Harness Human Sensor Networks for Situational Awareness in Disaster Reliefs: A Survey

Weiwei Yuan, Donghai Guan, Eui-Nam Huh and Sungyoung Lee

Abstract— **Complete, accurate and up-to-the-minute situational awareness can help disaster relief organizations stabilize the dangers and prevent further losses. Social media users can be regarded as human sensors since they are analogous to the response of physical sensors to stimuli. Human sensor network (HSN) provides a way to capture situational awareness information coming directly from the grassroots observers in the disasters. The disaster relief organizations can utilize the HSN data to gain the real-time live situations. It saves time and money. This paper surveys on the works of viewing social media as human sensor networks and extract the situational awareness information from HSN in disaster reliefs. It is found that HSN data, used together with other scientific data, can contribute to better situational awareness in the disaster reliefs.**

***Index Terms*—disaster relief, human sensor network, situational awareness, social media**

I. INTRODUCTION

Social media users can be regarded as human sensors since they are analogous to the response of physical sensors to stimuli [1-4]. Social media (SM) are Internet-based applications that enable people to communicate and share user-generated contents, such as blogs, wikis, photo sharing, video sharing, and micro-blogging sites [4-6]. As shown in Fig. 1, when an event occurs, the physical sensors respond with positive signals, while human sensors respond by making posts via human sensor network tools (i.e., SM), e.g., users might post "Highway #1 is blocked in the earthquake" on Twitter, and then, the sensor network platforms collect and analyze these inputs to produce outputs.

Human sensors have significant advantages over physical sensors [1-8]: (1) There is no (or very low) cost to set up the human sensors. The sensing hardware has already been deployed and has a relatively predictable power supply. (2) Human sensors are present in large numbers covering a vast spatial expanse. (3) Human sensors can give responses to any possible events. (4) The assistance from the human users can enhance application functionality. For instance, a human user may help by pointing the camera appropriately at the target object to be sensed.

The human sensor networks' potential ability on information aggregation has recently received a great deal of attention in disaster reliefs. Disaster is something that can cause harm to any one thing, person or corporation [7-10]. It includes natural (e.g. floods, earthquakes, cyclonic storms, tornadoes, wildfires), technological (e.g. structural fires, dam failures, hazardous materials incidents, nuclear accidents), social hazards, or circumstances (e.g. riots, wars, terrorism, CBRN incidents). Effective and immediate disaster reliefs rest on the ability of the situational awareness, which means to involve all knowledge that is accessible and can be integrated into a coherent picture, when required, to assess and cope with a situation [11-15]. Complete, accurate and up-to-the-minute situational awareness can help disaster relief organizations to stabilize the dangerous situation and prevent further losses.

It is found that most first responders in disasters are not trained professionals, but local people affected by the disasters [8, 16]: many people witnessed the damage post photos and videos, tweet from their smart phones and use other widely adapted social media to report time-sensitive disaster information. This sort of grassroots information from the ground raises the disaster situational awareness. Advances in computer technology have given raise to new and powerful devises: in additional to regular equipments like computers, increasing number of mobile communication devices like smart phones are equipped with sensitive microphones, high-resolution cameras, GPS receivers, motion and acceleration sensors, as well as multitasking operating systems running on increasingly powerful batteries, processors, memory and graphics processing units. This enables more and more people more actively use human sensors to respond to the disasters, making human sensor network (HSN) a new way of situational awareness.

In this paper, we make a survey on the works of viewing SM as HSN and extract the situational awareness information from HSN in disaster reliefs. HSN provides a way to capture situational awareness information coming directly from the grassroots observers in the disasters. The disaster relief organizations can utilize the HSN data to gain the real-time live situations. It saves time and money. HSN data used together

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with other scientific data such as remote sensing data, can contribute to better situational awareness in the disaster reliefs.

The rest of the paper is organized as follows: section 2 analyzes the existing disaster relief measures, section 3 points out the architecture of HSN platform and some key issues, section 4 presents some popular HSN platforms of disaster reliefs, section 5 gives the case study, and section 6 concludes this paper and points out the future directions.

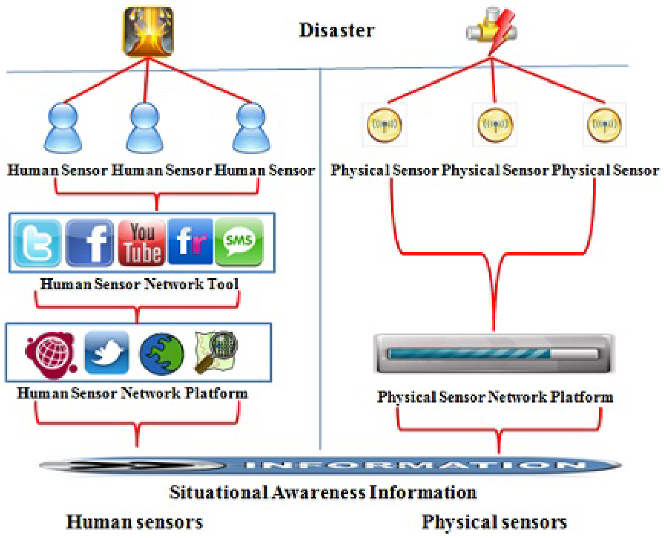

Fig. 1. Comparison between human sensors and physical sensors.

II. Existing Disaster Relief Measures

Traditional disaster relief organizations focus on collecting information through their own internal channels [8, 16-22]. They tend to deploy older while tempered technologies like documents and paper works to avoid risks. These measures are time-consuming, especially for the disaster relief organizations which are unfamiliar with the local environments. Traditional disaster relief organizations always face unprecedented information gaps in disasters. It is even hard to find the verified baseline information such as street-level maps for dispatching search and rescue teams, up-to-date hospital throughput rates for planning the shipment of medical supplies, road closures and routing for moving aid.

Traditional disaster relief systems are not capable of aggregating or prioritizing information come from outside sources. This makes them difficult to pull local intelligence into process [8, 16-25]. Existing disaster relief systems are rooted in a paradigm of documents and data bases passed through hierarchies. They had neither tools nor formal protocols for communicating with the human sensors. Despite the good will of the disaster responders, the policies and procedures of the disaster relief organizations were not designed to incorporate data from outside their networks.

Disaster relief organizations are expected to process the incoming data rapidly. However, no matter how fast the information is processed, it was always behind where it is expected to be [26-29]. Although the processing ability of the traditional disaster relief organizations has continuously improving, the volume of data flowing through these pathways, and the number of information sources, have increased at an even faster rate. Mechanisms used to handle these increased flows of information are lagging far behind. Disaster relief organizations are struggling to fill the information gap, arriving more quickly than ever before. This is a problem from the non-disaster world that is greatly amplified in disasters.

III. HSN as a New Measure for Situational Awareness of Disaster Reliefs

The traditional disaster relief systems can incorporate the HSN data in two ways: (1) incorporate the information directly provided the human sensors, and (2) incorporate the aggregated situational awareness information provided by the HSN platforms, which is extracted from the HSN data. The latter is more convenient for the disaster relief organizations in the real applications.

As shown in Fig. 2, the architecture of the HSN platforms consists of the following key entities:

1. Sensors: human sensors that sense the physical disaster situational information

2. Network Infrastructure, which includes a data collection module that collects all the sensor data provided by the human sensors, a data filtering module that extracts information closely related to the target disaster situations, a data parser module that interprets the information into useable formats, and a data aggregation module that aggregates the overall mass information and generates the situational awareness information that is concise to use for the disaster relief organizations. Note that the human sensors can be widely geographically distributed, not only including the primarily locals, but also including those who were not directly affected by the disaster [3]. The Web 2.0 technologies make it possible for people from around the world to participate in disaster reliefs.

3. Users: the disaster relief systems that use the produced situational awareness information through the interactive interface.

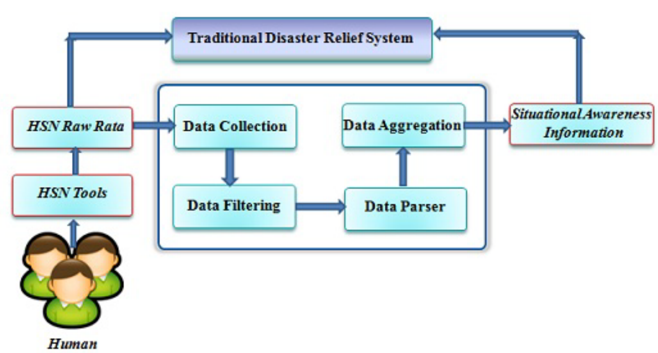

Fig.2. The architecture of the HSN platform for the situational awareness of disaster reliefs.

The Technical Requirements of the HSN platform include:

• Reliability: Since certain information (for example a request for help) may be critical to save human lives, its timely and accurate reception should be ensured.

• Energy Efficiency: In order to keep HSN work properly as long as possible, energy efficient algorithms should be used.

• Scalability: HSN platforms should incorporate data aggregation and data fusion techniques to handle a large amount of human sensor data.

• Localization: An important technical requirement is the ability to automatically obtain the current location of human sensors as accurately as possible.

• Interoperability: data format should be interoperable to enable information sharing between HSN platforms.

• Security and Privacy: HSN data should be verified to prevent false damage or hazard reports. Security is a preliminary challenge in the current HSN platforms [16-25]. It is found in the real disasters that a high proportion of HSN data turned out to be false. E.g., it is mentioned that overall 70% of the information about people being trapped was unreliable. Many people fully understood that their family members were dead, but wanted the disaster relief organizations to come to bring out the bodies. In order to permanently integrate HSN data, inaccurate information, whether intentional, exaggerated, or accidental, should be rapidly identified.

The most important situational awareness research issue in the disaster relief is the location awareness, especially in areas where maps have not been created or maps are outdated [23]. Location information includes street addresses and intersections, city names, county names, highways and place-names (schools, landmarks, etc.) By capturing, locating, and displaying data extracted from HSN, the HSN platforms create crisis maps to help disaster responders navigate areas that need assistance [27].

There are several sources of the location information in the HSN data [27-41]:

(1) GPS

Since the GPS devices are becoming smaller and cheaper, they have been widely used in many handheld devices like cell phones. This makes it possible for human sensors to provide the information tagged with geolocations. The GPS enabled location information is accurate, easy to process and represent on a map. However, only limited number users turned on geolocation in the real situations. So it is necessary to extract the location information from other location related data.

(2) Hashtags associated with places

A common case of the location information is provided by the textual descriptions of place (placenames and less-specific geographic features) with hashtags in HSN data, like those often included in an SMS text message. Placenames in text can be geocoded to assign location coordinates.

(3) Place references extracted from HSN data

Location-referencing refers to information that uses one place as a reference for another, i.e. “10 miles away from my house,” where the reference point is ambiguous without knowledge of situational context. The geo-location information cannot be easily extracted from the location-referencing HSN data. However, if the reference information is further uncovered, it contains valuable location information.

(4) Location information in user profiles

Majority of human users give the location information in the user profiles. This information can be extracted to represent the location of the HSN data given by the related human sensor. The accuracy of this information is not high, but it is still valuable in the emergencies.

Since the inputs are any form of location information, the biggest gap in the location awareness is extracting structured output from unstructured inputs, in which the outputs would be points on a map with a few key values that matter for disaster reliefs. The technology of natural-language processing and the participation of volunteers to manually monitor and sort the information might be necessary. Standards should also be proposed to convert the location information in the timely, cost-effective and valuable crisis maps for disaster reliefs.

IV. Popular HSN Platforms of Disaster Reliefs

The HSN platforms enable human sensors upload situational information with detailed eyewitness, such as “vital lines” information — food, water, and shelter, locations of field hospitals and distribution points, reports of trapped persons and urgent medical needs. Popular HSN tools include Twitter, Facebook, Youtube, Flickr and SMS. The situational information is then compiled by the HSN platform to contribute to the situational awareness, usually in the form of crisis map, of the disaster relief organizations.

Some representative HSN platforms include:

1. Ushahidi

Ushahidi [42] is a software platform aggregating and mapping information provided by human sensors. It pulls information from HSN such as Twitter, Facebook, and blogs to create reports that can be placed on a web-based, interactive map available to anyone with an Internet connection. Ushahidi organizes and encourages volunteers to help process the raw HSN data into structured reports.

Ushahidi was organically developed to map incidents of violence in Kenya following elections in 2008. It is now widely used for various purposes: monitoring elections, tracking the depletion of medical supplies, reporting human rights violations, tracking wildlife, building networks of peace actors, empowering disenfranchised communities through citizen journalism etc. Ushahidi’s crisis maps were deployed in many disaster relief activities, such as the Hurricane Sandy, the East Japan Great Earthquake, the Deepwater Horizon Oil Spill, and the Haiti Earthquake.

2. TtT

Tweak the Tweet (TtT) [43] utilizes the Twitter platform for HSN information provision during disasters. TtT asks users to tweet using a crisis specific microsyntax designed to enable real-time processing of Tweets. The TtT micro-syntax is based on primary or main hashtags that can be used in any crisis situation and are designed to indicate the “who, what, and where” of the Twitter message content. For example, #name or #contact can be used to indicate “who”; #need, #shelter, #road, #open, #damaged can be used to indicate “what”; and #loc can used indicate “where”. These hashtags are used in conjunction with an event tag to organize the crisis. Event tags can be spontaneously generated during an event, like #joplin or

#tornado, or prescribed by the TtT micro-syntax like #4MileFire. Used together, the primary and event hashtags format meaningful machine readable tweets. The format of reporting a need to TtT is: #eventtag #need [list your needs, like: rescue, or food and water] #loc [location or GPS coords] #contact [email, @ or #], e.g., #mytownfloods #road water on the road at #loc 3rd and Main #src @localnews.

3. OpenstreetMap

OpenStreetMap (OSM) [44] platform aims to build a free, editable and open map of the world. It is a knowledge collective that provides user-generated street maps. Its maps detail the locations of those in need of disaster reliefs. It is based on an open-source philosophy, and combines wiki-like user generated data, with free access, allowing users to create, edit, download, and use OSM data in their applications. OSM is built iteratively using the principle that the simplest approach to any problem is the best way to ensure the success of the project as a whole.

4. CrisisCommons

CrisisCommons [45] is a platform helping communities and people in disasters by supporting “the use of open data and volunteer technologies to catalyze innovation in crisis management and global development”. It enables the disaster relief organizations and the human sensors share disaster related information. CrisisCommons coordinates volunteers worldwide to create Crisis Camps. CrisisCommons gather volunteers to problem solve through managing of projects, translating information, editing and researching. Meanwhile, the CrisisCommons communities continue to grow and activate during disasters of all sizes.

V. Case Study

Different works have make case studies [5-37] on harnessing HSN in some main disasters in recent years, among which the Haiti Earthquake, the Indian Ocean Tsunami, and the Great East Japan Earthquake are the top three disasters which gained most concerns from HSN point of view [8]. In this paper, we choose Haiti Earthquake as the case study to show how HSN contributes to the situational awareness in the disaster reliefs.

In January 2010 a 7.0 magnitude earthquake struck the country of Haiti. It was the strongest earthquake measured on the island in over 200 years. The destruction was catastrophic: economic damage has been estimated at up to $13.9 billion with 200,000 to 250,000 lives lost [6, 8, 15, 19, 25], hundreds of thousands were injured, and nearly 1.5 million people had been displaced.

The Haitian earthquake is a good example of how HSN can contribute to the situational awareness of the disaster reliefs. By collecting, organizing, and disseminating grassroots information from the human sensors, the disaster relief organizations made faster and better relief decisions. The usage of HSN platforms in Haiti Earthquake has fundamentally changed the disaster reliefs by introducing new mapping and aggregating tools to traditional information gathering methods.

HSN platforms aggregated analyzed and plotted data about urgent needs to fill in the information gap of the disaster relief organizations. In the Haiti earthquake, for the first time, the affected populations issued pleas for help using SM and widely available mobile technologies. Around the world thousands of ordinary citizens mobilized to aggregate, translate, and plot these pleas on maps and to organize technical efforts to support the disaster response. In one case, hundreds of geospatial information systems experts used fresh satellite imagery to rebuild missing maps of Haiti and plot a picture of the changed reality on the ground. This work became an essential element for the response, providing much of the street-level mapping data that was used for logistics and camp management. Reports about trapped persons, medical emergencies, and specific needs were received and plotted on maps that were updated in real time by volunteers. These reports were available to anyone with an Internet connection. Responders on the ground soon began to use them in determining how, when, and where to direct resources.

HSN platforms, such as Ushahidi, collected data from HSN to identify actionable pieces of information that were useful for the disaster reliefs. If the information was useful and had a location attached to it, it is mapped to the crisis maps by finding the GPS coordinates through Google Earth and OpenStreetMap. SMS was also incorporated into the HSN platform, which greatly expanded the HSN sources. Specifically, a project named 4636 was held in Haiti to incorporate SMS sent by the Haitian. About 85% Haitian had mobile phones at the time of the earthquake. Though 70% cell phone towers were destroyed in the disaster, they were quickly repaired and mostly back online.23 People can directly post messages from a cellular phone to the HSN platforms identifying their situation or their witnesses. Through the aggregation of individual reports, the situational awareness was able to be identified, which helped the disaster relief organizations target their response efforts, such as directing people within Haiti to the nearest aid points, and passing on instructions about, for example, obtaining food vouchers, fuel, places to recharge phones, etc. Fig. 3 gives an example of the crisis map of Haiti Earthquake given by Ushahidi.

One example is to determine the location of the health facilities, which is extremely important and urgent, while requires great human efforts, in the disaster relief. The existing information was already out of data: some information was missing, some information was conflicting, and some was changed by the quake. Crisis Mappers community was asked by OCHA and MapAction to geo-locate 105 health facilities that had no location data. Coordinated through Sahana and OpenStreetMap, this effort used satellite imagery, OpenStreetMap data, and HSN data to locate almost all the health facilities. The team located 102 of the 105 missing hospitals used on the ground with only 35 hours. These data were made available in open data formats via several feed formats, including XML, KML, GeoRSS, and the XML schema designed for tracking hospital data, EDXL-HAVE. This resource became one the best resources for health facility data for the disaster relief in Haiti. Over 8,000 unique individuals visited the site or pulled from these feeds. HSN had contributed to the data that would take the rational disaster relief organizations days to complete and reduced it to a little more than a day of work.

The resulting information feeds given by HSN platforms, crisis maps of Haiti, are regarded as one of the most comprehensive and up-to-date map available to the humanitarian community. This greatly facilities the disaster reliefs in Haiti earthquake.

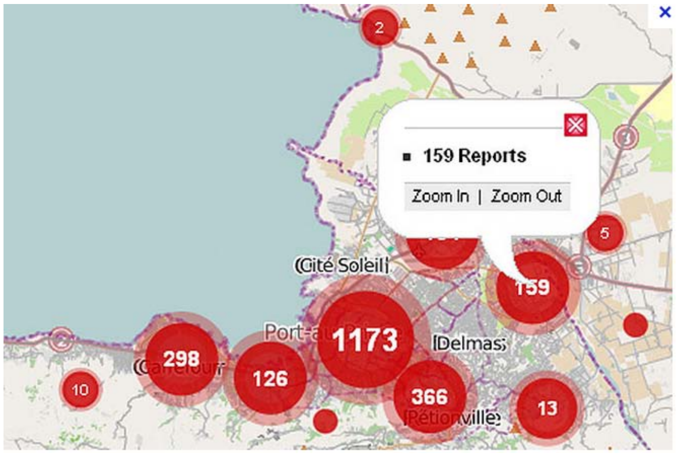

Fig. 3. Ushahidi crisis map of Haiti Earthquake [42].

VI. Conclusions and Future Works

The efforts in the existing disaster reliefs demonstrated the potential for harness HSN for situational awareness in disasters, but this is just the beginning. It is found that about half of the people would contribute information using HSN during disasters [8]. With more and more people access the HSN at an increasing rate, it is reasonable to expect the use of HSN in disaster reliefs to increase in the future. It is notable that the majority of the mapping, translating, and processing work of the HSN platforms was done purely by volunteers. Manual data collection and coding are extremely labor intensive. Future research efforts will best be accomplished using automated data alert, retrieval, and capture.

Note that collaboration between the disaster relief organizations and the HSN platforms does not need to wait until disaster strikes. Efforts should be combined to lay the foundation for key disaster-related services in advance that will be useful in case of emergency. Disaster responders should also be aware of the communication strategies in order to taking the advantage of HSN during disasters [8].

HSN alone is not a silver bullet in disaster reliefs. All appropriate technologies should also be incorporated for the situational awareness in the disasters.

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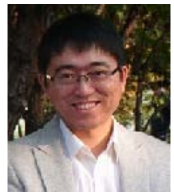

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