25 Crisis Informatics

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Contents

1 Introduction and Brief History

Social media is a part of everyday life today.[1] Tim O'Reilly (2007) first defined Web 2.0 as an architecture of participation with new possibilities for

[1] This essay is based on our previous article "Fifteen years of social media in emergencies: A retrospective review and future directions for crisis informatics" (Reuter & Kaufhold, 2018), which summarizes the development of 15 years in the field of crisis informatics research. The

social interaction. Over the years, this interaction has increasingly been subsumed under the term social media, which Kaplan and Haenlein (2010) have defined as a "group of internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of user-generated content." Here, user-generated content refers to "the various forms of media content that are publicly available and created by end-users" (Kaplan & Haenlein, 2010). Allen (2004) noted that the "core ideas of social software itself [*sic*] enjoy a much longer history, running back to Vannevar Bush's ideas about the storage-device Memex in 1945 through terms such as augmentation, groupware, and Computer Supported Cooperative Work (CSCW) in the 1960s, 70s, 80s, and 90s." In compliance, Koch (2008) argued that "most of what currently is advertised as a revolution on the web has been there as CSCW applications years (or even decades) ago – however, not as nice and as usable as today." According to statistics (Statista, 2020), the most frequently used types of social media currently include Facebook with about 2.6 billion active users monthly, YouTube (2 billion), WhatsApp (2 billion), WeChat (1.2 billion), Instagram (1 billion), TikTok (800 million), and Twitter (326 million).

Not only is social media part of everyday life, but it is also used in critical situations: Already after the attacks of 9/11 in 2001, citizens set up wikis to collect information about missing persons (Palen & Liu, 2007), and FEMA and the Red Cross used web-based technologies to inform the public and make status reports available internally and externally (Harrald et al., 2002). Since about 2006, the use of social media in emergencies has developed into a large field of research, which is often termed *crisis informatics*. The term coined by Hagar (2007) and later further elaborated by Palen et al. (2009) "views emergency response as an expanded social system where information is disseminated within and between official and public channels and entities." Today, crisis informatics "is a multidisciplinary field combining computing and social science knowledge of disasters; its central tenet is that people use personal information and communication technology to respond to disaster in creative ways to cope with uncertainty" (Palen & Anderson, 2016). In recent years, various studies have emerged that deal with the use of social media in emergencies. Journals worldwide have taken up the topic in special issues (Hiltz et al., 2011; Imran et al., 2020; Pipek et al., 2014; Reuter, Mentler, et al., 2015; Reuter, Stieglitz, et al., 2020) as well as tracks at various conferences, such as CSCW and ISCRAM (Reuter, Backfried, et al., 2018). Recently, corresponding researchers developed and published a literature resource on crisis informatics research to support research on the COVID-19 pandemic (Palen, 2020). As of 2020,

sections on usage, role, and perception patterns were modified and updated with recent developments thoroughly. Furthermore, a novel section on information patterns was added.

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considering published articles, leading researchers currently active in this area include (sorted in alphabetical order by institution) but are not limited to the groups of Amanda Lee Hughes at Brigham Young University (USA), Hemant Purohit at George Mason University (USA), Ira Helsloot at Radboud University Nijmegen (NL), Starr Roxanne Hiltz and Linda Plotnick at New Jersey Institute of Technology (USA), Andrea Tapia at Penn State University (USA), Muhammad Imran at the Qatar Computing Research Institute (Qatar), Christian Reuter and Marc-André Kaufhold at the Technical University of Darmstadt (Germany), Paloma Díaz Pérez at Universidad Carlos III de Madrid (Spain), Carlos Castillo at Universitat Pompeu Fabra (Spain), Kai Fischbach at University of Bamberg (Germany), Leysia Palen and Kenneth Anderson at the University of Colorado Boulder (USA), Stefan Stieglitz and Milad Mirbabaie at the University of Duisburg-Essen (Germany), Robert Soden at the University of Toronto (Canada), and Kate Starbird and Emma Spiro at the University of Washington (USA).

Most studies focus on the concrete use of social media during a specific emergency, such as the riots in London in 2011 (Denef et al., 2013), Hurricane Sandy in 2012 (Hughes et al., 2014), or the European floods in 2013 (Reuter, Ludwig, et al., 2015). These studies demonstrate the specific ways in which social media responded to different crises. Besides empirical investigations, crisis informatics comprises the collection and processing of social media data, the design, development, and evaluation of supportive technology, and increasingly cumulative and longitudinal research (Reuter, Hughes, et al., 2018). In various studies on emergencies and disaster events, numerous opportunities and challenges regarding social media were identified, user groups defined, and perceptions examined. However, after 20 years of social media in emergencies, it is time to summarize what has been achieved so far and to deduce what the next step should be. We will review usage patterns (Section 2), role patterns (Section 3), information patterns (Section 4), perception patterns (Section 5), and subsequently discuss future directions (Section 6).

2 Usage Patterns – Types of Interaction in Social Media

The range of different emergency situations, reactions to them and the wealth of case studies by renowned researchers such as Leysia Palen and Amanda Lee Hughes (Palen & Hughes, 2018) led to the categorization of the possible uses of social media. Following this approach, Christian Reuter et al. (2012) derived a classification matrix for cooperation in crisis situations depending on the sender (x-axis) and the recipient (y-axis) of digital content. Considering citizens (C) and authorities (A), such as emergency services, this crisis communication matrix distinguishes between four observed information flows or patterns of social media use in emergencies (Figure 25.1): On the inter-organizational level, organizations of crisis response communicate with each other (A2A). On the public level, citizens and volunteers communicate with

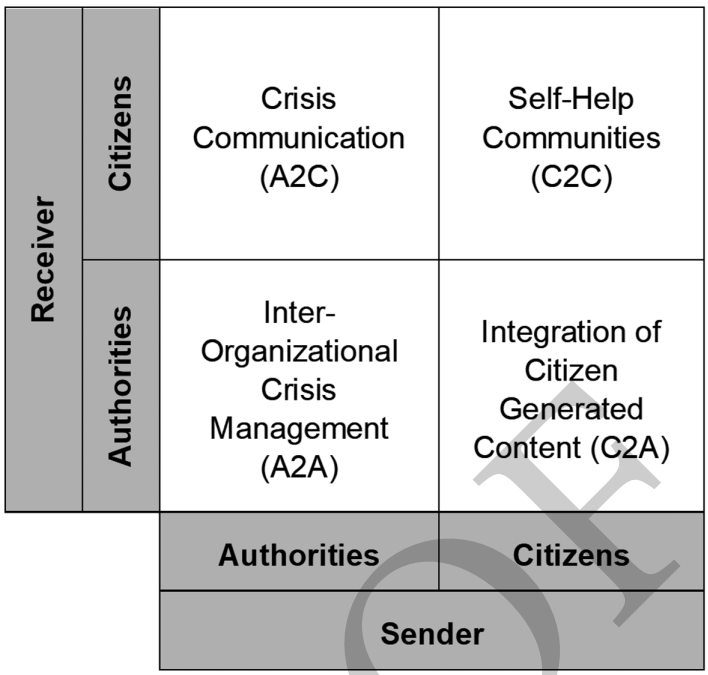

Figure 25.1. *Crisis communication matrix, adapted with minor changes in terminology (Reuter et al., 2012).*

each other in real or virtual form via social media, such as Twitter or Facebook (C2C). This citizen-generated content is also being analyzed by crisis response organizations (C2A). In addition to communication among citizens, organizations responsible for recovery work inform the public (A2C).

2.1 Citizens to Citizens (C2C) – Self-Coordination and Help

Citizens use social media as a tool to address other citizens within emergency situations; few of the activities are intended for emergency services. However, this form of self-coordination has already existed before the emergence of social media, as Quarantelli and Dynes (1977) as well as Stallings and Quarantelli (1985) characterized these "emergent groups" as "private citizens who work together in pursuit of collective goals relevant to actual or potential disasters but whose organization has not yet become institutionalized" already 40 years ago. According to Quarantelli (1984), the essential prerequisites for the emergence of such groups are a legitimizing social environment, a perceived threat, a supportive social climate, a network of social relationships, and the availability of specific (immaterial) resources. Some studies suggest that citizens react to crisis situations largely rationally, rarely in panic, are not helpless, and do not loot (Helsloot & Ruitenberg, 2004). Instead, they are able to participate in a wide range of rescue and assistance measures (Mirbabaie, Bunker, Stieglitz, & Deubel, 2020). Reuter et al. (2013) distinguish between activities in the "real" and the "virtual" world: real

"emergent groups" (Stallings & Quarantelli, 1985), which usually act in the form of neighborhood help and work on-site, and virtual "digital volunteers" (Starbird & Palen, 2011), who come from the Internet and work mainly online.

Several case studies reported the use of social media in emergencies. Analyzing Hurricanes Gustav and Ike in 2008, Hughes and Palen (2009) observed that Twitter is more heavily frequented in times of crises than in general use. Furthermore, people collected and aggregated information during the 2008 Sichuan earthquake (Qu et al., 2009), and a study of the Tennessee River technological failure in 2008 confirmed this observation, with the effect of information exceeding the boundaries of localized networks and raising citizens' awareness of emergencies (Sutton, 2010). The Yushu earthquake in 2010 showed that people use microblogging to obtain information about the status of the emergency or affected people (Qu et al., 2011). According to White et al. (2014), citizens undertook activities to relieve the official emergency services during Hurricane Sandy in 2012. Kaufhold and Reuter (2016) observed a similar behavior during the 2013 European floods when citizens supported in the construction of dykes and distribution of material goods. In addition, Goolsby (2010) and Kogan et al. (2016) reported the emergence of ad hoc crisis communities using social media to generate collaborative crisis maps. Throughout the 2011 Egyptian uprising (Starbird & Palen, 2012) and the 2011 Great East Japan Earthquake (Wilensky, 2014), citizens used social media to express solidarity and compassion. Based on a systematic literature review, Eismann et al. (2016) concluded that "sharing and obtaining factual information is the primary function of social media usage consistently across all disaster types, but the secondary functions vary."

However, there is also a risk that outdated or inaccurate information will be published and that useful information will be unequally distributed (Wilensky, 2014). Combined with chaotic and unorganized online behavior of volunteers, this can lead to uncertainty (Valecha et al., 2013). Another critical aspect pointed out by Starbird et al. (2019) is the existence of strategic information operations, such as disinformation and political propaganda, or other forms of online manipulation. Solutions for this could be cross-platform moderators (Reuter, Ludwig, et al., 2015) or public displays for the coordination of volunteers (Ludwig et al., 2016). Furthermore, Purohit et al. (2014) propose a system for identifying seekers and suppliers in social media communities to support crisis coordination. Cobb et al. (2014) suggest more coordination and integration in volunteer activities to share tasks and exchange expertise. Central to this is clarity and selection of relevant content, facilitating processes of moderation and autonomous work, encouraging feedback and updates in interaction relationships, and integrating technologies and interaction types (Kaufhold and Reuter, 2014).

2.2 Authorities to Citizens (A2C) – Crisis Communication and Public Alerting

Today and in the future, public authorities are increasingly integrating social media into their crisis communication to inform the public about preventive or

behavioral measures for emergencies (Reuter, Ludwig, et al., 2016). A case study of Public Information Officers (PIO) of the Los Angeles Fire Department underscores the importance of using new forms of media and technology within authorities to achieve effective organizational use of social media (Latonero & Shklovski, 2011). The Carlton Complex Wildfire 2014 case study showed that local news media provide the largest amount of relevant and up-to-date information compared to other information sources (Chauhan & Hughes, 2017). Hughes and Palen (2012) argue that members of the public "have a changed relationship to the institution of emergency response" through the authorities' use of social media. A comparative study of police units in the 2011 London riots identified not only closer relationships to citizens and increased potential reach but also high maintenance by the use of social media (Denef et al., 2013). Furthermore, a study on 2012 Hurricane Sandy also shows that communication depends on the type of media (Hughes et al., 2014), as certain features and tools are required "to better track, respond to, and document public information." However, due to the emerging risks of chaotic social media use, such as reported during the 2011 Thailand flooding (Kaewkitipong et al., 2012) or the 2011 Norway attacks (Perng et al., 2012), and the purposeful dissemination of misinformation, which was also termed infodemic during the COVID-19 pandemic (Cinelli et al., 2020), emergency services require suitable crisis communication strategies to serve their primary purpose of saving lives.

In the past, a variety of guidelines on how to use social media before, during, and after emergencies (Kaufhold et al., 2019) as well as strategies for crisis communication in social media, such as information dissemination, data monitoring and analysis, and conversations and coordinated action, have been developed (Wukich, 2015). Nevertheless, there are several barriers to the use of social media by authorities. A study about the collaboration among humanitarian aid organizations and Volunteer and Technical Communities (V&TCs) identified six barriers of collaboration: limited resources, management of volunteers, different levels of engagement, commitment, ways of working, and expertise (van Gorp, 2014). Humanitarian organizations are also confronted with the challenges of "near-real-time information processing, information overload, information extraction, summarization, and verification of both textual and visual content" (Imran et al., 2020). Plotnick and Hiltz (2016) complement barriers to effective use of social media in relation to US emergency managers at the district level: lack of adequately trained personnel, lack of guidelines and policy documents, trustworthiness, and information overload. Despite these challenges, emergency services increasingly use social media to share information with the public on how to avoid accidents or stay safe during emergencies (Reuter, Kaufhold, et al., 2020).

2.3 Citizens to Authorities (C2A) – Integration of Citizen-Generated Content

Besides the publication of information by public authorities, the use of citizen-generated content is important. In this way, problematic situations can be better

illustrated, for example, through posted photographs, and the vigilance of citizens can be better assessed (Johansson et al., 2012). However, the perceived unreliability and sheer volume of such information during large-scale emergencies is a major obstacle to exploring such opportunities (Kaufhold, Bayer, et al., 2020; Mendoza et al., 2010). In a comprehensive literature review on the integration of social media content, Hughes and Palen (2014) complement the challenges by verification, liability, credibility, information overload, and resource allocation. Still, Akhgar et al. (2013) describe how public safety organizations and volunteer groups are becoming increasingly aware of social media's added value in times of crisis; their social media behavior could contribute to general trustworthiness in the future (Hughes & Tapia, 2015).

Various approaches exist to integrate citizen-generated content and to support authorities in processing it. Several contributions aim at extracting *situational awareness* from social media (Vieweg et al., 2010). For instance, based on the case of Japanese earthquakes in 2009, Sakaki et al. (2010) propose an algorithm that incorporates Twitter users as social sensors for real-time event detection, and Pohl et al. (2015) propose clustering approaches for sub-event detection on Flickr and YouTube to automate the processing of data in social media. Furthermore, Castillo (2016) brings together computational methods (e.g., natural language processing, semantic technologies, data mining, etc.) to process social media messages under *time-critical constraints*. In addition, Alam et al. (2019) show how different artificial intelligence techniques from the fields of natural language processing and computer vision bring together complementary information from text and image content to improve situational awareness. Zade et al. (2018) go a step further and speak of *actionability* instead of situational awareness, assuming that "information relevance may vary across responder role, domain, and other factors" (Zade et al., 2018).

There are still unaddressed aspects in this area as well, including techniques for data characterization, acquisition, and preparation, event detection and tracking, clustering, classification, extraction, summarization, and semantic technologies (Imran et al., 2015). A study by Pohl (2013) summarizes existing frameworks and tools developed in the context of crisis-related (e.g., Twitcident or "Tweak the Tweet") and non-crisis-related (e.g., Twitinfo) research to analyze social media or to incorporate new functionalities into social media usage for crisis management. The comparison reveals that there are systems for different applications that consider one or several social media platforms specifically developed for crisis management and perform different types of analysis: monitoring, event-detection, and sentiment analysis. Simultaneously, however, other studies have shown that not all emergency responders in disasters make use of such data because it is difficult to receive and filter particularly large amounts of data in emergencies (Hughes & Palen, 2012; Reuter, Amelunxen, et al., 2016). While Imran et al. (2018) suggest the application of advanced machine learning methods, such as active, deep, or online learning, to extract more useful information from general-purpose

social media, Kaufhold et al. (2018) suggest the deployment of a crisis-specific mobile app for a more structured reporting of incidents by category, description, multimedia files, and GPS location.

2.4 Authorities to Authorities (A2A) – Inter- and Intra-Organizational Crisis Management

It can be assumed that inter- and intra-organizational collaboration (A2A) of authorities, as a final pattern, is often not supported by social media companies. Despite the availability of solutions for social media analytics supporting collaborative functionality, most of them are not tailored to the domain of emergency management (Kaufhold, Rupp, et al., 2020). However, social media can help to improve inter-organizational awareness, expertise sharing, and informal processes (Ley et al., 2014). White et al. (2009) examined the potentials of online social networks with emergency management students: information exchange, communication, and networking were the most popular features. They also show that possible concerns about these systems may be information integrity, user identification, privacy, and technology reliability. Experience shows that inter-organizational social networks could generate potential for authorities (Pipek et al., 2013; Reuter, 2014). Furthermore, social media can be used for internal communication. However, this pattern will not be examined in detail as it does not directly involve citizens.

3 Role Patterns – Types of Users in Social Media

The research on usage patterns was complemented by the identification of different social media roles in emergencies. Most remarkably, Kate Starbird and Leysia Palen (2011) established the notion of "digital volunteers," which was quickly supplemented by Christian Reuter et al. (2013), who proposed different types of social media users and a differentiation of roles in the real and virtual realm, leading to the design of a role typology matrix (Reuter & Kaufhold, 2018). According to the matrix, roles were identified that either (a) belong to the domain of citizens (public) or authorities (Reuter et al., 2012) or (b) perform their activities in the real (Stallings & Quarantelli, 1985) or virtual realm (Reuter et al., 2013). In this way, four different role patterns can be distinguished, which take into account the scope of action of the role (x-axis) and the affiliation of the role (y-axis). The idea of the role typology matrix (Figure 25.2) is to provide an overview, to promote the systematic analysis and development of role patterns, and to support the successful implementation of roles in the public and organizational domain. In contrast to the original matrix, the public-real response has been extended to include emergent and extending groups to consider already established structures, that is, groups or organizations that perform irregular response tasks during emergencies (Quarantelli, 1995).

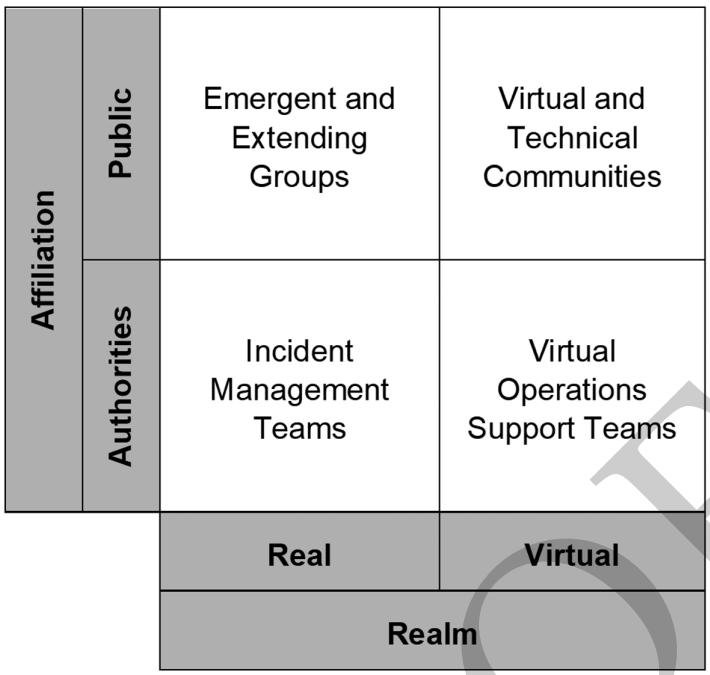

Figure 25.2. *Role Typology Matrix, adapted with minor changes in terminology (Reuter & Kaufhold, 2018).*

3.1 Public Perspective – Emerging, Expanding, and Extending Groups and Virtual and Technical Communities

The public-real reaction is represented by emergent and extending groups. Emergent groups are defined as "private citizens who work together in pursuit of collective goals relevant to actual or potential disasters [but] whose organization has not yet become institutionalized" (Stallings & Quarantelli, 1985). In contrast, extending groups comprise already established structures, such as associations and clubs, but which perform irregular tasks during an emergency (Quarantelli, 1995). These usually include *self-helpers and neighborhood helpers* who are directly affected by the event and work with or without organizational forces to cope with the event (Kircher, 2014). Furthermore, *unbound*, *ad-hoc*, and *spontaneous helpers* come from areas which are not directly affected, are motivated by news and the media, and work in a self-organized manner or within an organization. At this point, the line to public-virtual response becomes blurred. According to Reuter et al. (2013), some helpers are often involved in both real and virtual activities that offer and encourage help, provide emotional support, and disseminate recommendations for action. In addition, Kaufhold and Reuter (2016) identified the role of moderators who establish support platforms in social media, mediate donation offers and requests, mobilize resources, sometimes even interact with authorities, and integrate information into real and virtual space.

Beyond that, public-virtual response is best characterized with Virtual and Technical Communities (V&TCs) that "provide disaster support with expertise in geographic information systems, database management, social media, and online campaigns" (van Gorp, 2014). Hughes and Palen (2009) first identified *information brokers* who collect information from various sources to help affected citizens. For Starbird and Palen (2011), the second step was to recognize the actions of *remote operators* as *digital volunteers*, moving from simple internet-based activities, such as retweeting or translating tweets, to more complex ones, such as verifying or forwarding information. Building on this, Reuter et al. (2013) suggest a more specific classification of Twitter users in different roles, such as *reporters* who integrate external information sources into social media; *retweeters* who distribute important derived information to followers or users; *repeaters who* generate, synthesize, repeat, and distribute a certain message to concrete recipients; and *readers* who are passive information catchers that are participants interested in or affected by the situation. Without any claim of comprehensiveness, Table 25.1 presents terms that

Table 25.1. *Public perspective on social media roles*

Role	Description
Public roles in or interacting with the real realm	
Self-helpers and neighborhood helpers	Directly affected by the event and work with or without organizational forces to overcome it (Kircher, 2014).
Unbound, ad-hoc, and spontaneous helpers	Come from areas that are not directly affected, are motivated by news and the media, and work self-organized or in an organization (Kircher, 2014).
Helpers	Provide emotional support and recommendations for action, offer and encourage help, and are involved in virtual and real activities (Reuter et al., 2013).
Moderators	Establish support platforms, mediate offers and requests, mobilize resources, and integrate information in the real and virtual realm (Kaufhold & Reuter, 2014).
Public roles acting primarily in the virtual realm	
Digital volunteers	Element of the phenomena popularly known as crowdsourcing during crises. In the twitter sphere they are referred to as voluntweeters (Starbird & Palen, 2011).
Reporters	Integrate external information sources and thus provide generative and synthetic information as a news channel or eyewitness (Reuter et al., 2013).
Retweeters	Distribute important derived information to followers or users (Reuter et al., 2013) and correspond with the information broker (Hughes & Palen, 2009).
Repeaters	Generate, synthesize, repeat, and distribute a certain message to concrete recipients (Reuter et al., 2013).
Readers	Passive information-catching participants who are interested in or affected by the situation (Reuter et al., 2013).

authors have used to describe different (overlapping) social media users in crisis from the public perspective.

3.2 Authority Perspective – Incident Management and Virtual Operations Support Teams

Regarding the real-authority response, *incident management teams* perform on-the-ground operations aiming "to save human lives, mitigate the effect of accidents, prevent damages, and restore the situation to the normal order" (Chrpa & Thórisson, 2013). While emergency forces focus on the real realm, social media or the virtual realm offers new potential for incident managers, since they contain potentially relevant information on situation awareness, including situation updates, photos, public mood, or videos, that enable improved crisis response (Reuter, Ludwig, et al., 2016). Furthermore, social media is an additional channel for crisis communication and reaching the population. Here, Bergstrand et al. (Bergstrand et al., 2013) distinguish between *high-level formal organizational accounts* which formally inform the public about ongoing events; *accounts for formal functions and roles* that distribute information about certain entities or retweet other civil security actors; *formal personal accounts* which are used to disseminate role-specific information; and *affiliated personal accounts* that reflect personal opinions and social conversations. However, research also indicates that authorities use social media for unidirectional rather than bidirectional communication and face significant obstacles in integrating social media insights into their response to it, such as privacy and law compliance issues, lack of expertise and skills, organizational support or financial resources, as well as specific equipment or software (Plotnick & Hiltz, 2016; Reuter, Ludwig, et al., 2016).

To integrate the virtual-authority response, emergency services are deploying *virtual operations support teams (VOST)*, which adapt "to the need for emergency management participation in social media channels during a crisis, while also having that activity support but not interfere with on-the-ground operations" (St. Denis et al., 2012). Initially, Reuter et al. (2011) proposed community scouts as amateur "first informers" to counteract the perceived unreliability of social media information for authorities, and St. Denis et al. (2012) described the use of trusted digital volunteers during the 2011 Shadow Lake Fire in virtual teams to inform a Type I incident management team about social media activities. These VOST can be supported by *preregistered helpers* and *first responders*, who have registered prior to the event and contribute with personal but no special disaster control qualifications, as well as *honorary office* and *full-time helpers*, who are trained for specific disaster control tasks (Kircher, 2014). Detjen et al. (2016) further specify the characteristics of helper groups. For instance, unbound helpers perform reactive and (partially) bound helpers perform rather proactive activities. With more strongly bound helpers, prosocial behavior develops from spontaneous to sustainable characteristics; the helping process grows in terms of long-term, continuous, predictable, involved,

Table 25.2. *Organizational perspective on social media roles*

Role	Description
Organizational roles acting in the real and virtual realm	
High-level formal organizational accounts	Used to formally inform the public about ongoing events in a unidirectional form of communication (Bergstrand et al., 2013).
Accounts for formal functions and roles	Distribute information about certain entities, retweet other civil security actors, and maintain bidirectional communication (Bergstrand et al., 2013).
Formal personal accounts	Disseminate role-specific information and references to official work or current issues (Bergstrand et al., 2013).
Affiliated personal accounts	Used for expressive dissemination of information, personal opinions, reflections, and social conversations (Bergstrand et al., 2013).
Trusted volunteers acting in the real or virtual realm	
Amateur community scouts	Proposed as amateur "first informers" to overcome the perceived unreliability of social media information for authorities (Reuter et al., 2011).
Trusted digital volunteers	Deployed during the 2011 Shadow Lake Fire to monitor social media activities (St. Denis et al., 2012).
Preregistered helpers and first responders	Have registered prior to the event and contribute with personal but no special disaster control qualifications (Kircher, 2014).
Honorary office and full-time helpers	Trained in specific tasks for disaster control (Kircher, 2014).

professional, and formal engagement; and the qualities of helpers increase in awareness, commitment, experience, and professionalism. Table 25.2 presents terms that authors have used to describe different (overlapping) social media users in crisis from an organizational perspective.

4 Information Patterns – Gathering and Analysis of Big Crisis Data

In view of the diverse usage and role patterns in social media, an important research stream of crisis informatics is the integration of sometimes large amounts of citizen-generated content, which Carlos Castillo (2016) described as *big crisis data*, into professional emergency response. These efforts are often facilitated by methods and techniques of machine learning and social media analytics to extract relevant information from social media, including situational updates, multimedia files, and public mood (Reuter, Ludwig, et al., 2016). While Muhammad Imran focuses on machine learning for image and text processing during emergencies (Imran et al., 2015, 2018), Stefan Stieglitz and Milad Mirbabaie contribute with a framework for social media analytics and its adaptation to the domain of crisis informatics (Stieglitz et al., 2014;

Stieglitz, Mirbabaie, Fromm, et al., 2018). Furthermore, Marc-André Kaufhold examined information patterns in order to derive a crisis informatics framework for information refinement, which considers event-based, organizational, societal, and technological perspectives of crisis response (Kaufhold, 2020). In terms of information patterns, the technological perspective comprises the channels, access, and content present in social media, which serve as an input for the analysis, filtering, and evaluation of social data in crises.

4.1 Channels, Access, and Content in Social Media

Before interacting with information, emergency organizations and users must choose which *channels* are relevant to their objectives or intentions and develop supportive strategies. Wukich (2015) distinguishes the strategies and tactics of information dissemination (unidirectional from agency to public), data monitoring and analysis (unidirectional from public to agency), and conversations and coordinated actions (two or more directions) for the use of social media in emergencies. For example, the Frankfurt Fire Department is implementing its information dissemination strategy by limiting all operational communication to Twitter in a unidirectional manner, while Facebook, Instagram, and YouTube are used to maintain public image and attract new members, including conversations with citizens (Kaufhold & Reuter, 2017). The data monitoring and analysis strategy was implemented with the free tool TweetDeck, a dashboard application for managing Twitter accounts, due to its real-time functionality to monitor keywords and hashtags. However, the optimal social media tool should "provide a good overall usability, capabilities to prestructure actions and content, the flexibility to adapt it to the current emergency, support for all relevant social media, and possibilities to capture the mood of citizens" (Kaufhold & Reuter, 2017). The integration of multiple social media channels thus enables the analysis of different use patterns observed in social media: In the 2013 European floods, Facebook was used for a more private community exchange due to the availability of close or semi-open spaces (such as groups or pages), and the topic revolved around actions and volunteering, emotional support and thanks, and donations in kind (Gründer-Fahrer et al., 2018; Kaufhold & Reuter, 2016). In contrast, Twitter was used more for reporting alarm or water levels, the current situation, and situation overviews, including actions and status updates.

After selecting relevant analysis and communication channels, *access* to various social media must be established. For end-users, social media offers public and private spaces to varying degrees. For instance, while most communication on Twitter is public, accessible even without user login, Facebook offers a variety of restricted and private spaces, such as groups, pages, or the private timeline which is usually only visible to friends (Reuter & Scholl, 2014). However, the manual monitoring of diverse social media and their public or private substructures using heterogeneous interfaces can be a resource-intensive task in terms of organizational capabilities (Reuter, Ludwig, et al., 2016). Another approach lies

in the development of supportive tools that enable access to relevant social media (Kaufhold, Rupp, et al., 2020). To provide developers with access, most social media platforms offer programmatic access to their data via Application Programming Interfaces (APIs). Typically, search APIs to query past messages and streaming APIs to subscribe to real-time data feeds are included (Imran et al., 2015). Given that emergency services may be interested in tracking data on different types of social media to enhance situational awareness (Reuter, Ludwig, et al., 2016), different tracking approaches, such as tracking of keywords, actors, or URLs (Stieglitz, Mirbabaie, Ross, et al., 2018), and challenges, such as different levels of data access, different exchange formats, regular policy changes, different search query languages, and quota restrictions (Reuter & Scholl, 2014), must be considered when developing supportive social media technologies using platform APIs. As an alternative to APIs, developers may use HTML scraping or parsing techniques to gather social media data (Stieglitz et al., 2014); however, even this approach suffers from changes in the underlying HTML structure and violates the terms of use of most social media platforms.

Once access to information has been established, the structure and analysis of *content* come to the foreground. Starbird et al. (2010), for example, identified four types of user-generated content or information by analyzing Twitter data: Generative information refers to original raw material; synthetic information integrates external information, such as other tweets, web and news sources; derived information arises from informational interactions; and innovative information is characterized by the inclusion of cross-domain expertise and interpretation. Furthermore, Imran et al. (2015) classified information according to six dimensions of factual, objective, or emotional content, information provided, source, credibility, time, and place. In addition, Olteanu et al. (2015) distinguish information either as informative, such as topic-related information that contributes to situational awareness, or as non-informative, such as trolling or non-topic-related information. The identified characteristics of information are summarized in Table 25.3. When considering dimensions such as

Table 25.3. *Dimensions of information (Imran et al., 2015; Olteanu et al., 2015; Starbird et al., 2010)*

Dimension	Manifestations
Creation	Generative, synthetic, derivative, innovative
Credibility	Credible information, rumors
Informativeness	Informative, non-informative
Location	Ground-zero, near-by areas
Objectivity	Factual information, opinions, sympathy, antipathy, jokes
Source	Eyewitnesses/bystanders, government, NGOs, news media
Time	Pre-phase/preparedness, impact-phase/response, post-phase/recovery
Type	Caution/advice, affected people, infrastructure/utilities, needs/donations, other useful information

place and time, it becomes apparent that information in social media is based not only on the content of the message but also on the attached metadata. For instance, Moi et al. (2015) distinguish between message-related attributes such as date, time, title, comments, replies, number of views, likes, dislikes, retweets, or shares, and personal attributes such as age, age range, birthday, gender, location, education, number of uploads/watches/total posts, real name, or relationship status. Information or metadata relevant to emergency services varies depending on the task performed or the organizational role. While a public relations manager may be interested in credibility-related information to communicate against rumors, incident managers need informative information, including location and time metadata, to improve situational awareness (Kaufhold, Rupp, et al., 2020).

4.2 Analysis, Filtering, and Evaluation of Social Data

Once emergency organizations or users have determined the relevant content, they must also design the way they want to *analyze* the data. So far, the research field of crisis informatics has produced a wealth of algorithmic approaches for the analysis of social media content (Alam et al., 2019), often using methods and techniques from natural language processing (NLP), machine learning (ML), or statistics. Without claiming to be complete, Table 25.4 outlines algorithms that can be roughly categorized into the objectives of aggregation (e.g., clustering, event capture, topic modelling), classification (e.g., credibility, damage, humanitarian, relevance, sentiment), extraction (e.g., data enrichment, named entity recognition), and relationship analysis (e.g., social network analysis). In most cases, some steps of data preprocessing are required (Stieglitz, Mirbabaie, Ross, et al., 2018), including cleansing (e.g., removal of duplicates or stop words), annotation (e.g., part-of-speech tagging), and normalization (e.g., stemming, lemmatization) of data before analysis can take place. Thus, the choice of a single algorithm or a combination of algorithms depends on the identified objectives and the content relevant for achieving these objectives. For example, if emergency services want to reduce information overload in a large-scale emergency but also want to evaluate the credibility of the remaining information, they could use a tool that uses a combination of algorithms for relevance classification and credibility assessment.

Even if the information refinement process to date has improved the quality of information, for example, by selecting the right channels, establishing access, defining the relevant content, and using techniques to analyze the data, the volume of data might still be too large to be processed, or emergency services might be interested in different subsets of data, such as content related to a specific class, sentiment, or time. *Filtering* techniques can be applied at both backend and frontend level (Kaufhold, Rupp, et al., 2020). When major disasters such as floods, hurricanes, or forest fires generate up to hundreds of thousands of social media messages in a short period of time, emergency services have to deal with the problem of *information overload*. It is often

Table 25.4. *Exemplary application of machine learning techniques in crisis informatics (own overview based on the referenced literature)*

Analysis technique	Image	Text
Clustering: Categorization of text documents into similar groups using distance and similarity metrics, often combined with approaches for information aggregation (Fahad et al., 2014; Rudra et al., 2015).		x
Credibility assessment: The identification of credible information includes classification- and multifeature-based, graph- and propagation-based, indicator-based, and survey-based detection approaches (Hartwig & Reuter, 2019; Viviani & Pasi, 2017).		x
Damage assessment: Use of supervised machine learning to evaluate the severity of damage observed in an image, such as "severe," "mild," and "none" (Alam et al., 2019).	x	
Data enrichment: Refers to the computation of additional metadata that is not provided by any or all of the social media providers' APIs (Moi et al., 2015).		x
Duplicate detection: Hash techniques to identify exact or nearly duplicate images with minor modifications, such as cropping, resizing, background padding, changing intensity, or embedding text (Alam et al., 2018).	x	
Event detection: Detection and tracking of crisis events or subevents using techniques such as burst detection, dictionaries, or supervised classification (Imran et al., 2015).		x
Humanitarian classification: Semi-supervised classification of messages into humanitarian categories, such as personal update, damage to infrastructure and utilities, affected individuals, caution and advice, donation and volunteering, missing and found persons, sympathy and support, injured or dead persons, and other useful information (Alam et al., 2019).		x
Named entity recognition: Natural language processing, statistical or machine learning techniques for extracting entities, such as locations, persons, or organizations, from text (Ritter et al., 2011).		x
Relevance classification: Binary classification of relevant and irrelevant images (Alam et al., 2018) or crisis-related messages for crises, often using supervised machine learning models (Habdank et al., 2017).	x	x
Sentiment classification: Natural language processing, statistical or machine learning techniques to determine the emotional polarity, e.g., positive, neutral or negative, of a document, message or sentence (Pang & Lee, 2008).		x
Social network analysis: Methods and techniques for discovering patterns of interaction between actors in social networks, including the discovery or identification of most key actors using statistical measures, hubs, and authorities using link analysis, and of communities using community detection techniques (Oliveira & Gama, 2012).		x
Topic modelling: Identification of crisis-specific topics from textual data using modeling techniques, such as (unsupervised) Latent Dirichlet Allocation (Blei et al., 2003; Gründer-Fahrer et al., 2018).		x

defined as too much "information presented at a rate too fast for a person to process" (Hiltz & Plotnick, 2013) and carries the risk of getting lost in data which may be irrelevant to the current task and are processed and presented in an inappropriate way (Keim et al., 2008; Landesberger et al., 2011). Already Miller (1956) suggested "organizing or grouping the input into familiar units or chunks" (p. 93) to overcome the limits of the human capacity of information processing. This is further supported by the mantra of information search, which postulates, "overview first, zoom and filter, then details-on-demand" (Shneiderman, 1996, p. 2). At the frontend or *visualization* level, the overview could be established using dashboard-style interfaces that display aggregated or summarized information (Kaufhold, Rupp, et al., 2020; Rudra et al., 2018). A survey of 477 country-level emergency managers in the USA suggests that summarizing information, "chunking" or grouping social media messages through specific tools, positively influences the intention to use social media in emergencies (Rao et al., 2017). Second, zooming and filtering could be realized by interactive charts, keywords, hashtags, geographical locations, or time-frames, amongst others (Onorati et al., 2018). Furthermore, details on demand implies the possibility to switch from aggregated to original data, for example, to view individual social media messages grouped into a single chunk of information in the interface (Reuter, Amelunxen, et al., 2016). Based on supervised machine learning, configurable relevance classifiers could help to filter out irrelevant information and thus reduce the amount of data by displaying only relevant data (Habdank et al., 2017).

After the information has been analyzed and filtered, the user still has to *evaluate* the presented information to create situational awareness in case of emergency services or even to inform the decision-making process. While the evaluation may depend on event-based, organizational, or societal factors, the technology can assist the user's interpretation of the data by raising awareness or promoting explainability. First, considering that different information channels are used for different purposes (Hughes et al., 2014), the unequal access to information in practice could also lead to biases in the use of (cross-media) social media analytics tools. The mismatch between access and use becomes clear, for example, in the interplay of Facebook and Twitter. While in 2017 52% of the German population used Facebook and only 9% used Twitter (Reuter et al., 2017), access to Facebook's data is much more restricted than to Twitter's. As a consequence, (cross-platform) third-party applications for social media analytics and associated research rely more heavily on Twitter data. However, this does not reflect the social media use of the population (Reuter, Backfried, et al., 2018; Reuter, Hughes, et al., 2018). Moreover, as platform APIs return only a limited amount of data, which is confined by sampling and quota restrictions (Reuter & Scholl, 2014) as well as manual adjustments based on applied filters, the provided worldview by third-party tools is inherently limited. By raising awareness of such limitations, the technology could help emergency managers to contextualize the results presented by social media tools. Second, while machine learning techniques are capable to filter out

irrelevant or low-quality content (Moi et al., 2015), algorithms not only need to achieve high accuracy, but emergency managers also need to understand algorithmic learning and decision-making to establish trust in such a system during critical and life-threatening situations (Kaufhold, Rupp, et al., 2020). However, current black-box implementations restrict the explainability and transparency of algorithmic decisions; as a result, more effort is required to configure the system so that its behavior better meets the needs of emergency services (Burnett et al., 2017). Therefore, white-box approaches should be examined in future research to increase the *explainability* and *transparency* of algorithmic decisions and thus the acceptance and trust of users in complex algorithmic systems (Delibaši et al., 2013; Romero et al., 2013).

5 Perception Patterns – Views on Social Media

Even though social media offers a wide range of potentials for crisis communication, situational awareness and self-organizing citizen communities (Section 3) as well as algorithms and tools to support data analysis and management (Section 5), the use of technology is conveyed through the perception of the public (e.g., citizens) or organization (e.g., emergency services). Christian Reuter, together with his research group, is contributing extensive research on both citizens and emergency services with regard to social media by analyzing patterns, potentials, and barriers of use (Haunschild et al., 2020; Reuter et al., 2019).

5.1 Authorities' Perception of Social Media

There are a few quantitative studies on the perception of social media by authorities from both North America and Europe. First, San, Wardell III, and Thorkildsen (2013) analyzed the results of a survey conducted in 2012 by the American National Emergency Management Association (NEMA) among members of emergency services from all 50 Federal States of the USA on the use of social media in emergency management. Second, Plotnick, Hiltz, Kushma, and Tapia (2015) conducted a survey of 241 US county-level emergency managers in 2014 on usage patterns, barriers, and recommendations for improvement in the use of social media during emergencies. Third, the annual International Association of Chiefs of Police (IACP) study on the use of social media by law enforcement agencies reports on "the current state of practice and the issues agencies are facing in regard to social media" (International Association of Chiefs of Police, 2015). Fourth, Reuter et al. (2016) published their findings from a survey conducted with 761 emergency service employees across Europe in 2014 on current attitudes and influencing factors regarding the use of social media in emergencies. Recently, Reuter et al. (2020) repeated the above survey with 473 participants in 2017 to compare the development of social media perception.

On the one hand, there is a positive attitude toward the use of social media in general (San et al., 2013), including private and organizational use (Reuter, Ludwig, et al., 2016). The majority of US authorities already use social media because they appreciate its suitability for disseminating information (San et al., 2013). This includes warnings, advice and guidance on how to cope with or prevent emergencies or disasters, hints and advice on how to behave during an emergency, coordinating the help of volunteers, summarizing information after an emergency, and coordinating clean-up activities (Reuter, Ludwig, et al., 2016). Currently, the use of social media by authorities has already increased from 81% (77% Facebook, 37% Twitter, 16% YouTube) to 96% (94% Facebook, 71% Twitter, 40% YouTube) over the last 5 years (International Association of Chiefs of Police, 2010, 2015). Additionally, the number of social media policies has also increased from 35% to 78% (International Association of Chiefs of Police, 2010, 2015). A further increase in social media use is expected (74%), even more for organizations that already use it (Reuter, Ludwig, et al., 2016).

On the other hand, there are several restrictions on the use of social media: First, there is a huge gap between rhetoric and reality (Reuter, Ludwig, et al., 2016). Despite the overall positive attitude toward social media in order to obtain an overview of the situation and raise situational awareness, in fact only a few agencies have frequently or sometimes used social media sites for this purpose (Reuter, Ludwig, et al., 2016). Since the predominant use of social media is for information exchange (Reuter, Ludwig, et al., 2016; San et al., 2013) rather than for receiving messages (Reuter, Ludwig, et al., 2016), only a modest use of social media can be observed, while groundbreaking crowdsourcing and crisis-mapping activities are neglected (San et al., 2013). Furthermore, about 20% of the local and about 30% of the county agencies surveyed "had not identified a goal for social media operations" at all (San et al., 2013). Also, only about half of the observed emergency agencies at county level in the study of Plotnick et al. (2015) use social media at all. Identified barriers to use were, despite a lack of dedicated personnel (San et al., 2013), doubts about credibility and reliability (Reuter, Ludwig, et al., 2016; San et al., 2013), concerns about privacy (Reuter, Ludwig, et al., 2016), and still a lack of formal policies to guide the use of social media (Plotnick et al., 2015). But even for emergency agencies that have formal policies, there are still prohibitions on the use of social media (Plotnick et al., 2015). As reasons for limited success in the use of social media could be stated the limited reach of and the insufficient resources and capabilities for data collection and analysis (San et al., 2013). To this end, conditions conductive to the use of social media could be identified within the organizational culture and capabilities (Reuter, Ludwig, et al., 2016) and the verification of citizen-generated content (San et al., 2013).

The most recent survey by Reuter et al. (2020) reported some changes in emergency services' perception of social media between 2014 and 2017. During this time span, the perceived importance of social media for the exchange of information with citizens (78% vs. 88%) and the gathering of situational

information (68% vs. 78%) has increased, while at the same time the perception that emergency services are too busy to use social media has decreased (38% vs. 33%). However, emergency service personnel seem to be much more skeptical about the perceived reliability of information in social media (17% vs. 48%) and emphasize the danger of dis- or misinformation in emergencies.

5.2 Citizens' Perception of Social Media

In recent years, more quantitative studies have been carried out to examine citizens' perception of how they use social media in emergencies. The research on citizens' perceptions started with a variety of surveys using snowball-based samples. First, these include a comparative study by the Canadian Red Cross with over 1,000 participants (2012), which was designed to determine the extent to which Canadian citizens use social media and mobile devices in crisis communication and what they expect from emergency services now and in the future. Second, the American Red Cross (2012) surveyed 1,017 respondents in online and 1,018 respondents in telephone surveys to assess how citizens use social media in emergencies. In the third study worth mentioning, Flizikowski et al. (2014) present a survey within Europe that was conducted among citizens (317 respondents) and emergency services (130 respondents), which identified the opportunities and challenges of integrating social media in crisis response management. Furthermore, Reuter and Spielhofer (2016) analyzed the results of a survey conducted in 2015 among 1,034 citizens across Europe to explore citizens' attitudes toward the use of social media for private purposes and in emergency situations. In the following, these snowball-sampling studies were supplemented by representative surveys in Germany and Europe. For example, Reuter et al. (Reuter et al., 2017) conducted a representative survey of 1,069 German citizens in 2016 on their use of social media in emergencies, types of information exchange, expectations toward emergencies, and perceived barriers. The survey was repeated by Reuter et al. (2019) in Italy, the Netherlands, and the United Kingdom; the 7,071 citizen responses (including the German dataset) were analyzed comparatively using a risk culture framework. In 2019, Haunschild et al. (2020) conducted an extended representative survey with 1,219 German participants, exploring the perceived potential of social media and comparing findings and trends with the previous dataset of 2016.

In general, the participants' attitude toward the use of social media was largely positive (Flizikowski et al., 2014). The advantages of using social media during emergencies are evident in the reassurance of citizens, the provision of situational information, and monitoring (Canadian Red Cross, 2012). Due to these benefits, social media is seen as a support for existing channels but cannot replace them (Canadian Red Cross, 2012). In particular, friends, family, news media (or reporters), and local emergency officials are considered the most trusted sources (American Red Cross, 2012). Therefore, the Canadian Red Cross employs "trusted volunteers" to support the official response via social

media (Canadian Red Cross, 2012). In contrast to authorities' use, citizens use social media to search (43%) rather than to share information (27%) (Reuter & Spielhofer, 2017). Most likely, users seek information about weather, traffic, damage caused, and how other people cope with it (American Red Cross, 2012). When providing information, users not only share weather information, safety reassurances, and their feelings about the emergency, but also their location and eyewitness information (American Red Cross, 2012).

In Germany, the temporal sequence of two datasets in 2016 and 2019 showed that false rumors, privacy, and the issue that social media might not work in emergencies still represents the highest perceived barriers to the use of social media in emergencies (Haunschild et al., 2020; Reuter et al., 2017). Furthermore, despite some changes over time, German citizens expect the emergency services to regularly monitor social media (67% vs. 58%) and receive a response from the emergency services within an hour (47% vs. 53%). The comparative analysis of perceptions across Europe revealed that this could be due to the state-oriented risk culture in Germany, while individualistic risk cultures, such as the Netherlands, had lower expectations of the emergency services (Reuter et al., 2019). Despite varying use patterns and expectations toward emergencies in the four European countries surveyed, citizens in all countries saw similar advantages and barriers to the use of social media during emergencies.

6 Future Directions

Over the last 20 years, the cyber world and social media have had an increasing impact on crisis management. In particular, major events such as the 2012 Hurricane Sandy, the 2013 European floods, or the ongoing COVID-19 pandemic showed that citizens are not passive victims but active participants who use social media for crisis response (Reuter, Hughes, et al., 2018). Accordingly, the interdisciplinary research field of crisis informatics emerged, combining both computer science and social science knowledge of disasters (Palen & Anderson, 2016). This chapter contributed to this by discussing usage patterns of authorities and citizens in social media during emergencies (Section 2) and identifying different role patterns in both the real and virtual realm (Section 3). Furthermore, information patterns to be considered in the collection and analysis of social media data are analyzed (Section 4) before perception patterns of authorities and citizens, with a focus on attitudes toward the benefits, challenges, and use of social media in emergencies are reviewed (Section 5). In the following, we summarize our findings and outline open questions for future practice and research.

First, holistic integration of social media into crisis communication: With regard to patterns of use, *self-coordination and help (C2C)* among citizens have proven to be very important, but chaos is a characteristic pattern that has been recognized. Here, the automatic cross-media suggestion of relevant posts

according to crises dynamics (Kaufhold & Reuter, 2016), the coordination of needs and offers (Purohit et al., 2014), or the use of social media guidelines (Kaufhold et al., 2019) might help to structure communication in future. The visibility of different practices that have proven their worth seems important to facilitate appropriation among citizens and to improve disaster prevention and management in the long term. In *crisis communication (A2C)*, many citizens expect authorities to continuously monitor social media and to respond to messages within an hour (Reuter et al., 2019). However, not all authorities may be able to act at this speed, sometimes due to a lack of personal skills or assistive technology. Press officers must adapt to a new role that involves more dynamics compared to pre-social media times. They also need to review and carefully create their own posts, which conflicts with the need for a quick response. In terms of *integrating citizen-generated content (C2A)*, research has applied various algorithmic approaches to the aggregation, classification, extraction, and relationship analysis of social media data to inform situational awareness and decision making (Imran et al., 2015; Kaufhold, Bayer, et al., 2020). The approaches will be discussed below with respect to information patterns. Regarding *inter- and intra-organizational crisis management (A2A)*, social media can be used to coordinate crisis communication, share expertise and information, and more informally network authorities and employees (Ley et al., 2014). Here, social media structures could support the development of collaborative ICT or inform encapsulated social networks. The latter have the benefit of trust because the circle of users is limited and controlled. Since emergency services rather use social media for unidirectional crisis communication than establishing situational awareness (Reuter, Kaufhold, et al., 2020; Reuter, Ludwig, et al., 2016), examining a more holistic integration of social media is required to exploit its full potential in crisis communication.

Second, tailoring social media and analytics for role behaviors and collaboration: The systematization of *role patterns* and role properties potentially supports the interaction between authorities and citizens. For instance, a semi-automatic identification of role patterns (Reuter et al., 2013) and their display in social media may improve role awareness, sense-giving capabilities (Mirbabaie, Bunker, Stieglitz, Marx, et al., 2020), the self-discovery process, and the guidance of citizens to take on roles. Due to the chaotic organization in such emergencies (Valecha et al., 2013), well-defined role characteristics could also improve capacity planning for authorities and among citizens, for example, to crowdsource tasks to the appropriate audience. Considering these opportunities, the role typology matrix may be used to systematically optimize collaboration and communication structures between different crisis actors in the real and virtual realms, for example, to improve the communication between first responders and digital volunteers or to improve the awareness of the incident manager about the activities and scope of VOST (Fathi et al., 2020). Then, from an IT perspective, role patterns should be considered when adapting ICT to support role-specific activities (Kaufhold, Rupp, et al., 2020). This, however, is problematic because users tend to use general software they are familiar with, such as Facebook, during emergencies rather than

specific and perhaps better tools. Here, applications embedded in the social media ecosystems, for example, Facebook apps, may facilitate the smooth adoption of emergency-specific tools (Reuter, Ludwig, et al., 2015).

Third, explainable and transparent "white-box" machine learning for decision making: Looking at the *information patterns* identified, it becomes apparent that despite the wide variety of available social media channels and useful types of information and metadata, API restrictions and limitations often exist with regard to access to their data. This in turn limits the design scope of supportive and useful technology (Reuter & Scholl, 2014; Stieglitz, Mirbabaie, Ross, et al., 2018). Diverse algorithms applying machine learning techniques are designed, regularly optimized, and used to aggregate, classify, extract, and analyze patterns of social media information. Furthermore, filtering techniques are applied at both the algorithmic and frontend level to identify potential misinformation (Allcott et al., 2019; Kaufhold & Reuter, 2019) and to address the issue of information overload, that is, to reduce the amount of available data to the information relevant for the task at hand (Onorati et al., 2018). Considering the diversity of information, limitations in data access, and varying quality of algorithms and interfaces, third-party technology can only provide a limited worldview, which must be supported by explainable and transparent algorithmic decisions and system behavior (Kaufhold, Rupp, et al., 2020). This requires a shift from black-box toward interpretable or white-box models in machine learning (Du et al., 2020).

Fourth, implementation of measures and strategies in accordance with risk cultures: The *perception* of social media is both a result and a starting point of the abovementioned aspects and patterns. Both authorities and citizens indicated a positive attitude toward the use of social media but also emphasized similar challenges, such as the potential spread of misinformation (Haunschild et al., 2020; Reuter, Ludwig, et al., 2016). While authorities' skepticism toward the reliability of social media increased, the perceived importance of social media for the exchange of information with citizens and for situational awareness through continuous monitoring also increased (Reuter, Kaufhold, et al., 2020). However, legal, organizational, and technological measures are required to close the gap between rhetoric and reality or intention and actual use (Reuter, Ludwig, et al., 2016). As far as citizens are concerned, perceived barriers and expectations toward emergency services varied across countries and risk cultures, which underlines the need to tailor future social media crisis communication guidelines and strategies with respect to national characteristics (Reuter et al., 2019).

In summary, *crisis informatics* has established itself as an important research area in the ever-increasing complexity of the cyber world. Its importance is further amplified by the time-critical constraints of emergencies and disasters. However, crisis informatics will be challenged to evolve quickly to tackle global-scale emergencies, such as the ongoing COVID-19 pandemic and the increasing risks of natural hazards due to climate change. This chapter seeks to supplement this effort by analyzing interaction, role, information, and perception patterns, which were prevalent in the past 20 years of social media use in crises.

References

Akhgar, B., Fortune, D., Hayes, R. E., Guerra, B., & Manso, M. (2013). Social media in crisis events: Open networks and collaboration supporting disaster response and recovery. In *2013 IEEE International Conference on Technologies for Homeland Security (HST)* (pp. 760–765). IEEE. https://doi.org/10.1109/THS.2013.6699099

Alam, F., Ofli, F., & Imran, M. (2018). Processing social media images by combining human and machine computing during crises. *International Journal of Human–Computer Interaction*, *34*(4), 311–327. https://doi.org/10.1080/10447318.2018.1427831

Alam, F., Ofli, F., & Imran, M. (2019). Descriptive and visual summaries of disaster events using artificial intelligence techniques: Case studies of Hurricanes Harvey, Irma, and Maria. *Behaviour & Information Technology*, 1–31. https://doi.org/10.1080/0144929X.2019.1610908

Allcott, H., Gentzkow, M., & Yu, C. (2019). Trends in the diffusion of misinformation on social media. *Research and Politics*, *6*(2). https://doi.org/10.1177/2053168019848554

Allen, C. (2004). Tracing the Evolution of Social Software. www.lifewithalacrity.com/2004/10/tracing_the_evo.html

American Red Cross. (2012). More Americans Using Mobile Apps in Emergencies. Retrieved May 26, 2014, from www.redcross.org/news/press-release/More-Americans-Using-Mobile-Apps-in-Emergencies

Bergstrand, F., Landgren, J., & Green, V. (2013). Authorities don't tweet, employees do! In *Proceedings of the International Conference on Human–Computer Interaction with Mobile Devices and Services (MobileHCI)*. ACM. http://dx.doi.org/10.13140/2.1.3099.2644

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent dirichlet allocation. *Journal of Machine Learning Research*, *3*(4–5), 993–1022. https://doi.org/10.1016/b978-0-12-411519-4.00006-9

Burnett, M., Kulesza, T., Oleson, A., Ernst, S., Beckwith, L., Cao, J., . . . & Grigoreanu, V. (2017). Toward theory-based end-user software engineering. In F. Paternò & V. Wulf (Eds.), *New perspectives in end-user development* (pp. 231–268). Springer International. https://doi.org/10.1007/978-3-319-60291-2_10

Canadian Red Cross. (2012). Social Media during Emergencies. www.redcross.ca/cmslib/general/pub_social_media_in_emergencies_survey_oct2012_en.pdf

Castillo, C. (2016). *Big crisis data: Social media in disasters and time-critical situations*. Cambridge University Press.

Chauhan, A., & Hughes, A. L. (2017). Providing online crisis information: An analysis of official sources during the 2014 Carlton Complex wildfire. In *Proceedings of the 35th International Conference on Human Factors in Computing Systems (CHI 2017)*. ACM. https://doi.org/10.1145/3025453.3025627

Chrpa, L., & Thórisson, K. R. (2013). On applicability of automated planning for incident management. In *The international Scheduling and Planning Applications woRKshop* (pp. 1–7). University of Huddersfield. http://eprints.hud.ac.uk/id/eprint/24490/

Cinelli, M., Quattrociocchi, W., Galeazzi, A., Valensise, C. M., Brugnoli, E., Schmidt, A. L., . . . & Scala, A. (2020). The COVID-19 Social Media Infodemic, 1–18. http://arxiv.org/abs/2003.05004

Cobb, C., McCarthy, T., Perkins, A., Bharadwaj, A., Comis, J., Do, B., & Starbird, K. (2014). Designing for the deluge: Understanding & supporting the distributed, collaborative work of crisis volunteers. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)* (pp. 888–899). ACM. https://doi.org/10.1145/2531602.2531712

Delibaši, B., Vuki, M., Jovanovi, M., & Suknovi, M. (2013). White-box or black-box decision tree algorithms: Which to use in education? *IEEE Transactions on Education*, *56*(3), 287–291.

Denef, S., Bayerl, P. S., & Kaptein, N. (2013). Social media and the police – tweeting practices of British police forces during the August 2011 riots. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 3471–3480). ACM. https://doi.org/10.1145/2470654.2466477

Du, M., Liu, N., & Hu, X. (2020). Techniques for interpretable machine learning. *Communications of the ACM*, *63*(1), 68–77. https://doi.org/10.1145/3359786

Eismann, K., Posegga, O., & Fischbach, K. (2016). Collective behaviour, social media, and disasters: A systematic literature review. In *European Conference on Information Systems (ECIS)*. AIS Electronic Library (AISeL). https://aisel.aisnet.org/ecis2016_rp/104/

Fahad, A., Alshatri, N., Tari, Z., Alamri, A., Khalil, I., Zomaya, A. Y., … & Bouras, A. (2014). A survey of clustering algorithms for big data: Taxonomy and empirical analysis. *IEEE Transactions on Emerging Topics in Computing*, *2*(3), 267–279. https://doi.org/10.1109/TETC.2014.2330519

Fathi, R., Thom, D., Koch, S., Ertl, T., & Fiedrich, F. (2020). VOST: A case study in voluntary digital participation for collaborative emergency management. *Information Processing and Management*, *57*(4), 102174. https://doi.org/10.1016/j.ipm.2019.102174

Flizikowski, A., Hołubowicz, W., Stachowicz, A., Hokkanen, L., & Delavallade, T. (2014). Social media in crisis management – the iSAR + project survey. In *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (pp. 707–711). ISCRAM Digital Library. http://idl.iscram.org/files/flizikowski/2014/499_Flizikowski_etal2014.pdf

Goolsby, R. (2010). Social media as crisis platform: The future of community maps/crisis maps. *ACM Transactions on Intelligent Systems and Technology*, *1*(1), 1–11. https://doi.org/10.1145/1858948.1858955

Gründer-Fahrer, S., Schlaf, A., Wiedemann, G., & Heyer, G. (2018). *Topics and topical phases in German social media communication during a disaster*. *Natural Language Engineering*, 24. https://doi.org/10.1017/S1351324918000025

Habdank, M., Rodehutskors, N., & Koch, R. (2017). Relevancy assessment of tweets using supervised learning techniques mining emergency related tweets for automated relevancy classification. In *2017 4th International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*. IEEE. https://doi.org/10.1109/ICT-DM.2017.8275670

Hagar, C. (2007). The information needs of farmers and use of ICTs. In B. Nerlich & M. Doring (Eds.), *From mayhem to meaning: Assessing the social and cultural impact of the 2001 foot and mouth outbreak in the UK*. Manchester University Press.

Harrald, J. R., Egan, D. M., & Jefferson, T. (2002). Web enabled disaster and crisis response: What have we learned from September 11th? In *Proceedings of the*

Bled eConference (pp. 69–83). University of Maribor. https://domino.fov.uni-mb.si/proceedings.nsf/proceedings/d3a6817c6cc6c4b5c1256e9f003bb2bd/$file/harrald.pdf

Hartwig, K., & Reuter, C. (2019). TrustyTweet: An indicator-based browser-plugin to assist users in dealing with fake news on Twitter. In *Proceedings of the International Conference on Wirtschaftsinformatik (WI)*. Siegen.

Haunschild, J., Kaufhold, M.-A., & Reuter, C. (2020). Sticking with landlines? Citizens' and police social media use and expectation during emergencies. In *Proceedings of the International Conference on Wirtschaftsinformatik (WI)*. GITO. https://doi.org/10.30844/wi_2020_o2-haunschild

Helsloot, I., & Ruitenberg, A. (2004). Citizen response to disasters: A survey of literature and some practical implications. *Journal of Contingencies and Crisis Management*, *12*(3), 98–111. https://doi.org/10.1111/j.0966-0879.2004.00440.x

Hiltz, S. R., Diaz, P., & Mark, G. (2011). Introduction: Social media and collaborative systems for crisis management. *ACM Transactions on Computer–Human Interaction*, *18*(4), 1–6. https://doi.org/10.1145/2063231.2063232

Hiltz, S. R., & Plotnick, L. (2013). Dealing with information overload when using social media for emergency management: Emerging solutions. In T. Comes, F. Fiedrich, S. Fortier, J. Geldermann, & T. Müller (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (pp. 823–827). ISCRAM Digital Library. http://idl.iscram.org/files/hiltz/2013/583_Hiltz+Plotnick2013.pdf

Hughes, A. L., & Palen, L. (2009). Twitter adoption and use in mass convergence and emergency events. *International Journal of Emergency Management*, *6*(3-4), 248–260. https://doi.org/10.1504/IJEM.2009.031564

Hughes, A. L., & Palen, L. (2012). The evolving role of the public information officer: An examination of social media in emergency management. *Journal of Homeland Security and Emergency Management*, *9*(1), Article 22. https://doi.org/10.1515/1547-7355.1976

Hughes, A. L., & Palen, L. (2014). *Social media in emergency management: Academic perspective*. In J. E. Trainor & T. Subbio (Eds.), *Critical issues in disaster science and management: A dialogue between scientists and emergency managers*. Federal Emergency Management Agency.

Hughes, A. L., St. Denis, L. A., Palen, L., & Anderson, K. M. (2014). Online public communications by police & fire services during the 2012 Hurricane Sandy. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 1505–1514). ACM. https://doi.org/https://doi.org/10.1145/2556288.2557227

Hughes, A. L., & Tapia, A. H. (2015). Social media in crisis: When professional responders meet digital volunteers. *Journal of Homeland Security and Emergency Management*, *12*(3), 679–706. https://doi.org/10.1515/jhsem-2014-0080

Imran, M., Castillo, C., Diaz, F., & Vieweg, S. (2015). *Processing social media messages in mass emergency: A survey. ACM computing surveys* (Vol. 47). ACM. https://doi.org/10.1145/2771588

Imran, M., Castillo, C., Diaz, F., & Vieweg, S. (2018). Processing social media messages in mass emergency: Survey summary. In *Companion Proceedings of the The Web Conference 2018 (WWW'18)* (pp. 507–511). ACM. https://doi.org/10.1145/3184558.3186242

Imran, M., Ofli, F., Caragea, D., & Torralba, A. (2020). Using AI and social media multimodal content for disaster response and management: Opportunities, challenges, and future directions. *Information Processing and Management*, *57*(5), 1–9. https://doi.org/10.1016/j.ipm.2020.102261

International Association of Chiefs of Police. (2010). 2010 Social Media Survey Results. www.iacpsocialmedia.org/Portals/1/documents/Survey Results Document.pdf

International Association of Chiefs of Police. (2015). 2015 Social Media Survey Results. Retrieved from www.iacpsocialmedia.org/Portals/1/documents/FULL 2015 Social Media Survey Results.pdf

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*, 189–196. https://doi.org/10.1109/EISIC.2012.23

Kaewkitipong, L., Chen, C., & Ractham, P. (2012). Lessons learned from the use of social media in combating a crisis: A case study of 2011 Thailand flooding disaster. In *Proceedings of the International Conference on Information Systems (ICIS)* (pp. 1–17). AIS Electronic Library (AISeL). https://aisel.aisnet.org/icis2012/proceedings/ProjectManagement/8/

Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of social media. *Business Horizons*, *53*(1), 59–68. https://doi.org/10.1016/j.bushor.2009.09.003

Kaufhold, M.-A. (2020). *Information refinement technologies for crisis informatics: User expectations and design implications for social media and mobile apps in crises*. Dissertation (Dr. rer. nat.), Technische Universität Darmstadt.

Kaufhold, M.-A., Bayer, M., & Reuter, C. (2020). Rapid relevance classification of social media posts in disasters and emergencies: A system and evaluation featuring active, incremental and online learning. *Information Processing and Management*, *57*(1), 1–32. https://doi.org/10.1016/j.ipm.2019.102132

Kaufhold, M.-A., Gizikis, A., Reuter, C., Habdank, M., & Grinko, M. (2019). Avoiding chaotic use of social media before, during, and after emergencies: Design and evaluation of citizens' guidelines. *Journal of Contingencies and Crisis Management*, *27*(3), 198–213. https://doi.org/10.1111/1468-5973.12249

Kaufhold, M.-A., & Reuter, C. (2014). Vernetzte Selbsthilfe in Sozialen Medien am Beispiel des Hochwassers 2013 / Linked self-help in social media using the example of the floods 2013 in Germany. *I-Com – Zeitschrift Für Interaktive Und Kooperative Medien*, *13*(1), 20–28. https://doi.org/10.1515/icom.2014.0004

Kaufhold, M.-A., & Reuter, C. (2016). The self-organization of digital volunteers across social media: The case of the 2013 European floods in Germany. *Journal of Homeland Security and Emergency Management*, *13*(1), 137–166. https://doi.org/10.1515/jhsem-2015-0063

Kaufhold, M.-A., & Reuter, C. (2017). The impact of social media in emergencies: A case study with the fire department of Frankfurt. In Tina Comes, F. Bénaben, C. Hanachi, & M. Lauras (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (pp. 603–612). ISCRAM. Retrieved from http://idl.iscram.org/files/marc-andre kaufhold/2017/1494_Marc-AndreKaufhold+ChristianReuter2017.pdf

Kaufhold, M.-A., & Reuter, C. (2019). Cultural violence and peace in social media. In C. Reuter (Ed.), *Information technology for peace and security – IT applications*

and infrastructures in conflicts, crises, war, and peace (pp. 361–381). Springer Vieweg. https://doi.org/10.1007/978-3-658-25652-4_17

Kaufhold, M.-A., Rupp, N., Reuter, C., Amelunxen, C., & Cristaldi, M. (2018). 112. SOCIAL: Design and evaluation of a mobile crisis app for bidirectional communication between emergency services and citizens. In *Proceedings of the European Conference on Information Systems (ECIS)*. AIS Electronic Library (AISeL). Retrieved from https://aisel.aisnet.org/ecis2018_rp/81/

Kaufhold, M.-A., Rupp, N., Reuter, C., & Habdank, M. (2020). Mitigating information overload in social media during conflicts and crises: Design and evaluation of a cross-platform alerting system. *Behaviour & Information Technology (BIT)*, *39*(3), 319–342.

Keim, D., Andrienko, G., Fekete, J., Carsten, G., & Melan, G. (2008). Visual analytics: Definition, process and challenges. In Kerren A., Stasko J. T., Fekete JD., North C. (Eds.), Information visualization – Human-centered issues and perspectives (pp. 154–175). Springer. https://doi.org/10.1007/978-3-540-70956-5_7

Kircher, F. (2014). Ungebundene Helfer im Katastrophenschutz – Die Sicht der Behörden und Organisationen mit Sicherheitsaufgaben. *BRANDSchutz – Deutsche Feuerwehr-Zeitung*, 593–597.

Koch, M. (2008). CSCW and Enterprise 2.0 – Towards an integrated perspective. In *Proceedings of the Bled eConference*. AIS Electronic Library (AISeL). https://aisel.aisnet.org/bled2008/15/

Kogan, M., Anderson, J., Palen, L., Anderson, K. M., & Soden, R. (2016). Finding the way to OSM mapping practices: Bounding large crisis datasets for qualitative investigation. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 2783–2795). ACM. https://doi.org/10.1145/2858036.2858371

Landesberger, T. Von, Kuijper, A., Schreck, T., Kohlhammer, J., Wijk, J. Van, Fekete, J.-D., & Fellner, D. (2011). Visual analysis of large graphs: State-of-the-art and future research challenges. *Computer Graphics Forum*, *30*(6), 1719–1749. https://doi.org/10.1111/j.1467-8659.2011.01898.x

Latonero, M., & Shklovski, I. (2011). Emergency management, Twitter, and social media evangelism. *International Journal of Information Systems for Crisis Response and Management*, *3*(4), 1–16.

Ley, B., Ludwig, T., Pipek, V., Randall, D., Reuter, C., & Wiedenhoefer, T. (2014). Information and expertise sharing in inter-organizational crisis management. *Computer Supported Cooperative Work: The Journal of Collaborative Computing*, *23*(4–6), 347–387.

Ludwig, T., Kotthaus, C., Reuter, C., Dongen, S. Van, Pipek, V., van Dongen, S., & Pipek, V. (2016). Situated crowdsourcing during disasters: Managing the tasks of spontaneous volunteers through public displays. *International Journal on Human-Computer Studies*. In press.

Mendoza, M., Poblete, B., & Castillo, C. (2010). Twitter under crisis: Can we trust what we RT? In *Proceedings of the First Workshop on Social Media Analytics* (pp. 71–79). ACM. https://doi.org/10.1145/1964858.1964869

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review. American Psychological Association*. https://doi.org/10.1037/h0043158

Mirbabaie, M., Bunker, D., Stieglitz, S., & Deubel, A. (2020). Who sets the tone? Determining the impact of convergence behaviour archetypes in social media

crisis communication. *Information Systems Frontiers*, *22*(2), 339–351. https://doi.org/10.1007/s10796-019-09917-x

Mirbabaie, M., Bunker, D., Stieglitz, S., Marx, J., & Ehnis, C. (2020). Social media in times of crisis: Learning from Hurricane Harvey for the coronavirus disease 2019 pandemic response. *Journal of Information Technology*, *35*(3), 195–213. https://doi.org/10.1177/0268396220929258

Moi, M., Friberg, T., Marterer, R., Reuter, C., Ludwig, T., Markham, D., … & Muddiman, A. (2015). Strategy for processing and analyzing social media data streams in emergencies. In *Proceedings of the International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)* (pp. 1–7). IEEE. https://doi.org/10.1109/ICT-DM.2015.7402055

O'Reilly, T. (2007). What is Web 2.0? Design patterns and business models for the next generation of software. *International Journal of Digital Economics*, *65*(March), 17–37.

Oliveira, M., & Gama, J. (2012). An overview of social network analysis. *WIREs Data Mining and Knowledge Discovery*, *2*, 99–115. https://doi.org/10.1002/widm.1048

Olteanu, A., Vieweg, S., & Castillo, C. (2015). What to expect when the unexpected happens: Social media communications across crises. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing* (pp. 994–1009). ACM. https://doi.org/10.1145/2675133.2675242

Onorati, T., Díaz, P., & Carrion, B. (2018). From social networks to emergency operation centers: A semantic visualization approach. *Future Generation Computer Systems*. https://doi.org/10.1016/j.future.2018.01.052

Palen, L. (2020). *Crisis Informatics: Human-Centered Research on Tech & Crises – A Guided Bibliography Developed by Crisis Informatics Researchers*. Retrieved from https://docs.google.com/document/d/1g6I8Br3vTC04iXVHFTee6arKVld89x9bGvSEeN_NaPU/edit

Palen, L., & Anderson, K. M. (2016). Crisis informatics: New data for extraordinary times. *Science*, *353*(6296), 224–225. https://doi.org/10.1126/science.aag2579

Palen, L., & Hughes, A. L. (2018). Social media in disaster communication. In H. Rodríguez, W. Donner, & J. E. Trainor (Eds.), *Handbook of disaster research* (pp. 497–518). Springer International Publishing. https://doi.org/10.1007/978-3-319-63254-4_24

Palen, L., & Liu, S. B. (2007). Citizen communications in crisis: Anticipating a future of ICT-supported public participation. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 727–736). ACM. https://doi.org/10.1145/1240624.1240736

Palen, L., Vieweg, S., Liu, S. B., & Hughes, A. L. (2009). Crisis in a networked world: Features of computer-mediated communication in the April 16, 2007, Virginia Tech Event. *Social Science Computer Review*, *27*(4), 467–480. https://doi.org/10.1177/0894439309332302

Pang, B., & Lee, L. (2008). Opinion mining and sentiment analysis. *Foundations and Trends in Information Retrieval*, *2*(1–2), 1–135.

Perng, S.-Y., Büscher, M., Wood, L., Halvorsrud, R., Stiso, M., Ramirez, L., & Al-Akkad, A. (2012). Peripheral response: Microblogging during the 22/7/2011 Norway attacks. In L. Rothkrantz, J. Ristvej, & Z. Franco (Eds.), *Proceedings of the International Conference on Information Systems for Crisis*

Response and Management (ISCRAM) (pp. 1–11). ISCRAM Digital Library. http://idl.iscram.org/files/perng/2012/187_Perng_etal2012.pdf

Pipek, V., Liu, S. B., & Kerne, A. (2014). Special issue: Crisis informatics and collaboration. *Computer Supported Cooperative Work*, *23*(4–6).

Pipek, V., Reuter, C., Ley, B., Ludwig, T., & Wiedenhoefer, T. (2013). Sicherheitsarena – Ein Ansatz zur Verbesserung des Krisenmanagements durch Kooperation und Vernetzung. *Crisis Prevention – Fachmagazin Für Innere Sicherheit, Bevölkerungsschutz Und Katastrophenhilfe*, *3*(1), 58–59.

Plotnick, L., & Hiltz, S. R. (2016). Barriers to use of social media by emergency managers. *Journal of Homeland Security and Emergency Management*, *13*(2), 247–277. https://doi.org/10.1515/jhsem-2015-0068

Plotnick, L., Hiltz, S. R., Kushma, J. A., & Tapia, A. (2015). Red tape: Attitudes and issues related to use of social media by U.S. county-level emergency managers. In *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)*. ISCRAM Digital Library. http://idl.iscram.org/files/lindaplotnick/2015/1225_LindaPlotnick_etal2015.pdf

Pohl, D. (2013). Social Media Analysis for Crisis Management: A Brief Survey. Retrieved May 25, 2014, from http://stcsn.ieee.net/e-letter/vol-2-no-1/social-media-analysis-for-crisis-management-a-brief-survey

Pohl, D., Bouchachia, A., & Hellwagner, H. (2015). Social media for crisis management: Clustering approaches for sub-event detection. *Multimedia Tools and Applications*, *74*(11), 3901–3932. https://doi.org/10.1007/s11042-013-1804-2

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: The Journal of Collaborative Computing*, *23*(4–6), 513–545.

Qu, Y., Huang, C., Zhang, P., & Zhang, J. (2011). Microblogging after a major disaster in China: A case study of the 2010 Yushu earthquake. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)* (pp. 25–34). ACM. https://doi.org/10.1145/1958824.1958830

Qu, Y., Wu, P. F., & Wang, X. (2009). Online community response to major disaster: A study of Tianya Forum in the 2008 Sichuan earthquake. In *Proceedings of the Hawaii International Conference on System Sciences (HICSS)*. IEEE. https://doi.org/10.1109/HICSS.2009.330

Quarantelli, E. L. (1984). *Emergent citizen groups in disaster preparedness and recovery activities. Final project report*. University of Delaware Press.

Quarantelli, E. L. (1995). *Emergent behaviors and groups in the crisis time of disasters*. University of Delaware, Disaster Research Center.

Quarantelli, E. L., & Dynes, R. R. (1977). Response to social crisis and disaster. *Annual Review of Sociology*, *3*(1), 23–49. https://doi.org/10.1146/annurev.so.03.080177.000323

Rao, R., Plotnick, L., & Hiltz, S. R. (2017). Supporting the use of social media by emergency managers: Software tools to overcome information overload. In *Proceedings of the 50th Hawaii International Conference on System Sciences (HICSS)*. AIS Digital Library (AISel). https://aisel.aisnet.org/hicss-50/cl/crisis_and_disaster_management/9/

Reuter, C. (2014). Emergent collaboration infrastructures: Technology design for inter-organizational crisis management. PhD Thesis. Siegen, Germany.

Reuter, C., Amelunxen, C., & Moi, M. (2016). Semi-automatic alerts and notifications for emergency services based on cross-platform social media data – Evaluation of a prototype. In H. C. Mayr & M. Pinzger (Eds.), *Informatik 2016: von Menschen für Menschen*. GI-Edition-Lecture Notes in Informatics (LNI).

Reuter, C., Backfried, G., Kaufhold, M.-A., & Spahr, F. (2018). ISCRAM turns 15: A trend analysis of social media papers 2004–2017. In K. Boersma & B. Tomaszewski (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)*. ISCRAM Digital Library. Retrieved from http://idl.iscram.org/files/christianreuter/2018/2122_ChristianReuter_etal2018.pdf

Reuter, C., Heger, O., & Pipek, V. (2013). Combining real and virtual volunteers through social media. In T. Comes, F. Fiedrich, S. Fortier, J. Geldermann, & T. Müller (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (pp. 780–790). ISCRAM Digital Library. http://idl.iscram.org/files/reuter/2013/874_Reuter_etal2013.pdf

Reuter, C., Hughes, A. L., & Kaufhold, M.-A. (2018). Social media in crisis management: An evaluation and analysis of crisis informatics research. *International Journal on Human–Computer Interaction*, *34*(4), 280–294. https://doi.org/10.1080/10447318.2018.1427832

Reuter, C., & Kaufhold, M.-A. (2018). Fifteen years of social media in emergencies: A retrospective review and future directions for crisis informatics. *Journal of Contingencies and Crisis Management*, *26*(1), 41–57. https://doi.org/10.1111/1468-5973.12196

Reuter, C., Kaufhold, M. A., Schmid, S., Spielhofer, T., & Hahne, A. S. (2019). The impact of risk cultures: Citizens' perception of social media use in emergencies across Europe. *Technological Forecasting and Social Change*, *148*(119724). https://doi.org/10.1016/j.techfore.2019.119724

Reuter, C., Kaufhold, M. A., Spahr, F., Spielhofer, T., & Hahne, A. S. (2020). Emergency service staff and social media – A comparative empirical study of the attitude by emergency services staff in Europe in 2014 and 2017. *International Journal of Disaster Risk Reduction*, *46*(101516). https://doi.org/10.1016/j.ijdrr.2020.101516

Reuter, C., Kaufhold, M.-A., Spielhofer, T., & Hahne, A. S. (2017). Social media in emergencies: A representative study on citizens' perception in Germany. *Proceedings of the ACM: Human–Computer Interaction (PACM): Computer-Supported Cooperative Work and Social Computing*, *1*(2), 1–19. https://doi.org/10.1145/3134725

Reuter, C., Ludwig, T., Kaufhold, M.-A., & Pipek, V. (2015). XHELP: Design of a cross-platform social-media application to support volunteer moderators in disasters. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 4093–4102). ACM. https://doi.org/10.1145/2702123.2702171

Reuter, C., Ludwig, T., Kaufhold, M.-A., & Spielhofer, T. (2016). Emergency services attitudes towards social media: A quantitative and qualitative survey across Europe. *International Journal on Human-Computer Studies*, *95*, 96–111. https://doi.org/10.1016/j.ijhcs.2016.03.005

Reuter, C., Marx, A., & Pipek, V. (2011). Social software as an infrastructure for crisis management – A case study about current practice and potential usage.

In M. A. Santos, L. Sousa, & E. Portela (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)*. ISCRAM Digital Library. http://idl.iscram.org/files/reuter/2011/876_Reuter_etal2011.pdf

Reuter, C., Marx, A., & Pipek, V. (2012). Crisis management 2.0: Towards a systematization of social software use in crisis situations. *International Journal of Information Systems for Crisis Response and Management*, *4*(1), 1–16.

Reuter, C., Mentler, T., & Geisler, S. (2015). Special issue on human computer interaction in critical systems I: Citizen and volunteers. *International Journal of Information Systems for Crisis Response and Management*, *7*(2).

Reuter, C., & Scholl, S. (2014). Technical limitations for designing applications for social media. In M. Koch, A. Butz, & J. Schlichter (Eds.), *Mensch & Computer: Workshopband* (pp. 131–140). Oldenbourg-Verlag.

Reuter, C., & Spielhofer, T. (2017). Towards social resilience: A quantitative and qualitative survey on citizens' perception of social media in emergencies in Europe. *Journal Technological Forecasting and Social Change*, *121*, 168–180.

Reuter, C., Stieglitz, S., & Imran, M. (2020). Social media in conflicts and crises. *Behaviour and Information Technology*, *39*(3), 241–251. https://doi.org/10.1080/0144929X.2019.1629025

Ritter, A., Clark, S., Mausam, & O, E. (2011). Named entity recognition in tweets: An experimental study. In P. Merlo, R. Barzilay, & M. Johnson (Eds.), *Proceedings of the Conference on Empirical Methods in Natural Language Processing (EMNLP)* (pp. 1524–1534). Association for Computational Linguistics.

Romero, C., Olmo, J. L., & Ventura, S. (2013). A meta-learning approach for recommending a subset of white-box classification algorithms for Moodle datasets. In *Proceedings of the International Conference on Educational Data Mining (EDM)* (pp. 268–271). International Educational Data Mining Society. https://educationaldatamining.org/EDM2013/proceedings/paper_3.pdf

Rudra, K., Ganguly, N., Goyal, P., & Ghosh, S. (2018). Extracting and summarizing situational information from the Twitter social media during disasters. *ACM Transactions on the Web*, *12*(3), 1–35. https://doi.org/10.1145/3178541

Rudra, K., Ghosh, S., Ganguly, N., Goyal, P., & Ghosh, S. (2015). Extracting situational information from microblogs during disaster events: A classification-summarization approach. In *Proceedings of the 24th ACM International on Conference on Information and Knowledge Management* (pp. 583–592). ACM. https://doi.org/10.1145/2806416.2806485

Sakaki, T., Okazaki, M., & Matsuo, Y. (2010). Earthquake shakes Twitter users: real-time event detection by social sensors. In *WWW'10: Proceedings of the 19th International Conference on World Wide Web* (851). https://doi.org/10.1145/1772690.1772777

San, Y., Wardell III, C., & Thorkildsen, Z. (2013). *Social Media in the Emergency Management Field: 2012 Survey Results*. Retrieved from www.cna.org/sites/default/files/research/SocialMedia_EmergencyManagement.pdf

Shneiderman, B. (1996). The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings 1996 IEEE Symposium on Visual Languages* (pp. 1–8). IEEE. https://doi.org/10.1109/VL.1996.545307

St. Denis, L. A., Hughes, A. L., & Palen, L. (2012). Trial by fire: The deployment of trusted digital volunteers in the 2011 Shadow Lake Fire. In L. Rothkrantz,

J. Ristvej, & Z. Franco (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (pp. 1–10). ISCRAM.

Stallings, R. A., & Quarantelli, E. L. (1985). Emergent citizen groups and emergency management. *Public Administration Review*, *45*(Special Issue), 93–100. https://doi.org/10.2307/3135003

Starbird, K., Arif, A., & Wilson, T. (2019). Disinformation as collaborative work: Surfacing the participatory nature of strategic information operations. *Proceedings of the ACM on Human–Computer Interaction (CSCW)*, *3*, 1–26. https://doi.org/10.1145/3359229

Starbird, K., & Palen, L. (2011). Voluntweeters: Self-organizing by digital volunteers in times of crisis. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 1071–1080). ACM. https://doi.org/10.1145/1978942.1979102

Starbird, K., & Palen, L. (2012). (How) will the revolution be retweeted? Information diffusion and the 2011 Egyptian uprising. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)* (pp. 7–16). ACM. https://doi.org/10.1145/2145204.2145212

Starbird, K., Palen, L., Hughes, A. L., & Vieweg, S. (2010). Chatter on the red: What hazards threat reveals about the social life of microblogged information. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)* (pp. 241–250). ACM. https://doi.org/10.1145/1718918.1718965

Statista. (2020). Most popular social networks worldwide as of July 2020, ranked by number of active users. Retrieved August 25, 2020, from www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/

Stieglitz, S., Dang-Xuan, L., Bruns, A., & Neuberger, C. (2014). Social media analytics: An interdisciplinary approach and its implications for information systems. *Business and Information Systems Engineering*, *6*(2), 89–96. https://doi.org/10.1007/s12599-014-0315-7

Stieglitz, S., Mirbabaie, M., Fromm, J., & Melzer, S. (2018). The adoption of social media analytics for crisis management – Challenges and opportunities. In *Proceedings of the 26th European Conference on Information Systems (ECIS)*. AIS Electronic Library (AISeL). https://aisel.aisnet.org/ecis2018_rp/4/

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. https://doi.org/https://doi.org/10.1016/j.ijinfomgt.2017.12.002

Sutton, J. (2010). Twittering Tennessee: Distributed networks and collaboration following a technological disaster. In S. French, B. Tomaszewski, & C. Zobel (Eds.), *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)*. ISCRAM Digital Library. http://idl.iscram.org/files/sutton/2010/987_Sutton2010.pdf

Valecha, R., Oh, O., & Rao, R. (2013). An exploration of collaboration over time in collective crisis response during the Haiti 2010 earthquake. In R. Baskerville & M. Chau (Eds.), *Proceedings of the International Conference on Information Systems (ICIS)* (pp. 1–10). AIS Electronic Library (AISeL). Retrieved from https://aisel.aisnet.org/icis2013/proceedings/ResearchInProgress/96/

van Gorp, A. F. (2014). Integration of volunteer and technical communities into the humanitarian aid sector: Barriers to collaboration. In *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (pp. 620–629). ISCRAM Digital Library. http://idl.iscram.org/files/vangorp/2014/1042_VanGorp2014.pdf

Vieweg, S., Hughes, A. L., Starbird, K., & Palen, L. (2010). Microblogging during two natural hazards events: What Twitter may contribute to situational awareness. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 1079–1088). ACM. https://doi.org/10.1145/1753326.1753486

Viviani, M., & Pasi, G. (2017). Credibility in social media: Opinions, news, and health information – A survey. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *7*(5), e1209–n/a. https://doi.org/10.1002/widm.1209

White, J. I., Palen, L., & Anderson, K. M. (2014). Digital mobilization in disaster response: The work & self – organization of on-line pet advocates in response to Hurricane Sandy. In S. R. Fussell, W. G. Lutters, M. R. Morris, & M. Reddy (Eds.), *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)* (pp. 866–876). ACM. https://doi.org/10.1145/2531602.2531633

White, C., Plotnick, L., Kushma, J., Hiltz, S. R., & Turoff, M. (2009). An online social network for emergency management. *International Journal of Emergency Management*, *6*(3/4), 369–382.

Wilensky, H. (2014). Twitter as a navigator for stranded commuters during the Great East Japan earthquake. In *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (pp. 695–704). ISCRAM Digital Library. http://idl.iscram.org/files/wilensky/2014/1091_Wilensky2014.pdf

Wukich, C. (2015). Social media use in emergency management. *Journal of Emergency Management*, *13*(4), 281–294. https://doi.org/10.5055/jem.2015.0242

Zade, H., Shah, K., Rangarajan, V., Kshirsagar, P., Imran, M., & Starbird, K. (2018). From situational awareness to actionability: Towards improving the utility of social media data for crisis response. In *Proceedings of the ACM on Human-Computer Interaction*. ACM. https://doi.org/10.1145/3274464