Designing for the Deluge: Understanding & Supporting the Distributed, Collaborative Work of Crisis Volunteers

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ABSTRACT
Social media are a potentially valuable source of situational awareness information during crisis events. Consistently, "digital volunteers" and others are coming together to filter and process this data into usable resources, often coordinating their work within distributed online groups. However, current tools and practices are frequently unable to keep up with the speed and volume of incoming data during large events. Through contextual interviews with emergency response professionals and digital volunteers, this research examines the ad hoc, collaborative practices that have emerged to help process this data and outlines strategies for supporting and leveraging these efforts in future designs. We argue for solutions that align with current group values, work practices, volunteer motivations, and organizational structures, but also allow these groups to increase the scale and efficiency of their operations.

Author Keywords
Civic participation; crisis informatics; crowdsourcing; digital volunteers; disaster response; machine learning; natural language processing; social computing.

ACM Classification Keywords
H.5.3 Groups & Organization Interfaces—collaborative Computing, computer-supported cooperative work

INTRODUCTION
The converging trends of mobile computing, social media use, and citizen reporting have precipitated a rich and potentially valuable new stream of information during crises [24]. During natural disasters and other mass emergency events, social media data have—among other uses—become a source of real-time, first-hand information.

Research suggests that this information could help improve situational awareness for affected people, aiding them in making better decisions [37]. For example, after a hurricane, knowledge about the locations of downed power lines could help individuals avoid hazardous areas. Individuals stranded by high water could use social media to connect with nearby neighbors who have extra supplies or a safe means of transportation.

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This information has potential value for formal response efforts as well. Emergency managers (EMs) and first responders are increasingly considering strategies for leveraging it for their own situational awareness [12;15;31]. However, there are several difficulties in utilizing these new information streams, including the massive volume of available information after events and the fact that much of the data can be considered noise [33].

In recent years, some research and development efforts have focused on building tools to help people process this information, e.g. TweetTracker [14], Geofeedia, and Crisis Tracker. Related research seeks computational solutions for automatically processing social media data, using algorithms to classify and filter the streams [2;13]. The ongoing research program outlined by Meier [20] examines the potential for automatically processing tweets using machine learning classifiers.

Another approach to addressing the information-processing problem can be seen within the emerging phenomenon of *digital volunteerism*. Digital volunteers are unaffected individuals who use social media and other online tools to assist in disaster response efforts, often taking on information-processing tasks, e.g. filtering and mapping crisis-related social media data [34]. After disaster events, digital volunteer efforts often *emerge* [3]—i.e. groups of remote volunteers (and often locals as well) come together and self-organize response efforts [34]. This work has sometimes been referred to as *crowdsourcing* [6]. However, it is worth noting that these collaborative efforts are less like the microwork variety of crowdsourcing (i.e. that enabled by Amazon's Mechanical Turk) and more like the Open Source roots of that term [10].

Recently, ongoing communities of digital volunteers have taken shape (e.g. CrisisMappers, the Standby Task Force, CrisisCommons) and a few groups have established non-profit organizations for their work, (e.g. Humanity Road). In the realm of formal emergency response, another organizational form, the Virtual Operations Support Team (VOST), was created to address challenges related to information overload [38]. VOSTs are distributed teams of volunteers who assist emergency managers in information processing and communicating during disasters [32;38].

Digital volunteers often work collaboratively, initially improvising and later formalizing and sharing work practices within and across groups [34;35]. A core task of many of these efforts is *media monitoring*— monitoring incoming feeds, including social media posts, to find new, relevant, actionable information. Volunteers often work to assemble—or *curate*— this data into usable resources.

Through this research, we seek to gain insight into how emergency managers and experienced digital volunteers currently curate social media data during crisis events. We conducted contextual interviews with emergency managers and experienced digital volunteers to (1) assess commonly used tools for monitoring a disaster and finding relevant social media posts; (2) assess commonly used tools for collaborating during a disaster; (3) understand processes for collaborating in this space; and (4) gain insight into participants' motivations for doing this type of work. We report on common themes, concerns, and insights from our interviews and suggest implications for design motivated by these findings.

Our research outlines a complementary approach to the computational solutions recently put forward by Meier and his colleagues [1;13]. Evidence suggests that machine learning classifiers will need training and re-training across event types and event stages [36]. We also argue that the output of these algorithms will need human validation and interpretation to be usable for decision-making in safety-critical situations. This research points to a strategy that integrates these computational tools into the existing and evolving work practices of digital volunteers and distributed teams of emergency managers.

BACKGROUND AND PREVIOUS WORK

Social Media and Crisis Response

Research studies show people turn to social media sites after disasters to look for and share information [e.g. 25;27;30], to help coordinate response efforts [29;34], and to collectively make sense of the event [9].

Twitter as a Crisis-Reporting Platform

Several affordances of the Twitter platform, including the short message format and the public searchability of tweets, make it particularly useful in the crisis context. Vieweg et al. [37] report that a significant percentage of tweets sent during disasters contain information that could contribute to situational awareness, and evidence suggests that some emergency responders are turning to this platform as a potential information source, as well as an outgoing communication channel, during events [12].

Photo-sharing Sites

Eyewitness photographs taken on mobile phones and shared through photo-sharing sites like Flickr and Instagram are another potentially valuable information source [18], providing near real-time evidence of damage and emerging hazards.

Making Social Media Data Useful

Though social media are enabling new information-sharing behaviors and providing a potentially valuable information source during disaster events, significant challenges remain in converting the tremendous stream of social media data into usable bits of information [2]. Affected citizens and emergency managers have limited capacity for analyzing this data during events. Considering these new information streams, responders complain of having to "drink from the fire hose" [6].

Disaster events often spark online convergence events, where people—locals as well as remote "participants" from all over the world—come together to make sense of the event [11], generating a large amount of data, much of which can be considered noise. Even for the subsection of the data that is on-topic and relevant to response, only a small fraction is new information coming into the space for the first time [33]. Misinformation is another significant problem with this data, and was cited as such after Hurricane Sandy [4].

A final aspect of the information-processing problem relates to the unstructured nature of social media data. Though many posts have some metadata (e.g. timestamps, author details, and geo-coordinates for tweets), the primary content of status updates and photos is "unstructured" and requires significant processing to get it into standard formats for analysis on a large scale [6].

Computational Solutions for Automated Processing

Researchers have proposed a number of computational solutions to filter, classify, or process incoming tweets. As the amount of social media data generated during disasters increases, automated means of processing this data become increasingly desirable. Solutions that leverage natural language processing (NLP) or machine learning (ML) could help cull, verify, and categorize Twitter posts.

Meier and others have proposed a "Twitter Dashboard" to support automatic tagging and filtering of incoming tweets [21]. Automated techniques can identify tweets posted by an eyewitness, including photos or video, communicating caution or advice, contributing to situational awareness, or otherwise containing informative content [2;13;23;36]; however, these classifiers only achieve high accuracy when trained on posts from the same or a similar event [36].

Most of these techniques identify tweets with around 80% accuracy and precision compared to manual work; the maximum precision was 90% for a classifier trained on data from the same event [13]. While these accuracies and precisions seem high, they may privilege certain types of information—possibly information that is already known—over others. For example, an ML tool may find that tweets containing URL links are more likely to be relevant, which could mean that citizen-reported "nuggets" will be missed. Additionally, all of these are post-hoc analyses; there are currently few tools for real-time processing.

Digital Volunteerism

Catalyzed by the challenge of making citizen-reported information usable, and enabled by online tools that allow them to access this information and coordinate their work with others, digital volunteerism has quickly become an established feature of crisis events [35]. Palen and colleagues have connected this new phenomenon to well-established patterns of "convergence" and "spontaneous volunteerism" that are known to occur after disaster events [11;26;34]. Digital volunteer work currently takes place within a handful of different organizational forms.

Emergent Organizations of Digital Volunteers

Empirical research on historical disaster events shows response efforts taking four different organizational forms: established, extending, expanding, and emerging [3]. Emerging organizations are ones that have no pre-existing structure and come together as individuals who begin to connect and coordinate their work [3]. Starbird & Palen characterized a group of digital volunteers who came together on Twitter and attempted to provide remote assistance after the Haiti earthquake as an emergent organization [34]. Similar groups of Twitter volunteers formed after the Alabama and Joplin tornados in 2011 to help in relief efforts. Following Hurricane Sandy, communities in New Jersey turned to Twitter to help locate open gas stations, and digital volunteers played a role in connecting those seeking information with those who had it [19]. These examples suggest that emergent organizations of remote actors connected through social media are now a feature of the disaster response milieu.

Ongoing Virtual Volunteer Organizations

Though many emergent groups dissipate as relief efforts wind down, some virtual volunteer groups have established an ongoing presence with a more formalized organizational structure. CrisisCommons, CrisisMappers, the Standby Task Force, and Humanity Road are all examples of virtual organizations that attempt to use online tools to provide remote assistance during disaster events. Most of these groups can be considered *expanding* organizations—ones that have an established structure between events, but increase capacity for response during events by activating part time volunteers and bringing in new ones [35].

Ziemke provides a high level description of "crisis mapping" and outlines the structure, role and mission of groups like CrisisMappers and the Standby Task Force who have developed an ongoing presence in virtual disaster response [39]. Starbird & Palen [35] offer a detailed account of the organizational structure and evolving work practices within the Humanity Road organization.

Virtual Operations Support Teams

The concept for Virtual Operations Support Teams (VOSTs) originated in 2011, developed by emergency manager Jeff Phillips [38]. VOSTs seek to integrate distributed teams of "trusted agents" (often other emergency response professionals) into emergency monitoring and response by establishing volunteer teams to monitor social media, manage communication with the public, and handle other matters than can be dealt with remotely; notably, VOSTs conduct both information processing and outgoing communication. VOSTs utilize remote volunteers, some of whom are professional EMs, and serve to connect emergency management and digital volunteerism.

> *Beth (emergency manager & VOST leader): "A VOST is different from a digital volunteer because it has a pinpoint, an internal connection to an emergency operation."*

VOSTs arose from a need to address information overload, as emergency managers struggled to deal with an increasingly tech savvy public communicating via social media. The cooperative, distributed work of VOSTs melds together professionals and volunteers, as well as disaster response veterans and relative novices. Early leaders within the VOST community shaped the idea around existing volunteer-based disaster response structures, including Voluntary Organizations Active in Disaster (VOADs) and Community Emergency Response Teams (CERTs). A VOAD is a group of individuals and organizations who work to share knowledge and resources during crisis events. CERTs work to bring together and train individuals to be active in emergency response within their community.

Existing Tools that Support Crisis Curation

Those monitoring crises online often use client applications designed for general use, but a few tools have been developed specifically for crisis monitoring, including *TweetTracker*[1]*, Crisis Tracker*[2]*, Geofeedia*[3]*, Ushahidi*[4]*, and SwiftRiver*[5]. These tools support manual monitoring of Twitter data through filtering and labeling tweets, mapping and data visualization. A few provide some computational analysis. Though many of these tools have overlapping functionality, no tool fulfills the needs of every crisis monitoring group, and many are in limited use or remain at various stages of development.

METHODS

We designed our research study to assess the work practices of people who have worked to remotely process social media streams during crisis events either as digital volunteers or as emergency response professionals. Our methodology reflects dual goals of understanding the work practices of these individuals and the groups within which they work and of designing to support this activity.

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[1] http://tweettracker.fulton.asu.edu/

[2] http://ufn.virtues.fi/crisistracker/about.php

[3] http://corp.geofeedia.com/

[4] http://www.ushahidi.com/

[5] https://swiftapp.com

Contextual Interviews

We recruited participants for this study using Twitter posts with the hashtag "#SMEM" (Social Media in Emergency Management). This hashtag is used to organize conversations within a growing community of Twitterers interested in the use of social media for emergency response, including emergency managers, humanitarian response professionals, and digital volunteers. Nine individuals participated in this study—six emergency response professionals (i.e., individuals connected with official response in a particular geographic area) and three digital volunteers. Most of the emergency managers interviewed also act as digital volunteers for events outside their jurisdiction.

The two-hour interviews were conducted in our lab (two interviews), on-site at the participant's workspace (one interview), and virtually (six interviews). Virtual interviews were conducted via WebEx. Interviews were either audio recorded or a combination of audio recorded and screen captured, depending on the participants' preferences. In all interviews, participants used their own devices—laptops, iPads, and mobile phones.

These were contextual interviews because participants used their own hardware and software tools. Interviews conducted at our lab simulated their mobility and flexibility of working in multiple environments (ex. home, coffee shops, office). To avoid hindering crisis response efforts, we interviewed participants at a time when they were not actively contributing to a response effort.

Interview Structure and Questions

We conducted semi-structured interviews to establish consistency across interviews, plus allow opportunity to drill into emerging topics. Participants were generally enthusiastic and often spoke freely, answering many of our prepared questions without prompting. Thus, each participant fielded questions in a different order and/or context. Participants were asked about their:

- Responsibilities, goals, and motivations in their role as either a digital volunteer or an Emergency Manager
- Workspace and technology devices
- Workflow in a crisis situation, from initial assessment to the end of involvement for an event
- Formal and informal collaborations with others online and on the ground
- Use and perceptions of social media
- Reflections on impact and workload

Throughout the interviews, participants were encouraged to demonstrate and articulate their processes using the think aloud protocol. Researchers were aware of current disaster events and in some cases prompted participants to simulate their processes for an unfolding event.

Monitoring Exercise by Research Team Members

To gain better insight into the experience of conducting social media monitoring, members of the research team also performed a social media monitoring exercise and self-reflection during Hurricane Sandy and during the Pemex explosion and building collapse in Mexico.

Persona	Description
Newcomer	New to group. New to crisis monitoring in general. May struggle with use of social media monitoring tools. May struggle with emotional difficulties of this work.
Local expertise	Gets involved in a specific event because of a connection to the geographic area. Has specific skills related to local expertise (knowledge of language, culture, contacts on the ground etc.) that can help the group. Likely to work on different tasks than other newcomers (i.e. ones that use their special skill set).
Experienced team member	Has already worked remotely on multiple crisis events. Identifies as a part of the team. Often helps mentor newcomers.
Free Agent	Has worked several events, but not always with the same group. Moves from team to team. Shares knowledge and experience across teams.
Team Leader	Determines crisis monitoring tasks. Coordinates shifts of team members. Looks out for team member wellbeing. May delegate tasks (or members might self-select tasks). Corresponds with EMs, humanitarian responders, and other digital volunteer groups.

Table 1. Abstractions of Personas

Human-Centered Design Process

To generate insights from our contextual interviews, we created affinity diagrams. Themes emerged around managing information, collaboration models, and factors influencing workload and gratification. We created detailed personas based on the study participants and collaborators they described in the interviews. Table 1 provides short abstractions of those personas for reference here. These personas are representative of the roles an individual may have within a distributed crisis monitoring group; however, many of interviewees take on more than one role or change roles depending on the event. For example, some participants act as VOST leaders for events in certain geographical locations and volunteer for events in other locales. The participants in our study are not evenly distributed amongst these roles. Most are experienced team members, free agents, and/or team leaders. Newcomers and individuals who participate because they have local

expertise for a specific event were not represented in our sample, likely because our recruiting method reached only individuals who already identified either as emergency managers or digital volunteers. However, there is substantial evidence of these other two personas in the interviewees' descriptions of their co-workers and in existing research [34;35].

Grounded Qualitative Analysis

Finally, we conducted a second round of qualitative analysis. Taking the themes identified through our affinity building activity along with questions we wanted to explore in greater depth, we returned to the interview notes and transcripts with the goal of substantiating and expanding our initial findings. Through this process, we categorized parts of each interview according to the pre-identified themes and design implications that we missed in the initial affinity building exercise.

FINDINGS

Characteristics and Work Practices of Distributed Crisis Monitoring Groups

We interviewed individuals from different virtual volunteer organizations and communities, though almost all had experience working in multiple groups and group boundaries were often porous. Because they were all participants in the #SMEM Twitter community, most of the participants were connected online and had worked with each other (virtually) previously.

Although the groups with which participants affiliated have developed distinct work practices, they have some common characteristics. Interviewees described their activities as occurring in small groups of three to 15 active members. In all of them, members work collaboratively but are geographically distributed. Some, especially VOSTs, have a hierarchical leadership structure, while others try to maintain a more lateral structure. During an event, there is often some kind of "backchannel" conversation among group members—where they coordinate their efforts and collaboratively make judgments about the relevance, importance, or truth of certain pieces of information. Five participants mentioned having a "trusted group" of team members who help process information.

Beyond these shared characteristics, there is a significant amount of variation in work practices due to group leaders' preferences; the nature, size, or location of the crisis; organizational values or structures; or the availability and specific expertise of volunteers.

The Work of Crisis Monitoring

The interviewees' responses, along with our observations of them at work, revealed the process of monitoring social media to be fast-paced and somewhat frantic. Members use a variety of tools and employ sophisticated work processes to accomplish varied goals for monitoring and collaboration. While monitoring, they often have to deal with a tremendous amount of incoming information and manage a large cognitive load to keep track of all the information at any one time.

Individuals monitoring crises use a variety of general-purpose tools, including TweetDeck, TweetGrid, TwitterFall, HootSuite, Bottlenose, and Monitter, with participants in our study indicating different preferences depending on task, familiarity, and expertise. Four of our interviewees explicitly reported that tools must be free (or inexpensive) if they are to be adopted by EMs and disaster response organizations. Two participants mentioned that although Radian6[6] could be a powerful tool, it did not fit in their small budgets.

In explaining their preferences for different tools, interviewees cited features that enabled them to display multiple searches in columns across a page, filter tweets based on location or retweet, create lists of twitterers, save and share searches, color-code search terms, view analytics such as related hashtags or "influential" users, and search for geolocated tweets within a given radius. Some interviewees expressed a desire for a tool that allows users to tag both social media posts and authors, and to share that tagging information with collaborators.

Participants used a number of tools to accomplish a variety of goals. We found that individuals often use various tools for different functions successively, taking the output from one tool and moving it over manually (copying/pasting) to use as the input to another. John, an experienced digital volunteer who works officially as an emergency responder, laid out a sophisticated strategy: first, he identifies the terms that he is "supposed to be looking for" (often using Bottlenose), then he inputs the terms into Twitter, Hootsuite or Tweetgrid for ongoing monitoring. Similarly, Rachel, a technically savvy social media user who is new to online crisis response, initially discovers hashtags on Twitterfall, uses them in Twitter to verify that they are "relevant", and then adds them to her Twitterfall page for continued monitoring. Throughout our interviews, it was clear that individuals monitoring crises use a wide array of tools concurrently to perform different tasks. Beth (emergency manager and VOST leader) commented on the positive effects of this, suggesting information might be missed if all team members are using the same tool.

Some tools are preferred for their ability to enable the monitoring of a large number of streams of tweets, as many interviewees often need to do. John, for instance, uses a 2x3 grid of six different hashtags he follows in Tweetgrid, but will use Tweetdeck or Hootsuite if he is only following one or two hashtags. The work of these individuals often involves monitoring many sources of tweets covering different topics. Beth described how she usually has eight to ten columns open for monitoring in Tweetdeck, and has had

[6] http://www.salesforcemarketingcloud.com/products/ social-media-listening/

as many as 26 open at one time. She also operates at least three different crisis-related Twitter accounts. Another interviewee, Abe, uses nine different Twitter handles for monitoring and communicating during disasters.

Through the research members' experiences monitoring social media during crises during this study, we were able to experience first-hand the stressful environment of social media monitoring. An important factor we noted was the speed with which new tweets came in during a disaster. By the time a tweet had been noted, saved, or otherwise processed, too many more had accumulated at the top of the page to be able to read. Interviewees mentioned that the speed at which tweets pass by while using one application is too fast for them to handle, and that managing information is easier in some applications than in others.

> *Rachel (technically savvy newcomer): "Twitterfall is too much information. It's good for seeing trends and commonality but it's too fast for specific things."*

Working Collaboratively

Emergency monitoring professionals and volunteers do not work in isolation—they often connect with others as they collectively monitor events. Skype and shared Google documents are used extensively for coordination and backchannel communication. Seven interviewees explicitly mentioned using Skype, and six said they use Google Drive documents. Group members discuss the relevance or credibility of certain posts in Skype chat rooms, and have conversations to coordinate tasks and provide emotional support to one another. Google Drive documents are used to schedule shifts, coordinate work, and collaboratively collect and curate relevant data by copying and pasting social media posts and their metadata into spreadsheets.

Verifying Information

All of the interview participants mentioned verifying information as an important part of their work. Rick, whose job involves monitoring social media for information about hyperlocal events, verifies claims made on social media by physically going to the location of the incident (e.g. fallen tree, downed power line). Other interviewees discussed techniques for virtually verifying information, including considering something verified if they could find multiple distinct reports, glancing at the public profile of the person who posted the information to determine their reliability, and searching for other information about the poster's reliability (e.g. a LinkedIn profile).

Division of Labor and Assigning Tasks

Groups have a variety of techniques for determining, assigning, and managing tasks. Some of the interviewees described group practices where leaders define what the tasks are and assign them to specific individuals. Others described work practices that allowed team members to self-select tasks based on their availability and expertise.

A common tactic for dividing work is to split up search terms so that every individual monitors different terms and therefore sees a different set of tweets. Other methods include giving volunteers distinct geographic regions to monitor and having volunteers look for different types of data—e.g. injury reports vs. damage reports.

The work of assigning tasks becomes its own task and leads to more division of labor. Experienced volunteers and leaders determine which searches to do, which regions to cover, and what kinds of reports to monitor, while less experienced volunteers execute those searches.

Working within VOSTs

Within the SMEM community, the VOST concept is growing in popularity. Five study participants act as VOST team members. Three of those work as team leaders, and two of these three are EMs who coordinate VOSTs as part of their official job.

VOST groups have a more hierarchical structure than emergent virtual volunteer organizations and other ongoing digital volunteer communities. This hierarchical structure, along with a related desire for standardization across groups, aligns well with traditional practices in official response. Within VOSTs, EMs serve as the connection between the team and official response. This is an important distinction, as other digital volunteer groups do not always have a formal connection with an emergency response team during an event. Study participants explained that EMs rarely act as leaders for their "own events."

Many VOSTs are established outside of any specific event, often for response within a certain geographic region. When a crisis event occurs or events such as extreme weather are predicted, EMs in those areas can deploy the VOST by contacting their trusted group of team members.

Though some elements of workflow vary across VOSTs, two participants in our study who were affiliated with them discussed a push for interoperability and standardization among teams. In response to this perceived need, VOST teams use "workbooks"—Google Drive spreadsheet templates that leaders can quickly adapt for a specific event. Within these workbooks, leaders specify "missions" for team members based on the EM's requests. The EM also determines how and when the team leader should report back with the group's findings, which might affect how the leader structures or describes missions.

Though their structure is more top-down than other digital volunteer organizations, VOSTs maintain a collaborative, team-oriented approach, reflected in their use of the term "mission" instead of "task." Leaders attempt to foster a sense of work ownership among team members. Compared with other volunteer groups, VOSTs have more people who overlap between different teams, and are growing similar in some of their practices.

Becoming a Digital Volunteer

Volunteers become involved in digital response teams for a variety of reasons. High among the motivators, regardless

of background, is the evident belief that social media and non-local responders can have an impact during crises.

> *Sara (leader of a digital volunteer organization): "So the volunteers, why they engage varies. It may be for their career, it may be to give back to society because they want to pay it forward and they were impacted, or it may be because they have some extra time on their hands… Sometimes it's because they have a personal connection to that area."*

Eight of the participants in our study were either currently employed as emergency response professionals or had previous experience in the emergency and/or humanitarian response domain. However, about half of these entered the digital response space first as a volunteer. Among participants' whose first forays into social media were in an official capacity, three reported that they started using these tools as a means of gauging community opinions and misunderstandings so that outgoing messages could be tailored to specific needs. They then connected with other people in this space already doing digital volunteer work, and two of these individuals became active digital volunteers themselves. All but one participant mentioned having become connected to the community via Twitter through the #SMEM hashtag.

Some volunteers described how they first responded as a digital volunteer for a specific event that they felt impacted them, and then continued on to volunteer with other events. For these participants, their volunteerism was catalyzed by a disaster situation that hit especially close to home—e.g., a crisis in an area where they formerly lived or where they had loved ones.

> *Rick (emergency responder & PIO): "I was active in the week after the hurricane [Sandy], putting out info to my own friends & followers, because it was so close to me."*

Continuing as a Digital Volunteer

The motivations for becoming a digital volunteer are not always the same as the motivations for continuing on as a volunteer. Many of the interviewees described how responding to event after event could produce a kind of disaster fatigue, indicating that continued participation had a significant cost and suggesting that these volunteers must have reasons to keep going.

Altruism is certainly a factor for sustained membership. Making an impact is a related driver. Many interviewees offered anecdotes connecting their work to outcomes on the ground or expressed the frustration of wondering if their work was helpful, suggesting that knowledge of definitive impact is an important motivating factor in continued participation as a digital volunteer.

A related motivation is tied to the formation of an identity as a digital volunteer. Starbird & Palen [34] reported that some volunteer Twitterers after the 2010 Haiti earthquake changed their online profiles to include "crisis tweeter," a reflection of this same effect. Seven interviewees tie their work in the crisis space into their self-identity. For example, Phil, now an experienced digital volunteer and free agent, traces his interest in disaster response back to his previous work ensuring that museums were safe from damage due to disasters and to his involvement in the Ham radio community.

Another motivator for continued involvement may be the personal relationships that volunteers forge with each other. The following quote alluded to the bonds that volunteers form while working together:

> *Sara: "I get a sense for the fact that they [the other volunteers] feel like a family."*

Finally, one community leader suggested volunteers may seek to gain new skills through this work, skills that may benefit them in other areas of their lives or in future disaster (and non-disaster) scenarios.

Some volunteers only participate in digital volunteerism for a short time. Although former volunteers were not included among the participants, we were able to learn about these individuals through the observations of the interviewees. Sara suggested that some volunteers may stop working because the work of social media monitoring is intimidating, or because they had a connection to a specific event that did not carry over to subsequent disasters.

Membership in the Virtual Volunteer Team

Through our interviews with volunteers and personal reflections on monitoring during a major event, we gained insights into the processes, stressors, and challenges of working as a digital volunteer or VOST team member.

What it's Like to be a Team Member

Being a team member in a distributed crisis-monitoring group often involves a great deal of stress. Volunteers try to do the right thing—to complete assigned tasks for their teams or to respond directly to affected people. But to do this often requires filtering through a massive amount of information that is literally moving too fast to process. The information deluge can be stressful in and of itself, a fact that Beth made clear in her remark about a VOST training exercise in 2012: "The Superbowl gave us all PTSD."

In the context of an actual crisis, the stakes and the stress get higher. Volunteers worry that they might be missing things, or that the information they find is incorrect. Additionally, the content of many of these posts can be traumatizing, as social media contain messages about people trapped in collapsed building after earthquakes, images of homes burnt in wildfires, and names of people missing in floods. Beth, an emergency responder and VOST team leader, discussed fears that inexperienced volunteers are unprepared to deal with some of these impacts:

> *"With digital volunteering, we have to switch leaders every four hours. It's more emotionally intense… I see paralysis [among volunteers] when things happen online. People are getting to the emotional brink during the*

event, and we need to evaluate volunteers who aren't emergency responders."

In addition, distributed crisis monitoring can be a lonely experience. Volunteers are rarely collocated, and new volunteers may not yet feel that they are part of the surrounding community. Whereas offline emergency responders have access to a concrete, physical network of individuals around them when they experience something traumatic, digital volunteers are not often afforded this.

Beth: "Partly it's being alone when you're activated virtually … and not really sure how the info's being used. Sometimes they [EMs] get so wrapped up in response that they don't touch back as often as you'd like them to."

Team leaders employ several strategies to ease the stress. For example, Beth maintains a steady schedule of work and break, which she feels discourages individuals from over-exerting themselves. Additionally, virtual volunteer groups organize trainings for new volunteers to help them become more familiar with crisis response and to forestall severe adverse reactions to trauma on the job.

Integrating New Volunteers

An important part of sustaining the virtual volunteer organization is integrating new volunteers into the group [35]. Sara (leader of a digital volunteer organization) reported assigning new members different amounts and different kinds of work—easier tasks that do not require the technical or contextual expertise that experienced volunteers bring to their work. Other interviewees share similar strategies:

Rachel (technically savvy newcomer): "People flagging things don't need to think too much, they're just flagging things… you might be able to pull people in… who aren't being needed right now but don't have a lot of experience in the area."

Since many new volunteers are "spontaneous"—i.e. they only show up after an event occurs—training volunteers before their first deployment is difficult. The interviewees described different methods for utilizing inexperienced volunteers so that they have opportunities to become more included into the group over time. Sara described how this structure helps integrate new volunteers and discussed how the group with which she works has online training "modules" to, in theory, address this problem, but she mentioned these are difficult to keep up-to-date, indicating a low priority and possibly a perceived low utility for this method. Carey and Beth described similar aims to develop structured training materials that can be shared across the entire VOST community:

Carey (EM and VOST leader): "I would like to see us develop something to help train people to do this kind of [social media monitoring] work."

Almost all of the digital volunteer groups and VOST teams described by the participants had an outgoing, broadcast component to their work that accompanied their information gathering and processing tasks. Interviewees, however, pointed out that new volunteers are often not given access to transmit outgoing information, and are instead encouraged to gain a better understanding of the crisis response context before going on to perform this task.

Sara: "When it comes to new volunteers, we don't just put them right behind the seat and let them start driving the car. They're going to be working with the more seasoned volunteers for a while."

Research shows that new volunteers sometimes develop unofficial mentoring relationships with more experienced volunteers [34], a relationship that both provides them a means of learning and helps them become integrated into the social structure of the group.

Continued Learning and Sharing Knowledge

Individuals performing social media crisis monitoring have devised a number of techniques for transmitting work practices and supporting continued learning. One way this is done is through the explicit sharing of search and monitoring strategies. Phil (experienced volunteer and free agent) stated that he creates a series of searches on Tweetgrid and then posts a link to the search page to a shared Skype window during an event so other volunteers can bring up a window with the search terms he defined. Phil also demonstrated how he creates templates for executing different levels of a geographical search—setting up one search within a region with a radius of one mile from a given GPS location, another search with a radius of ten miles, etc. When a disaster strikes, he can quickly access his templates, change the center point for each search, and start monitoring posts from the affected regions. These templates are designed for his future use, but he also suggested that they could be shared with other volunteers. This method of sharing search strategies facilitates work in the moment for less experienced volunteers and also provides them a learning opportunity, but is currently employed by only a few volunteers.

Other sharing of community and "professional" know-how occurs through groups such as the "leadership coalition," a network of VOST leaders from various locations who meet monthly by phone to share tools and skills. Beth (emergency manager and VOST leader) mentioned that she sends out messages to the coalition looking for specific expertise when needed, and described how she and others from her organization engage in local "tweetups," stressing the value of these as places where individuals could participate in a "collaborative learning environment."

Sharing work practices within and across groups can also aid in interoperability between teams. Beth noted that despite her experience with digital volunteerism and VOSTs, it takes her at least 45 minutes to become adjusted and begin working when she joins a new VOST group. This may not sound like much time, but during a crisis, when information is accumulating quickly, it can be incredibly

important. Interoperability is seen as a method for easing this transition between groups.

DISCUSSION

This research investigates the work practices of crisis monitoring teams with the aim of informing the design of tools and platforms to support this work.

Current Work Practices

Currently, digital volunteers and VOST members primarily use freely available, online tools to cobble together ad hoc infrastructures that are extremely flexible and often in flux. Their work is both collaborative and distributed—i.e. they work with others, but they rarely see each other in person. Along with the manual work of monitoring, they currently do considerable work "by-hand" to stitch together the separate pieces of information, such as copying and pasting information into Skype conversations or shared Google documents, which become their work products. Previous research examining how a digital volunteer community works during active events reveals heavy articulation work to coordinate action within textual chatrooms [35], something to which interviewees in this study also alluded.

Distributed Crisis Curation within Communities of Practice

This research supports a view of digital volunteer groups as communities of practice [16, 35] organized around a core group of "trusted" volunteers but with others at the periphery, including occasional and spontaneous volunteers who elect to help in various capacities during an event. By participating in relatively simple tasks, those on the periphery are able to contribute while learning skills used within the group, enabling them to gradually become more involved and move toward the center of the community.

New digital volunteers are often assigned different yet meaningful tasks from more experienced group members. Sara said, "Volunteers are motivated by self-actualization. They want to be masters, they want mastery of their skill sets." Because communities of practice cannot be sustained or grown without new members moving from the periphery to the center, it is vital that systems for collaborative crisis curation are designed to allow inexperienced volunteers to legitimately participate and learn relevant skills.

Motivations for Participating

An important aspect of digital volunteer and VOST work is *why* they do it. This is significant for understanding the capacity of this work, and speaks to the sustainability of these efforts over time [35]. This research reveals, through interviewees' descriptions of themselves and of other volunteers, a variety of motivations for participation. Significantly, it suggests that individuals with previous emergency management experience may enter the space for different reasons—and with different skillsets and expectations—than those who spontaneously volunteer in response to a specific event. However, volunteers from both of these persona types appear to be partially driven by a sense of identity drawn from their activities in the space—a finding that supports Starbird & Palen's account of crisis-volunteering Twitter users [34]. Social interactions with other team members and a growing sense of community are also important factors in ongoing participation.

Designing to Support Distributed Crisis Curation

Repeated evidence of emergent volunteer groups and the establishment of ongoing virtual volunteer communities suggests that people continue to make themselves available to help remotely and participate in information processing tasks during disaster events. During crisis events, there will be workers available to monitor social media and other sources. However, to increase their effectiveness and to accommodate the ever-increasing flood of data, individuals and teams who do this work need flexible tools that allow them to collaborate, coordinate, and sync their work with other people and other platforms in real time.

Our research reveals several design opportunities in this space. Importantly, informed by the empirical findings presented here, we argue for situating solutions within current work practices and infrastructures.

Situating Solutions with Current Work Practices

Digital volunteer work often takes place within communities. Even when volunteers begin alone, many soon connect and coordinate their work [34].

Value Sensitive Design (VSD) emphasizes consideration of stakeholder values when making design decisions [5]. Applying this rationale to the goal of leveraging the capacity of digital workers during crisis events, we identify design solutions that fit the underlying community dynamics, including current work practices, organizational structures, and motivations of digital volunteer work.

In introducing new tools and processes into this work, we risk inadvertently designing out the creative appropriation work that has heretofore characterized these groups. This could have the undesired effect of making them less flexible and less adaptable to emerging needs—a consistent feature of crisis events—and new technologies. In a related vein, one interviewee emphasized the need to use a variety of tools and strategies to get diverse input, saying, "I think that if we prescribe one way of doing things, [the volunteers] will miss things." Additionally, prescribing a top-down work process may have detrimental effects on volunteer motivations. This is particularly true for a process that supports the institutional context of the VOSTs, as equality and lateral organization are valued within digital volunteer communities. Therefore, our design seeks to support current work practices without disrupting the ecosystems within individual or collective communities.

Our research suggests that current communication practices have dual effects: to coordinate action *and* to support the social (and therefore motivational) structure of participation. We therefore situate solutions within an existing, multi-channel communication infrastructure that includes Skype, Twitter, and other tools.

Figure 1 illustrates a potential new system for supporting the work of distributed crisis monitoring teams, highlighting several design implications that emerged from this research. This design represents part of an ongoing research effort, and we are working to develop a usable platform based on it.

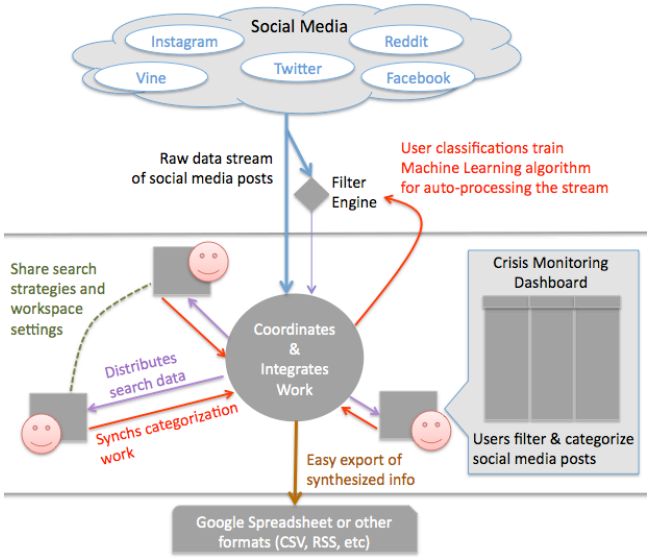

Figure 1. Design to Support Current Work Practices

Crisis Monitoring Dashboard

At the primary point of user-interaction within this design is a Crisis Monitoring Dashboard that enables collaborative monitoring of social media data (see Figure 1). It consists of multi-column streams of tweets defined by search terms, geographic regions, user lists, and more—aligning with similar features in existing platforms that interviewees indicated are popular in crisis monitoring groups. Our design aims to help volunteers collaborate and coordinate by integrating their work within a common data store—i.e. when one user categorizes a social media post, other users will be able to see and work off of that categorization. By making the work of individual volunteers visible to the whole group, this could increase situational awareness within the group, and help less experienced volunteers learn new skills. A central data store also allows for the data stream to be divided into different subsets—e.g. randomly, by search term, by geolocation, etc.—and distributed across the volunteers, which could reduce redundancy and help volunteers deal with information overload.

Shared Search Strategies and Work Space Configurations

Related to the idea of learning within a community of practice, another design idea that emerged from our interviews is a feature that enables easy sharing of search strategies and workspace configurations. Currently, this process involves considerable meta-work, including moving between different tools, and is very time consuming. A collaborative system that enables team members to seamlessly share dashboard configurations (Fig. 1, dotted line on the left) could extend the impact of this technique, allowing members to share new search strategies as event conditions change, and, perhaps more importantly, to help train less experienced workers during events.

Exporting Curated Data in Structured Formats

To facilitate connections between the various applications used by digital volunteer groups, and to help eliminate the time-consuming work of copying, pasting, and toggling between windows, our findings also suggest features for easily exporting "found information" in structured formats. For example, our proposed design includes one-click functionality for exporting social media posts and associated meta-data, including user tags, into shared Google Spreadsheets that groups are already using to coordinate and synthesize (see Fig. 1, at bottom).

Using "Natural" Actions to Train Automatic Classifiers

One promising area of research explores the use of computational solutions, such as automatic filtering and classification tools, to process crisis data during disaster events [2;13;23;36]. Importantly, current solutions require large amounts of "training" data that has been manually classified by humans. Meier, a leader in the online crisis response community, outlines a research program for creating real-time tools for computational processing and advocates using a microwork approach both for increasing the scale of manual classification efforts and to help train automatic classifiers [20]. Microwork is a form of crowdsourcing that distributes small "micro" tasks to an (often anonymous) crowd using small financial or other incentives.

Our research findings support a slightly different approach, one that situates these computational solutions within digital volunteer communities and other distributed crisis monitoring teams. Following Quinn & Bederson's vision of tightly integrating human and machine work in hybrid systems [28], and instead of a microwork approach that attempts to recruit a new crowd using micropayments or other incentives, we advocate designing workflows that take advantage of digital volunteers' current work practices—i.e. algorithms that learn from manual work to filter and categorize social media posts (e.g. the Filter Engine in Fig. 1), perhaps nudging volunteers to do specific categorization tasks as needed. The actions within the system would provide the training data for the machine learning algorithms. We suggest a classifier "fuel gauge" in the shared monitoring dashboard that declines over time and can be "filled" by dedicating a few minutes to a training task—e.g. classifying unmarked tweets as relevant or not relevant, or verifying that a set of automatically classified photos have accurate labels. Importantly, within our proposed design, this classification work is integrated with the "real" work of identifying important posts. Since classification can be seen as an entry-level task that allows new volunteers to productively—and *legitimately* [16]—participate in the team's work while they learn skills,

integrating computational solutions in this way may provide opportunities for incorporating inexperienced volunteers.

Additionally, the products of these machine learning algorithms (the filtered and pre-processed data streams) become input streams for the digital volunteer communities. By providing volunteers with data that has already been automatically filtered and classified, these algorithms could increase their ability to sift through massive amounts of data. In other words, the products of their work have utility to the groups themselves.

Importantly, the work discussed here would be visible and integrated into the community, rather than separated off on another platform or site, and could access the full range of motivations for digital volunteers—moving beyond mere altruism to the sense of community, social connections, identity, and reputation motivations currently driving the more experienced volunteers.

Informed by the findings of this research, we advocate designing a workflow that integrates automatic classifiers and other machine-computational strategies with the rich work practices of digital volunteers. Instead of designing volunteers out, we suggest creating computational solutions that learn from their work, producing an invaluable resource for volunteers and external clients of the data.

CONCLUSION

From interviews with digital volunteers and emergency response professionals, this research examines the current work practices of distributed teams who work to curate social media data during crisis events. We describe the tools and processes currently used by digital volunteer teams to collaborate and work together, as well as their inherent motivations for continued participation in crisis response. From our findings, we identify design implications for supporting this work, including coordinating and integrating the activities of distributed volunteers; facilitating connections between different tools and tasks; enabling team members to share their actions (i.e., making them visible to others) to scaffold learning for less experienced and spontaneous volunteers; and using the current work of volunteers to train machine learning algorithms to increase the scale of their impact.

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