Designing an Application for Social Media Needs in Emergency Public Information Work

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ABSTRACT
Emergency responders increasingly use social media as a means to monitor public information, gather information that could be used in response efforts, and communicate important information during emergency events. However, the adoption of social media into emergency management processes poses socio-technical challenges such as issues of credibility and trust, lack of organizational support, poor tools, and a shortage of resources and training. This study designs, implements, and evaluates an application that supports the work practice of emergency public information officers and their need to gather, monitor, sort, and report social media activity. Based on prior work that examines how social media and the forms of public participation enabled by it are changing public information practice, we iteratively design and evaluate application prototypes using a human-centered process—moving from low-fidelity paper prototypes to a high-fidelity digital prototype that is ready for field use.

Keywords
Social Media; Crisis Informatics; Participatory Design

1. INTRODUCTION
As social media become more pervasive, emergency responders increasingly use social media to communicate with the public, monitor the public information arena during an emergency event, and gather information that could be helpful to response efforts [8, 14, 16, 35, 38]. In turn, members of the public are coming to expect that emergency responders will provide information through social media streams and even respond to requests for assistance made through these streams [2].

In the United States (US), the emergency responder role that is most affected by social media is the Public Information Officer (PIO). The PIO role is a formalized public relations position under the Incident Command System that all US response organizations are required to use for managing their emergency response efforts. The PIO's primary responsibility is to communicate correct, up-to-date information concerning the status of emergency incidents to the media, members of the public, and other directly or indirectly affected stakeholders [12]. They monitor public communications to answer questions, provide needed information, and correct false rumor and/or misinformation [36]. PIOs also find useful crisis information generated by the public and distribute it to response organizations that can best use it. Despite social media's potential for PIO work, adoption poses many socio-technical challenges such as issues of credibility and trust, lack of support from management, organizational conflicts, poor tools, and a shortage of resources and training [12, 16, 37].

This paper describes a multi-year, ongoing project to design, implement, and evaluate a tool—the PIO Monitoring Application (PMA)—that supports the work practice of PIOs and their needs to gather, monitor, sort, and report social media activity and data. Building upon prior empirical research [12] and the results of a participatory design workshop [11], we report the human-centered process used to create this application and the insights gained around how social media is changing the work practice of PIOs.

2. BACKGROUND
2.1 Emergency Responder Social Media Use
Traditionally, emergency responders have perceived public information work as happening over one-way communication channels [24]—flowing from response organizations to the public but not in the other direction. Recently, this perception has been challenged as emergency responders increasingly use social media to communicate and interact with the public they serve [8, 14, 30, 39]. Through social media, responders can reply to requests for assistance and information from a globally distributed audience with unprecedented speed [5, 25]. The public can participate more broadly as they find, generate, and share online crisis information [5, 13, 27, 31]. In turn, emergency responders find that the online information the public generates during a crisis event can be useful in their own efforts [6, 12]. These new information flows—supported by social media—have led emergency responders to rethink the one-way communication model in favor of a two-way model that accounts for new interactions between emergency responders and the public [12, 23].

Initial studies regarding social media use for emergency public information work focus on how emergency responders adopt social media platforms and the challenges in fitting these new communication platforms with needs and practice [4, 12, 16, 34, 37]. As online communication use by emergency responders has continued to increase, researchers have engaged in more focused studies of its use. These studies have primarily examined Twitter use across a variety of crisis events such as the London Riots of

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2011 [8], the 2010 Deepwater Horizon oil spill [38], and the 2013 Boston Bombings [39]. A few recent studies have expanded this inquiry to include other online media beyond Twitter, such as websites, blogs, and/or Facebook [14, 35]. While these studies reveal much about how PIOs use social media, including strategies for monitoring data and communicating with the public, they are limited in scope and do not explore how online media use fits within a broader, all-hazards public information strategy. Researchers acknowledge the limitations of these studies and recognize a growing need to classify emergency social media use and practice, both by type and by disaster [9].

2.2 Limitations of Existing Tools and Methods

In recent years, academia, industry, and members of the public have created many solutions that attempt to process and manage social media in times of disaster [26]. Many of these applications attempt to filter and analyze the large amounts of social media data following a major disaster event. Using supervised learning techniques, the *Enhanced Messaging for the Emergency Response Sector* (*EMERSE*) system automatically classifies and aggregates tweets to make them more accessible to emergency responders and members of the public [7]. *Twitcident* uses semantics techniques to filter tweets during a crisis event and provide better search capabilities to help people explore Twitter data [1]. *TwitInfo* visualizes and summarizes tweets around events using a timeline to help users make sense of the data [19]. These tools provide automated methods for analyzing and exploring Twitter data but they do not support the social media documentation and reporting needs of PIOs. Further, these methods rely heavily on pre-existing, coded datasets to perform well. Such datasets are highly contextual to specific events (i.e., they do not generalize well) and require much time and expertise to create.

Other applications are aimed at supporting the efforts of members of the public as digital volunteers [32], and as a result they do not directly address the needs of PIOs. For example, to make tweets more readable by machines and allow for automatic analysis, the *Tweak the Tweet* project proposes a prescriptive syntax using descriptive hashtags [33]. *Ushahidi* is a computing platform that supports human-entered data and analysis in an array of humanitarian situations [20, 21]. *XHELP* [29] supports the digital activities of citizens and volunteers in disasters, while *CrowdMonitor* [18] supports emergency service groups in their efforts to coordinate citizen volunteers.

Commercial applications such as *TweetDeck* [40], *TweetFall* [41], and *Hootsuite* [10] provide generalized tools and dashboards for monitoring and managing social media streams, but they do not fully support the documentation, reporting and organizing needs of PIOs. *Radian 6* [28] provides powerful social media monitoring and analysis tools but is too expensive for most PIOs.

3. PRIOR RESEARCH

This work builds upon prior empirical and participatory design research that are reported in full elsewhere [11, 12]. However, we summarize the approach and findings of these studies to demonstrate how design decisions were informed by this research.

3.1 Empirical Investigation

Hughes and Palen [12] conducted interviews with 25 PIOs in the US to learn how they perceived social media was affecting their work practice. The study found that PIOs work for a wide variety of organizations, such as fire and police departments, public health departments, hospitals, and county-, state-, and federal-level emergency management agencies. In addition, PIOs are found in a variety of jurisdiction sizes (e.g., rural, urban, metro, etc.). PIOs from larger jurisdictions tend to work full-time and have more organizational support. PIOs from smaller jurisdictions tend to work part-time; often, the PIO role is just one of many roles played in his/her organization.

Many PIOs, especially part-time PIOs, were already overwhelmed with their current duties and adding social media as yet another communication tool presents challenges. Using social media requires additional effort; they must acquire proficiency with social media and the tools associated with them while also devoting more time to monitoring and using a new communication channel. Rarely were these PIOs given more time or resources to handle the extra workload.

Hughes and Palen [12] examined the range of PIO work tasks. PIOs are often called to the scene of an emergency to help manage journalists. The PIO's job is to corral the press, keep them from interfering with the response efforts and out of harms way, while also sharing the most recent incident information. Interestingly, PIOs have been forced to adjust their practice to accommodate changes in the field of journalism. Information that used to only be available through traditional media streams is now available through blogs, websites, and other social media, and citizens produce much of it. These worlds further blend as professional journalists increasingly rely on story leads, photos, and video from the public. To stay relevant in a changing world, journalist must release information more quickly to avoid being scooped by other sources. As a result, PIOs face increasing pressure to produce more information and to release it more quickly to the press and to members of the public over social media streams as well as other traditional communication channels. We aim to address the PIO social media challenges and needs described here with PMA.

3.2 Participatory Design Workshop

To involve PIOs in creating tools for their social media needs, Hughes [11] led a full-day participatory design workshop with 8 PIOs and 7 researchers. The workshop began with focused group discussion around how social media was affecting the work practices of PIOs. Following this discussion, the PIOs created low-fidelity prototypes of their ideal social media information space. Each PIO then shared his/her prototype and the workshop participants discussed what they liked and disliked about the design. Next, the PIOs worked in teams with researchers to develop new low-fidelity prototypes that further developed the ideas explored earlier in the workshop. After reporting on and discussing these group prototypes, everyone met together to debrief for the day and determine future directions. This workshop produced several design recommendations—which we use in the design of PMA—for tools that would address the social media needs of PIOs [11].

3.2.1 Support Information Monitoring & Analysis

PIO participants expressed the need for tools that would help them monitor, sift, and make sense of the potentially large amounts of data available across social media streams during an emergency event. However, they wanted any tool that analyzed social media data to be transparent so they could understand how the results were derived.

3.2.2 Provide Ways to Organize Information

During the workshop, PIOs prototyped different organizational schemes for the social media data they planned to collect. For

example, one prototype organized the data by who had sent the data, while another organized data by who would be most interested in the content. Existing tools limit how information can be organized and if organization was supported it tended to be in fixed, predetermined ways that were not always helpful.

3.2.3 Provide Report Capabilities

PIOs have a need to report social media activity to those whom they work with during an event, whether it is other team members or organizations. PIOs described copy-and-pasting online content in an attempt to email it to others, often resulting in awkward formatting and inclusion of extraneous text. They wanted to have the data in a format that was easy to share and work with.

3.2.4 Document Activity

Most emergency response organizations are publically funded in the US and as such they must keep public records of their activity for after-action reports, public accountability, and possible litigation cases. Few tools exist to help in these efforts, and those that do, often capture the data in formats that are inaccessible for non-technical users (such as in a database or json file).

4. THE FINAL PMA PROTOTYPE

PMA is a web application (built using Yii—a PHP web application framework) that supports the social media monitoring, documenting, reporting, and organizing needs of PIOs during emergency events. PMA monitors social media (only Twitter at this time) by collecting and storing tweets based on keywords. PIOs often work in teams and as such PMA supports use of the tool by multiple users at the same time. To use PMA, one must first create an event to monitor. The user then enters keywords to find relevant Twitter messages for that emergency event. Once these keywords are entered and activated, PMA uses the Twitter streaming API to collect tweets that match the provided keywords. After tweets are collected, PMA provides two views—streaming and archive—for viewing and working with these tweets.

4.1 Streaming View

Once a PIO creates an event and specifies search terms, s/he can begin to monitor data in the streaming view. In this view, PMA displays the tweets that match the active search terms (keywords) for the selected event (see Figure 1). The streaming view shows the most recent 20 tweets in real-time. New messages appear at the top of the screen and scroll down with a two second delay.

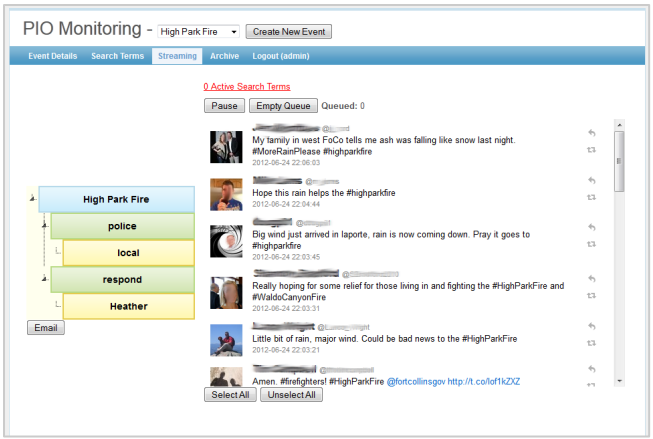

Figure 1: PMA Streaming View

On the left-hand side of the streaming view, users can create categories. These categories are customizable and can be used to sort and store tweets by topic. Users can drag-and-drop tweets into these categories. In addition, categories can have sub-categories. To indicate a hierarchical relationship, a sub-category is indented to the right and appears in a different color than the parent category. When the user clicks any of the categories, the user is taken to the archive view (described below) that displays all the tweets in that category. All tweets in a sub-category also belong to the parent category and therefore they are also displayed when viewing the parent category. Finally, an option available on the category right-click menu is the ability to create a rule.. Rules allow PMA to automatically categorize tweets based on features of a tweet, such as a username or the tweet content. The rule management interface appears as a Pop-up and can be seen in Figure 2. Each rule is comprised of a category to look for tweets within, a category to move the tweets to if they match the condition, and a condition to match, which consists of a string and a place to look for the string (i.e., within the tweet text or the tweet username). Once a rule is created, all new tweets will be tested against it to see if they match the rule's condition and if a tweet matches, it will be categorized in the manner specified by the rule. The rule management interface also has a button labeled "Run Rules Now" which will run the rules against all the tweets currently stored in PMA. This option allows users to apply rule auto-categorization on tweets that have already been loaded into PMA before rule creation.

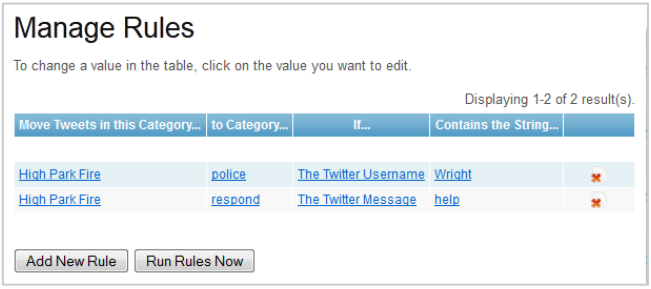

Figure 2: PMA Rule Interface

At the top of the streaming view, clickable text tells the user how many search terms are active. Clicking this status message sends the user to the search terms page. If there are active search terms, the text is green. Conversely, if there are no active search terms, the text is red.

Finally, the PMA streaming view provides an email reporting function. To email a tweet (or several tweets), the user selects the tweets that they want to email and clicks the "Email" button. The email function uses a "mailto" link that opens the default email client for the computer PMA is accessed from and creates a message that the user can send. This reporting option can help PIOs send tweets to others quickly and efficiently.

4.2 Archive View

The archive view of PMA (see Figure 2) allows the user to view all of the event tweets that PMA has captured given the search terms for the event. This interface uses paging, with 10 tweets displayed at a time (this number can be adjusted). Each header row name in the table can be clicked to sort the displayed tweets by ascending or descending order. Below the table header row, a search row appears that lets users enter search parameters for each of the columns: Text, User, Time Sent, and Categories. For

example, if a PIO enters the word "fire" in the Text search field and hits the enter key, the interface will return only those tweets that contain the word "fire." These search and sort features let PIOs perform advanced queries on the collected data, which can help them analyze it.

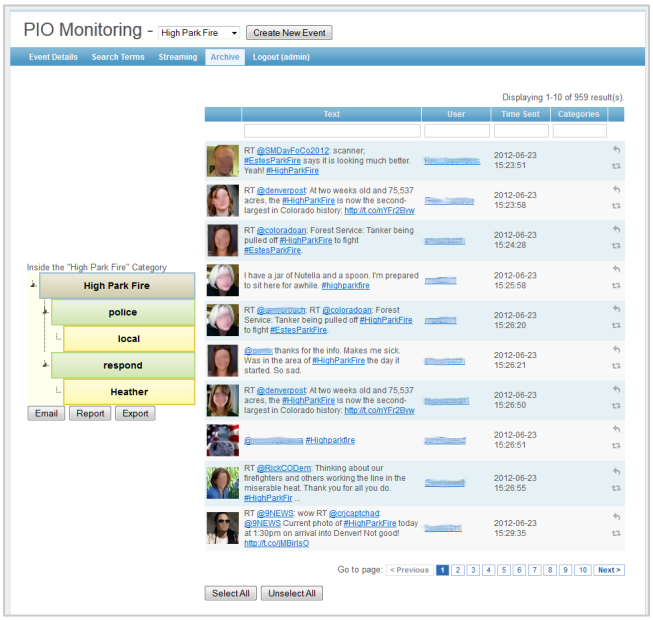

Figure 3: PMA Archive View

For consistency and convenience, the categories work the same way in the archive view as they do in the streaming view. This allows PIOs to categorize messages after an event happens, when they have more time. If a category is left-clicked with no messages selected, it shows the archive view with only the tweets in that category.

4.3 Export and Report Options

Additional features that appear only on the archive view are the export and report options. Clicking the "Export" button creates an Excel spreadsheet with information about each of the tweets contained in the currently selected category. Using this feature, PIOs can create and save a record of the collected tweet data around an event. Further, because the tweet data is inserted into an Excel spreadsheet, the data can be manipulated easily; PIOs can sort, search, and create their own charts, graphs, and statistics.

PMA can also create reports using collected Twitter data. PIOs can click on the "Report" button to automatically generate metrics, charts, and graphs. The report is created as a Microsoft Word file containing various charts and graphs of the 1) top twenty hashtags, 2) top ten twitter users, 3) top twenty retweets, 4) recent twitter activity, and 5) a category breakdown of tweets. An example graph that shows the number of tweets PMA captured by day around the High Park Fire event can be found in Figure 4. Different analyses of the collected tweet data can help PIOs answer questions and demonstrate to their organization how social media is used as well as their value.

A significant advantage of the export and report features of PMA is the quick execution time—usually a matter of seconds. With these features PIOs can export data and generate reports as often as needed and in almost real-time. Previously, these kinds of activities took significant time and effort, so they could not be done frequently. The ability to create and share timely information around social media activity can help PIOs collaborate more effectively with their own organization and other response groups.

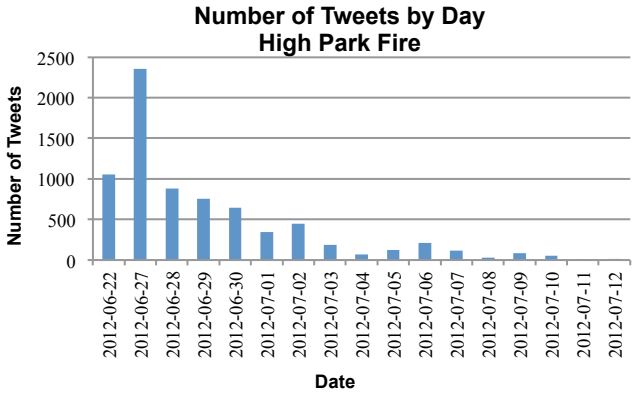

Figure 4: A Graph Generated by PMA that Shows the Number of Tweets by Day Over the High Park Fire Event

5. DESIGN, IMPLEMENTATION & EVALUATION

This section outlines the iterative process used to produce the final PMA prototype just described. This human-centered process comprises 5 cycles to date—with each cycle consisting of a design/implementation phase and an evaluation phase with representative users.

5.1 Cycle 1: Low-Fidelity Paper Prototypes

The design process began with the iterative refinement of five low-fidelity paper prototypes based on the empirical work [12] and participatory design workshop [11] described earlier:

1. *Social Media Template Manager* - a web-based tool that manages social media templates for the most common messages that PIOs send.
2. *Social Media Training Tool* – an application for training PIOs in social media use for emergency management.
3. *Digital Volunteer Coordinator* - a tool that would let PIOs interface more directly with digital volunteers [32] during an emergency event.
4. *History Reporting Tool* – an application that imports social media data around an emergency event and lets PIOs search and create reports using this data.
5. *Twitter Bucket Sorter* - an interface for sorting social media data into "buckets" that are defined by the PIO. The design allows any number of people to sort tweets, making the task less demanding.

5.1.1 Evaluation Procedure

Informally, we sought feedback on these five prototypes from three user interface design experts and five PIOs from the prior workshop. The goal was to discover which prototype(s) best reflected the workshop results and showed potential (i.e., usefulness, feasibility) for further work.

5.1.2 Evaluation Results

The first three prototypes were rejected for further development based on evaluator feedback. The Social Media Template Manager could save time for PIOs when creating social media messages. However, PIO evaluators told us that every event response is

different and usually requires unique messaging; few messages would fit the template criteria. Next, the Social Media Training Tool could help train PIOs in social media use. Still, the effort required to create new training modules, tailor the modules to the different types of PIOs, and maintain this training was estimated to be large. Further, the solution showed little innovation; it simply provides training. Finally, the Digital Volunteer Coordinator sought to support a growing trend in emergency management to utilize digital volunteers [29, 32, 34]. But when shown to PIOs, it was met with resistance—mostly concerns about whether digital volunteers could be trusted. At the time (2012), the tool would have faced slow acceptance, making it hard to find PIOs to assist with the development and testing of the tool.

PIO evaluators identified the History Reporting Tool and the Twitter Bucket Sorter as the most useful prototypes. The ability to document and store social media data around an emergency event is a growing need for PIOs and the History Reporting Tool meets that need. The Twitter Bucket Sorter provided a novel mechanism for sorting and organizing social media data, where available tools lacked this ability. Through exploration, we found that the features of both prototypes could be combined in a single tool.

5.2 Cycle 2: Mid-Fidelity PMA Prototype

In this cycle, we created the PIO Monitoring Application (PMA) that combined the features of the History Reporting Tool and the Twitter Bucket Sorter prototypes. The original PMA prototype was primarily based on the Twitter Bucket Sorter, except the buckets changed to categories that resembled a folder hierarchy on the left hand side of the interface. This hierarchy allowed users to sort Twitter messages into any category at any time. We also created a separation of sorting the data and viewing the data in this prototype. When a user switches to the "View" page of PMA the functionality of the category tree on the left of the page changes. Instead of showing only those messages that are waiting to be categorized, it shows all messages that are contained in the current category. When PMA is in the "View" state, the user can export the collected data and create a report; this functionality came from the History Reporting Tool.

After constructing a low-fidelity paper prototype of PMA, we built a mid-fidelity digital version. Though the functionality was limited and often incomplete, this digital prototype allowed PIOs to experiment with PMA—creating categories and sorting tweets—which generated much discussion and feedback.

5.2.1 Evaluation Procedure

We tested the mid-fidelity PMA prototype with eleven PIOs recruited from a state-wide PIO organization. This testing not only evaluated PMA functionality, but also explored whether the underlying idea of sorting information is helpful to PIOs. Test sessions were video recorded and lasted approximately one hour at the PIOs' place of work. Each session began with a background questionnaire. Next, we asked the participants to perform several tasks while thinking aloud [17].

The first task—a card sorting activity [15]—was designed to show how PIOs filter and sort information and to test whether sorting information supports PIO practice. For this task, we created a stack of 50 business cards; each card had one Twitter message printed on it from a recent wildfire event. We gave the stack of cards to the participant and asked him/her to look at each card and read the message out loud. After reading the message, s/he was asked to organize the cards into piles that made sense to him/her. As the piles of messages became more defined, we encouraged the PIOs to assign labels (written on post-it notes). For the next task, participants tried different ways of interacting with and categorizing emergency tweets using the PMA prototype. We first showed the participants how to create their own categories and then instructed them to sort the tweets by assigning each tweet to a category. Finally, we provided PIO participants with several lists of tweets that corresponded with different categories, and asked them what they would do with the information. The aim of this task was to discover how PIOs might use information once it had been categorized using PMA.

During analysis, we captured all the PMA suggestions, critiques, and ideas for improvements. We also analyzed the card sorting data by looking for patterns and significant groupings across participants.

5.2.2 Evaluation Results

Overall the response to PMA was positive. PIOs were excited by the ability to collect tweets around an emergency event and export those messages into an Excel spreadsheet that could be archived or shared with others. Few tools exist that provide this capability, and those that do are paid services which most organizations cannot afford. Though the ability to create a report was not functional in the prototype, participants could still see the value in creating reports from the data they collect.

Creating Category Schemes. While there were similarities across the category schemes developed by participants, every scheme was different. For instance, different Twitter messages were deemed more or less important depending on the type of PIO that was looking at the message. This finding supports the design of PMA in which users can customize their category schemes. However, some participants were unsure what categories to start with. These participants wanted to have a categorization scheme developed by someone else that they could then modify to fit their needs.

The names PIOs chose for categories during the card sorting exercise and the prototype testing proved to be a powerful organization method that aided in sensemaking [43]. A common organizing method was to categorize tweets by the agency that sent them. While other participants named categories with the name of a coworker or an organization to which they wanted to route tweets for processing. Another method involved naming a category to describe the physical action that the participant wanted to take on the message (e.g., call someone, reply to, verify, and follow up). A couple of PIOs created a "retweet" category where they placed important messages that they wanted to retweet.

Evaluating Tweet Content. Trust was important for PIOs when deciding how to process tweet information. Most PIOs looked at the Twitter account associated with a tweet to determine if the information could be trusted. Since data from real local events were used in testing, sometimes a PIO would recognize a Twitter account as belonging to an organization or person that s/he had worked with before. Previous experience could then be used to judge whether the information was trustworthy. When the Twitter account was not recognized, PIOs relied on other mechanisms to determine whether the information could be trusted, such as checking the Twitter account profile associated with the message or contacting the user of the account directly.

Adapting the Sorting Task to Practice. The PMA mid-fidelity prototype forced users to categorize tweets before more tweets could be retrieved. During testing, we discovered that this method

of categorizing tweets prevented PIOs from effectively monitoring Twitter data. If the Twitter stream moved quickly, PIOs would get a backlog of tweets that needed to be sorted before they could view the most recent tweets. Further, sometimes PIOs did not want to do anything with a tweet, but the prototype design kept the tweet in the interface as long as it was not categorized, preventing a new tweet from taking its place. To work around this restriction, some PIOs created a "discard" category where they could drop tweets they didn't want to handle. Based on these findings, we significantly redesigned the prototype.

5.3 Cycle 3: Usability Testing with High-Fidelity Prototype

Using feedback from Cycle 2, we refined the mid-fidelity prototype and started moving toward a functional high-fidelity prototype. This new prototype has two modes (streaming and archive) and operates in much the same way that the final prototype does (described above). We also modified the appearance of tweets in PMA to include more information about the sender of each tweet. In addition, we added the ability to reply to a Twitter message so that PIOs could easily contact the source of each tweet. We also added the ability to retweet a message.

5.3.1 Evaluation Procedure

We recruited seven new PIO participants from a state-wide PIO organization to step through a set of tasks designed to test and improve the usability of PMA. Each test session lasted approximately one hour.

Before testing PMA, we asked each participant a few questions about their background to better understand their experience and skill level as a PIO. The interface testing component began with a brief overview of PMA's features, following which, we gave each participant a list of tasks to complete using PMA. Tasks focused on testing the major features. The session concluded with a short interview to better understand the PIO's experience with the application and whether they would use PMA for their work.

PIO participants were encouraged to use the think-aloud method [17] as they stepped through the tasks. We observed the participants and took notes as they completed the tasks. Sessions were audio-recorded for future reference and analysis.

5.3.2 Evaluation Results

This usability evaluation of PMA yielded many user interface issues. We organize these findings by the different tasks that PIO participants were asked to perform.

Creating Search Terms. Participants liked the ability to create as many search terms as they needed. Most PIOs finished this step with little difficulty, but there were several questions about how to construct the search terms. For example, participants wondered if they should include the "#" symbol when searching for a hashtag.

Using the Live Streaming Mode. PIOs found the features associated with each tweet helpful. Study participants also appreciated that usernames were clickable and would open the Twitter profile of that user. When investigating a tweet of interest, PIOs wanted to know more about the sender and providing a quick link to the sender's profile helps them do this. All URLs that appear in tweet messages are clickable as well. The information provided in these URLs is publically available so PIOs want to be sure that it is accurate. Finally, PIOs were asked to experiment with pausing and resuming the live stream. PIOs saw value in this feature because there were many times when the tweet stream moved too quickly for them to process in real-time.

Creating Categories and Categorizing Tweets. The ability to create their own categories let PIOs customize the interface to suit the particular needs of their organization and the events to which they respond. However, when dragging a tweet over a category, participants found that the highlighting of the category did not change, which made it difficult to know if dropping the tweet in that location would place it in the desired category.

Creating Rules. The rule feature can help automate categorization and speed the social media organization and sense-making processes of PIOs. A common scenario for using rules that many PIOs identified as useful during testing is to help them extract messages about their own organization. Once all the messages from their organization are in one category, they can simply export the messages into a file that they can store as a record. Rules can also be helpful if there is a particular user or key word within their search results that a PIO wants to watch.

PIOs encountered several problems with the Rule Management interface. First, PIOs expected to enter values for a new rule before it was created, so it was confusing that a default rule was created that they must then edit. Second, participants were unsure how to edit the rule values in the table, despite instruction provided at the top of the interface. Third, the editing capability was unreliable; participants usually had to click on a value several times before they could edit it. Finally, once a participant changed a rule value they were required to push an "OK" button that would save the changes. Often participants lost their changes when they navigated away from a field without clicking the "Ok" button.

Using the Archive Mode. In archive mode, users can search collected tweets for the current event by entering search parameters in the text boxes contained directly under the table header row. Most PIOs understood how to use the search capability without explanation and all PIOs found basic searches easy to perform. Some wanted to perform complex searches, however, which proved difficult. For example, several PIOs tried to enter a time or date to search by and were unsuccessful because they had not entered the query in the correct format.

Exporting. All PIO participants reported liking the export feature and wanted to use the resulting Excel spreadsheet as a record of Twitter activity. During one test session, a PIO participant chose a particularly active search term and by the time they got to the export task, PMA had collected over 20,000 tweets. PMA's export function failed to create a spreadsheet, which was concerning because relative to other emergency Twitter data sets this number is small. This issue is part of a larger set of concerns around the scalability of PMA that we address in a later cycle.

Reporting. PIO participants liked the ability to generate reports as often as they like using the most recent collected data. They imagined creating daily or even hourly reports to share with their team. Also, because this report is generated as a Microsoft Word Document, one PIO saw the potential to enhance the report by inserting her own commentary and interpretations of the data.

5.4 Cycle 4: Field Testing with High-Fidelity Prototype

We improved the PMA prototype based on the usability results of the previous cycle. Changes included making the creation of a new

event and the rule management interface more intuitive, as well as improving the contextual help.

5.4.1 Evaluation Procedure

For this study, we wanted to understand how PMA might be used in a contextual setting. The field study took place at an emergency operations center (EOC) in Denver, Colorado, during a difficult wildfire season for the state of Colorado. Four PIOs (a complete sample) participated in this field study. We sat next to each PIO for a one-on-one session where we demonstrated PMA and its features. PIOs were then asked to use PMA while we observed them. The length of observation varied by participant (between 15 and 30 minutes). Conducting these sessions was sometimes difficult because the PIOs had responsibilities that drew their attention away from using PMA.

Throughout the study, we took extensive notes using a datasheet developed beforehand and we audio recorded each of the one-on-one sessions. We also took photos of the EOC workspace. To organize and group notes from the session, we used the affinity diagram method [3].

5.4.2 Evaluation Results

Overall perceptions of PMA were positive. All PIOs stated that they would use the tool and that it provides a significant improvement over current practice.

Supporting Analysis. Within the context of the Colorado Wildfires, PIOs found several ways PMA could help them analyze the social media data they were monitoring. One PIO stated that when examining social media data around an event, she is usually trying to answer a question. For example, "What are the public's concerns around fire containment?" To answer this question, she her team would need to capture relevant information and then query for keywords like "containment." She was excited that PMA's tweet collection and search features would allow her team to perform this type of analysis.

Another PIO categorized the tweets she monitored around sentiment so that she could analyze how members of the public felt about the Colorado wildfires. She created categories such as "angry", "sad", "confused", and "grateful" and dropped tweets into these categories. She explained how organizing tweets in this manner would help her understand the public's response to the event and their perceptions of the messages she released as a PIO. She could then shape future messages to address the mood of the public. She also imagined creating a report that would chart the sentiment category tweets.

Another PIO was proficient in Excel. When she saw that PMA could export Twitter data into an Excel spreadsheet, she knew she could create graphs and statistics from this data that would help her analyze the event's Twitter traffic.

Supporting Documentation. PIO participants described the cumbersome and inefficient ways in which they currently captured social media activity. One PIO used a screen capture tool to document the tweets she sends during an event. The resulting screen shots are stored in large pdf files that are difficult to parse and read. Another PIO described how several members of her team worked full-time for two days taking screen shots of social media activity following a recent event.

PMA lets users collect Twitter messages around an event and export these messages into an Excel Spreadsheet that can be used for documentation. All PIOs noted how simple it was to document tweets using PMA and how much time such a capability could save.

Supporting Reports. The PIOs in this study were assigned to the EOC team because each was seen as a social media leader within his/her respective organization. Interestingly, despite a proven track record of successful social media use, these PIOs still felt they had to prove the value of the technology. Not only would PMA's reporting function save PIOs significant time by automatically generating metrics, charts, and graphs, but it would also help them convince management of the usefulness of social media.

Participants shared many ideas about the types of metrics they would like to see in the PMA social media report. One metric is the number of people who potentially saw each tweet they sent during an event (also known as the tweet reach). PIOs also wanted to see how many times each tweet was retweeted and which messages were retweeted the most. One PIO wanted PMA to report how often keywords that she specifies appear in collected tweets.

5.5 Cycle 5: Usability Testing with Final PMA Prototype

By this point, PMA had seen many improvements; however, its use by PIOs in the field was still limited. When the number of tweets collected reached roughly 50,000 messages, creating reports and viewing live message streams became difficult—often causing the application to error or timeout. Further, PMA was running on a small webserver that did not scale well with heavier use. These limitations made PMA hard to use outside of a controlled setting. Thus, to increase PMA's data scalability and deployability, we made significant enhancements to PMA during 2014 and the spring of 2015. These enhancements include optimizing the database configuration and queries, streamlining report generation algorithms, fixing remaining usability issues found in Cycles 3 & 4, and moving the application to use Amazon Web Services.

5.5.1 Evaluation Procedure

We ran a series of tests to measure how the performance improvements we made to PMA improved system response and scalability and decreased the time to generate reports on large data sets. Then we conducted a usability study to verify these changes using the same procedure described in Cycle 3. Three new PIOs were recruited from a state-wide PIO organization to participate in this study.

5.5.2 Evaluation Results

In this most recent testing (2015), we found that PIOs still struggled with using Twitter, particularly archiving and reporting information found there. Thus, we still found a strong need for PMA. The performance tests showed marked improvement in PMA's report generation feature. Reports that used to take more than 30 seconds to generate (the point at which PMA would timeout), now take less than 1 second. Overall, the participants in the usability study found the application intuitive, but some of the features were not always understood.

Creating an Event. The names of some of the fields were confusing and did not help the user understand the fields' purpose. The participants found that some of the form fields to create an event were ambiguous. One participant did not understand the format of the information to be entered in the "location" field. All

participants did not know what to do with the "summary" field on the create event page.

Setting Search Terms. One participant could not determine how to edit a search term, as there was no "Edit" button like there was a "Delete" button. Editing the search term by double-clicking was not intuitive for that participant but was understood by others.

Reporting. All participants liked the reporting feature and the parameters provided for generating reports. However, one participant suggested that an hourly report for the "Twitter Daily Activity" report feature would be helpful.

5.6 Overall Evaluation Findings

Not only can PMA help individual emergency PIOs with their social media needs, but it can also help the larger PIO community. One participant shared how many PIOs are struggling to manage their current duties. It can be overwhelming for these PIOs to adopt social media into their communication plan because it can require resources and skills that they do not have. Other PIOs are using social media but they only have bare minimum support. This participant expressed the belief that PMA could provide these PIOs with the tools they need to make social media manageable and possibly even efficient.

5.6.1 Unexpected Use

At the conclusion of each test session, we asked the PIOs if they would use PMA and if so, how. All PIOs responded that they would use PMA—some even asked when they could begin. Most of the ways these PIOs imagined using the tool have been covered in previous sections; however, we describe two uses of the tool that we did not expect below.

The first use came from a PIO who imagined using PMA everyday (during emergency and non-emergency times) to track tweets that refer to his organization. He wants to understand how people talk about and refer to his organization and learn from it.

The second use came from a PIO who had acted as a representative for the family of a shooting victim. This PIO helped the family respond to media requests and understand what they could and could not talk about given the pending criminal case against the shooter. Because the case was high profile, the PIO received nearly 300 media calls per day at one point. The PIO talked about how PMA could monitor and archive the positive things people shared about the victim over Twitter, and a record of these messages could then be given to the victim's family.

5.6.2 Desired Features & Future Work

The most requested feature was to add support for more social media platforms. We began with Twitter because it is the most accessible platform (i.e., data is available through a public API and messages are 140 characters or less) and we know from past research that it is used in emergency events [8, 38, 42]. We plan to add this support in the future.

Several suggestions centered on the search options for collecting tweets. Some participants wanted to perform complex search queries, such as searching by date, location, or Twitter username. Other participants wanted to search by geographic region. Another frequently requested feature was the ability to perform a back-in-time search for each newly activated search term. A back-in-time option would allow PIOs to collect previous Twitter activity that matches their search terms even if it occurred before they activated the search. PMA could use the Twitter Search API to accomplish this task.

Finally, a natural extension of this research would be to make PMA publically available for anyone to use. Once this is done, a prolonged study of PMA use by PIOs in real-world settings could take place. Though all PIOs in this research claimed they would use PMA, an extended study of their use would reveal if PMA continues to meet PIO social media needs beyond initial adoption. This type of study would also likely provide insight into the operation of emergency management organizations and the changes that result to that organization from the use of PMA.

6. DISCUSSION

In this research, we employed a human-centered approach to design and development. This approach advocates that to create technology that meets user needs, the target users must actively participate in the design and evaluation process; therefore, we involved the study subjects—PIOs—at every stage of this research. As we built prototypes, we consulted with PIOs to ensure that the proposed tools met their needs. We also involved PIOs in the testing and evaluation of PMA at various stages of development. This paper documents the results of this human-centered, longitudinal design and development effort. Contributions include the design, development, and evaluation of PMA, suggestions for how to conduct human-centered research with emergency responders, as well as insight into how social media is changing PIO work practice.

6.1 Obtaining Research Access to Events

When an emergency event occurs, emergency responders (such as PIOs) are often overwhelmed. Thus, during an event is usually not the time to establish new relationships and embed oneself in the response effort as a researcher. Further, responders are unlikely to use untested and unproven tools during this time, nor to spend the time to be trained in their use. A better way to obtain research access to an active emergency event is to establish and maintain relationships with emergency responders beforehand. Our strategy has included training and becoming certified to act in the PIO position as well as participating in local emergency exercises. Unfortunately, due to these challenges, PMA has yet to be tested in a highly realistic non-supervised setting. We are currently pursuing this type of testing as a next step for this research.

6.2 Balancing the Researcher Role

A human-centered research approach necessitates close researcher and participant involvement. During this research, we developed friendships with many of the participants, which sometimes made it difficult to maintain an objective perspective. On the other hand, building rapport with participants offered benefits, such as access to protected research sites and increased willingness to participate in research activities.

Because we are PIO researchers, we sometimes found that PIOs looked to us as experts on their work; they did not necessarily trust their own experience as a valid perspective. We tried to combat this issue by encouraging PIOs to share their experiences, and we only related opinions or the experiences of other PIOs when deemed necessary.

Finally, at times PIOs were less critical of PMA because they knew we had created it and they did not want to offend. We assured participants that we would not be upset by their comments and that we needed their constructive comments to improve the tool. Also, because PIOs knew we had created PMA, we often felt pressured by PIO participants to make PMA available as quickly

as possible and to create custom features that would benefit the specific needs of one PIO.

6.3 Reflecting on Changing PIO Practice

Conducting these evaluation studies offered new insight into the many ways PIOs could use PMA to support their work. PIOs shared examples of how PMA could be used in all types and sizes of emergency events. Participants also provided insight into how PMA could be used as a tool for analysis among multiple emergency responders. Before conducting these studies, we thought that much of the advantage PMA offered over other applications was to facilitate the task of sorting tweets into user-defined categories. These studies revealed, however, that the biggest advantage of PMA lies in its ability to analyze, document, and report tweets once they have been sorted.

These abilities play a major role in a PIOs capacity to create and collaboratively construct important information for the public during an emergency event. The ability to document and report social media activity around an event also plays a role in helping PIOs bring social media data to response organizations in an actionable and accessible way.

We found that the most popular features of PMA reflect the current state of emergency management—a kind of probe for understanding PIO needs in a changing socio-technical environment. For example, interest in PMA's documentation feature reflects how PIOs are struggling to find ways to effectively document and share social media activity within their organizations. The ability to create reports was also a popular feature and reflects how PIOs are facing pressure within their organizations to prove the value of social media through statistics and reports.

PMA is a unique application that fills the specific social media needs of PIOs in a way that no other single application currently can. Though the tool is simple, it has the potential to simplify and ease the transition as PIOs work together to incorporate social media into their response efforts.

7. CONCLUSION

In this research, we designed and developed a novel application—grounded in empirical understandings of PIO work—to help PIOs monitor, analyze, document, and report social media data around an emergency event. Using a human-centered approach, PIOs participated in the exploration, design, and evaluation phases of this research, resulting in an application (PMA) that all participants claimed they would use. Using social media in current PIO work practice requires a different set of skills and tools than before to manage and perform required tasks. PMA helps to ease the transition as PIOs learn to use and adapt social media and, as such, helps them perform their jobs more effectively in a changing technical and institutional environment.

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