Community Seismic Network for Rapid Shakemap Notification

Rishi Chandy
Rita A. and Øisten Skjellum SURF Fellow

Daniel Obenshain
Kiyo and Eiko Tomiyasu SURF Scholar

Daniel Rosenberg
Kiyo and Eiko Tomiyasu SURF Scholar

Annie Tang

Mentors: K. Mani Chandy, Robert Clayton, Andreas Krause
California Institute of Technology
Outline

- Background
- Benefits of Early Warning
- Introduce the Community Seismic Network
  - Client-side
  - Server-side
- Web interface
- Future Directions
Background

- Earthquakes are dangerous threats
  - USGS estimates 2000 deaths and $200 billion damages from 7.8 magnitude quake in LA
Background

- Earthquakes are dangerous threats
  - USGS estimates 2000 deaths and $200 billion damages from 7.8 magnitude quake in LA

- Early warning could minimize suffering
  - Activate safeguards in critical operations
Background

- Earthquakes are dangerous threats
  - USGS estimates 2000 deaths and $200 billion damages from 7.8 magnitude quake in LA

- Early warning could minimize suffering
  - Activate safeguards in critical operations

- Providing early warning is an interesting problem
  - Computer Science + Geology
  - Bayesian decision theory
  - Distributed computing
Early Warning Can Help

Slow trains
Early Warning Can Help

- Slow trains
- Stop elevators
Early Warning Can Help

- Slow trains
- Stop elevators
- Open fire station doors
Sensor Network is too Sparse

A sensor network of one hundred sensors.

A sensor network of one thousand sensors.

SCSN (Southern California Seismic Network) has ~350 sensors right now.
Community Seismic Network

- Global distributed network
  - Rapid shakemap notification
- Citizen Science

A new earthquake monitoring system based on a dense array of low-cost sensors. The goal of the system is to produce block-by-block estimates of strong ground shaking.
Community Seismic Network

- Global distributed network
  - Rapid shakemap notification
- Citizen Science
- Analysis in the “cloud”

A new earthquake monitoring system based on a dense array of low-cost sensors. The goal of the system is to produce block-by-block estimates of strong ground shaking.
Community Seismic Network

A new earthquake monitoring system based on a dense array of low-cost sensors. The goal of the system is to produce block-by-block estimates of strong ground shaking.

- Global distributed network
  - Rapid shakemap notification
- Citizen Science
- Analysis in the “cloud”
- Inexpensive USB accelerometers and cell phone sensors
Benefits

- Shakemap Notifications

- Easy deployment in areas without existing seismic networks
  - Cell phones are prevalent
Benefits

- Shakemap Notifications
- Easy deployment in areas without existing seismic networks
  - Cell phones are prevalent
- Identify hard-hit areas quickly
  - Direct first responders
Cloud Computing
Google App Engine
Client-side Overview

- Registration
- Heartbeat
- Pick Messages
- Playback Streams
Picking Algorithm

Short Term Average

Long Term Average

New Data

Accelerometer
Picking Algorithm

Message Condition:
STA/LTA > threshold
Picking Algorithm

1. Detected significant shaking
2. Maximum shaking
3. Sent message to server

Pause for this length of time before sending a message to the server.
Sensor Validation

- Comparison with existing sensor in Millikan Library basement.
- Artificial event: sledgehammer strike seismic activity
Sensor Validation

- Comparison with existing sensor in Millikan Library basement.
- Artificial event: sledgehammer strike seismic activity

Better noise filtering

Visible Correlation
Server-side Challenges

- Incoming messages from a vast network
  - Can’t get overwhelmed
  - Want to grab as much data as we can
  - Application must be scalable
Server-side Challenges

- **Incoming messages from a vast network**
  - Can’t get overwhelmed
  - Want to grab as much data as we can
  - Application must be scalable

- **Response time is critical**
  - Excessive latency is unacceptable
  - Indiana Jones effect
Server-side Challenges

- **Incoming messages from a vast network**
  - Can’t get overwhelmed
  - Want to grab as much data as we can
  - Application must be scalable

- **Response time is critical**
  - Excessive latency is unacceptable
  - Indiana Jones effect

- **Methods must be accurate and precise**
  - Early Warning is useless otherwise
Server-side Challenges

- Incoming messages from a vast network
  - Can’t get overwhelmed
  - Want to grab as much data as we can
  - Application must be scalable

- Response time is critical
  - Excessive latency is unacceptable
  - Indiana Jones effect

- Methods must be accurate and precise
  - Early Warning is useless otherwise
Server-side Overview

- Registration Handler
- Pick Handler
- Heartbeat Handler
- Database
- Associator
Messaging

- Open and extensible XML schema
  - Allows others to join the network
Example Registration XML

<registration>
  <publicKey>349oi3j4oij32ui23</publicKey>
  <location>
    <latitude>40.779761</latitude>
    <longitude>-74.0310</longitude>
  </location>
  <locationDescription>
    1200 E California Blvd Pasadena, CA 91125
  </locationDescription>
  <sensor>usb:deviceID</sensor>
</registration>
Security

- All messages from the client are verified using XML signatures.
- This prevents any message interception attacks
- We can control valid clientIDs
Playback Operation

- We can distribute waveforms for clients to simulate
Playback Operation

- We can distribute waveforms for clients to simulate
- Stress-test the network
- Evaluate new algorithms
- Determine network latencies
Server-side Analysis

- Bayesian decision-making
Server-side Analysis

- Bayesian decision-making

\[
P(I, L, T|D) = \frac{P(D|I, L, T)P(I, L, T)}{P(D)}
\]

- Once posterior is sufficient, we send alerts
Normalized Acceleration: 13.9283882771841
Pick Time: 2009-09-07 12:37:00
clientID: 1

Last 2 minutes:  
Last 3 minutes:  
Last 4 minutes:  
Last 5 minutes:  
Points older than 5 minutes are removed.
Future Work

- Cell phones with accelerometers
  - Android phones
- Laptops with accelerometers
Future Work

- Cell phones with accelerometers
  - Android phones

- Laptops with accelerometers

- Google App Engine
  - Robust, scalable
Acknowledgements

Our generous SURF sponsors

- Rita A. and Øisten Skjellum
- Kiyo and Eiko Tomiyasu

Dr. K. Mani Chandy
Professor of Computer Science

Dr. Andreas Krause
Assistant Professor of Computer Science

Dr. Rob Clayton
Professor of Geophysics

Michael Olson
Grad Student Computer Science
Thank You

Q&A Session