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Crowd Sensing for Disaster Response and Preparedness

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Introduction

Crowd sensing systems are opening up a vast design space for crisis-response applications by collecting, recording, and using disaster information in context. We present a succinct overview of the recent developments of crowd sensing environments for disaster response and preparedness, and discuss how crowd sensing can be extended and integrated with external systems to make useful information available for citizens and professionals quickly. Some scholars talk about "human sensors," "citizens as sensors" or "human-in-the-loop sensing" [1] suggesting the different roles humans can play in sensing disasters. We highlight the uses of social media and smartphone sensing in disaster situations, each requiring different levels of human involvement. We then introduce a general framework that focuses on the roles of crowd sensing in relation to external resources such as professionally managed high-quality sensors, disaster simulation systems, and "responsive objects."

Social Media

People use social media tools to respond to natural disasters such as earthquakes, floods, and hurricanes. They are often used as a means to collect (or "sense") critical information by organizing and coordinating volunteers. Such a form of crowdsourcing enables swift sharing of disaster information although it has certain limitations in terms of data quality as well as ease of collaboration and coordination [2].

Crowdsourced disaster information is often linked to location information and can be visualized on a map. For example, volunteers monitored wildfires in Santa Barbara by showing text reports, photos and videos on a digital map [3]. Crowds can generate such maps much before authoritative information becomes available, which is an important benefit that can outweigh the cost of error-prone crowdsourcing data. Likely relevant to this discussion is that not only grassroots organizations but also governmental agencies are now exploiting crowdsourcing. For example, the Federal Emergency Management Agency (FEMA) in the U.S. recently introduced a crowdsourcing feature in their mobile app [4].

Smartphone Sensing

There are a number of experimental projects that explore the uses of ubiquitous sensors in smartphones to infer critical information such as shakes, infrastructural damages, and fires in earthquakes.

Shakes and Infrastructural Damages

Smartphones' accelerometers can be used to measure and communicate the strengths of shakes quickly and cheaply with much higher spatial resolution than professionally managed high-quality sensors such as K-NET in Japan. Existing research by Naito et al. has shown that smartphones' accelerometers are particularly effective for monitoring shakes with the seismic intensity over 2 on the Japanese seven-stage seismic scale [5]. Monitoring strong shakes in buildings with high spatial resolution can be extremely useful for analyzing cumulative impact of shakes on buildings and even for designing safer physical structures. Community Sense and Response system (CSR) exploits accelerometers in smartphones and dedicated devices to monitor shakes cheaply and infer complex spatial patterns of shakes based on a machine learning mechanism [6]. Citizen Seismology Project interestingly senses web traffic on a popular earthquake website and Twitter messages to detect earthquakes quickly [7,8].

Fires

Fires, which can be triggered by earthquakes, often cause significant damage to inhabitants. Early detection of the locations of fires is very important for predicting the spread of the fires and making appropriate evacuation plans in time.

There is a relative scarcity of projects that explore smartphone-based fire detection. Some recent high-end smartphones such as SAMSUNG Galaxy S4 are equipped with temperature and humidity sensors that can be useful for detecting high temperature and low humidity as well as their temporal variances in proximity to fires. Amjad's recent project exploits such high-end smartphones to build FireDitector that infers occurrences of fires in indoor environments using Naive Bayes Classifier with the data from smartphones' temperature, humidity, pressure and light sensors [9]. One of the limitations of this approach however is the dependency of classification results on environmental factors such as weather conditions and regional climates. In other words, a classifier that is trained in one region may not work in other regions. This can be problematic if the cost of training is high.

Towards a Framework of Integrated Crowd Sensing for Disaster Situations

We now discuss a framework of integrated crowd sensing for disaster situations, which focuses on the roles of crowd sensing in relation to professionally managed high-quality sensors, disaster simulation systems, and responsive objects.

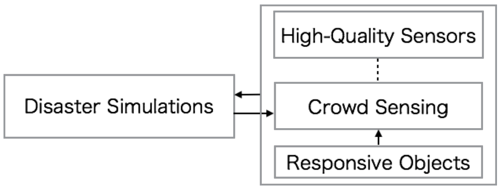

Figure 1: A framework that situates crowd sensing within the network of relevant systems

Professionally managed high-quality sensors

Oftentimes disaster-monitoring infrastructures are of national and/or regional concerns. Infrastructures, such as Japanese K-NET, are deployed and managed under different budgetary restrictions, which may lead to compromised spatial resolutions of sensors. In the Japanese context, it is particularly important to consider complementary relationships between cheap, quick and dense crowd sensing and reliable infrastructural sensors. Moreover, as people often face scarcity of information in disaster situations, providing more data through crowd sensing can help reduce *false negative* problems of failing to issue alarms and warnings.

Disaster simulation systems

Computer-based simulation systems help us understand how things behave in disaster situations without actually experiencing them in the real world. Connecting simulations to real-world events could effectively narrow down the space for *what-if* explorations for pertinent decision-making. Crowd sensing then can play a significant role in making simulations useful in time-critical disaster situations as it provides a way to feed real-world information quickly into simulations, much before authoritative information is made available. Also, microscopic simulations of shakes and fires at a building scale require fine-grained feed of real-world data that crowd sensing could cater well for. Furthermore, simulations could be useful for making crowd-sensing systems including crowd behaviors and computational processing mechanisms smarter. For example, simulation results could be used to request sensing tasks efficiently by prioritizing data collection based on the most critical goals such as saving lives.

Responsive objects

Crowd sensing can be enhanced by populating the world with objects that responds to critical disaster events in ways that can be easily discerned by sensors. Smoke detectors for example make certain kinds of loud sound that can be heard by smartphones' microphones, thereby helping to detect occurrences of fires using smartphones without temperature or humidity sensors. Responsive objects can be Internet of Things, information appliances, or dumb physical objects. Smartness can also be embedded in the design and deployment of such objects.

Conclusion

We have presented a short overview of crowd sensing for disaster situations, including the ones that exploit social media and smartphone sensing, and discussed how crowd sensing can be extended and integrated within the network of relevant systems to make useful information available for citizens and experts quickly. Some mechanisms could be devised within the proposed framework to address issues such as lower quality of crowd sensing data by replicating tasks, verifying data, and validating participants. Additionally, mechanisms for supporting communication (or argumentation) can be useful for collaborative decision-making based on crowd sensing.

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