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EQ Alert: AN APP OF ON-SITE EARTHQUAKE EARLY WARNING

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Abstract

Large magnitude earthquakes continue to thread Taiwan and worldwide countries. Earthquake early warning (EEW) provides seconds to minutes of warning, allowing people to move to safe zones and automated slowdown and shutdown of transit and other machinery. Existing EEW systems only operating in a few nations, mainly due to high cost for establishment and maintaining. Smartphones are prevalent to populace and contain accelerometers that can also be used to detect earthquakes. In this study, a mobile application software called "EQ Alert" is developed to estimate peak acceleration of the coming earthquake using artificial neural network with measured P-wave features of a single smartphone. The APP will detect the quality of the recorded acceleration signal automatically and apply suitable parameters. Shaking table tests are conducted to verify the feasibility of "EQ Alert". The results show that the APP can detect the event of an earthquake and predict the peak acceleration successfully during both the world significant earthquake events and the Meinong earthquake in Taiwan. Compared to the seismometers, in general, the lead-time using smartphone reduces approximately 2 s, but the predicted peak acceleration is more accurate. However, some smartphones equipped with high-pass filter with low cut-off frequency are not suitable to install the APP for EEW.

Keywords: on-site earthquake early warning, smartphone, EQ Alert, peak acceleration

1. Introduction

Large magnitude earthquakes continue to thread Taiwan and worldwide countries. Earthquake early warning (EEW) provides seconds to minutes of warning, allowing people to move to safe zones and automated slowdown and shutdown of transit and other machinery. Existing EEW systems only operating in a few nations, mainly due to the high cost for establishment and maintenance. Smartphones are prevalent to the populace and contain accelerometers that can also be used to detect earthquakes. In this study, a mobile application software called "EQ Alert" (Fig. 1) is developed to estimate peak acceleration of the coming earthquake using an artificial neural network with measured P-wave features of a single smartphone. The APP will detect the quality of the recorded acceleration signal automatically and apply suitable parameters. In order to understand the performance of the app during earthquakes, shaking table tests are conducted, and the results of the shaking table tests are illustrated in this study.

2. EQ-Alert APP

Because smartphones will measure the vibration due to human activities, in order to detect an earthquake, the EQ Alert APP should distinguish the vibration due to an earthquake from others. The APP has three states, detrigger state, trigger state, and steady state. During the normal operating condition of the smartphones, the APP remains trigger state because of the vibrations due to user activities. When the smartphone is placed on a stable surface, the APP goes into the steady state after a continuously detrigger state. Once the APP is triggered during the steady state, the APP will classify the trigger event as an earthquake or not using the embedded classifier model constructed by an artificial neural network. The classifier is constructed mainly according to the work done by Kong et al. [1]. If the event is classified as an earthquake, the peak ground acceleration (PGA) of the whole earthquake event will be predicted using the embedded predictor model constructed by an artificial neural network. The predictor is constructed mainly according to the work by Hsu et al. [2]. The classifier and prediction models will update the results every second after triggering until 10 s. If the predicted PGA is larger than 25 Gal, the alert could be issued for the smartphone user. The detail flow chart of the EQ Alert APP is illustrated in Fig. 2.

Fig. 1 – EQ Alert APP

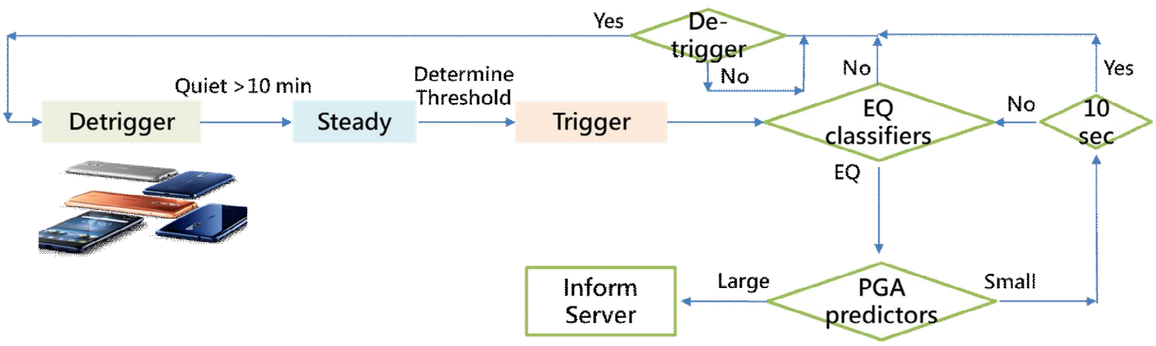

Fig. 2 – Flow chart of EQ Alert APP

3. Shaking table test results

The test setup is shown in Fig. 3. The 10 smartphones were mounted on the shaking table via double-side tape. Because the EQ Alert app requires the tri-axial components of accelerations of vibration to distinguish earthquakes from human activities, and the low noise floor on the shaking table is necessary to let the APP go into the steady state, the electric derived shaking table is used. The list of the 10 smartphones and their noise floor and resolution are summarized in Table 1.

The table tests include 17 strong motions of worldwide large earthquakes (Table 2) and 43 ones of the 2016 Meinong earthquake, Taiwan (Table 3). The results of earthquake classification of all the smartphones of the worldwide large earthquakes and Meinong earthquake are summarized in Table 4. The results show that except a few strong motions were misclassified due to unexpected trigger by shaking table noise or low signal to noise ratios of strong motions with small PGA, most of the strong motions were correctly classified as earthquakes events. The predicted PGAs of each smartphone of the worldwide earthquakes and Meinong are compared to the real ones in Fig. 4 and 5, respectively. The predicted PGAs are the values when they first become larger than 25 Gal. The predicted PGAs will be updated every second until 10 s after trigger, but they are not shown here for conciseness of the paper. The warning time is defined as the time difference between the time when the alert is uttered and the time the strong motion reaches its PGA. The histograms of the warning time of each smartphone of the worldwide earthquakes and Meinong are plotted in Fig. 6 and 7, respectively. For the large worldwide earthquakes, the APP can provide several seconds to 28 s depending on the hypocentral distance. As for the strong motions of the Meinong earthquake, the APP can provide at least 6 s for most of the strong motions.

Table 1 – List of the 10 smartphones and their noise floor and resolution

Brand	Model	Processor	Accelerometer	Noise floor (gal)	Resolution (gal)
ASUS	ZenFone Selfie	Snapdragon 615	MPL Linear Acceleration	3.357	0.239
ASUS	ZenFone Max Pro	Snapdragon 636	BMI160 Accelerometer	0.912	0.478
LG	Stylus 2 (Black)	Snapdragon 410	LGE Accelerometer Sensor	1.129	1.915
LG	Stylus 2 (White)	Snapdragon 410	LGE Accelerometer Sensor	1.142	1.915
HTC	Desire EYE	Snapdragon 801	Accelerometer Sensor*	3.209	1.000
HTC	U11	Snapdragon 835	BMI160 Accelerometer	2.417	0.239
SAMSUNG	Galaxy A8	Exynos 7885	LSM6DSL Accelerometer	1.035	0.239
Xiaomi	POCOPHONE F1	Snapdragon 845	BMI160 Accelerometer	1.124	0.239
Redmi	Note 4	Helio X20	BOSCH Accelerometer Sensor	0.883	0.120
HUAWEI	P9	Kirin 650	iNemo Linear Acceleration	1.252	0.958

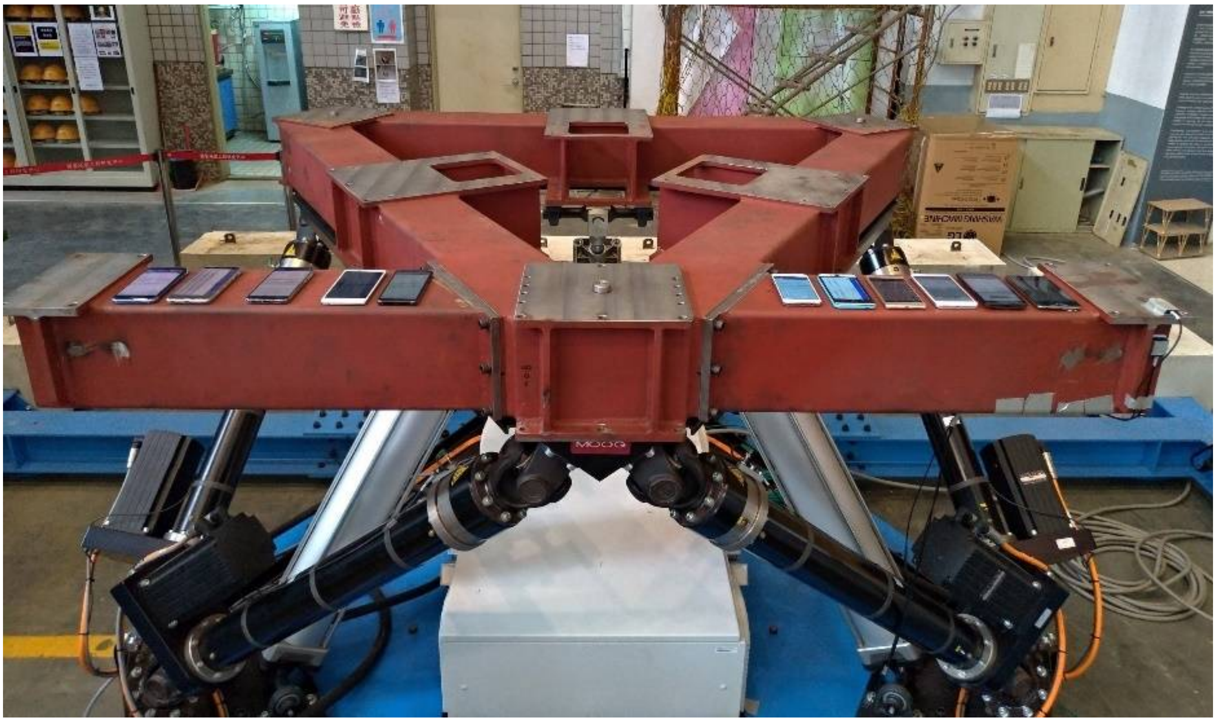

Fig. 3 – Test setup of the shaking table tests.

Table 2 – List of the worldwide large earthquakes.
(the Wenchuan and Valparaiso earthquakes are tested twice)

Earthquake	Region	Station	Epiventer distance (km)	Date	Magnitude (Mw)	PGA (Gal)
Anchorage	US/AK	Rabbit Creek AK USA	46	2018/11/30	7.0	651.5
Hector Mine	US/CA	Mill Creek; Ranger Station	91.3	1999/10/16	7.1	59.5
Miyagi	Japan	Shiogama - MYG012	142	2011/04/07	7.1	1447
Northern Norcia Italy	Italy	Forca Canapine	11.7	2016/10/30	6.5	910.4
Duzce	Mexico	Unam - Mexico, Mexico	116.4	2017/09/19	7.1	53.7
Samoa Islands Region	Samoa	Afiamalu, Samoa	179	2009/09/29	8.0	103
Valparaiso	Chile	Torpederas, Chile	39	2017/04/24	6.9	889
India-Burma Border	Indonesia	Berlongfer	220.1	1988/08/06	7.2	331
Northridge	US/CA	Cedar Hill Nursery A	16.7	1994/01/17	6.7	1744.5
Kobe	Japan	Nishi-Akashi	38	1995/01/17	7.3	605.3
Chi Chi	Taiwan	TCU084	18	1999/09/21	7.6	681.6
Hawlian	Taiwan	ENA	35.6	2018/02/06	6.2	428.3
Lefkada	Greece	Lefkada No1	10	2003/08/14	5.9	417.5
Northwest China	China	CSB station 19001	27.7	1997/04/11	6.1	376.6
Wenchuan	China	051WCW	14	2008/05/12	8.0	957.7

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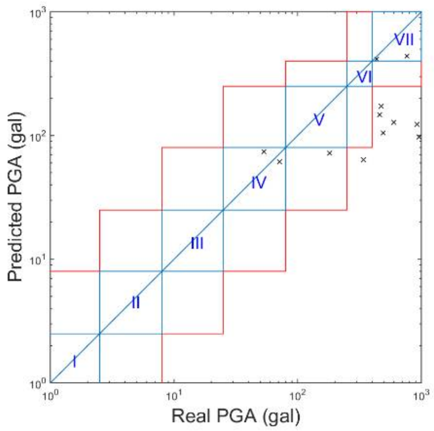
Table 3 – List of the number of strong motions of the 2016 Meinong earthquake, Taiwan.

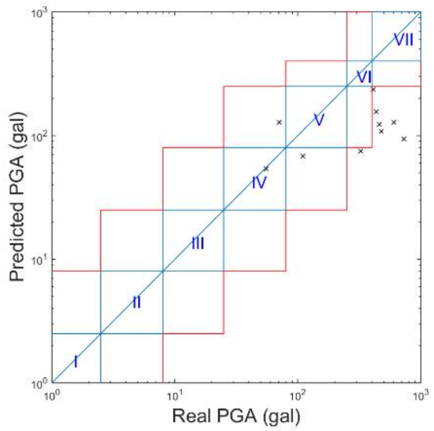
PGA (Gal)	8-25	25-80	80-250	250-400	400-
Number	11	9	9	12	2

Table 4 – Earthquake classification results of the 10 smartphones.

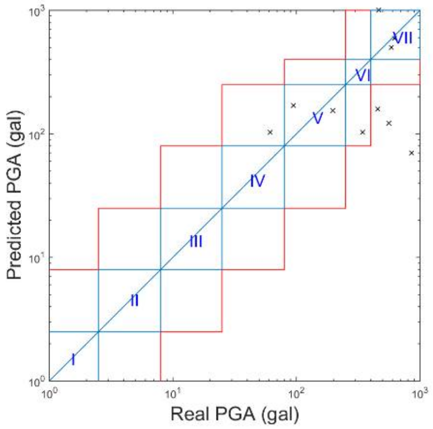
Smartphone	Correct rate (%)	
	worldwide earthquakes	Meinong earthquake
ASUS ZenFone Selfie	88%	95%
ASUS ZenFone Max Pro	94%	95%
LG Stylus 2 (Black)	100%	100%
LG Stylus 2 (White)	94%	91%
HTC Desire EYE	94%	91%
HTC U11	100%	95%
SAMSUNG Galaxy A8	94%	95%
Xiaomi POCOPHONE F1	100%	95%
Redmi Note 4	100%	95%
HUAWEI P9	100%	95%



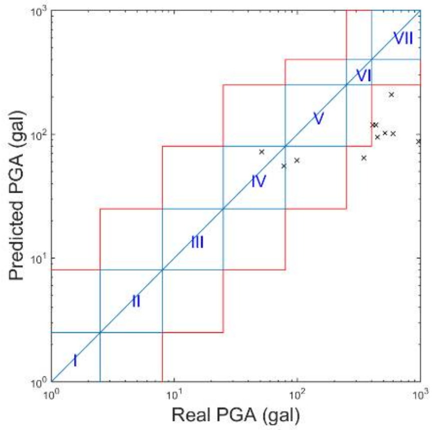
(a) LG Stylus 2 (Black)



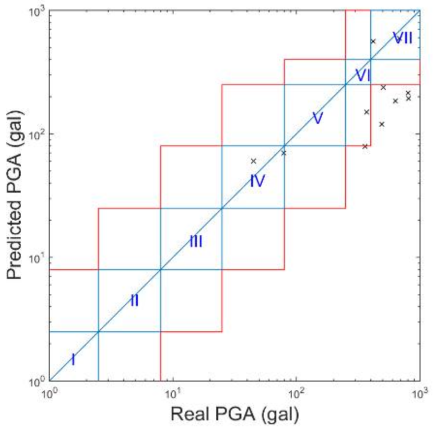
(b) LG Stylus 2 (White)



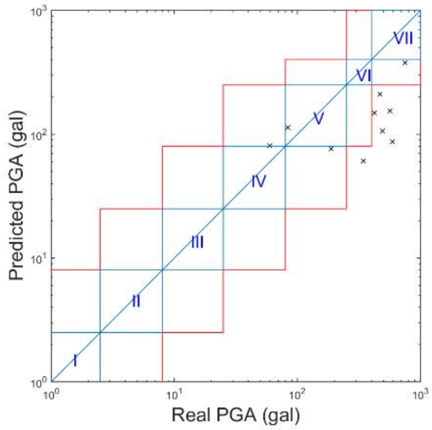
(c) ASUS ZenFone Selfie



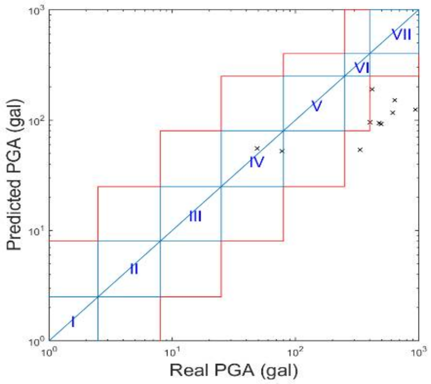
(d) Redmi Note 4



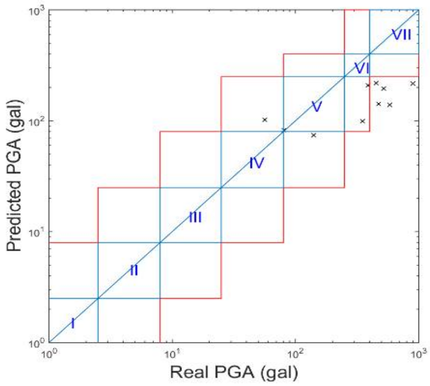
(e) HTC Desire EYE



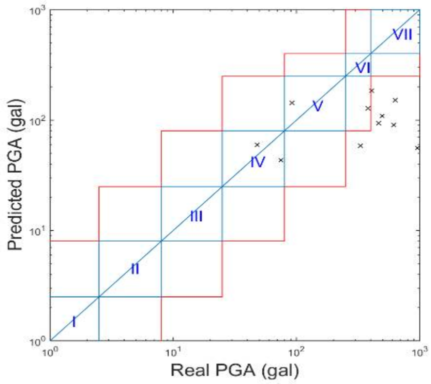
(f) HUAWEI P9



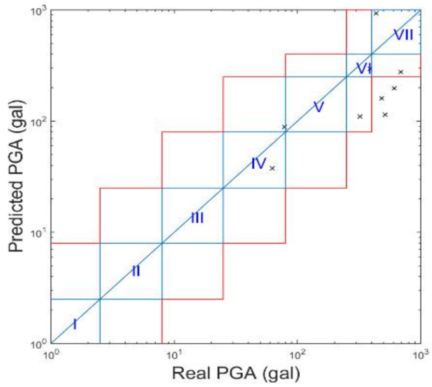
(g) ASUS ZenFone Max Pro



(h) SAMSUNG Galaxy A8

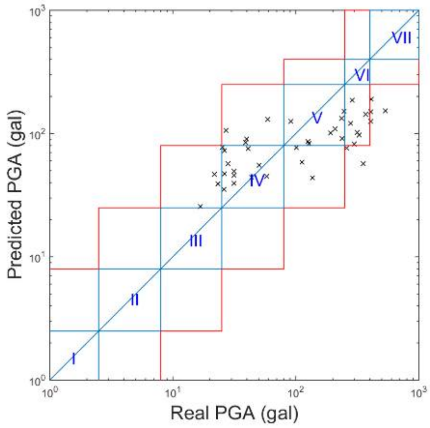


(i) Xiaomi POCOPHONE F1

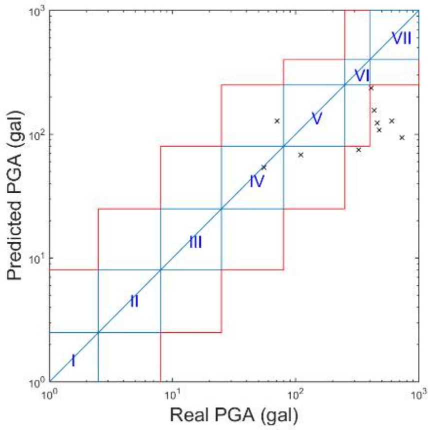


(j) HTC U11

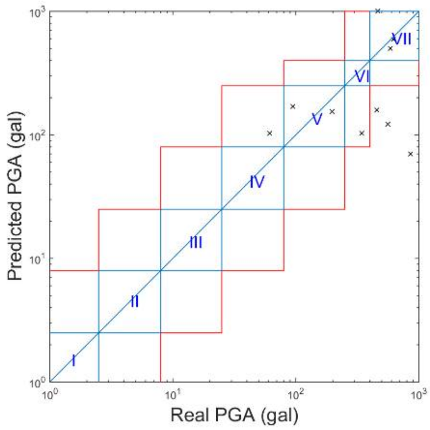
Fig. 4 – The comparison of predicted PGAs and the real ones of the worldwide earthquakes.



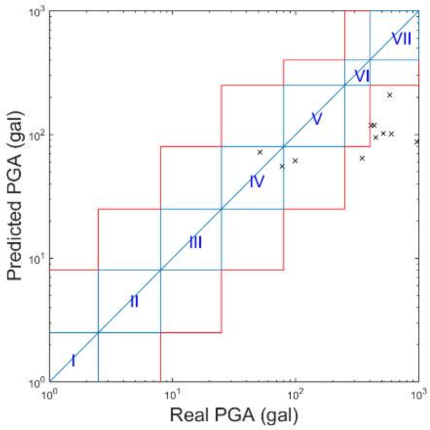
(a) LG Stylus 2 (Black)



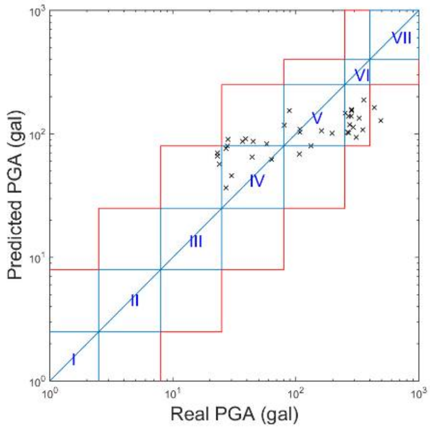
(b) LG Stylus 2 (White)



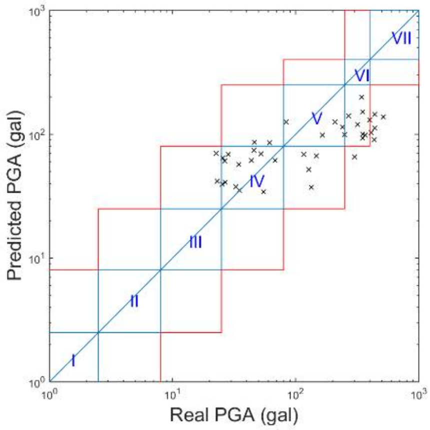
(c) ASUS ZenFone Selfie



(d) Redmi Note 4



(e) HTC Desire EYE



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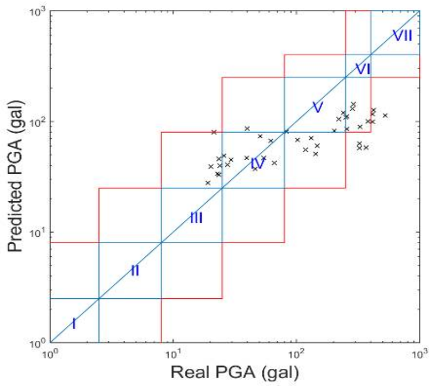
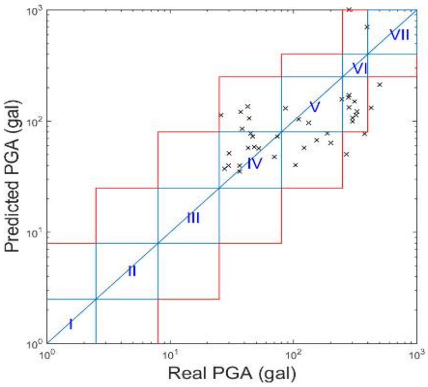
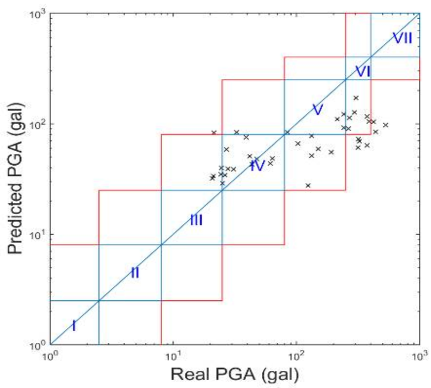


(g) ASUS ZenFone Max Pro



(h) SAMSUNG Galaxy A8



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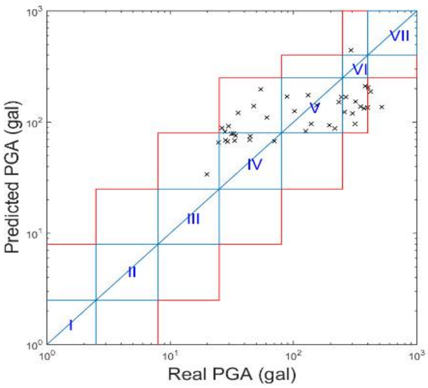
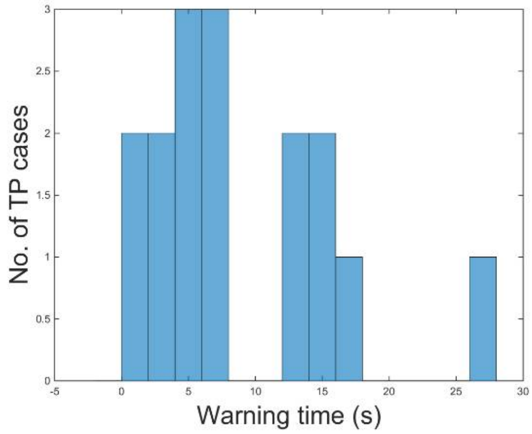
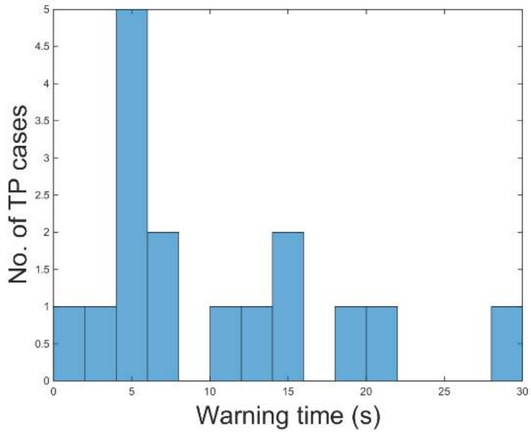


(j) HTC U11

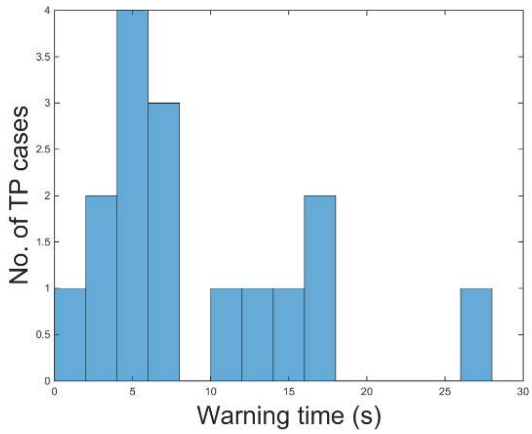
Fig. 5 – The comparison of predicted PGAs and the real ones of the Meinong earthquake.



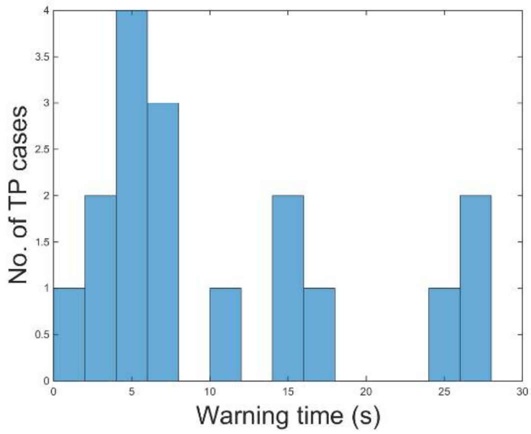
(a) LG Stylus 2 (Black)



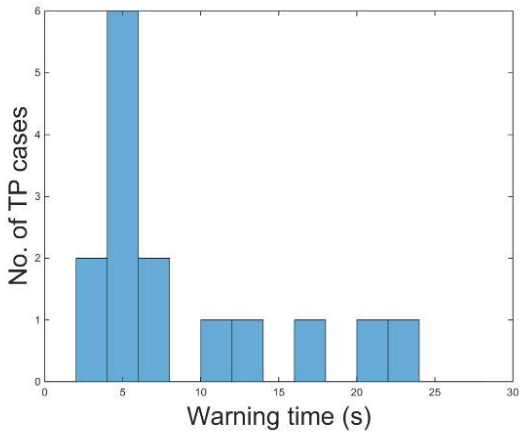
(b) LG Stylus 2 (White)



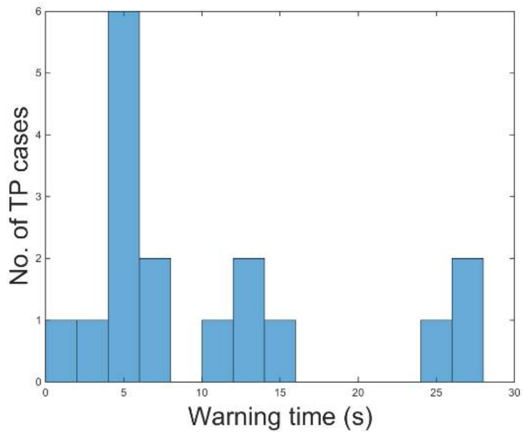
(c) ASUS ZenFone Selfie



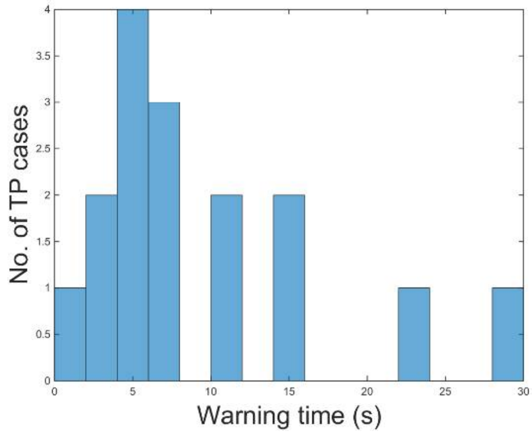
(d) Redmi Note 4



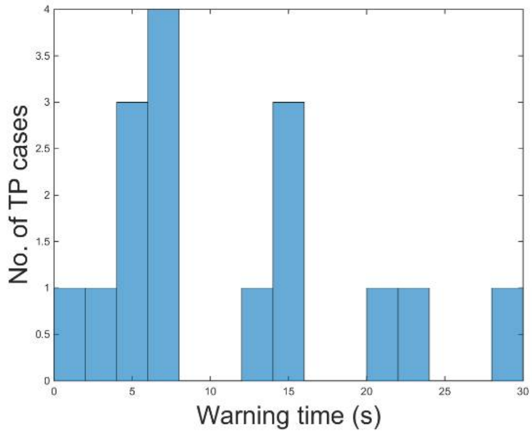
(e) HTC Desire EYE



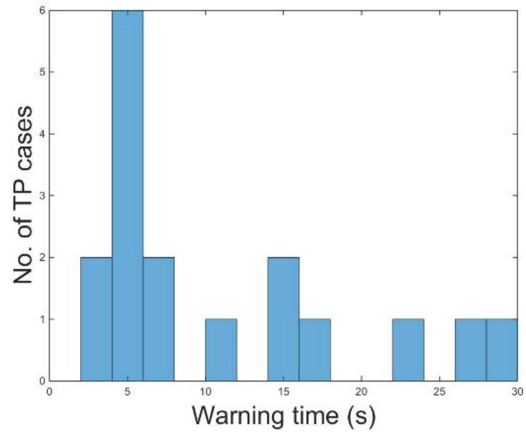
(f) HUAWEI P9



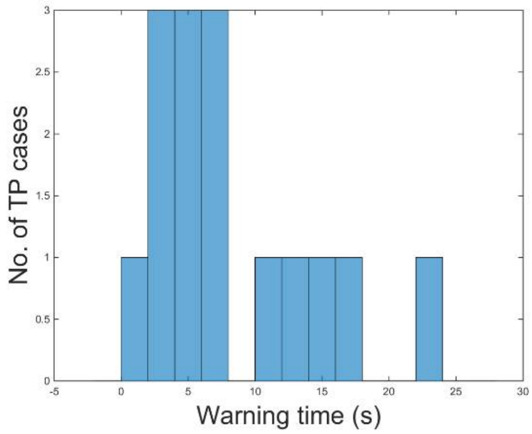
(g) ASUS ZenFone Max Pro



(h) SAMSUNG Galaxy A8

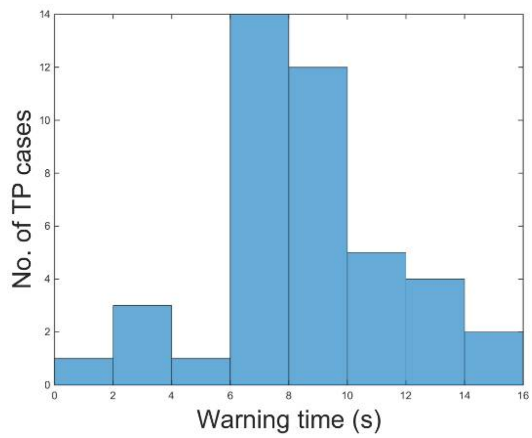


(i) Xiaomi POCOPHONE F1

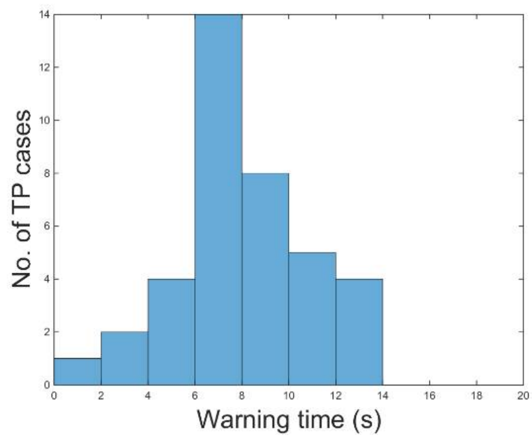


(j) HTC U11

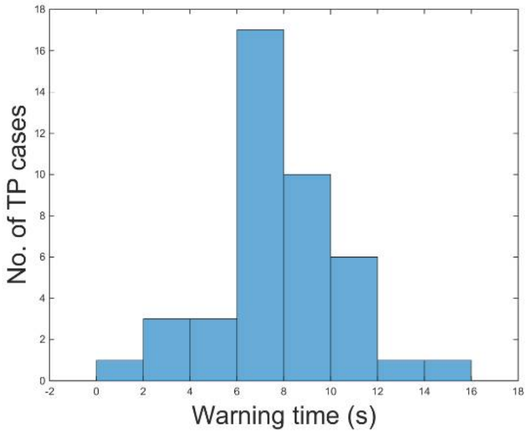
Fig. 6 – The histograms of the warning times of the worldwide earthquakes.



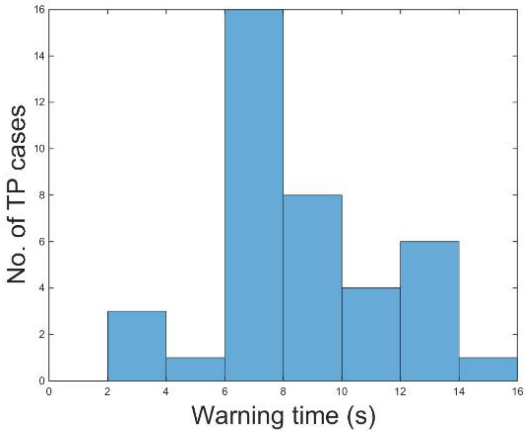
(a) LG Stylus 2 (Black)



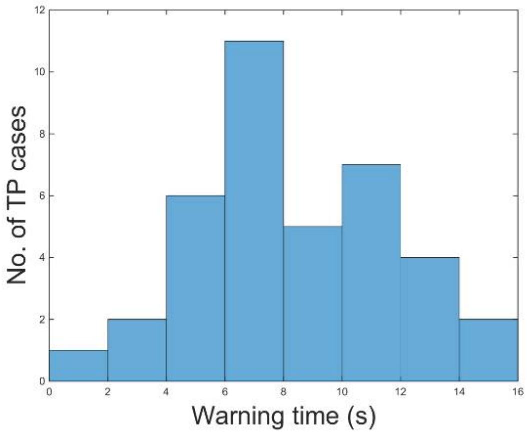
(b) LG Stylus 2 (White)



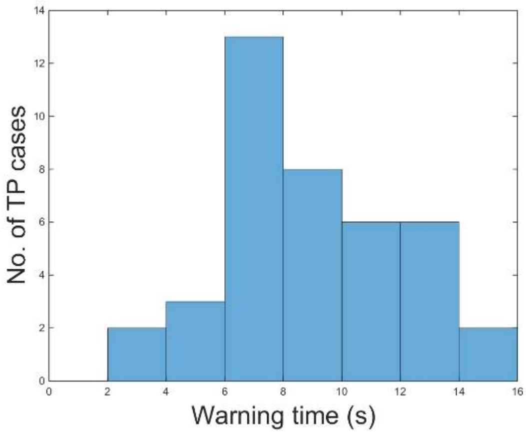
(c) ASUS ZenFone Selfie



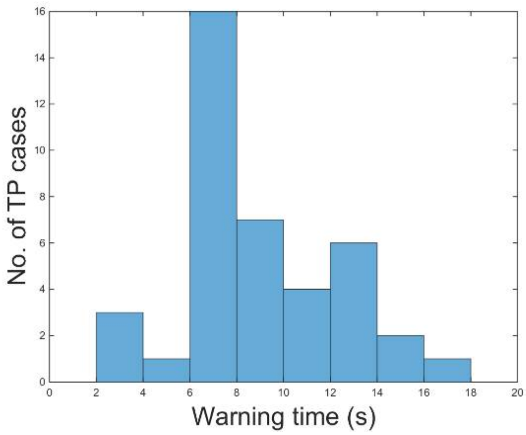
(d) Redmi Note 4



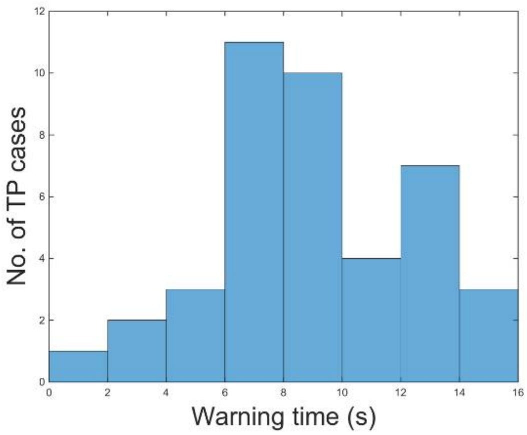
(e) HTC Desire EYE



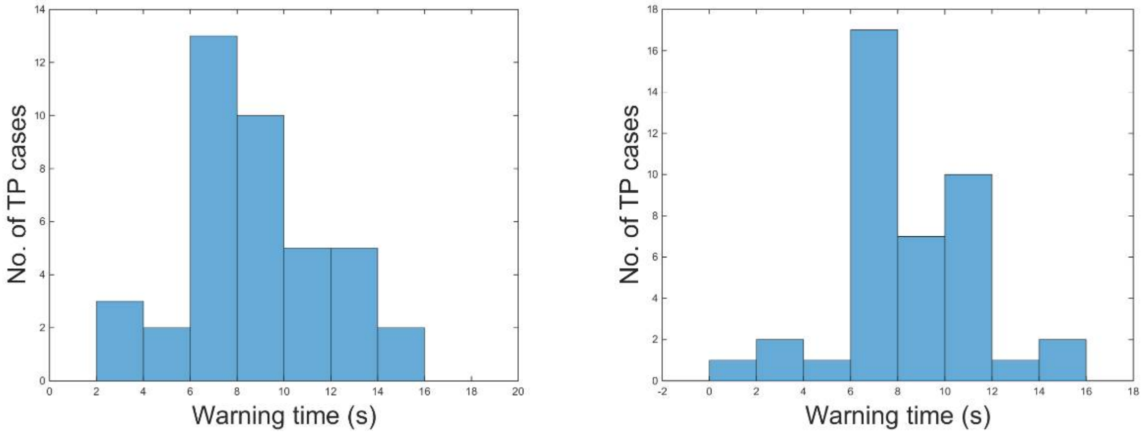
(f) HUAWEI P9



(g) ASUS ZenFone Max Pro



(h) SAMSUNG Galaxy A8



(i) Xiaomi POCOPHONE F1 (j) HTC U11

Fig. 7 – The histograms of the warning times of the Meinong earthquake.

4. Conclusion

Based on the shaking table tests, the EQ Alert APP illustrates its ability to utter alerts in time for earthquakes with PGA larger than 25 Gal, either for the worldwide large earthquakes or the Meinong earthquake in Taiwan. At the time of writing, EQ Alert APP is in the testing stage with an expected release in June 2020. Further studies are necessary for the real application for earthquake warning. The development of EQ Alert APP requires help from the users. The authors greatly appreciate it if anyone can download the APP and test the ability of the APP.

5. Acknowledgments

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6. References

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