Pervasive Computing for Disaster Response – June 2012 Status

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The objective of this project is to develop key components of community-based pervasive systems which will allow citizens to respond to disasters. The research will enable a new generation of community-based cyber-physical systems, in which the community helps to detect, communicate and respond to rapidly evolving events such as earthquakes, tsunamis, fires, floods and epidemics. The research has a strong pragmatic focus on developing sensors and software which enable the collection of situational information and the dissemination of alerts. Methods for performing sensing analysis and data fusion in the Cloud are being incorporated so as to address tradeoffs among rates of false positive alarms, false negative alarms, and time to detection. Techniques are also being developed for reliable and timely alerting of communities and individuals; these techniques exploit geographical and societal scale correlations to improve the speed and resilience of the dissemination process.

Since the project began in October 2011, we have focused on sensor and software systems that are likely to be of most use in the event of a disaster in a particular target area: the Gujarat region in India. In collaboration with IIT Gandhinagar (S.K. Jain), we have used project funds to invite three undergraduate students from IITGN to Caltech to work with us on the development of affordable accelerometers that can be connected to cheap portable computers (single board computers, smartphones, tablets) and which can communicate sensor readings into the Cloud over the cellular data or voice networks. Our target is to design an affordable system that can be deployed in Gujarat in numbers of around 50 or more, by the Fall of 2012. This work benefits from our experience with Caltech's CSN "Community Seismic Network" (funded by the Moore Foundation) where several hundred accelerometers have been deployed in the Pasadena area to obtain dense sensing measurements of ground motion due to seismic activity, and to estimate damage to structures during severe earthquakes. The Gujarat deployment will use the same Cloud based (App Engine) software for CSN, but will be extended to include early warning features. A replicate version of the CSN platform is being deployed and tested in the Irvine-Sensorium infrastructure (funded by an NSF CRI award) at UC Irvine.

In addition to the work on detection of seismic activity, we have engaged several undergraduate students at Caltech in the design and prototyping of other sensors that detect environmental and health hazards. In particular we have been working on a device called the "Home Hazard Weather Station" which integrates a variety of commonly available sensors into an enclosure and connects them to a single board computer (we use Arduino, but are also evaluating Raspberry Pi, and Android devices with IoIo interface boards). The sensors we are using include those for radiation (simple Geiger Muller tube based detectors), noxious gasses (Carbon Monoxide, Methane, etc.), pollution (particulate matter detectors, as well as a completely new device developed by Rich Flagan et al at Caltech that measures aerosols in the Angstrom size range, which are prevalent near dense road traffic and especially dangerous), ground motion, light, sound, temperature, humidity, barometric pressure, and so on. These environmental hazard stations will collect data continuously and relay those data into the Cloud, using the same protocols as used in the CSN, where data aggregation will take place, and software algorithms used to detect hazardous events locally or across the region. Our research will evaluate the robustness of the CSN participatory sensing system to a range of failures and design techniques to improve information resilience under diverse failure conditions .

Research on alerting and notification at UC Irvine considers disasters where geographically correlated failures hinder the ability to reach recipients inside the corresponding failed regions. We are currently developing techniques to (a) create redundant geo-aware overlays for reliable message delivery in events such as earthquakes and fires where significant portions of the geography experience damage and (b) explore the possibility of delayed diffusion of messages in these regions through multiple networks including human social networks. The outcome is a geosocial notification system where the social network characteristics of intended recipients (e.g. relatives/friends of those impacted by an event) are used in order to trigger a social diffusion process to maximize/increase the coverage and reliability of the alert. Note that the social diffusion process can operate through out-of band channels such as humans travelling in buses, carts and bicycles, phone calls and human contacts, in order to reach recipients which are isolated in the failed region. Such an approach is vital to ensure continued risk communications to rural Indian populations who have limited access to communication infrastructure in disasters. Our initial experiments using simple simulation settings are promising, desired recipients receive the alert even under massive geographically correlated regional failures. We will continue to experimentally validate and refine our ideas in this direction. Our next challenge is to support such reliable delivery when the number of recipients are massive – again a relevant challenge in the Indian context. We will explore the design of a distributed publish subscribe architecture using broker networks to provides societal scale, reliable, fast and geocorrelated event notifications. Since most end users are connected over mobile devices, the notification process may cause a significant increase in network traffic; the frequently changing locations of the mobile subscribers poses an additional challenge. We will explore alternate overlay structures and social diffusion mechanisms that cater to the dynamic mobility changes and large scale nature of users in the Indian setting. For an implementation platform, we will leverage CrisisAlert, an organizational notification system (in use by government agencies) as the starting point for an implementation of a geosocial, delay-tolerant notification system – the prototype will be tested in drills with IITG in the coming year.