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Alivelu Mukkamala
IT University of Copenhagen, ammu@itu.dk

Roman Beck
IT University of Copenhagen, romb@itu.dk

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Alivelu Mukkamala, Information Management Section, IT University of Copenhagen, Denmark, ammu@itu.dk

Roman Beck, Information Management Section, IT University of Copenhagen, Denmark, romb@itu.dk

Abstract

Twitter became an important channel to contribute and consume all kinds of information, especially in times of disasters, when people feel the need for fast, real-time flows of information. Given the wealth of information Twitter provides, that information can be used by practitioners and researchers alike to study what people affected by a disaster talk about, e.g., to develop a situation awareness and to coordinate disaster management accordingly. In our research, we analyze 11 million tweets that deal with hurricane Sandy, one of the strongest hurricanes that ever hit the US east coast in 2012. First, we extract the tweets by narrowing down the hurricane affected path along the US east coast, based on geo-spatial information. Further, drawing on the situation awareness literature and previous coding schemes, we analyze the nature and characteristics of the tweets. Our research reveals that there are significantly more tweets from original sources than from secondary sources and that individuals tend to share valuable personal experiences and observations at the time of disasters. In analyzing those individual level perceptions, we illustrate how one can generate situation awareness at the collective level. This situation awareness will enhance the decision-making of disaster management agencies at the time of uncertain and volatile situations.

Keywords: Social Media Analytics, Disaster Management, Situation Awareness

1 INTRODUCTION

@tweetuser (2012-11-01 03:28:59) "What's amazing is how Twitter and Facebook are more current and up to date with events on #Sandy then the actual news on tv...#media #fail"

Among the different social media platforms, Twitter is not only one of the largest but also one of the fastest when it comes to reliably disseminating news and information in the form of short messages known as tweets (Java et al. 2007;Velichety & Ram 2013). Twitter also allows us to enrich the messages exchanged by adding links, pictures, hashtags, and video clips thereby empowering users to exchange information they regard as important, which in turn makes Twitter an interesting source of information for researchers and practitioners alike (Acar & Muraki 2011;Ahmed & Sargent 2014;Ha & Ahn 2011;Oh et al. 2010;Sinnappan et al. 2010). Thus, Twitter is an effective medium to share information, opinions, and emotions in real-time (O'Connor et al. 2010;Pak & Paroubek 2010).

Initially, Twitter was designed to be used as a convenient way to share short messages with family and friends, but over time it became a platform to share impressions and news, as seen in the Arab spring with its democratic movements, e.g., in Tunisia and Egypt. Thus, Twitter users are able to learn about events taking place from exchanged messages, thereby decreasing their situational uncertainty while promoting certain collective goals (Lotan et al. 2011;Oh et al. 2012;Starbird & Palen 2012).

In our research, we are interested in the value of Twitter messages to develop a situation awareness in areas that are affected by a natural or man-made catastrophe. Moreover, it is in the human nature to communicate and get closer together in times of unsettling events, thereby creating a feeling of closeness with each other and thus share and read news and messages more often, e.g., when floods, wildfires (Starbird et al. 2010;Vieweg et al. 2010), or earthquakes (Qu et al. 2011) occur.

Despite an increasing interest in social media analytics in information systems research, there is only a limited number of publications on, e.g., the use of Twitter messages for disaster management. With our research, we are addressing this gap and analyse how different information categories shared in social media messages can be identified and used to provide disaster response agencies with better intelligence and situation awareness. In order to illustrate what a disaster management agency can learn from social media data, we analysed approximately 11 million tweets that have been sent between October 25th and November 5th 2012, dealing with hurricane Sandy that hit the US east coast and made landfall at New York City at the end of October 2012. We will illustrate how we processed the Twitter messages, including data cleansing and pre-processing before we conducted a manual coding to extract and classify information that allows for an improved situational awareness. In doing so, we strive to answer our research questions, namely *which different types of disaster management relevant information can be identified* and *what is the nature and characteristics of this shared information?*

The remainder of the paper is organised as follows. In section 2, we will explain the literature background, followed by methodology in section 3, where we describe the methodology where we systematically pre-processed and narrowed down the data using a series of methodologies, before we describe the qualitative content analysis that we applied for the coding of the data. The subsequent analysis of the data will be presented in section 3. In section 4, we will discuss the theoretical and practical implications, before we conclude our work with section 5 where we also discuss the limitations of our work as well as future research directions.

2 LITERATURE BACKGROUND

2.1 Social Media Analytics in Times of Disasters

In information systems, social media analytics and research on Twitter data in times of disasters has gained some prominence in recent years, focusing on both, man-made as well as natural disasters.

While some early work was focused on information production and distribution, as illustrated by the Red river flood in central North America in 2009, where individuals not only shared information about their situation but also re-tweeted the available, useful information, later work already differentiated in original and secondary information, synthesized or derivative from prior sources (Starbird et al. 2010). In any case, it has been discovered that the information shared contains situational updates that are used to create situational awareness, such as illustrated in the Oklahoma wildfire case (Vieweg et al. 2010). However, Twitter is not only used by the people affected by a disaster, but also by local authorities to inform and manage the situation, as the Queensland flood case illustrates, where the interactions between Twitter users were analyzed (Cheong & Cheong 2011). The case clearly illustrates that Twitter is not only an important source to gain information and develop situational awareness but that it can also be used by disaster management agencies to actively manage a crisis.

When an earthquake struck Yushu in China, the people affected by the disaster not only provided information about the situation on the ground but they also used social media to ask for help or for showing empathy with those who suffered most losses (Qu et al. 2011). It furthermore seems to be irrelevant if the disaster is a natural catastrophe or a man-made disaster, the prime concern always seems to be to share information of the situation rather than sharing opinions and thoughts, as research on a police shooting case in Seattle revealed (Heverin & Zach 2010). The same finding has been made when Twitter messages dealing with the Boston marathon bombing case were analyzed (Venkatesan et al. 2014).

2.2 Situation Awareness

In order to support good decision making, accumulating information to develop a certain understanding about what is happening in a certain situation is important (Reilly et al. 2007), especially in times when disasters take place suddenly which require immediate action to respond and help affected people. As illustrated in 2.1, some empirical research uses Twitter data in times of disasters with the aim to shed light on the role of information creation and sharing on social media platforms to create situation awareness (SA). Situation awareness refers to the way human beings extract meaning from information about their surroundings to develop mental models of a situation by integrating the extracted information with their own knowledge to explore and anticipate further action (Seebach et al. 2011;Vidulich et al. 1994). Often, SA helps in emergency situations to implement the response strategies and to derive decisions to combat the crisis (Vieweg et al. 2010). Even though SA has often been analysed from an individual point of view, it can also be aggregated at the group level (Seebach et al. 2011). It can be argued that Twitter is facilitating group level SA that can be subsequently used by disaster management agencies to develop an understanding about the situation on the ground. The situation updates that started at an individual level lead to engage at a collective level activity. This collective level sharing of knowledge enhances the SA in a broader prospect and helps emergency organizations act immediately in disaster response.In relation to situational awareness, currently, research is focusing on employing machine-learning approaches to extract the situational awareness information from Twitter data during disasters (Sen et al. 2015;Verma et al. 2011).

3 METHODOLOGY

3.1 Data Collection

For our research, we used a Twitter message dataset containing hurricane Sandy tweet IDs (Zubiaga & Ji 2014) that are publicly accessible (Zubiaga 2015). The original dataset contains nearly 15 million tweets posted on Twitter between October 25th and November 5th, 2012 when hurricane Sandy hit the east coast of the US. In order to comply with the terms of service of Twitter, the researchers only shared the tweet IDs and not the actual tweets from the dataset of hurricane Sandy. Using those tweet IDs, we were able to retrieve tweets between May and June 2015, using the Twitter Rest APIs (Twitter

2016). The originally shared dataset comprised nearly 15 million tweets, but when we downloaded the tweets we were only able to retrieve approximately 11 million tweets.

As mentioned, the total dataset of Hurricane Sandy contains approximately 11 million tweets that originated across the world. The descriptive statistics of the dataset are provided in Table 1. The Twitter data collection starts October 25th, 2012 and ends November 5th, 2012, which is the period when Hurricane Sandy hit the east coast of the US. Altogether, 3,983,288 unique Twitter accounts sent messages about Hurricane Sandy during this time, writing tweets in 61 different languages. As depicted in Table 1, only 0.93% of the tweets are written in English and contain geo-location information as well.

Twitter messages (tweets)	Absolute numbers	Percentage
Total tweets	1,658,279	100%
Original tweets	5,369,520	49.50%
Retweeted tweets	5,478,562	50.50%
Tweets with geo-location	115,800	1.07%
English tweets with geo-location	100,700	0.93%

Table 1 Descriptive Statistics of Hurricane Sandy dataset

Even though the majority of the tweets has been sent in English, a considerable percentage of tweets are also composed in Spanish and Portuguese.

3.2 Data Pre-processing

As a first step in data pre-processing, we used Tableau which is a business analytics and visualization software (Tableau 2015). Initially, with the help of Tableau we visualized the dataset of 11 million tweets to get an overview of how the tweets were distributed over the covered period.

In general, users' privacy settings play an important role in the availability of geo-location information in tweets as metadata in form of latitude and longitude coordinates. These longitude and latitude coordinates indicate the exact location of a Twitter user at the time of sharing the information (Graham et al. 2014). For our purposes, we used Cosmos software which provides the geo-located information (Burnap et al. 2015) from the tweets in our first phase of data pre-processing. Using Cosmos, in doing so, we identified 115,800 tweets, or 1.07% of our initial 11 million tweets, which actually contained such geo-location information

During the second phase, we used CartoDB to 1) filter the English language tweets, 2) visualize the data, and 3) narrow down the tweets geographically to the path hurricane sandy took along the coastline (CartoDB 2015). Since we were only interested in tweets sent in English language, the number of tweets further declined to 100,700. In subsequent steps, we narrowed down the focus on tweets from hurricane-affected areas of US east coast. As a result, we ended up with 68,800 tweets that originated from the hurricane-affected area between 25th October and 5th November, 2012. In addition to the message content, the obtained dataset also contains meta-data such as time stamps, geo-information, and user IDs.

In the third phase of data pre-processing, we manually screened the tweets to exclude the ones with commercial content such as advertisements, spam tweets, etc. We also excluded the tweets that had mentioned the word hurricane but were not related to the hurricane Sandy (e.g. talking about hurricane Katrina instead). And subsequently conducted the content analysis.

3.3 Qualitative content analysis

Subsequently, after the data pre-processing phase, we conducted a manual content analysis on the remaining 68,800 tweets. In this regard, we followed a directed content coding and analysis approach (Hsieh & Shannon 2005;Risius et al. 2015) based upon a coding classification framework we developed.

In the first step, we explored different coding schemes and adapted two different coding classifications from prior research (Qu et al. 2011;Starbird et al. 2010) to develop our coding framework. The primary reasons for choosing prior coding classifications are: firstly, both coding classifications were evolved from and developed for analysis of disaster-related Twitter data in an earthquake and floods respectively. Moreover, one of the coding schemes (Qu et al. 2011) was developed based on the previous coding scheme (Qu et al. 2009;Vieweg et al. 2010) that also originated from prior disaster management research on Twitter data. Secondly, these coding classifications were designed to understand the importance of social media content during disasters.

The first coding classification introduced by Starbird et al. (2010) where tweets were classified based on information source, which are: original source (reflecting the users' personal observations, experiences), secondarily synthesized (from other tweets and news sources), resourced (passing-on other online sources) and finally retweets (forwarding the tweets). In order to aggregate the tweets at a higher level, in our coding scheme we merged secondarily synthesized, resourced, and retweet categories into a single category as secondary source. Therefore, our first level of coding scheme consists of two information source categories: original and secondary.

The other coding scheme (Qu et al. 2011) evolved through a mixed process where classification was based on two previous coding schemes (Qu et al. 2009; Vieweg et al. 2010). Primarily it consists of four major categories based on the nature of messages: informational messages, action-related, opinion-related and emotion-related. Furthermore, we combined both the coding schemes to obtain an integrated classification of hurricane Sandy tweets. Due to this, we were able to aggregate the tweets on the highest level, thereby not following the more granular coding approach of Qu et al. (2011) since we were primarily interested in the real-time nature of the data. In the process of developing our coding scheme, both the authors were involved in the discussions from the beginning and reached consensus on the proposed integrated coding scheme.

Due to our new coding scheme, it is feasible to analyze a tweet along the two dimensions: information source and nature of message. Therefore, our classification of tweets provides a basic understanding of distribution of tweets among original and secondary sources. At the same time, it also presents the nature of messages shared by the individuals, in terms of informational, action-related, opinion-related and emotion-related. Our primary focus is to study the type and nature of information that will contribute to the situation awareness of a disaster to emergency management agencies. Primarily, original, and informational messages with personal experiences and observations about a certain situation will contribute to the situation awareness. Even though the secondary source information does not contain the personal status updates but it will still contribute to situation awareness indirectly by providing useful information about situation.

The qualitative content analysis of 68,800 geo-located tweets was conducted by the first author manually to screen for the tweets with relevant information, which resulted in 677 identified tweets. Subsequently, those 677 geo-located tweets with relevant information were further analyzed by both the authors based on the previously mentioned coding scheme. The results from the analysis were checked again by a linguistic expert from our research group.

4 ANALYSIS

It is obvious that people share and discuss information before, during, and immediately after any major event such as disasters and the same can be witnessed while analyzing tweets from hurricane Sandy. As expected, the number of tweets gradually increased beginning in October 27th, just before the disaster hit New York City and the first peak with around 2.2 million tweets per day was noticed on October 29th, while the highest peak with 2.7 million messages per day was on October 30th 2012. Soon after that, the number of tweets decreased sharply for the following two days, but a trend of approximately half a million tweets per day continued until November 4th. As mentioned earlier, we extracted the tweets that originated from the affected area of hurricane Sandy along the US east coast, based on geo-location coordinates. The resulting tweet density map is shown in *Figure 1* where a vis-

ualization containing 68,800 tweets for a period of roughly two weeks in the months of October and November 2012. It is evident from the map that more and more tweets were generated along east coast, mainly from Florida, Connecticut, New Jersey, Massachusetts, and New York and so on.

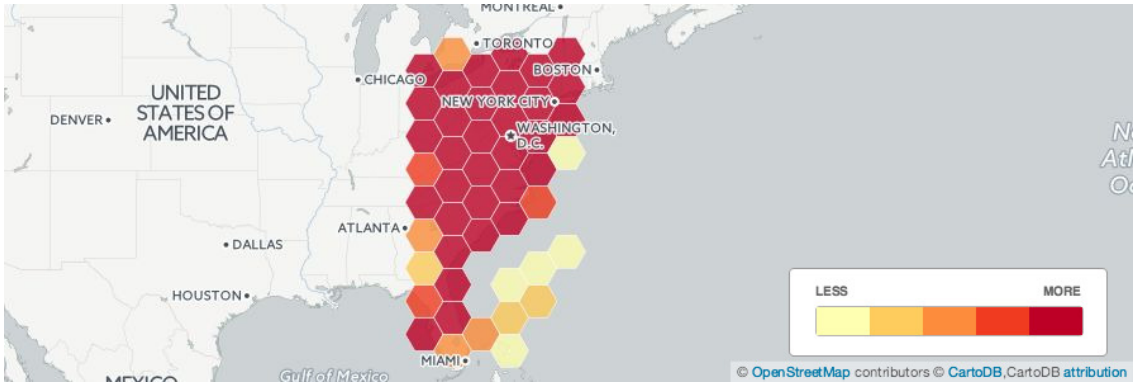

Figure 1 Sandy affected area (East coast of the US)

In the qualitative content analysis, we have manually coded the tweets according to our coding scheme and further narrowed down the tweets to 677 tweets, which is around 1% of the geo-located tweets. The graph in Figure 2 shows the representation of the 677 tweets that were categorized. As we have considered three separate phases of disaster; namely the pre-disaster, during-disaster and post-disaster phases, we considered the time line of 25th October to 5th November which encompasses the aforementioned phases. The tweets are classified based on whether the source of information in the tweets were original or secondary. Furthermore, based upon the content of the message and the links included in the tweets, we categorized them into original and secondary source categories. The tweets were put under heavy scrutiny to ensure effective categorization.

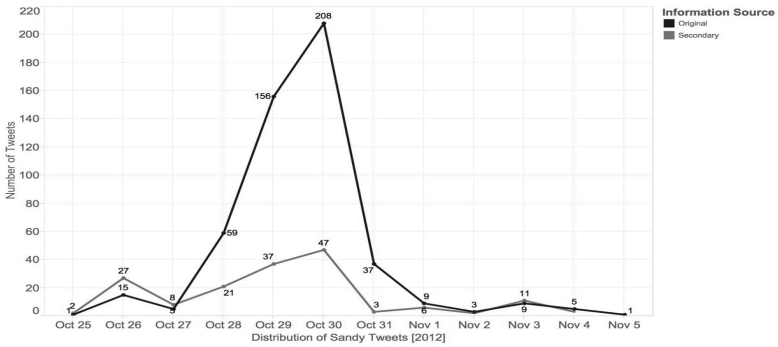

Figure 2 Information Source

Basically, if the content of a message contains first hand observations and experiences, then the tweet is considered as from "original source". In order to cross-verify the original tweets, if a tweet contains a URL or a link, then we followed the link in an effort to find out if the person who created the tweet was also the creator of the link itself. If this was the case, the tweet would be classified as an original tweet. On all other cases, the tweets were classified as a "secondary source" tweet.

Figure 2 shows distribution of coded tweets among original and secondary sources. Altogether 75% of the tweets represent original tweets, whereas 25% belong to the secondary tweet category. In the initial days of pre-disaster phase, the number of tweets from secondary source is more than the tweets from original source, as users were mostly resourcing and re-tweeting the information from other information sources such news articles, weather reports, or showing forecasted severity of the disaster. It is obvious that when people are awaiting an impending disaster that would potentially affect them, they tend to vent on their concerns, fears and also discuss the preventative measures that are being taken. In this process, they also share whatever information they gain from other sources. As the disaster unfolds slowly, people started sharing their own personal experiences, observations and also dis-

cussed the situation based on common knowledge or adapting from other sources (Starbird et al. 2010). Hence, from 27th onwards, the tweets in the original category started increasing till 31st October as on 29th hurricane Sandy hit New York City. During the disaster phase, people's curiosity to understand, know, share and estimate the impact of current situation increased considerably. This was more so the case for people who were affected by the hurricane.

As part of further classification, based on the nature of information in tweets, the tweets were classified into four categories such as informational messages, action-related, opinion-related and emotion-related. In this step, the tweets were classified based on the content, and distribution of four categories is shown in Figure 3. Approximately 73% of the tweets were informational messages, 15% tweets were emotion-related, whereas opinion and action-related tweets were 8% and 4%, respectively. As discussed previously, in our analysis, most of the informational messages were providing the situation updates, which are important for all phases of a disaster.

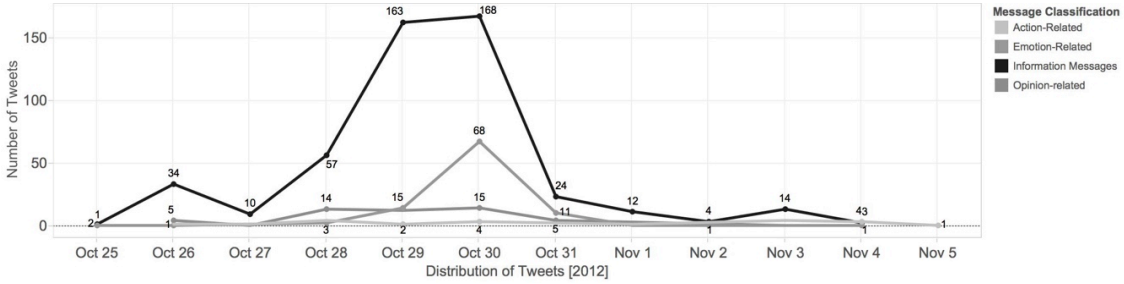

Figure 3 Message occurrence according to different classification

We further subdivided the tweets based on information source and nature of messages. In both, original and secondary source categories, information messages are predominant throughout the disaster period, even though the majority of the informational messages came from the original source category only. In respect to other message categories, emotion-related tweets started increasing from 28th October and peaked on 30th October. It is obvious that people expressed their sympathy as well as provided emotional and social support during the time the hurricane raged. Emotions are often personal hence we noticed them in only the original source. Not only emotion-related but also opinion and action-related discussions are often personal and therefore they appeared only in the original source category.

5 DISCUSSION

In our current research, our focus was to explore the relevant type and nature of information in disaster twitter messages. For that we have collected 11 million tweets that were produced during the time of hurricane Sandy, which were further systematically narrowed down to a meaningful sample. The motive of our study is to affirm that self-organized, affected individuals' can develop individual level situation awareness from others, sharing their personal observations, experiences, and opinions that can also be used to develop situation awareness at the collective level among community members. This will be useful to the emergency management agencies

5.1 Situation Awareness in Disaster Management

So far, the research focus on disaster twitter data has been predominantly on analyzing tweets from a communication point of view. Very scarce research has focused on disaster twitter data from the situation awareness point of view especially focusing on the real-time information to support disaster management agencies.

This is of crucial importance since it is evident that disaster management agencies depend on proper information in times of disasters, which can be gained from individuals which share information to

decrease the uncertainty and anxiety among followers (Kaewkitipong et al. 2012). The realization of the potential use of social media during disasters made emergency agencies adopt and focus more on social media tools like Twitter. However, in initial attempts, disaster management agencies used social media, such as Twitter as broadcasting channel for their emergency information communication (Chavez et al. 2010) or to maintain public relationships, but failed to establish a dialogue with the community (Muralidharan et al. 2011;Waters et al. 2009). The reason could be that the emergency agencies do not have proper strategies and methodologies to extract and handle social media based information streams in close to real-time yet. However, this is going to change with more and more disaster management officials being aware of the importance of social media also in order to play an active role during crises (Cheong & Cheong 2011). Moreover, top management is playing a crucial role in the adoption of twitter for emergency services, as we have seen in a case from New South Wales (Fosso Wamba & Edwards 2014).

It is evident that Twitter is being used by ordinary people during times of disasters to provide up to date and real-time information of the disaster situation. This information is useful for disaster management agencies to keep track of real-time situations in the affected area. This type of community level situation awareness helps emergency management officials to make better decisions to handle the disaster response effectively.

Our research findings also revealed that most of the informational messages are situation updates, whether it is produced by the original source or secondary source. However, the percentage of original tweets is larger, indicating the affected individuals share the real-time information either to provide the situation updates or because they are in need of real-time help. This bottom-up generated information is needed by the emergency agencies.

5.2 Implications for Theory and Practice

Our study offers significant contributions to research and practitioners alike. We are not aware of any other research within IS that analyzed the disaster twitter data from a situation awareness point of view, specifically focusing on supporting disaster management agencies., We are among the first to advance the research to the field of SA from the real-time angle, while reflecting it in disaster management agencies. Furthermore, from an organizational point of view, our findings reveal that the individuals share situational updates hence disaster management agencies need to have social media integrated centralized information technology infrastructure to exploit the situation awareness.

5.3 Limitation and Future Work

This study has certain limitations as well. We were able to access most of the links or URLs posted in the tweet messages, but very few were not available, therefore based on the content of the message we divided them into original and secondary categories. We also were not able to analyze those messages that were sent without geo-location information. Thus, we had to sacrifice the majority of the Twitter message from peoples directly affected by the hurricane, but did not share their whereabouts.

We also included the tweets that were posted by the emergency agencies, even though they were very negligible, and classified them as messages in the secondary category. It is important and challenging to extract the valuable information from huge amount of data in real-time. Hence the future research should consider developing systematic methodologies and analytical capabilities to handle the huge amount of data. Our current research shed light on the real-time information that has practical and societal level implication of disaster management.

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