**An Investigation of Rapid Earthquake Characterization Using Single-Station Waveforms and a Convolutional Neural Network**

**利用單一測站地震波形及卷積神經網路快速辨認地震之調查**

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**ABSTRACT**

Effective early warning, emergency response, and information dissemination for earthquakes and tsunamis require rapid characterization of an earthquake’s location, size, and other parameters, usually provided by real-time seismogram analysis using established, rule-based, seismological procedures.

就地震及海嘯而言，具有影響力的地震預警、災害管理及資訊傳播需要快速的地震辨認，包括地震發生地點、大小及其他因素。透過即時地震儀分析，可以建立一個有規則的地震程序系統。

Powerful, new machine learning (ML) tools analyze basic data using little or no rule-based knowledge, and an ML deep convolutional neural network (CNN) can operate directly on seismogram waveforms with little preprocessing and without feature extraction.

強大且新型的機器學習工具可以分析一些資料或是無基礎概括的資料，而深度機器學習的卷積神經網路(CNN)可以在沒有抽取特徵的情況下對地震波波形進行簡單的預先處理

How a CNN will perform for rapid automated earthquake detection and characterization using short single station waveforms is an issue of fundamental importance for earthquake monitoring.

要如何利用單一測站短波形資料應用至CNN上去快速且自動的做出地震檢測及辨認對於地震監測是一個的基本且重要的問題。

For an initial investigation of this issue, we adapt an existing CNN for local earthquake detection and epicentral classification using single-station waveforms (Perol et al., 2018), to form a new CNN, ConvNetQuake\_INGV, to characterize earthquakes at any distance (local to far-teleseismic).

在剛開始探討這個問題時，我們利用單一測站波形套用至現有的CNN模型去做當地的地震檢測及震央分類。並產生出一套新的CNN，ConcNetQuake\_INGV，來分類不同距離的地震(當地或是遠程地震)。

ConvNetQuake\_INGV operates directly on 50-s three-component broadband single-station waveforms to detect seismic events and obtain binned probabilistic estimates of the distance, azimuth, depth, and magnitude of the event.

ConcNetQuake\_INGV模型透過50-s三分量寬頻的單一測站波形資料來偵測地震事件，分類概括來估計距離、方位角、深度及地震規模。

The best performance of ConvNetQuake\_INGV is obtained using a last convolutional layer with fewer nodes than the number of output classifications, a form of information bottleneck.

ConcNetQuake\_INGV的最佳性能使用了最後一個卷積層來獲得，卷基層的節點數少於資料輸出分類的數量。

We show that ConvNetQuake\_INGV detects very well (accuracy 87%) and characterizes moderately well earthquakes over a broad range of distances and magnitudes, and we analyze outlier results and indications of overfitting of the CNN training data.

我們發現ConcNetQuake\_INGV對於地震檢測相當傑出(87%的正確率)，廣泛的距離及深度也分類的不錯，而我們亦分析了離群值結果是適應於CNN訓練資料的。

We find weak evidence that the CNN is performing more than high-dimensional regression and pattern recognition, and is generalizing information or learning, to provide useful characterization of new events not represented in the training data.

我們發現有微弱的證據顯示CNN有較好的概括了資訊及學習之高維迴歸及圖形辨認，對於不在訓練資料內的新型地震是個有用的辨認依據。

We expect that real-time ML procedures such as ConvNetQuake\_INGV, perhaps incorporating rule-based knowledge, will ultimately prove valuable for rapid detection and characterization of earthquakes for earthquake response and tsunami early warning.

我們期待透過即時機器學習程序，像是ConvNetQuake\_INGV，或許包括了基礎規則概括的知識，最終能夠提供實用性的成果去快速的做地震檢測及辨認，以利用於地震預報及海嘯的早期警報。