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EQMamba - Method Suggestion for Earthquake Detection & Phase Picking

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Abstract : Accurate and efficient earthquake detection and phase picking are crucial for seismic hazard assessment and emergency response. This study introduces EQMamba, a deep-learning method that combines the strengths of the Earthquake Transformer and the Mamba model for simultaneous earthquake detection and phase picking. EQMamba leverages the computational efficiency of Mamba layers to process longer seismic sequences while maintaining a manageable model size. The proposed architecture integrates convolutional neural networks (CNNs), bidirectional long short-term memory (BiLSTM) networks, and Mamba blocks. The model employs an encoder composed of convolutional layers and max pooling operations, followed by residual CNN blocks for feature extraction. Mamba blocks are applied to the outputs of BiLSTM blocks, efficiently capturing long-range dependencies in seismic data. Separate decoders are used for earthquake detection, P-wave picking, and S-wave picking. We trained and evaluated EQMamba using a subset of the STEAD dataset, a comprehensive collection of labeled seismic waveforms. The model was trained using a weighted combination of binary cross-entropy loss functions for each task, with the Adam optimizer and a scheduled learning rate. Data augmentation techniques were employed to enhance the model's robustness. Performance comparisons were conducted between EQMamba and the EQTransformer over 20 epochs on this modest-sized STEAD subset. Results demonstrate that EQMamba achieves superior performance, with higher F1 scores and faster convergence compared to EQTransformer. EQMamba reached F1 scores of 0.8 by epoch 5 and maintained higher scores throughout training. The model also exhibited more stable validation performance, indicating good generalization capabilities. While both models showed lower accuracy in phase-picking tasks compared to detection, EQMamba's overall performance suggests significant potential for improving seismic data analysis. The rapid convergence and superior F1 scores of EQMamba, even on a modest-sized dataset, indicate promising scalability for larger datasets. This study contributes to the field of earthquake engineering by presenting a computationally efficient and accurate method for simultaneous earthquake detection and phase picking. Future work will focus on incorporating Mamba layers into the P and S pickers and further optimizing the architecture for seismic data specifics. The EQMamba method holds the potential for enhancing real-time earthquake monitoring systems and improving our understanding of seismic events.

Keywords : earthquake, detection, phase picking, s waves, p waves, transformer, deep learning, seismic waves
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