Digital Volunteers for Emergency Management: Lessons from the 2016 Central Italy Earthquake

Completed Research

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Abstract

In several recent crises, digital volunteers' organizations showed a remarkable ability to support government agencies during relief operations. Digital volunteers can collaborate and contribute remotely, supporting information collection and presentation from a variety of digital data streams sources (e.g., social media, news feeds, physical sensors). From a Representation Theory perspective, we frame their effort to help government agencies collecting actionable information as one to achieve a better (digital) representation of a crisis. However, Representation Theory (RT) has not been applied yet to a chaotic environment – such as the aftermath of a disaster – and has not been proven yet to be a valid theory of Information Systems (IS) use in that context. For RT, individuals pursue IS effective use iterating over learning and adaptation actions. Nonetheless, we posit that the time constraints of chaotic environments uniquely affect the circularity of learning-adaptation processes leading to learning driven or adaptation driven initiatives. Our paper discusses a case study of the latter type.

Keywords

crisis, disaster, emergency, representation theory, volunteer

Introduction

In the aftermath of a disaster, the disruption of the functioning of the society might exceed the government's ability to cope with the crisis. Therefore, it is common for volunteers to offer their support to help victims of disasters. First responders face severe information scarcity about the aftermath of the disaster, but today's technological development offers unprecedented possibilities for volunteers to support the disaster response by filling the information gap. The ubiquity of internet connectivity, the diffusion of mobile technologies, and the increasing capability of Information Technologies (IT) to collect and process digital data streams (Pigni et al. 2016) can significantly improve the ability to inform Emergency Management (EM) initiatives and support the disaster response remotely. The digitalization of crisis-related information virtually enables countless volunteers to support a response initiative (anyone with an internet connection), and to pick from a wider skill set than the government agencies.

Communities of digital volunteers (also called civic hackers) can coordinate with professional respondents to support EM operations in a variety of contexts (Adrot and Robey 2008; Bajpai et al. 2010; Sebastian and Bui 2009). The contribution of these organizations is crucial particularly when there is no information system in place or when the one in place fails, preventing the authorities to comprehend the status of a disaster. However, compared to government organizations, volunteer organizations usually operate relying on a limited budget, which adds up to the sever time constraints that characterize emergency scenarios. Time and resource constraints typically lead to develop and deploy *frugal systems* (Watson et al. 2013). Designers of frugal systems focus on a very circumscribed scope and aim at deploying the system as fast as possible to cope with the peak of the emergency; but the way organizations seek timely deployment can drastically change on a case-to-case basis. Intuitive thinking might suggest that organizations would leverage existing and ready-to-use systems. For instance, the literature documented about the use of Ushahidi, an application for crisis-mapping, to aggregate and present crisis-related information in the aftermath of 2010 Haiti Earthquake (Mulder et al. 2016; Valecha et al. 2013). However, adopting an existing

system is not the only strategy to pursue rapid deployment. For instance, another way to cope with a time constraint is to timely adapt a technology that volunteers are already familiar with.

In particular, we present the case of a digital volunteer organization that emerged in the aftermath of the 2016 Central Italy Earthquake CentralItalyEarthquake (TerremotoCentroItalia, https://www.terremotocentroitalia.info/) to support relief operations in the aftermath of the 2016 Central Italy Earthquake. Our goal is to explain how this organization pursues frugality by adapting an open source software development platform (https://www.github.com) for EM purposes.

The scope of the platform is to provide an accurate digital representation of the aftermath of the disaster (e.g., number of victims, affected areas, needs). Those representations are essential for increasing respondents' *situational awareness*, the "perception of environmental elements during incidents, emergencies, and crises concerning time, space, and meaning, critical to the decision- making processes" (Silvius 2016, p. 239). Following the idea of information systems as tools for digitally represent the reality, our theorizing builds on Representation Theory (RT) (Burton-Jones and Grange 2012). RT posits that to achieve representations, users pursue effective use of IS by iterating between *adaptation* and *learning actions*. Our analysis focuses whether this holds true in chaotic context, which present "high turbulence, unclear cause-effect relationships, and acute time pressure" (Burton-Jones, et al. 2017, p.17). RT has not been applied to a chaotic context yet, therefore it is unclear to what extent the theory would hold true in explaining system's use in turbulent environments. From a RT standpoint, the investigation of IT use in EM is a contextualization of representation problems in chaotic environments, which might lead to corroborate RT (Burton-Jones et al. 2017).

Therefore, we look at a real-case study to discuss whether the RT theorization of effective use as the product of iterating over learning and adaptation actions holds true in chaotic environments. Our main contention is that EM scenarios present time constraints that will disrupt the recursive iterative nature of the learning-adaptation cycle as originally posited in RT. Thus, we contribute to pursuing RT success through *extension,* by contextualizing RT in EM, and intension, by discussing the unique impact of time constraints on the RT nomological network, and in particular on the learning-adaptation loop (Burton-Jones et al. 2017).

Research Background

Digital Volunteers in Emergency Management

Emergency Management (EM) studies how to cope with crisis events, such as natural or man-made disasters. In EM, scholars use the terms *disaster* and *crisis event* interchangeably to indicate "an unpredictable, uncertain and urgent event that imposes severe threats to life, well-being or other significantly held values" (Tim et al. 2017, p. 199). Crises present severe time-pressure and the disruption of the typical organizational structures, which lead affected communities to seek for external help for coping with the disaster. Apart from government agencies, private citizens might also group into volunteer organizations to help with the disaster relief operations. Traditionally, volunteers needed to be physically present in the area where relief operations occurred. Today, IT allows volunteers to operate remotely, offering.

IT does not simply streamline traditional core activities of volunteer organizations; instead, it enables radically new forms of organizational structures. Communities of volunteers can be entirely IT-enabled, and build on loose digital social tights to create "communities that work to expand field capacity" of government agencies "mostly in a remote and distributed manner" (Sabou and Klein 2017). Digital communities are often temporary (or frugal) and arise reactively in response to crises. Prior research frames the phenomenon of digital volunteers as a special instance of crowdsourcing (Mulder et al. 2016) where volunteers are not exactly "proposed the voluntary undertaking of a job" (Estellés-Arolas and González-Ladrón-de-Guevara 2012, p. 8). Instead, we focus on the context-specific ways in which non-profit organizations adopt and use the technology to perform EM tasks. Frugal systems for EM are developed and deployed minimizing time and resources, and with a circumscribed scope. Typically, organizations opt for open source software, and leverage technologies that would-be users already have (Watson et al. 2013). That is more likely to lead to design platforms rather than *ad hoc* applications. A frugal IS should integrate as much as possible with the existing applications (Watson et al. 2013). Moreover, it is harder for individuals to adopt applications/devices that they are not familiar in the disruption of the aftermath of a disaster (Sakurai et al. 2014). Also, the limited bandwidth – or even limited access to electric power – might simply block the victims from downloading/installing new applications. Besides these context-specific design

requirements, the socio-technical aspects (Silver and Markus 2013) of volunteer organizations' shape their ability to design and deploy system for EM too. For instance, volunteer organization typically suffer high turnover: Volunteers gather together for collaborating to humanitarian initiatives only temporarily. Eventually, from a socio-technical perspective, the frugality of the system is necessarily intertwined with frugal aspects of the organization too. For instance, compared to government organization, for volunteer organization it might harder to retain the know-how to operate effectively. Thus, scholars advocate for longer tenures within volunteer organization (Sabou and Klein 2017). Ideally, this should improve volunteer organizations' ability to retain the know-how and use technology more efficiently. Engaging volunteers over time might turn frugal initiatives, into broader EM initiatives that expand among different phases of the disaster response, entailing preparedness (pre-crisis initiatives) and recovery (mid and long-term response). Whether this happens depends on the ability of the organization to retain and keep its members engaged over time in a digital environment.

Representation Theory

Representation Theory (RT) posits that individuals seek *faithful* (digital) *representation* of the real-world to guide their decision-making process (Burton-Jones and Grange 2012). The notion of faithful representation mirrors the three-dimensional construct of *accuracy*: The extent to which the representation reflects the *truth*, the *whole truth*, and *nothing more* about a domain of interest (Burton-Jones and Volkoff 2017), which in RT constitutes the *deep structure* (Burton-Jones and Grange 2012). Thus, information systems should be error-free (the truth) and offer a complete (*whole* truth) and pertinent (*nothing but* the truth) representation of the domain of interest. So far there is no clear evidence that RT holds true in chaotic environments. Thus, our theorizing moves from prior application of research on RT to complicated or complex environments – where time is not a constraint – to disentangle the role of acute time pressure on use. A key difference in chaotic contexts such as crises, is that events unfold quickly in a highly turbulent environment, and even the burdens of the domain of interest might blur. Time constraints straitjacket the decision-making process, and digital representations must be timely – on the top of being truthful, pertinent, and complete (Burton-Jones et al. 2017) – otherwise information will not constitute actionable knowledge. Therefore, information is accurate when it faithfully represents the reality at a specific point in time. Thus, timeliness in an enabler of *informed actions* (Burton-Jones and Grange 2012).

Nevertheless, because in EM actions are processes potentially involve a wide spectrum of subjects, we limit the scope of faithful representations to enable *situational awareness*, which allows understanding of the current situation and the *projection* of informed action (but not the action itself). Therefore, in our adaptation of RT to chaotic contexts, timeliness is also an enabler of situational awareness together with truthfulness, completeness and being error-free.

In non-chaotic contexts, individuals strive to obtain more faithful representations from the system by iterating between *learning* actions, which entail *learning* the system "as is" and *adaptation* actions, consisting in improving the fit between the surface and the deep structure of the information system (Burton-Jones and Grange 2012). The learning-adaptation cycle enables improving *effective use* across two dimensions: *consistency* and *accuracy* (Burton-Jones and Volkoff 2017). Accuracy is the extent to which the system represents the truth, the whole truth, and nothing but the truth. *Consistency* instead incorporates four main dimensions[1]: (i) *utilization*, all users use a given feature, (ii) *place*, all users input a specific data item in the same place, (iii) *form,* all users input the records in the same format/structure and using the same level of detail, (iv) *meaning*, all users have the same interpretation of the meaning of data. Accuracy and consistency jointly enable *effective use*, which is the goal-directed use of a system to attain goals leveraging representations that the system provide (Burton-Jones and Grange 2012). Thus, individuals iterate over learning and adaptation to progressively obtain more accurate representation and use the system more consistently. However, scholars have not agreed yet on whether RT holds valid in chaotic environments, nor whether such a contextualization of faithfulness and effective use might affect the current formulation of RT (Burton-Jones et al. 2017).

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[1] In its original conceptualization, consistency consists of five dimensions. However, we collapsed consistency of form and amount under *consistency of form* since it provides enough detail for the scope of our research.

Elaborating on the strive for timeliness in a chaotic environment, we speculate that a possible way to cope with the acute time pressure is minimizing the iterations of the learning-adaptation cycle. Therefore, in chaotic environments, we would expect individuals to achieve effective use with fewer iterations, but heftier adaptation or learning actions. That leads us to suggest two possible ways of achieving effective use under acute time pressure: By producing *adaptation-driven* or *learning-driven* initiatives. In adaptation-driven initiatives, those volunteer communities that can leverage highly adaptable systems without the need for much learning will try to do to so. More malleable technologies, which enable layered and modular architectures (Yoo 2013), offer opportunities for organizations with more skilled volunteers to undergo adaptation-driven initiatives. That means we would expect considerable development to adapt the system into one that can fulfill the requirements, and which individuals can use effectively without investing extra time in learning. Moreover, adaptation is also an enable for accuracy, since it might enhance the ability of the system to create a more faithful representation of the real-world phenomenon.
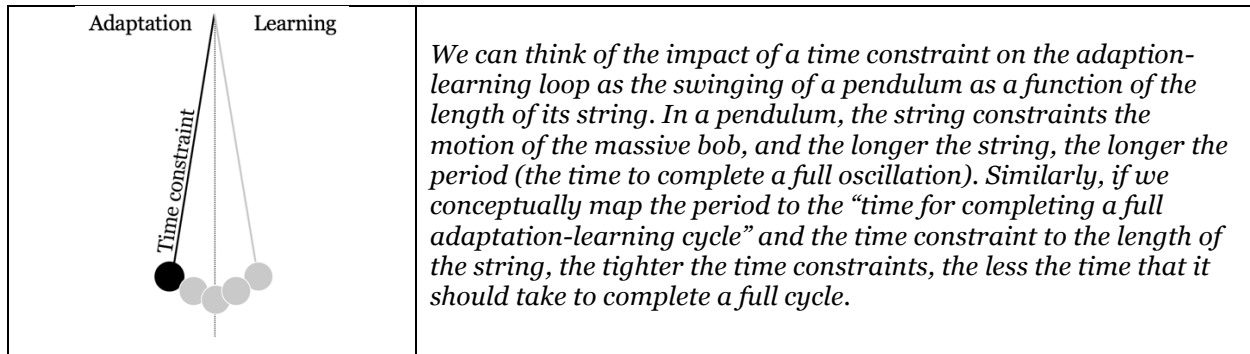

We can think of the impact of a time constraint on the adaption-learning loop as the swinging of a pendulum as a function of the length of its string. In a pendulum, the string constraints the motion of the massive bob, and the longer the string, the longer the period (the time to complete a full oscillation). Similarly, if we conceptually map the period to the "time for completing a full adaptation-learning cycle" and the time constraint to the length of the string, the tighter the time constraints, the less the time that it should take to complete a full cycle.

Figure 1 Conceptualizing the learning-adaptation cycle under time constraints

Instead, when a ready-to-use application is available, or when the organization does not have the right skillset to produce an adaptation-driven initiative, organizations prefer *learning-driven* initiatives. Learning-driven initiatives are more likely to present a higher level of consistency since improvements in the design of the system iteratively occurred beforehand without the incumbency of an ongoing crisis. Learning-driven initiatives are more likely to lead to higher level of consistency of use, assuming the learning is successful. Volunteers who cannot use the application effectively might decrease the ability to collaborate within the organization during the initial phase of the disaster response (Valecha et al. 2013), paradoxically when effective collaboration is needed the most. Adaptation-driven initiatives instead are more likely to provide more accurate representation in those scenarios where a ready-to-use application fails to map the deep structure of the event of interest.

Research Context

The 2016 Central Italy Earthquake

The event of interest is the earthquake swarm that affected Central Italy in 2016, characterized by three main events: August 24th 6.2 M_w, October 30th 6.5 M_w, and January 18th 5.5 M_w. The first event registered 299 casualties and 388 injuries, with a financial loss estimated at \$32.5 Million[2]. The municipality that was affected the most was Amatrice, a small village in the province of Rieti. Many streets were obstructed by debris from collapsed buildings, preventing first responders from entering the worst affected areas. In the early hours after the first shock, the authorities used UAV footages to collect information about the most affected areas. The second shock affected the municipality of Norcia (26 miles from Amatrice), in the province of Perugia. Although the October 30th shock was the worst shock that affected Italy since 1980 (with ca. 3000 casualties), this time no victims were registered. Nevertheless, the situation of many of the already profoundly compromised buildings in the area worsened, eliciting new requests for help. The reason why no casualties occurred is both because the Civil Protection was still active since the first shock and

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[2] Cronache, di Redazione. "Terremoto: nuova stima dei danni, il conto è di 23,5 miliardi di euro." Corriere della Sera, 15 Feb. 2017, www.corriere.it/cronache/17_febbraio_15/terremoto-nuova-stima-danni-5db6d2f6-f364-11e6-a927-98376e914970.shtml.

because many citizens of the affected municipalities had already been evacuated or spontaneously left their homes after the first shock. The January 18th shock caused 34 casualties[3].

Particularly during the first event, the earthquake compromised IT infrastructures too, slowing down (or interrupting in few extreme cases) the internet connectivity, which however was quickly restored to the pre-crisis levels in most of the affected area. Thus, this case study holds that internet connectivity is resilient to crises or that basic connectivity can at least be restored within few hours (e.g., through a satellite connection).

The Italian Emergent Management Agency

The agency that is responsible for coordinating EM operations in Italy is the National Civil Protection Service. The idea behind a national agency for EM, is to pursue a highly centralized response system to minimize interoperability issues. At the same time, this centralized structure shows flexibility at the local level: The head of the Civil Protection in each municipality is the mayor, but higher levels are activated depending on the magnitude of the threat, up to a state level response under the direct responsibility of the prime minister. In this respect, the Italian Civil Protection differs from the US agency (FEMA), where a centralized agency does exist, but many states have their own agencies, and the FEMA's command chain does not directly branch in each municipality. The National Fire Department, the Armed Forces, the Police, the National Forestry Corps, the scientific community, the Italian Red Cross, the structures of the National Health Service, voluntary organizations, the National Mountain and Alpine Rescue Corps, are instead all coordinated by the Italian Civil Protection in case of national emergencies; NGOs as well consult with Civil Protection to effectively collaborate in the response phase. That avoids emotionally-driven initiatives that might be ineffective or even hinder the relief operations. For instance, within a few hours after the response, the Civil Protection asked to stop collecting and delivering food and clothes[4]. To allocate resources to store the donated goods means to subtract them from rescuing; moreover, the vehicles transporting donations could interfere with rescuers' vehicles approaching the area.

The Volunteer Organization

In the immediate aftermath of the first shock, the volunteers of CentralItalyEarthquake (TerremotoCentroItalia, https://www.terremotocentroitalia.info/) activated to remotely support the disaster response operations remotely. The goal of the organization was to aggregate crisis-related information from different sources to help any agencies involved in disaster response initiatives. Thus, their scope was twofold: aggregating and sharing. As is typical of frugal IS, the volunteers opt for an open source platform (GitHub) and seek to develop a system which is reusable and scalable for future crisis events. Their mantra is "aggregate, open, and distribute." Aggregate entails collecting and organizing data that are relevant to build a common operating picture. Open, pertains guaranteeing full access to the deep structure of the system. Distribute, is about processing data, and transforming them into meaningful and actionable information nugget. Based on these criteria, volunteers designed an infrastructure using GitHub, a hosting service for version control repositories primarily adopted by software developers.

CentralItalyEarthquake: A GitHub-Based Crisis Mapping System

Crisis mapping is enjoying increasing popularity in solving crisis-related information sharing issues, for example through Google Maps (Valecha et al. 2013) but also through more dedicated applications. Although some argue that designing systems specifically for crisis events is flawed (Allen et al. 2014), the literature presents some notable success cases. For example, Ushahidi (https://www.ushahidi.com/), is an application that became popular to coordinate disaster response; in particular, scholars focused on its use in the aftermath of 2010 Haiti Earthquake (Mulder et al. 2016; Valecha et al. 2013). Its goal is to collect requests for aid via SMS, web form, and present them meaningfully, particularly leveraging interactive maps. The case of the 2010 Haiti Earthquake is probably the first crisis mapping initiatives by digital volunteers operating remotely. Their job mainly consisted in translating the requests from Creole to English and label them appropriately. The frugal nature of information systems for EM, which requires to "develop

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[3] "Dipartimento della Protezione Civile." Terremoto Centro Italia | Dipartimento Protezione Civile, www.protezionecivile.gov.it/jcms/it/terremoto_centro_italia_2016.wp.

[4] "L'appello di Luigi D'Angelo (Protezione Civile): 'Non inviate alimenti e indumenti'." La7.It, www.la7.it/lariadestate/video/lappello-di-luigi-dangelo-protezione-civile-non-inviate-alimenti-e-indumenti-25-08-2016-191951.

and deploy with minimum resources" to meet a preeminent need (Monteiro et al. 2014, p.3) might suggest a tendency to prefer a ready-to-use application such as Ushahidi. Instead, in our case study, the volunteers adapt GitHub (a technology designed for software development) into a full-stack tool for digital EM management, from data entry to analysis and front-end presentation. Thus, severe time constraints do not necessarily impede to develop frugal systems that lean on substantial adaptation.

GitHub is a popular tool for collaborative coding which allows sharing scripts online and coordinating developments or fixing bugs by opening *issues* in the GitHub repository. Typically, issues refer to specific parts of the code to fix or to requests such as implementing additional features. What is unusual in this case is that besides using GitHub for software development (website, maps, mobile app, etc.), volunteers used it for real-world issue tracking. Nevertheless, the volunteers quickly realized, that the issue-tracking system on GitHub could translate into a tracker for real-life issues (e.g., victims' help requests from the affected area). Thus, a new use of GitHub arose from what RT sees as violating the consistency of meaning: The GitHub issue does not reflect a software development issue anymore, but a real-world EM issue. Interestingly, the labeling feature that GitHub offers translates quite effectively to real-world phenomena; for instance, volunteers can label a fundraising for a PSTD therapy program for children[5] as "Children" and "Fundraising," enabling faster search. At the same time, individuals need to establish new guidelines to pursue consistency of use with respect to the new scope of the system. For instance, the volunteers provided some guidelines on the minimal information required in each issue tracking a need (e.g., location, source, contact). On the top of the needs that volunteers directly post as GitHub issues, the requests flowing into GitHub results from monitoring an array of sources: social network, chat application, web application, Feed RSS and email (Table 1). Nevertheless, also the requests from any of those sources are preprocessed (e.g., verified, labeled, integrated) and turned into a new GitHub issue.

Table 1 The ports available arranged by their type

Social Network	Chat app	Web app	Feed RSS	Email
Facebook Twitter Flickr Instagram Waze	Messenger Channel Telegram Channel Telegram BOT	Website GitHub repo Android App Medium Channel	Updates on blog posts Civil Protection National Geophysics Institute	

In the jargon of the organization, a source is called a *port* (Table 1), because it enables two-way communication: Information can enter the system, but volunteers can use the same port to broadcast processed information. For instance, the volunteers and victims can submit a help request through the website (using a web-form), yet the organization can use the site also to communicate with the victims.

Hypotheses
In the context of our case-study, the RT (developed initially for non-chaotic environments) suggests that the use of the system is characterized by an ongoing learning-adaptation loop. Moreover, prior research suggests that organization should pursue longer tenures of their volunteers to enable successful initiatives. However, when considering both time-constraints and the frugal nature of the EM system in this study, we suspect that the phenomenon could change. Thus, we decide to challenge the predictive power of RT on two hypotheses:

1. In chaotic environments, the iterative nature of the learning-adaptation loop regresses to unidirectional initiatives, which are predominantly either adaptation-driven or learning-driven.
2. Longer tenures are not necessary when the initiative is adaptation-driven (rather than learning driven) for the initiative to be effective.

Data Collection
The data collection involved two sources: The GitHub repository hosting the artifact, and the Telegram chat group that volunteers used for coordination purposes. In particular, our analysis of the GitHub usage

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[5] https://github.com/emergenzeHack/terremotocentro_segnalazioni/issues/254

focused on the analysis of GitHub issues (496 Issues, from August 25th) collected through the GitHub API[6]. Those issues mostly track bugs, enhancements, or suggestions for guiding the development of a platform, for instance, "Add a Twitter RSS to our webpage," or "Update the list of casualties." Once someone solves the issue, they can "close" it. Thus, issues represent a proxy measure for the volume and duration of actions to build and adapt the platform.

The other measure we look at is the engagement of volunteers over time, using data from the Telegram group chat (~8k messages, from August 25th, 2016 to December 24th, 2017). Although GitHub allows users to comment on issues, volunteers used the Telegram group more extensively as a channel for coordination purposes instead of GitHub threads. Thus, we consider the frequency of Telegram messages to be a more accurate measure of volunteers' engagement over time since it does not suffer the sparsity of posts on GitHub. Finally, a semi-structured interview with one of the coordinators provided an insider perspective on the project, which is crucial to test the face validity of our proxy measures from Telegram and GitHub usage. The platform was activated during the first shock (August 2016) and remained active over time, meaning that it was already active when the next shocks (October 2016 and January 2017) happened. That allows measuring the volunteers' use of the platform over time for three main seismic events.

Results

Figure 2 shows the density plot of the count of GitHub issues (opened and closed) over time, referenced with the dates of the four main shocks over time. One *issue* is a proxy for an adaptation action that volunteers perform to improve the platform's ability to collect and present crisis-related information. Each issue is a request for a development (e.g., adding a new feature, fixing a bug, integrating a new data source). Thus, the amount of opened issues reflects the magnitude of the requests for adaptation actions, and the closed issues the amount of those successfully addressed. Figure 3 instead shows the weekly count of Telegram messages, grouping volunteers according to three profiles: *Starting*, volunteers who message to the group for the first time; *Quitting*: volunteers who never messaged again after that week; *Returning*: volunteers who message at least once in the current week, but not for the first time.
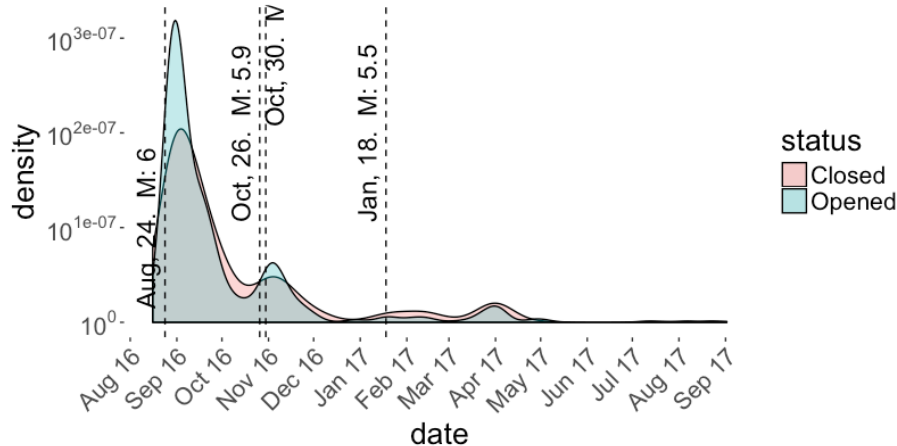

Figure 2 Density plot of GitHub issues over time

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[6] The issues in our dataset refer only to system-related development issues, which volunteers use for crisis-data presentation and collection. Issues are also used for data-entry purposes (e.g., to track needs), but those are stored in a separate repository which is not part of our analysis.
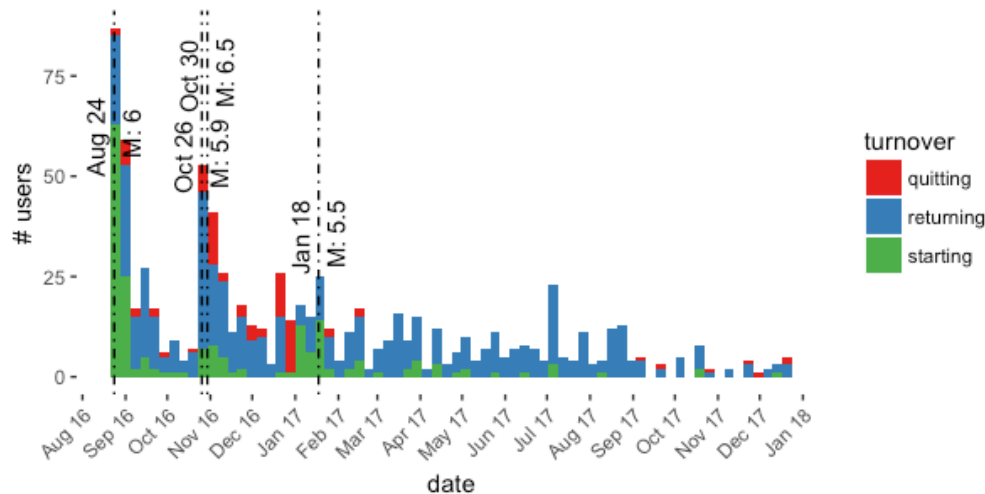
Figure 3 Engagement of digital volunteers (using engagement on Telegram as a proxy)

Analysis

The density plot (Figure 2) suggest that the development of the systems presents a steep adaptation phase, characterized by a high number of issues being opened and closed almost simultaneously. The skewness of the distribution of the issues shows that adaptation peaks immediately after the first shock, but then drastically decreases. That suggests the absence of significant adaptation initiatives following the first deployment, which partially contradicts what RT predicts about the iterative learning-adaptation cycle. If a recursive adaptation-learning loop occurred, we would expect a flatter and more uniform curve, or perhaps several subsequent peaks indicating adaptation initiatives following learning stages.

The second peak on the chart follows the second major seismic event in October, but with a much lesser magnitude. That suggests that the volunteer community rapidly implemented the features needed for developing the platform, without further ongoing re-adaptation. Because more volunteers quit after the second shock, this suggests that the platform maintains operational stability in spite of shorter tenures and possible losses in the know-how, corroborating the idea that the community can largely rely on adaptation (rather than learning).

A concurrent interpretation is that a learning-adaptation loop does occur, but with fast iterations that makes challenging to discriminate sharply between learning and adaptation moments. Because of time constraints characterizing chaotic environments, volunteers cannot rely on several iterations of the adaptation-learning loop to achieve effective use, unless those iterations occur extremely fast. That interpretation is sounding, and at the current stage of our research we cannot rule out that the iterative nature of the phenomenon preserves in chaotic environments.

A counterargument to this concurrent explanation (i.e., that the learning-adaptation cycle preserves), is that if effectiveness resulted from iterating over subsequent learning moments, then part of the know-how would probably dissolve together with those quitting volunteers. That is precisely why prior literature advocates for longer tenures within volunteer organizations. Such is not the case with our organization, which seems resilient to quitting volunteers. Preliminary evidence of the ability to maintain effective use of the platform comes from the lag between opened and closed issues: The red shadow in Figure 2 shows comparable profiles in the ability to address open issues across the August and the October events. Resilience to volunteers' disengagement is a desirable attribute of frugal EM systems since disasters are likely to pull many volunteers who approach the initiative emotionally but cannot guarantee long-term commitment. According to our interviewee, the studied organization was not immune from such phenomenon, but Figure 3 shows that a substantial part of the volunteers remained engaged over time, enabling the organization to tackle longer terms issues. As Figure 2 shows, the activity of the organization continues well after the initial acute response phase, entailing the recovery and humanitarian relief operations too.

To conclude, we would like to discriminate the adaptation-driven approach emerging in our case-study, from a more simplistic "gold hammer" attitude guiding adoption. As the interviewee stressed, the volunteers adopted GitHub because they were already familiar with it, thus with the intention of minimizing learning aspect in developing the platform. Many digital volunteers had extensive experience using GitHub for traditional purposes (e.g., software development), and thus preferred to adopt a familiar and highly adaptable technology, rather than investing time learning how to use a pre-built – but perhaps more effective – system. However, the familiarity with a system is *per se* insufficient to lead to an adaptation-driven initiative. A necessary condition is that the community needs to compound familiarity with an informed expectation about how fast the technology can be adapted to fulfill unusual tasks effectively (e.g., using GitHub to track real-world issues instead of coding ones). Thus, volunteers need to recognize the inherent malleability of the technology in the first place, independently from the learning that may occur from observing the technology-in-use within the new context.

Limitations and Future Directions

Our work presents some interesting limitations which motivate us to move forward with the investigation of this case-study. First, Representation Theory has not yet shown convincing evidence of its validity in chaotic environments. Although we acknowledge that the generalizability of RT to chaotic contexts has yet to become evident, we believe that our attempt to apply elements from the RT ontology to EM situations represent a step forward to extending RT to frugal systems development in chaotic context. To validate these early findings, we need to provide stronger evidence that GitHub issues are a valid proxy for adaptation actions. For instance, we might compare GitHub issues' patterns from development initiatives in chaotic versus non-chaotic ones. Such a comparison would show whether GitHub issues mirror the learning-adaptation cycle that the theory claims would occur under normal conditions.

In our analysis, we acknowledge this aspect and propose an alternative explanation, which still contributes to extending RT: The chaotic nature of the environment, and the time constraints, in particular, shape learning-adaptation actions of volunteer organizations very differently than for other types of organizations in non-chaotic contexts.

Conclusions

All EM initiatives deal with a fundamental paradox: The need to cope with new and unexpected issues without much time for acquiring new resources to coordinate the response (Adrot and Robey 2008). Intuitive thinking would suggest that technology adoption under such circumstances aims at minimizing any development efforts which might delay the deployment of a system. However, in our case-study, the exact opposite occurs, and the organization undertakes a development-driven initiative. Instead of adopting other available apps with built-in EM features (e.g., Ushahidi), the volunteers prefer to adapt the features of a platform for software development (GitHub) to address EM tasks. That suggests that different communities of digital volunteers solve the EM paradox differently and that time-constraints push towards polarized approaches that are either adaptation or learning-driven. Elaborating on this dichotomy, we rule out the "gold hammer" interpretation of adaptation-driven initiatives, explaining why familiarity with the system is necessary but *per se* insufficient to lead to adaptation-driven initiatives. Instead, we frame the phenomenon using RT and articulate why organizations might choose adaptation-driven approaches in spite of severe time constraints. The precondition is that individuals mature an informed expectation about the malleability of the system and its ability to represent the real-world event.

Obviously, adaptation-driven initiatives are hardly purely adaptation-focused and require a certain extent of learning: New volunteers might join the organization, new guidelines to collectively pursue consistency arise, and improvements to the first design of the system might become necessary. However, to encourage participation, it is critical that volunteers can interact with the system seamlessly, and ideally with little training. Reducing training efforts is not trivial since imposing to learning a completely new system to a volunteer community might dramatically fail. For instance, during the 2010 Haiti Earthquake, an attempt to use SharePoint for organizing and sharing crisis-related information failed because users disliked having to learn from scratch an artificial pre-built classification structure (Yates and Paquette 2011).

Our contribution to the current body of literature on RT is to enhance the understanding of how chaotic environments uniquely shape the use of information systems, possibly straitjacketing systems use into adaptation-driven approaches (which tend to minimize learning) and learning-driven approaches (which tend to minimize adaptation efforts). That partially disconfirms the iterative nature of learning and

adaptation moments, which RT posits would occur for system use is non-chaotic environments. However, even maintaining that the learning-adaptation loops preserve in chaotic environments, we show that the entry point to a would-be adaptation-learning cycle is going to be sharply learning or adaptation focused. Our intent for future research is to investigate further the actualization of learning and adaptation actions in chaotic environments, and the impact of time constraints when adapting RT theory to an EM context.

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