Community Sense and Respond – Theory and Applications

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..where theory and practice collide

How can we build community-held CPS that allow sensing and responding to crises?


Smart Meters


Personal Navigation Devices




Community-held Accelerometers

Contribute sensor data

Sense

Cascading failures, & traffic jams
earthquakes,
…

Respond

Stabilize electrical grid, reroute traffic
stop trains, elevators,
…

Fundamental CPS Challenges

Uncertainty:

Noisy sensor observations
Limited historical data

Continuous/discrete:

Continuous sensor data but discrete hypotheses & decisions;

Safety-critical:

False positives impact infrastructure
False negatives can cost lives
Infrastructure must be robust against failures, flooding and security breaches

Scale:

Need to make real-time decisions based on data from millions of sensors
Need to deal with limited resources

Our Approach

Robust Bayesian reasoning

Addressing both statistical uncertainty and worst-case guarantees

$$\max_d \min_\theta \mathbb{E}_s[U(d,\theta,s)]$$

No regret online learning

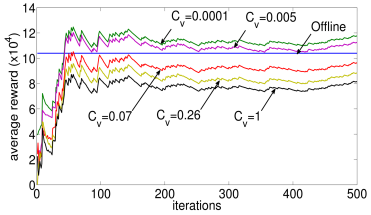
Sensors learn to adapt to noise conditions

Distributed anomaly detection

Distributed algorithms with performance guarantees

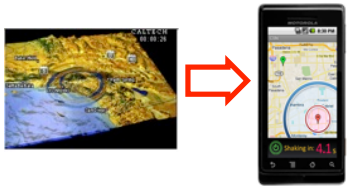
Cloud computing

Automatic replication
Designed to cope with peaked load



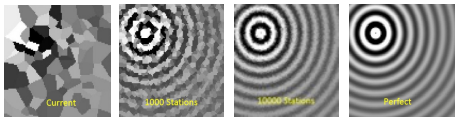
Convergence of our distributed algorithm
[D. Golovin, M. Faulkner, A. Krause IPSN 2010]

The Community Seismic Network



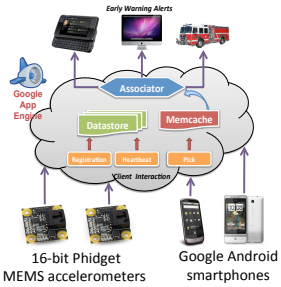
Community-based earthquake early warning

Larger, denser network ➔ earlier detection
➔ Use inexpensive, community-held sensors



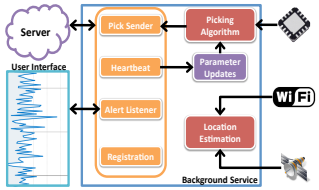
Representing seismic events with varying number of sensors
Left: resolution of Southern California Seismic Network

Prototype implementation

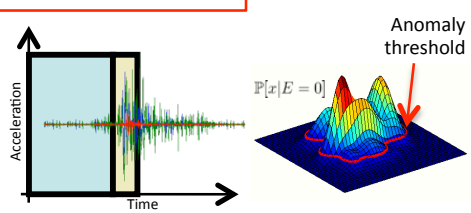


16-bit Phidget MEMS accelerometers

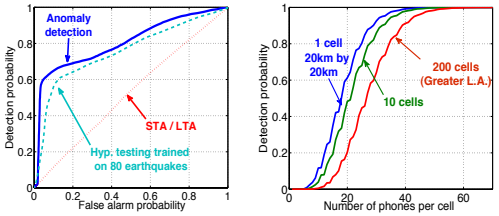
Google Android smartphones



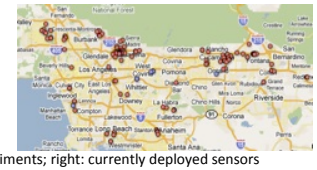
Left: Cloud computing architecture
Right: phone client implementation



New theory for decentralized anomaly detection allows to optimize detection while bounding false alarms [Faulkner et al. IPSN '11]

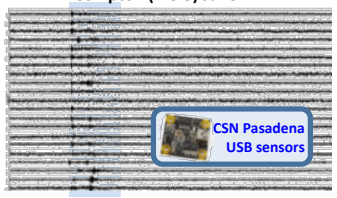


Simulation results (M5). Left: Detection performance per phone sensor;
Right: Network wide detection probability after fusion at < 1 false alarm/year

Left: Shaketable experiments; right: currently deployed sensors

Compton (M3.5) June '11



Actual earthquake recorded with CSN (Phidget sensors)

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