RAPID EARTHQUAKE DETECTION OF EEWS - FIRST RESULTS

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1. INTRODUCTION

The M7.7 Myanmar earthquake on 28 March 2025 (22.01 °N, 95.92 °E) with a focal depth of 10 km, generated long-period ground motions that affected Bangkok's high-rise buildings, in some cases severely, at approximately 1,050 km epicentral distance. An earthquake early warning system (EEWS) could mitigate such effects, as earthquakes cannot currently be forecasted. Here, we developed a machine learning-based early warning approach utilizing data from the TGI station (20.77 °N, 97.03 °E) of the Myanmar Seismic Network. Our approach uses ensemble learning algorithms to detect earthquakes and estimate source parameters from initial P-wave recordings. The system utilizes multiple stacked models trained on regional seismicity to progressively estimate the magnitude, location, and depth, as P-wave information accumulate over time. This study presents a performance analysis of the system for the 28 March event, in retrospect, focusing on detection speed, magnitude estimation accuracy, and practical warning times achieved for Bangkok. Here, we analyze and discuss these key performance metrics to validate the efficacy of our machine learning approach in mitigating far-field seismic risk and to contribute to enhanced earthquake early warning capabilities for regional seismic hazard mitigation in Thailand.

2. METHOD

The system presented here has three processing stages: (1) Detection: training with both global earthquake datasets and station-specific continuous recordings to optimize discrimination accuracy; employing sliding window analysis with temporal, spectral, and cepstral domain attributes; (2) P-phase picking: applying fine temporal resolution for precise P-wave onset determination; (3) Source parameter estimation: utilizing stacked ensemble models for progressive magnitude, epicentral distance, depth, and back-azimuth estimation from expanding P-wave windows.

The training datasets incorporated global seismic catalogs from multiple regions, together with mel-frequency cepstral coefficients (MFCCs), which demonstrating superior performance relative to traditional seismic parameters. High-performance computing infrastructure facilitated efficient model training through parallel processing.

3. RESULTS AND DISCUSSION

Our system detected the Myanmar earthquake, achieving critical magnitude thresholds within seconds of the P-wave onset (Table 1). The progressive magnitude estimates evolved from M 5.4 at initial detection to M 7.4 after 60 seconds, reflecting the extended source duration of this M 7.7 event. Warning times for Bangkok (13.76 °N, 100.50 °E) were calculated from each estimated epicenter using:

$$T_{warn} = t_P - (\Delta TGI/V_p) + (\Delta BKK/V_s) - t_{current},$$

where tP is the P-arrival time at TGI station, ΔTGI is the estimated epicenter-to-TGI distance, ΔBKK is the estimated epicenter-to-Bangkok distance, Vp = 6.21 km/s, Vs = 3.56 km/s, and tcurrent is the detection time. The M ≥7.0 detection at 5 seconds post-P-arrival yielded 3.1 minutes warning prior to S-wave arrived in Bangkok. This a time window is sufficient for critical automated responses and public alerts.

Table 1. Critical Detection Thresholds and Warning Times for Bangkok

Time after P (s)	Magnitude	Time Before S-wave at Bangkok (min)	Estimated Epicenter	Location Error (km)
3	5.4	N/A	19.69 °N, 96.73 °E	270
5	**7.0**	**3.11**	**20.33 °N, 98.35 °E**	**265**
9	7.3	3.96	21.27 °N, 96.13 °E	85
10	6.9	2.90	20.72 °N, 96.05 °E	95
20	7.3	2.71	20.89 °N, 96.00 °E	120
30	7.3	3.78	21.67 °N, 95.95 °E	80
60	7.4	3.34	22.18 °N, 96.39 °E	51.6
USGS epicenter: 22.01 °N, 95.92 °E				

The epicentral accuracy improved progressively, from initial errors exceeding 250 km to a final error of 51.6 km. The magnitude evolution pattern confirms the system's ability to track rupture progression and provide timely early warnings. The 3.11-minute warning interval at the M ≥7.0 threshold demonstrates that the machine learning approaches are effective for earthquake early warning applications in Thailand's seismically vulnerable metropolitan areas.