International Journal of Information Management 43 (2018) 196–208

Contents lists available at ScienceDirect

International Journal of Information Management

journal homepage: www.elsevier.com/locate/ijinfomgt

Review

Twitter as a tool for the management and analysis of emergency situations: A systematic literature review

María Martínez-Rojas*, María del Carmen Pardo-Ferreira, Juan Carlos Rubio-Romero

University of Málaga, E.I Industriales, C/Dr. Ortiz Ramos, s/n (Teatinos), 29071 Málaga, Spain

ARTICLE INFO

Keywords:
Twitter
Management
Emergencies
Review
Social network
Data

ABSTRACT

The importance of timely, accurate and effective use of available information is essential to the proper management of emergency situations. In recent years, emerging technologies have provided new approaches towards the distribution and acquisition of crowdsourced information to facilitate situational awareness and management during emergencies. In this regard, internet and social networks have shown potential to be an effective tool in disseminating and obtaining up-to-date information. Among the most popular social networks, research has pointed to Twitter as a source of information that offers valuable real-time data for decision-making. The objective of this paper is to conduct a systematic literature review that provides an overview of the current state of research concerning the use of Twitter to emergencies management, as well as presents the challenges and future research directions.

1. Introduction

An emergency situation occurs when there is an interruption in the normal dynamics of the economic, cultural, social or political life of a location (Hagar, 2011). These situations produce both an increase in communication and complex information scenarios, which are difficult to manage (Laylavi et al., 2017). Furthermore, these situations present a challenge for the responsible authorities and emergency services, since they may present physical dangers for the people who provide information, as well as a high demand in the active management of them. Understanding what is happening during and in the aftermath of an emergency situation is essential for the reduction of human and economic impacts of the incident. Therefore, access to timely and accurate information is essential to make timely decisions and to take immediate actions (Alexander, 2015; Laylavi et al., 2017; Kim, Bae, & Hastak, 2018; Li, Zhang, Tian, & Wang, 2018).

Traditionally, newspapers, radio and television were the responsible media for the dissemination of information regarding an emergency situation. These media provide only one-way communication in which information was usually produced by official organizations (Schneider & Check, 2010). Nowadays, the use of communication devices is growing significantly, thanks in large part to technological advances and the new Information and Communication Technologies (ICT). These advances have caused that the current communication devices are becoming more and more accessible to the society, generating a new communicative space in which communication is bidirectional or multidireccional, that is, they allow an active communication between sender and receiver (Avvenuti, Cimino, Cresci, Marchetti, & Tesconi, 2016; Capriotti & Ruesja, 2018; Han, Min, & Lee, 2015; Kamboj, Sarmah, Gupta, & Dwivedi, 2018; Martínez-Rojas & Rubio-Romero, 2017; Wang, Gao, & Yang, 2017; Wu & Shen, 2015). In this context, mobile phones, Internet and social networks symbolize this new channel of information, which assists in the generation of situational awareness. This concept refers to having an accurate perception of the situation, ability to quickly recognize a change in that situation, understanding the impact of any change and being able to project the situation in the near future (Alcaide, 2013). Nowadays, in most cases, the first news about an emergency situation appears on social media channels rather than traditional new sources (Kim & Hastak, 2018; Laylavi, Rajabifard, & Kalantari, 2016).

Focusing on the social networks, Twitter is one of the platforms which presents a greater potential in providing information in the management of emergency situations due to the ease of use and its instant nature (Simon, Goldberg, & Adini, 2015; Williams, Terras, & Warwick, 2013). This social network has around 313 million active users monthly, 1000 million unique monthly visits to sites with embedded Tweets and 82% active users on mobile devices (Twitter, 2018). Twitter allows users to quickly share information and the interaction with other users, who may not be connected to your network, through specific topics, *hashtags*. The hashtags allow to search for information

* Corresponding author.
E-mail address: juro@uma.es (J.C. Rubio-Romero).

https://doi.org/10.1016/j.ijinfomgt.2018.07.008
Received 2 April 2018; Received in revised form 17 July 2018; Accepted 17 July 2018
Available online 14 August 2018
0268-4012/

on specific topics (Aladwani, 2015).

Once the user posts a tweet, it is expanded instantly to a large community, providing some advantages but also some drawbacks. The strengths of this social media include: audience increase, instant communication, real-time information, direct support for response efforts (Aladwani, 2015; Gao, Barbier, & Goolsby, 2011; Landwehr, Wei, Kowalchuck, & Carley, 2016; Schneider & Check, 2010; Schulz, Thanh, Paulheim, & Schweizer, 2013; Yates & Paquette, 2011). Nevertheless, Twitter also presents limitations that make the use of these data difficult in the context of a emergency situation: no verified information, rumor spread, imprecision in data, irrelevant information (Carley, Malik, Landwehr, Pfeffer, & Kowalchuck, 2016; Castillo, Mendoza, & Poblete, 2011; Hughes & Palen, 2009; Kapoor et al., 2018; Laylavi et al., 2017; Stieglitz, Mirbabaie, Ross, & Neuberger, 2018; Thomson et al., 2012).

Nowadays, there is a growing interest in this research line since data from Twitter might represent an interest in all phases of an emergency situation, namely, from the initial to later phases. In the literature there are proposals focusing on the early warning phase or the planning phase (Carley et al., 2016; Landwehr et al., 2016). In this regard, some public institutions are present in the social network in order to provide alarms and offer new information through the network (Ai, Comfort, Dong, & Znati, 2016; Basher, 2006; Chatfield & Brajawidagda, 2012). On the other hand, many proposals focus on the use of social media for disaster response in order to coordinate resources and identify the needs of the affected people (Gao et al., 2011; Muralidharan, Rasmussen, Patterson, & Shin, 2011). Therefore, Twitter is becoming an essential media for sending alerts, identifying critical needs, and focusing the response. Additionally, there is a growing interest in the use of Twitter not only for the communication of information, but also for knowledge discovery of Twitter data (Williams et al., 2013). This research line takes advantage of already published data by applying data mining and information retrieval approaches, which provide improvements for the management of emergencies from another perspective (Sotsenko, Jansen, Milrad, & Rana, 2016; Zheng et al., 2013).

The main objective of this article is to review the existing literature where Twitter data are used to support the management of emergency situations. For this purpose, a methodological approach based on a systematic literature review is proposed, which provides an overview of the current state of research, as well as presents the challenges and future research directions.

After this introduction, the remainder of the paper is structured as follows. Section 2 is devoted to explain the methodological approach to analyze the current state of literature. Section 3 details the results according to different analyzed variables. Section 4 summarizes current state and challenges while Section 5 provides a research agenda for practitioners and researchers. Finally, Section 6 presents the conclusions.

2. Review method

This section outlines the methodological approach that will provide an overview of the current state of research regarding the use of Twitter for the management of emergencies.

For this purpose, the systematic literature review is proposed, which is a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest (Kitchenham, 2007). The review follows the guidelines developed by Kitchenham (2007), dividing the research into three phases: (i) planning the review, (ii) conducting the review, and (iii) reporting the final review results itself. Fig. 1 graphically summarizes the objectives of each of these phases, that are addressed in next sections.

2.1. Planning phase

Prior to address a systematic review it is necessary to confirm the need for such a review (Kitchenham, 2007). Then, in this phase, it is necessary to set the research questions that the systematic review will address as well as to define the criteria regarding both literature sources and keywords search.

2.1.1. Research questions

In the first phase, it is necessary to draft clear and concise research questions which drive the entire systematic review methodology. As the objectives of this article are; to analyze the use of Twitter in emergencies, to explore technologies and to identify use cases, the following questions have been selected:

- Q1. How much Twitter activity has there been regarding emergency situations?
- Q2 Which journals and conferences lead this research topic?
- Q3. What are the main objectives addressed by the authors?
- Q4. What are the application domains where Twitter has been applied?
- Q5. What are the applied methodologies?
- Q6. What are the limitations of current research?

To address Q1 and Q2, the number of documents published per year and the journal/conferences that published them are identified. Regarding Q3, Q4 and Q5, the scope of the study is analyzed, as well as the use case and the applied techniques applied by authors. Finally, Q6 points out the main limitations and disadvantages of the analyzed proposals.

Additionally, in this initial phase, the criteria in relation to the literature sources and keyword search are established. For example, the analysis may include documents written only in English language or published in a given database. Next section details the criteria concerning the search process that will allow us to analyze the proposals using Twitter information for emergency management.

2.2. Conducting phase – data collection search process

In this section, firstly, the search process is described and secondly, the qualitative process for document filtering is detailed.

The following digital libraries have been selected in this review since they are identified as relevant to the domain of information and communication technologies and social science: IEEE Xplore,[1] Scopus,[2] ScienceDirect[3] and ISI Web of Science.[4] These databases enable to search through different fields such as title, author, Keywords, abstract, references, etc. as well as to select research domains, publication years, type of documents, etc. The way of performing the search on these databases is different depending on the database itself and the operators and fields we used. For example, ScienceDirect allows to perform a search considering, at the same time, the “Title/Abstract/Keyword” while IEEE Xplore or ISI Web of Science allows a more exhaustive search by taking into account different fields for each term we want to search.

In this work, we focus on the title, abstract and keyword as searching fields. By using these fields we make sure that we will obtain a large number of documents as a result of the search, which goes beyond the scope of this work. Therefore, in order to obtain adequate results concerning the objective of this work, we consider “Twitter”, “emergencies”, “emergency and management” as terms to perform the

[1] https://ieeexplore.ieee.org/.
[2] https://www.scopus.com/.
[3] https://www.sciencedirect.com/.
[4] http://wos.fecyt.es/.

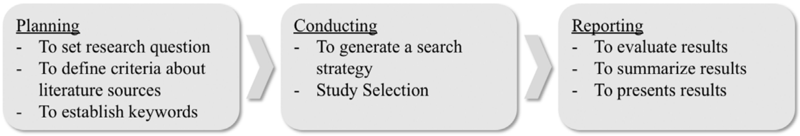


Fig. 1. Main objectives of the three phases of the systematic literature review.

search on the basis of the mentioned fields. It is important to remark that, in this process, named data collection, we will perform several queries in each of the databases by combining the input terms and by using different boolean logic operators over the fields with the aim of obtaining the largest number of retrieved documents.

In this data collection process, duplicate documents can be obtained, either by performing different queries on the same database or because a same document can be indexed in different databases. Therefore, a removal process is necessary in order to eliminate duplicated records, firstly, in the same database and secondly among the different sources. For example, in ISI Web of Science database, the following searches were performed: (1) Twitter (title) and Emergencies (title) providing as a result a total of 20 documents. (2) Twitter (topic) and Emergencies (topic) and management (topic) providing as a result a total of 234 documents. (3) Twitter (title) and Emergencies (topic) and Management (title) providing as a result a total of 14. (4) Twitter (topic) and Emergencies (title) and Management (title) providing as a result a total of 16. It is observed that more search combinations do not include more results, so the mentioned removing process is performed.

Following, the inclusion and exclusion criteria to assess each result in the qualitative review are detailed in Tables 1 and 2 respectively. These should be clear, as they will allow the classification of results correctly. Following, the flow diagram of the entire process is illustrated in Fig. 2, where the study selection can be observed.

As can be seen in the Fig. 2, a total of 456 records are obtained in the initial phase, which are reduced to 380 after removing duplicates records among the same electronic database. Following, during the paper screening process, 158 records were included which present relevance to our formulated research questions. However, in this process, 249 records were excluded according to the exclusion criteria: documents which used other social media data or duplicated content. In the *backward reference search*, further qualitative review is performed, where 37 records were identified from which 27 were added to the previous 131. Therefore, 158 records remain for the further analysis.

Next section presents the final phase of the systematic review, which involves the analysis of results.

3. Review results

The results of the systematic literature review from diverse perspectives are detailed in this section. Firstly, the analysis of the 158 records is developed from a general point of view. Secondly, the records are detailed according to the stage, the event and the objective in which they are focused on. Finally, proposals are analyzed from a methodological point of view.

3.1. Overall results

In this section, the records are explored from a general perspective, in which the temporal evolution, the type of publication, as well as the means where the works are published are considered.

Table 1
Inclusion criteria in the qualitative review.

Id	Criteria
I1	Documents which clearly depict their research applications regarding Twitter data
I2	Documents which clearly describe the objective
I3	Documents which clearly describe their applied methods

Table 2
Exclusion criteria in the qualitative review.

Id	Criteria
E1	Documents which not apply Twitter social media
E2	Duplicate content, i.e., extension of a conference document to journal article

3.1.1. Year of publication

This section addresses the answer to the first research question detailed in Section 2.1.1: “How much Twitter activity has there been regarding emergency situations?”.

To do this, we classified records based on its publication year. As can be seen in Fig. 3, the first documents related to the research topic were published in 2009. During the next few years, the number of documents increases moderately and it is in the 2015 year when the number of documents increases considerably.

3.1.2. Type of document

To solve the second research question (Q2), the records have been classified according to whether they have been published in a scientific journal or in a conference proceedings. In this way, it is possible to analyze the number of documents for each of these types as well as the relevant journals or conferences that lead the research topic.

As can be seen in Fig. 4, generally, the number of documents in conference proceedings is greater than the number of documents in scientific journals until 2016 year, where that difference decreases. Notice that the number of papers in 2018 is similar to the previous year even though only documents until June are included. This aspect highlights the growing interest in this research line. The number of conference documents in 2018 year is very low compared to previous years. This is due to the fact that reference conferences to this domain are usually held in the second half of the year, so they will be reflected in the following year.

Next, Table 3 presents the journals in which at least two records have been published. As the total number of different journals is 40 so, for the sake of extension, not all journals are presented in the table. However, in these journals almost the 50% of articles were published (31 out of 64).

Additionally, Table 3 present 2017 Journal Citation Reports (JCR) Impact Factor (IF) which reflects the average number of citations and allows to measure the quality of the journal. Thus, journals with higher impact factors deemed to be more important than those with lower ones. As can be appreciated in the table, most of the recorded articles are published in journals ranked in the first or second quartile.

In order to conduct a more in-depth analysis, the categories of these main journals have been extracted in order to explore the areas of knowledge in which this research topic has a greater impact. Notice that a journal might have associated with more than one subject category. Table 4 details, in alphabetical order, the different categories in which the journals in Table 3 are indexed. The second column indicates the number of times that the category is repeated among the different journals. These results provide quantitative evidence about the multidisciplinary character of this research topic.

Following the same criteria of the journal's analysis, Table 5 presents the most relevant conferences of the research domain. In this case, the total number of conferences is 55, most of which are of

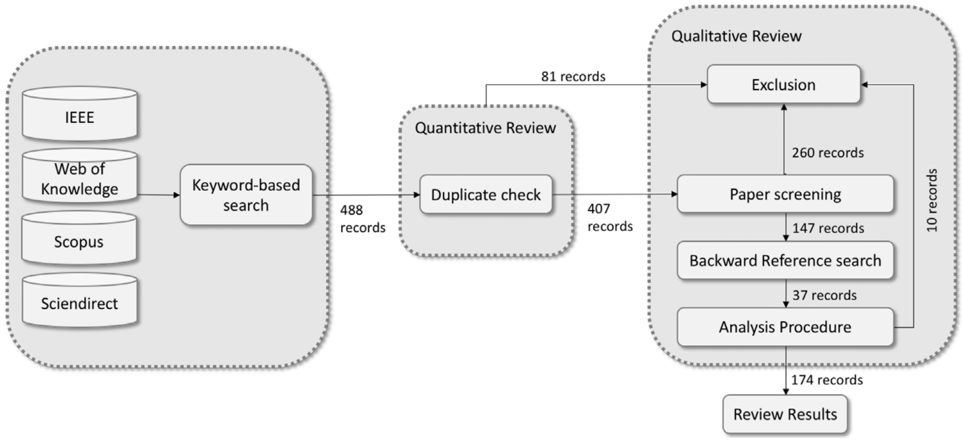


Fig. 2. Flowchart of systematic Literature review process and number of included and excluded papers in each step.

international scope. Similar to the journal study, these conferences represent the 50% of records concerning conference type (42 out of 94). Finally, the last column shows the 2017 CORE Conference Ranking, which provides assessments of conferences in the computing disciplines (CORE, 2017). The conferences are classified according to the following categories: A* (flagship conference), A (excellent conference), B (good conference), C (other ranked conference venues that meet minimum standards), Australasian (a conference for which the audience is primarily Australians and New Zealanders) and Unranked (a conference for which no ranking decision has been made).

To conclude this section in which documents are analyzed from a general perspective, the documents are then analyzed according to the main objective of the research work.

3.1.3. Objective

When using Twitter for the management and analysis of emergency situations, five main objectives have been identified in the qualitative analysis of the records: detection, disaster risk assessment, emergency planning, response and general information. Fig. 5 graphically represents the number of documents according to the objective that the authors address in the analyzed period. Notice that a record may address more than one objective, so the number of documents per year does not correspond to the previous results presented in Fig. 3. The objectives that have attracted more attention in the literature are detailed below.

Firstly, as can be observed in the Fig. 5, the detection of novel information related to emergencies has increased since 2010 year. As we will see in next section, diverse methods and technologies have been applied to address this objective. Secondly, many proposals attempt to take advantage of Twitter information to process and analyze it in order to extract useful information to provide response and recovery efforts for those affected. Finally, many proposals analyze the use of Twitter data from a general point of view. For example, analyzing the role of public authorities in emergency situations, emphasizing the importance of Twitter data, analyzing Twitter messages from a general perspective, data organization, etc. In general, as can be observed in the figure, the evolution of the objectives has been increasing in a similar proportion over time.

3.1.4. Methodologies

In this section, the research question regarding the applied techniques is addressed. Firstly, we summarize the process to obtain data and, secondly, we analyze the applied methodologies.

Data collection is the starting point for any proposal, which usually use freely available Twitter Application Programming Interface (API). Once data have been extracted, a pre-processing should be performed in order to obtain a uniform textual content. This process consists on removing multiple dots, user mentions, hashtag signs, punctuation marks, numbers, etc.

After the pre-processing data, different techniques have been used in the literature. As can be seen in the Fig. 6, machine learning algorithms and data mining are the most techniques applied in the proposals, which are subfields of computer science. On the one hand, machine learning allow to explore the study and construction of

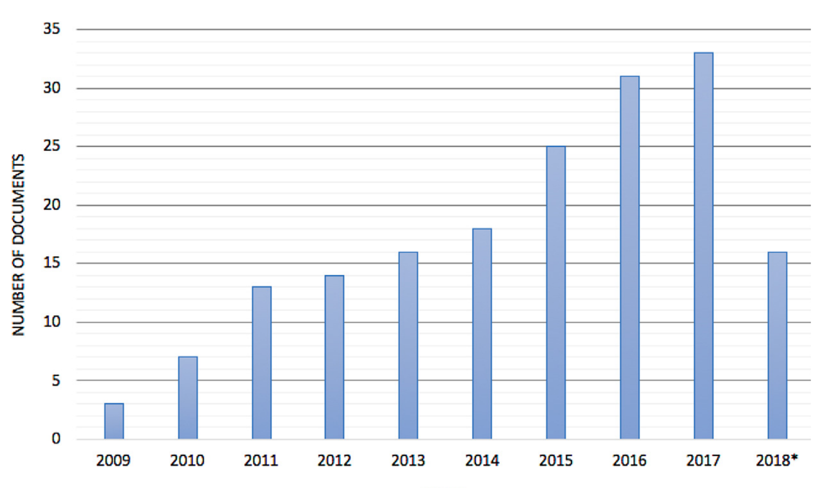


Fig. 3. Distribution of documents per years (*2018 until June 2018).

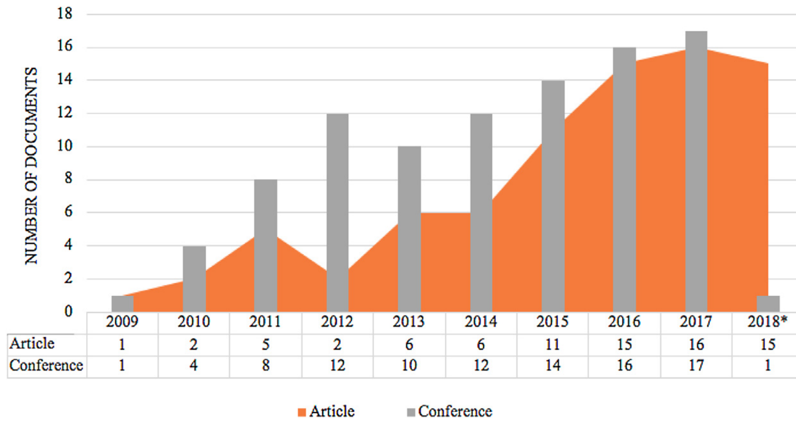


Fig. 4. Number of documents per year and typology.

Table 3
Reference journals for the research topic and their impact factor.

Journals	No. doc	JCR-IF (2017)	Quartile
Computers in Human Behavior	5	3536	Q1
International Journal of Information Management	5	4516	Q1
Safety Science	3	2835	Q1
Natural hazards	3	1901	Q2
International Journal of Geographical Information Science	2	2370	Q2
IEEE Transactions on Visualization and Computer Graphics	2	3078	Q1
IEEE Intelligent Systems	2	2596	Q2
Computer Supported Cooperative Work	2	725	Q4
Information, Communication &Society	2	3084	Q1
SpringerPlus	2	1130	Q2
Information Processing and Management	2	3444	Q1
International Journal of Disaster Risk Reduction	2	1968	Q2
Journal of Ambient Intelligence and Humanized Computing	2	1423	Q3
Information Systems Frontiers	2	3232	Q1
IEEE Transactions on Knowledge and Data Engineering	2	2775	Q1
	38		

Table 4
Indexed categories of journal in Table 3.

Subject categories	No. journals
Communication	1
Computer Science, Artificial Intelligence	3
Computer Science, Information Systems	5
Computer Science, Interdisciplinary Applications	1
Computer Science, Software Engineering	1
Engineering, Electrical &Electronic	1
Engineering, Industrial	1
Geography, Physical	1
Geosciences, Multidisciplinary	2
Information Science &Library Science	1
Meteorology &Atmospheric Sciences	2
Multidisciplinary Sciences	1
Operations Research &Management Science	1
Psychology, Experimental	1
Psychology, Multidisciplinary	1
Sociology	1
Telecommunications	1
Water Resources	2

algorithms that can learn from and make predictions on data (Kohavi & Provost, 1998). On the other hand, the overall goal of the data mining process is to extract information from a data set and transform it into an understandable structure for further use (Fayyad, Piatetsky-Shapiro, Smyth, & Uthurusamy, 1996; He, Zha, & Li, 2013). In the previous section, the results showed that the *detection* objective was the one that had attracted more attention in the literature. Those results are in concordance with the ones in this section, since these techniques are applied to explore data.

It should also be noted the use of techniques that allow to further explore the content of texts. This way, on the one hand, *content analysis* was used to explore text of tweets in order to analyze information through Twitter Aswani, Kar, Ilavarasan, and Dwivedi (2018), Lipizzi, Iandoli, and Marquez (2015). This perspective lends insight into future applications of how organizations can leverage social media as a means of sustained coordination for long-term (Opdyke & Javernick-Will, 2014). On the other hand, similarly, *Natural Language Processing* (NLP) has been widely applied in the proposals, which explore how computers can be used to understand and manipulate natural language text Shirdastian, Laroche, and Richard (2017).

3.1.5. Events

Throughout this review study, the wide acceptance of Twitter for the management of emergency situations has been shown. In this section, the different emergency situations that have been analyzed as use cases in the revised proposals have been identified.

Fig. 7 illustrates the events along the time (2008–2017 period) according to the following categories, such as: safety (natural disasters, industrial) and security (politics and terrorism events). In each of these general categories, the different types of events that have been addressed in the literature have been detailed. Additionally, the total number of proposals for each type is detailed in the table. As can be seen from the table, emergencies caused by weather conditions are widely explored in the literature. Notice that, some events have been analyzed by several authors, as for example: 2011 Japan tsunami, 2015 Earthquake Nepal, and 2013 Sandy Hurricane.

It should be mentioned that, in addition to the proposals focused on specific use cases, there are also proposals that address the research study from a general perspective. The objective of these proposals is to develop methodologies that allow to detect a given emergency situation in the early phase. Then, these proposals focuses on a particular emergency situation such as earthquakes, flood, etc.

3.2. Phases of emergencies management

In this section, we explore the opportunities and challenges of exploiting Twitter information at the different phases of an emergency situation: before, during and after (Coyle & Meier, 2009; Ni, Shu, &

Table 5
Reference conferences for the research topic where records are published.

Conference	No. doc	Acronym	CORE 2017
International Conference on World Wide Web	8	WWW	A*
Hawaii International Conference on System Sciences	5	HICSS	A
International Conference on Information Systems for Crisis Response and Management	11	ISCRAM	–
Australasian Conference on Information Systems	3	ACIS	Australasian
International Conference on Information and Communication Technologies for Disaster Management	3	ICT-DM	–
International AAAI Conference on Web and Social Media	2	ICWSM	–
IEEE Symposium on Visual Analytics Science and Technology	2	IEEE VAST	C
International Conference on Advances in Social Networks Analysis and Mining	2	ASONAM	–
IEEE Global Humanitarian Technology Conference	2	GHTC	–
Signal Processing and Communications Applications Conference	2	SIU	
International Conference on Availability, Reliability and Security	2	ARES	B
	42		

Song, 2018; Pogrebnyakov & Maldonado, 2018; White, 2014).

- Prior to a emergency occurs, it is important to be as prepared as possible. For this purpose, on the one hand, Twitter gives emergency services a means with which to communicate with the public. For example, to give them a plan for what to do if an emergency situation occurs or to keep the public informed on the location and movement of storms or other potential hazards Carley et al. (2016).
- While a emergency is occurring it is important for government authorities and emergency services to be able to communicate in a quick and efficient manner with the users. For example, to provides information on evacuations in specific regions, to keeps the public aware of regions that they should avoid, to dispel rumors about the disaster before they can spread, etc. In this scenario, Twitter' users might act as data sources themselves, providing situational awareness (Avvenuti et al., 2016).
- Once the emergency has finished, the process of recovery starts. Through Twitter, emergency services and users are able to provide information on recovery efforts to survivors. Furthermore, after an emergency, data from a given situation might be useful to extract knowledge and develop models to be applied to detect future events.

In Table 6 all the revised documents in the systematic literature review are presented. Each proposal indicates to which phase of the emergency they are focused: Before (B), During (D) and After (A). As can be observed, the phase that has attracted most attention is *After* phase. This result is in accordance with the results detailed in previous sections. In Section 3.1.4, we concluded that the most applied methodologies were those that allow to explore previous data to learn

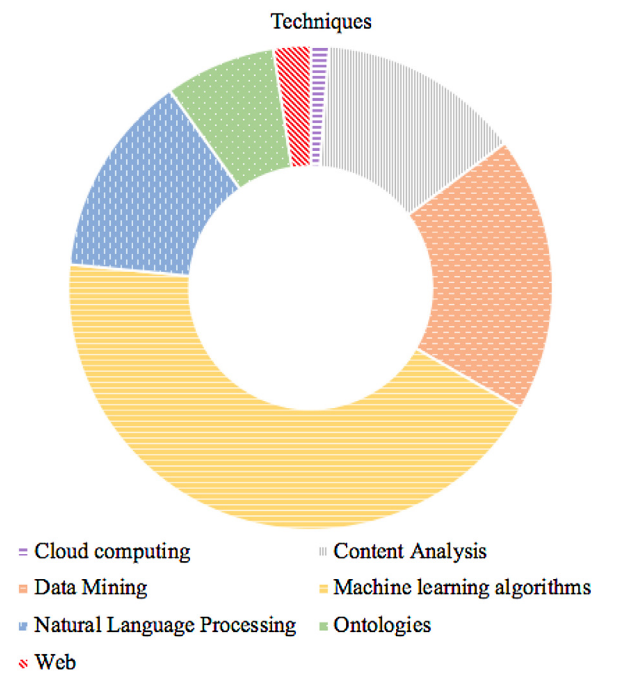


Fig. 6. Most applied methodologies to achieve the objective.

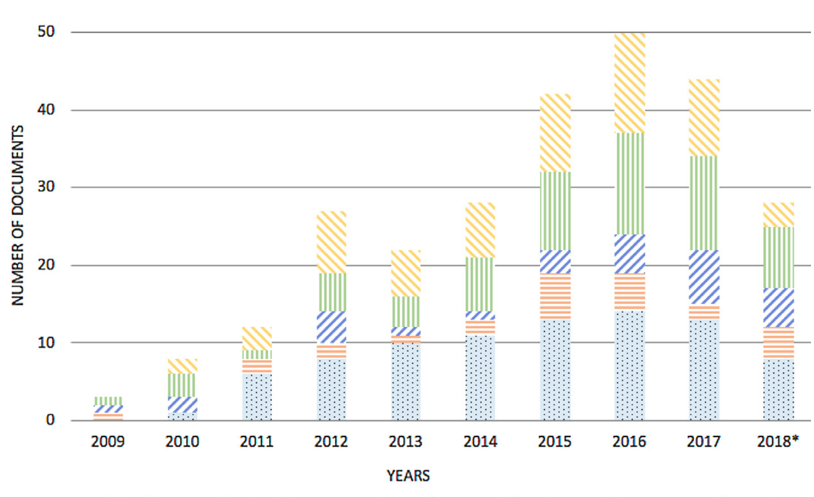
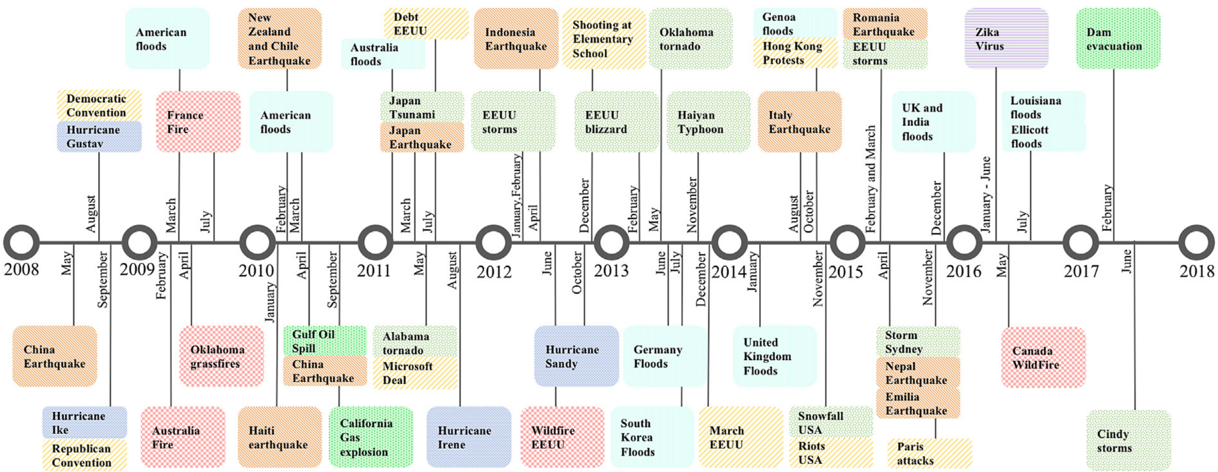


Fig. 5. Number of documents per year and objective.



	Safety											Security	
	Natural disasters							Industrial					
	Earthquakes	Fires	Floods	Hurricane	Storm, Tornado	Typhoon & Tsunamis	Various	Dam Evacuation	Gas explosion	Nuclear power plant	Oil Spill	Politics	Terrorism
Total number	40	8	20	20	11	12	2	1	1	1	2	6	4

Fig. 7. Events analyzed in the proposals.

models and to extract information. Then, these techniques have to be mainly applied when the emergency has finished. In addition, Section 3.1.5 has present a large number of events that have been analyzed after the development of the emergency situation.

4. Current state and research challenges

After reviewing the proposals from diverse perspectives, this section analyzes current situation which will allow us to point out future directions with the aim of fostering and directing further research on the application of Twitter in emergency situations.

Data collection is the primary source for any proposal. Although it is possible to obtain data by purchasing from commercial data vendors, the use of freely available Twitter Application Programming Interface (API) seems more suitable for research purposes (Laylavi et al., 2016). APIs allow to extract both past messages and real-time data feed, but they present the following general constraints:

- Twitter REST APIs are 100% free of charge but present certain limitations in relation to the acquisition period. For example, API calls are limited to 350 queries every 15 min for one user account, or 3500 total tweets per REST query, whichever comes more restrictive. The second type, Twitter streaming APIs, requires users to keep an uninterrupted HTTP connection to access the most recent (mostly within 1 day) Twitter data up to 1 percent of public tweets (Gu, Qian, & Chen, 2016; Itakura & Sonehara, 2013; Karami, Dahl, Turner-McGrievy, Kharrazi, & Shaw, 2018). These constraints present a limitation when attempting to obtain large amounts of data to propose models to automatically detect events (Imran et al., 2015).
- When collecting tweets from a given emergency through the Twitter API, information about the user's location can be obtained. On the one hand, the location that the user details when registering on Twitter and, on the other hand, the location that is extracted through GPS. Both locations present disadvantages when considering them in emergency management. The first one does not usually correspond to the location of the user at the time of the accident, but rather to the location where he or she normally lives Gao et al. (2011). In addition, as the location field is freeform in structure, a user may enter anything from a well-formed location (Murthy & Longwell, 2013). The second one, only can be obtained in the case that GPS was activated. Laylavi et al. (2016) stated that less than 2% of tweets are geotagged. Therefore, this represents a significant disadvantage during a crisis, since it is essential to emergence personnel to know the locations of specific incidents (Laylavi et al., 2017; Martínez-Rojas, Pardo-Ferreira, López-Arquillos, & Rubio-Romero, 2017; Spielhofer et al., 2016).
- Another problem is the difficulty of retrieving related and informative data about a specific situation of the tremendous and continuous stream of Twitter updates (Kapoor et al., 2018). Data collection process usually focuses on the exact matching of target keywords or hashtags to acquire related tweets (Imran et al., 2015). This method, Keyword-based data retrieval, has proved not to be totally successful in the social media domain for identifying events, since it does not evaluate the content of tweets in terms of their relatedness to a specific situation (Laylavi et al., 2017).

As detailed in previous section, several proposals take advantage of soft computing domain in order to develop models and algorithms that lend themselves to prediction. However, it is still necessary to develop automated mechanisms to find critical and actionable information on Social Media in real-time (Becker et al., 2011; Huang et al., 2014; Win & Aung, 2017). This is a difficult task due to the fact that each crisis situation is different with regard to essential and unforeseen information which must be included in the models (Groen et al., 2017). In addition, for a given emergency, tweets can be found in several languages and often exhibit low quality (e.g., with typos and ungrammatical sentences). This heterogeneity represents a challenge when developing models to explore the information contained in the tweets Becker et al. (2011), Laylavi et al. (2017), Lipizzi et al. (2015). As detailed in previous section, in the literature there are several proposals focused on analyzing the content of the tweets, but only consider one language (Laylavi et al., 2016).

In crisis situations, insufficient or incorrect information can lead to either complete inaction or disastrous action (Dearstyne, 2005). This may arise due to limitations in telephone-based systems or, from fake images and rumors propagation Lee, Qiu, and Whinston (2018). Regarding the first limitation, with limited telephone capacities, emergency services would have serious problems when sharing information, coordinating efforts, gathering data, identifying false information, and directing efforts (Jaeger et al., 2007; Win & Aung, 2017). Regarding the propagation of false information, it is still a challenge the identification of malicious content spread during emergencies (Gupta et al., 2013).

Table 6
Phases in which proposals focus.

	B	D	A
De Longueville, Smith, and Luraschi (2009)			x
Dork, Gruen, Williamson, and Carpendale (2010)			x
Sakaki, Okazaki, and Matsuo (2010)		x	
Li and Rao (2010)			x
Vieweg, Hughes, Starbird, and Palen (2010)			x
Sinnappan, Farrell, and Stewart (2010)			x
Sinnappan et al. (2010)			x
Castillo et al. (2011)			
Gao et al. (2011)			
Muralidharan et al. (2011)			x
Artman, Brynielsson, Johansson, and Trnka (2011)			x
Aramaki, Maskawa, and Morita (2011)			
MacEachren, Robinson, et al. (2011b)		x	
Becker, Naaman, and Gravano (2011)		x	
Hao et al. (2011)			
MacEachren, Jaiswal, et al. (2011a)			
Verma et al. (2011)			x
Oh, Agrawal, and Rao (2011)			x
Malizia, Bellucci, Diaz, Aedo, and Levialdi (2011)			x
Tapia, Bajpai, Jansen, Yen, and Giles (2011)		x	
Chatfield and Brajawidagda (2012)	x	x	x
Thomson et al. (2012)			x
Tatsubori, Watanabe, Shibayama, Sato, and Imamura (2012)			x
Johansson, Brynielsson, and Quijano (2012)	x	x	
Li, Lei, Khadiwala, and Chang (2012)	x		
Cao et al. (2012)		x	x
Chun, Hwang, and Kim (2012)		x	x
Panagiotopoulos, Ziaee Bigdeli, and Sams (2012)			x
Doan, Vo, and Collier (2012)			x
Nagy and Stamberger (2012)		x	x
Cameron, Power, Robinson, and Yin (2012)			x
Stollberg and De Groeve (2012)		x	x
Nguyen, Kawamura, Tahara, and Ohsuga (2013)		x	x
Miyabe, Miura, and Aramaki (2012)			x
Chatfield and Brajawidagda (2013)		x	x
Murthy and Longwell (2013)			x
Sakaki, Okazaki, and Matsuo (2013)	x		
Imran, Elbassuoni, Castillo, Diaz, and Meier (2013)	x	x	
Morstatter, Kumar, Liu, and Maciejewski (2013)			x
Gupta, Lamba, Kumaraguru, and Joshi (2013)			x
Zheng et al. (2013)		x	
Gelernter and Balaji (2013)			
Tyshchuk, Li, Ji, and Wallace (2013)			x
Itakura and Sonehara (2013)			x
Schulz et al. (2013)			x
Tapia, Moore, and Johnson (2013)		x	
Pohl, Bouchachia, and Hellwagner (2013)	x	x	
Dong, Halem, and Zhou (2013)			
Karimi, Yin, and Paris (2013)			x
Purohit et al. (2013)		x	x
Boididou, Papadopoulos, Kompatsiaris, Schifferes, and Newman (2014)			x
Regalado et al. (2014)	x	x	
Huang, Dong, Yesha, and Zhou (2014)			x
Torkildson, Starbird, and Aragon (2014)			x
Li and Zeng (2014)			x
Opdyke and Javernick-Will (2014)			x
Carter, Thatcher, and Wright (2014)		x	x
Genes, Chary, and Chason (2014)			x
Chatfield and Brajawidagda (2014)			x
Avvenuti, Cresci, Polla, Marchetti, and Tesconi (2014)		x	
Ilyas (2014)		x	x
Purohit et al. (2014)			x
Temnikova, Varga, and Biyikli (2014)			x
Nguyen et al. (2014)			x
Kim (2014)			x
Middleton, Middleton, and Modafferi (2014)		x	x
Guan and Chen (2014)			x
Sutton et al. (2014)			x
Imran, Castillo, Diaz, and Vieweg (2015)			
Thom et al. (2015)			x
Rudra, Ghosh, Ganguly, Goyal, and Ghosh (2015)		x	x
de Albuquerque, Herfort, Brenning, and Zipf (2015)		x	x
Takahashi, E, and Carmichael (2015)			x
Hara (2015)			
Moi et al. (2015)			x
Saleem, Zamal, and Ruths (2015)			x
Nguyen, Kitamoto, and Nguyen (2015)		x	x
Athanasia and Stavros (2015)			x
Yin et al. (2015)		x	x
Olteanu, Vieweg, and Castillo (2015)			x
Ai et al. (2016)			x
Carley et al. (2016)	x		
Landwehr et al. (2016)			
Onorati and Díaz (2016)			x
Riquelme and González-Cantergiani (2016)			
Sotsenko et al. (2016)		x	
Toriumi and Baba (2016)		x	x
Pirnau (2016)			
Ikeda, Sakaki, Toriumi, and Kurihara (2016)			x
Glasgow, Fink, Vitak, and Tausczik (2016)			x
Avvenuti et al. (2016)		x	
Laylavi et al. (2016)		x	x
Spielhofer, Greenlaw, Markham, and Hahne (2016)		x	x
Radianti, Hiltz, and Labaka (2016)			x
Gründer-Fahrer, Berger, Schlaf, and Heyer (2016)			x
Nazer, Morstatter, Dani, and Liu (2016)		x	x
Pandey and Natarajan (2016)		x	x
Girtelschmid, Salfinger, Pröll, Retschitzegger, and Schwinger (2016)		x	
Musaev and Hou (2016)			
Comito, Pizzuti, and Procopio (2016)		x	
Pohl, Bouchachia, and Hellwagner (2016)		x	
Zoppi et al. (2016)			x
Lachlan, Spence, Lin, Najarian, and Greco (2016)	x		
Panagiotopoulos, Barnett, Bigdeli, and Sams (2016)			x
Wang, Ye, and Tsou (2016)		x	x
Gunawong and Butakhieo (2016)		x	x
Kim et al. (2016)			x
Zhang, Kelly, and Ahmad (2016)		x	x
Rice and Spence (2016)			x
Dufty (2016)			x
Nugroho, Zhao, Yang, Paris, and Nepal (2016)		x	x
Laylavi et al. (2017)	x	x	
Subba and Bui (2017)			x
Mejri, Menoni, Matias, and Aminoltaheri (2017)			x
Sarda and Chouhan (2017)			x
Neppalli, Caragea, Squicciarini, Tapia, and Stehle (2017)			x
Groen, Pavlin, Winterboer, and Evers (2017)	x	x	
Ohtsuka, Ishii, Utsu, and Uchida (2017)		x	x
Lai (2017)		x	x
Bolea (2017)			x
Amirkhanyan and Meinel (2017)			x
Basnyat, Anam, Singh, Gangopadhyay, and Roy (2017)			x
Ghenai and Mejova (2017)			x
Piedra, Chicaiza, and Torres-Guarnizo (2017)			x
Lai, She, and Tao (2017)			
Lozano and Vaca (2017)			x
Nayebi, Marbouti, Quapp, Maurer, and Ruhe (2017)			x
Cecaj and Mamei (2017)	x	x	
Wang et al. (2017)	x		
Chaniotakis, Antoniou, and Pereira (2017)		x	x
Abedin and Babar (2017)			x
Fontes, Fonte, and Cardoso (2017)		x	x
To, Agrawal, Kim, and Shahabi (2017)			x
Fosso Wamba, Edwards, and Akter (2017)			x
Gray, Weal, and Martin (2018)			x
Win and Aung (2017)			x
Li, Caragea, and Caragea (2017)			x
Sheikh, Masood, Khan, and Imran (2017)		x	
Alshareef and Grigoras (2017)		x	x
Scott and Errett (2017)		x	
Wang and Zhuang (2017)			x
Pirnau (2017)			x
Fersini, Messina, and Pozzi (2017)	x	x	
Singh, Dwivedi, Rana, Kumar, and Kapoor (2017)		x	x
Li, Wang, Emrich, and Guo (2017)		x	
Kim et al. (2018)			x
Tagliacozzo (2018)			x
Zoppi et al. (2018)		x	x

(continued on next page)

Table 6 (*continued*)

	B	D	A		B	D	A
Saravanou, Valkanas, Gunopulos, and Andrienko (2015)			x	Li et al. (2018)			x
Graham, Thompson, Wolcott, Pollack, and Tran (2015)			x	Kim and Hastak (2018)			x
Antoniadis, Litou, and Kalogeraki (2015)		x		Wang and Ye (2018)			
Buribayeva, Miyachi, Yeshmukhametov, and Mikami (2015)	x	x	x	Zou, Lam, Cai, and Qiang (2018)			x
Nar and Akgul (2015)			x	Onorati, Díaz, and Carrion (2018)		x	x
McCreadie, Macdonald, and Ounis (2015)			x	Manna and Phongpanangam (2018)			x
Bakillah, Li, and Liang (2015)		x	x	Hasan, Orgun, and Schwitter (2018)		x	
Ghahremanlou, Sherchan, and Thom (2015)		x	x	Cvetojevic and Hochmair (2018)			x
Kebabc and Karslgil (2015)			x	Ragini, Anand, and Bhaskar (2018)		x	x
Temnikova, Castillo, and Vieweg (2015)		x		Ni et al. (2018)	x		
Avvenuti, Vigna, Cresci, Marchetti, and Tesconi (2015)		x		Wu, Cao, Xiao, and Guo (2018)		x	x
Onorati and Díaz (2015)			x	Zheng, Han, and Sun (2018)		x	x

Note: Before (B), during (D) and after (A).

5. Implications for research and practice

After presented the current challenges that have been identified in the literature, this section provides a research agenda for practitioners and researchers concerning the use of Twitter for the management of emergency situations. The items that require additional research by the emergency management research community are the following:

Interoperability: As previously mentioned, the extraction of information from Twitter is not an easy task because of the nature of data. One the one hand, messages are very heterogeneous containing abbreviations, misspellings, links, emojis, different languages, etc. On the other hand, information may contain rumors and false news, that makes difficult the proper management of information in Twitter. Additionally, messages in Twitter may include images and videos of the emergency which may provide useful information for emergency services, but also can contain malicious information. For this regard, emergency manager may benefit from mechanisms that allow to extract, process and analyze automatically relevant information and, identify false information not only in textual information but also in multimedia content.

Diversity: In an emergency situation, there is a diversity of participants during the phases. Firstly, prior to an emergency occurs, diverse emergency services communicate with citizens for various purposes previously mentioned, as for example: police, firemen, local authorities, etc. Secondly, during the emergency, communication media and citizens share information. Finally, once the emergency has finished, all the mentioned participants are actively participating with different objectives. For example, the emergency services provide information for the survivors, the authorities provide recommendations to return to normality, and citizens to ask for help or provide information. For this regard, it might be interesting to go further in terms of the automatic detection of tweets according to the user who publishes the tweet and the objective. In this line, the analysis of sentiments and emotions in tweets may be useful for emergency management since it allows organizations to get closer to the emotion that lies behind each publication.

Credibility: Many citizens believe that anything online in digital format is true and that the information is accurate and reliable. However, rumors spread a large quantity of misinformation on microblogs as Twitter. To take advantage of Twitter data as a source of information, the control of false information is increasingly important but still quite challenging. This is especially crucial in cases of emergencies where information in real time may be essential for the success of emergency management.

Visualization: During an emergency situation, a huge amount of tweets are generated making the management of information really difficult. As mentioned above, one of the challenges is the development of mechanisms that allows extracting relevant information from this large amount of data to integrate it into management systems. Particularly, such mechanisms may be a big help if the data stream can be analyzed, visualized and interpreted in real time. In this sense, research in interpretable visualization and user interfaces can provide a better decision-making process especially for emergency managers.

Regulatory initiatives: Governance initiatives for social media management in emergency situations are limited both from the perspective of emergency services and citizens. It is necessary the creation of procedures, policies and regulations that facilitate the use of social media during the phases of emergency management: before, during, and after.

Advances in this agenda will mean a basis for the development of better proposals that will facilitate and improve the management of emergency situations. Those in charge of making decisions will be able to take advantage of the content of social networks to improve the decision-making process during the different phases.

6. Conclusions

This paper has conducted a systematic literature review on the state of research concerning the use of Twitter information in emergency situations. One of the main advantages of this methodology is the confidence that the available literature has been thoroughly and systematically searched. For this purpose, in the planning phase, diverse research questions have been defined, as well as the search criteria. Next, in the conducting phase, the search and qualitative process have been detailed. Finally, we have present the results with the aim to answer to the research questions posed in the first phase. Therefore, the following results are detailed: evolution of publications, type of documents, reference journals and conferences, methodologies, events and, finally, the phases they are focus. Once the systematic literature review has been finished, we have analyzed current situation and point out future directions with the aim of fostering and directing further research on the application of Twitter for the management of emergency situations.

Acknowledgements

This work has been partially supported by the Spanish Ministry of Economy and Competitiveness (Programa Juan de la Cierva - FJCI-2015-24093) and the Spanish Ministry of Education, Culture and Sports for it support through the predoctoral contracts (FPU 2016/03298).

References

Abedin, B., & Babar, A. (2017). Institutional vs. non-institutional use of social media during emergency response: A case of Twitter in 2014 Australian bush fire. *Information Systems Frontiers, 20*(4), 729–740.

Ai, F., Comfort, L. K., Dong, Y., & Znati, T. (2016). A dynamic decision support system based on geographical information and mobile social networks: A model for tsunami risk mitigation in Padang, Indonesia. *Safety Science, 90*, 62–74 Building Community Resilience to Global Hazards: A Sociotechnical Approach.

Aladwani, A. M. (2015). Facilitators, characteristics, and impacts of twitter use: Theoretical analysis and empirical illustration. *International Journal of Information Management, 35*, 15–25.

de Albuquerque, J. P., Herfort, B., Brenning, A., & Zipf, A. (2015). A geographic approach for combining social media and authoritative data towards identifying useful information for disaster management. *International Journal of Geographical Information Science, 29*, 667–689.

Alcaide, C. (2013). Food for thought, conciencia situacional. *Tribuna Libre,* 48–49.

Alexander, D. (2015). *Disaster and emergency planning for preparedness, response, and recovery.* Oxford University Press.

Alshareef, H. N., & Grigoras, D. (2017). Using social media and the mobile cloud to enhance emergency and risk management. *International symposium on parallel and distributed computing (ISPDC)*.

Amirkhanyan, A., & Meinel, C. (2017). Analysis of data from the twitter account of the Berlin police for public safety awareness. *IEEE 21st international conference on computer supported cooperative work in design (CSCWD),* 209–214.

Antoniadis, S., Litou, I., & Kalogeraki, V. (2015). A model for identifying misinformation in online social networks. In C. Debruyne, H. Panetto, R. Meersman, T. Dillon, G. Weichhart, Y. An, & C. A. Ardagna (Eds.). *On the move to meaningful internet systems: OTM 2015 conferences: Confederated international conferences: CoopIS, ODBASE, and C &TC 2015* (pp. 473–482). Cham: Springer International Publishing.

Aramaki, E., Maskawa, S., & Morita, M. (2011). *Twitter catches the flu: Detecting influenza epidemics using twitter. Proceedings of the conference on empirical methods in natural language processing.* Association for Computational Linguistics1568–1576.

Artman, H., Brynielsson, J., Johansson, B. J., & Trnka, J. (2011 May). Dialogical emergency management and strategic awareness in emergency communication. *ISCRAM*.

Aswani, R., Kar, A. K., Ilavarasan, P. V., & Dwivedi, Y. K. (2018). Search engine marketing is not all gold: Insights from twitter and seoclerks. *International Journal of Information Management, 38*, 107–116.

Athanasia, N., & Stavros, P. T. (2015). Twitter as an instrument for crisis response: The typhoon Haiyan case study. *12th international conference on information systems for crisis response and management*.

Avvenuti, M., Cimino, M. G. C. A., Cresci, S., Marchetti, A., & Tesconi, M. (2016). A framework for detecting unfolding emergencies using humans as sensors. *SpringerPlus, 5*, 43.

Avvenuti, M., Cresci, S., Polla, M. N. L., Marchetti, A., & Tesconi, M. (2014). Social sensing is based on the idea that communities or groups of people provide a set of information similar to those obtainable from a single sensor. This amount of information generate a complex and adequate knowledge of one or more specific issues. *2014 IEEE international conference on pervasive computing and communication workshops (PERCOM WORKSHOPS),* 587–592.

Avvenuti, M., Vigna, F. D., Cresci, S., Marchetti, A., & Tesconi, M. (2015). Pulling information from social media in the aftermath of unpredictable disasters. *2nd international conference on information and communication technologies for disaster management (ICT-DM),* 258–264.

Bakillah, M., Li, R.-Y., & Liang, S. H. (2015). Geo-located community detection in twitter with enhanced fast-greedy optimization of modularity: The case study of typhoon Haiyan. *International Journal of Geographical Information Science, 29*, 258–279.

Basher, R. (2006). Global early warning systems for natural hazards: Systematic and people-centred. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences, 364*, 2167–2182.

Basnyat, B., Anam, A., Singh, N., Gangopadhyay, A., & Roy, N. (2017). Analyzing social media texts and images to assess the impact of flash floods in cities. *IEEE international conference on smart computing (SMARTCOMP)*.

Becker, H., Naaman, M., & Gravano, L. (2011). Beyond trending topics: Real-world event identification on twitter. *ICWSM, 11*, 438–441.

Boididou, C., Papadopoulos, S., Kompatsiaris, Y., Schifferes, S., & Newman, N. (2014). Challenges of computational verification in social multimedia. *Proceedings of the 23rd international conference on world wide web* (pp. 743–748).

Bolea, S. C. (2017). An analysis of tweets related to earthquakes, for the Romanian language. *International conference on speech technology and human–computer dialogue (SpeD),* 1–6.

Buribayeva, G., Miyachi, T., Yeshmukhametov, A., & Mikami, Y. (2015). An autonomous emergency warning system based on cloud servers and sns. *Procedia Computer Science, 60*, 722–729.

Cameron, M. A., Power, R., Robinson, B., & Yin, J. (2012). Emergency situation awareness from twitter for crisis management. *Proceedings of the 21st international conference on world wide web,* 695–698.

Cao, N., Lin, Y. R., Sun, X., Lazer, D., Liu, S., & Qu, H. (2012). Whisper: Tracing the spatiotemporal process of information diffusion in real time. *IEEE Transactions on Visualization and Computer Graphics, 18*, 2649–2658.

Capriotti, P., & Ruesja, L. (2018). How CEOs use twitter: A comparative analysis of global and Latin American companies. *International Journal of Information Management, 39*, 242–248.

Carley, K. M., Malik, M., Landwehr, P. M., Pfeffer, J., & Kowalchuck, M. (2016). Crowd sourcing disaster management: The complex nature of twitter usage in Padang Indonesia. *Safety Science, 90*, 48–61 Building Community Resilience to Global Hazards: A Sociotechnical Approach.

Carter, L., Thatcher, J. B., & Wright, R. (2014). Social media and emergency management: Exploring state and local tweets. *47th Hawaii international conference on system sciences,* 1968–1977.

Castillo, C., Mendoza, M., & Poblete, B. (2011). Information credibility on twitter. *Proceedings of the 20th international conference on world wide web*.

Cecaj, A., & Mamei, M. (2017). Data fusion for city life event detection. *Journal of Ambient Intelligence and Humanized Computing, 8*, 117–131.

Chaniotakis, E., Antoniou, C., & Pereira, F. C. (2017). Enhancing resilience to disasters using social media. *International conference on models and technologies for intelligent transportation systems (MT-ITS)*.

Chatfield, A., & Brajawidagda, U. (2012). Twitter tsunami early warning network: A social network analysis of twitter information flows. *Australasian conference on information systems*.

Chatfield, A. T., & Brajawidagda, U. (2013). Twitter early tsunami warning system: A case study in Indonesia's natural disaster management. *2013 46th Hawaii international conference on system sciences,* 2050–2060.

Chatfield, A. T., & Brajawidagda, U. (2014). Crowdsourcing hazardous weather reports from citizens via twittersphere under the short warning lead times of ef5 intensity tornado conditions. *47th Hawaii international conference on system sciences,* 2231–2241.

Chun, Y., Hwang, H. S., & Kim, C. S. (2012). A study on the extraction of damage locations using twitter messages. In T.-h. Kim, C. Ramos, H.-k. Kim, A. Kiumi, S. Mohammed, & D. Ślęzak (Eds.). *Computer applications for software engineering, disaster recovery, and business continuity: International conferences, ASEA and DRBC 2012* (pp. 218–224). Berlin, Heidelberg: Springer.

Comito, C., Pizzuti, C., & Procopio, N. (2016). Online clustering for topic detection in social data streams. *IEEE 28th international conference on tools with artificial intelligence (ICTAI),* 362–369.

CORE (2017). URL: http://www.core.edu.au/conference-portal.

Coyle, D., & Meier, P. (2009). *New technologies in emergencies and conflicts: The role of information and social networks.* Washington, DC and London, United Kingdom: UN Foundation–Vodafone Foundation Partnership.

Cvetojevic, S., & Hochmair, H. H. (2018). Analyzing the spread of tweets in response to Paris attacks. *Computers, Environment and Urban Systems* In press.

De Longueville, B., Smith, R. S., & Luraschi, G. (2009). "omg, from here, i can see the flames!": A use case of mining location based social networks to acquire spatio-temporal data on forest fires. *Proceedings of the 2009 international workshop on location based social networks* (pp. 73–80).

Dearstyne, B. W. (2005). Fighting terrorism, making war: Critical insights in the management of information and intelligence. *Government Information Quarterly, 22,* 170–186.

Doan, S., Vo, B.-K. H., & Collier, N. (2012). An analysis of twitter messages in the 2011 Tohoku earthquake. In P. Kostkova, M. Szomszor, & D. Fowler (Eds.). *Electronic healthcare: 4th international conference, eHealth 2011* (pp. 58–66). Berlin, Heidelberg: Springer.

Dong, H., Halem, M., & Zhou, S. (2013). Social media data analytics applied to hurricane sandy. *International conference on social computing,* 963–966.

Dork, M., Gruen, D., Williamson, C., & Carpendale, S. (2010). A visual backchannel for large-scale events. *IEEE Transactions on Visualization and Computer Graphics, 16*, 1129–1138.

Dufty, N., et al. (2016). Twitter turns ten: Its use to date in disaster management. *The Australian Journal of Emergency Management, 31*, 50.

Fayyad, U. M., Piatetsky-Shapiro, G., Smyth, P., & Uthurusamy, R. (1996). *Advances in knowledge discovery and data mining.* Menlo Park: AAAI Press.

Fersini, E., Messina, E., & Pozzi, F. A. (2017). Earthquake management: A decision support system based on natural language processing. *Journal of Ambient Intelligence and Humanized Computing, 8*, 37–45.

Fontes, D., Fonte, C., & Cardoso, A. (2017). Integration of vgi and sensor data in a web gis-based platform to support emergency response. *Experiment@ International Conference*.

Fosso Wamba, S., Edwards, A., & Akter, S. (2017). Social media adoption and use for improved emergency services operations: The case of the nsw ses. *Annals of Operations Research* In press.

Gao, H., Barbier, G., & Goolsby, R. (2011). Harnessing the crowdsourcing power of social media for disaster relief. *IEEE Intelligent Systems, 26*, 10–14.

Gelernter, J., & Balaji, S. (2013). An algorithm for local geoparsing of microtext. *GeoInformatica, 17*, 635–667.

Genes, N., Chary, M., & Chason, K. (2014). Analysis of twitter users' sharing of official new york storm response messages. *Medicine 2.0, 3*.

Ghahremanlou, L., Sherchan, W., & Thom, J. A. (2015). Geotagging twitter messages in crisis management. *The Computer Journal, 58*, 1937.

Ghenai, A., & Mejova, Y. (2017). *Catching Zika fever: Application of crowdsourcing and machine learning for tracking health misinformation on twitter.* arXiv:1707.03778.

Girtelschmid, S., Salfinger, A., Pröll, B., Retschitzegger, W., & Schwinger, W. (2016). Near real-time detection of crisis situations. *International convention on information and communication technology, electronics and microelectronics (MIPRO),* 247–252.

Glasgow, K., Fink, C., Vitak, J., & Tausczik, Y. (2016). "Our hearts go out": Social support and gratitude after disaster. *2016 IEEE 2nd international conference on collaboration and internet computing (CIC),* 463–469.

Graham, C., Thompson, C., Wolcott, M., Pollack, J., & Tran, M. (2015). A guide to social media emergency management analytics: Understanding its place through typhoon Haiyan tweets. *Statistical Journal of the IAOS, 31*, 227–236.

Gray, B., Weal, M., & Martin, D. (2018). Social media during a sustained period of crisis: The case of the UK storms. *ISCRAM conference*.

Groen, F. C., Pavlin, G., Winterboer, A., & Evers, V. (2017). A hybrid approach to decision making and information fusion: Combining humans and artificial agents. *Robotics and Autonomous Systems, 90*, 71–85 Special Issue on New Research Frontiers for Intelligent Autonomous Systems.

Gründer-Fahrer, S., Berger, C., Schlaf, A., & Heyer, G. (2016). Computational, communicative, and legal conditions for using social media in disaster management in Germany. *11th international conference on availability, reliability and security (ARES),* 811–820.

Gu, Y., Qian, Z. S., & Chen, F. (2016). From twitter to detector: Real-time traffic incident detection using social media data. *Transportation Research Part C: Emerging Technologies, 67*, 321–342.

Guan, X., & Chen, C. (2014). Using social media data to understand and assess disasters. *Natural Hazards, 74*, 837–850.

Gunawong, P., & Butakhieo, N. (2016). Social media in local administration: An empirical

study of twitter use in flood management. *Conference for e-democracy and open government (CeDEM),* 77–83.
Gupta, A., Lamba, H., Kumaraguru, P., & Joshi, A. (2013). Faking sandy: Characterizing and identifying fake images on twitter during hurricane sandy. *Proceedings of the 22nd international conference on world wide web,* 729–736.
Hagar, C. (2011). *Crisis information management: Communication and technologies.* Elsevier.
Han, S., Min, J., & Lee, H. (2015). Antecedents of social presence and gratification of social connection needs in sns: A study of twitter users and their mobile and non-mobile usage. *International Journal of Information Management, 35*, 459–471.
Hao, M., Rohrdantz, C., Janetzko, H., Dayal, U., Keim, D. A., Haug, L.-E., & Hsu, M.-C. (2011). Visual sentiment analysis on twitter data streams. *2011 IEEE Conference on Visual analytics science and technology (VAST)* (pp. 277–278).
Hara, Y. (2015). Behaviour analysis using tweet data and geo-tag data in a natural disaster. *Transportation Research Procedia, 11*, 399–412.
Hasan, M., Orgun, M. A., & Schwitter, R. (2018). Real-time event detection from the twitter data stream using the twitternews+ framework. *Information Processing & Management* In press.
He, W., Zha, S., & Li, L. (2013). Social media competitive analysis and text mining: A case study in the pizza industry. *International Journal of Information Management, 33*, 464–472.
Huang, Y., Dong, H., Yesha, Y., & Zhou, S. (2014). A scalable system for community discovery in twitter during hurricane sandy. *2014 14th IEEE/ACM international symposium on cluster, cloud and grid computing,* 893–899.
Hughes, A. L., & Palen, L. (2009). Twitter adoption and use in mass convergence and emergency events. *International Journal of Emergency Management, 6*, 248–260.
Ikeda, K., Sakaki, T., Toriumi, F., & Kurihara, S. (2016). An examination of a novel information diffusion model: Considering of twitter user and twitter system features. In N. Osman, & C. Sierra (Eds.). *Autonomous agents and multiagent systems: AAMAS 2016 workshops, Best papers* (pp. 180–191). Cham: Springer International Publishing Revised Selected Papers.
Ilyas, A. (2014). Microfilters: Harnessing twitter for disaster management. *IEEE global humanitarian technology conference (GHTC 2014),* 417–424.
Imran, M., Castillo, C., Diaz, F., & Vieweg, S. (2015). Processing social media messages in mass emergency: A survey. *ACM Computing Surveys, 47*, 67.1–67.38.
Imran, M., Elbassuoni, S. M., Castillo, C., Diaz, F., & Meier, P. (2013). Extracting information nuggets from disaster-related messages in social media. In: *Proc. of ISCRAM, Baden-Baden, Germany*.
Itakura, K. Y., & Sonehara, N. (2013). Using twitter's mentions for efficient emergency message propagation. *International conference on availability, reliability and security*.
Jaeger, P. T., Shneiderman, B., Fleischmann, K. R., Preece, J., Qu, Y., & Wu, P. F. (2007). Community response grids: E-government, social networks, and effective emergency management. *Telecommunications Policy, 31*, 592–604.
Johansson, F., Brynielsson, J., & Quijano, M. N. (2012). Estimating citizen alertness in crises using social media monitoring and analysis. *2012 European intelligence and security informatics conference (EISIC)*.
Kamboj, S., Sarmah, B., Gupta, S., & Dwivedi, Y. (2018). Examining branding co-creation in brand communities on social media: Applying the paradigm of stimulus-organism-response. *International Journal of Information Management, 39*, 169–185.
Kapoor, K. K., Tamilmani, K., Rana, N. P., Patil, P., Dwivedi, Y. K., & Nerur, S. (2018). Advances in social media research: Past, present and future. *Information Systems Frontiers, 20*, 531–558.
Karami, A., Dahl, A. A., Turner-McGrievy, G., Kharrazi, H., & Shaw, G. (2018). Characterizing diabetes, diet, exercise, and obesity comments on twitter. *International Journal of Information Management, 38*, 1–6.
Karimi, S., Yin, J., & Paris, C. (2013). *Classifying microblogs for disasters. Proceedings of the 18th Australasian document computing symposium ADCS'13*. New York, NY, USA: ACM26–33.
Kebabc, K., & Karslgil, M. E. (2015). High priority tweet detection and summarization in natural disasters. *23rd signal processing and communications applications conference (SIU),* 1280–1283.
Kim, J., Bae, J., & Hastak, M. (2018). Emergency information diffusion on online social media during storm cindy in U.S. *International Journal of Information Management, 40*, 153–165.
Kim, J., & Hastak, M. (2018). Social network analysis: Characteristics of online social networks after a disaster. *International Journal of Information Management, 38*, 86–96.
Kim, K., Kim, K., Jung, K., Jung, K., Chilton, K., & Chilton, K. (2016). Strategies of social media use in disaster management: Lessons in resilience from Seoul, South Korea. *International Journal of Emergency Services, 5*, 110–125.
Kim, T. (2014). Observation on copying and pasting behavior during the Tohoku earthquake: Retweet pattern changes. *International Journal of Information Management, 34*, 546–555.
Kitchenham, B. A. (2007). *Guidelines for performing systematic literature reviews in software engineering* Technical Report, Ver. 2.3 EBSE Technical Report. EBSE. sn.
Kohavi, R., & Provost, F. (1998). Glossary of terms. *Machine Learning, 30*, 271–274.
Lachlan, K. A., Spence, P. R., Lin, X., Najarian, K., & Greco, M. D. (2016). Social media and crisis management: Cerc, search strategies, and twitter content. *Computers in Human Behavior, 54*, 647–652.
Lai, C.-H. (2017). A study of emergent organizing and technological affordances after a natural disaster. *Online Information Review, 41*, 507–523.
Lai, C.-H., She, B., & Tao, C.-C. (2017). Connecting the dots: A longitudinal observation of relief organizations' representational networks on social media. *Computers in Human Behavior, 74*, 224–234.
Landwehr, P. M., Wei, W., Kowalchuck, M., & Carley, K. M. (2016). Using tweets to support disaster planning, warning and response. *Safety Science, 90*, 33–47 Building Community Resilience to Global Hazards: A Sociotechnical Approach.
Laylavi, F., Rajabifard, A., & Kalantari, M. (2016). A multi-element approach to location inference of twitter: A case for emergency response. *ISPRS International Journal of Geo-Information, 5*, 56.
Laylavi, F., Rajabifard, A., & Kalantari, M. (2017). Event relatedness assessment of twitter messages for emergency response. *Information Processing and Management, 53*, 266–280.
Lee, S.-Y., Qiu, L., & Whinston, A. (2018). Sentiment manipulate ion in online platforms: An analysis of movie tweets. *Production and Operations Management, 27*, 393–416.
Li, J., & Rao, H. R. (2010). *Twitter as a rapid response news service: An exploration in the context of the 2008 China earthquake.* The Electronic Journal of Information Systems in Developing Countries42.
Li, J., & Zeng, M. (2014). A human-oriented mutual assistive framework using collaborative filtering towards disasters. *2014 IEEE international conference on systems, man, and cybernetics (SMC),* 2216–2220.
Li, L., Zhang, Q., Tian, J., & Wang, H. (2018). Characterizing information propagation patterns in emergencies: A case study with Yiliang earthquake. *International Journal of Information Management, 38*, 34–41.
Li, R., Lei, K. H., Khadiwala, R., & Chang, K. C. C. (2012). Tedas: A twitter-based event detection and analysis system. *2012 IEEE 28th international conference on data engineering,* 1273–1276.
Li, H., Caragea, D., & Caragea, C. (2017a). *Towards practical usage of a domain adaptation algorithm in the early hours of a disaster.* ISCRAM.
Li, Z., Wang, C., Emrich, C. T., & Guo, D. (2017b). A novel approach to leveraging social media for rapid flood mapping: A case study of the 2015 south Carolina floods. *Cartography and Geographic Information Science,* 1–14.
Lipizzi, C., Iandoli, L., & Marquez, J. E. R. (2015). Extracting and evaluating conversational patterns in social media: A socio-semantic analysis of customers' reactions to the launch of new products using twitter streams. *International Journal of Information Management, 35*, 490–503.
Lozano, E., & Vaca, C. (2017). Crisis management on twitter: Detecting emerging leaders. *International conference on eDemocracy eGovernment (ICEDEG)*.
MacEachren, A. M., Jaiswal, A., Robinson, A. C., Pezanowski, S., Savelyev, A., Mitra, P., Zhang, X., & Blanford, J. (2011a). Senseplace2: Geotwitter analytics support for situational awareness. *2011 IEEE conference on visual analytics science and technology (VAST)*.
MacEachren, A. M., Robinson, A. C., Jaiswal, A., Pezanowski, S., Savelyev, A., Blanford, J., & Mitra, P. (2011b). Geo-twitter analytics: Applications in crisis management. *25th international cartographic conference,* 3–8.
Malizia, A., Bellucci, A., Diaz, P., Aedo, I., & Levialdi, S. (2011). Estorys: A visual storyboard system supporting back-channel communication for emergencies. *Journal of Visual Languages & Computing, 22*, 150–169.
Manna, S., & Phongpanangam, O. (2018). Exploring topic models on short texts: A case study with crisis data. *IEEE international conference on robotic computing (IRC)*.
Martínez-Rojas, M., Pardo-Ferreira, C., López-Arquillos, A., & Rubio-Romero, J. C. (2017). Using twitter as a tool to foster social resilience in emergency situations: A case of study. *11th international conference on industrial engineering and operations management*.
Martínez-Rojas, M., & Rubio-Romero, J. C. (2017). Uso de las nuevas tecnologías para la gestión y comunicacíon de informacíon en situaciones de emergencia. *Proceding of III Jornadas Andaluzas de Informática*.
McCreadie, R., Macdonald, C., & Ounis, I. (2015). Crowdsourced rumour identification during emergencies. *24th international conference on world wide web,* 965–970.
Mejri, O., Menoni, S., Matias, K., & Aminoltaheri, N. (2017). Crisis information to support spatial planning in post disaster recovery. *International Journal of Disaster Risk Reduction, 22*, 46–61.
Middleton, S. E., Middleton, L., & Modafferi, S. (2014). Real-time crisis mapping of natural disasters using social media. *IEEE Intelligent Systems, 29*, 9–17.
Miyabe, M., Miura, A., & Aramaki, E. (2012). Use trend analysis of twitter after the great east Japan earthquake. *Proceedings of the ACM 2012 conference on computer supported cooperative work companion ACM,* 175–179.
Moi, M., Friberg, T., Marterer, R., Reuter, C., Ludwig, T., Markham, D., Hewlett, M., & Muddiman, A. (2015). Strategy for processing and analyzing social media data streams in emergencies. *2nd international conference on information and communication technologies for disaster management (ICT-DM),* 42–48.
Morstatter, F., Kumar, S., Liu, H., & Maciejewski, R. (2013). Understanding twitter data with tweetxplorer. *Proceedings of the 19th ACM SIGKDD international conference on knowledge discovery and data mining*.
Muralidharan, S., Rasmussen, L., Patterson, D., & Shin, J.-H. (2011). Hope for Haiti: An analysis of facebook and twitter usage during the earthquake relief efforts. *Public Relations Review, 37*, 175–177.
Murthy, D., & Longwell, S. A. (2013). Twitter and disasters. *Information, Communication and Society, 16*, 837–855.
Musaev, A., & Hou, Q. (2016). Gathering high quality information on landslides from twitter by relevance ranking of users and tweets. *IEEE 2nd international conference on collaboration and internet computing (CIC),* 276–284.
Nagy, A., & Stamberger, J. (2012). Crowd sentiment detection during disasters and crises. *Proceedings of the 9th international ISCRAM conference,* 1–9.
Nar, S., & Akgul, Y. S. (2015). Analysis of social media messages for disasters via semi supervised learning. *23rd signal processing and communications applications conference (SIU),* 1126–1129.
Nayebi, M., Marbouti, M., Quapp, R., Maurer, F., & Ruhe, G. (2017). Crowdsourced exploration of mobile app features: A case study of the Fort McMurray wildfire. *International conference on software engineering: Software engineering in society track (ICSE-SEIS)*.
Nazer, T. H., Morstatter, F., Dani, H., & Liu, H. (2016). Finding requests in social media for disaster relief. *International conference on advances in social networks analysis and mining (ASONAM),* 1410–1413.

Neppalli, V. K., Caragea, C., Squicciarini, A., Tapia, A., & Stehle, S. (2017). Sentiment analysis during hurricane sandy in emergency response. *International Journal of Disaster Risk Reduction, 21*, 213–222.

Nguyen, D. A., Abdelzaher, T., Borbash, S., Dang, X. H., Ganti, R., Singh, A., & Srivatsa, M. (2014). On critical event observability using social networks: A disaster monitoring perspective. *IEEE military communications conference,* 1633–1638.

Nguyen, M.-T., Kitamoto, A., & Nguyen, T.-T. (2015). Tsum4act: A framework for retrieving and summarizing actionable tweets during a disaster for reaction. In T. Cao, E.-P. Lim, Z.-H. Zhou, T.-B. Ho, D. Cheung, & H. Motoda (Eds.). *Advances in knowledge discovery and data mining: 19th Pacific-Asia conference, PAKDD 2015* (pp. 64–75). Cham: Springer International Publishing.

Nguyen, T.-M., Kawamura, T., Tahara, Y., & Ohsuga, A. (2013). Toward information sharing of natural disaster: Proposal of timeline action network. In J. Filipe, & A. Fred (Eds.). *Agents and artificial intelligence: 4th international conference, ICAART 2012* (pp. 145–157). Berlin, Heidelberg: Springer Revised Selected Papers.

Ni, W., Shu, J., & Song, M. (2018). Location and emergency inventory pre-positioning for disaster response operations: Min–max robust mode land a case study of Yushu earthquake. *Production and Operations Management, 27*, 160–183.

Nugroho, R., Zhao, W., Yang, J., Paris, C., & Nepal, S. (2016). Using time-sensitive interactions to improve topic derivation in twitter. *World Wide Web,* 1–27.

Oh, O., Agrawal, M., & Rao, H. R. (2011). Information control and terrorism: Tracking the Mumbai terrorist attack through twitter. *Information Systems Frontiers, 13*, 33–43.

Ohtsuka, Y., Ishii, H., Utsu, K., & Uchida, O. (2017). A smartphone application for location recording and rescue request using twitter. *International conference on information networking (ICOIN),* 386–388.

Olteanu, A., Vieweg, S., & Castillo, C. (2015). *What to expect when the unexpected happens: Social media communications across crises. Proceedings of the 18th ACM conference on computer supported cooperative work and social computing.* ACM994–1009.

Onorati, T., & Díaz, P. (2015). Semantic visualization of twitter usage in emergency and crisis situations. *International conference on information systems for crisis response and management in Mediterranean countries*.

Onorati, T., & Díaz, P. (2016). Giving meaning to tweets in emergency situations: A semantic approach for filtering and visualizing social data. *SpringerPlus, 5*, 1782.

Onorati, T., Díaz, P., & Carrion, B. (2018). From social networks to emergency operation centers: A semantic visualization approach. *Future Generation Computer Systems* In press.

Opdyke, A., & Javernick-Will, A. (2014). Building coordination capacity: Post-disaster organizational twitter networks. *IEEE global humanitarian technology conference (GHTC 2014),* 86–92.

Panagiotopoulos, P., Barnett, J., Bigdeli, A. Z., & Sams, S. (2016). Social media in emergency management: Twitter as a tool for communicating risks to the public. *Technological Forecasting and Social Change, 111*, 86–96.

Panagiotopoulos, P., Ziaee Bigdeli, A., & Sams, S. (2012). 5 days in august" – how London local authorities used twitter during the 2011 riots. In H. J. Scholl, M. Janssen, M. A. Wimmer, C. E. Moe, & L. S. Flak (Eds.). *Electronic government: 11th IFIP WG 8.5 international conference, EGOV 2012* (pp. 102–113). Berlin, Heidelberg: Springer.

Pandey, N., & Natarajan, S. (2016). How social media can contribute during disaster events? *International conference on advances in computing, communications and informatics (ICACCI),* 1352–1356.

Piedra, N., Chicaiza, J., & Torres-Guarnizo, D. (2017). Characterization of natural events and epidemics from twitter: El ni a ± o, zika and chikungunya. *12th Iberian conference on information systems and technologies (CISTI),* 1–6.

Pirnau, M. (2016). Analysis of the use of social networks in acquiring information on disastrous events. *2016 15th RoEduNet conference: Networking in education and research*.

Pirnau, M. (2017). Word associations in media posts related to disasters a statistical analysis. *International conference on speech technology and human–computer dialogue (SpeD)*.

Pogrebnyakov, N., & Maldonado, E. (2018). Didn't roger that: Social media message complexity and situational awareness of emergency responders. *International Journal of Information Management, 40*, 166–174.

Pohl, D., Bouchachia, A., & Hellwagner, H. (2013). Online processing of social media data for emergency management. *12th international conference on machine learning and applications (Vol. 1),* 408–413.

Pohl, D., Bouchachia, A., & Hellwagner, H. (2016). Online indexing and clustering of social media data for emergency management. *Neurocomputing, 172*, 168–179.

Purohit, H., Hampton, A., Bhatt, S., Shalin, V. L., Sheth, A. P., & Flach, J. M. (2014). Identifying seekers and suppliers in social media communities to support crisis coordination. *Computer Supported Cooperative Work (CSCW), 23*, 513–545.

Purohit, H., Hampton, A., Shalin, V. L., Sheth, A. P., Flach, J., & Bhatt, S. (2013). What kind of # conversation is twitter? mining# psycholinguistic cues for emergency coordination. *Computers in Human Behavior, 29*, 2438–2447.

Radianti, J., Hiltz, S. R., & Labaka, L. (2016). An overview of public concerns during the recovery period after a major earthquake: Nepal twitter analysis. *International conference on system sciences (HICSS),* 136–145.

Ragini, J. R., Anand, P. R., & Bhaskar, V. (2018). Big data analytics for disaster response and recovery through sentiment analysis. *International Journal of Information Management, 42*, 13–24.

Regalado, R. V. J., Chua, J. L., Co, J. L., Cheng, H. C., Magpantay, A. B. L., & Kalaw, K. M. D. F. (2014). Adaptive information extraction of disaster information from twitter. *International conference on advanced computer science and information system,* 286–289.

Rice, R. G., & Spence, P. R. (2016). Thor visits lexington: Exploration of the knowledge-sharing gap and risk management learning in social media during multiple winter storms. *Computers in Human Behavior, 65*, 612–618.

Riquelme, F., & González-Cantergiani, P. (2016). Measuring user influence on twitter: A survey. *Information Processing and Management, 52*, 949–975.

Rudra, K., Ghosh, S., Ganguly, N., Goyal, P., & Ghosh, S. (2015). Extracting situational information from microblogs during disaster events: A classification–summarization approach. *24th ACM international on conference on information and knowledge management,* 583–592.

Sakaki, T., Okazaki, M., & Matsuo, Y. (2010). *Earthquake shakes twitter users: Real-time event detection by social sensors. Proceedings of the 19th international conference on world wide web WWW'10*. New York, NY, USA: ACM851–860.

Sakaki, T., Okazaki, M., & Matsuo, Y. (2013). Tweet analysis for real-time event detection and earthquake reporting system development. *IEEE Transactions on Knowledge and Data Engineering, 25*, 919–931.

Saleem, H. M., Zamal, F. A., & Ruths, D. (2015). Tackling the challenges of situational awareness extraction in twitter with an adaptive approach. *Procedia Engineering, 107*, 301–311.

Saravanou, A., Valkanas, G., Gunopulos, D., & Andrienko, G. (2015). Twitter floods when it rains: A case study of the UK floods in early 2014. *Proceedings of the 24th international conference on world wide web*.

Sarda, R., & Chouhan, P. (2017). Extracting non-situational information from twitter during disaster events. *Journal of cases on Information Technology, 19*, 15–23.

Schneider, S., & Check, P. (2010). Read all about it: The role of the media in improving construction safety and health. *Journal of Safety Research, 41*, 283–287 Special Topic: Construction Safety.

Schulz, A., Thanh, T., Paulheim, H., & Schweizer, I. (2013). A fine-grained sentiment analysis approach for detecting crisis related microposts. *International conference on information systems for crisis response and management*.

Scott, K. K., & Errett, N. A. (2017). Content, accessibility, and dissemination of disaster information via social media during the 2016 Louisiana floods. *Journal of Public Health Management and Practice*.

Sheikh, Z., Masood, H., Khan, S., & Imran, M. (2017). User-assisted information extraction from twitter during emergencies. *ISCRAM*.

Shirdastian, H., Laroche, M., & Richard, M.-O. (2017). Using big data analytics to study brand authenticity sentiments: The case of starbucks on twitter. *International Journal of Information Management* In press.

Simon, T., Goldberg, A., & Adini, B. (2015). Socializing in emergencies – A review of the use of social media in emergency situations. *International Journal of Information Management, 35*, 609–619.

Singh, J. P., Dwivedi, Y. K., Rana, N. P., Kumar, A., & Kapoor, K. K. (2017). Event classification and location prediction from tweets during disasters. *Annals of Operations Research* In press.

Sinnappan, S., Farrell, C., & Stewart, E. (2010). Priceless tweets! A study on twitter messages posted during crisis: Black Saturday. *Australasian conference on information systems 2010 proceedings (Vol. 39)*.

Sotsenko, A., Jansen, M., Milrad, M., & Rana, J. (2016). Using a rich context model for real-time big data analytics in twitter. *2016 IEEE 4th international conference on future internet of things and cloud workshops (FiCloudW),* 228–233.

Spielhofer, T., Greenlaw, R., Markham, D., & Hahne, A. (2016). Data mining twitter during the UK floods: Investigating the potential use of social media in emergency management. *International conference on information and communication technologies for disaster management,* 1–6.

Stieglitz, S., Mirbabaie, M., Ross, B., & Neuberger, C. (2018). Social media analytics – Challenges in topic discovery, data collection, and data preparation. *International Journal of Information Management, 39*, 156–168.

Stollberg, B., & De Groeve, T. (2012). The use of social media within the global disaster alert and coordination system (GDACS). *21st international conference on world wide web* (pp. 703–706).

Subba, R., & Bui, T. (2017). Online convergence behavior, social media communications and crisis response: An empirical study of the 2015 Nepal earthquake police twitter project. *Proceedings of the 50th Hawaii international conference on system sciences*.

Sutton, J., Spiro, E. S., Johnson, B., Fitzhugh, S., Gibson, B., & Butts, C. T. (2014). Warning tweets: Serial transmission of messages during the warning phase of a disaster event. *Information, Communication and Society, 17*, 765–787.

Tagliacozzo, S. (2018). Government agency communication during postdisaster reconstruction: Insights from the Christchurch earthquakes recovery. *Natural Hazards Review, 19*.

Takahashi, B., Jr., E, C. T., & Carmichael, C. (2015). Communicating on twitter during a disaster: An analysis of tweets during typhoon Haiyan in the Philippines. *Computers in Human Behavior, 50*, 392–398.

Tapia, A. H., Bajpai, K., Jansen, B. J., Yen, J., & Giles, L. (2011). Seeking the trustworthy tweet: Can microblogged data fit the information needs of disaster response and humanitarian relief organizations. *Proceedings of the 8th international ISCRAM conference,* 1–10.

Tapia, A. H., Moore, K. A., & Johnson, N. J. (2013). Beyond the trustworthy tweet: A deeper understanding of microblogged data use by disaster response and humanitarian relief organizations. *10th international information systems for crisis response and management (ISCRAM),* 770–779.

Tatsubori, M., Watanabe, H., Shibayama, A., Sato, S., & Imamura, F. (2012). Social web in disaster archives. *Proceedings of the 21st international conference on world wide web* (pp. 715–716).

Temnikova, I., Castillo, C., & Vieweg, S. (2015). Emterms 1.0: A terminological resource for crisis tweets. *12th international conference on information systems for crisis response and management*.

Temnikova, I. P., Varga, A., & Biyikli, D. (2014). Building a crisis management term resource for social media: The case of floods and protests. *International conference on language resources and evaluation conference,* 740–747.

Thom, D., Krüger, R., Ertl, T., Bechstedt, U., Platz, A., Zisgen, J., & Volland, B. (2015). Can twitter really save your life? A case study of visual social media analytics for situation awareness. *2015 IEEE Pacific visualization symposium (PacificVis),* 183–190.

Thomson, R., Ito, N., Suda, H., Lin, F., Liu, Y., Hayasaka, R., Isochi, R., & Wang, Z. (2012). Trusting tweets: The Fukushima disaster and information source credibility on twitter. *Proceedings of the 9th international ISCRAM conference,* 1–10.

To, H., Agrawal, S., Kim, S. H., & Shahabi, C. (2017). *On identifying disaster-related tweets: Matching-based or learning-based?* Information Retrieval.

Toriumi, F., & Baba, S. (2016). Real-time tweet classification in disaster situation. *Proceedings of the 25th international conference companion on world wide web WWW'16 companion* (pp. 117–118).

Torkildson, M. K., Starbird, K., & Aragon, C. (2014). Analysis and visualization of sentiment and emotion on crisis tweets. In Y. Luo (Ed.). *Cooperative design, visualization, and engineering: 11th international conference, CDVE 2014* (pp. 64–67). Cham: Springer International Publishing.

Twitter (2018).

Tyshchuk, Y., Li, H., Ji, H., & Wallace, W. A. (2013). Evolution of communities on twitter and the role of their leaders during emergencies. *IEEE/ACM international conference on advances in social networks analysis and mining (ASONAM 2013),* 727–733.

Verma, S., Vieweg, S., Corvey, W. J., Palen, L., Martin, J. H., Palmer, M., Schram, A., & Anderson, K. M. (2011). Natural language processing to the rescue? Extracting "situational awareness" tweets during mass emergency. *ICWSM*.

Vieweg, S., Hughes, A. L., Starbird, K., & Palen, L. (2010). Microblogging during two natural hazards events: What twitter may contribute to situational awareness. *SIGCHI conference on human factors in computing systems,* 1079–1088.

Wang, B., & Zhuang, J. (2017). Crisis information distribution on twitter: A content analysis of tweets during hurricane sandy. *Natural Hazards, 89*, 161–181.

Wang, Y., Gao, Y., & Yang, B. (2017). E-patroller: A semantic technology-based public emergency monitoring system. *International conference on big data analysis (ICBDA)*.

Wang, Z., & Ye, X. (2018). Social media analytics for natural disaster management. *International Journal of Geographical Information Science, 32*, 49–72.

Wang, Z., Ye, X., & Tsou, M.-H. (2016). Spatial, temporal, and content analysis of twitter for wildfire hazards. *Natural Hazards, 83*, 523–540.

White, E. T. (2014). *The application of social media in disasters.* International Institute of Global Resilience.

Williams, S. A., Terras, M. M., & Warwick, C. (2013). What do people study when they study twitter? Classifying twitter related academic papers. *Journal of Documentation, 69*, 384–410.

Win, S. S. M., & Aung, T. N. (2017). Target oriented tweets monitoring system during natural disasters. *International conference on computer and information science (ICIS),* 143–148.

Wu, B., & Shen, H. (2015). Analyzing and predicting news popularity on twitter. *International Journal of Information Management, 35*, 702–711.

Wu, X., Cao, Y., Xiao, Y., & Guo, J. (2018). Finding of urban rainstorm and waterlogging disasters based on microblogging data and the location-routing problem model of urban emergency logistics. *Annals of Operations Research* In press.

Yates, D., & Paquette, S. (2011). Emergency knowledge management and social media technologies: A case study of the 2010 Haitian earthquake. *International Journal of Information Management, 31*, 6–13.

Yin, J., Karimi, S., Lampert, A., Cameron, M., Robinson, B., & Power, R. (2015). Using social media to enhance emergency situation awareness. *Twenty-fourth international joint conference on artificial intelligence*.

Zhang, X., Kelly, S., & Ahmad, K. (2016). The slandail monitor: Real-time processing and visualisation of social media data for emergency management. *11th international conference on availability, reliability and security (ARES),* 786–791.

Zheng, L., Shen, C., Tang, L., Zeng, C., Li, T., Luis, S., & Chen, S. C. (2013). Data mining meets the needs of disaster information management. *IEEE Transactions on Human–Machine Systems, 43*, 451–464.

Zheng, X., Han, J., & Sun, A. (2018). A survey of location prediction on twitter. *IEEE Transactions on Knowledge and Data Engineering*.

Zoppi, T., Ceccarelli, A., Lo Piccolo, F., Lollini, P., Giunta, G., Morreale, V., & Bondavalli, A. (2018). Labelling relevant events to support the crisis management operator. *Journal of Software: Evolution and Process,* 30.

Zoppi, T., Ceccarelli, A., Lollini, P., Bondavalli, A., Piccolo, F. L., Giunta, G., & Morreale, V. (2016). Presenting the proper data to the crisis management operator: A relevance labelling strategy. *IEEE 17th international symposium on high assurance systems engineering (HASE),* 228–235.

Zou, L., Lam, N. S., Cai, H., & Qiang, Y. (2018). Mining twitter data for improved understanding of disaster resilience. *Annals of the American Association of Geographers* In press.