EARTHQUAKE EARLY WARNING USING SMARTPHONES

A collaboration between UC Berkeley Seismological Laboratory, Deutsche Telekom’s Silicon Valley Innovation Lab, and Sense Observation Systems (Sense OS)

Dr. Richard Allen, Qingkai Kong, Steven Allen, Dr. Jennifer Strauss
UC Berkeley Seismological Laboratory
Dr. Young-Woo Kwon, Utah State University
Louis Schreier, Deutsche Telekom Silicon Valley Innovation Lab
Ted Schmidt, Sense OS
EARTHQUAKE EARLY WARNING (EEW)

- Global and unpredictable
- Seismic networks only beginning to provide early warning
- Limit to the number of sensors
- Greatest risks: populated areas, industrial facilities, transportation systems, hospitals and schools

Innovative Science

- Turn commodity smartphones into sensors & warning devices
- Smartphone penetration matches population density
  - Greatest coverage in areas of greatest risk
- Model for future sensors and early warning networks
A SIMPLE IDEA

Activity-based data Captured by smartphone’s sensors Classified by the neural network algorithm developed by UC Berkeley

BUT, Smartphones are black boxes:

- Consumer technology
- Various manufacturers
- Different applications, state
- Connected or battery powered

And generate an Early Warning or Not
IS IT FEASIBLE?
CHARACTERIZE THE NOISE FLOOR
COMPARE REFERENCE
ACCELEROMETER

The diagram shows the acceleration (m/s²) over time (s). The data is represented for different conditions:
- Blue line: table
- Red line: fixed phone
- Black line: free phone

The x-axis represents time in seconds, ranging from 8 to 22. The y-axis represents acceleration, ranging from -20 to 20.
CAPTURE HUMAN MOTION AND SHAKE DATA
CHECK THE CLOCK’S SAMPLING ACCURACY

**MotoX1, Native, Battery, 6x 100k Samples**

<table>
<thead>
<tr>
<th>(msec)</th>
<th>first</th>
<th>second</th>
<th>third</th>
<th>fourth</th>
<th>fifth</th>
<th>sixth</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>max</td>
<td>51</td>
<td>49</td>
<td>47</td>
<td>52</td>
<td>51</td>
<td>41</td>
</tr>
<tr>
<td>median</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>variance</td>
<td>0.48</td>
<td>0.43</td>
<td>0.41</td>
<td>0.45</td>
<td>0.42</td>
<td>0.46</td>
</tr>
<tr>
<td>std dev</td>
<td>0.69</td>
<td>0.65</td>
<td>0.64</td>
<td>0.67</td>
<td>0.65</td>
<td>0.68</td>
</tr>
</tbody>
</table>

**New Sampling Runs - Java based**

<table>
<thead>
<tr>
<th></th>
<th>GS4A-R1</th>
<th>GS4A-R2</th>
<th>GS4B-R1</th>
<th>GS4B-R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS4A-R1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS4A-R2</td>
<td>0.978</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS4B-R1</td>
<td>0.998</td>
<td>0.962</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>GS4B-R2</td>
<td>0.987</td>
<td>0.932</td>
<td>0.995</td>
<td>1</td>
</tr>
</tbody>
</table>
WHICH BRINGS US TO ....

CLASSIFICATION ACCURACY

Initial Results:
99.8% earthquake Windows were classified as earthquakes
AND, AN OPPORTUNISTIC EVENT

Napa, CA.

- August 2014, 3 AM PST: A 6.0 Magnitude Earthquake Struck South Napa.

Above: Berkeley, CA

- 38 km away – the Napa ‘Quake was recorded on a MyShake Smartphone

A nearby Seismic Station’s recording
ONGOING THIS SEMESTER:
BETA TRIALS AT BERKELEY

• SCALE USERS
• DATA COLLECTION & ANALYSIS
• APP AND SYSTEM BEHAVIOR
A VISION OF FUTURE EEW NETWORKS

TENS OF MILLIONS OF SMARTPHONES, VERY LOW-COST, HIGH CAPABILITY PROCESSORS, AND SMART INTERNET ENABLED APPLIANCES

CONNECTED TO A HIGH-PERFORMANCE, INTELLIGENT, BACK-END PROVIDING REAL-TIME TRIGGERING, CLASSIFICATION AND ALERTS
Thank You

And if you want to sign up (Android only, please), email: myshake2014@gmail.com,
A QUICK BACKGROUND

- UC Berkeley Seismology Laboratory is part of the California Integrated Seismic Networks (CISN)
- UCB’s Earthquake Early Warning research is sponsored by
  - Moore Foundation,
  - the USGS,
  - google among others
- Deutsche Telekom, Silicon Valley contributes funding, smartphones, and smartphone s/w engineering to UCB’s Seismology Lab
- MyShake: A UC Berkeley / DT collaboration in advanced research to integrate traditional seismic, commodity and mobile technologies for the purpose of developing a large, dynamic EEW network based on smartphones