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# CRISIS INFORMATICS: FROM CROWDSOURCING TO CROWDSOURCED DATA ANALYTICS

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**Abstract : -**

Since 2008, crowdsourcing platforms have played a crucial role in crisis management. Responses to disaster events in the past, is undoubtedly valuable sources of information to manage current and future crisis events. Although use of crowdsourcing allows a higher availability of information, inaccurate reports provided by volunteers are increasing that requires some filtering and proper selection from experts. The lack of coordination between emergency response groups and digital humanitarians has also blurred the initial expectations of using crowdsourcing for crisis events. Automatic crowdsourced data analytics- a new generation of crisis informatics that combines crowdsourcing with data analytics is emerging. With the help of past events, this new methodology not only contribute to validate current information (accuracy), but also helps rank users' inputs and usefulness (accuracy and coordination) and even infer new data (data analytics). After analyzing different crowsourcing platforms for crisis management, the answer of the question - whether automatic decision-making support system alone has the ability to empower volunteers during any crisis event, will be explored in this research paper.

**Keywords:** Crowdsourcing, Crisis management, Data Analytics, Crisis Informatics, Crisis apping, Crowdsourced Data Analytics, Situational Awareness Support, Decision Support Systems.

## 1 INTRODUCTION

By deploying the crowdsourcing platform to monitor incidents of post-election violence and peace efforts throughout the country in Kenya in 2008, Ushahidi paved the way for crowdsourced crisis informatics [1]. Today, by using Ushahidi's products, Crisisnet and Crowdmap, volunteers and other users can send "reports", either directly, or through social media or conventional media updates. Moreover, a GPS location complements the report when available and possible. Since 2010, more crowdsourced crisis informatics tools have been introduced, such as SahanaEden*[2], which was used by individuals, organizations and governments for several disasters§. CrisisTracker is another example of first generation crowdsourced crisis platforms. All these tools improve the

* Eden: (Emergency Development Environment) for Rapid Deployment Humanitarian Response Management website - http://sahanafoundation.org/accessed on 15/05/2015

§ Flooding in Venezuela and in Pakistan on 2010; hurricane in Veracruz, Mexico on 2010; earthquake and Tsunami in Japan on 2011; flooding in Colombia on 2011; wildfires in Chile on 2012; Typhoon Haiyan (Yolanda) – November 2013, Typhoon Ruby – Philippines – December 2014 and Earthquake in Nepal (April – May 2015).

decision-making of expert response teams by providing updated knowledge and information. Users and volunteers are a source of relevant data and these tools gather information and connect non-experts with experts, enhancing the situational awareness of the latter. Today, increasing amounts of data used by experts come from social networks, mobile phones and digital volunteer communities[#], and the involvement of volunteers and non-experts is clearly relevant. Current crowdsourced crisis informatics is not limited to data retrieval, but complements it with two new capabilities: first, the empowerment of trusted volunteers gradually consolidated as support teams; second, the use of data analytics. As a result, current crowdsourced crisis informatics combines human collective intelligence with big data and machine learning [3,4,5,6,7,8,9,10,11].

Why is disaster management evolving this way? Crowdsourcing crisis management has shown to be successful at producing more data than traditional governments and news reports, but it has yet to reach its potential impact [12]. However, having more data does not necessarily imply a more efficient response. Experts need accurate, relevant and updated information on time [13,14,15]. Data filtering and selection are therefore crucial. Digital volunteers can detect and select relevant information (see below, 3.1.1), but then the trustworthiness and reliability of volunteers need to be verified. Data mining and machine learning offer a new, alternative automatic procedure to accurately select information (see 3.1.2).

However, accuracy and reliability are not the only aspects to consider for an efficient disaster response. Direct access to the top emergency response team in real-time could be overwhelming. Therefore, coordination strategies between experts and selected non-experts are emerging. In other words, an intermediate layer of decision-support teams is envisioned (see 3.2). Volunteers are increasingly empowered to participate in the decision-making process, and new strategies of coordination are being proposed, such as situational awareness services (see 3.2.3).

The decision-making process of the first response teams is conditioned by previous selection and situational awareness processes. The initial rigid separation between volunteers, as data source, and first response teams, as decision-makers, is not taken for granted in current crowdsourced crisis informatics. The empowerment of volunteers makes them be part of the initial decision-making process, although their participation is still monitored and led by experts. However, digital volunteers might also be replaced by Artificial Intelligence i.e AIDR. Retrieved and classified data of past events allows modelling the risks of future events. However, still the question remains, whether the automatic decision-making support system alone has the ability to empower volunteers during any crisis event. Thus, in this research paper, the proper use of these automatic decision support tools will be discussed.

## 2. RESEARCH METHODOLOGY

Though the crowdsourcing allows gathering huge information, the inaccuracy of the reports provided by volunteers increasingly requires some filtering and selection from experts. It has also been identified that the lack of coordination between emergency response groups and digital humanitarians has also blurred crowdsourcing initial expectations.

However, crowdsourced data analytics, a new generation of crisis informatics is now emerging that combines crowdsourcing with data analytics. The ability of this new tool to combine

[#] Some examples of current crowdsourcing disaster management platforms are OpenIR; Google Person Finder; ArcGIS; Ping; Recovers; PADDDtracker.org; **Google Crisis Map;** GeoChat; InaSAFE; Geofeedia; LEEDIR; Geo-pictures; CrisisCommons etc.

past events and reports not only contribute to validate current information (accuracy), but also help rank users' inputs and usefulness (accuracy and coordination) and even infer new data (data analytics).

### 2.1 Open-ended Approach

As open-ended questions are rich and explanatory in nature, we took the approach using open-ended queries while investigating crowdsourcing platforms. This approach allowed us to understand initial research on crowdsourcing crisis platforms and to check the difference between earlier research and our research on the issue of privacy, security and data protection in crowdsourcing process for disaster management.

### 2.2 Research questions

Based on this background the following research questions would guide this research article:

- Whether the automatic decision-making support system alone has the ability to empower volunteers during any crisis event?

To find answers of above-mentioned broad research question, answers of the following questions need to be identified as well:

- Whether there is a need for more data in the decision-making stage during a crisis event to empower volunteers at the selection and coordination stages?
- Whether the next generation crowdsourced crisis informatics would focus more on automatic decision-making support system?
- Whether raw data sources and analytics are taking the position of human volunteers in crisis management activities?
- Whether the empowerment of automatic decision tools is less risky for experts than the empowerment of volunteers?
- Is there any possibility that the decisions made by experts could soon become raw data for data analytics and automatic decision support tools?

### 2.3 Sampling: Identification of Crowdsourcing Crisis Management Platforms and Tools

As we had some pre-selected criteria relevant to our particular research questions, we used purposive sampling. We could not fix the number of crowdsourcing platforms to be investigated prior to the data collection. On the basis of the theoretical saturation i.e. the point in data collection when new data no longer bring additional insights to the research questions, we decided to use purposive sampling. Also the identification of the platforms depended on the on the resources and available time we had, as well as our research objectives. As we conducted data analysis and review in conjunction with the data collection, we found purposive sampling was most useful for our research.

As this research paper mainly covers the first stage of three different stages in using crowdsourcing platforms for crisis management i.e. a) Retrieval and Selection (RS); b) Situational Awareness (SA); and c) Decision Support Systems (DSS), some crowdsourcing platforms and tools have been critically analysed through an intensive secondary research. To understand these aspects within existing different crowdsourcing crisis management framework, a qualitative research study

was conducted among Uhahidi, Digital Humanitarian Network, MicroMappers and Google Crisis Map.

### 2.3.1 Ushahidi

Ushahidi crowdsourcing platform has been identified for this research as this platform is considered as this pioneer and innovative crowdsourcing platform paved the way for using ICT based crowdsourcing in crisis management works. Ushahidi first started its ground breaking work with the deployment of an innovative crowdsourcing platform to monitor incidents of post-election violence in Kenya in 2008 and peace efforts throughout the country based on reports submitted via the web and mobile phones.

### 2.3.2 Digital Humanitarian Network (DHN) and others

There are numbers of networks that voluntarily works to address different crisis situations. As the Digital Humanitarian Network (DHNetwork) is the first volunteer network of crowds i.e. masses and technical communities of its' kind to leverage digital networks in support of humanitarian response, DHN has been identified for the research. Some other volunteer networks have also been identified as 'research case'. These networks also do almost the same type of coordination works during any disasters / crisis.

### 2.3.3 MicroMappers

The platform 'MicroMappers' has been identified for the research as it has started using AI (Artificial Intelligence) for the first time to select data and information by users. Meier (2013) has identified that 'the free and open source Artificial Intelligence for Disaster Response platform leverages machine learning to automatically identify informative content on Twitter during disasters'.

### 2.3.4 Google Crisis Map

Google Crisis Map has been selected for this research to identify, having all latest technological facilities, how does it care about privacy, security and data protection issues. Google has been responding to natural disasters since Hurricane Katrina in 2005 by making information such as storm paths, shelter locations, emergency numbers, and donation opportunities easily accessible.

## 3. DISCUSSIONS BASED ON RESEARCH OUTCOMES

As mentioned in the research methodology, to understand different aspects (i.e. Retrieval and Selection, Situational Awareness, and Decision Support Systems) within existing crowdsourcing crisis management frameworks, a qualitative research study was conducted among Uhahidi, Digital Humanitarian Network, MicroMappers and Google Crisis Map. Brief findings are discussed in this chapter.

### 3.1 Retrieval and Selection of data

Disaster Management Systems or Crisis Informatics tools deal with two core issues- a) aggregating relevant data from different sources (crowdsourcing); and b) supporting decision-making processes. Crowdsourcing platforms initially focused on the earlier one e.g. Ushahidi, and recently it has been trying to give more emphasis on the later one e.g. supporting decision making processes by platforms like DHN, PeaceGeeks, Stand By Task Force etc. It has been identified that data relevance

and accuracy are two of main challenges to enhanced disaster management activities.

### 3.1.1 Selection by digital volunteers

It has been recognized that reports from first responders, such as firemen or emergency medical personnel, crisis response coordinators working on the ground assure highly accurate information. In terms of the participation of ordinary people to provide information on incidents, internet users or online volunteers can provide additional perspectives, and this might sometimes be crucial for response teams and even for other citizens who can make informed decisions based on near-real-time information [16]. Sometimes, the relevance or the accuracy of crowdsourced information is very low, thus appropriate selection is needed. Users and volunteers filter and select information by reading reports, or visualizing a photograph or an aerial picture, or sometimes identifying the geolocation of a particular incident. All crowdsourced platforms that have been identified for this research do one or the other mentioned in this section.

#### A. Collective task-solving from online communities

Tools like Verily and The Internet Response League (IRL) collect crowdsourced evidence, and provide important information for crisis responses. In the present 'Disinformation Age', finding the truth is very difficult when the huge amount of contradictory and confusing information is becoming increasingly and easily available. Verily is an experimental web tool designed to rapidly share verified information during humanitarian disasters, it uses a time-critical crowdsourcing process to verify information during major disasters on behalf of humanitarian organizations and media groups [17].

Humanitarian organizations and emergency management responders are completely unprepared to deal with this volume and velocity of crisis information [18]. The Internet Response League (IRL) is based on online gamers. Because more than half a billion people worldwide use computers and videogames for at least an hour a day and are frequently connected to the internet, they can play a significant role in supporting disaster response operations worldwide. Indeed, it has been estimated that if all these gamers had been invited to search through the 20 million tweets posted during Hurricane Sandy that would have taken just 20 seconds [19].

According to experts, initiatives like Verily and IRL show how different types of online communities (i.e. online gamers, social networking site users, etc.) can help solve small tasks in just few seconds, and also assist crisis experts and humanitarians in the management of disasters and in providing prompt and effective responses to crisis situations [17, 18, 19]. However, as the most of the online gamers' age is below 20 years and are not matured enough, utilizing gamers for verification of crisis incidents could be dangerous.

#### B. Crisis Mapping

In crowdsourcing, geo-location reports usually convert locations to GPS locations and plot on a map. Normally, reliability and accuracy of incidents are verified by the disaster management team. The team of experts verifies reports and additional about crisis incidents. Trust is associated with group membership created by users. The group administrator requests high reliability level from a system administrator. Users then filter reports and rank them by trustworthiness or by another factor, for example, location or type of incidents like flood, earthquake, and road displacements etc. 'MicroMappers' is a crowdsourcing platform that uses by online volunteers to select information on incidents. It is a collection of websites or

Clickers (beta version) and each clicker or volunteer can easily tag different types of information. There are several categories of digital volunteers associated with MicroMappers[#]. 'Text Clickers' for instance identify the relevance of Tweets during an emergency or disaster. 'Image Clickers' are volunteers who rate the damage by looking at images. These volunteers check, verify and rate different crowdsourced information and then the platform passes that information to 'Geo Clickers' who put those tweets, pictures and videos on the map. In the recent earthquake in Nepal in May 2015, over 2800 volunteers from all over the world reviewed tweets and images to support humanitarians with information insights. These 'clicks' and 'selections' of texts by volunteers produced a highly accurate dataset about the earthquakes in Nepal that was shared and incorporated into the damage assessment and decision-making processes. At the end of the process, some empowered group of volunteers insert the obtained information on a map, where the type and seriousness of incidents are reported. At this stage the support teams and the decision-makers work together to accelerate the crisis management.

### 3.1.2 Selection of Crisis Incidents by Data Analytics Tools

Crowdsourced data analytics also has its selection tools. Without the participation of volunteers, the relevance and accuracy of data, and the trustworthiness and reliability of users and volunteers etc could be completed by automatic devices.

#### A. Social Network Data Mining

The first selection option for data analytics consists in social networks data mining (SNDM). SNDM is useful not only for customised advertising, but it can also help to extract data from public pages for emergency platforms. For instance, users' actions, likes, comments and posts on the Facebook page have allowed the creation of a training set for the "Hurricane Sandy lost and found pets" page [20]. The number of reports submitted or bookmarked, and successful or unsuccessful matches have been extracted and used to label the user as active or not, and as effective or not. To obtain a model of highly active users, users were also ranked based on the number of their likes, comments and posts. Active and effective users are thus preferred when assessing the relevance and accuracy of data.

#### B. User Ranking

Machine learning and data mining and game theory can also combine to assign users a score or weight [16]. Users are evaluated as active or effective, but the ultimate goal is to rank them. Initially everyone has zero points; then users can get points added or deducted. The selection of data shifts then into a users' ranking. For instance, valuable information can be collected from mobile sensors and locations and this information is sent to remote databases where machine learning takes place. Interconnections between collection of reports, classification of crowdsourced information and the resulting network models after using machine learning might offer fascinating statistic correlations to improve trustworthiness models. In such cases data accuracy is not obtained or checked directly but is rather retrieved from selected trustworthy participants.

#### C. Semi-supervised Content Classification

[#] Volunteer categories are 1. 'Text Clickers' for Tweets, 2.'Image Clickers' for Pictures, 3.'Aerial Clickers' for Aerial Pictures, 4.'Video Clickers' to tag videos and finally, 5. 'Geo Clickers' to map tweets, pictures and videos. There will be another category called 'Translate Clickers' to crowdsource the translation of tweets very soon.

In certain recent cases, data accuracy becomes be the main goal for number of reasons. For instance, machine learning has been used to automatically evaluate (within seconds) tweet trustworthiness based on social media message contents. For instance, based on semi-supervised learning *TweedCred*[21] requires first training set of tweets with well-known trust. Tweets are first to be considered informative, and then definitively credible. The next step is the extraction of tweet meta-data (number of seconds since the tweet, source of tweet...), tweet content (number of characters, presence of negative emotion words…), tweet author (number of followers…), tweet network (number of retweets…) and tweet links (ratio of likes…).

Another interesting example of using machine learning in crowdsurcing tools is the Artificial Intelligence Disaster Response (AIDR). Twitter messages are classified by at least three volunteers. If they agree and come to one conclusion, then AIDR starts to learn and auto-tags twitter messages. AIDR evaluates and share the confidence level (for instance 75%) of the auto-classification, and the more tweets a person sends the higher AIDR's confidence level [6][6]. Interestingly, classified tweets are then provided to first responders, aid agencies and NGOs.

MicroMappers, as before mentioned, also combines volunteer filtering with machine learning on a "Text-Clicker" option. Semi-automatic image "Aerial-Clicker" and video streaming "Streaming-Clicker" options will be soon ready.

### D. Sensors

Social Networking Data Mining (SNDM) and machine learning are not the only automatic selection tools. Risk analysis can be based on sensors. For instance, visual and audio analysis can alert of high or low level risk events, *i.e.* anomalous events [13], according to algorisms. Past anomalous events are added to a map to obtain correlations with new alerts with the same level of risk to eventually update the model or generate alarms. This sensor detection can be a perfect complement and can even confirm previous alarms coming from mobile phones. Parameters of the alarm map resulting from sensors can be modified to obtain added information and confirm or discard previous alarms.

### E. Ultimate Meta-Data Crisis Map

The MicroMappers community aims to have an ultimate comprehensive map to display the resulting data filtered both via data analytics and with Geo Clickers (volunteers). This enhanced map would display filtered tweets, text messages, photos, videos, satellite and unmanned aerial vehicles (UAVs) imagery. Each data type would be a different layer on a "Meta-Data Crisis Map". This eventually will be an ultimate selection and classification platform, based on crowdsourced data analytics for crisis management. However, selection and classification are only the first step towards decision-making. Situational awareness and decision support can also be envisioned.

## 3.2 Situational Awareness provided by Digital Volunteers

### 3.2.1 Human sensors and support teams

Communities of trusted volunteers can be effective support teams to discover and select relevant data. Access to users' live video streaming from mobile devices could help experts coordinate their activities. Users would provide their devices' sensors to improve the situational awareness of emergency response teams [22]. Users of location-based services, like microblogs for instance, create time-stamped and geo-located data using smart phones with GPS [23]. The augmented view of their environment might be crucial in scenarios of limited visibility like fire

rescues.

These virtual volunteers are only active during the event. They search and filter relevant information in social media and in the news, and receive indications from the emergency response team. They also warn against negative users' comments. Experts can view the video stream and interact with the source of the video if needed. Volunteers provide geo-referenced information, like sensors would do, to contribute to crisis situational awareness. Virtual volunteers usually employ group chat and Skype conversations, and some crisis informatics is now offering management tools to these small support teams [24].

### 3.2.2 Humanitarian Networks' Solution Teams

#### A. Digital Humanitarian Network

The Digital Humanitarian Network (DHNetwork) is a network of Volunteer & Technical Communities (V&TCs) to leverage digital networks in support of humanitarian response. More specifically, the aim of this platform is to 'provide an interface between formal, professional humanitarian organizations and informal yet skilled-and-agile volunteer & technical networks' (Humanitarian UAV Network (UAViators), Planetary Response Network for crowdsourcing satellite imagery analysis for humanitarian response). Numbers of services, for example, i) Real-time media monitoring of mainstream and social media; 2) Rapid geo-location of event-data and infrastructure data; 3) Creation of live crisis maps for decision support; 4) Data development and data cleaning; 5) GIS and Big Data analysis; 6) Satellite imagery tagging and tracing and others are being offered by the DHNetwork.

With the plan to organize a crisis simulation to assess workflows of DHNetwork in the near future, a number of DHNetwork Coordinators are engaged regularly to 'review activation-requests and rapidly liaise with the different volunteer and technical teams who are members of Digital Humanitarians to build a Solution Team best able to act on' a particular request.

#### B. Standby Task Force

In the aftermath of some of the recent disasters we have witnessed an increasing number of informal actors, largely volunteer based, entering the field of crisis mapping for humanitarian response. The development of ICTs has opened unprecedented space for engagement to a variety of individuals and groups, regardless of their physical location and affiliation to traditional responders. Similarly, with increased access to technology local communities – always the first responders in crisis situations – are not only building and improving their own preparedness and response systems, but are also more effectively engaging in traditional humanitarian preparedness.

#### C. Peace Geeks

Esri Canada highlights how GIS technologies are being used by groups like PeaceGeeks to aid in disaster strikes, emergency responders and aid organizations on the ground. These digital volunteers are able to gather information, have technologies and technical skills to assess the status of an emergency remotely. They are "tasked with the acquisition, verification, summarization and geolocation of data including: the categorization of social media posts and photos to indicate which areas and individuals have been affected; the location of emergency shelters and health facilities to direct those in need; and even the mapping of basic road network infrastructure to

assist aid workers in accessing affected areas"[#]. This volunteer group also uses GIS technologies such as Esri's Web mapping technologies reacting to these emergencies all over the world.

### D. Humanitarian OpenStreetMap Team

The goal of OpenStreetMap is 'to create a free and open map of the entire world, built entirely by volunteers surveying with GPS, digitizing aerial imagery, and collecting and liberating existing public sources of geographic data'. The mapping community believes that the information in OpenStreetMap can fill in the gaps in base map data to assist in responses to any disaster and crisis.

The Humanitarian OpenStreetMap Team's (HOT) reaction to Haiti earthquake on January 2010 remains one of the most significant 'examples of what's possible when volunteers, open source software and open data intersect' [25]. After the 7.0 magnitude earthquake struck, information on the Google Map of downtown Port-au-Prince was not possible to use humanitarian response as the map was simply incomplete. However, within days, hundreds of volunteers from the 'OpenStreetMap[$] (OSM) community used satellite imagery to trace roads, shelters and other important features to create the most detailed map of Haiti ever made'[25].

### E. GisCorps

Another volunteer-driven crisis response community GisCrops[@] helps to improve the quality of life by supporting humanitarian relief works during different crises and disasters by adopting and using information technology. GISCorps volunteers are highly specialized GIS expertise and they use spatial information technologies to benefit the communities in need.

One of the remarkable works done by GISCorps in collaboration with Standby Volunteer Task Force (SBTF) and ESRI[!] was to identify the geo-location of "Mild" and "Severe" damaged tagged images out of over 7,000 images, in the aftermath of Typhoon Yolanda, clicked by users using MicroMappersImageClicker tool [25, 19]. They have created a live crisis map[*] of the disaster damage tagged using the ImageClicker[±].

### F. Humanity Road

Humanity Road[ϒ] depends on volunteers to monitor 'emerging events; slow moving natural disasters and natural calamities, such as floods or typhoons and fast moving events such as an earthquakes or tornadoes'[♣]. A team of global volunteers of Humanity Road monitor employ social platforms to check the activities of the online chatters associated with disaster events. Thus, volunteers around the world collect situational information and amplify official messaging and 'route critical emergency aid information to those in needs, connecting official charity, aid

[#]See more about PeaceGeeks at http://peacegeeks.org/tags/peacegeeks Accessed 26/05/2015.
[$]See more about OpenStreetMap at www.openstreetmap.org/ Accessed 26/05/2015.
[@]See more about GISCrop at http://giscorps.org/ Accessed 26/05/2015.
[!]See more about ESRI at http://www.esri.com/ Accessed 26/05/2015.
[*]See the crisis map at http://arcg.is/1rMRKPK Accessed 26/05/2015.
[±]See http://crowdcrafting.org/project/MM_ImageClicker/ to know more about ImageClicker. Accessed 25/05/2015
[ϒ]See more about Humanity Road at http://humanityroad.org/ Accessed 06/06/2015.
[♣] Visit 'About' page of Humanity Road at http://humanityroad.org/abouts Accessed 06/06/2015.

organizations and nonprofits with those requiring assistance or aid'[♣]. By utilizing new technologies such as crowdsourcing and crisis mapping, Humanity Road accomplishes these tasks through trusted techniques, and use strict policy of "verify-times-2".

One of the remarkable tasks of Humanity Road was 'to deliver a detailed dataset of pictures and videos (posted on Twitter) which depict damage and flooding following the Typhoon Pablo[♦] in 2012, which was projected on a map[⊗]. Humanity Road (HR) was one of the two volunteer groups worked under the Digital Humanitarian Network's Solution Team to rapidly consolidate and analyze data to compile a customized Situation Report[″] for OCHA's team in the Philippines.

### 3.2.3 Situational Awareness Services

#### A. Visual analytics

Crowdsourced data analytics, for instance visual analytics, will probably support rapid situational decision-making in the near future [23]. Time-stamped and geo-located data from smart phones with GPS, for example, allow pre- and post-event comparisons. This information can unveil trends difficult to detect for humans. As a result, geo-located abnormal use of smart phones due to natural disasters can help in the identification of the main affected areas.

Crowdsourcing is also combined with sensors located in specific areas and UAVs [20]. The idea is to merge data and information from different sources and to generate a better situational awareness, thus faster and more accurate event detection. Moreover, this kind of platforms is supposed to offer a decision-planning tool for a prompt response in case of an emergency [20, 23].

This is a clear example of the continuum between situational awareness and decision-making: the former allows the latter, but also anticipates it. This is what is claimed with some decision-planning functionalities. Data coming from different sources are merged and classified as emergency event or normal situation, according to general risk management.

#### B. Automatic Risk Estimation and Management

Situational Awareness is a prerequisite for decision-making, and decision support systems [26]. Therefore, a tool supporting automatic situational awareness is fundamental. Such a tool collects data and offers situation assessment, in this case based on risk estimation. An estimation of the event probability and severity produces an estimation of the risk. If the risk is unacceptable according to some known parameters, then a recovery is suggested. The identification of the risk-reduction components leads to risk management and decision-making. This is only an approximate model of experts' risk level classification.

First response teams mayhaveincorrectinformationprovidedbyfailed sensors or unreliable users, or maynot even have any informationat all. In these cases, having an automatic risk estimation can be useful for unskilled or semi-skilled operators [26]. Well-skilled response team may still trust more their education and experience rather than determine risk levels using only automatic tools. In these complex cases another option is to trust humanitarian networks, with their digital volunteer teams and data analytics tools.

### 3.3 Decision Support

[♦] See https://en.wikipedia.org/wiki/Typhoon_Bopha to know more about Typhoon Pablo. Accessed 25/05/2015

[⊗] Find the map on Typhoon here at http://arcg.is/1FI5yRg. Accessed 25/05/2015.

[″] See http://irevolution.net/2012/12/06/digital-disaster-response-typhoon/ to read the summary of the report i.e. 'Digital Disaster Response to Philippine Typhoon'. Accessed 02/06/2015.

### 3.3.1 Humanitarian Networks and Decision-making Support Teams

In crisis response work, common users, responders and other volunteers work mainly under the advice and direction of core decision-making support groups. There should be a core decision making team for every crisis. The core team members are consists of experts from different fields like, GIS experts, communication experts, relief experts etc.

#### A. United Nations Office for the Coordination of Humanitarian Affairs (OCHA)

The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) is the 'part of the United Nations Secretariat responsible for bringing together humanitarian actors to ensure a coherent response to emergencies'. Either directly or indirectly, OCHA takes part in any humanitarian crisis management work. By mobilizing and coordinating effective and principled humanitarian action in partnership with national and international actors in order to alleviate human suffering in disasters and emergencies. Over the years, OCHA has assisted millions of humanitarian beneficiaries in four continents. As OCHA ensures there is a framework within which each actor can contribute to the overall response effort, one of the important efforts it makes is to work directly with digital activists and volunteers to understand the crisis well as it allows OCHA to get reports from the ground. This initiative helps OCHA advocating for the rights of people in need, promoting preparedness and prevention and facilitating sustainable solutions. This UN organ has partnered and worked with different digital humanitarian groups. To deliver OCHA's action plan on the ground, it forms a core decision-making support team that decides on different aspects of crisis response works.

#### B. Digital Humanitarian Network (DHN)

The Digital Humanitarian Network[∝] is a network-of-networks, 'enabling a consortium of Volunteer and Technical Communities (V&TCs) to interface with humanitarian organizations that seek their services'[ϒ]. The DHNetwork, has been created specifically in order to coordinate the activities of digital humanitarian volunteers. The network brings together many of the major volunteer and technical communities to increase their visibility both amongst themselves and amongst the traditional humanitarian community. This approach of DHNetwork has helped to define a clear activation process among the volunteer communities. Organizations like OCHA and other traditional organizations are able to submit a request and rely on the DHNetwork to build a solution team with the relevant volunteer members within the volunteer communities. This core solution team is responsible for any decision for further course of actions in regards to a particular deployment to manage disaster response activities. As disaster responders use numerous innovative digital tools and techniques, and also other human volunteers, they could easily gather the digitally analyzed information on a particular situation. Such type of analyzed information helps core 'solution team' or 'decision makers' to take the final decision on further actions in disaster situations.

### 3.3.2 Decision Support Systems

#### A. Simulation to support decision-making

[∝] Visit the main website of the Network at https://digitalhumanitarians.com. Accessed 25/05/2015.

[ϒ] Also available here at http://en.wikipedia.org/wiki/Digital_Humanitarian_Network. Accessed 25/05/2015.

Forest fire spread predictions can successfully assess decision support systems. If those tools want to be effective, they need to run quickly enough to provide the output before the real fire evolution, with real-time constraints [27]. In simulation's output is limited to three hours maximum and this leads to a trade-off between resolution and availability. The optimization of algorithms is the way to offer on time enough accurate data to expert response teams.

Housing decision support systems are also starting to provide simulations for the post-disaster housing problem [25]. Real-time housing recommendation needs complex heuristics, and even then two more emerging problems are still unsolved: temporaryworkersinvolved in therecoverymust be housed, whichmaynot have been included in the simulation, and coordination between housing recommendation institutions has also to be taken into account.

### B. Geomatics for crisis management

Rapid mapping, *i.e.* "on-demand and fast provision (within hours or days) of geospatial information in support of emergency management activities immediately after an emergency event"[¥] is another data analytics valuable technique for disaster management [28]. Rapid mapping is increasingly used in crisis management and there is even an International Working Group on Satellite Emergency mapping[¢].

Some crowdsourced mapping initiatives like OpenStreetMap (OSM) and the Humanitarian OpenStreetMap (HOT) complement national agencies[¬]. Data analytics is, nonetheless, also used to generate information. For instance, part of the map production is based on automatic affected population estimations or potential infrastructure damages evaluation. Obviously, this is only possible when there are areas with detailed reference datasets available, otherwise *ad-hoc* crowdsourced mapping would be necessary. Image analytics can also start with volunteer identification of objects and places, and then use data analytics or be available for expert response teams[°].

### C. Emotion classification of social media posts

Social Networks and media are not only source of data. They can also be important for becoming aware of how communicated alert messages are perceived by citizens. Tweets sent during the Sandy hurricane, where annotators have manually tagged the emotional content: anger, fear, positive and others. This initial work has been used to train algorithms [20]. The resulting classifications have allowed new retrieval of crisis tweets, previously unseen.

## 4. CONCLUSIONS AND FURTHER WORK

Crisis informatics is now based on crowdsourced data analytics, a combination of crowdsourcing retrieval, filtering and situational awareness, and decision support systems. Volunteers not only provide information, they also participate in collective task-solving requests. At the earlier stage of using crowdsourcing for crisis management, the main contribution of digital volunteers was crisis mapping. At the later stage, the digital volunteer's involvement and commitment towards using crowdsourcing for crisis mapping has increased rapidly. They have started using sophisticated tools and technologies i.e. machine learning, artificial intelligence, use of drones to gather crisis information etc. As a result, real-time estimations of reliability and relevance

[¥] European Union, http://emergency.copernicus.eu/mapping/ems/service-overviewAccessed 24/05/2015.
[¢] IWG-SEM, http://www.un-spider.org/network/iwg-semAccessed 23/05/2015.
[¬] See more at https://www.openstreetmap.org/#map=5/51.500/-0.100 and http://hot.openstreetmap.org/, both accessed 24/05/2015.
[°] See more at http://www.tomnod.comaccessed on 25/10/2015

of incidents are also available for digital communities and crisis response coordinators. Different volunteers communities like DHN and othersalso offer data analytics to volunteer communities and others to use during crisis. These networks coordinate solution teams that offer situational awareness to first response teams. Moreover, the combination of OCHA and DHN is a major contribution to the crisis management decision-making process. Data analytics not only empowers humanitarian digital communities, but it also complements - and soon will substitute - some of the volunteers' contributions. Indeed, data analytics adds a new layer to final data mapping, with sensors, UVA or satellite images; and it replaces volunteers' relevance selection with algorithms. Visual analytics and risk estimation fuel situational awareness services. In this research, it has been identified that first response teams are usually reluctant to let non-experts participate in the decision-making process. Nonetheless, they have informal support-teams to enhance the context information. The emerging automatic support systems based on simulation, geomatics and emotion classification can anticipate the decision-making. Similarly to many other fields, experts should not decide solely based on automatic tools. The DHN-OCHA decision support is an alternative that should be enhanced in order to offer external supervision to automatic decision tools. First response teams should also check those tools, and limit their use to recurrent and clear cases. In more complex cases,confirmation from skilled experts is necessary. Thus, the automatic decision-making support system alone does not have the ability to empower volunteers during any crisis event.

After describing and classifying the human and machine contributions to crowdsourced data analytics, a thorough impact and risk assessment can be performed as future activities. The detection of risk scenarios, according to legal and ethical general perspectives, will require concrete recommendations. Therefore, offering regulatory frameworks for concrete crowdsourcing disaster platforms will be of crucial importance.

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