Human-Centered Sensing for Crisis Response and Management Analysis Campaigns

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ABSTRACT

Human-centered sensing (HCS) is an emerging research field that leverages mobile devices carried by people to collect useful information in support of myriad analytic activities. In this paper, we explore ways in which HCS can be applied to support a variety of analytic campaigns in the context of crisis response and management (CRM). We first summarize the concept of HCS and then investigate the potential advantages of complementing traditional sensing platforms and analytic tasks with an HCS system. By recognizing the potentials of HCS, we offer a scheme for classifying HCS systems and envision three application scenarios of HCS in CRM as well as a general architecture of HCS systems.

Keywords

Human-centered sensing, analytic campaigns, forensics, prognostics, diagnostics, awareness

INTRODUCTION

The development of electronics and communication technology has enabled the manufacturing of inexpensive, multi-functional, and network-accessible sensors. Thousands of sensors can be connected into a network to observe environmental phenomena for different analytic purposes. The study of such sensor networks has become a popular research area that focuses on extending both theoretical and practical knowledge of distributed sensors.

Research on sensor networks traditionally focuses on hard sensors such as thermometers and accelerometers. These sensors are hardware devices and are usually unattended by humans. In recent years, mobile devices have become ubiquitous in people's daily life. Meanwhile, the capabilities of modern mobile devices are expanding and diversifying. Many mobile devices are now equipped with both camera and GPS in addition to the traditional microphone, while some such as the Apple iPhone also sports light sensors, an accelerometer and a magnetometer. In Japan, many mobile devices are also equipped with bar code readers. Moreover, recent reporting in popular news outlets suggest that the capabilities of such devices can be readily extended by third parties, such as the outfitting of the iPhone with a chemical sensor package to support persistent surveillance of atmospheric chemical concentrations for homeland security purposes (Stevens, 2009). At the same time, the network connection speed and bandwidth of mobile devices has also improved significantly. For example, Third Generation (3G) Network technology has already been implemented in many countries like the United States, Japan and South Korea, offering the capability to simultaneously transmit voice and data. Increasing bandwidth and data transmission speeds are essential for collecting diverse, high-resolution observational data sets on a persistent basis.

These advances enable mobile devices, many of which may be originally designed for other purposes, to be used as sensors. Recently, the complementary ideas of participatory sensing (Burke et al., 2006) and opportunistic sensing (Lane et al., 2008) have emerged that take advantage of the ability of humans and mobile devices to collect information useful for a variety of external analysis campaigns. The difference between these two concepts lies in whether human intervention is needed during sensing tasks. Campbell et al., (2008) lumped both participatory sensing and opportunistic sensing into the broader category people-centric sensing (PCS). Hall and Jordan, (2009) further consider the technologies underlying human-centered sensing as types of "soft sensors," which as a broader category includes all forms of human-contributed data.

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In this paper, we extend the concept of PCS and use the term "human-centered sensing" (HCS). Potential applications of HCS with human-as-collector in Crisis Response and Management are discussed. We begin with an introduction to HCS followed by a discussion comparing HCS with traditional sensing. A classification scheme of HCS is then proposed and the potential applications of HCS are described on the basis of the scheme. Finally, the paper presents its conclusions.

HUMAN-CENTERED SENSING

Human-centered sensing (HCS) leverages devices carried by humans to collect useful information in support of one or more analytic tasks. Within the HCS domain, such devices include mobile phones, portable air quality sensors or any other device that is capable of observing some aspect of the environment so long as one or more humans serve at least as the carrier as they perform their sensing tasks. Most of the recent research in HCS focuses on personal mobile devices since they are now ubiquitous and are becoming increasingly capable to collect diverse and high-resolution data. Many modern personal devices can be used to take pictures, record sounds, locate position and orientation and in some cases be extended through tethered hardware (wired or wireless). Some advanced devices can also be outfitted with on-board data processing. Moreover, the captured information can be transmitted through high-speed wireless connections like 3G cellular networks and wireless Internet networks. Combined, these advances in technology enable mobile devices to be used as sensors.

Currently, there are two domains of research in HCS: participatory sensing and opportunistic sensing. Participatory sensing requires human intervention by the owner of the device during sensing activities. For example, in the case of a photoreconnaissance task, the owner needs to decide what picture to take and from which perspective to take it. In contrast, opportunistic sensing also relies on the human as a carrier of the sensor, and does not require any intervention from the user as it carries out its sensing tasks. For instance, a mobile device can record the level of background noise present at different locations simply by remotely activating a device's microphone at different times without user participation. HCS has already been tested and/or implemented in various areas such as price dispersion tracking (Deng and Cox, 2009), atmosphere sensing (Paulos et al., 2007) and daily recording of personal activities (Reddy et al., 2007). From these, one can identify two data collection perspectives – the human as consumer and human as collector, the latter being the case where the data collected by one or more individuals serve the interests of some other entity.

By extending the architecture of wireless sensors by (Akyildiz et al., 2002), we identify six basic subsystems of a human-centered sensor in HCS (see Figure 1): carrier, controller, collector, location finder, communicator and power, each of which is described in Table 1. These subsystems provide the essential capabilities that are needed for a sensor in HCS. Among these six subsystems, the nature of the carrier distinguishes HCS from traditional sensing. In traditional sensing, a sensor either does not have carrier or the carrier is a robotic device. In contrast, human owners of the mobile devices are the carrier in HCS; they carry the device with them while they are moving and thus enable the mobility of sensors. The difference between participatory sensing and opportunistic sensing lies in the actors of controller and collector. In opportunistic sensing, people only play the role of carrier. Mobile devices do the jobs of controller and collector. In participatory sensing, people are always the controller: they need to decide what specific data they will collect and report. In some applications of participatory sensing, people can also be the collector and controller simultaneously. In other words, people use

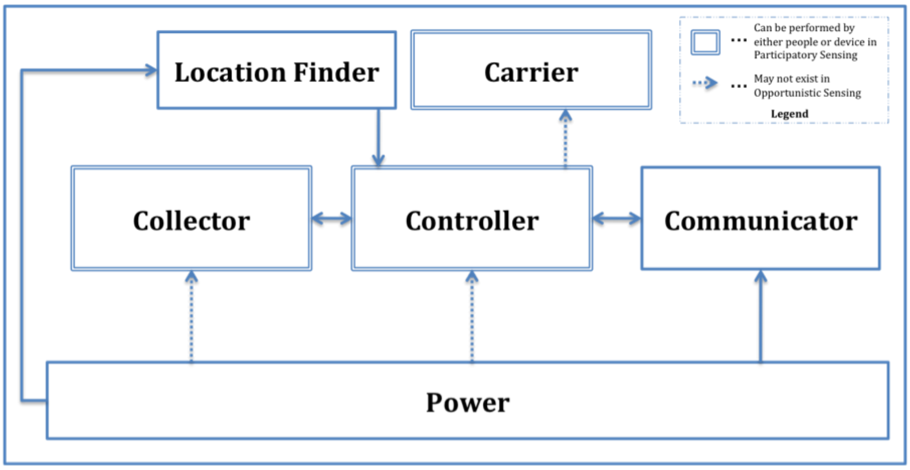

Figure 1. Architecture of a Human-centered sensor system

Subsystem	Description
Carrier	Carries the device and enables the mobility of the sensor
Controller	Decides what, when, and where to collect data.
Collector	Observes and measures the environmental and physical conditions
Location Finder	Computes the current location of the device
Communicator	Handles the transmission of both inbound and outbound data
Power	Provides electricity to other subsystems.

Table 1. Subsystems of a Human-centered sensor

their biological sensors to observe and measure environmental and physical conditions instead of using embedded sensors in the mobile device. In such applications, the major function of a mobile device is communicator.

Table 2 lists the differences among traditional sensing, participatory sensing and opportunistic sensing. The pros and cons of participatory sensing and opportunistic sensing are task-dependent. Since CRM is a broad area and can include different sensing tasks, adopting a hybrid approach is more reasonable. Under certain situations, participatory sensing will be used in that human intervention can accomplish more complex tasks that hard sensors cannot fulfill. Opportunistic sensing is better when human intervention is unneeded, costly or difficult.

Unit	Traditional Sensing	Human-centered sensing	
		Opportunistic sensing	Participatory sensing
Carrier	Device	People	People
Controller	Device / People	Device	People
Collector	Device	Device	People /Device

Table 2. Comparisons among tradition, opportunistic and participatory sensing

Hereafter, we will use the word "campaign" to describe sensing tasks in HCS that support a particular analytic activity, whether for awareness, diagnostic, prognostic or forensic purposes. In general, HCS campaigns are a type of crowdsourcing (Hall and Jordan 2009). Humans that carry mobile devices in HCS will be called "campaign participants" or simply "participants". A human-centered sensor denotes the combination of a human and his/her mobile device, that is, the human is at least the carrier of one or more sensors and the data is collected and stored or transmitted by a mobile device.

HUMAN-CENTERED SENSING V.S. TRADITIONAL SENSING

Although traditional sensing using hard sensors has a long history of research, four major technical challenges still exist in most deployed and proposed sensor networks: power, coverage, adaptability and autonomous ability (Poduri and Sukhatme, 2004, Huang and Tseng, 2005, Meguerdichian et al., 2001, Reddy et al., 2007, Estrin et al., 2001). The following sections compares HCS systems with traditional sensing along the latter these four dimensions.

Power

In most real applications, wired sensors are often preferred because they possess connected communication channels and continuous power sources (Estrin et al., 2001). Despite this preference, wired sensors are not always feasible owning to limitations associated with infrastructure and costs. Under such situations people must resort to using wireless sensors. Yet, wireless sensors are limited by the power afforded to them from batteries or other depletable energy sources though these limitations of local power can be offset somewhat by smart collection strategies (e.g., motion operated, intelligent sampling) and costly in-situ energy generation (e.g., solar cells, wind turbines).

One characteristic of the types of HCS systems considered here is that each sensor is constantly charging, to include the owner who eats food and burns calories as a matter of course. Although the device portion of a human-centered sensor is in essence a battery-operated wireless sensor, human dependence on these devices promotes constant charging and thus approximates a continuous supply of energy. Therefore, power is less a concern for HCS relative to traditional sensing system.

Coverage

Coverage is one of the fundamental issues of a sensor network (Meguerdichian et al., 2001). It represents the network's quality of service (QoS). Currently, most hard sensors are stable; this means they are constrained to a fixed position or predictable trajectory when they are deployed. The coverage of a stable network relies on its deployment of sensors. This requires people to identify the areas or aspects of the environment they want to monitor before the deployment (a priori positioning). Not surprisingly, sensor placement is an area of active research interest. However, in crisis settings and other rapidly evolving or unique situations, a basis for optimal or even sufficient coverage of the situational environment is often elusive. For example, we cannot predict the exact location of next house fire and deploy cameras to observe the scene beforehand. Although mobile hard sensors have been designed such as the one proposed by (Batalin and Sukhatme, 2002), the mobility of these sensors is still limited.

Two significant characteristics of HCS – ubiquity and mobility – make it possible to complement the coverage of traditional sensing. By the end of 2008, there were already more than 4-billion mobile phones around the world (Wikipedia, 2009). Considering other types of mobile devices, the total number of potential human-centered sensors could very well be much larger than this number. The ubiquity of mobile devices suggests significant potential of HCS to complement traditional sensing systems or when hard sensors cannot meet the requirement of coverage. Moreover, as the layperson's label "mobile device" suggests, human-centered sensors are highly mobile since people operate as the carrier. Humans generally possess much better mobility than current mobile sensors. Especially during and after a crisis, humans might be the only carrier that can access and negotiate the scene. A person's mobility allows him or her to provide real-time and close-to-the-scene information of a crisis.

Adaptability

In most real applications, the environmental conditions and task requirements are dynamic. Accordingly, such applications would benefit from a sensor that can adapt to a situation in real-time. Hard sensors work according to pre-compiled programs; they are generally poor at handling external events that are not explicitly coded a-priori. Although people can program hard sensors to adjust their behaviors, their adaptability is still limited by the bounds of its program. During a crisis, however, the situational environment, decision requirements, and consequently the sensing requirements change rapidly and unexpectedly; these circumstances demand high degree of adaptability in the sensing platform.

Human-centered sensors, especially in participatory sensing, are more sophisticated than hard sensors in terms of intelligence, interactivity and versatility. Human intelligence allows us to adapt to unexpected changes by experience and improvisation, such as figuring out what data to collect and how to collect it. Also, people can communicate in natural language, thus sensors in HCS can adjust their behaviors according to complex evolving instructions (of seemingly infinite scope) that hard sensors cannot handle. An example instruction that is trivial for humans yet largely complicated for computers is "take a picture of the most recent six-foot tall man you have seen wearing green sunglasses." Moreover, sensors in HCS are not dedicated to a specific task. People have considerable versatility in that they can fulfill different sensing tasks as long as the phenomena are observable by humans. For example, people can help to take a picture of a building fire and they can also report damages of infrastructure after an earthquake.

Autonomy

Although adaptability of hard sensors can be improved to some extent by human interventions, it is not always possible to assign personnel to control each sensor in the network. In application, one person might be in charge of thousands of sensors in one network. Therefore, each sensor should possess autonomous ability in order to minimize human interventions. However, current hard sensors are still limited in their autonomous ability. They cannot fulfill tasks that are not stored in the chip. For example, if a mobile sensor encounters a large obstacle like a wall, it might not be able to figure out how to cross the wall by itself.

In contrast, human intelligence enables HCS to work autonomously. Humans are able to adjust to changing environmental conditions, figure out solutions to problems locally and mitigate faults without external help.

Therefore, sensors in HCS can either work highly collaboratively because of their interactivity, or they can also work alone without any support by their natural intelligence.

A Potential Problem of HCS

One potential problem of HCS is that the benefits of HCS depend on whether we can recruit enough participants in the network and whether they will really help us to collect data. In most applications, data collection is a secondary task for participants. Participants are not necessarily and persistently dedicated to a particular sensing campaign – at some point they might become bored or disinterested in the mission or no longer perceive a net benefit from its incentives (e.g., after an earthquake, a participant may be more interested in saving his friends and family than collecting data on neighborhood damage). As a result, they may stop participating temporarily or permanently. Therefore, HCS and traditional sensing complement each other. We should balance our dependence on them according to different conditions of each situation.

CLASSIFICATION SCHEME FOR HUMAN-CENTERED SENSING SYSTEMS

In what follows we propose a first-order scheme for classifying HCS systems. Here we define an HCS system as one that is focused on collecting data for a single analytic campaign. The objective of the HCS system is to collect data that enables a clear discrimination between alternative hypotheses or conclusions for an analytic problem on the basis of confidence. An analytic campaign can be viewed as being comprised of five phases modeled after the intelligence cycle (Shreeve, 1985): tasking and requirements, data collection, processing, synthesis and summarization. Each phase is described in Table 3. Of particular interest to HCS systems are the tasking and requirements and data collection phases, though the extent and manner in which these phases operate depend on remaining phases. An HCS system provides a link between the requirements and processing phases of an analysis campaign, or rather represents only a piece of the larger human-centered information fusion problem (Hall and Jordan 2009). The following proposes a way of classifying HCS systems in terms of how it goes about completing the tasks associated with the tasking and collection phases of an analytic campaign.

Phase	Description
Tasking and Requirements	Specifies the scope of the HCS campaign (defines the question at issue) and the types of data needed to form credible inferences.
Data Collection	Participants interact with the environment in order to capture data. Here the participants may either act as the carrier of a sensor, act as a facilitator of collection or serve as the sensor itself.
Processing	Data is massaged and organized into a form that lends itself for processing by an inference engine.
Inference	Conclusions are drawn regarding the question at issue based on the processed data.
Communication	Data is communicated in summary form for consumption by decision makers. Summaries include narrative reports, charts, graphs and other visualizations.

Table 3. Phases of an HCS analytic campaign

Tasking and Requirements

The tasking and requirements phase specifies the scope of the HCS campaign and the types of data needed to form credible inferences. Here we consider two attributes associated with the tasking requirements layer, namely the *type of campaign* and *tasking strategy*.

Type of Campaign

A key discriminator between all analytic campaigns lies in the underlying question at issue (Paul and Elder, 2008). Two or more analytic campaigns associated with slightly different questions at issue may have entirely different data requirements. Here we discriminate between HCS systems based on the type of campaign it supports. This includes awareness campaigns (e.g., what is happening?), diagnostic campaigns (e.g., why is it happening?), forensic campaigns (e.g., what caused this to happen?) and prognostic campaigns (e.g., what will happen in the future?). Each of these four campaign types is summarized in Table 4.

Campaign Type	Description
Awareness	Provides awareness of the present values of variables, characteristics, attributes, etc. that enable inferences about the present state of things. Everything associated with an awareness campaign is directly observable by HCS sensors.
Diagnostic	Focuses on the reasons why some particular situation is happening. Diagnostic campaigns are associated with variables, characteristics, attributes, etc. that cannot be observed directly but rather only inferred from observables. The goal of a diagnostic campaign is to infer the current state of a system. In many cases, a diagnostic campaign is a prelude to a forensic or prognostic campaign.
Forensic	Focuses on the cause (root cause, proximate cause) for a particular situation or realized scenario. Here the campaign uses observed outcomes (e.g., observed response variables or "Y"s) to backcalculate the inputs needed to make these outcomes come about (e.g., the values of the predictor variables or "X"s). The goal of a forensic campaign is to establish the most likely cause of events with a prescribed level of confidence.
Prognostic	Focuses on what will happen in the future given knowledge of present values of variables, characteristics, attributes, etc. The goal of a prognostic campaign is to construct a probability distribution among all possible futures relevant to the particular question at issue.

Table 4. Types of analytic campaigns

Tasking Strategy

We can distinguish HCS systems on the basis how it tasks participants in the data collection process. Here we consider three types of tasking: spontaneous, elicited and hybrid. In a *spontaneous system*, the sensors are trained to understand the data requirements at the beginning of their participation. The system will not actively elicit data from users; rather, the sensors provide data whenever they want throughout the life of the campaign. In an *elicited system*, sensors do not provide data spontaneously but rather only when they receive specific requests or tasking from the analytic engine. A *hybrid system* allows for both spontaneous and elicited contributions.

Data Collection

HCS systems can be classified according to different attributes of different analytic campaigns such as the lifespan of a campaign and types of data the campaign collects. For instance, some systems focus on collecting static data (e.g., the location of a restaurant) while others are designed to collect dynamic data (e.g., oil price). In this section, we define six attributes that can be used to classify PCS systems, namely *duration* of the campaign, *type* of data, *stationarity* of the data, *level of participation*, *incentivization*, and the nature of *human involvement*.

Duration

Based on the duration or timespan of campaigns, we can categorize HCS systems into two categories: persistent and time-limited. A *persistent* system is interested in collecting data continuously over an indefinite period of time. For example, the grocery bargain collection system described by (Deng and Cox, 2009) is a persistent system. In contrast, a *time-limited* system collects data over a fixed timeframe, such as over the course of a month or when certain events or certain types of events occur. For example, an HCS system that collects data only during a fixed time period surrounding an event of interest would be considered a time-limited system.

Type of Data

The type of data needed governs the type of sensor required to collect it and the manner in which it is processed. HCS systems can be classified based on the type of data it collects, namely tangible data, testimonial data and mixed data (Schum, 2001). *Tangible data* is directly observable by the physical sensors within the mobile device, such as photographs, sounds, etc. *Testimonial data* is data communicated by a human, such as reports of what was seen (first hand or direct testimony), what was heard about what others have seen (second-hand information or hearsay) or what is believed based on environmental cues (inference). *Mixed data*, which is perhaps the most common data type in participatory sensing, is tangible data whose collection was facilitated by a human. For mixed data, the testimonial aspect is applied to the warrant of the tangible data with respect to the particular tasking (e.g., was this photo, in fact, one of the nearest white building).

Stationarity

We can also classify HCS systems on the basis of the stationarity, or stability, of the data they collect. In general, there are two types of data: static (or stationary) and dynamic (or non-stationary). If the data collected is not expected to change significantly enough to affect the conclusions of the campaign, then the HCS can be said to collect *static* or *stationary* information. Otherwise, if the data is expected to change or in a manner that does influence the conclusions, the data can then be labeled as *dynamic* or *non-stationary*. For example, if the duration of a time-limited analytic campaign is 24 hours, the location of a building is stationary and the crowdedness of a building is dynamic or non-stationary. Of course, an HCS system can also be designed to collect both stationary and non-stationary information, in which case it is called a hybrid system.

Level of Participation

We can distinguish between HCS systems on the basis of how the participant engages in an analytic campaign. Here we consider two levels of participation: direct participation and indirect participation. *Direct participation* means that the participants are signed on and aware that they are participating in a particular analytic campaign. The participant collects the data specifically to support the analysis. For example, a user that collects photographs of stream water weight and gauge locations would be directly participating in a flood warning campaign. *Indirect participation*, as its name suggests, means that the participants are engaging in an analytic campaign indirectly, such as by collecting useful data for other unrelated reasons. One example of this could be a distributed mobile game that asks players to collect images of hazards for points. Here the participant is collecting data not to support the campaign directly, but rather to earn prestige in online social networking communities.

Incentivization

We can further distinguish between HCS systems on the basis of the incentives it offers participants for engaging in the associated analytic campaigns. Here we consider three different incentivization schemes – altruistic, mandated and compensated. An *altruistic* system is one that encourages user participation on the basis that participation is good for society. There is no immediate other than the perceived (or perhaps personally realized) downstream benefits. A *mandated* system is one that requires users to participate. This includes systems in use by participants as part of their professional duties (e.g., civil service employees, first responders). A *compensated* system pays participants for their participation. Here such a system may pay users on a pay-per-measurement or pay-per-time on task basis.

Human Involvement

The final means for classifying HCS on the basis of collection is centered of the nature of human involvement in the sensing task. Three progressively more involved classifications are proposed: human as carrier, human as facilitator and human as sensor. As a *carrier*, the human merely is the medium for moving the sensor around the observational space. More involved is human as *facilitator*, in which the human is responsible for operating the sensor so as to fulfill the requirements of the sensing task. Finally, the most involved type of HCS is where the human himself acts as *sensor*. In this case, the human reports on what he senses (e.g., visually, aurally, etc.) and reports these observations via the mobile device. Human involvement correlates with the type of data, where in most cases human as carrier is largely concerned with tangible data, human as sensor centers on testimonial data and human as facilitator centers on mixed data.

POTENTIAL APPLICATIONS IN CRM

The classification scheme we proposed in the previous section helps us to envision potential applications of human-centered sensing (HCS) in crisis response and management (CRM). In this section, we propose four potential applications of HCS. A general architecture for HCS systems is described first.

Architecture of HCS Systems

In general, an HCS system consists of eight components: sensor network, communication channels, data receiver, data fusion engine, database, inference engine, user interface, and message sender. The architecture is plotted in Figure 2. The sensor network is composed of human-centered sensors (i.e., owners and their mobile devices) that are capable of fulfilling the data collection requirements. The collected data are transferred through communication channels such as short message service (SMS), multimedia messaging service (MMS), email, Instant Messaging (IM) and HTTP requests. Different channels have different data receivers that are responsible for receiving data from the sensor network. Since data are collected from various devices and are transferred through different ways, the data will be very diverse in terms of data format and quality. The data fusion engine will do the cleansing and transformation in order to provide a consistent data collection in the database. In some applications, the data fusion engine will also take the responsibility to evaluate the reliability of collected data and filter out false data. After that, the inference engine will try to reason about the information according to predefined rules. Finally, the user interface will deliver the information to different types of users such as various information visualizers (e.g., maps), external systems (e.g., warning system), and end users. If needed, feedback can be sent to the sensor network through the message sender.

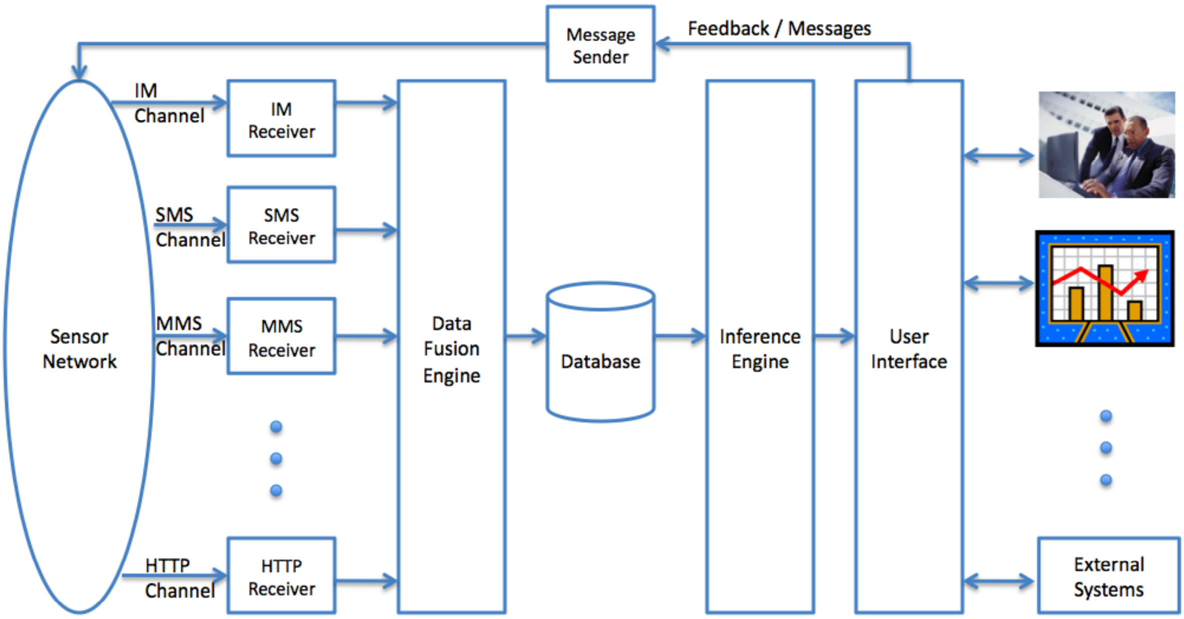

Figure 2. Architecture of a Human-centered sensing system

Regional / Local Hazards Game

As we have mentioned, clues of many potential crises are hidden in our daily life. Ordinary people see dangers from time to time. However, it is inconvenient for them to search for the right place to report. Meanwhile, professionals are not able to monitor every corner of an area all the time. As a result, we envision a regional hazards report system to recruit ordinary people to help collect this information. They can use their mobile devices to report potential hazards they observe. The output of the system can be shared among local residents to enhance their vigilance. In addition, each report will be sent to the corresponding department and officers can view the system as real-time feeds of problems that need to be taken care of.

According to our classification scheme, this is a prognostic HCS system since data are collected on potential sources of harm. The system allows participants to provide hazard information when they perceive any so that it is a spontaneous system. The campaign would be persistent since it is continuously active and dynamic since the situational environment is constantly changing. The report should at least include testimonial description of the hazard, though most often the data collected would be in the form of a tangible image with testimonial metadata.

However, a main challenge with such a system is incentivizing participation. Thus, we consider an indirect participation system via a regional / local hazards game that compensates participants with points for participation. In such a scheme, player (participants) will collect images of hazardous situations and will be awarded points on the basis of their severity (which might correspond to the level of action taken to mitigate the hazard). As more points are earned, the status of the player rises and as such the player inherits greater levels of responsibility (e.g., assessing severity of the hazard, providing peer review of lower ranked players, etc.). A diagram of such a game is shown in Figure 3.

Emergency Planning Support

HCS can also be applied to support emergency planning. As being discussed by (Schafer et al., 2007), geocollaboration is one important aspect of community emergency management planning. Different stakeholders such as emergency managers, first responders, and local transportation managers need to exchange information regarding the location and surrounding areas of potential emergency event. Residents are the best

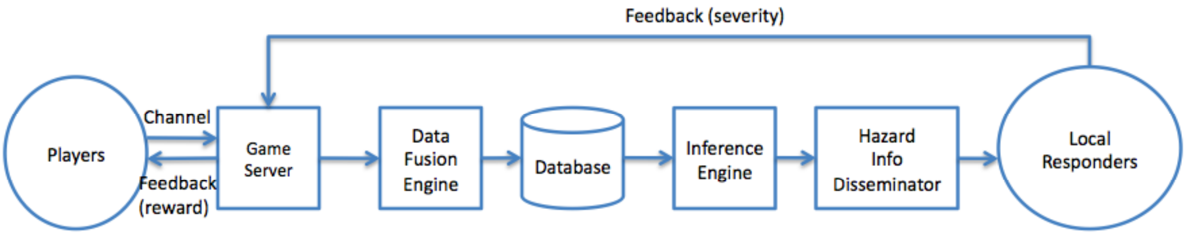

Figure 3. Architecture of a regional / local hazards Game

source of local information. When planners need fine-grained information to gain more insights in planning activities, it can be obtained from the human sensor network constructed by local residents. For instance, planners might be interested in the local transportation patterns. Instead of direct observation, we consider an HCS system that automatically record people's current location by their mobile devices. Moving speed of each person can be obtained on the basis of their past locations. When we have accumulated enough data, we can acquire traffic conditions of each road during different period of day.

To design such a system, the sensor network should be constructed of GPS-enabled sensors that can spontaneously report its current location on a regular basis without interrupting users' other tasks. The collected data include current timestamp and geo-coordinates. Such data is tangible since no human testimony is involved; the human only serves as the carrier of the sensor. The campaign will be time-limited and it will be active only when such data are needed.

During- and Post-blast Analysis

When a disaster happens, immediate during- and post-blast analysis is very important. This can help investigators to quickly identify the causes of the event. For example, if a boom just happened, investigators need to identify the center of the explosion. One way to accomplish it is to compare the patterns of injuries and damages to former incidents (Okoye and Wecht, 2007). We can design an HCS system to collect such data. Whenever an event happens, campaign participants can immediately start to use their mobile devices to record the situation and report injuries and damages they perceive. This information provides real-time data about the event and facilitates further analysis. In fact, people have already started to use their mobile devices to record crises and share this information on websites such as Twitter (Hughes and Palen, 2009) and Flickr (Liu et al., 2008). However, these websites are not designed to post crises data exclusively, which increases the difficulty to discover useful data. The proposed system here provides a venue for real-time crises documentation. Based on the time and location of incoming data, the system can automatically discover emergent events and elicit for more information from nearby participants. The system could help stakeholders to get more information for their decision-making during crisis response. It could also be used as a social journalism site that publishes latest events and keeps documents of old ones.

Admittedly, under situations where the owner of the device is in danger during a crisis, people are not likely to participate in the sensing task. At this point, we can leverage mobile devices to automatically record owners' behaviors. That is, the device will automatically record information such as owner's moving trajectory and velocity. There are at least three benefits of this type of campaign. First, by viewing the moving patterns of people, investigator can estimate the center of the event. Second, by reviewing the trajectory of a person, it will be easier to search for the person if s/he is missing in the crisis. Third, this information could help researchers to gain insights of people's behaviors during crises. Researchers are now studying people's improvisation in response to emergency events. This strand of research is based on post-crisis recall of previous behaviors, which might be incomplete and inaccurate. If mobile devices can automatically record owners' behaviors during the crisis, the quality of post-crisis recall would be improved and the study of improvised behaviors will also be enhanced.

FUTURE DIRECTION

Human-centered sensing (HCS) is still evolving and we believe it will become a backbone of information for future crisis response and management (CRM). However, HCS is just a beginning for ordinary people to participate in risk analysis and management. In addition to eliciting information from participants of their daily life, we can recruit them to do more things. They can help to accomplish tasks that are formerly done by professionals. For example, people who pass by a yardstick on a bridge regularly can help to monitor the water level. They can also help to eliminate or alleviate potential hazard. For instance, people who see an open manhole on the ground can help to cover the hole temporary or put some signs around the hole. Currently, our research team at Penn State is working on the topic of Participatory Risk Management (PRM), to include such programs as these for direct and indirect (e.g., games) participation in what could become an emergent risk management process. HCS is of course one important part of PRM. Our goal is to engage local residents in the management of their own risks more than ever before.

CONCLUSION

As a research area, human-centered sensing (HCS) is increasing in popularity. In this paper, we extended the concept of PCS. We categorized different components of each sensor in HCS. We compared HCS with traditional sensing on the basis of the four major technical challenges of hard sensors: power, coverage, adaptability, and autonomy. Based on the comparison, we argued that HCS system has a significant potential to complement traditional sensing in certain situations where hard sensors cannot meet the information needs. This is enabled by the six characteristics of human sensor networks: approximately continuous power source, mobility, ubiquity, intelligence, interactivity, and versatility. We also proposed a first-order classification scheme for HCS according to the first two of the five phases of a typical analysis campaign: tasking and requirements, data collection. This classification scheme helps us to envision the potential applications of HCS. We described three potential applications of HCS in crisis response and management along with a general architecture of HCS systems. We do not mean to be exhaustive in the discussion. We hope this paper can inspire more innovative research in this area.

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