A neural network for ground motion quality classification from New Zealand earthquakes of variable magnitudes and tectonic types

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1. Record quality problem

High-quality earthquake ground motion records are required for various applications:

- Response-history analysis of structures;
- Seismic hazard development;
- Site response analysis; and
- **Validation of ground motion simulations**.

Beauty is in the eye of the beholder—the definition of *high-quality* is wholly dependant on the intended application, i.e. a record considered to be *high-quality* by an academic for simulation validation may not be appropriate for structural response-history analysis. This is apparent within the diverse dataset of earthquakes records (Figure 1) considered in this work.

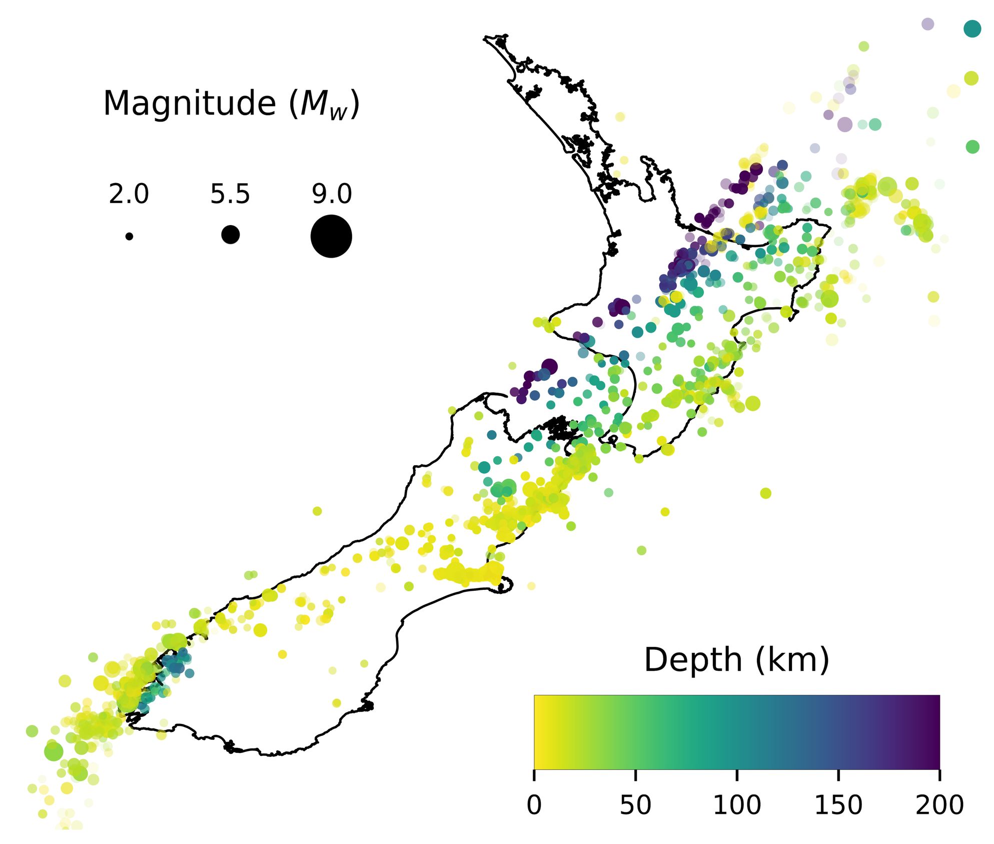

Figure 1: Earthquake hypocentres for GeoNet records

2. Challenging to automate

The determination of whether a ground motion record is high-quality is poorly handled by automation with mathematical functions, and can become prohibitive if done manually. Multiple characteristics may affect the quality of a record (Figure 2):

- **Instrument malfunction**: low-resolution, low-sampling rate, multiple baselines, spikes (jerks), late triggering, early termination, or clipped amplitudes;
- **Multiple earthquakes**: from large overlapping ruptures to well-spaced small aftershocks; and
- **Minimum usable frequency** as determined by the signal strength relative to background noise.

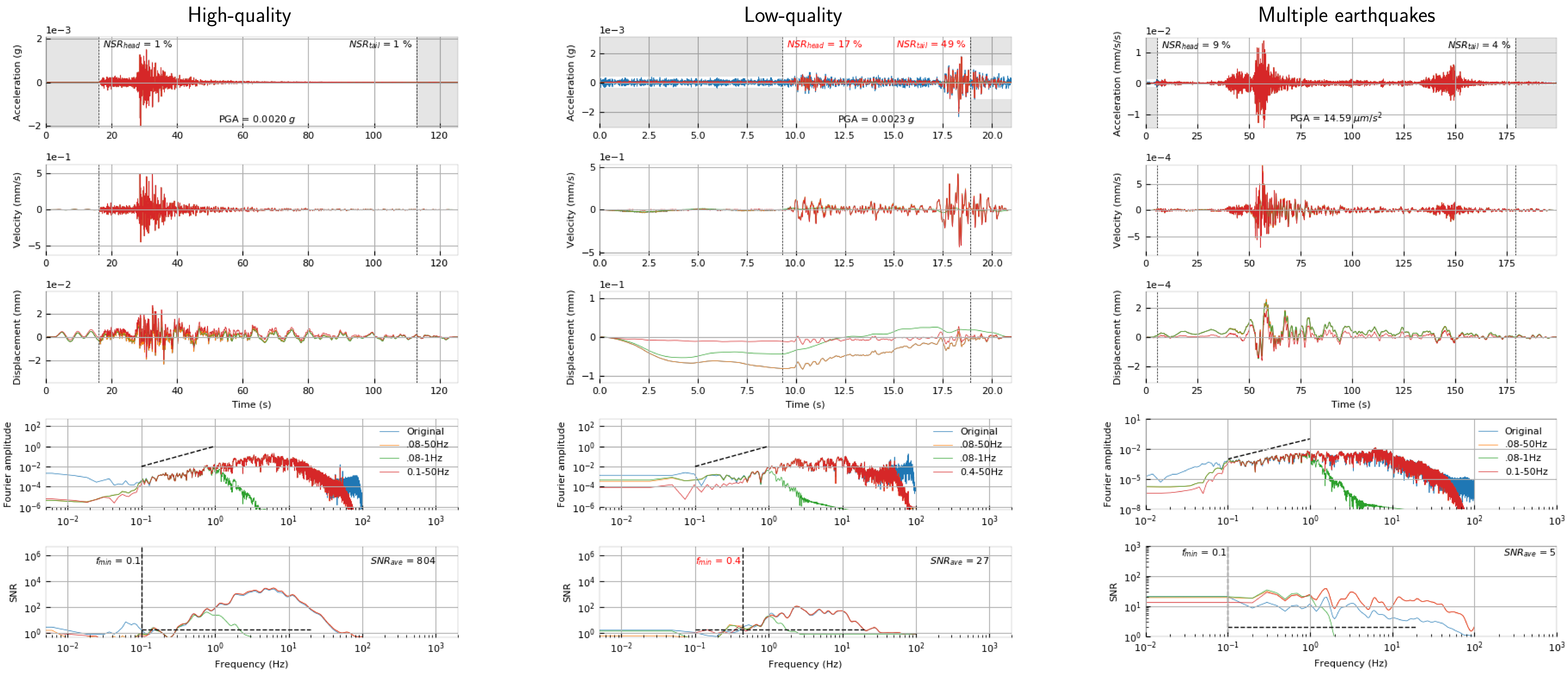

Figure 2: Left: a high-quality record component with a minimum usable frequency of 0.3 Hz, minimal pre-event noise, diminished coda waves, approximate slope of 2 (log-log) in the low-frequency range of the Fourier amplitude spectrum, and signal-to-noise ratio above 2 at 0.3 Hz and above. Centre: a low-quality record component characterized by strong pre-event noise, early termination indicated by the ongoing coda decay, and signal-to-noise ratio below 2 at frequencies up to 0.4 Hz. Right: a multiple earthquake record component containing a small magnitude foreshock and a moderate magnitude aftershock.

3. Improvements on previous work

A feed-forward neural network (FNN) was previously developed to determine high-quality records from small crustal Canterbury and Wellington earthquakes. Table 1 compares the records considered and output provided by the previous FNN and neural network.

Table 1: Neural network improvements from the previous FNN

	Prior work	This study
Magnitudes	$3.5 < M_w < 5$	All
Tect. types	Crustal	Crustal Subduction interface Subduction intraslab
Multiple earthquakes	Implicitly considered in Q	Explicitly identified
f_{min}	Implicitly considered in Q	Explicitly provided to user
Output	Q_{record}	q_x, q_y, q_z $f_{min,x}, f_{min,y}, f_{min,z}$

4. Architecture and output

The neural network workflow uses a pre-processing step for identifying P- and S-wave arrival for extraction of input features for the neural network (Figure 3) and flagging records with multiple earthquakes.

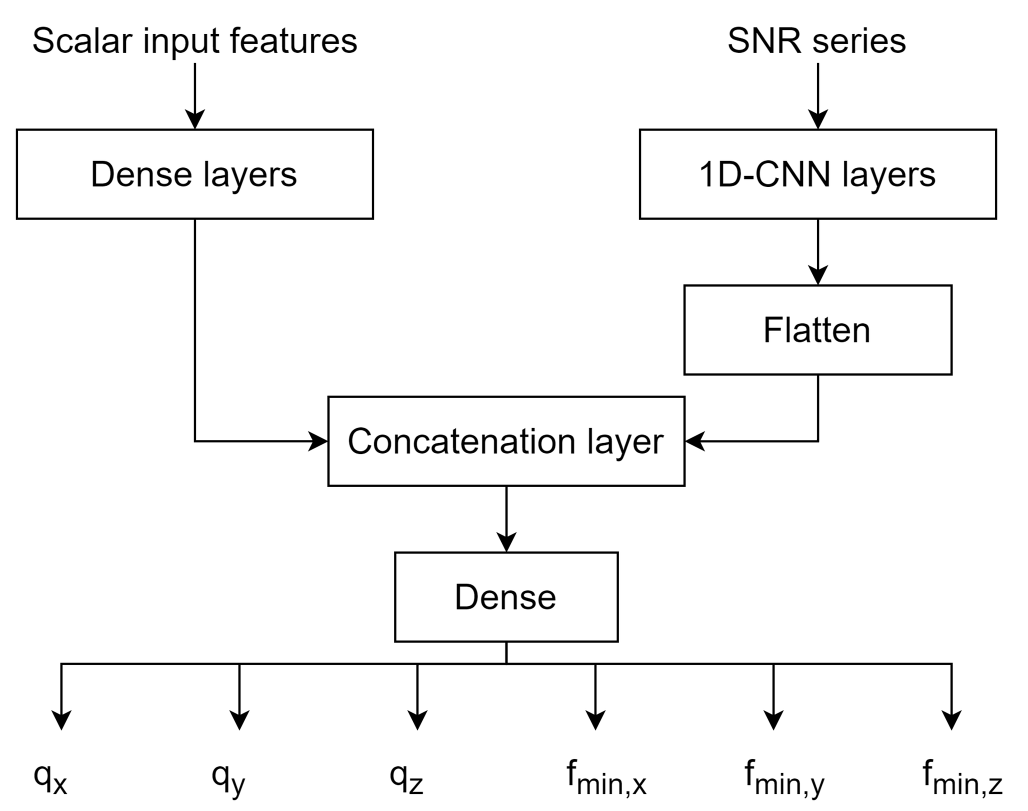

Figure 3: Neural network designed to output mappable quality and frequency labels for each record component

Six outputs are provided, which the user can provide to custom functions to make quality predictions for specific applications in their own post-processing:

$$\mathbf{Q_{record}} = \mathbf{f_{user}}(\mathbf{q_x}, \mathbf{q_y}, \mathbf{q_z}, \mathbf{f_{min,x}}, \mathbf{f_{min,y}}, \mathbf{f_{min,z}}) \quad (1)$$

5. Results and future steps

The neural network performs as well as the FNN for small crustal records and extends this performance to large magnitude and subduction earthquakes (Figure 4). Future work will focus on improving P-and S-wave detection for more accurate identification of multiple earthquake records and more precise feature extraction, as well as experimenting with additional features.

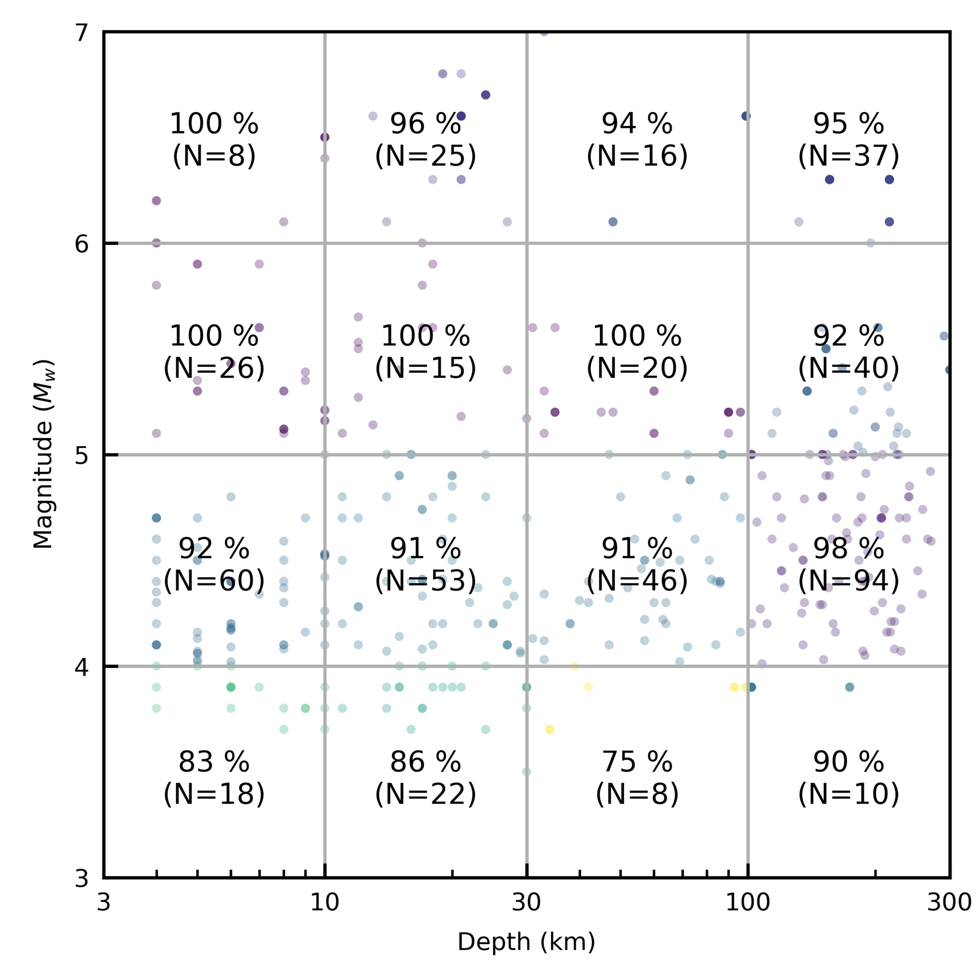

Figure 4: Prediction accuracy of the neural network, where N is the number of records