Characterization of the Use of Social Media in Natural Disasters: A Systematic Review

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Abstract— **Social media sites are playing a significant role in rapid propagation of information when disasters occur. This effective communication platform is a great useful tool for emergency (disaster) management agencies during all phases of disaster management life cycle: prevention (mitigation), preparedness, response, and recovery. This study has conducted a systematic review of social media use in disaster management literature to identify how social media sites have been used during these four critical phases of disaster management life cycle in order to recommend strategies for government officials. a systematic method has been used to search four major academic databases for this review. The search resulted in 40 articles and categorized the findings in six main themes: situational awareness, data collection methods, distributed sensor systems, news and rumors, sentiment analysis, and digital volunteerism.**

Keywords—Social Media, disaster management, systematic literature review

I. INTRODUCTION

Information exchange is pivotal during the disaster management processes (i.e., prevention, preparedness, response, and recovery) and specially response phase. Due to the dynamic and complex nature of the extreme natural or man-made disasters as the rate of communication increases vastly [1,2] and often personal and technical facilities are unable to operate properly as expected and detailed in prepared standard operating procedures and emergency response plans which very often led to the communications failure, which has been claimed as one of the main problems during disaster response management [1].

The enhancement of telecommunication networks and the widespread diffusion of mobile devices and new Web technologies are helping to recover (treat) this communication challenge. Recent studies find telecommunication services such as Short Message Services (SMSs) or social media sites (e.g. Twitter, Facebook, YouTube) enhances the consistent and timely transmission of valuable information throughout the disaster management life cycle which help to establish a disaster resilient community [1-4].

Disasters are complex in nature, which can have disproportionate effects at varying speed. Social media sites can be used to enhancing a community capacity and preparing for disasters [5]. For example, in a disaster, emergency management authorities may access social networks and blogs to find out the source and severity of the disaster and create situational awareness appropriate to the affected communities [4]. Authorities may monitor online communities to identify emerging trends and potential hotspots which can be flashpoints for disaster.

While past studies have provided some mechanisms and recommendations for the use of social media to manage disasters [5-7], it is still unclear how social media have been used to support the safety of the community [5]. Identification of various ways of using social media is important, as it helps in providing high level guidance on disaster management to federal, state, territory and local governments and it is first step towards longer term goals of delivering sustained behavior and enduring partnership with the communities [5].

Therefore, this study is an attempt to answer 'in what ways do social media applications contribute to natural disaster management?' To answer this question a systematic review of the social media literature needs to be conducted which would help to synthesize best quality scientific studies on the role of social media in disaster management. Systematic Literature review (SLR) acts as a methodology of the synthesis. In contrast to expert view, SLR would not just aggregate all the existing evidence on the above research question it would also support the development of evidence-based guidelines for emergency authorities.

II. METHODOLOGY

The objective of this study is to conduct a systematic review of the literature on the characterization of social media response to natural disasters. This study has customized the guidelines for systematic reviews laid by Kitchenham (2004) and applied in several reviews [6] and conducted the review in four steps (as shown in Figure 1): (a) Identification of Resources (b) Selection of Studies (c) Data extraction and synthesis (d) Data analysis.
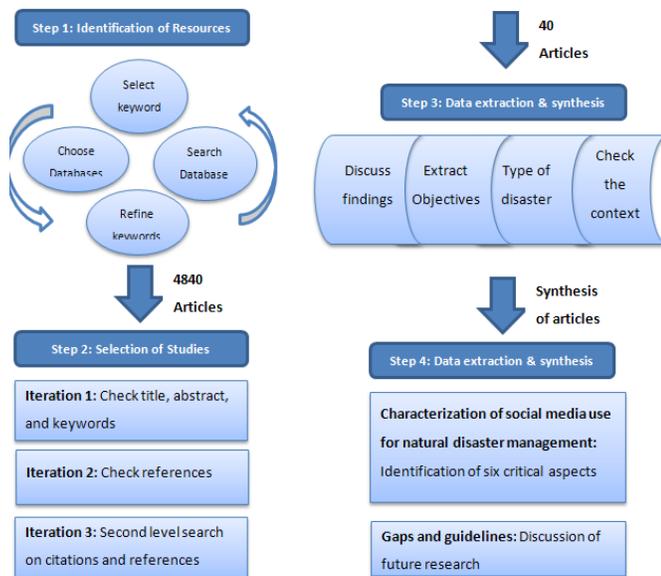
Fig. 1. Systemtic review process

A. Identification of Resources

In order to identify the resources (i.e., publications reflecting the research area: social media applications contribute to natural disaster management) for our data collection, first we need to come up with the relevant phrases or keywords. Therefore, this step begins with the identification of relevant keywords. A trial search on Google scholar was performed by using the terms 'social media' and 'natural disaster' as these terms are the key facets of our research question. A brief overview of the first 200 search results indicated that the terms 'emergency', 'hazard' or 'crisis' (in addition to the term 'natural disaster') can be used in combination with the term 'social media' to identify appropriate resources as shown below:

'Social media' and 'natural disaster'

'Social media' and 'emergency'

'Social media' and 'natural hazard'

'Social media' and 'crisis'

Once the keywords were finalised, four databases, IEEE Explore, Science Direct, Springer Link and Google Scholar were searched for studies which resulted in altogether 4840 articles. Distribution of these 4840 articles upon four databases is shown in Table 1. For the initial screening, only titles, abstracts and keywords were considered and the search was contained to the studies published between 2000 and 2014 as from the turn of the century, the development of social media websites and their users increased exponentially and studies into the usefulness of social media particularly in natural disaster started late 2000.

Databases	No of articles
IEEE Xplore	1204
ScienceDirect	203
SpringerLink	197
Google Scholar	3973
Total	**4840**

B. Selection of Studies

This step of SLR demands filtering of papers from the initial list of extracted articles from the databases and excludes papers based on the criteria. This process is carried out in three iterations as presented in Figure 1.

The first iteration involved searching for the keywords over the four databases and excluding articles based on title, abstracts, keywords and full texts. The articles addressing the following exclusion criteria were not considered:

- Did not considered social media during natural disasters
- Did not collect social media response during natural disasters
- Did not consider natural disasters or any other relevant term
- Were in language other than English
- Repeated articles
- Not peer reviewed
- Not available online

The 4,840 articles were divided among the three researchers for iteration 1. Each researcher manually evaluated nearly 1,200 articles based on the criteria which resulted in 16 articles candidate for literature review. The results support the calls for studies into the use of social media during natural disasters.

The second iteration has two sub-iterations: (1) search on references of the articles found in iteration 1; and (2) search on articles, which have cited the articles found in iteration 1. These sub-iterations were performed by using Google Scholar and excluded paper based on the criteria provided above. These iterations found 19 new articles (14 articles from search on references and five from search on citations) candidate of literature review. At the completion of the second iteration, 35 articles were achieved.

The third iteration is a repeat of the second iteration on the articles extracted in the second iteration. This is basically a second level search on citations and references of the articles. This search achieved five more articles (three articles from search on references and two from search on citations) and the total was 40 articles. These findings confirm the shortage of studies into the use of social media to manage natural disasters.

C. Data Extraction and Synthesis

In this step, the key details of each of 40 selected papers were retrieved.

TABLE II: SYNTHESIS OF SOCIAL MEDIA STUDIES

Studies	Context	Natural disasters	Objectives of the studies	Results
Krishnamurthy et al. (2008) Imran et al., 2013	Twitter	- Tornado Joplin 2011 - Hurricane Sandy 2012 - Japan earthquake 2011	Evaluate data collection methods	methods have strengths and weakness, however none of the methods is superior over others
Vieweg et al. (2010) Kavanaugh et al. (2011)	Twitter	-Red river floods spring 2009 -Oklahoma grassfire spring 2009	Create situational awanress	Levelof situational awareness varies w.r.t. the location and type of an event.
Mendoza et al. (2010) Morris et al. (2012) Castillo et al. (2011) Popool et al. (2013)	Twitter	Chilean earthquake 2010	assess the credibity of the postings	Not all the postings are credable, development of mechanisms differentiating rumors from valid news has been realised
Crook et al. (2013) Nagar et al. (2012)	Twitter	-VA earthquake 2011 -Philippine typhoon 2010 -Brazil floods 2011 -Japan earthquake 2011	Harvest geospatial info from social media feeds for event detection and analysis	users with geospatial information can act as an early warning system
Starbird et al. (2011) Cobb et al. (2014)	Twitter	Haiti Earthquake 2010	How emergency managers and experienced digital workers curate social media data during crisis events.	Digital volunteers use tools and processes to colleborate and work together, however desing implications to this work exist.
Mandel et al. (2012) Diakopoulos et al. (2010) Marcus et al. (2011)	Twitter and faceboo k	- Hurricane Irene, 2011 - Vicoria floods 2011	To assess the sentiments of the communities	There is difference in sentiments based on gender and location of a person

It includes the context of the study (e.g.,), natural disaster type and information (e.g., location, time), objectives and results of the study in addition to the demographics of the paper (e.g.,). Studies having similar purposes were grouped to show the streams of research as shown in Table 2.

III. CRITICAL ASPECTS OF SOCIAL MEDIA USE FOR NATURAL DISASTER MANAGEMENT

This section discusses and summarizes the findings from the studies reviewed in Table 2 into six characteristics:

A. Data Collection Methods

The rise of social media and other forms of user-generated contents have created the demand for real-time search on the provided online information (i.e. posts) [9]. It requires methods and tools which can effectively extract data via APIs and then analysing these data to extract information of interest [3, 10]. Social media research has introduced various methods for the effective collection of disaster related posts such as Bloom Filter Chains for real-time tweet search [9], TAKMI technology for content analysis [8] and twitter APIs – 'crawl' and 'timeline' [11]. Krishnamurthy et al. (2008) used these two methods, both relying on API functions provided by Twitter for the collection of large amount of data through crawl and timeline functions of Twitter. The analysis of the two datasets, i.e. 'crawl' and 'timeline', indicate that there is no considerable difference between the two datasets on the characterization of Twitter users, status updates and validation of crawling methodology. However, the shift in the Internet traffic toward program or machine generated data and consumption by processes on behalf of human users have been concluded as a future trend by the study.

B. Developing Situational Awareness

Social media platforms are overwhelmingly useful to create situational awareness among the affected communities of natural disasters. For many social media researchers a situational awareness view is helpful for anticipating how individuals, groups and communities can use information contributed by others on social media platforms [3, 12-14]. Vieweg et al. (2010) conducted a study in which they extracted microblogging posts of two natural hazards, Red River Floods and Oklahoma Grassfires both occurred in Spring 2009, and identified and measured features that are useful for situational awareness. The net result of this study is that the activities differ with respect to the location of the event and thus initiates discussion on how these findings can serve as a foundation for designing and implementing systems that can be used in future emergency events for better and targeted situational awareness.

C. Classifying News and Rumours

Mendoza et al (2010) argue that if Twitter, as a social media platform, is effective in broadcasting valid information, it is also effective in spreading the baseless rumours which can contribute to the general chaos in the affected areas [15]. Social media researchers such as [16, 17] have also questioned the credibility of the social media feeds during natural disasters. They argue that during a natural disaster when information from official sources is scarce, rumours on social media can surface contributing to the chaos on the ground. Studies such as [18] indicate that the users generally have difficulty discerning

truthfulness of tweets based on their contents. To develop a deeper understanding of the difference between valid news and baseless rumours, Mendoza et al (2010) collected Twitter data, 4,727,524 tweets, on Chilean earthquake from February 27 to March 2 in 2010 and performed two studies to investigate, (1) how the news and rumours propagate through networks and (2) the ability of the network to discriminate between false rumours and confirmed news. The results postulate that the propagation of tweets that correspond to rumours differs from tweets that spread news in a way that false rumours are questioned much more than the confirmed truths by the users [15]. From this perspective, the Twitter community acts as a collaborative filter of information that does not allow rumours to penetrate deep in the social graph [15]. The studies suggest creating a state-of-the-art text classification mechanism at the social media platform level providing instant warnings to the affected community about the information being questioned by the other users.

D. Distributed Sensor System

Crooks et al. (2013) argue that the proliferation of social media feeds and Ambient Geographic Information (AGI) contents fosters the emergence of microblogging as a new type of a distributed system, with bloggers acting as sensors, and their comments in the form of tweets, convey relevant information often with a corresponding geographic footprint [3]. This study analysed the microblogging posts with geo-location footprints about Mineral, VA earthquake of August 23, 2013. One of the critical observations of this study is that the microblogging posts such as tweets can travel faster than the physical event to distant locations and therefore act as an early warning system for large scale incidents [3]. In addition, harvesting geospatial information from microblogging posts can rapidly provide valuable information on the impact of physical event. In this regard, systems that perform real-time trend detection over the twitter stream are suggested to be adopted [19]. Use of adaptive sliding window application of a lexicon-based content analysis solution by Zao, Zhong [20] is one of the examples that detects events particularly in Twitter within 40 seconds of the unfolding event. Integration of such systems with the analysis conducted by this study demonstrates Twitter as an effective distributed sensor system for event detection and impact assessment [3].

E. Digital Volunteerism

Cobb et al. (2014) recognize the importance of processing real-time and first-hand information from disaster-affected-community for a better decision making and designing strategies [4]. Starbird et al. (2011) call individuals and groups involved in this task digital volunteers who predominantly monitor incoming feeds to find new, relevant, and actionable information [21, 22]. Digital volunteers often work to treat the social media data into useable resources. Cobbs et al. (2014) conducted contextual interview with digital volunteers and emergency managers to provide insights into their collaboration and the use of tools for monitoring disasters. The results of the study indicate that the design implications for supporting this work, including coordinating and integrating activities of distributed volunteers exist

F. Sentiment analysis

Fothergill et al. (1999) argue that minorities differ in their risk perception and in their response to emergency warnings, with some having fatalistic sentiments leading to greater fear and less preparedness[23]. These sentiments need to be understood by the emergency authorities to better tailor emergency warnings, preparedness and responses [24]. Public sentiments towards unfolding natural disasters are measured various ways by the social media platforms. For example, Facebook measures the level of public concern through 'likes' and 'dislikes' [6]. Since Twitter has extensively been used for posting opinions and situations, it has become the focus of sentiment analysis [25].
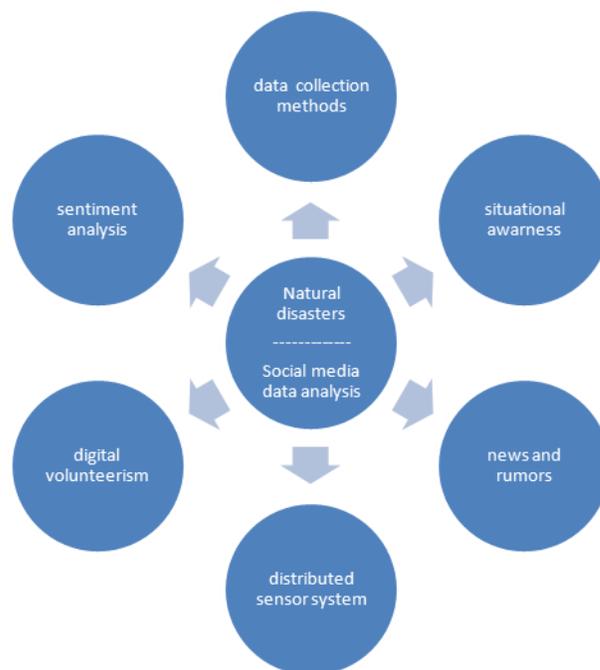

Fig. 2. Dominant aspects of the use of social media

A variety of methods have been introduced to perform sentiment analysis during natural disasters. For example, some scholars use a naïve Bayes classifier trained on unigram features to place tweets into positive and negative classes [24]. Others use Twitter based sentiment analysis algorithms in aggregate form, in which number of occurrences of positive and negative words in each tweet is counted to determine the tweet's sentiment score [26]. Mandel et al. (2012) used a similar approach to conduct sentiment analysis on 65,000 tweets referencing Hurricane Irene in 2011. This study used an existing sentiment classification technology that categorises messages based on degree of apprehension, fear or general concern about Hurricane Irene. The results of this study indicate that the sentiments vary based on persons' gender or location however accounts for classifier errors in hypothesized testing and adjusting classification proportions using quantitative methods have been considered future challenges [24, 27].

IV. DISCUSSION AND CONCLUSION

This research began with the arguments that social media is being quickly adopted as it offers ways to retrieve, produce and spread information [12]. The nature of that sharing has been recognized as a life cycle of information production and consumption which is rapid and repetitive [22]. Since social media is a platform for emergency communication it has been considered a place to harvest information about natural disasters to determine what is happening on the ground [28]. Therefore, social media has gained momentous attention both from researchers and practitioners. On the one hand, practitioners are developing skills and knowledge to better utilize social media services, on the other hand, researchers are developing models to examine various aspects of the use of social media in dissimilar settings [13, 29].

This study conducted a systematic review of the literature particularly focusing on the use of the social media in natural disasters to determine aspects of interests for the researchers. Initially 4,840 articles were retrieved from four databases. This total was reduced to 40 when article selection and finalization procedures were applied. Evaluation of the 40 finalised articles indicates that the researchers have focused on six aspects (see figure 2) of the use of social media based on the analysis of a vast amount of data related to natural disasters around the world. For example, a group of researchers have argued that the selection of an appropriate method is crucial for effective collection and analysis of disaster related data during any stage of the disaster. The majority of the selected articles are in the favour of general perception that social media is an effective platform to create situational awareness among the affected communities before, during and after a disaster. Some of the researchers have looked into the social media data in terms of good and bad information for the communities in the affected areas. They have proposed mechanisms to distinguish rumours from valid news and curb them to avoid further panic among the affected area communities. To some researchers, people from disaster areas, posting location enabled messages on social media platforms, define a distribute sensor system which helps to immediately identify and localize the impact area of the event. Some of the researchers have focused on the importance of collecting and processing real-time first-hand information about an event for the purpose of formulating strategies and decision making. This phenomenon has been recognized as a digital volunteerism in which volunteers use social media to assist in disaster response efforts through filtering and mapping crisis related social media data. Since the social media has been used as a means for emergency communication, to some researchers, it becomes important to understand how people in the affected area feel about the unfolding situation. Sentiment analysis has been focused on by many studies and the results highlight the importance of sentiment of the people of area in relation to devise response strategies by the authorities. All the studies into the six aspects of the use of social media have highlighted challenges and improvements to the existing research.

Since social media has become a popular platform to disseminate and harvest information about events, its importance has particularly been recognized for natural disaster management [14]. A systematic review of the literature on the role of social media in natural disasters characterises social media into six aspects: data collection methods, create situational awareness, classify news and rumours, distributed sensor system, digital volunteerism and sentiment analysis. These six aspects have been considered important in the studies related to natural disasters in various parts of the world.

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