Relief Work after the 2010 Haiti Earthquake: Leadership in an Online Resource Coordination Network

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ABSTRACT

The US Navy directed its vast resources at the relief effort following the Haiti Earthquake on January 12, 2010. To coordinate with non-governmental-organizations (NGOs) participating in the relief effort, the US Navy used an online discussion forum. What follows is an examination of the emergence, rise, on-the-ground utility and decline of this "walled-garden" style discussion forum. Our findings show that most site activity is broadcast oriented and does not result in discussion, but in the small percentage of cases where discussion emerges, participants are focused on the exchange of medical, Global Information Systems (GIS) and equipment on the ground oriented information. We show how activity on the discussion forum changes over time, and corresponds with events on the ground in Haiti. Four archetypical users are profiled to demonstrate how invisible brokerage style leadership, identified through grounded theory analysis of posts, can be made visible through network analysis of interaction traces. Our findings have implications for the use of forum style, "walled garden" technology for coordination and information sharing in future crises.

Author Keywords

Disaster Relief, Online Coordination, Government, NGO.

ACM Classification Keywords

H5.3. Collaborative Computing

INTRODUCTION

Effective coordination and information sharing in disaster situations is a matter of life and death. Social media, first responders, non-governmental organizations (NGOs) and both civil and military government organizations cooperate to respond to and manage the crisis that follows any disaster. Improving information sharing and coordination between government agencies with significant resources, NGOs and affected civilians will save lives by saving time and improving the information available for decision makers about resource distribution. The All-Partners Access Network (APAN) is a US Navy sponsored electronic forum that enables coordination between US

government agencies – principally the Navy – and organizations that do not have access to government systems, such as NGOs. In this study we examine Government-NGO coordination in APAN[1] during the crisis that followed the January 12, 2010 7.0 earthquake disaster in Haiti.

Prior work in CSCW focuses on understanding and designing social and participatory media to help members of the public contribute to disaster response in a coordinated manner [32]. Similar coordination gaps exist between government resources like the US Navy and NGOs during a crisis. In the latter case, governments have logistical, medical and transportation resources that can both assist and be augmented by NGOs. Unlike current modes of citizen participation in relief efforts, Government-NGO coordination and information sharing relies on conventional, "walled garden" discussion forums like APAN. In a walled garden, access is vetted. In this way, information is at once more trustworthy and less available to those outside the network. This type of coordination and information sharing work is unexamined in prior CSCW studies of disaster relief.

Government-NGO crisis coordination through discussion forums centers on getting locally relevant information, responding to the need for information, connecting to others in crisis; and community computing [31]. The Haiti relief APAN forum is used for information-related discussions and coordination discussions, similar to the findings of Kodrich and Laituri [1]. This study examines how Government-NGO crisis coordination is facilitated by tools like APAN from three perspectives. First, we analyze and group topics of discussion to understand the most prominent types of interaction. Second, we relate activity in the forum to key government-NGO coordination events in the field. Third, we innovate methodologically to better understand participant behavior on the Forum.

In this paper we integrate grounded theory with network analysis of APAN page view (read) and forum contribution (post) data for two purposes. First, we identify interaction networks that emerge in the forums. Second, we also identify users who are not among the most active people in the forums, but who play key, "invisible broker" roles." An invisible broker is a leader who connects two networks of

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[1] http://community.apan.org

activity within APAN, but is not identifiable from raw post activity. Our examination of the contributions of "invisible brokers" whom we identify through electronic trace data, shows that the substance of their post activity in the forums is focused on, literally, brokering and coordinating relief efforts on the ground.

Physical, Virtual and Technology Context of Study

The relief effort related to the Haiti earthquake has been examined from a number of other perspectives. For example, Mission 4536, a collaboration of private companies and emergency relief agencies, leveraged crowd sourced translation and geo-location with SMS-based reporting to collect and organize information from a distributed human network in Haiti [15]. The resulting system helped address immediate emergency needs, expanded employment opportunities during the disaster response and increased opportunities for participation in the disaster recovery period. Our work builds on these and other efforts by bringing focus to the role of government organized information and communications technologies (ICTs) designed to support information and coordination that leverages substantial government infrastructure; in this case, the US Navy's medical, equipment and GIS information capacity.

The 2010 Haiti Earthquake offers a unique context for analysis of government-NGO coordination because the destruction of the capital city of Port-Au-Prince, Haiti eliminated a significant portion of the telecommunications infrastructure, hampering coordination and rescue efforts. The analysis of information sharing and coordination through APAN during the Haiti crisis helps us to understand how individuals, representing NGOs and government agencies, participated in coordination of relief efforts *from a distance* and contributed to targeted action on the ground.

Given the scale of the Haiti disaster and the significant resources of the US Navy, it may be surprising that basic discussion forum technology is the center of coordination and information sharing [1]. Understanding the levels, types and leaders of interaction in this forum will inform future use of technology in disaster situations. For example, responsiveness to users, timeliness of information, ease of site navigation and information monitoring are key attributes in successful forum sites in disaster relief scenarios [27]. Here, we analyze a vivid, exemplar crisis.

CSCW AND DISASTER RELIEF

There are numerous systems in place to try to predict, prevent and respond to disasters; however the unique and chaotic nature of large disasters often means that standard procedures break down. The resulting confusion is compounded by the fact that despite the inferred meaning of the colloquialism "first responders," the first people on the scene of a disaster are usually the members of the local community and not professionals trained to respond to the emergency at hand [5]. In the past, these individuals would have affected the disaster locally (e.g., by providing disaster relief support to victims), but with recent innovations in ICTs, such as smart phones, camera phones, mobile texting, email, and GPS capability, they are able to communicate information more easily and are affecting the way people outside the disaster see and understand it as it is happening [24]. In fact, disasters often lead to innovative uses of ICTs [32]. Most prior CSCW research on disasters focuses on connecting the community with relief.

In time of disaster, information seems to flow in three directions – from authorities to the public [18; 19], from the public to authorities [10; 35; 38] and from peer-to-peer [24-26; 29; 31; 36]. For example, following the 2001 Gujarat Earthquake, the news media in India helped deliver key information using multiple lines of communication, including chat rooms, help lines and information dissemination. The electronic groups that emerged within these forums helped relief workers solicit donations for disaster relief [18]. Laituri and Kodrich [19] show that online news media does enable the public to be more involved in disaster relief through awareness and promotion of trusted charities. The public, in turn, seeks information verification to augment what they hear from official sources. They often do this using social connections both in their community and online [6; 12; 22; 35].

Through the use of ICTs and social media, the public is often able to contribute to the knowledge of the authorities in addition to communicating with their community [38]. For example, residents of the area affected by the 2007 wildfire in California reported about their experience and provided essential information about the crisis to people outside the area [10]. While looking at this disaster, Sutton et al. [35] learned that faced with disaster, the public seeks information from any available source "regardless of whether the source is considered authoritative or not." This idea of "citizen journalism" is relatively new, but has become commonplace in society [8].

The 2010 Haiti earthquake was the first time that social media was used as part of the US Government's formal response to a disaster [2]. Research into the role these online communities play suggests that when properly employed, they create "transformational knowledge sharing between communities", but when not properly employed are useless and distracting. The research also suggests that since timely information is of the essence during a disaster and it is often unclear who has the "best" information, in some cases more authoritative sources of information have an important, complementary role to play with social media. Connecting authoritative sources with social media then, is an area for future investigation that begins with our study of how more authoritative information sources, like APAN, function in a disaster.

Beyond communicating and sharing information with authorities, information in times of disaster often flows from peer-to-peer. For example, after Hurricane Katrina,

people were able to connect with one another through social media and online neighborhood-based forums to locate missing family members, and organize relief efforts such as seeking and offering donations, shelter, and employment opportunities [24; 29; 31]. Websites were specifically created to facilitate "connected giving," providing a link between people who wanted to donate goods and services and people in need in the disaster area [36]. This peer-to-peer approach was efficient and bypassed the need to involve a third organization. Information and communication is also important while a crisis is occurring, and in the first hours of response. In the wake of the April 2007 shooting at Virginia Tech University, students were able to determine the welfare of their friends and fellow students through peer-to-peer communication across crisis stages [25] and generate an accurate list of the 32 victims using Wikipedia, Facebook and other social media before Virginia Tech released an official list [26].

Information communicated during disaster situations is diverse in its mode, nature and trustworthiness. Beyond simply sharing personal, situational or coordination information, people use online communities during disasters for interpersonal and emotional support. Torrey et al. [36] found that online communities are crucial for trust development in disaster relief efforts. For example, a computer network set up for people dealing with the foot and mouth disease crisis in the UK provided "a virtual space for interpersonal contact, community discussion, and mutual help among farmers at a critical time [13]."

Numerous schemas for categorizing and understanding the information communicated in the crises following a disaster have been discovered by prior research. Yan et al. [38] observed online discussions related to the 2008 Sichuan earthquake and identified four primary ways that the Tianya forum supported the community - information-related discussions, opinion-related discussions, emotion-related discussions, and action-related discussions. Similarly, Shklovski et al. [32] suggested that online disaster-related discussions fall into four main categories; getting locally relevant information, responding to information needs, connecting to others in crisis and community computing.

ICTs are crucial for bridging the gap between authority and information in a crisis. Garshnek and Burkle [7] articulated the importance of understanding the relative advantages and disadvantages of three basic pathways for communication: landlines, airwaves and satellite links. Social media and forums like APAN have altered this landscape. Now, disaster relief efforts rely on access to the Internet. Jaeger et al.'s [17] study of the Katrina Crisis found that Internet access was crucial for connecting members of a disaster struck community [17]. In a crisis, people, governments and NGOs rely on the Internet, including social networks, blogs and forums like APAN to share all types of information. Information sharing is a central issue in crisis management

because those responding to the crisis seldom have both the best information and authority for making decisions [34].

Bui et al. [27] developed a framework for conceptualizing the types of issues that emergency relief workers must overcome, suggesting that the central issues in disaster relief management are information, coordination and the effects of disaster relief work on workers [3]. Information issues include information distortion and inconsistencies that must be reconciled. Coordination between governments and NGOs can be problematic because of government reluctance to release information with potential security implications and communication incompatibilities, including both language and technology. [3].

Most existing research on the use of ICTs in disaster relief is focused on how ICTs support emergency management [30] and the activities of disaster relief workers [20; 28]. But much of the research also attempts to develop a framework for understanding the issues or make suggestions for a future disaster relief model [29,37]. Haghani and Oh [14] developed a multi-commodity multi-modal model for logistics management in the time of disaster. Palen et al. [32] developed a vision for the future of disaster management, which leverages the use of ICTs by focusing on the potential of members of the public during disaster situations. They suggest that supporting the public and enhancing their ability to make good, timely decisions can reframe disaster relief as a socially distributed information system [23].

Many experts in the disaster relief field are advocating for the widespread adoption of a global information network like ReliefWeb[2], which was developed by the UN Department of Humanitarian Affairs in 1996. ReliefWeb is a central repository for maps, press releases, field reports, and important forms. Extending this idea, Okada recommends the implementation of a "one stop shop" that uses GIS technology and integrates with web-based groupware [33]. Similarly, Bui et al. [27] propose the development of a web-based global information network to link information, opportunities for collaboration and decision focus before, during and after a disaster [3].

This paper extends prior work through an analysis of how a walled garden, APAN, facilitates relief activities during the Haiti crisis. With the rest of this paper we present our research questions, methods and three main findings. Our discussion suggests future CSCW research on disaster relief integrates public, government and NGO coordination and information sharing.

RESEARCH QUESTIONS AND DATA

Our study is focused on understanding how government-sponsored coordination forums are utilized during disaster situations, how this use changes over time, and how

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[2] http://www.reliefweb.int

leadership emerges in these forums. Our research questions are 1) What kinds of information and coordination occurred on the US Navy sponsored APAN site during the Haiti crisis; 2) How does coordination and information exchange change over time and 3) To what extent do mediation and coordination activities (invisible brokerage) by forum members become visible through electronic trace data.

We perform network analysis and grounded theory analysis of the electronic trace data from the APAN site and triangulate these activities with news reports of events on the ground to answer our research questions. Our analysis of the electronic trace data from the APAN Haiti Forum focuses on collaborative behavior within the forum, and use of the forum for information dissemination over time. There were 5,606 total discussion threads. To answer research question one (information and coordination behavior), we focus our content analysis of topics on the 228 (4%) initial posts that generated a response (threads). We chose to topically group threads because users did not focus on specific threads, they sought out multiple threads, often following a focus of interest discerned from our grounded theory analysis. Of the 5,378 posts without responses, 898 were image uploads and the remainder were standard format status updates.

Our network analysis, used to answer research questions two and three, incorporates read and post behavior across all threads. The posts on the APAN Haiti Forum began in the second week of 2010 and the *data are represented at the "week of the year 2010" unit of analysis*, not the week of the forum. The dataset incorporates all data on the forum from January 13, 2010 (Week 2) – June 3, 2010 (Week 24). We include all 23 weeks of data from the forum to demonstrate differences between read and post behavior.

METHODS

Our mixed-methods analysis follows our group informatics approach for building weighted social networks from electronic trace data [11; 21], which mitigates important theoretical and validity concerns previously identified [16]. Initially, the 228 threads where collaboration takes place were categorized based on salient themes that emerge through open coding [4; 9]. After open coding, the codes were grouped and then the authors performed axial coding on the 228 threads with responses until saturation of theme for each thread was obtained. The resulting codes and number of corresponding threads are provided in Table 1.

Table 1 - Top Five Discussion Topic Codes

Code	Count
GIS Information Need	26
Ground Status	26
Medical	25
Transportation Logistics	24
GIS Information Provision	18

Following the coding, the researchers constructed a weighted social network from the electronic trace data of post and read data independently. In our construction of the network, each comment in a thread has some relationship to all the comments before it, but the strength of that relationship decays along two dimensions. First, the strength of connection between a post and the posts immediately before it in the same thread, which are displayed while a comment is being added, are strongest. This strength is calculated using both time and proximity on a page. Comments that occur within one hour of each other have a more significant strength of connection (~50x at 1 hour as at 1 day, with a sloped decline) than comments that occur after a 1-hour window.

After constructing the network, we performed weighted network analysis on the trace data using two units of analysis: the week and the code of the discussion thread. We calculated network centralization for the entire network and weighted post and read betweenness for each actor within that network using the TNET package in the statistical software program, R. We also calculated weighted in and out degree centrality for each participant who posted or read data on the APAN discussion threads.

Betweenness is a social network measure that identifies actors who play a broker role between clusters of people. Betweenness in electronic trace data has two semantics: one related to the broker role, derived from post data, and another related to read behavior [11], sometimes referred to as lurking; though our content analysis suggests that in this case this behavior is more like information consumption than lurking. In social network analysis, degree centrality is a measure of a person's relative network participation. We use a weighted degree centrality measure that shows both in degree and out degree centrality separately. In our findings, the post "in degree" of user A is represented as user B responding to User A's post and post "out degree" is user A's response to user B's post. Similarly, read "in degree" of user A is an indication of user B reading user A's post and the read "out degree" of user A is calculated by analyzing the posts that user A is reading. Our combination of directed and weighted degree centrality analysis with betweenness centrality analysis of this electronic trace data enables us to discern the emergence of different types of leadership, information and coordination behavior. Degree centrality tells us about dominance; betweenness conveys two forms of brokerage behavior within topics and across forums and time.

FINDINGS

In total, 336 individuals posted information within the 228 discussion threads and 2,557 individuals read an item within those same threads. The individual with the most posts had 1,231 posts and the individual with the most reads had 3,093. These disparities between posters and readers are consistent across time and topic category.

Post and read frequency among participants varied over time. The drop off of posts was very steep. The number 11 poster had 112 posts after which there was a steep drop off and a long tail of individuals who had less than 10 posts (n=280). This is a classic power law distribution of activity by participants, which illustrates this forums similarity to other Internet forums. The read data illustrates a similar, but more gradual slope from the most active readers to those who rarely engaged in the forum. Read behavior continues months longer than post behavior (Figure 1). The top 16 posters all had more than 1,000 reads and the bottom 2,052 individuals all had less than 50 reads, illustrating a clustered group of active and inactive lurkers.

Topics Categorization

The 23 codes developed during our open coding (see methods) were applied during axial coding to each of the 228 discussion threads. Two of the most prevalent codes were those related to requesting GIS information (n=26) and those providing GIS information (n=18). Combined, these two areas of discussion reflect how information about the physical location of people, crisis events and resources can be coordinated from a distance during a crisis.

The other prevalent codes in the 228 discussion threads with responses were Ground Status (n=26), Medical (n=25) and Transportation Logistics (n=24). These topics reflect coordination efforts of individuals physically located in the United States and other countries attempting to provide assistance to Haiti. Much of the discussion related to finding out the status of relief and medical efforts in specific areas and coordination of transportation for supplies to and from areas within Haiti.

Table 2 - Relief Events Identified Through Forum Activity

Event	Date	Description
RE0	1/18/10	Major US Relief assets, including ships and supplies, begin arriving
RE1	1/19/10	Canadian relief forces install runway lighting to enable 24/7 arrival of aid
RE2	1/23/10	Haitian government declares an end to rescue efforts
RE3	1/25/10	Donors conference begins in attempt to develop ways to channel aid
RE4	2/1/10	USS Carl Vinson, USS Bunker Hill, USNS Henson leave Haiti
RE5	2/7/10	The USS Nassau ends its relief mission to assist world food program
RE6	2/9/10	The 22nd Marine Expeditionary Unit relieves the 24th Marine Expeditionary Unit in relief efforts
RE7	2/12/10	The US Relief force is reduced from 20,000 to 13,000 as other international aid arrives

Codes that received less activity represented niche information requests and the provision of specialized services. For example, the code Language Assistance (n=3) represented a set of three individuals who were interested in providing language support for individuals needing to communicate with those within Haiti. Codes such as Communication Infrastructure and Communication Status were two closely related categories that represented a set of discussions about the damage and rebuilding of the communication infrastructure and the status of communication mechanisms in certain parts of Haiti. These categories were used by individuals outside of Haiti to coordinate relief efforts and provided understanding of the parts of Haiti with limited capacity to communicate need. The most prevalent uses of the forum related to the unique resources available from the US Navy's extensive medical, transportation and GIS data related resources both at sea and on the ground.

Temporal Activity of the Network

The temporal nature of the network and its participants follow a definite ramp up and decrease of interactions that coincide with the events and stages that occur during the Haiti relief effort. Figure 1 illustrates post and read activity annotated with key events for the first 31 days of the relief effort. The specific events are enumerated in Table 2. Figure 1 and Table 2 illustrate the temporal rhythm of the network of participation in both posts and reads as it corresponds to important events on the ground. The most active posting and reading days on the forum correspond with events in the relief effort, coordinated through the site.
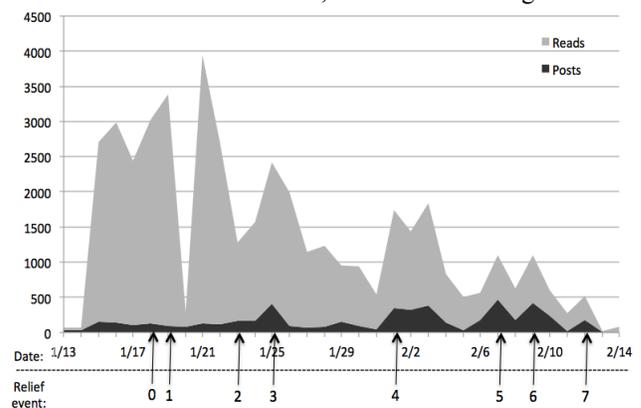

Figure 1 - Forum and Relief Event Timeline

On January 18, 2010, major United States relief assets began to arrive and foreign relief efforts ramped up. At this same time runway lighting was installed at an auxiliary airport to further assist in logistical transportation efforts. Five days later on January 23, the Haitian government declared rescue efforts over, shifting to a relief and recovery mission. Two days after the Haitian government declared rescue efforts over, Haitian Prime Minister Jean-Max Bellerive met with US Secretary of State Hillary Clinton and other world leaders in Montreal to determine how to best channel aid that was being collected to Haiti.

Two weeks later on February 7, US assets began to wind down immediate relief efforts with the departure of the USS

Nassau, which was responsible for coordinating with the United Nations World Food Program. As US assets were leaving Haiti, units that were on the ground were shifting purpose to help establish long-term relief. On February 10, electricity was restored to large portions of the capital city of Port Au Prince and two days after that the United States reduced its relief force from 20,000 to 13,000 troops.

Relating Forum Temporal Rhythm to Activity on the Ground
The posting behavior on the forum had a highly active period during the 31 days immediately following the Haiti Earthquake (an average of 167 posts per day). The three most active days were January 25 (n=408), February 7 (n=464) and February 9 (n=418). The number of posts quickly declined after February 13 to an average of 11 posts per day from February 14 to February 28. In March, there were just over 4 posts per day on average and in April an average of just over 2 posts per day. The number of posts became more sporadic in May. The last posts in the dataset occurred on June 3, 2010.

The read behavior within the network illustrates a similar ramp up and decline as the post behavior, but it is a more gradual decline and is sustained for much longer than the post behavior. This is likely due to the passive nature of reading as opposed to active nature of posting, and suggests that, while posting behavior diminished as the US Navy reduced its force, NGO users continued to access the forum for information. The most active days of read behavior were January 21 (n=3,813) and January 19 (n=3,290). These two days represent the second week of the forum's operation and followed a very active period of posting. It is likely that this activity represents individuals getting acquainted with activities on the ground. The highly active reading days were followed by highly active posting days as the five days including and following January 21st were some of the most active posting times on the forum (196 posts per day). This period immediately follows the arrival of substantial US and Canadian relief forces on January 18 and 19.

In the first 31 days of the forum there is an average of 1,277 reads per day, followed by an average of 127 reads per day from February 14 to February 28. The average reads per day declines from 58 in March to an average of 20 in April and 9 in May. This decline in number of reads per day, coupled with the decline in number of posts per day corresponds closely with relief events on the ground and relief force configuration changes.

Participant Behavior
We select four exemplar actors in order to provide a rich analysis of several actor types. For each specific actor we highlight, there are several actors who take on similar roles within the network, but would not surface through analysis of the forums that did not include thematic classification of topics and examination of electronic trace data across threads with the same topic category. Our coding enabled subsequent processing of the electronic trace data by category. Analysis of the temporal behavior of exemplar,

high betweenness centrality actors in the network enables us to identify actors who play important, but invisible information brokering roles as discussion participants. We include a few representative quotations from the discussion board from our exemplar actors in order to establish the relationship between their network position (invisible brokers), derived from analysis of electronic trace data, and the nature of their contributions, derived from analysis of each discussion thread and post.

None of the four "invisible broker" actors that we use as exemplars of a set of similar users in our data set are in the top 10 of the individuals in post or read counts and none take any overt action to make their presence known. A table of these four individuals, their specific role and their background along with their raw activity count and rank are shown in Table 3.

Table 3 - Significant, Invisible Mediators

Position and ID	Post	Read
APAN RFI Manager (Lucy)	14	14
Government Contractor (Andrea)	15	38
Senior GIS Specialist (Mike)	35	58
NGO Executive Director (Ruth)	26	468

Lucy: APAN Request for Information Manager
Lucy is the Request for Information (RFI) Manager for APAN and her role was reflected in her network activity. Though Lucy's title indicates that she is an important part in the network, she is still outside of the top 10 in both read and post data. She had the highest participation rate of the users we chose as exemplars. In total, Lucy initiated 44 threads that received 267 responses, and contributed to an additional 59 threads with a total of 285 responses.

Lucy had the highest betweenness score in the categories of GIS Information Provision and Medical, and also placed high in betweenness in many other categories including Military Coordination, Request for Equipment and Security Information Request. For these topics, Lucy is an integrative information gatherer and provider. One example of this behavior is Lucy's use of information from one forum to assist a cruise line, asking in another forum where to send ships for temporary housing: *In another Forum, "Control of Vessel Traffic in and out of PaP", it is also stated that "the host nation has control of port traffic." Further it reports that the number that was good before the earthquake was* [ommitted]*".*

In addition to placing high in those categories and actively participating in many other categories, Lucy had the highest overall post betweenness in week 2 and the second highest overall betweenness in weeks 3 and 4. These weeks correspond with the earthquake, the launch of the APAN site and the first arrival of US Aid to Haiti. Lucy's post betweenness dropped to the middle of the group in week 5, as the relief effort became established. After week 5, Lucy was non-existent in the post data. Additionally, Lucy had

high post in degree and out degree in weeks 2-5 and more specifically had the highest post out degree in weeks 2-4. Lucy was a leader in the traditional sense, and an information broker during the first 3 weeks of relief.

Lucy established the purpose and activity of the forum in the early weeks; not surprising, given her title of APAN RFI Manager. Our analysis of the content of her posts consistently shows her in the middle of information flows. Her high post in and out degree during the first couple of weeks of the forum further confirm leadership role. Though Lucy did not post a lot after week 5, she did actively read. Lucy's transition from visible leader to invisible broker in the forum shows that changes in disaster relief missions are detectable from the analysis of forum trace data.

Measures of read in and out degree for Lucy illustrate that even though she was less active after week 7 in her read activity and after week 5 in her post activity, Lucy's posts were still being read throughout the course of the forum. This indicates that Lucy's posts were an integral part of the APAN Haiti Forum for those individuals participating in the later time periods, after the forum was initially established. The persistence of Lucy's importance in the network, independent of active posting or read behavior by her, illustrates a shift in her contributions from active collaboration to an information reference leader.

Andrea: Disaster Relief Consulting Firm Principal

Andrea is another important contributor to the forum as illustrated by her post and read ranks of 15 and 38. Her role as a principal of a disaster relief consulting firm helps to explain the difference between her activity and the activity of the APAN RFI Manager Lucy. Andrea, had the highest betweenness in the following categories: Communication Infrastructure, Communication Status, General Coordination Information, Ground Status, and Request for Equipment. Andrea also had high betweenness centrality in many other categories, including Coordination of Efforts, General Information Requests and Medical.

In addition to the high betweenness in posts based on categories, unlike Lucy, Andrea's "invisible broker" status, indicated by the betweenness measure, was consistent during the whole time period. Andrea had the highest post betweenness in weeks 3 and 4. Like Lucy, during this period Andrea had high in and out degree centrality as well; but unlike Lucy, Andrea's degree centrality was much lower after week 4. Additionally, Andrea had relatively high betweenness in weeks 2 and 7. This behavior, coupled with analysis of the text of Andrea's posts and her early high degree centrality, indicate initial efforts to build awareness of her firm on the forum, followed by more targeted participation in discussions where Andrea could offer her services. Though less central in her post behavior as time passed, forum users continued to pay attention to Andrea's posts throughout the relief period, as indicated by Andrea's in degree centrality during weeks 2-9.

Andrea's overall activity suggests a person who was trying to make herself known on the board by posting often to garner attention, but her betweenness centrality and analysis of her post content shows that she is more of an invisible broker than a leader. She initiates 51 threads that receive a total of 474 responses, placing her in the middle of much forum discussion. For example, as US Relief Forces begin arriving on January 18th, Andrea relays information about spotty and at risk cell phone infrastructure in Port au Prince in response to requests for information: *Yes - if you click on the link (title of the article) I posted it will direct you to digicel's website and map of coverage. ... fuel is a priority for the three cell towers that they have running. Coverage is not good in the PaP area.*

In the days after the US Navy relief effort began on January 18th, Andrea coordinated efforts to re-establish communication infrastructure in Haiti: *Update: The proposal is now at the stage where additional datasets will be required. a) Locations of Community WIFI network hubs desired by NGO; Command, and Haitian Government b) High resolution Imagery and GPS coordinates of said locations c) Priority of installation sites.* Her post in degree illustrates that she was not the most central poster, but that her high participation throughout the course of the forum increased her visibility to forum users. Andrea's high post in degree in the early and middle weeks illustrates that other forum participants paid more attention to her activity early in the time period but, unlike Lucy, did not revisit her topics later. This corresponds with the difference between Andrea, who participated in more transient topics, and Lucy, who coordinated topics that served as a foundation for the APAN forum. The contrast between Lucy and Andrea illustrates the difference in behavior between two very active individuals that are highly central and participate in many parts of the network. One is a government "connector", the other is an private sector or NGO "connector"; that is the meaning of high betweenness centrality.

Mike: GIS Specialist

Mike is in a different role than Lucy and Andrea. He receives many requests for new GIS information or clarification of previously supplied GIS information. His user profile indicates that he is a GIS Specialist at a disaster relief organization. His use of APAN is focused on GIS topics. Mike ranks number 35 in post data and 58 in read data. Fitting his title, Mike has the highest betweenness in the category, GIS Information Need and also places high in betweenness in General Information Requests. Mike *initiates no threads*, but responds to 16 threads that received a total of 100 responses; all categorized as GIS related.

The overall post and read betweenness measures for Mike also illustrate an interesting set of behaviors. In weeks 3-6, Mike appears in the top 10 each week for post betweenness, but is not present in post betweenness in any of the other weeks. This corresponds with the time period when US

relief was initially arriving, and our analysis of the text of Mike's posts show that his work was facilitating the identification of specific locations for relief activity.

Mike has low (not top 15) in degree and out degree centrality in all weeks except week 6. It is during this time that he is very active in the forum responding to requests for information. Our analysis of Mike's post activity shows that during week 6 he is posting GIS information that can be consumed by NGOs and foreign government sources following the reduction in US Forces in Haiti.

The combination of the network measures with qualitative analysis of post content for Mike illustrates how somebody with specialized knowledge plays a vital role in maintaining relevance of the forum for NGOs. The high post betweenness in the early part of the forum's time period coincides with Mike's provision and clarification of GIS related questions and also points individuals to resources to help them better understand the situation in Haiti.

If we look only at the people who are "most active" in the forum, Mike does not appear. It is only through analysis of the data by specific categories that Mike's role as an invisible information broker becomes visible. The identification of individuals who play integral specialized roles is important in disaster relief efforts; and all information dissemination efforts, as they are important to ensure that decision makers also have the best information.

Ruth: NGO Executive Director
Ruth, like Mike, does not post a lot. Her rank in forum activity for posts (#26) and reads (#468) would not cause her to be noticed without the approach we use; but Ruth plays an important and central role in one niche aspect of the APAN forum supporting Haiti relief. Ruth is the Executive Director of an NGO that helps assist local community residents recover from disasters. Ruth has the highest betweenness in the category Orphanage Assistance and was the third highest betweenness actor in the category Coordination of Online Efforts. Ruth initiated 20 threads that received only 83 responses, and responded to 18 additional threads, with 83 total responses. The fact that Ruth was an invisible broker in those two categories surfaces her specialization. Her posts demonstrate that she focused on helping orphanages that were affected by the earthquake and coordinated online support for the relief efforts. This specialized activity is similar to Mike's participation in posts focused on GIS. For example, Ruth is active coordinating relief supply deliveries with a new person in the field via APAN on February 3, shortly after international forces grow in participation (i.e., new people on the ground): *Please let know when Susan returns from DR to PaP so that we may coordinate the kits to got to the clinics and orphanages we pre-designated.*

The post and read betweenness measures of Ruth illustrate the short and limited duration of Ruth's participation in the network. Ruth had the highest post betweenness in week 5,

and was also relatively high in other weeks she participated: 3, 4, 8, and 9. Ruth's read data began in week 2, but her betweenness was very low at that point indicating limited participation. Ruth's read betweenness eventually climbed to be the second highest user in week 5. After week 5, Ruth had a read betweenness of zero, which indicates that she did not read other posts after week 5 and only contributed to the discussion at that point. This was likely the result of Ruth's ongoing, targeted efforts to help orphanages affected by the disaster. On the ground, week 5 is also when there is a transition in US forces, with three ships ending their missions. This led to coordination work for NGO experts with knowledge of the situation in Haiti to help transition the relief mission to international and local forces.

Ruth and Mike both illustrate different behaviors from Lucy and Andrea. Ruth and Mike are specialists involved in certain aspects of the coordination efforts online and thus only appear in specific parts of the network that become evident after qualitative analysis of the content. Lucy and Andrea are active in a broader scope of forum topics. These two different classes of invisible broker in the forum illustrate the importance of understanding the underlying activity and actions of users in a disaster relief network. They highlight the roles of specialized leadership and coordination for both governments and NGOs, made visible by the provision and discussion of information in forums like APAN during disaster scenarios. The identities of these information and coordination brokers are not evident without the mixed methods analysis we conducted.

DISCUSSION
This work has implications for future crisis informatics research. Here, we first analyzed how forum technology was used to help coordinate relief work in response to the earthquake in Haiti on January 12, 2010 by describing the kinds of information sharing and coordination that occurred. Second, we showed how the use of the forum changed over time and the extent to which people collaborated around specific topics. Lastly, we showed how certain types of individuals coordinated and brokered information in the forums, and how these behaviors are connected to relief activity on the ground and network patterns discernable from forum interactions.

Ours is the first study to look at Government-NGO information sharing and coordination behavior in an online forum. Though our topical categories of activity fit in the general categories found in earlier work looking at discussion forum use in disasters more broadly, the topics we find, like our study, are more specific. GIS information, transportation logistics, medical information and ground status information are dominant topics across many of the forums during the Haiti relief effort.

Several important questions are raised. How are the gaps in coordination and information sharing filled after the decline of government sponsored coordination sites for NGOs? Is it possible or advantageous to sustain coordination and

communication through these sites during longer-term rebuilding projects? To what extent might communities be reinvigorated or reinvented following disaster scenarios if the role of such sites evolved, instead of ending with the end of US Government-NGO coordination?

The APAN site is a walled garden style forum, isolated from general citizen participation following disasters. Future designs that integrate closed, trusted communities like APAN with social media have the potential to increase direct support for the public during a crisis, as suggested by Palen [23]. Future CSCW research may consider the notion of a Government-NGO "aquarium" style discussion forum or coordinative tool. In this kind of forum the government and NGOs are able to share information with each other, and a central administrator decides what information can be distributed through social media, or made available through an APAN style forum.

Citizen contributions to government-NGO coordination forums through social media or direct access could be treated as annotations to verified information. To make a clear distinction between trusted and unverified information, citizen provided cell phone pictures, tweets or text messages could be represented in the style of Facebook comments or through the use of visually distinct text styles. Selectively sharing content from forums like APAN through social media could increase intrinsic motivation among both APAN participants and citizens to exchange information with each other. Such an exchange would increase perceived timeliness of information and responsiveness of site participants, which our work and prior work demonstrates are key dimensions of crisis response forum uptake and use. Citizen participation also has potential to help sustain crisis response forums and the resources of their members through the rebuilding phase.

Making invisible brokers visible is an important next step for CSCW work focused on crisis informatics. We triangulated coding of discussion boards with network analysis to surface a category of user we refer to as "invisible brokers". Many such brokers exist in the forum (~15% of users), but they are not visible through cursory examination of the forum itself. These are people who, in two cases (Lucy and Andrea) do make significant contributions to the forum at different times; and in two other cases (Mike and Ruth), are users who are generally not visible. In all four cases, we connect their high network betweenness centrality at different times with the content of their posts. Like all human relationships, the statistical measures and the coordinative behavior have an ambiguous relationship, but in this disaster relief data set, they clearly live together. The combination of a person's role, and events on the ground are connected to **when** different people are visible. This is also important, as NGOs focused on aid and GIS specialists are called for during different phases of a crisis.

Future CSCW research on crisis informatics should consider focusing on the use of our group informatics form of analysis, integrating electronic trace data with knowledge of the activities they correspond with to provide real time identification of invisible brokers. Unlike other forms of collaborative computing, where central project leaders sustain online community, in a crisis response situation there are a multitude of foci. Invisible brokers are vital to sustaining each of the key communication topics, and benefits to areas in crisis are likely to accrue if these key players are recognized for their important role, and identified to agencies responsible for crisis response and citizens.

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