Community-based Sense and Response Systems:
The Community Seismic Network

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Our research addresses the following fundamental problem in cyber-physical systems: *How can we design systems that respond to critical events, such as earthquakes, based on data from large numbers of noisy, community-held sensor devices?*

People help each other after hurricanes, floods, and blackouts. The efficacy of "crowd-sourcing" of tasks, such as tagging photographs, shows that people are comfortable with using technology to help one another. The general goal of our research is to develop theory and practical systems that enable ordinary people to use technology collectively to respond to critical events. We are pursuing several application domains in order to ensure that the fundamental scientific and engineering principles we develop will be applicable to many areas of Cyber-Physical Systems. The first application warns and then responds to intensive shaking from earthquakes, thus saving lives; the second detects possible brownouts and takes action to ensure uninterrupted power; and the third detects possible contamination of the water supply and alerts civil engineers and public health officials, identifying areas of contamination.

As a concrete instance of a community sense-and-respond system, we present our work on a *community seismic network (CSN)* that relies on inexpensive accelerometers (as accessories to standard desktop computers, as well as those built into cell-phones) with the goal of detecting, mapping and responding to strong ground shaking. Our research involves aspects from statistical modeling (how can we robustly fuse data from multiple, diverse, noisy sensors?), decision theory (how can we trade off false positives and false negatives?), machine learning (how can we learn to adapt sensors to individual noise characteristics, e.g., due to human motion?), sensor networks (how should we communicate in a distributed manner in order to trade off bandwidth, power and detection performance?) and large-scale distributed systems (how can we scale up to massive numbers of sensors?). We will report on our new results, including

- A rigorous framework for distributed anomaly detection based on community-held sensors, allowing to trade accuracy and delay.
- An algorithm for online learning of normal activity for each sensor, with provable performance guarantees.
- Updates on our CSN implementation with clients based on USB MEMS accelerometers and Google Android-based smartphones, as well as a cloud-computing based server running on the Google AppEngine.
- A simulation study investigating the suitability of different sensors and their noise characteristics, as well as on estimates regarding the required network density.
- Initial experiences with our CSN system during actual earthquakes.