Centralized Crowdsourcing in Disaster Management: Findings and Implications*

Full paper

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ABSTRACT

Computer supported cooperative work (CSCW) has become an important aspect in crisis and disaster management. Volunteers undertaking relief efforts in affected areas are increasingly using information and communication technologies to coordinate their work. Relief organizations are recognizing this trend and have started to adapt new communication channels to interact with citizens. In this paper, we describe the crowdtasking approach, a centralized form of crowdsourcing for crisis and disaster management. We present a prototype implementation of the approach and report on our findings from the system's first field trial. We conclude by discussing implications of this approach for CSCW and community building in crisis and disaster management. Lastly, we give an outlook on future research based on our experience with crowdtasking.

CCS CONCEPTS

• **Information systems** → Crowdsourcing • **Human-centered computing** → Computer supported cooperative work; Empirical studies in collaborative and social computing

KEYWORDS

Crisis and disaster management; volunteers; crowdsourcing; crowdtasking; computer supported cooperative work

1 INTRODUCTION

The ever-increasing pervasiveness and availability of Information and Communication Technology (ICT) in our society heavily influences the way we communicate. This is also true in the context of Crisis and Disaster Management (CDM). Citizens utilize new technologies in order to share information and organize themselves into grassroots movements for disaster relief. This has led to the emergence of informal, self-organized groups of volunteers during disasters and crises. Formal relief organizations are also beginning to see these new ICTs as a useful channel and look for viable ways to integrate them into their volunteer management efforts. These socio-technical developments of communication technologies become especially important when seen in the light of an on-going shift from traditional forms of long-term commitments to a more short-term and situational community engagement (the so called "project-oriented volunteering").

The increased use of ICTs in CDM enables new approaches and solutions when it comes to cooperation in times of crises and disasters. Accordingly, Computer Supported Cooperative Work (CSCW) has become the subject of research efforts in CDM. CSCW research topics in the CDM context include: reasons and applications for the use of social media in volunteer organization and orchestration, enabling interoperability between organizations in times of need as well as the utilization of volunteer potential through new communication technologies. This subject was not dealt with in the CSCW literature so far, especially not with the focus on topologies and crowdtasking workflow in the preparation, activation and execution phases of crisis management.

In this paper, we evaluate "crowdtasking", a new crowdsourcing approach to manage volunteers and community engagement. Crowdtasking was co-designed by the Austrian Red Cross, Austrian Institute of Technology, TU Wien (Vienna University of Technology), and Frequentis. We explain the notion of crowdtasking for CDM and present a prototype evaluation that was used in field-testing. We discuss the benefits and disadvantages that the prototype has exhibited during evaluation. We try classifying crowdtasking as a crowdsourcing solution and compare it to other crowdsourcing approaches. Based on our observations, we take a look at possible drawbacks when using ICT solutions for volunteer management that adhere primarily to command and control principles: a lack of support for lateral communication, and thus community building. Finally, based on our results with crowdtasking, we describe plans for future work on the topics of community building and CSCW between informal groups and formal organizations for disaster relief.

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2 VOLUNTEERS, TECHNOLOGY AND COOPERATIVE WORK

Coping with crises and disasters requires the cooperation of many different actors. One category of such actors is that of volunteers: people who wish to contribute to relief efforts on accord of their own, personal motivations (as opposed to, e.g., employees of formal relief organizations). They may be directly affected by the event that necessitated relief efforts or come from surrounding areas to help their neighbors. Volunteers may organize relief efforts amongst themselves, something that we refer to as "grassroots" movements, or offer their help to formal relief organizations, if present. During the last decade, the rise of (mobile) ICT has changed the way that volunteers collaborate and organize. CSCW is now an inherent part of many grassroots relief efforts. Relief organizations are also increasingly looking to employ new technologies to cooperate with volunteers.

In this section, we give an introduction to volunteering in CDM and how it is influenced by technology. We discuss three aspects that are relevant to the remainder of our paper: 1) the different types of volunteer we distinguish, 2) previously observed adaption of ICT by volunteers for disaster response, and 3) previous research into the collaboration with or among volunteers through ICT. This provides a setting and context for the reader, in order to better classify the subject matter of our paper later on.

2.1 Differentiating Volunteers in CDM

It would be inaccurate to speak of *the volunteers* in CDM as if they were one, homogeneous group. People of many different backgrounds, skillsets and motivations come together in a disaster situation, accompanied by the emergence and adaption of social networks and organizational structures [7]. Volunteers differ in their motivations, their level of integration into organizations, their capabilities and remoteness to the affected area. For the purpose of this work, we mainly differentiate between degrees of volunteer's integration into existing formal structures.

We consider volunteers to be *formal* (sometimes also referred to as *traditional*) if they are part of a pre-existing, hierarchical organization that is concerned with disaster relief efforts, first response or humanitarian aid. They do service with formal organizations on a regular basis and are familiar with emergency procedures. Common examples of formal volunteers are, e.g., voluntary paramedics or firefighters. Traditionally, formal volunteering has a high significance in many parts of Europe, most notably Central Europe and Scandinavia [24]. On the other hand, there are also volunteers that arrive at affected areas on their own initiative and try to provide support where they feel that it would be most useful. They receive (or take) no orders from formal organizations. We refer to them as *unaffiliated* volunteers. In between exist several shades of grey, the two most relevant being *pre-registered* and *pre-organized* volunteers. Pre-registered volunteers are those that would be willing to sign up on a platform to support relief efforts, but do not seek to become part of an organization, while pre-organized volunteers are already part of an organizational structure, but one that is either not permanent or not primarily concerned with CDM [21]. Fig. 1 visualizes these distinctions.

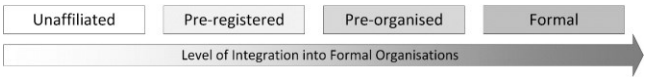

Figure 1: Types of volunteers categorized by affiliation with formal organizations.

Apart from their integration into an existing formal structure, another dimension to differentiate volunteers is their physical presence at the time of need. Where they are during the mitigation, preparation, response and rebuilding efforts dictates which types of task a volunteer can execute. We have found that, for the discussion of crowdsourcing in CDM, distinguishing between the following three location-based categories of volunteers is useful: *On-site volunteers* are located in the crisis or disaster area and are likely themselves affected by the event. Those able and willing to help may conduct search and rescue, evacuation or mitigation. *Off-site volunteers* are able and willing to support relief efforts outside of the immediate disaster area. Such volunteers can help by sorting commodity donations or preparing shelter for those that are being evacuated. *Virtual volunteers* participate in relief efforts solely through ICT. They may gather, aggregate, filter and forward information, translate or help in matching supply and demand. They are not physically present during relief efforts [5,12,30]. Virtual volunteers are one manifestation of the increasing pervasiveness of ICT during crises and disasters.

A third perspective by which to differentiate volunteers is their motivation. The reasons, which members of the public to participate in the relief efforts for, vary. There exist multiple models to explain the motivation of volunteers. One possible approach would be to apply Herzberg's two-factor theory [13], thereby classifying volunteers into those with intrinsic and those with extrinsic motivations. A more detailed classification could be based on Self-Determination Theory [6,9]. Other viable options for classification include, e.g., the Volunteer Function Inventory [4].

For the purpose of this work and the research project it is based on, we differentiate volunteers only by their level of integration into existing organizations and their physical location relative to the site of the disaster or crisis. The third dimension, motivation, was not extensively considered during the research that yielded the subject matter of this paper. We hope to address this aspect more thoroughly in future work.

2.2 Volunteer Convergence

The combination of volunteers being both unaffiliated (acting independently) and on-site has implications for CDM. The phenomenon of convergence, whereby a large number of unaffiliated volunteers are drawn to the immediate disaster area, can cause complications in relief efforts. The fact that people gather to provide aid and relief to disaster victims is neither new in itself nor a blank page to research [25] and the behavior has been subject to research since at least the middle of the 20th century. Since that time, however, the effects have been amplified by new media technologies – causing an increase of the speed at which information travels and, consequentially, convergence happens.

The sheer number of people converging on a disaster site can impede relief efforts of formal organizations. “Mass assault” is one term that has been used to describe the initial collective response to an emergency situation [7]. This quickly becomes a challenge, as local responders are overwhelmed, making collaboration with unaffiliated volunteers, an important topic to mitigate potential problems caused by convergence. The challenge is twofold: to make use of the potential that (a possibly large number of) volunteers provide and to avoid local authorities being overwhelmed by the influx of new volunteers on site.

2.3 Volunteers Using Existing Technologies

It has been observed and studied that citizens take to existing online communications channels such as social networks (like Facebook), micro blogging platforms (like Twitter) or collaborative online tools (like Google Documents) to share information and distribute work in times of need. The implications of ICT for crisis settings (and vice versa) have been discussed for some years now [22]. In an early work on this topic, Palen et al. investigated the use of multiple online tools for information sharing and collaborative sense making during and after a shooting that occurred in April 2007 at the Virginia Tech campus [23]. They report, “peer production of accurate information” and “self-organization around a well-defined task”. Relatedly, Vieweg et al. describe the use of the Micro blogging service Twitter during the Oklahoma Grassfires in April 2009 and the Red River Floods in March and April of the same year [31], investigating it regarding improved situational awareness. Meier describes several case studies of “crisis mapping”, whereby volunteers supplement interactive online maps with their own, local knowledge, aiding humanitarian response [20]. Starbird and Palen give another example of volunteers using social media: they describe the formation and ultimately formalization of the purely virtual organization “Humanity Road” by digital volunteers via social media [30]. Also on the topic of self-organization of volunteers, Kaufhold and Reuter describe the use and importance of social media for independent self-organization of volunteers during the floods in Germany in 2013 [14].

As you can see by the (non-exhaustive) list of previous work summarized above, ICTs and their influence on volunteers in crisis and disaster situations have been a topic of research for several years. In these works, investigation has focused on volunteers using existing communication channels and adapting them for their needs in the crisis and disaster context. There have also been proposals and implementations of new approaches that are specifically designed for these needs.

Hofmann et al. have designed and implemented a mobile app-based system, which enables volunteers and response organizations to advertise or request relief capacities [11]. Their system was developed in response to mass convergences of volunteers during flooding in Germany, overwhelming local authorities. They define criteria for IT-based coordination of volunteers on site. Lanfranchi et al. describe their approach towards “citizen observatories” that aim to improve situational awareness of communities and authorities by encouraging citizens to provide information to authorities, who in turn selectively provide information suited for consumption by the public [15]. Link et al. describe a solution for disaster management professionals and affected populations to share situational reports, which are relevant for decision-making on both ends [16]. Current observations are submitted by volunteers through smartphone apps or Twitter, then moderated by trusted users and, if appropriate, shared with all users of the system. In contrast to many other works, which revolve around online smartphone applications and social media, Ludwig et al. recently described an approach using public displays [19]. They place displays showing current needs and required help at locations with high visibility to better inform and direct volunteers on-site. Thus, adverse effects of volunteer convergence may be mitigated. Soden describes an approach to geographic data collection that is not purely technological, but also takes into account growth and sustainability of local communities to increase resilience – adding the important aspect of community building for resilience [29].

3 “RE-ACTA” AND CROWDTASKING

The subject matter of this work is the approach of crowdtasking. This approach was originally designed, implemented and evaluated in the scope of a national research project called “Resilience Enhancement by Advanced Communication for Team Austria” (RE-ACTA, http://blog.roteskreuz.at/reacta/das-projekt/). The project was funded by the Austrian security research program KIRAS of the Federal Ministry for Transport, Innovation and Technology. RE-ACTA started in 2013 and was finished in 2015. Involved in the project were the TU Wien (Vienna University of Technology) (also the first author of this paper was in the team of TU Wien), the Austrian Institute of Technology (AIT), the Austrian Red Cross (ARC), Frequentis AG, and Inset Research and Advisory. The aim of the project was to investigate the use of ICT for volunteer management. ARC at that time already operated a tried and tested volunteer management initiative called “Team Österreich” (Team Austria, TeamA). RE-ACTA would investigate the use of new media technologies to enhance this community engagement effort. The ARC in cooperation with a nationwide radio station in August 2007 has instigated TeamA. Its inception was a response to observing and having to manage the large number of unaffiliated volunteers at disaster sites. It has since grown to over 40.000 members. The experience gathered by community managers in TeamA provided the basis for RE-ACTA and *CrowdTasker* to build upon.

3.1 Approach

The project was initiated by doing an analysis of existing literature, previous work and related solutions. Project partners compiled a list of crowdsourcing solutions that were already in use at the time of writing, analyzing them regarding their features and workflow. Based on this list, partners extracted a set of functional requirements for volunteer management in CDM. This list was iteratively trimmed, refined and categorized into must-have, nice-to-have and out-of-scope features. To achieve this, the TU Wien conducted two focus groups together with the ARC. TU Wien also

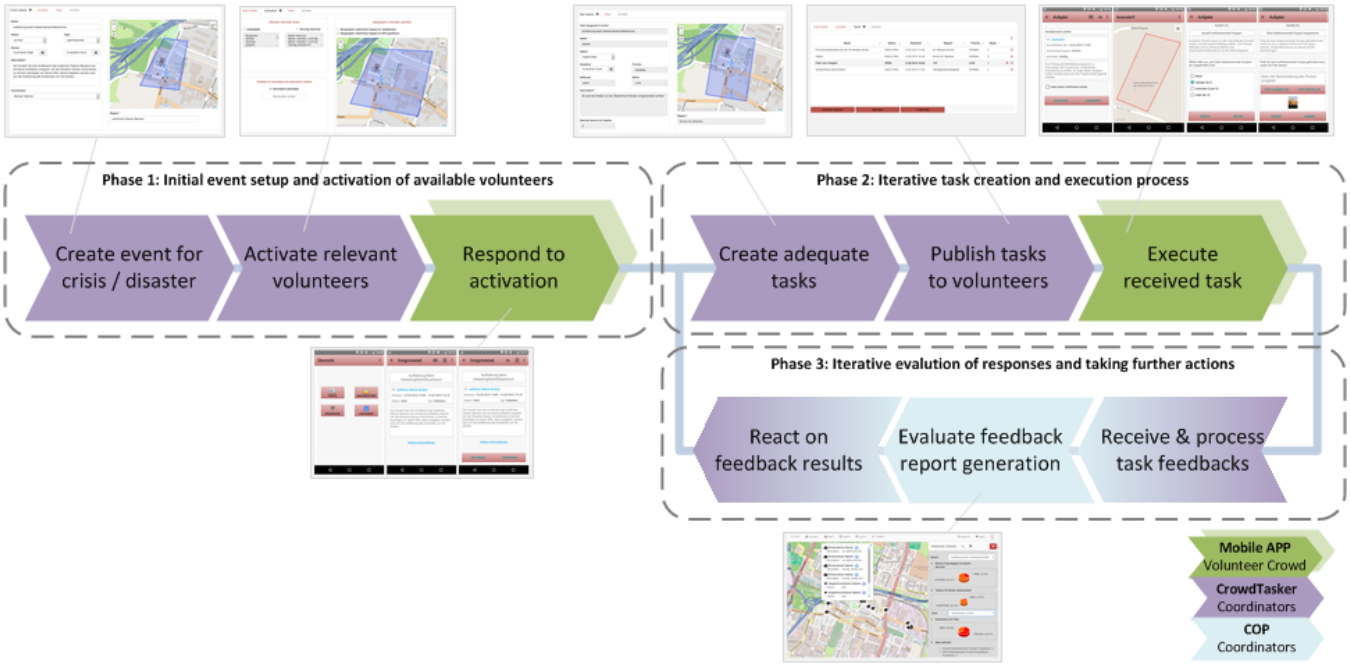

Figure 2: Simplified version of the crowdtasking workflow.

analyzed the workflows of TeamA and formalized them during these focus groups.

The refined list of functional requirements and insights into TeamA served as a basis for the next step of the project: defining a formal process model. This was done by Frequentis AG and yielded an extensive catalogue of UML process models. Due to the substantial nature of the diagrams, we will refrain from discussing them in their entirety. The entire process model was discussed with representatives of the ARC (who had previous experience with community engagement in the context of TeamA) and refined iteratively. The last phase of project RE-ACTA was concerned with implementing and evaluating the process model for crowdtasking.

AIT engineered a prototype called *CrowdTasker*, which incorporated the central workflow and main features (but not the entire process model), consisting of a web interface and smartphone application, while Frequentis AG provided a common operational picture tool to analyze data gathered with *CrowdTasker*.

The web interface of *CrowdTasker* was evaluated as a paper based prototype first. The evaluation of all components of the actual prototype took place in the form of a field test. Evaluation methods and outcomes are discussed in more detail later.

3.2 Crowdtasking

The approach of crowdtasking contains a request for concrete and well-defined actions within a limited temporal and spatial scope, resulting in the performance of micro-tasks with no further obligations – not limited to online activities, thereby putting an emphasis on the aspects of space and time of a task [28]. In the context of CDM, crowdtasking is a workflow between trained crisis/disaster managers and volunteers. More specifically it is aimed at unaffiliated volunteers on-site, off-site or virtual. From this point onwards we refer to trained personnel of a formal relief organization that use crowdtasking to distribute tasks as *coordinators*. Unaffiliated volunteers that receive tasks and execute them will simply be referred to as *volunteers*. The crowdtasking workflow can be summarized in the following steps (Fig. 2):

(1) *Create event for crisis/disaster*: The highest level of information artifact in crowdtasking is an *event*. The event represents any cause for which a coordinator might want the support of volunteers. Examples for such an event include: flooding of an area, impeding draughts or heat waves. Any coordinator might define such an event, providing a name for reference as well as a description and geographic boundaries.

(2) *Activate relevant volunteers*: For an event, the coordinator defines which volunteers s/he wants to ask for participation. To do so, s/he defines several criteria such as the current physical location of the volunteer, his/her home address or the volunteer's skills (e.g., languages spoken, driver's license, medical skills, etc.)

(3) *Respond to activation*: Once the coordinator has defined criteria for an event to his or her satisfaction, a request for participation is sent out to all volunteers that fulfill said criteria. This process is referred to as *activation*. Volunteers may accept or decline the activation. If they decline, they will receive no further messages pertaining to the event. If they accept, they become eligible to receive tasks connected to the event. In this way, a pool of volunteers is defined.

(4) *Create adequate tasks*: The second level of information artifacts in crowdtasking is the *task*. Each task is part of an event and any event can have an arbitrary number of tasks. Any coordinator can define tasks for an event by giving a name for reference and a description of what the task will entail. He or she also must define an arbitrary number of task steps, which is the third and lowest (atomic, if you will) level

of information artifact. Each step consists of an assignment for the volunteer and has a well-defined end result, which dictates the type of response the volunteer can give. Each task may have an arbitrary number of steps and combination of step types. Step types (as defined by the nature of information being submitted) include:

a. Choosing one of several pre-defined answers
b. Choosing multiple of several pre-defined answers
c. Making a photo
d. Responding with a number
e. Responding with free text

(5) *Publish tasks to volunteers*: Once a coordinator has defined a task to his/her satisfaction (by defining assignments in the form of steps), s/he can choose a crowd of volunteers to execute it. Only such volunteers that have accepted the activation are eligible. This pool can further be restricted based on volunteer attributes such as current location, place of residence or skillset.

(6) *Execute received task*: Volunteers receive the task published by the coordinator (previous step) and execute it by following the task steps. Once all task steps are finished, the user input for each step is sent back to the coordinator. We will refer to this data received from volunteers as *feedback*.

(7) *Receive and process task feedback*: Volunteer feedback is received at the crowdtasking backend and saved for later visualization and interpretation. The crowdtasking system may make the data available for trusted sources (e.g., systems of other response organizations).

(8) *Evaluate feedback and generate report*: Crisis managers visualize volunteers' feedback for interpretation. This is done by, e.g., a common operational picture system, where feedback may be handled as one of multiple data sources. Analyzing and aggregating feedback may generate reports. Processing data in this way is made possible and facilitated because it is known in advance which type of data will be returned for each task.

(9) *React to feedback results*: After the feedback of volunteers has been analyzed and assessed by crisis managers, they may decide to take further actions pertaining to volunteers. This may lead to a feedback cycle, where the workflow starts again at step 4, with the creation of additional tasks. Steps 4 through 9 may be repeated until the crisis/disaster event is resolved and the help of volunteers is no longer needed.

3.3 Prototype

The crowdtasking workflow we have described in the previous section has been realized in the form of a prototype implementation. The prototype consists of three components, as shown in Fig. 3:

(1) Web interface where coordinators define events and tasks. (CTA)

(2) Smartphone application for volunteers to accept activations and execute tasks. (APP)

(3) Web interface where crisis managers can view visualizations of volunteers' feedback. (EVA)

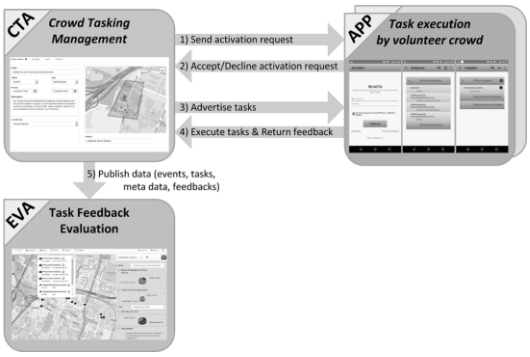

Figure 3: Components of the crowdtasking implementation.

The component CTA and APP were implemented by AIT (*CrowdTasker*[2]). Frequentis AG developed the component EVA, a common operational picture system. This system is used to aggregate and visualize data that was submitted by volunteers in response to tasks. Together these components implement the main workflow of the formal approach of crowdtasking for CDM: defining, distributing, executing and analyzing tasks and their feedback. This system is functional and has had multiple trials in the field under realistic conditions, including qualitative and quantitative evaluations.

As such, the workflows bear obvious similarities. In TeamA, potential volunteers can sign up through a website and then receive an invitation for an introduction course (hosted regularly by the ARC). In case of an emergency, selected volunteers receive text messages from ARC, which they reply to with text messages of their own that have to adhere to a certain formatting template (this is equivalent to the activation in crowdtasking). If they accept, they receive information about the time and place of a briefing event. If they attend the briefing, agree to participate and sign an informed consent sheet, they become part of the relief efforts. Such volunteers are split into groups, which are supervised by trained representatives of ARC. Tasks are relayed through group supervisors and work is done in shifts until the relief efforts have run their course (the equivalent of crowdtasking's task phase). Afterwards, all TeamA volunteers gather again for debriefing. Crowdtasking has obviously inherited its two-step approach (activation vs. tasking) from TeamA. During our interviews and focus groups with community and crisis managers we found this to be a best practice for them. It facilitates better judgment as to how big the initial pool of volunteers would be before sending out invitations and tasks.

We wish to stress that for us, crowdtasking and crowdsourcing are *not* synonymous and that we treat crowdtasking as a specialized form of crowdsourcing. In our most recent paper we have attempted to classify the crowdtasking approach for CDM using Liu's crowdsourcing framework [3]. The result is included in Table 1.

[2] https://crowdtasker.ait.ac.at/

We hope that this will clarify what crowdtasking is supposed to represent with regards to CDM.

Table 1: Categorizing crowdtasking using Liu's framework [18], in [3].

Why – Identify information to the problem to determine crowd task	To provide instructions for preparation before a disaster as well as coordinate volunteer efforts and receive information from the site during a disaster.
Who – Types of crowds to target for the task	Individual, pre-registered volunteers without differentiation and including as many social milieus as possible.
What – Interaction flows for engaging crowds	The term "crowd-seeding" used in [18] fits the crowdtasking interaction: an active, one-way request, strategically targeting members of a crowd.
When – Temporal aspects in relation to the disaster management lifecycle	Primarily intended for mitigation, prevention, preparedness, response and recovery.
Where – Spatial aspects of the crisis, crowds and crowd tasks	Applicable for mitigation, prevention and preparedness at potential disaster sites. Not intended for use inside hazard areas during response.
How – Social, Technological, Organizational & Policy (STOP) interfaces	Technological. *CrowdTasker* provides a web interface for professional responders and a smartphone application for volunteers.

3.4 Relation to Other Crowdsourcing Approaches in CDM

Compared to other crowdsourcing solutions for volunteers, crowdtasking uses a more centralized and one-sided form of interacting with the crowd. While the Hands2Help concept also works via an online smartphone application, it allows for every user of the system to publish requests and needs [11]. In contrast, assignments in crowdtasking and the *CrowdTasker* implementation are published only by a single source – the relief organization operating the volunteer network. *CrowdTasker* also seemingly targets a different kind of assignment, whereby volunteers are asked to fulfill a series of micro tasks that they should be able to complete quickly and easily.

GDACSmobile also allows every user (volunteer) to submit information about the situation in a dedicated area [16], which is published after it has been reviewed by a trusted operator. To alleviate the problem of having to verify large amounts of submitted data a semi-automated approach, based on the GDACSmobile workflow, has been proposed by Link et al. in a recent publication [17]. GDACSmobile focuses on gathering information about the situation on site by asking users to submit data about relevant occurrences and conditions, where the judgment of what is relevant for submission lies with the volunteer. The crowdtasking approach and *CrowdTasker* implementation, on the other hand, are meant to ask volunteers about very specific data, such as the availability of electricity at a certain address. We will later in this paper touch upon the implications of quantity and extent of data as opposed to relevance and depth.

The approach of utilizing public displays to share needs and commitments described by Ludwig et al. follows a similar route [19]. Users share equal permissions, where any user may create content on the public display and indeed control the display itself for up to five minutes. The main advantage of these displays, then, is to make apparent the needs of citizens at a location with high visibility. The local crowd is encouraged to serve the immediate, local requests – unlike in crowdtasking, where tasks come from a central location that is most likely removed from the actual disaster area. It is unlikely that the tasks in *CrowdTasker* will represent the needs of citizens on site, rather serving a tactical purpose for relief organizations. Unlike *CrowdTasker*, GDACSmobile or Hands2Help, these public displays, as they were proposed, work without Internet connection, by broadcasting a local WiFi network.

4 Evaluating Crowdtasking

The output of RE-ACTA was evaluated by TU Wien together with crisis management professionals of the ARC at several stages of the project, resulting in iterative improvements. Through this evaluation we have gained insights we wish to share. For additional details and discussion of these evaluation efforts, which would exceed the boundaries of this paper, we also refer to our previous publication [3].

4.1 Methodology

The first evaluation was done in the context of a focus group, to discuss and refine the list of functional requirements for a volunteer management system. Participants consisted of officers of the ARC concerned with community management/engagement on the operational and tactical level; they represented the primary target group of potential users. The second evaluation was to be concerned with the process models defined as a result of these functional requirements. Due to the large amount of data represented in the process model, the straightforward approach of sending all diagrams to our experts and requesting feedback was considered impracticable. Instead, we took a different route. We compiled a scenario to serve as framework and instantiated each of the UML diagrams within this scenario by giving the actors, actions and data exchanges non-abstract names and background. We also drafted a short story for each sequence diagram, describing what would happen in our presumed scenario. All this served us well in anchoring very abstract diagrams in a context that appeared more relatable to disaster response of professionals. Even though the work involved in the preparation was quite substantial, we were able to evaluate the entirety of the process model with experts in no more than three hours.

RE-ACTA was concluded with an evaluation of the prototype implementation. The insights we have gained from it have also been the topic of our most recent work [3]. This evaluation took place in the form of a field test. The purpose of the trial was to assess the acceptance of both professionals and volunteers towards the general approach of crowdtasking, as well as the usability of the specific prototype implementation. Because this was the first test and evaluation of a live crowdtasking tool, there was no experience for us – the evaluators and researchers – to build upon, making it difficult to define specific hypotheses to test against. Instead, we opted for an exploratory approach, using qualitative methods, to assess the topic with an open attitude. We opted for non-

participatory observation during the actual field test and interviews as well as group discussions directly afterwards.

The field trial was conducted at the premises of ARC's disaster relief center at the outskirts of Vienna. This facility is used by the ARC for actual CDM activities, which made it especially suitable to serve as command and control center for our exercise. The trial involved 12 participants, nine of those acting as volunteers executing tasks in the field and the remaining three taking the role of coordinators at the control center. All participants were contacted and recruited through internal calls for voluntary participation by ARC. "Volunteer" groups were comprised of two adults with prior experience in the volunteer initiative TeamA, one adult who had previously served as volunteer paramedic, two young adults in the service of the ARC and three members of the ARC youth group. "Coordinators" were comprised of disaster management professionals of the Red Cross who have had training and experience in volunteer management as well as crisis relief efforts.

The field trial proceeded as follows: All participants were gathered at the control center and given an introduction into the research being conducted, how this event fit into that and how their participation contributed. They were asked to voice their thoughts about workflows and device interaction during the coming exercise (thinking-aloud method). All participants were informed about which data we would collect during the event, how we would handle that data and that they had the right to opt out of participation at any time. After this, we split participants into three groups consisting of one coordinator and three volunteers each – meaning that one coordinator was to be responsible for three volunteers. Each volunteer was given a smart mobile device (smartphone or tablet with the *CrowdTasker* app pre-installed) and wired with a microphone connected to said device. Each group of three volunteers, after being outfitted, was sent to a specific starting location in the vicinity of the control center (none of them more than four blocks away). In the meantime, coordinators took their positions at workstations in the control center. They were given a short introduction to the *CrowdTasker* system of no more than 10 minutes. Then each of them was provided with a sheet of tasks to solve with the help of *their* volunteer group. The tasks were of increasing difficulty (for coordinators) in that each one provided less hints on how to use the *CrowdTasker* system. All tasks had been designed in advance in cooperation with crisis managers of the ARC in an effort to provide realistic assignments. They revolved around reconnaissance, clarification of situations in the field or acquisition of commodities. For example, the tasks of one group were to: 1) check the operability of water pumps at a nearby Red Cross training ground, 2) determine current fuel prices at a specific petrol station, 3) check for an electricity outage at a given address, 4) acquire a specific amount of fuel reserves, and 5) determine the number of operational response vehicles at a nearby Red Cross station. The two other groups executed tasks of a similar nature. The events and tasks were to be entered into the system by the coordinators unassisted. While doing this, they were observed by members of the TU Wien and recorded by video cameras. Volunteers, in the meantime, executed the given tasks in the field (also unassisted). Each group was observed by one member of the TU Wien. Additionally, audio recording software was activated on the smart devices used by volunteers to capture thinking-aloud. In combination with the connected microphone, this provided audio recordings of sufficient quality for later analysis.

4.2 Crowdtasking Workflow

To practitioners that consider implementing a crowdsourcing or crowdtasking approach, we can recommend two aspects of crowdtasking that worked well in our experience: the activation phase as well as the step-by-step nature and execution of assignments. Task steps are an integral part of the crowdtasking workflow and were carried by using the smartphone application. When executing a task, the volunteer is only shown one task step at a time and only progresses to the next once he has finished the current one. Through this workflow, the coordinator can define each assignment as small and manageable as he or she considers necessary.

The other aspect we like to highlight is the activation phase of crowdtasking. We are aware that this approach seems counter-intuitive at first – indeed, it also did for the participants of our field trial, both coordinators as well as volunteers. Both parties had difficulties during their first event: coordinators where unsure of the purpose of activations whereas volunteers where confused about the difference between tasks and activations. The approach has, however, proven useful once the coordinator grasps the approach and how to use it to advantage. This became more apparent in later field trials of the *CrowdTasker* system, which involved a larger audience of up to 200 participants and 9 coordinators. By generating a pool of eligible volunteers through activation, crowdtasking provides a way to estimate the number of recipients for tasks a priori. This knowledge influences which types of task are viable in a given situation. For example, it would be unwise to task a crowd of 500 people to bring spare warm blankets for one displaced family or to task a crowd of only 5 volunteers with searching a large area. Thus, activation constitutes a trade-off: a more difficult learning process for coordinators and volunteers during their very first event (due to having to understand the differences between tasks and activations) versus relevant a priori knowledge about crowd size (because activations allow for a relatively precise estimate of volunteers that will be addressed with each task request). Our current opinion is that this benefit outweighs the detriments, which may be further alleviated by user interface design and training.

4.3 Usability Aspects

If you design a workflow that heavily features geographic information, the user interface element of the corresponding (mobile) application should be a map and be positioned at the centre of the screen. The interface of the *CrowdTasker* mobile application during the field test revolved around several lists for open and closed tasks and activations. While this made sense from a developer's point of view, it quickly becomes cumbersome as the number of items increases. According to volunteer's statements, distance to target location and finding tasks near them were

important factors in choosing which tasks to accept. Item lists are not the best suited way to display this type of information. The majority of volunteers furthermore exhibited difficulties in finding target locations, despite accurate textual descriptions. Instead of item lists, an interactive map showing assignment location(s) in relation to the user's current position would likely have alleviated this. We advise making such an interactive map the centerpiece of location-focused crowdsourcing applications.

We also recommend, based on statements and observation during the field test, to reduce system-wide notifications issued by the smartphone application to items that are actionable by the user. In the first iteration of the *CrowdTasker* smartphone application, we notified volunteers about events in their vicinity, even if they required no immediate input by them. The goal was to make them aware of upcoming events and tasks. This was received badly by all participants. The purpose of the application being that of distributing tasks set expectations in such a way that participants were irritated by not being able to act upon items they received through the app. We believe similar assumptions can be made for other crowdsourcing mobile applications: If you decide to distribute purely informative content and assignments through the same application, it is advisable to only notify the user about items that require his/her input. In *CrowdTasker*, we have since changed application behavior to only display items that are actionable by the volunteer.

Lastly, we noticed that, most likely also due to the expectations set by the applications context, volunteers became restless very quickly when idle. In our field test, after receiving and accepting the initial activation, volunteers did not receive any new assignments for some time – due to coordinators still learning how to use the *CrowdTasker* web interface. This led to increasing unrest among volunteers who were unsure as to why they received no further instructions. Most started wandering around, checking the GPS and connection status of their device or restarting the application multiple times. As time went by, they increasingly voiced their dissatisfaction with being in the dark about the current status. Because of these observations, we recommend integration status indicators into similar mobile applications to assure volunteers that their connection is working, they have GPS signal and their application is up-to-date with central servers. All of this has been implemented in the *CrowdTasker* mobile app since the field test.

4.4 Caveats

We want to point out the caveats of our research, most of which we assume are apparent to the reader by now. Our evaluations involved a very limited number of participants. We did not test with enough participants to make a general statement on the validity of crowdtasking for disaster management. Further, though we took care to select representatives from different age groups to get a wide variance in feedback, not all relevant social milieus were included during the evaluation. Most notably, no evaluation of RE-ACTA was done with representatives of ethnic minorities or elderly – though these aspects were certainly taken into consideration during the design process, as were gender aspects.

5 DISCUSSION

Having introduced crowdtasking and the *CrowdTasker* implementation and describing our evaluation of the approach, we wish to discuss aspects that we found to be of note during the field trials and de-briefings of participants.

5.1 Communication Structure

Firstly, when comparing crowdtasking to TeamA, which can in many ways be considered a predecessor, one may observe a clear shift towards ICT – a topic that we have previously addressed [2]. The evaluation of *CrowdTasker's* field trial has made clear for us that one specific aspect that is lost by this move is community building. TeamA offers much face-to-face interaction with supervisors and fellow volunteers. In the strict one-to-many communication of *CrowdTasker* lateral communication is not included by design. Yet a demand for this form of group building was clearly indicated by participant feedback in field-testing. Especially younger volunteers sought to communicate with their peers to request help and band together. They opined that, if there was no option to get in contact with headquarters, at least they should be able to request help from their friends. Some stated that they would like to coordinate their travel to the target destination with other volunteers to facilitate, e.g., car sharing. One participant asked where in the app he could see his friend list or whether there was any way to find other volunteers through the application. All of this hints at a demand for lateral, social interaction and coordination between volunteers, aside from having a centralized command and control entity. The lack of social features seemed frustrating for young adult participants to the point where one of them asked what the application was even good for, i.e., questioning the added benefit of the application. We believe this dissatisfaction is the result of crowdtasking's heritage: being based on a hierarchical organization, but removing the aspect of face-to-face communication without compensation.

The young adult participants also wanted to show more initiative than offered by the crowdtasking workflow. They were disappointed at not being able to submit any information that they considered important, instead having to rely on receiving the right tasks. They asked what they should do in case they encountered situations that were potentially relevant to relief efforts (they cited, namely, collapsed houses) but had received no corresponding tasks. While this question is reasonable from the volunteer's perspective, such a workflow was purposefully not included in crowdtasking. Crowdtasking deliberately trades off quantity of data in the hope of increasing relevance and quality. The idea behind this was to acquire manageable amounts of information that is of higher interest than if volunteers were allowed to submit anything that they considered important. These explanations aside, it would be unwise to disregard the volunteer's point of view, who wants to show initiative. For such demands, a hybrid solution could be found by combining crowdtasking with, e.g., the GDACSmobile approach, which specifically allows for these activities. A possible scenario could be to use the GDACSmobile approach for discovering critical situations and crowdtasking to verify and mitigate them.

5.2 An Approach for community building and coordination

In the previous sections, we have discussed that there was, during the field test of *CrowdTasker*, a demand for supporting communication and coordination between volunteers. *CrowdTasker* works well for rapid acquisition of data from the field and directing volunteers as well as facilitating learning through small, informative tasks. But it does not, by design, take into consideration citizen's tendency for self-organization. Even though this is not the role of *CrowdTasker* in its current state, we believe it would be ill-advised to ignore this drive of people to band together and improvise coordination for problem solving. Based on our experience with *CrowdTasker* so far we consider the integration of existing communities and facilitation of self-organization to be two important topics that have to be tackled in future developments of the crowdtasking approach.

Building communities and establishing networks is an important part of improving societal resilience to crises and disasters. They increase chances of rescue and survival for individuals, provide encouragement to take preventive action and motivate volunteers to provide labor for disaster mitigation [8]. This provides us with a new direction for further research regarding the crowd-tasking approach. Armour argues that "new communication media can help formal systems – institutions and organizations – connect through informal systems – faith and community based organizations – with individuals and neighborhoods" [1]. He goes on to highlight the importance of engaging such communities and that formal and informal systems must work together.

Dynes argues that communities possess "social capital" through their existing connections and networks that is resilient to physical and even human capital loss [8]. He further states that authority structures that exist pre-crisis do (and indeed should) remain in place in the response phase. It is thus preferable that existing social structures – be they sports clubs, choirs or university departments – should not be broken up and forcefully fit into authority structures that are alien to them. It would therefore be important to try and make such existing communities visible to other actors in crisis and disaster relief, in order to enable cooperation and connection. Eventually, this could be taken one step further by not only investigating the integration of existing communities, but also to facilitate the emergence of self-organized volunteer groups. Similar views seem to be shared by Reuter, Heger and Pipek who have also investigated emergent volunteer groups and self-help of volunteers [26]. In their study of virtual activities during the 2011 tornado crisis (USA), they notice that there is a great variety of websites being circulated, but no central point for self-help activities and a lack of coordination platforms designed for volunteers.

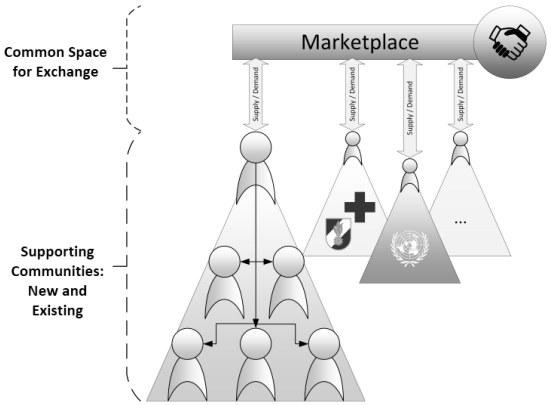

Figure 4: A combined approach for community building and coordination.

Command and control structures, similar to those that inspired the crowdtasking workflow, have their traditional place in CDM. They operate under the assumption that the principles of "command" and "control" are the means to reduce disaster situations to manageable proportions [10]. They allow formal organizations to coordinate and cooperate efficiently in times of need. However, they are not unconditionally applicable when dealing with citizens and communities of the public. Indeed, some informal groups actively distance themselves from formal relief organizations and do not want to be part of existing volunteer initiatives. Rather, they opt to retain their egalitarian structure. It seems unlikely that such communities would take part in a communication structure like crowdtasking. To connect them with other relief efforts a different approach will be necessary. Dynes has stated, regarding the utilization of the social capital of community organizations, that "rather than attempting to centralize authority, it is more appropriate to structure a coordination model" [8].

These notions, together with our observations, have convinced us that crowdtasking could bring together informal volunteer efforts and formal relief organizations better by expanding the approach to support existing and emerging social structures. In the wake of the recent migration crisis that has affected Europe, we have witnessed the rise of self-organized groups of volunteers that aim to provide humanitarian aid and social integration to migrants. To us, they represent the most recent example of citizen's tendencies to self-organize during crises and disasters. Citizens with similar goals, to assist incoming refugees or help them integrate into society, found together through social media and town hall meetings. They organized collective efforts with online communication tools, forming an emergent structure over days and weeks. We are in the process of talking to founding members of such initiatives (seven interviews were conducted as of the time of this writing). They use various forms of ICT for CSCW to conduct their internal affairs, yet seldom for cooperation with other grassroots initiatives or formal relief organizations. Preliminary findings indicate that all of them have formed consistent and sustainable structures for their daily operations, mostly revolving around working groups and a central committee for steering decisions. Crowdtasking, as a way to address individual, unaffiliated volunteers, is not the right approach to cooperate with solidified community structures. Therefore, new forms of

cooperation are required to interact with emergent communities that have already formed internal structures. The research field of CSCW, in our opinion, offers excellent opportunities to establish collaborative efforts between grassroots volunteer communities and formal organizations in CDM. We envision the modification of crowdtasking towards a common space where all parties – relief organizations, formal and informal communities – can request and offer goods and services for relief efforts, thereby providing an added benefit to *all* participants, which is currently lacking in the crowdtasking workflow. In such a space the stakeholders would be equal and focused on solving supply/demand related problems rather than being occupied with enforcing structures in an effort to prevent chaos. We have provided a visualization of our envisioned approach in Fig. 4. How crowdtasking can sensibly be modified to accommodate this vision will be part of our future research on the topic.

6 CONCLUSIONS

In this paper, we have described how ICT has changed the way volunteers organize for CDM. We provided examples regarding how these new forms of emergent volunteer communities use CSCW to handle their relief efforts. We have discussed how crowdsourcing is used as another form of CSCW connecting individual, unaffiliated volunteers and relief organizations. In this context we introduced crowdtasking, a centralized form of crowdsourcing for volunteer engagement and management. We discussed our findings from a field trial of a prototype implementation. Based on the insights gained from this evaluation, we have proposed a modification of crowdtasking towards community building (Fig. 4). It is our hope that the introduction of these aspects will increase the added value for volunteers through the support for emergent communities, while maintaining the possibility of coordination as desired by formal organisations and crisis managers.

In conclusion, we would like to say that the topic of voluntarism in CDM is an exciting and challenging topic for CSCW. Technological advances have altered the nature of how communities and structures emerge during crises and disasters. The use of ICT is prevalent before, during and after crisis and disaster situations, influencing cooperative workflows and information exchange. This opens promising avenues for building bridges between actors in times of need. The context of CDM is especially challenging for research due to its unforeseeable, hard to replicate nature and the upheaval of everyday structures and routines. The approach of crowdtasking that we have presented herein is one tool in a box of many that can be used to tackle the task of disaster mitigation. We have touched on other approaches with different approaches and aims, which also try to facilitate CSCW with and between volunteers. All of this research is, to our knowledge, still very much ongoing. It is also topical, in the face of a large humanitarian crisis, as we see forced migration rise to its highest point since World War II and an increase in the number and scale of natural disasters [27].

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