Development and feasibility testing of a low-cost earthquake early warning system in Nepal

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How does an Earthquake Early Warning system work?

The seismic network continually records the ground motion.

The data are transmitted to remote servers for real-time processing.

When an earthquake is detected, the system evaluates the risk and decides whether to issue a public alert.

Earthquake alerts are delivered to smartphones or other devices before arrival of the destructive shaking.
Existing EEW systems

Global Earthquake Model

Global Seismic Risk Map

US West Coast

Mexico

Italy

Japan

Taiwan
A low-cost, open-source EEW system based on IoT infrastructure.

Low-cost sensor  Cloud-based platform  Smart alert
Seismic sensor

MICROCONTROLLER ESP32

ACCELEROMETER ADXL355

BUZZER

UART INTERFACE

NEOPIXEL LIGHTS

ETHERNET PORT
Cloud platform
We want to test the feasibility of the OpenEEW Earthquake Early Warning system in a densely populated area between Pokhara and Kathmandu, where the next strong earthquake may initiate.

### EARTHQUAKE EARLY WARNIGN SYSTEM

#### Design

**Seismic network**
A network of 40 seismometers will observe the ground motion. When it detects a potential earthquake, it sends the data to the cloud server and the data center.

**Cloud server**
The cloud server will identify earthquakes and determine their location and magnitude in real-time. When an earthquake is detected, the system will issue a test alert.

**Local data center & workshop**
The local data center will oversee and manage the network operation. Same as the cloud server, it will process data in real-time and issue test alerts.

### System testing in Nepal

![Map showing the testing location in Nepal]
Seismic hazard and risk in Nepal
Gorkha earthquake - April 25, 2015, M 7.8

- ~9,000 fatalities
- Damage: 10$ bilion
Potential actionable times provided by EEW system

The map and table show theoretical actionable times for the 2015 Gorkha earthquake, which ruptured about 150-km-long fault segment.

<table>
<thead>
<tr>
<th>Distance from the epicenter (km)</th>
<th>Theoretical actionable time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 km</td>
<td>0 sec</td>
</tr>
<tr>
<td>50 km</td>
<td>5-10 sec</td>
</tr>
<tr>
<td>100 km</td>
<td>25-30 sec</td>
</tr>
<tr>
<td>150 km</td>
<td>55-60 sec</td>
</tr>
</tbody>
</table>

The actionable time (the time between the delivery of the alert and the arrival of the strong shaking) depends on the user's distance from the earthquake epicenter. Unfortunately, the alert will always arrive too late in the area close to the earthquake epicenter. However, strong earthquakes (with magnitude > 7.5) rupture long fault segments (often > 100 km). This may take over a minute. In these cases, the actionable time may be tens of seconds to over a minute, providing people time to exit the building or seek cover.
NepalEEW experiment 2021/2023
November 2021 station deployment
November 2021 station deployment
Real-time earthquake determinations

Test alert issued
Station connectivity and data transmission latency

Connectivity (% of data)

latency [s]

no. of messages

Data transmission latency [s]

- KUSM: 406 ms
- SYNJ: 480 ms
Thank you for your attention!

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• Dr. John Nabelek (Oregon State University)
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• Dr. Anil Pokhrel (National Disaster Risk Reduction & Management Authority)
Rapid earthquake characterization

1. Detection: STA/LTA, Neural-network picking

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MODEL PREDICTION EVALUATION

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>noise</th>
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</thead>
<tbody>
<tr>
<td>Tag</td>
<td>4987</td>
<td>185</td>
</tr>
<tr>
<td>No tag</td>
<td>273</td>
<td>84865</td>
</tr>
</tbody>
</table>

Precision: 0.96
Recall: 0.95
Hit misfit: mean 0.03, std 0.30

\\\------------------------------------------
// F1 score: 0.96 //
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![Histogram of Misfit (s)](#)

- Too late
- Too early

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Number of segments
Rapid earthquake characterization

1. Detection: STA/LTA, Neural-network picking
2. Magnitude: Bayesian estimation from peak ground displacement of initial portion of P-wave

Rapid earthquake characterization

1. Detection: STA/LTA, Neural-network picking
2. Magnitude: Bayesian estimation from peak ground displacement of initial portion of P-wave
3. Location: Bayesian estimation from P-wave arrivals

NAMASTE experiment 2015/2016

Previous seismic investigations of the central Nepal

- HICLIMB seismic experiment (2002-2005)
- NAMASTE seismic experiment (2015-2016)
Collaborations

NepaEEW

INSTITUTION
NATIONAL DISASTER RISK REDUCTION & MANAGEMENT AUTHORITY
NEPAL ACADEMY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF MINES AND GEOLOGY

RESPONSIBILITY
DDR management
Technology, Solutions
Science

DRR portal integration
Alert dissemination
Fundraising
System latency

- Earthquake
- Grillo sensors: message transfer
- Cloud platform
- End users: SMS, IoT speakers

Latencies:
- Wave travel-time latency (depends on network density)
- Data transmission latency: <0.5 s
- Signal processing latency: <2 s
- Alert delivery latency: <1 s