time that the flooding events occur, being disabled after the event ends.

Analysis of metadata and quality of volunteered geographic information

The metadata of VGI projects presented through the analysed application correspond to the information related to the data provided by users. Some projects have been developed on the same platform, so they have similarities in the metadata constitution. These projects are QLD Flood Crisis Map, Christchurch Recovery Map and Sinsai.info, which were developed through the Crowdmap/Ushahidi platform. In these cases, there are automatic metadata such as date, time and geographical coordinates besides the name, email user, and comments on reports.

Other more structured systems, such as OpenStreetMap, TrackSource Project, OakMapper and eBird, have a record of users where is possible to get more information about the data source. According to Mooney and Corcoran (2014), the 'tags' of the OpenStreetMap project are considered metadata. The 'tags' are labels referring to the information provided by users that contain street names, names of areas and types of use.

Table 2 shows how the metadata and data quality are treated in the examples of projects with VGI.

According to Al-Bakri and Fairbairn (2012) the number of people involved in creating VGI has a significant impact on the quality of data. Information created by a large number of volunteers tends to be more precise in relation to information created by a small number of volunteers.

Table 2 shows the possible measures of quality present in each VGI project. The automated methods for detection of errors, statistics and filters used to improve the quality of information can be identified in projects like Open Street Map and Track Source Project. The use of data from official sources is also used as an information quality parameter, as it can be observed in the project Injury Hotspots.

Material and methods

The conceptual scheme of the proposed system corresponds to the first implementation phase of a collaborative web

Table 2 Examples of how metadata and data quality are addressed in different VGI projects

Project	Description	Local	Metadata	Quality measurements	Data information way
Flooding points	System that informs the volunteered and collaborative flooding points	Sao Paulo/SP	User data, day, time of the report and comments	Verification of information by the administrator, credibility vote and comments	Mobile app and web site
OakMapper.org (Connors *et al*., 2011)	Mobile app and website Website created to monitor diseases in trees (oaks).	Western United States	Profile data of users, taxpayer ID, date of submission and date of confirmation	The data are separated between those who have been officially tested by laboratory and those not yet evaluated	LBS for iPhone, Flickr and Twitter
QLD Flood Crisis Map (McDougall, 2011)	Collaborative flooding map.	Queensland/Australia	User data, day, time of the report and comments	Verification of information by the administrator, credibility vote and comments	Email, Twitter, SMS, web site
OpenStreetMap (Mooney and Corcoran, 2014)	Free editable map of the whole world.	Global	Tags (user, date and time of publication, changes made)	Error detection tools, statistics, monitoring, report bugs etc)	Web site
Interactive Injury Hotspot Mapping Tool (Cinnamon and Schuurman, 2013)	Locations of accidents by interviewing the emergency medical service.	Cape Town (South Africa)	Occupation volunteer who helped with the given description and details of the accident site.	Integration with data provided by the hospital.	Web application, Google Maps
eBird (Ferster and Coops, 2013)	Data from observations of birds. The system reports in real-time notifications submitted on the day.	USA	Date, time, name and e-mail user	Assessment given by experts after automatic quality filter.	Web site and mobile applications
Jesusita Fire (Goodchild and Glennon, 2010)	Map of fire outbreaks.	Santa Bárbara – California, USA	Date, time and discussion forum	discussion forum	Web site
Projeto Tracksource (Lima *et al*., 2010)	Road maps	Itajubá, MG, Brazil	Developer registration data	Auxiliary programs that indicate errors and control by the compiler	Web site
Ushahidi Christchurch Recovery Map (McDougall, 2012)	Map with the location of services such as food, water, toilets, fuel, ATMs and post-disaster medical care.	Australia	Date, time, name, e-mail and user comments	Verification of information by the administrator, credibility vote and comments	Twitter, SMS and email
Sinsai.info (McDougall, 2012)	Location of areas at risk of earthquakes, food and water.	Japan	Date, time, name, e-mail and user comments	Verification of information by the administrator, credibility vote and comments	Web site and application
AbandonedDevelopments.com (Werts *et al*., 2012)	Collection and dissemination of data relating to the beds of abandoned or unfinished residential construction and their potential for sediment pollution.	South Carolina, USA.	Place, date, description of the photo and comments from users		Web site

ATM, automated teller machine; LBS, location-based services; QLD, Queensland; SMS, short message service.

system where anyone can report flooded points in Sao Paulo. The data can be entered via mobile app or web page, and are loaded dynamically in the map.

The development of work has followed the steps shown in Figure 1.

The first step was the achievement of literature review on the topics covered by the study. Thus, research on floods in Sao Paulo was carried out in order to define part of the object of study.

The concept of VGI was explored through the existing literature. The technologies involved were also found to demonstrate the potential and feasibility of developing dynamic systems of collaborative mapping.

After checking the 'state of art' of the items involved, an analysis was done on some characteristics considered relevant in projects with VGI. The question of temporality was highlighted due to the nature of the phenomenon studied. Issues relating to metadata and data quality to meet the research objectives were also raised.

The conceptual scheme of the dynamic collaborative flood mapping of São Paulo city was developed based on analysis of the main aspects involved in VGI projects, from literature review. The conceptual scheme development phase also involved the definition of competency questions. These questions are related to the main tasks that should be answered by the system during flooding event.

Finally, the prototype 'flooding points' was implemented as a proof of concept to validate and test the proposed scheme. Therefore, the Crowdmap platform (USHAHIDI, 2015) was used. The Crowdmap is an Ushahidi's platform where the maps and databases are hosted, without the need for server installation. It is a service provided by the Ushahidi web application to facilitate the use of people in the implementation of collaborative systems. With Crowdmap, it is possible create a page and customise it, choose themes, edit categories, request reports, among others. Everything is done online, requiring just setting up an email account with a password, as well as filling out a short form. Since then, the website is already implemented and can be configured according to user's needs (USHAHIDI, 2015).

The prototype was published in the internet to be tested by users. During testing phase, a questionnaire was applied to users in order to identify issues that should be improved in the conceptual scheme.

System description

The conceptual scheme of the system

This topic presents the description of conceptual scheme of the system, regarding how users interact with it.

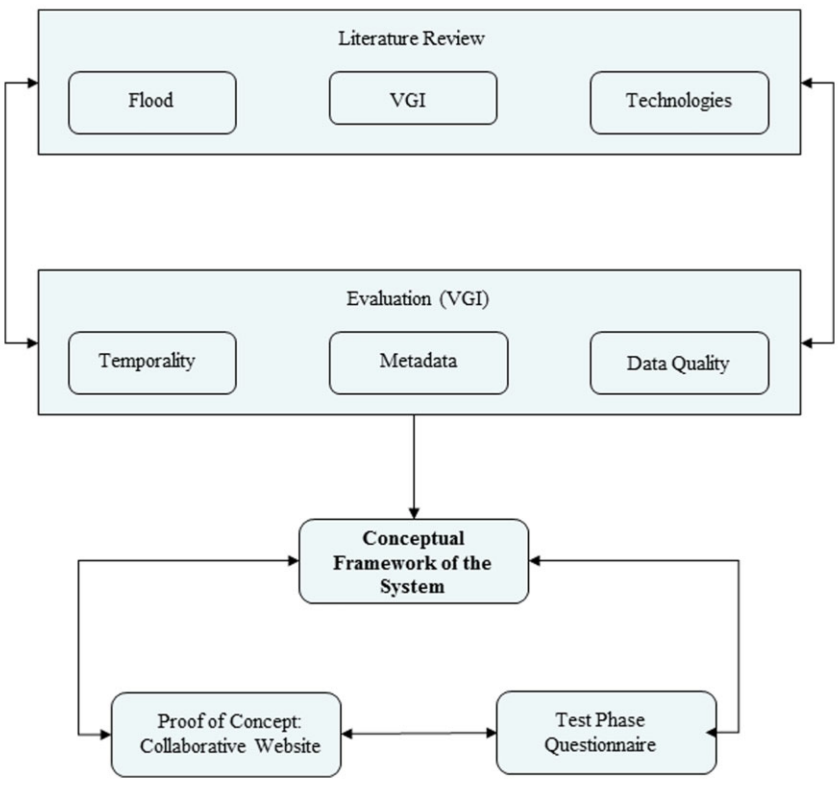

Figure 1 General scheme of the stages of work.

The conceptual scheme developed in this article consists of the use of case diagram, activity diagram and class diagram, proposed based on the Unified Modeling Language (UML) language, which was used for visualisation, specification, construction and documentation of software systems artefacts (Booch *et al*., 2005).

Part of what was devised for the system through the conceptual schemes was implemented by using the Crowdmap/Ushahidi platform. However, some points appear only in the scheme, given the platform customisation limit for non-programmers.

The term 'flooding' used to describe the conceptual schemes does not rule out the possibility of information about flooded places. An option for the term 'flooding' was made due to the existing familiarity between it and the Sao Paulo population, as well as the use of the term by the media to refer to the event.

Figure 2 shows the conceptual scheme of the developed system.

The user can interact with the system when he informs where the flooding points are, checks them and receives alerts. The data registration occurs when the user who is in a flooding situation informs its location and the data are logged in the system through the mobile app or web site. When checking the points, the user accesses the system and checks the points where there is a flood.

The system requires user registration, which includes the possibility of specifying the addresses from the places where the user want to receive alerts from. The registration also set a distance around the address to limit the space for notification. The alert messages are received through emails or mobile phones.

The user can also perform a query with the following objectives:

– Explore the map which shows the flooding points;
– Check the historical data stored in a database, which can be filtered by dates or time periods, according to the user's interest;
– Check the metadata.

The steps in sending data, checking them and receiving alerts are described in the diagram in Figure 3.

Data can be provided through the mobile app or via the web site. It is assumed that the application should be simple for the data to be transmitted quickly. Then, when sending a flooding point, the user must only enter an acronym class so that the database can be organised for any future queries. The acronym classes were based on those used by Emergency Management Center (CGE), the official agency that informs points of flooding in the city. These classes are: 'impassable location' – places where vehicle traffic is completely blocked; 'passable location' – places where there is flooding, however, they are open to vehicular traffic; 'Inactive' – places where there was flooding, but it is now ended. The class entitled 'CGE' was also added for official data provided by the institution itself. Location descriptions, as text or photo, are optional fields that do not prevent sending the data even if these are not filled in.

When data are sent through the web site, it is possible to make the field of the local description mandatory. This option would help in more accurate localisation of the flooding point, since in this case the point was manually drawn on the map, which can lead to incorrect information on the informed location.

The user can register by informing the email or mobile number to receive alerts when the system is informed of any flooding point within the registered area of interest.

The registration consists in one or more locations (addresses) selected by the user. From that address, the user

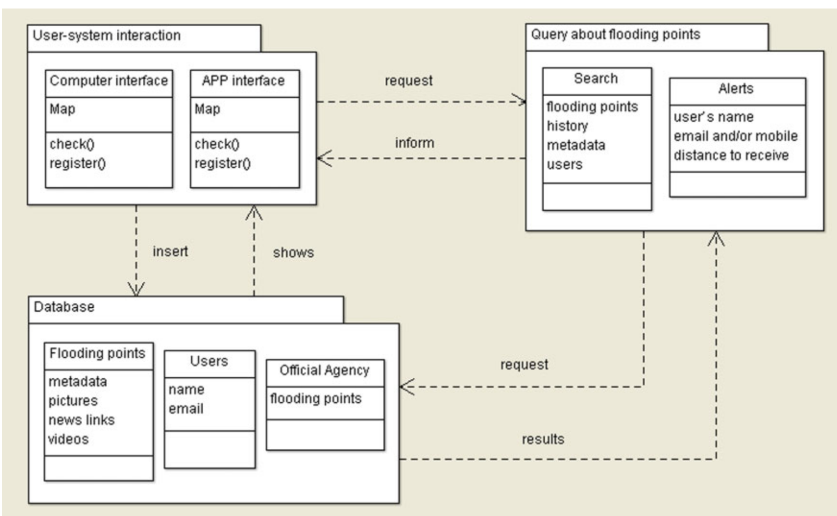

Figure 2 Conceptual scheme of the system.

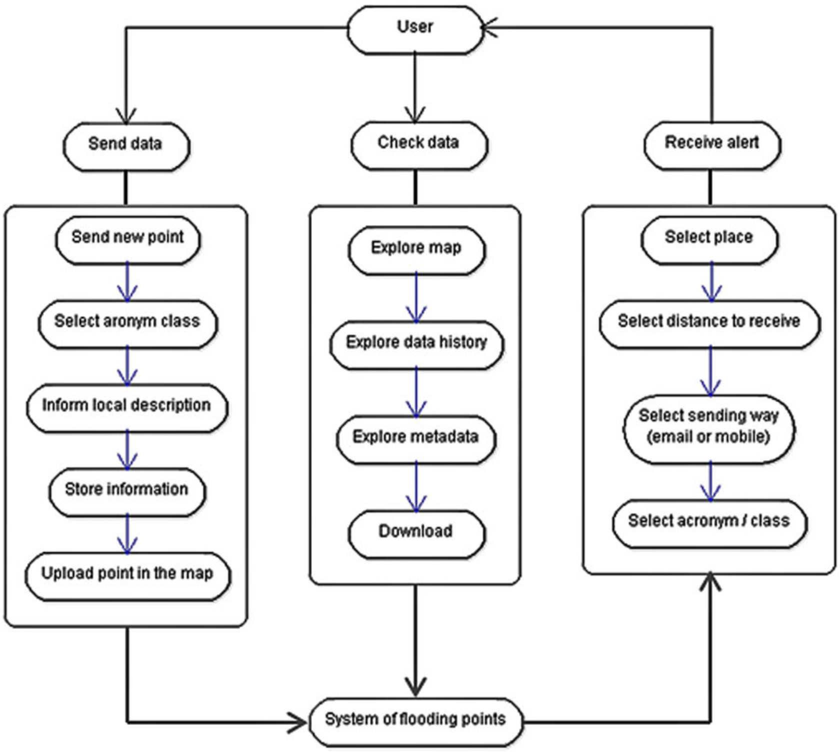

Figure 3 Diagram of activities.

can choose a distance to receive alerts. This distance can vary from 5 km to 100 km, and is defined by the user according to his needs.

The next step is the selection of how the information will be sent by the system and received by the user. There are two options: via email or via mobile. Afterwards, it must select one or more acronym classes, which the user is interested in receiving notification when there are indications of flood.

The alerts sended informing, for instance, blocked areas to be avoided, are very useful as they contribute to inform other drivers.

The interaction between the user and the system is through the personal computer's interface (web) and with the mobile app, which operation consists of recording data and querying the system. Through the interface, data can be set on the map and displayed as information.

The event classifier corresponds to the data auto-update mechanism. Through the counter, the data are reviewed within a period of 24 h, and as time goes by the data are being classified and given a score ranging from 0 to 10. Grades are assigned according to the amount of hours that had passed since the data were included in the system. At the first hours following the point registration, the grade is raised (10), as the time goes by the grade decreases, reaching 0 at the end of 24 h. The moment the grade attributed to the data reaches zero, the acronym class to which this data belongs is automatically changed to 'inactive'. The classifier's grades are considered evaluations of data reliability that can provide a parameter to the user. Data with a grade of 10 is considered reliable, data with grade of five may be considered average reliability, and data getting a score of 0 cannot be considered very reliable. The event classifier is found only in the conceptual scheme for the development of the system. Its implementation is no longer performed for the need of more knowledge in programming, since the code for the function is not available in the Crowdmap platform.

Proof of concept: 'flooding points' prototype

The prototype system can be accessed at the link https://pontosdealagamento.crowdmap.com/. As a test, data provided by the CGE were included in the system in the period between 23 October 2012 and 1 December 2012. Through the media, it was possible to verify the interest of the population in the system. However, it also detected the difficulty in motivating users to contribute with data at the moment of the event.

Some possible justifications for such a situation were raised:

- The rains and consequent floods and inundations are everyday phenomena of the summer months in the city;

Table 3 Number of occurrences of floods in the city of Sao Paulo

	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013
December	95	38	22	27	65
January	245	540	581	174	114
February	200	377	324	172	284
March	116	0	20	73	118
Total	656	955	947	446	581

Source: Adapted from CGE (2013).

- The granularity of hours makes the event extremely dynamic;
- The data are not cumulative in the system;
- The impact of degree of the phenomenon is not catastrophic;
- The functional issues of usability of the platform where the page is hosted are not attractive.

The quantification of flooding points that have occurred in the city of Sao Paulo in the last five summer periods can be observed through the data shown in Table 3. The data correspond to the period from 21 December to 20 March collected by the CGE, a body linked to the City Hall of Sao Paulo.

The data show that flooding events have been occurring on a large scale in the city, with the record of flooding points up to 80 in 1 day (CGE, 2013). Moreover, inundations and floods are everyday phenomena with which Sao Paulo people face on rainy days. The flooding events occur at an average of about 50% of the days in the summer months with a duration ranging from minutes to hours. On the other hand, events considered of major natural disasters are scarcer.

McDougall (2012) points the same situation of difficulty in obtaining information for the project Sinsai.info after earthquake in 2011. The launched system also got little contribution compared to other VGI post-disaster projects. In this case, the author points out the cultural reluctance to share information publicly, lack of evidence, level of devastation and consequent lack of infrastructure for communication or access to the disaster area, as possible reasons for the low volume of contributions.

Likewise, Neis and Zipf (2012) analysed the contribution rate to the OpenStreetMap project. The data refer to the total number of members checked in December 2011, which had more than 500 000 registered members. The analysis showed that only 38% of this total, about 190 000 members, accounting for at least one information during membership.

The survey also showed that only 5% of members actively contribute to the project and that in the total, 312 000 members never contributed with data. An analysis of the period of time that members contributed with data showed that most members made their contributions within the first 3 months of membership (Neis and Zipf, 2012).

This demonstrates that because the system is cumulative, few collaborators can make the VGI project succeed, different from the proposed application to flooding points.

Schade *et al*. (2011) highlight the complexity which involves the VGI issue. For the authors, events like floods occur within a relatively short period of time and can affect people immediately. Such events have different geospatial and temporal features among VGI patterns.

Evaluation of the system – questionnaire

Given the small number of contributions, it was decided to conduct a questionnaire, available on the prototype page, with the goal of trying to gather more information that could contribute to a better understanding of issues relating to VGI.

The questionnaire was available in the period from 1 November 2012 to 25 March 2013 for the purpose of analysis. In this period, 100 valid responses were recorded, i.e. responses whose user has accessed the system to answer the questions.

The survey questions were formulated with the aim of investigating the issues considered relevant to the operation of a dynamic system of collaborative mapping, such as motivation to contribute, data reliability, and prototype usability and system disclosure.

The results showed that there is significant interest and approval of the population to the prototype 'Flooding Points'. For questions regarding the utility of the system, 51% of respondents attributed the grade of 10 very good, as shown in Figure 4.

The answers concerning the motivation of people to contribute with data indicated the action of helping others as the main reason. It also mentioned altruism, social engagement, interest in the application technology, and the system utility for persons subject to flooding, municipalities, street cleaning companies, and construction companies.

The issue of data quality in VGI leads to the question of information reliability provided by the system. Poser and Dransch (2010) state that credibility is based on trust and

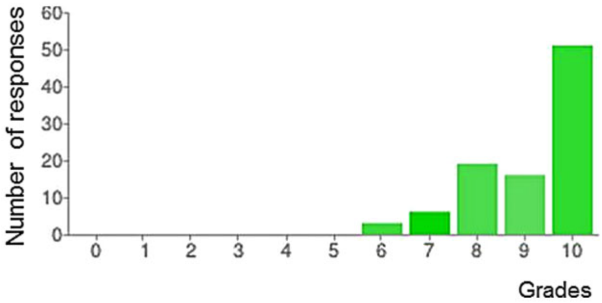

Figure 4 Graph of the question related to system public utility.

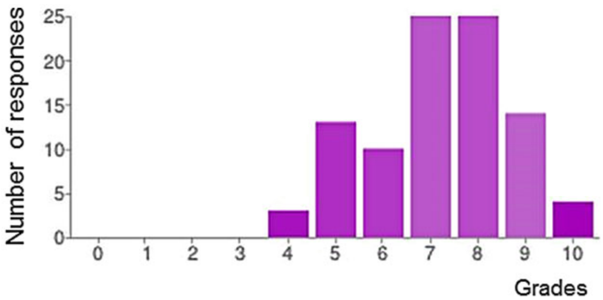

Figure 5 Graph of the question related to data reliability.

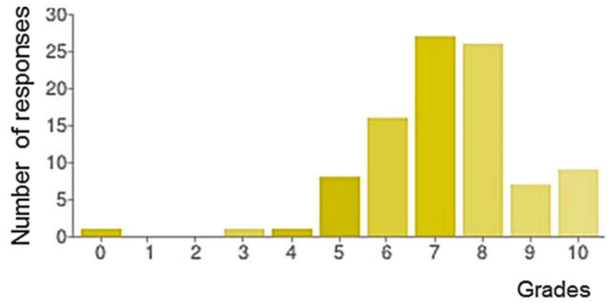

Figure 6 Graph of the question related to the ease of surfing the website.

reputation, whose base is the assessment of the data veracity provided by the community of users. According to the authors, this concept can be interpreted as an implicit assessment of the data's external quality carried out intuitively as opposed to standards-based assessment.

When asked about the aspect of data reliability, the responses varied widely, although most people gave grades considered medium and good (between 5 and 10), as shown in Figure 5.

Questions about the system usability were also made with the expectation of identifying what aspects would contribute to the greater use of the web site, considering the platform on which the system is hosted.

In this question, respondents agreed that the significant key points to use the system would be improved graphical aspects of the page and improved mobile app. Furthermore, the maintenance of formats related to the homepage, the four categories of the acronym and the distance of about 12.5 miles from registered place to receive flooding alerts also contribute to the greater use of the system.

Moreover, it was asked about the ease of navigation on the web site 'Flooding Points'. The responses indicated a certain degree of difficulty to surf on the Crowdmap/Ushahidi platform, since there are restrictions for non-developers about the system settings of that platform. Figure 6 shows the results for that question.

Among other suggestions, the link to the official data sources, such as CGE and Traffic Engineering Company (CET, 2015), was also mentioned to provide greater reliability to the system. Furthermore, it suggested the inclusion of other traffic-related information systems, such as the alternative routes, the estimated travel time and other factors that could present some interference.

Conclusions

This article presented a conceptual scheme for dynamic and collaborative mapping systems of flood. The system objective was to map the flooding points in the city of São Paulo through volunteer data informed by citizens during the event. The prototype "Flooding Points" has been implemented and analysed. The development of the system was performed through the free and open source Crowdmap/Ushahidi platform.

Although there are aspects of implementation to be improved, it can be concluded that the concept proof of the system through the prototype 'Flooding Points ' was sufficient to assess and improve the proposed conceptual schemes.

The results of the questionnaire, applied to evaluate the system, demonstrated the public utility of the application and the interest of the population for a dynamic system that enables the exchange of information on the problem of inundation and flooding in near real time. In addition, they confirmed the feasibility of developing collaborative and dynamic mapping of flooding with volunteer data provided by mobile phones.

Therefore, the social contributions of the application can be considered relevant, because they help prevent problems in the traffic system, as the citizens who receive alerts through email and text messages might fail to circulate the information on flooded pathways. The system can also join efforts with official bodies responsible for information about floods in the city.

The use of mobile devices for the transmission of data contributes to the dynamic characteristic of the system, since the user may inform the occurrence in real time the event and rely on other tools provided by the mobile, such as photo and video cameras to add and enhance the information sent. This provides greater reliability of the information.

The system also allows the storage of data in and make them available for download, allowing such records of flooding points to be used for subsequent studies.

The possible integration of information in social networks such as Facebook and Twitter promotes more dinamism to information dissemination.

The characteristics of integration between different sources of information, data warehousing, receiving alerts and exclusivity in just map points from floods correspond to the contributions of the proposed system, although there are other applications that inform flooding in the city, as the Waze application (2015).

However, the evaluation of a dynamic event, VGI, such as flooding, has its complexities. Particularly, flooding is an event that predominates in one season only, and although it is daily, it occurs at a short time, usually within 1 day. The temporal nature of the flooding phenomenon requires a dynamic format system, whose functional characteristics require disclosure and awareness of the population.. This factor directly affects the web site's usability and the user's data contribution.

As for the data and metadata quality, it was noticed that there is a relationship between the two projects in VGI. In many cases, metadata are used as measures of quality. VGI initiatives that historical data are not kept in the system, face a major chalenge regarding data quality. In these cases, population participation is differential, since data quality, and consequently, the generated information will be a consequence of the contribution of each person.

The use of other information sources, such as the radio, as well as the integration of VGI projects with official sources of the same data, is also an important means of ensuring greater credibility to the system data.

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