EARTQuAKE EARLY WArNING

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Center of Excellence in Disaster Mitigation and Management
Introduction

- Earthquakes are deadly and can destroy entire city in few seconds.
- Reliable Earthquake prediction is not possible at this point of time.
- EEW can be used for alerting people few tens of seconds before arrival of damage causing waves.

INDIAN CONTEXT

<table>
<thead>
<tr>
<th>Seismic Hazard</th>
<th>Vulnerability</th>
<th>Risk</th>
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</thead>
<tbody>
<tr>
<td><strong>Deterministic</strong></td>
<td><strong>Multi-dimensional</strong></td>
<td>Life Loss</td>
</tr>
<tr>
<td>Statistical</td>
<td>Physical, social, economic, environmental, institutional, human factors</td>
<td><strong>Economic Loss</strong></td>
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<tr>
<td>Probabilistic</td>
<td>Dynamic changes over time</td>
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<tr>
<td>Classical DSHA</td>
<td>Scale-dependent expressed at different scales from human to household to community to country resolution</td>
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<td>Geological evidences</td>
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<td>Geophysical evidences</td>
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<td>Deformation studies</td>
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<td>Paleo seismic Studies</td>
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<td>Parametric Studies</td>
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<td>Past data analyses</td>
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<td>Classical Approaches</td>
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<td>Extreme Value</td>
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<td>Statistics</td>
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Seismic Hazard
Regional EEW for Northern India - PILOT PROJECT

- Funded by MOES for North India
- IIT Roorkee Deployed 84 stations streaming data in real time in 2015
- 26 stations installed at blocks/tehsils/districts networked using SWAN Uttarakhand
- 58 stations were installed inside BSNL towers and are connected using VPNoBB
- Algorithm were tested for real time simulation for performance of the software successfully completed using previously recorded data of Taiwan of similar instruments installed in similar conditions.
Sirens were deployed in IITR student hostels
Present Status

- Taken over by Uttarakhand State Government
- All sensors working successfully

Objectives of the new project
- Maintenance of the 84 sensor network
- Deployment of 100 new sensors
- Expansion of the network towards Dharchula area
- Develop algorithms to issue warning to society
- Installation of sirens at District Headquarters
- Installation of sirens at SEOC, Dehradun and Haldwani
Diagram Showing VPBoBB circuit

Remote Location BSNL Exchange
- ADSL Modem
- DSLAM
- Sensor

BSNL NIB Network

Central Server IIT Roorkee
- Switch
- Router
- Server 1
- Server 2

Roorkee OCLAN
- Optical fiber network between IIT Roorkee and BSNL Roorkee

BSNL’s Roorkee Exchange

Service Provider

V SAT AT ROORKEE

Signal receiving at IIT Roorkee

Data processing and decision making

Issue of warning

ADSL: Asymmetric digital subscriber line
DSLAM: Digital Subscriber Line Access Multiplexer
BSNL: Bharat Sanchar Nigam Limited
NIB: National Internet Backbone
Algorithm

Cumulative Absolute Velocity
$$CAV = \int_0^{t_{\text{max}}} |a(t)| \, dt$$

Bracketed Cumulative Absolute Velocity
$$BCAV = \sum \int_{t_i}^{t_{i+\Delta t}} |a(t)| \, dt$$

Pd is maximum displacement

Characteristic

$$r = \frac{\int_0^{t_0} u^2(t) \, dt}{\int_0^{t_0} u^2(t) \, dt}$$

$$r = \frac{4\pi^2 \int_0^\infty f^2 |\bar{u}|^2 df}{\int_0^\infty |\bar{u}|^2 df} = 4\pi^2 \langle f^2 \rangle$$

$$\tau_c = \frac{1}{\sqrt{\langle f^2 \rangle}} = \frac{2\pi}{\sqrt{r}}$$

$$\tau_{p,i} = 2\pi \frac{\sqrt{V_i}}{D_i}$$

$$V_i = \alpha V_{i-1} + v_i^2$$

$$D_i = \alpha D_{i-1} + \left(\frac{dv}{dt}\right)_i$$

Predominant
Scaling relations developed for Garhwal Himalaya

<table>
<thead>
<tr>
<th>Time window</th>
<th>Obtained scaling between $\tau_p^{\max}$ and magnitude</th>
<th>Conversely, in terms of magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 sec</td>
<td>$\log \tau_p^{\max} = (0.1832M - 1.1208) \pm 0.1161$</td>
<td>$M = 6.080 + 3.5542 \log \tau_p^{\max}$</td>
</tr>
<tr>
<td>2 sec</td>
<td>$\log \tau_p^{\max} = (0.2107M - 1.2614) \pm 0.0700$</td>
<td>$M = 5.990 + 4.1542 \log \tau_p^{\max}$</td>
</tr>
<tr>
<td>3 sec</td>
<td>$\log \tau_p^{\max} = (0.2156M - 1.2698) \pm 0.0775$</td>
<td>$M = 5.878 + 4.846 \log \tau_p^{\max}$</td>
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<tr>
<td>4 sec</td>
<td>$\log \tau_p^{\max} = (0.2183M - 1.2708) \pm 0.0733$</td>
<td>$M = 5.802 + 5.312 \log \tau_p^{\max}$</td>
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<tr>
<td>5 sec</td>
<td>$\log \tau_p^{\max} = (0.2226M - 1.2751) \pm 0.0728$</td>
<td>$M = 5.680 + 5.3634 \log \tau_p^{\max}$</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Time window</th>
<th>Obtained scaling between $P_d$, hypocentral distance and magnitude</th>
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</thead>
<tbody>
<tr>
<td>1 sec</td>
<td>$\log P_d = (0.3817M - 1.5603 \log R - 1.6421) \pm 0.4699$</td>
</tr>
<tr>
<td>2 sec</td>
<td>$\log P_d = (0.5187M - 1.6497 \log R - 2.0705) \pm 0.4113$</td>
</tr>
<tr>
<td>3 sec</td>
<td>$\log P_d = (0.6127M - 1.8471 \log R - 2.149) \pm 0.3719$</td>
</tr>
<tr>
<td>4 sec</td>
<td>$\log P_d = (0.6852M - 2.0767 \log R - 2.0767) \pm 0.3403$</td>
</tr>
<tr>
<td>5 sec</td>
<td>$\log P_d = (0.7158M - 2.1850 \log R - 1.9883) \pm 0.3289$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Window (in sec)</th>
<th>$\tau_c$ (in sec)</th>
<th>$\tau_p$ (in sec)</th>
<th>$P_d$ (in cm)</th>
<th>CAV (in cm/sec)</th>
<th>RSCV (in cm/sec)</th>
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<tbody>
<tr>
<td>1</td>
<td>1.02</td>
<td>0.95</td>
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<td>1.17</td>
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<td>3</td>
<td>1.20</td>
<td>1.06</td>
<td>0.51</td>
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<tr>
<td>4</td>
<td>1.42</td>
<td>1.10</td>
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<td>5</td>
<td>1.55</td>
<td>1.14</td>
<td>1.38</td>
<td>41.0</td>
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</table>
### Examples of records

<table>
<thead>
<tr>
<th>Date</th>
<th>Time (UTC)</th>
<th>IST</th>
<th>LAT</th>
<th>LONG</th>
<th>Depth</th>
<th>Mag</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-04-10</td>
<td>08:50:34</td>
<td>14:20:34</td>
<td>30.7 N</td>
<td>78.6 E</td>
<td>10</td>
<td>3.8</td>
<td>Uttarkashi, Uttarakhand</td>
</tr>
</tbody>
</table>

#### Map

- **10/04/2017 Uttarkashi Earthquake M 3.8**
- **Legend**
  - Triggered_stations
  - Epicenter
Examples of records

2. 2017-04-16 23:09:53 04:39:53 30.5 N 79.1 E 10 3.5 Rudraprayag, Uttarakhand
Example of Dec 06, 2017 earthquake recorded on EEW system

Mag 5.5
Origin Time : 2017/12/06 15:19:52.77
latitude: 30.5194
longitude: 79.0776
depth : 15 Km
Work in progress

- Development of Earthquake Early Warning Dissemination System in context of India.
- Development of SHAKE MAP/INTENSITY MAP using EEW
- Hardware development for disseminating earthquake early warning using various medium such as Internet, Radio Waves etc.
- Development of location based warning system which incorporates local site effects and attenuation.
- Development of a dedicated GIS for maintenance of EEW warning system.
- Development of an algorithm which can be used for various purposes in On-Site Early Warning System (Hybrid).
- Development of smart phone apps which can transmit a warning message without any network (peer to peer).
- Preparation of app for identification of victims of disaster.
EEW Warning Server (Architecture)

(In house Development)

Earthworm Server

Web Server

Application Server

Web APIs

Database

EEW Warning Server

Internet

EEW Sirens
Sirens working on Radio Waves
(In house Development)
Sirens working on Internet
(In house Development)
Improved Version of EEW Siren
(In house Development)

Raspberry Pi
5V Regulator
Circuit Power
Sockets

12-0-12V 2 Amp Transformer

LED Lights

Push Buttons

Solid State Relay

12-0-12V 5Amp Transformer

Internal View
Topology of System

Main Warning Server

District level Server

District level Server

District level Server

City/Village Server

City/Village Server

City/Village Server

Radio Waves

Siren

Siren

Siren

Siren

Siren

Siren

Siren
Proposal for Himalayas and its vicinity

Return period of magnitude 6 and 7 in seismic source zones

<table>
<thead>
<tr>
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<th>4</th>
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<td>93</td>
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</tbody>
</table>
Seismic Hazard assessment for Dams, TPP and NPP
AOI is 5 million km$^2$.

Habitat approx. 2.5 million km$^2$.

Further 50% Well connected

Sensor locations 5000

URGENT NEED TO INSTRUMENT
EEW for Himalayas

**Facts**
- 16 States
- 24 clusters
- 5000 sensors

**Make in India**
- Sensors (dBs)
- Seismology (HF LF)
- Earthquake Engineering
- Application software
- Dissemination Apps

**Stake holders**
- MHA – NDMA
- Foreign Manufacturer
- DOT
- Private partners (Inst)
- Private Partners (Comm)
Thank you