Quantizing Quakes: Exploring Neural Codecs for Earthquake Signal Analysis

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Abstract

In recent years, neural codecs and quantization techniques have gained prominence in audio processing and speech technology. These methods compress continuous high-dimensional audio waveforms into discrete tokens, reducing data complexity while preserving essential information. While originally developed to reduce transmission latency, these compressed representations have found utility in various tasks such as speaker verification, voice style transfer, and music generation Chen et al. [2024], Peng et al. [2024], Lam et al. [2024]. Interestingly, beyond audio, a similar quantization approach has been applied to simplify complex protein structures, facilitating efficient computation and improved structure generation Haiyan et al. [2023].

Inspired by these developments, we introduce EQcodec, an approach that applies neural codec principles to earthquake and seismic signal analysis. Based on Meta AI's Encodec architecture Défossez et al. [2022], our model has been adapted for seismic waveforms and employs residual vector quantization to efficiently compress seismic signals into discrete tokens. EQcodec demonstrates the ability to reconstruct earthquake signals at different quantization levels, each representing varying degrees of information content. Figure 1 demonstrates the model's ability to encode seismic signals at varying levels of discretization, showcasing the potential for efficient representation of seismic data.

The tokenization of seismic signals through EQcodec opens up potential avenues for earthquake analysis. This discrete representation could enable efficient similarity searches across large seismic databases and allow for novel applications of transformer models to tokenized seismic sequences. Drawing parallels with language modeling techniques, where discrete tokens represent words or subwords, our tokenized seismic data could be processed using similar architectures, potentially uncovering complex patterns and relationships in earthquake signals. Our research investigates these possibilities, focusing on efficiency gains and new analytical approaches. Potential applications include improved time series prediction, development of generalized predictive deconvolution strategies, and more compact storage and transmission of seismic data. Our ongoing work aims to quantify EQcodec's performance and explore its potential to enhance various aspects of seismological analysis.

References

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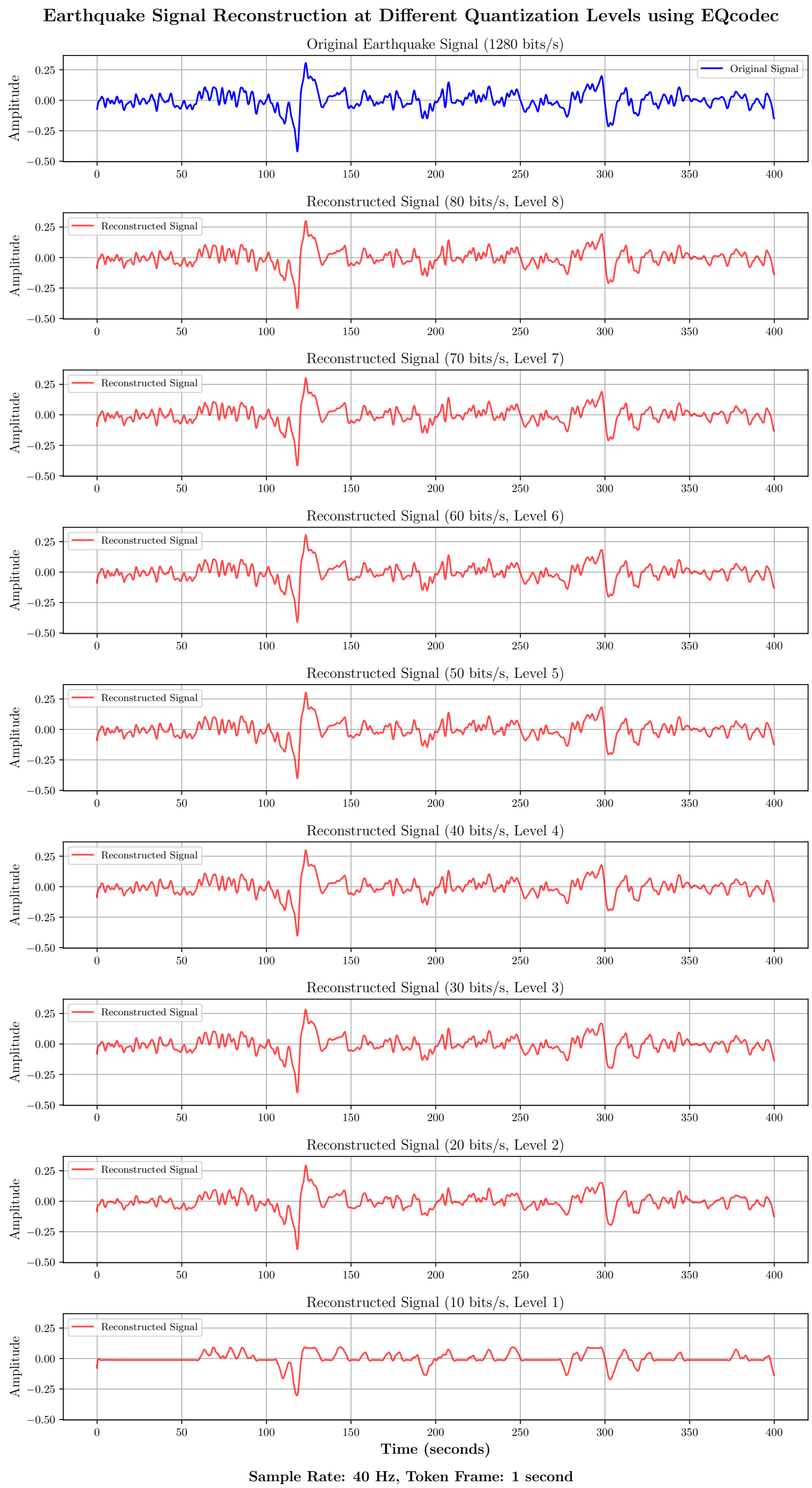

Figure 1: Earthquake signal reconstruction using EQcodec demonstrates progressive compression of seismic waveforms through residual vector quantization using 8 codebooks. The original signal (top) is sampled at 40 Hz with 32-bit precision, yielding 1280 bits/s. Below are reconstructions using progressively fewer codebooks, with bit rates decreasing from 80 to 10 bits/s (levels 8 to 1, corresponding to the number of codebooks used). Each reconstruction compresses 1-second segments (40 samples) independently. The visualization reveals how different quantization levels balance data reduction against signal fidelity in the encoded seismic waveforms.

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