The Usage of Twitter Data for Early Crisis Detection

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Abstract. The establishment of novel information and communications technologies, such as social media, has changed how individuals and organizations behave. Particularly during uncertain situations caused by natural or man-made disasters, people communicate and share information via social media. Emergency services could use published content of social media participants for an early detection of crisis situations and thus enhance crisis management. However, exploiting these information bears several challenges. To gain insights from large amounts of unstructured data in time-critical situations, emergency services are in the need of tools that enable them to gather, process, and analyze relevant information. In this research article, we follow the design science paradigm and propose a concept (artifact) of an early crisis detection tool. Based on expert interviews, design implications for the concept tool are derived. In addition, we conducted a design thinking workshop to evaluate the artifact, highlighting its practical relevance and usability.

Keywords: Crisis Management, Crisis Communication, Social Media, Early Warning System

1 Introduction

The continuous development of new technologies in recent years has changed our everyday lives profoundly. Mobile technologies and embedded computing devices, as well as network and communication services, such as Facebook and Twitter, have changed the way how people communicate and share information with others [1]. Social media has become an important medium in particular during disaster situations [2, 3]. There is a growing consensus about the fact that social media can be valuable for emergency services in all disaster phases [4–7]. But other than the use of social media in crisis response, only little is known about the use of social media for Emergency Management Agencies (EMAs) in the early detection of a crisis [4–6]. By having the knowledge of how to detect a crisis and how to gather these data in time-critical events, unleash the potential to minimize the damages and possibly save lives. Furthermore, regarding the massive amount of unstructured data available in social

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media, it becomes apparent, that EMAs need technological tools to support crisis management efforts by automatically collecting, aggregating and visualizing important information [8]. Regarding existing tools intended to solve these challenges, [9] reported that the state of the art in the field of social media-based crisis management systems comprises a multitude of heterogeneous, domain-specific solutions instead of general applicable, modular and flexible tools. Thus, the design of a concept for a comprehensive crisis detection tool, deployable in the control center of EMAs, is one major research aim of this work.

To reach the mentioned research aim of developing an innovative IT artifact in form of a concept for an early crisis detection tool, we seek to address the following general question. *How can Twitter data be used for an early crisis detection tool?*

First, we investigated which Twitter data can serve as indicators to early detect a crisis. Second, we studied the design of an early crisis detection tool, by investigating which features the tool should comprise for processing, analyzing and visualizing the gathered data. Hence, this work starts with the research design following the design science approach [10]. The design science research methodology (DRSM) by [11] is further used for structuring this paper. Accordingly, an unsolved problem will be identified and the motivation to close the defined research gap will be presented. Afterwards, the objectives of the newly designed IT artifact indented to solve the identified problems, will be defined. To assess the state-of-the-art of current literature as well as practical demands, the chosen research methods are a literature research and expert interviews. Based on the results, the design and development of the tool will be described. In a further step, the tool will be demonstrated and evaluated by experts in the field of crisis management during a design thinking workshop and in a second step during a test scenario including three participants testing the tool in a two-day period in the emergency management context. Last, we discuss the results and point out relevant aspects for further research.

2 Research Design

This research follows the Design Science paradigm by [10] and is structured according to the design science research methodology (DSRM) by [11]. During an incremental and iterative process, an artifact in form of an instantiation was developed (see figure 1). The result of this research will be an innovative IT artifact, i.e. a tool for the early detection of crises.

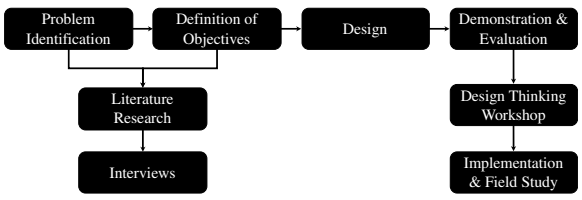

Figure 1. The Design Science Process and the applied Methods [adapted from 11]

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2.1 Problem Identification

Existing research in the context of using social media for crisis management focuses on the development of automated systems and algorithms to gather information from social media to support response and recovery activities in later stages of a disaster [4, 12]. Although it is stated, that social media can benefit in all phases of the crisis management cycle, including the pre-crisis phase, most research focuses on post-crisis phases. Even though, the importance and relevance of social media for EMAs in every phase of a crisis is proven, only little research exists regarding the use of social media in the pre-crisis phase for the early detection of disasters. Accordingly, especially information collection activities by exploiting social media can be used to detect potential crises and contribute to situation awareness and impact assessment [13, 14]. The main challenge thereby lies in the transformation of unstructured large amounts of data into detailed, actionable insights at early disaster stages [3, 14–18]. To be able to extract relevant and actionable information from social media, data mining techniques are required. The possibility of forecasting crisis events based on social media data is not considered in current systems. Even though there are several existing tools that may assist EMAs in crisis management by analyzing social media data [32, 33], currently, there is no holistic tool focusing on the early detection of disasters. Rather different domain-specific approaches do exist [9]. Furthermore, most EMAs do not use social media in a systematic way for information retrieval. This may be reasoned by a lack of awareness of analyzing social media for crisis management [19]. However, early crisis detection plays a significant role, because it could enable EMAs to react faster and thus limit a disasters impact.

2.2 Definition of Objectives for a Solution

Defining the objectives for a solution, draws upon existing knowledge from literature and current solutions and is interfered from the previously defined problem. Further it requires knowledge about what is applicable in the organization and what might be expected from a solution [10, 11]. Following these guidelines for transforming the problem definition into precise objectives two research questions are formulated for guiding this research. The identified problem relates to the need for a technical solution to support crisis management by early detecting (arising) crises based on social media data. For this purpose, we investigate, which information from Twitter can be used as reliable crisis indicators. Accordingly, the first research question (RQ 1) is stated as follows: ***Which Twitter data can be used as indicators to early detect crises?***

Existing research in this area, offers a wide range of different approaches, ranging from event detection, location determination and content analysis. For designing a new technological tool, important features and functionalities to support the crisis detection task must be revealed. Previous research has resulted in several recommendations how post crisis-relevant data should be processed and presented to deliver valuable insights. Still, regarding the focus of existing solutions on later crisis phases, it is possible that an early crisis detection tool requires several additional

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features for processing, analyzing and visualizing social media data. Thus, the second research question (RQ 2) is stated as follows: ***Which features should a tool compromise for the early detection of a crisis based on the identified Twitter indicators?***

To answer these research questions, a literature review, as well as expert interviews are conducted. Thus, the state-of-the-art of existing approaches and solutions is revealed and furthermore, by investigating and integrating the expectations of experts and future users, the practical applicability should be ensured. By finding answers regarding the research questions, design implications for an early crisis detection tool are be derived. Accordingly, based on the results, we designed a concept of an innovative IT artifact.

3 Methods

3.1 Existing Literature & Interviews

For answering the predefined research questions, the state of the art in literature was identified and furthermore an assessment of demands regarding practical uses was analyzed. Regarding the literature search process, a keyword-search in reputable electronic databases, which include the most important journals in the field of Information Systems, was done. The selected databases comprise ACM, AISeL, IEEE, ISCRAM, Science Direct and Scopus. For identifying relevant literature relating to the early detection of crises by using Twitter, the following search query was defined: ("Social Media" OR "Social Network") AND (detect* OR predict* OR forecast OR "early warning") AND (crisis OR crises OR disaster OR disasters). The query was slightly adapted according to the requirements of the different databases. Regarding the interviews, 14 semi-structured interviews with experts in the field of crisis management were conducted, following a predefined interview guide including a list of open questions. Using a semi-structured approach allowed more flexibility during the interviews and gave the opportunity to focus on different aspects according to the answers of the interviewees, while simultaneously establishing consistency by sifting through the main topics. The interview topics included questions about the current processes in crisis management as well as the use of social media within the respective organizations. For example, the participants were asked, if they think using social media in an urgent crisis situation might be reasonable. Furthermore, participants were asked about their views on the use of social media for crisis management, especially which social media data might serve as crisis indicators, how a tool for the early detection of crises might be designed. Questions in this section were, for example: "Which social media information should be used to detect crises early?" or "Which functions should a tool for early crisis detection comprise?". Lastly, interviewees were asked what they envision regarding possible future developments. To enable a common understanding of the term 'crisis', the UNISDR disaster definition was provided to the interviewees. Accordingly, it is described as "a serious disruption of the functioning of a community or a society involving

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widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" [31]. The participants were employed by German EMAs and therefore have access to a special expertise in the management of crisis situations. The organizations stretched across the fire department, including professionals and volunteers, Deutsches Rotes Kreuz (relief organization), Die Johanniter (relief organization), Arbeiter-Samariter-Bund (relief organization) and Technisches Hilfswerk (technical relief organization) as well as a police department. The interviewees were acquired via email invitations or via personal contacts. Each interview took about one hour and was conducted by two interviewers. It was payed heed, that the interviewer did not personally know the participant. To enable an analysis, the interviews were recorded and manually transliterated. The evaluation of the interviews was further conducted following the guidelines for qualitative content analysis from Mayring (2015), including the establishment of a coding system.

3.2 Design and Evaluation

Following the design science approach of [11], an innovative IT artifact, intended to solve the identified organizational problems, was designed as a research outcome. Based on the results of the literature review and the assessment of demands via expert interviews, the resulting artifact in this work was a first mockup of an early crisis detection tool. For the development of the mockup, the open source website development tool Wix was used. After having designed an innovative artifact, intended to solve revealed practical problems, it has to be demonstrated and evaluated by experts and possible future users to ensure utility and get feedback for future improvements to enhance user acceptance [11]. The goal of the evaluation was to compare the previously formulated objectives of the solution to the actual achieved results based on the demonstration of the designed artifact. For conducting a systematic evaluation, the framework for evaluation in design science (FEDS) by [20] was applied. In the context of this work, which aims at designing a socio-technical artifact, the "human risk and effectiveness" evaluation strategy was chosen. To implement the evaluation strategy, a design thinking workshop was chosen with a strong focus on the phase "Test". The aim of the workshop was to design and evaluate the first concept of a tool for the early detection of disasters by asking participants to design their own solutions and further matching them with our ideas of an artifact. Design thinking, as an approach for creative problem solving and innovation development, aligns well with the design science approach, aiming at designing new and innovative artifacts. Both design thinking and design science are characterized by an incremental and interactive process containing several build-and-evaluate loops [10, 21]. Furthermore, both consider the interplay of human, business and technical factors in the innovation process. Therefore, design thinking fits well into the design science research paradigm, by delivering different methods for prototyping and testing (evaluation).

Based on the evaluation during the design thinking workshop, several improvements of the artifact were proposed and implemented for the second

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evaluation iteration. The integration of experts and possible future users in the design process of an innovative artifact assured the consideration of the business environment and practical needs. Thereby, the evaluation by using a design thinking workshop as evaluation method, enabled the investigation of the estimated utility of the artifact based on expert opinions and further provides feedback to support further development [11].

As stated above, in a second iteration, the concept of the early crisis detection tool was implemented and tested in a realistic use context by three crisis management professionals during a two-day period. The professionals included crisis management experts working at a strategic level in the control center of EMAs, including the fire department and two relief organizations. The implementation of the tool was done under consideration of the adjustments mentioned during the first evaluation iteration.

4 Research Results

4.1 Existing Literature

Summarizing existing literature, it becomes apparent that currently, there is no tool that fulfills all needs of crisis management professionals. Most research focuses on the development of single algorithms. Furthermore, many of the existing tools are limited regarding their context of use or remain at initial stages of development [9]. There are a small amount of comprehensive tools enabling the collection, processing, analysis and visualization of social media data [17]. However, the vast amount of different approaches for event detection, location estimation and data collection as well as the diverse computational and visual components can serve as a broad base for the development of a new tool for the early detection of crises [7, 30]. By including these features in a social media monitoring and analysis system, which is integrated in the routines of emergency services and easy to use, the early detection of arising crises could be enhanced and thus the whole crisis management process [7, 30].

4.2 Interviews

Based on the knowledge derived from existing literature, the aim of the interviews was to assess the demands of experts regarding an early crisis detection tool. Accordingly, the interviews should aid to formulate statements about what the target group, experts in the field of crisis management, think about the use of social media and especially how they would envision a tool for the early detection of crises based on social media data. Statements of the interviewees were translated in English.

Summarizing the results of the interviews it becomes apparent, that an early crisis detection tool is a desired facilitator for the work of EMAs. Especially enabling a fast overview of a situation, by presenting aggregated information in form of maps, pictures or content clusters, were rated as a very important features of the tool. Even though, all participants assigned a high value to the use of social media for crisis detection, only two out of 14 interviewees mentioned that they already use social

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media for information retrieval. The current use of social media is mainly limited to communication purposes.

Asking about possibilities to detect an event based on social media data, 50% of the interviewees mentioned an increasing number of similar messages containing certain crisis-related keywords as an initial point. Furthermore, all participants mentioned the importance of geo-information to estimate the location of a crisis. Even though the interviewees had difficulties to range the different existing approaches for location determination, namely extracting geo-coordinates from metadata, extracting information directly from the text or using the geo-information of the user profile, there was consensus, that information about the location is essential for detecting and managing a crisis.

Moreover, additional content information, especially about the kind of disaster, its scope and consequences, for example regarding injured or missed people and damages on buildings or infrastructure, were rated as important indicators by 13 participants. Summing up, the interviewees described information relating to the key questions of who, what, and where as inevitable indicators to detect and manage a crisis.

"[…] place, time, what, when, what kind – so, that at least location and time are certain, because it is important to know, where it is and where the relevant data come from and if something has happened already. So clearly what, who, how, where […]".

Multimedia data, such as photos and videos were described as a further important information source that can indicate a crisis. The majority reported that multimedia data could provide additional insight about an evolving crisis. After having identified, which social media information the crisis management experts consider as relevant and would want to collect, we investigated, how this information should be processed and displayed. To answer this second research question, the interviewees were asked several questions regarding features a tool for early crisis detection should include.

The most discussed features were clustering techniques to group similar messages, filtering approaches to classify messages and methods for event detection and tracking. Regarding event detection methods, the most frequently mentioned approaches were burst detection methods, to detect an increase in the occurrence of crisis-relevant keywords. Event detection was described as an initial starting point to get first-hand information. One interviewee highlighted the possibility to *"get there before the crisis expands"* and to anticipate evolving trends by using methods for event detection. *"With regard to any trends that I might detect or prognosis for the operation. Especially for crisis management it's important not to act in the crisis, but rather act before it. So, thinking about what might happen in one, two, three hours, what might happen in twelve hours. That is what I can use social media for."*

Another interviewee mentioned the importance of being able to detect subevents within a crisis. Thereby, possible unfolding smaller events resulting from a large-scale disaster, might be detected. Asking participants about their rating of geographic, temporal and topic-related clustering techniques, the main benefit was described as grouping similar messages relating to the same topics to aggregate the amount of information. In addition, two interviewees mentioned the possibility to cluster

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relevant messages based on their geo-coordinates to detect local subevents. In this context, the possibility to extract relevant information, for example names of places or the kind of disaster situation, were mentioned to be important for crisis management. Similarly, methods for filtering and classifying crisis-relevant data were highly discussed. One interviewee pointed at the difficulty of designing filter algorithms that are open enough not to miss any relevant information, but simultaneously as narrow as possible to filter out all irrelevant data. In this context, the importance of verifying the collected information was addressed multiple times. All interviewees agreed that the verification of social media data poses a challenge that must be tackled and depicts a crucial requirement for the tool to guarantee trustworthiness. A main concern was the reliability of social media data as source for information retrieval, especially regarding the subjectivity and incompleteness of information as well as the threat of fake news and rumors. Even though there was consensus, that the validation of social media information depicts an essential part of an early crisis detection tool, five participants mentioned doubts about how and if the verification of information could be technically realized.

One of the most relevant rated visual features were maps. According to the importance of location estimation, based on geo-information, this feature was described as an indicator for crisis detection. Participants further proposed the possibility to mark the location of an event by displaying icons on maps. Additionally, for investigating the course of an ongoing crisis, as well as past events, timelines were described as a crucial requirement. Interviewees rated the visualization of message clusters as important. Again, they focused on the importance of getting a fast overview by categorizing and aggregating the information in clusters. All participants further mentioned the need for a filtering function to focus on certain aspects and details of the analyzed data. An alert function was rated as important by 57% of the interviewees, mentioning that this feature would be necessary to call the user's attention.

Next, the interviewees were asked about some additional useful functions the tool should comprise. The export of data and the integration of a historic database were described as additional features, primarily useful at later stages of the crisis management process, but not relevant for the early detection of crises. A database storing past crisis data was described as useful to learn from past activities and make future prognosis based on the analyzed data. Moreover, the automatic generation of reports and summaries was rated as useful to aggregate and share relevant information with other units. In this context, a collaboration support and the interoperability of the tool with existing systems were highlighted. For example, in combination with the gathered social media data, the integration of weather data from official meteorological services was mentioned to be a beneficial. One interviewee further pointed at the importance of interconnectedness between different organizations to enable information sharing and enhance collaboration.

"Data export…well, thinking about the control center, if they could implement it [data export functionality] in their system or pass their information to other organizations or agencies. They should be more interconnected…the police and fire department […]"

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Furthermore, in this context, one participant mentioned that there should be a function to export reports containing the most relevant operation information directly to the relief units or the head of operations, who could receive the information on portable devices like tablets or smartphones. Next to enhancing collaboration within and across organizations involved in crisis management, four interviewees proposed a warning component to spread important information like warnings or advices to the public as an additional feature.

The most important aspect, that was mentioned by all interviewees was that the tool should enable a faster overview of the crisis by presenting aggregated information displayed in simple visualizations. At later stages of the crisis management lifecycle, additional features like a report builder, data export functions and information storage in databases become more important.

4.3 Design and Evaluation

After a careful consideration of existing literature in the field of Information Systems regarding the usage of social media during crises and existing tools to enhance crisis management, it becomes apparent, that no comprehensive tool exists for the early detection of crises. However, the literature research revealed first insights into how such a tool might be designed, and which features it should comprise. Additionally, the interviews provided an assessment of demands and highlighted the expectations and needs of EMAs regarding the features and the design of such a tool. Thus, by following [10], and including possible future users in the development process, the applicability and utility of the designed artifact can be ensured. In the context of this work, the developed IT artifact is an instantiation in form of a first web-based mockup. Regarding the design concept of the tool, the focus was to design a user-interface fulfilling the needs of possible future users, the employees in the control center of EMAs. Thus, the design focuses on a comprehensive monitoring dashboard, displaying relevant information and features to enable early crisis detection and a quick situation assessment.

The first view of the tool contains an overview of all ongoing search queries that are monitored. In this view, a timescale is depicted on top, displaying a user-defined time dimension on the x-axis and the number of messages relating to a certain search query on the y-axis. On the left side, a timeline with a slide control is displayed, which enables the user to look at different time periods and to have an overview of the long-term course or to focus on certain shorter periods. Underneath the timescale, the created search queries are displayed. The queries can be created based on predefined crisis-relevant keywords or specific geographic regions. Accordingly, messages containing the keywords or matching the selected region are tracked via the provided API of the social media platforms [22]. The user can adjust, delete and add new queries. Furthermore, if no previous knowledge about the type of crisis and hence no keywords are available, the user can track all social media data for a selected region without entering any specific keywords. Because the system is able to track bursts resulting from increasing numbers of similar messages or evolving geo-topic clusters, new unexpected events can be detected [23]. If the number of messages

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relating to any tracked query reaches some predefined thresholds, an automatic alert, in form of a visual or acoustical signal, is triggered.

The main view, shown in figure 2, displays multiple analysis in smaller windows according a specific crisis. It offers a quick overview and enables the simultaneous presentation of interrelated information. This details view comprises a live-stream, a keyword-cloud, a timescale, a map, a list of influential users, a bar graph depicting the sentiment as well as a bar diagram presenting identified topic clusters. The live-stream feature presents the collected messages in real-time in a customizable order. For example, the user can adjust the order to show the most recent messages first, or those with the highest number of shares. Furthermore, messages in the live-stream can be filtered by selecting certain keywords, users, timespans or geographic regions. This feature affords the investigation of unprocessed messages, which are not aggregated or clustered. Thus, the user can get detailed information about what is being discussed in real-time and has the option to dip deeper into the specific messages and topics [22, 24]. The keyword-cloud displays the most frequent occurring keywords or hashtags, thus affording a quick overview of the discussed topics and relevant themes. Frequently mentioned keywords are displayed larger and bold, while less discussed topics are smaller, possibly indicating the importance of single topics [25]. Clicking on single keywords of the cloud opens a further window showing more details that are linked with the specific keyword. By enabling a quick overview of important topics, the keyword-cloud affords a better situation assessment. The following figure presents the main view of the system.

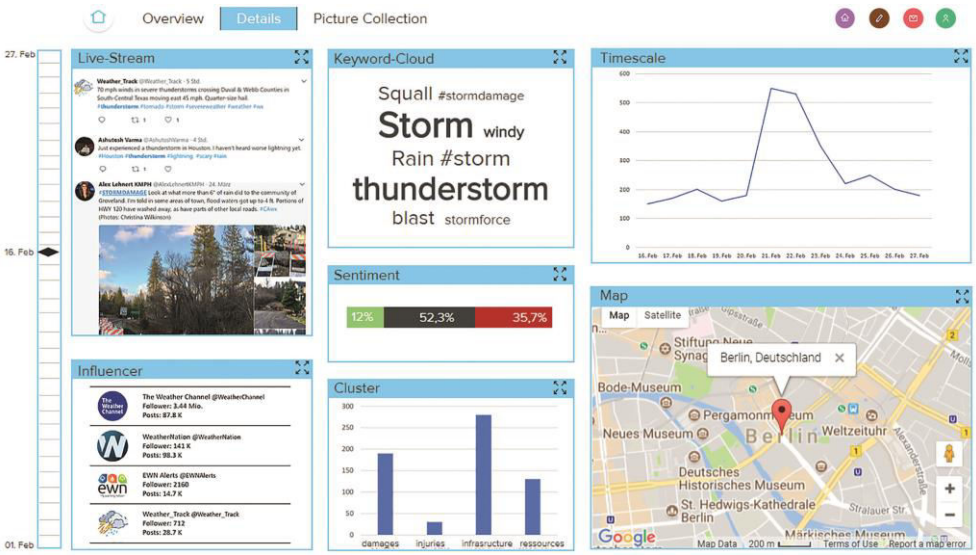

Figure 2. The details view of the early crisis detection tool, displaying the aggregated information relating to the search query “storm” in several analysis windows

By visualizing the volume of crisis-related communication in relation to customizable time dimensions, for example days or hours, the timescale feature, affords a quick

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overview about the course of the event. Based on this information, the planning, preparation and realization of relief actions can be adjusted and enhanced [26]. During the interviews, the visualization of information on a map was described as a fundamental feature. The tool extracts available geo-information from the collected social media data using a combination of the approaches presented earlier, e.g. georeferencing and geotagging and displays the corresponding information on a map. Visualizing information by using maps enables a fast and easy detection of geo-clusters and hotspots, possibly indicating areas to concentrate relief actions on. Maps predominantly serve for enhancing geographic SA and thus enable a better overview and overall situation assessment [7, 14, 26]. As stated by all interview participants, knowing what happened where are essential information for coordinating relief actions and manage an unfolding crisis. Still, it must be acknowledged, that imprecise, incomplete or for some reason unbalanced distributed geo-information may result in setting the wrong geographic focus for relief activities and thus must be dealt with carefully.

A further visual feature displaying the results of a sentiment analysis is the sentiment bar in the middle of the pageview. It gives a quick overview about the publics mood by displaying the percentage of messages classified as positive, neutral or negative. To aid a quicker evaluation of the sentiment, the percentages are highlighted in colors, green for positive, grey for neutral and red for negative. Clicking on the colored sections opens a detailed view containing information about all messages relating to the selected sentiment. Investigating the sentiment enables a better estimation of the public mood and thus possible evolving behaviors [24]. EMAs can adjust their activities according to the atmosphere and possibly prevent the emotions from blowing up. However, because of the subjectivity of emotions, relying on sentiment may lead to a misinterpretation of the situation and hence constrain decision making.

Displaying important users in the “influencer”-window, may afford the verification of information and thus aid in defeating rumors. Social media users can be marked as reliable or influential if they are assumed to share trustworthy information or have high numbers of followers. According to [24], the identification of influencers and relevant communities could enable the crisis management process by spreading important information to the public via their social media accounts. Thus, warnings, advices or corrections of misinformation can be easily spread. Furthermore, by taking a closer look at users posting crisis-related messages, those that are rated as unreliable, but whose messages were not excluded during the preprocessing and filtering steps of the tool, can be manually blocked and be discharged from the analyses.

The last element of the details view is a bar chart of detected topic clusters. The clusters can be created based on predefined crisis-relevant labels or be automatically labeled according to the collected data [27, 28]. Aggregating information in topic clusters enables taking a more detailed look by zooming in into the detected themes and thus possibly detect subevents. By visualizing the clusters in a bar chart, that presents the detected topics on the x-axis and the volume of messages on the y-axis, a quick overview of the most discussed topics is given. The users can define the

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priorities of the clusters and take a deeper look at the most relevant clusters by clicking on the corresponding bar. Additionally, every analysis window contains a button to maximize the view. Clicking on it opens a more detailed view containing additional information relating to the selected window. Our tool should not only allow getting a fast overview of the overall situation, but also support zooming in into certain details. In doing so, the analyzed information could enhance decision making processes [29].

The first evaluation of the designed artifact during the design thinking workshop revealed a high estimation of utility of the tool. The participants were interested in using the tool and integrating it into current crisis management processes. Additionally, several improvements including additional features that should be integrated in the tool were derived. These features are among others a traffic light system to prioritize and mark high-value information as well as forecasts analysis to make predictions of the course of an evolving event. Furthermore, existing features can be improved. The sentiment analysis feature for example would be more valuable, if different emotions could be identified and visualized. The triggering of alerts could be improved by considering further indicators beyond the number of messages. Furthermore, the alerts should be automatically sent to a number of crisis management experts. Additionally, it was noted, that it is important to include other social media platforms than Twitter, for example Facebook and Instagram, to gather as many data as possible to gain a holistic picture. Based on these results, the designed artifact was adjusted by integrating new and improving the existing features. Subsequently, the mockup was implemented in form of a technical prototype. The first prototype version of the tool gathers and analyzes social media data from Twitter.

The second iteration (see figure 3) of the evaluation, a small field study, including three participants testing the adjusted tool in a two-day period, revealed some further improvements.

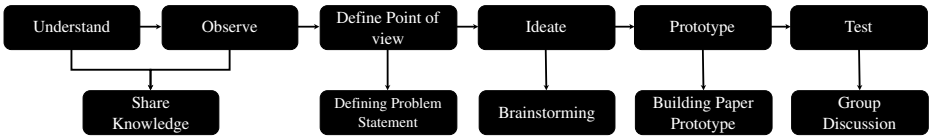

Figure 3. The Design Thinking Process and the applied Methods

First, the participants desired the analysis of other sources, additional to Twitter, for example data from Facebook or Instagram. Furthermore, information from news websites should be integrated and analyzed by the tool. Another important aspect the participants mentioned, was the improvement of the tool's performance. Short loading times and a fast data processing are inevitable requirements of a crisis detection tool to guarantee a smoothly workflow. In this context, participants also desired the integration of the tool into existing practices enabling the interaction with existing tools in use.

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5 Discussion

The interviews highlighted the need for a quick and comprehensive overview to enhance situation assessment, thus the designed artifact should enable the achievement of this goals. The tool should enable the enhancement of the overall crisis management process by improving operation planning and flow and furthermore offering a decision support [24, 29]. The research results revealed that the expectations practitioners have about features and functionalities of a crisis detection tool are mostly in line with approaches and solutions of existing research. The results indicate, that maps, picture or video collections, time graphs or timelines, keyword-clouds as well as clustering tools are the most valuable features. Additionally, the implementation of mechanisms to guarantee trustworthiness of gathered information, depicts a crucial requirement.

Studying existing solutions for using social media data for the early detection of crises revealed that currently there are no comprehensive tools fulfilling all practical demands. Thus, integrating insights from existing research and business needs depicts a promising approach to enhance crisis management by developing a new, innovative IT artifact for the early detection of crises [10]. The evaluation of the artifact revealed that the proposed features fulfill most needs. Still, the workshop participants mentioned further promising features which should be integrated. The implementation of predictive analytics provides an innovative approach. By developing a timeline feature, considering fixed and possible future events that might have an impact on the course of a crisis, further consequences could be anticipated and acted on at early stages. However, the aspect of including predictive analytics did neither came up during the interviews nor in the context of the conducted literature review. The evaluation of the adjusted and implemented tool during the field study highlighted further improvements, like the analysis of multiple data sources, importance of integrating the new tool in existing practices and systems as guaranteeing a flawless functionality and performance. Considering the time-critical and stressful nature of crisis management as well as the dependence on external information to initiate relief efforts and take actions, technological tools to support these activities are inevitable.

6 Conclusion and Further Research

The aim of this research was to examine the status quo of Information Systems research regarding the usage of social media, in this case Twitter, for an early warning system, and to unveil the requirements of EMAs for such a tool. Thus, by following the design science research paradigm, we developed an innovative IT artifact, a concept of an early crisis detection tool based on Twitter data. By revealing crisis-relevant indicators in social media and furthermore investigating possible features of such a tool, we developed a concept for a comprehensive crisis detection and management tool, by considering the complete process from gathering, processing, analyzing and visualizing relevant information. Despite these results, the presented research obtains some limitations. Even though the literature review aimed at being

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exhaustive and revealed a large amount of relevant papers, it is possible that some relevant contributions might have been missed, particularly from other field than Computer Science and Information Systems as well as contributions in other languages than English. Furthermore, the conducted interviews bear some limitations. As the participants only had abstract visions about the tool and its features, but no implementation at hand, it might have been difficult to imagine the functionalities. Thus, future research should conduct a more detailed analysis by means of interacting with the implemented tool. Even though this was partly realized during the evaluation in form of a field study, the implemented system should be tested in a greater extent, including a higher number of participants testing the system in a longer time period. Furthermore, future research should include data from additional social media platforms. Our results as well as existing literature indicate, that Facebook or Instagram might offer further relevant information. Despite these limitations, the interview results indicate first insights regarding the goals EMAs want to reach, by using an early detection tool and thus, give implications of the realization of such a tool.

Following the DRSM of [11], our presented artifact is a first concept, which is based on a combination of existing literature and on expert interviews. The evaluation of the concept highlighted the positive attitudes, the experts have towards the development of the designed tool and further revealed innovative features like the integration of a predictive analytics approach. By considering and anticipating possible future developments, potential risks can be detected at early stages of an unfolding crisis event. Thus, by reacting early, the expansion of a crisis can be hindered. Furthermore, participants using the implemented tool during a field study, highlighted their willingness to use the tool, although they mentioned some considerations regarding a flawless performance, that must be guaranteed. Regarding the use of social media in crisis management, most EMAs are only at the beginning, mostly not even aware of the huge potentials of respective systems.

References

1. Lindsay, B.R.: Social Media and Disasters: Current Uses, Future Options and Policy Consifderations. (2011).
2. Brynielsson, J., Granåsen, M., Lindquist, S., Narganes Quijano, M., Nilsson, S., Trnka, J.: Informing crisis alerts using social media: best practices and proof of concept. J. Contingencies Cris. Manag. 1–13 (2017).
3. Spielhofer, T., Greenlaw, R., Markham, D., Hahne, A.: Data mining Twitter during the UK floods: Investigating the potential use of social media in emergency management. In: Proceedings of the 3rd ICT-DM. IEEE, Vienna, Austria (2016).
4. Lee, N.-S., Hirschmeier, S., Müller, S., Luz, L.J.: Enablers in Crisis Information Management: A Literature Review. In: HICSS. pp. 274–283 (2017).
5. Panagiotopoulos, P., Barnett, J., Bigdeli, A.Z., Sams, S.: Social media in Emergency Management: Twitter as a Tool for Communicating Risks to the Public. Technol. Forecast. Soc. Change. 111, 86–96 (2016).
6. Wendling, C., Radisch, J., Jacobzone, S.: The Use of Social Media in Risk and Crisis Communication. (2013).
7. Karl, I., Nestler, S.: Nutzung von sozialen Medien als bürgerzentriertes Frühwarnsystem

https://doi.org/10.30844/wi_2020_v1-mirbabaie

für Krisensituationen. In: Koch, M., Butz, A., and Schlichter, J. (eds.) Mensch und Computer 2014 - Workshopband. pp. 125–130.
8. Singh, J.P., Dwivedi, Y.K., Rana, N.P., Kumar, A., Kapoor, K.K.: Event classification and location prediction from tweets during disasters. Ann. Oper. Res. 1–21 (2017).
9. Avvenuti, M., Cimino, M.G.C.A., Cresci, S., Marchetti, A., Tesconi, M.: A framework for detecting unfolding emergencies using humans as sensors. Springerplus. 5, 1–23 (2016).
10. Hevner, A.R., March, S.T., Park, J.: Design Science in Information Systems Research. MISQ. 28, 75–106 (2004).
11. Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S.: A Design Science Research Methodology for Information Systems Research. J. Manag. Inf. Syst. 24, 45–77 (2007).
12. Huang, Q., Xiao, Y.: Geographic Situational Awareness: Mining Tweets for Disaster Preparedness, Emergency Response, Impact, and Recovery. ISPRS Int. J. Geo-Information. 4, 1549–1568 (2015).
13. Ahmed, A.: Use of Social Media in Disaster Management. In: Proceedings of the 32nd International Conference on Information Systems (ICIS). , Shanghai, China (2011).
14. MacEachren, A.M., Jaiswal, A., Robinson, A.C., Pezanowski, S., Savelyev, A., Mitra, P., Zhang, X., Blanford, J.: SensePlace2: GeoTwitter Analytics Support for Situational Awareness. In: IEEE Conference on VAST. pp. 181–190., Rhode Island, USA (2011).
15. Alshareef, H.N., Grigoras, D.: Using Social Media and the Mobile Cloud to Enhance Emergency and Risk Management. In: 15th ISPDC. pp. 92–99. IEEE, China (2016).
16. Ashktorab, Z., Brown, C., Nandi, M., Culotta, A.: Tweedr: Mining Twitter to Inform Disaster Response. In: 11th ISCRAM. pp. 354–358. , Pennsylvania, USA (2014).
17. Cobb, C., McCarthy, T., Perkins, A., Bharadwaj, A., Comis, J., Do, B., Starbird, K.: Designing for the Deluge: Understanding & Supporting the Distributed, Collaborative Work of Crisis Volunteers. In: 17th CSCW (2014). pp. 888–899. ACM, Baltimore, USA.
18. Imran, M., Castillo, C., Diaz, F., Vieweg, S.: Processing Social Media Messages in Mass Emergency: A Survey. ACM Comput. Surv. 47, 67:1-67:38 (2015).
19. Stieglitz, S., Mirbabaie, M., Fromm, J., Melzer, S.: The Adoption of social media analytics for crisis management – Challenges and Opportunities. In: ECIS. , Portsmouth (2018).
20. Venable, J., Pries-Heje, J., Baskerville, R.: FEDS: A Framework for Evaluation in Design Science Research. Eur. J. Inf. Syst. 25, 77–89 (2016).
21. Grots, A., Pratschke, M.: Design Thinking — Kreativität als Methode. Mark. Rev. St. Gall. 26, 18–23 (2009).
22. Robinson, B., Power, R., Cameron, M.: A Sensitive Twitter Earthquake Detector. In: Proceedings of the 22nd International Conference on World Wide Web - WWW '13 Companion. pp. 999–1002. ACM, Rio de Janeiro, Brazil (2013).
23. Manaskasemsak, B., Chinthanet, B., Rungsawang, A.: Graph Clustering-Based Emerging Event Detection from Twitter Data Stream. In: 5th International Conference on Network, Communication and Computing - ICNCC '16. pp. 37–41. ACM, Kyoto, Japan (2016).
24. McCreadie, R., Macdonald, C., Ounis, I.: EAIMS: Emergency Analysis Identification and Management System. In: 39th International ACM SIGIR Conference on Research and Development in Information Retrieval. pp. 1101–1104. ACM, Pisa, Italy (2016).
25. Cameron, M.A., Power, R., Robinson, B., Yin, J.: Emergency Situation Awareness from Twitter for Crisis Management. In: Proceedings of the 21st International Conference on World Wide Web - WWW '12 Companion. pp. 695–698. ACM, Lyon, France (2012).
26. Yin, J., Karimi, S., Robinson, B., Cameron, M.: ESA: Emergency Situation Awareness via Microbloggers. In: 21st ACM CIKM '12. ACM, Maui, Hawaii (2012).
27. Imran, M., Elbassuoni, S., Castillo, C., Diaz, F., Meier, P.: Extracting Information Nuggets from Disaster-Related Messages in Social Media. In: 10th ISCRAM. pp. 791–

https://doi.org/10.30844/wi_2020_v1-mirbabaie

800. , Baden-Baden, Germany (2013).
28. Pohl, D., Bouchachia, A., Hellwagner, H.: Automatic Identification of Crisis-Related Sub-Events using Clustering. In: 11th ICMLA 2012. pp. 333–338. IEEE, Boca Raton, USA.
29. Avvenuti, M., Cresci, S., Marchetti, A., Meletti, C., Tesconi, M.: EARS (Earthquake Alert and Report System): a Real Time Decision Support System for Earthquake Crisis Management. In: 20th ACM SIGKDD '14. pp. 1749–1758. ACM, New York, USA (2014).
30. Rother, Karl & Nestler: Ein Konzept für die Klassifizierung subjektiver Sicherheit in Tweets, In: B. Weyers, A. Dittmar (Hrsg.): Mensch und Computer Workshopbeiträge, Aachen, 2016
31. UNISDR. (2009). *UNISDR Terminology on Disaster Risk Reduction*.
32. Yang, J. A., Tsou, M. H., Jung, C. T., Allen, C., Spitzberg, B. H., Gawron, J. M., & Han, S. Y. (2016). Social media analytics and research testbed (SMART): Exploring spatiotemporal patterns of human dynamics with geo-targeted social media messages. Big Data & Society, 3(1), 2053951716652914.
33. Denecke, K., Krieck, M., Otrusina, L., Smrz, P., Dolog, P., Nejdl, W., & Velasco, E. (2013). How to exploit twitter for public health monitoring. Methods of information in medicine, 52(04), 326-339).

https://doi.org/10.30844/wi_2020_v1-mirbabaie