Information Cascades in Social Media in Response to a Crisis: a Preliminary Model and a Case Study

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ABSTRACT

The focus of this paper is on demonstrating how a model of the diffusion of actionable information can be used to study information cascades on Twitter that are in response to an actual crisis event, and its concomitant alerts and warning messages from emergency managers. We will: identify the types of information requested or shared during a crisis situation; show how messages spread among the users on Twitter including what kinds of information cascades or patterns are observed; and note what these patterns tell us about information flow and the users. We conclude by noting that emergency managers can use this information to either facilitate the spreading of accurate information or impede the flow of inaccurate or improper messages.

Categories and Subject Descriptors

J.4 [**Computer Applications**]: Social and Behavioral Sciences

General Terms

Measurement

Keywords

Social networks, Twitter, Information diffusion, Cascades, Crisis communication

1. INTRODUCTION

During disasters and crisis events, it is important for warnings and disaster related information to spread to the population at-risk as well as enhance the public's situation awareness of the event. When an emergency event occurs, individuals may receive critical warning information through various channels of communication. In any case, the individual may choose to seek for more information or spread the information to others. As individuals choose to propagate information, the warning information may spread through the network, creating a form of information cascade as the information reaches the larger population. Information cascades may occur when within a social system when each individual is given the decision to adopt a behavior or perform some action. Individuals make their decisions sequentially, where they can observe the decision of those around them. As a result, their decision to perform the action may be influenced by the decision of those around them [1].

Twitter is a good medium for studying such information flows during disasters and emergency events [6]. Users can send messages using various platforms, such as mobile devices, and broadcast those messages to a large audience. Each message, or tweet, is limited to a 140 character limit, creating the need for concise but effective messages. When a user posts a tweet, their message is visible to all their followers. Messages can be retweeted, as a form of propagation. Twitter also allows for direction communication between users and followers via a private direct message, i.e. user A can send a private message to user B if B follows A, or a public reply, i.e. user A can send a tweet to user B that is visible publicly. There is also a public timeline displaying all public tweets along with trending topics, and the ability search for tweets on a specific topic in real time.

The focus of this work is on looking at information cascades dealing with specific emergency events, in particular, how messages spread among users on Twitter during the occurrence of the event and what kinds of information cascades or patterns are observed. Ultimately, we are interested in what these patterns reveal about the nature of information flow and the users in the network. The remainder of the paper is organized as follows. We review related work on Twitter use in emergency events in Section 2, followed by a description of the event and dataset. Section 4 describes a general diffusion model for actionable information and discusses how it may map to the context of Twitter for the purpose of studying information flows in emergency events. Section 5 presents an analysis of the collected dataset, focusing on the retweet activity and the information cascades observed during the event. Lastly, we conclude the paper with a discussion of conclusions and future work.

2. RELATED WORK

Twitter can be particularly useful in emergency events especially for facilitating the spread of information and providing situation awareness [3, 9]. Past research found that a majority of the user interactions on Twitter were one-way rather than reciprocal and inferred that the medium operated like a information sharing network where news stories originate from media outlets and spread into the population of users [5, 11]. Past study has also found similarities between the two-step flow theory of communication and the way information diffuses on Twitter. Information originates from the media and reaches the rest of the population indirectly through opinion leaders and hubs, who may be ordinary users, but tend to be more connected to the media than their followers [10]. During emergencies, public officials, emergency agencies, and news and media outlets post real time updates and announcements on Twitter. Users then gather and share critical emergency information to their network of followers and the public, as demonstrated during the 2007 southern California fires [7], the 2009 Red River Floods, and the 2009 Oklahoma Grassfires [9]. The use of Twitter during emergencies differs from the general Twitter use [3]. During emergency events, activity on Twitter displays more signs of information sharing and broadcasting activities such as retweets, with a higher percentage of tweets contain URLs and a lower percentage of directed or reply tweets when compared to the general Twitter use.

The ability to retweet messages is a key function for information propagation on Twitter. When a message is retweeted, the user reposts the contents of the message along with either the intermediate or original source of the message content creating a form of information cascade [2]. In order for messages to propagate, the user must be attentive and see the information at the right time and make the decision to pass it on. Similarly, information cascades occur in situations where individuals observe the actions of others, i.e. tweets posted by other users, and follow the behavior of preceding individual, i.e. retweet, [1]. In emergency events, users may choose to retweet information for various reasons regardless of their geographical location. Users' proximity to the event may influence what type of information they choose to retweet. People who are more local to the event will tend to retweet more specific and locally-relevant information while people who are outside of the area will retweet more broad information [9]. In general, users will retweet messages because they want to share and pass on information they feel is important for others to know.

3. DESCRIPTION OF EVENT AND DATA COLLECTION

On April 6th, 2010, an armed robbery occurred at 8:15am at the Regina Check Cashing Corporation located about one mile away from the Rensselaer Polytechnic Institute (RPI) campus. Hours later, the perpetrator was seen on campus at the East Campus Athletic Village. The RPIAlert system was used to notify the campus community about the potential threat, which included the use of campus loudspeakers, email alerts, phone calls, voice mails and text messages [8]. At 9:30am, the RPIAlert system issued its first "stay in shelter" warning, followed by two addition warnings at 10:48am and 11:48am. About an hour later, an "all clear" message was broadcast at 12:52pm informing the community that there was no longer an apparent threat.

Data was collected from the Twitter public timeline using the Twitter API. The dataset was generated using the search term "RPI" and the hashtag "#RPI", observed on April 6th, 2010. There were 318 users identified in the dataset and a total of 641 tweets. The tweets spanned from 8:56 a.m. to 6:23 p.m on April 6th, 2010. For each tweet, we retrieved the username of the user who posted the tweet, the unique status identifier for the tweet, the date and time at which the tweet was posted, and the message content of the tweet. This dataset provides a depiction of the activity on Twitter relating to RPI during the day of the incident.

4. MODEL FOR DIFFUSION OF ACTIONABLE INFORMATION

This section presents a general diffusion model followed by a discussion on how it can be mapped to the context of Twitter. The general diffusion model simulates the spread of actionable information in dynamic networks based on [4]. The model takes as input a network of nodes with configurable attributes. The weighted edges in the network represent social relationships between the nodes based on the concept of trust, i.e. likelihood that a message will be believed as it passed from one node to another. External sources introduce messages into the network by reaching a subset of nodes, called seeds, and messages spread as nodes interact. Nodes may receive information from various nodes, either directly from the information source or intermediary social contacts. Nodes evaluate the information they receive and perform various actions and behaviors, such as share information with their social contact if certain conditions are met depending on their perception of the information.

The model defines how information flows through the network and how nodes process the information from incoming messages and update their properties. Multiple sources may exist for a message, each with its corresponding perceived information value. Nodes determine their evaluation of the information by merging all the pieces of information they receive from messages from various sources. Nodes store a list of source-value pairs representing the information they have received in terms of who the source was and the perceived value of the information from the source. Nodes enter various states, depending on whether their assessment of the information exceeds certain thresholds as summarized in Table 1. Similarly in Twitter, users may have the following states.

- User is susceptible to new information and may become exposed to information when monitoring their Twitter feed (Uninformed)
- User may see a tweet and is not affected by the information in the tweet, e.g. information not relevant (Disbelieved)
- User may see a tweet and is influenced or finds it interesting (Undecided/Believed)

When a user is influenced by the tweet, they might retweet the message to all their followers or direct the message to specific users, i.e. share the information, or compose a directed message to the source, i.e. respond to the tweet. The user may also choose to compose a new tweet related to the topic that is not directed to specific users but is visible to their followers. Although it is also possible for the user to

State	Description	Behavior
Uninformed	Node has not received any messages	No action
Disbelieved	Node has received a message but does not believe the message	No action
Undecided	Node has received a message and is uncertain of what to do	Query neighbors in the network
Believed	Node has received a message and believes the value of the message	Spread the message to its neighbors
Removed	Node is no longer in the network	No action

Table 1: Description of node states and corresponding behaviors

simply read the post and choose not perform any action on Twitter, we will only consider subsequent actions that are observed on Twitter, such as retweeting or public replies.

So information cascades originate from information sources and propagate through the users that "follow" the information source when the user retweets the message. We can assume that people that retweet the message are influenced or believe the information. The information in the message tweeted by a source will only have an effect on the user if the user is exposed to the information. Meaning, the user follows the message source and sees it.

The diffusion model described assumes that information sources are external to the network and inject information into the network through seed nodes. The model assumes information sources send separate, independent pieces of information, which are then fused by the recipient nodes in the network. In the context of Twitter, information sources are part of the network itself and can perform more actions than just broadcast information. For example, information sources can send direct messages to particular users to query for information. They can also retweet each other's messages. Information sources can be identified as formal sources, media sources, or informal sources. Formal sources may refer to Twitter accounts operated by emergency management offices or authoritative figures. Media sources are users representing news channels or local newspapers. Informal sources introduce information into the network either obtained external to the network or from their own observation.

5. OBSERVATIONS FROM TWITTER DATA ANALYSIS

This section discusses the information cascade patterns observed in the data. From the data, 318 unique users were identified, out of which 136 users retweeted at least one earlier tweet and 113 users sent at least one directed tweet, or a public reply, to another user. Out of the 641 total tweets, 168 were retweets and 90 were public replies. We generate a series of Retweet graphs where there is a directed edge from user A to user B if user A retweeted a message by user B. Based on the timeline of warnings, we partition the data into five subsets. Table 2 displays the number of tweets observed at each time period.

A public reply occurs when a user sends a directed tweet to another user using the convention of placing an "@" symbol in front of the recipient's user name. This form of communication allows users to hold conversations, ask questions, and direct information to specific users. On the other hand, the retweet functionality is essentially used for sharing and propagating information to their followers and the public.

Figure 5 shows that retweet activity among users was occurred most frequently during the time periods between

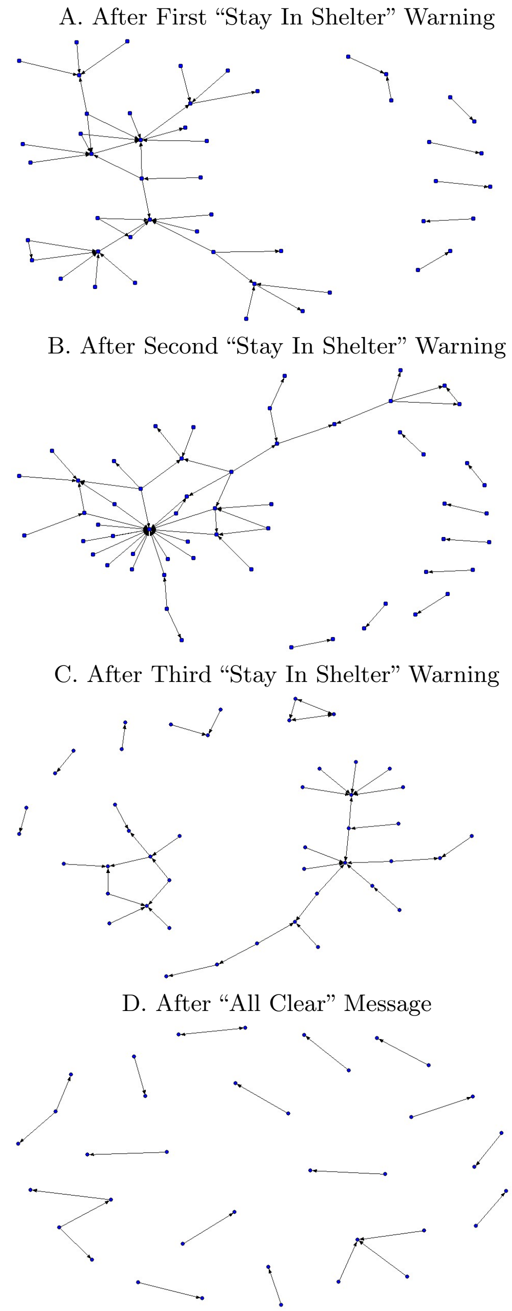

Figure 1: Graphs depicting retweet activity over the course of the event as new warnings and notifications occur.

Time	Tweets	Retweets	Replies
Prior First Warning	7	0	1
First Warning	142	43	13
Second Warning	176	60	23
Third Warning	166	43	25
After All Clear	150	22	28

Table 2: Number of tweets, retweets, and replies observed between subsequent warnings

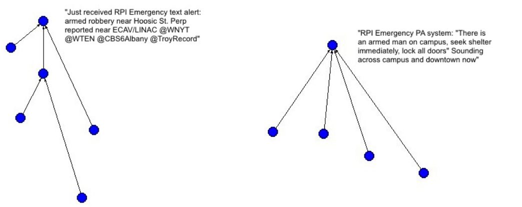

Figure 2: Two instances of information cascades observed in the data.

warnings, particularly during the time between the second and third warnings. The graphs show a large component of users that are retweeting and propagating information to a larger audience. Most of the retweet activity observed after the "all clear" message occurred mostly between dyads and small chains. The degree centrality of the users also provides insights about the user. A high in-degree would infer that the user may be a reliable source or provides valuable information since their messages are frequently re-shared with others via retweets. The users with highest in-degree included local media, RPI staff and a RPI student organization. A high out-degree would infer that the user propagates information, as they frequently retweet other user's messages. Figure 5 displays the information cascade pattern for two messages that were found to be retweeted. One originated from a user in the RPI community and the other was from a local newspaper. From the data, we find most information cascades originate from local media users and certain key users from the RPI community. The cascades tend to be wide, reaching a number of users, but not very long. A small number of retweeted messages are passed on to a large audience. Most retweeted messages terminate after it has been shared once. There are not many long chains of retweets found in the data.

6. CONCLUSIONS AND FUTURE WORK

This paper focused on information cascades observed on Twitter dealing with a university emergency event. We looked at how emergency information spread among the users on Twitter, and how the patterns observed provide insights on the nature of the information flow and the users involved. While we focused on retweets, further work can look at comparing the relative roles that broadcasts via public tweets, information sharing via retweets, and direction communications via replies, in Twitter play in the spread of emergency information together. Our contribution, a model of the diffusion of actionable information in the social media that incorporates trust, is designed to capture the network dynamics due to the actions of the individuals faced with responding to warnings or other disaster related information. These individuals, as members of social networks, will evaluate the information received and exhibit different behaviors, such as information seeking, information spreading, or possibly departing the network, depending on their assessment of the information. Emergency managers tasked with disseminating the actionable information, such as warnings to move to safety, will be able to gain insights on the diffusion process during the course of the emergency event and depending on the current situation, utilize more effective ways to facilitate the spreading through social media or impede the spread of information.

7. ACKNOWLEDGMENTS

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