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Seismic Phase Picking

Final Project of Computer Vision

Yuchen Wang Ruihuan Wang


01
Introduction
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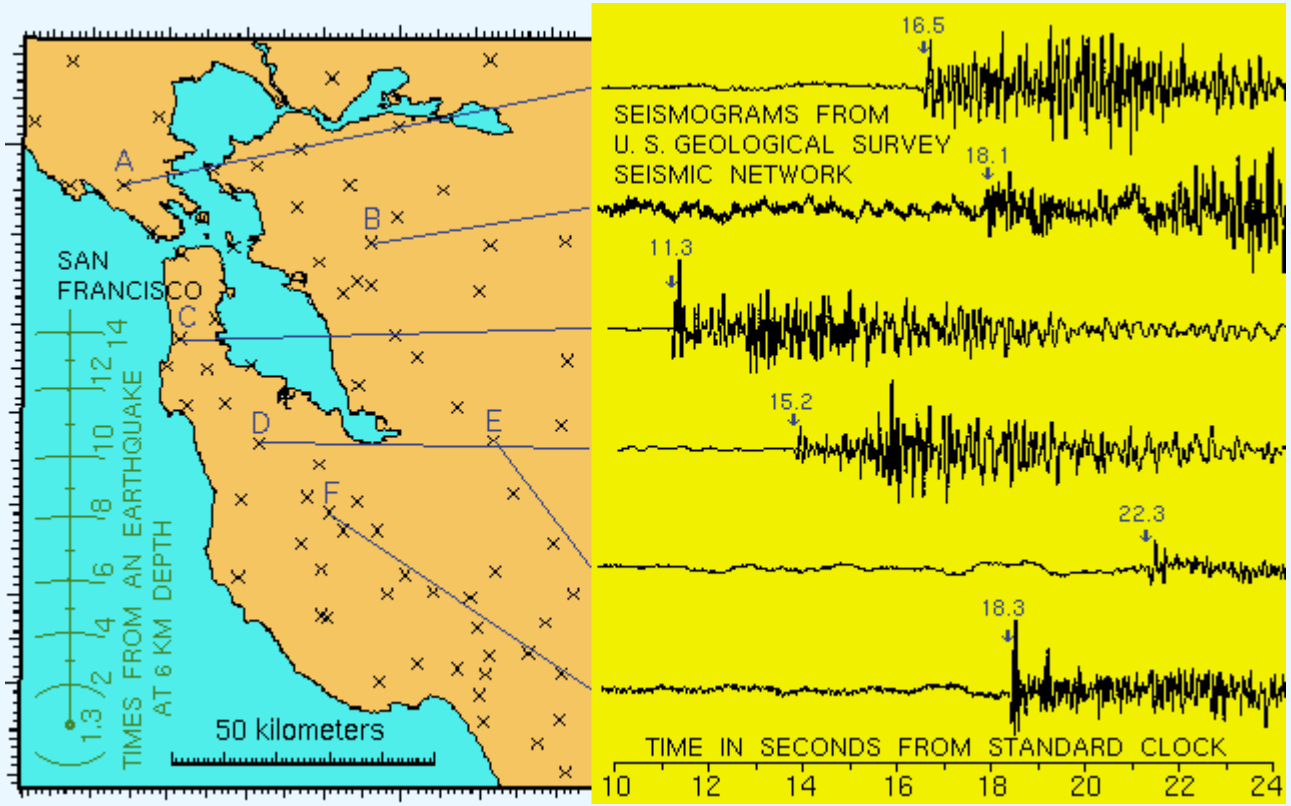
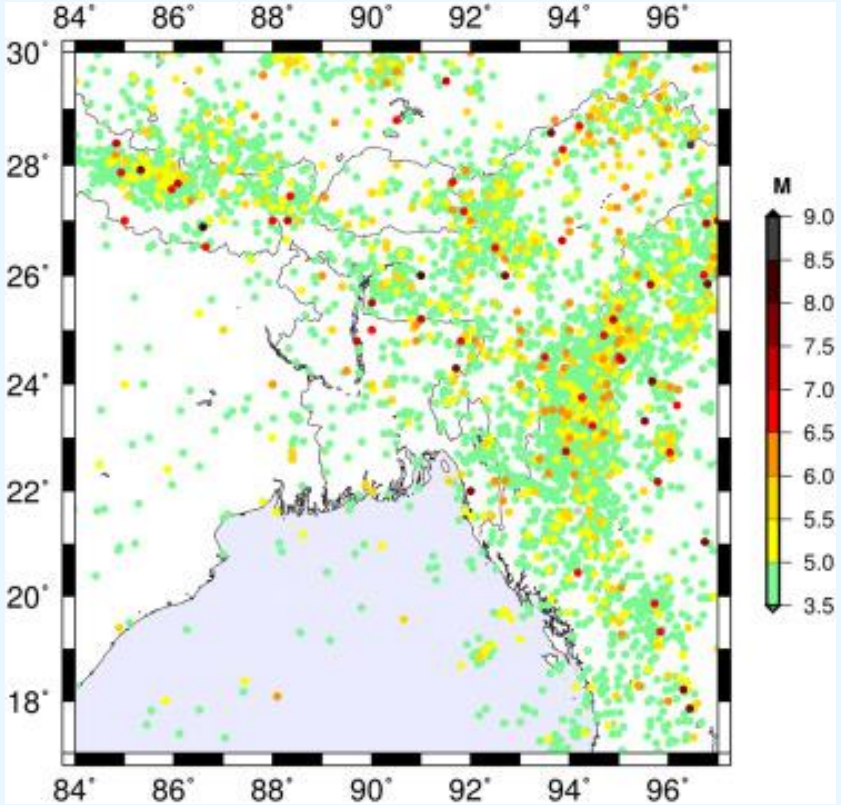
Introduction ►►► Motivation

Earthquake Localization



https://www.usgs.gov/faqs/how-do-seismologists-locate-earthquake

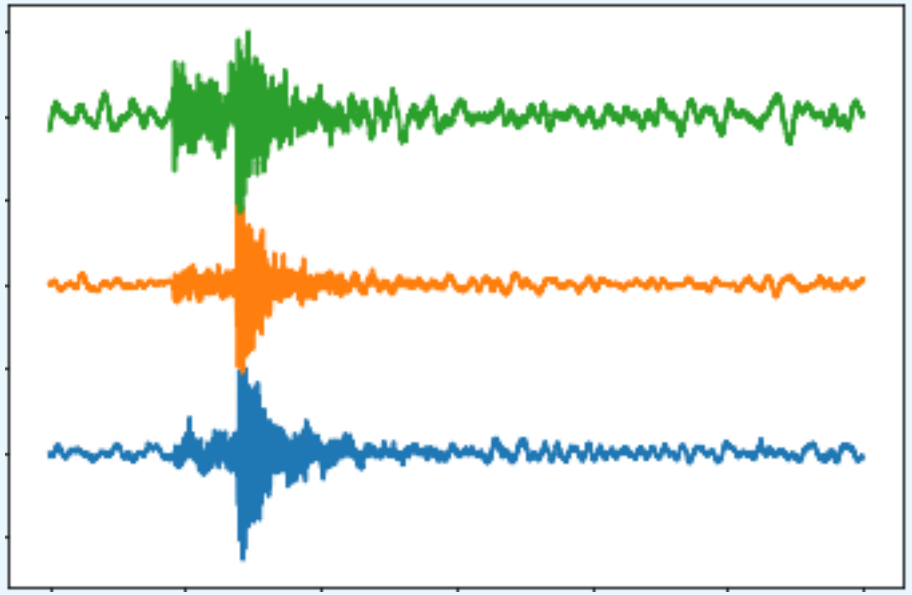
Catalog



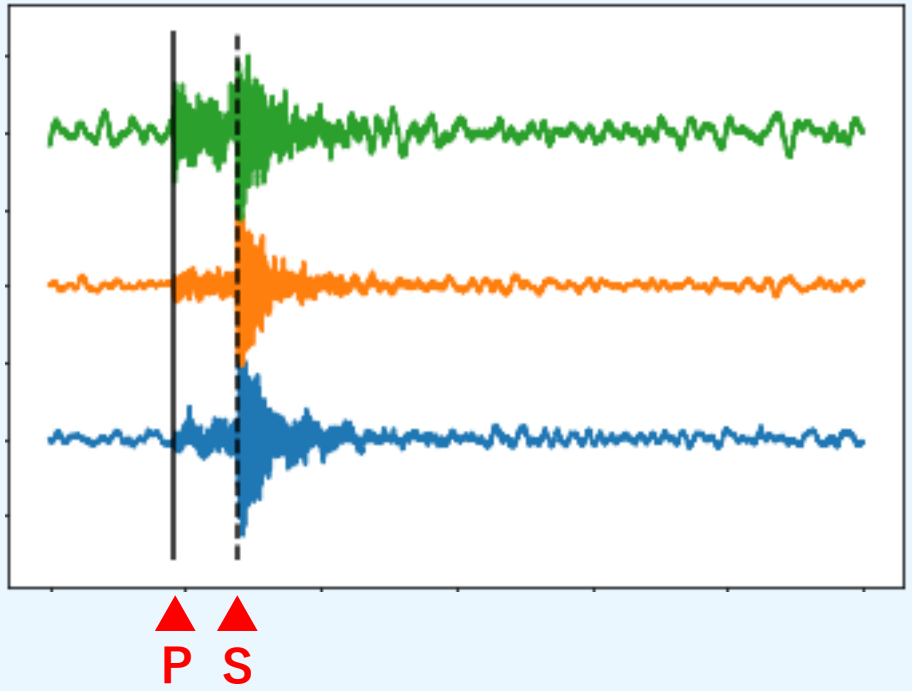
https://www.sciencedirect.com/topics/earth-and-planetary-sciences/earthquake-catalogue

Introduction ►►► Goal

Given

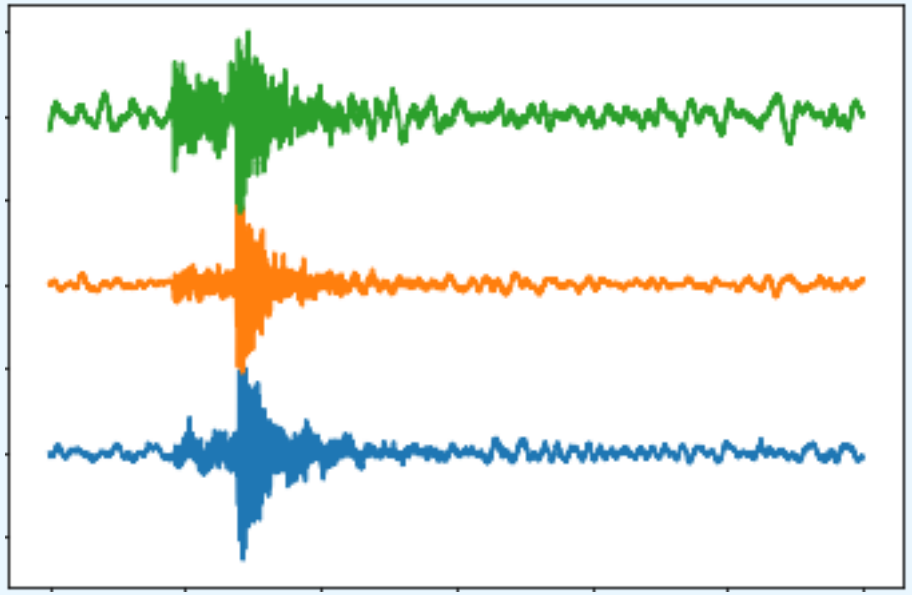


Target

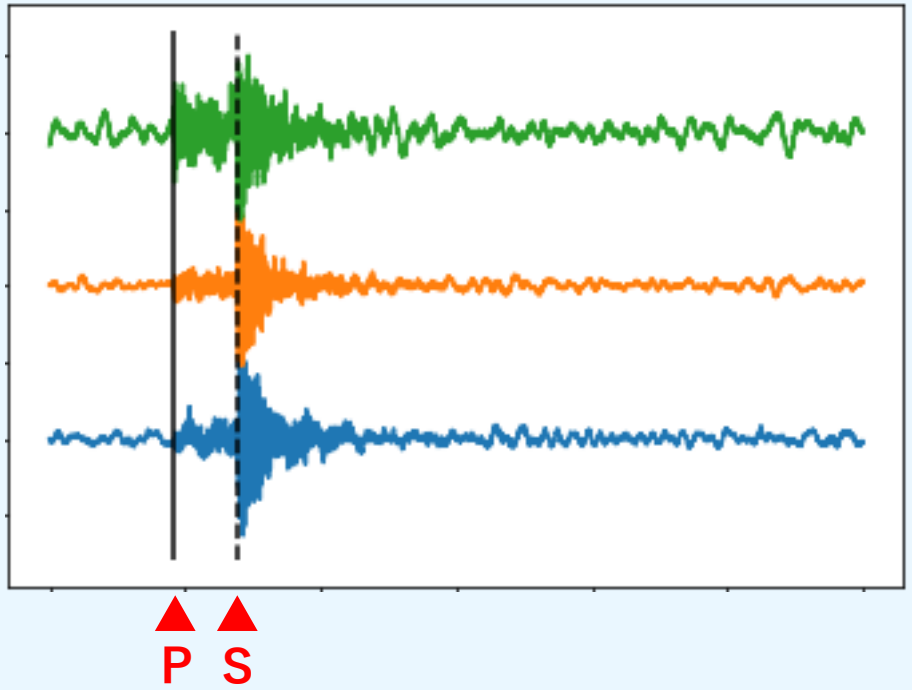


Introduction ►►► Goal

Given



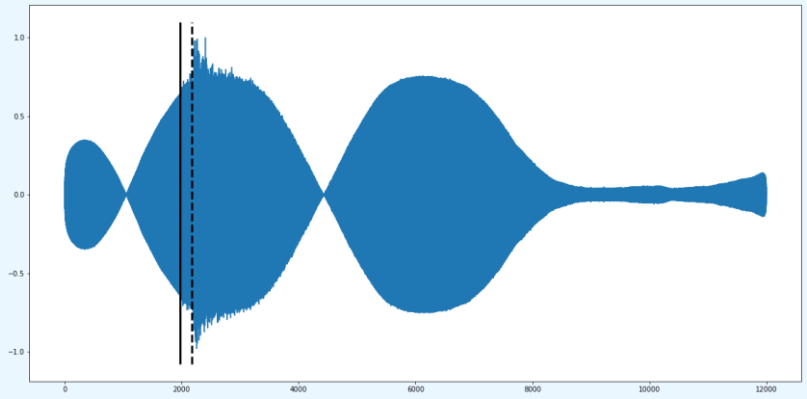
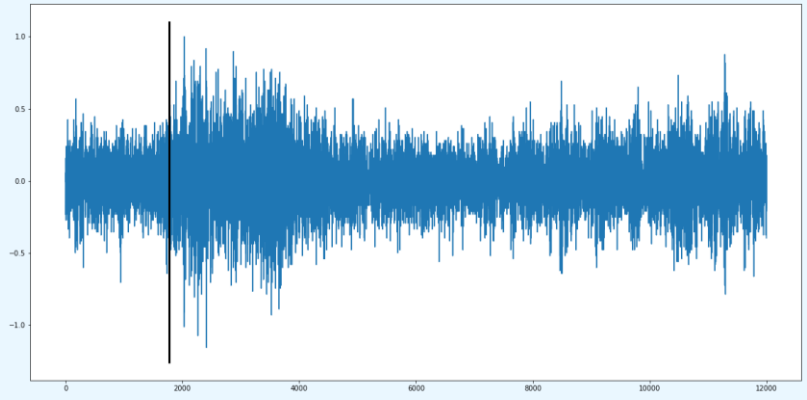
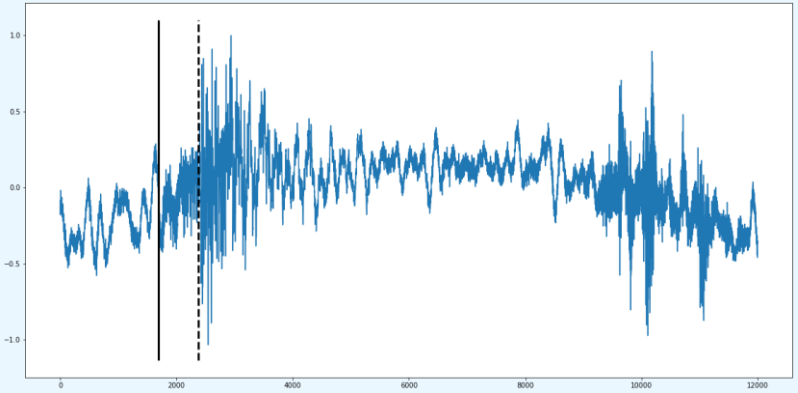
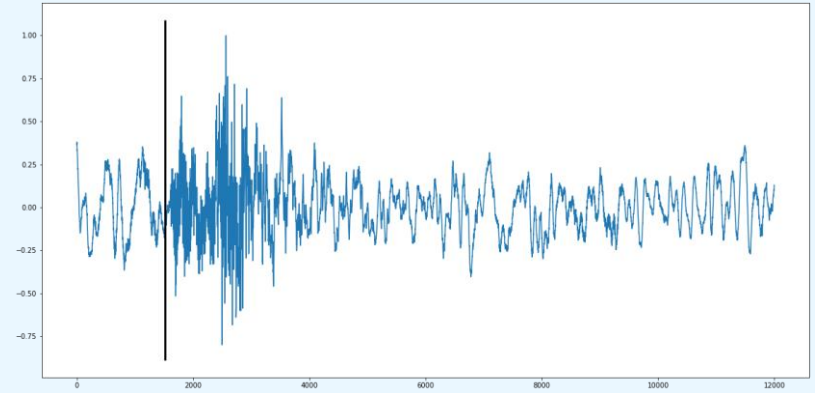
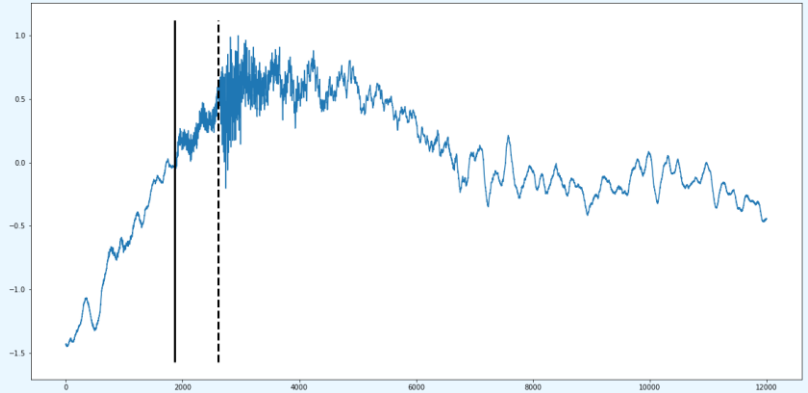
Target



Seemingly easy? Just take peaks?

Introduction ►►► Challenges

- Irregular Shapes
- Great Noise
- S-wave Missing


02
Tasks
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Tasks

Data

- Dataset
- Preprocessing
- Labeling

Single-Trace

- Traditional Method
- Learning-Based Method
- Results
- Ideas

Multiple-Trace

- Motivation
- Ideas

Data ►►► Dataset

- About 50,000 earthquakes
- 1.2 million 3-component waveform traces
- Each with more than 100 parameters

INSTANCE

THE ITALIAN SEISMIC DATASET FOR MACHINE LEARNING

Large

+

Comprehensive

=

Suitable for Machine Learning

Tasks

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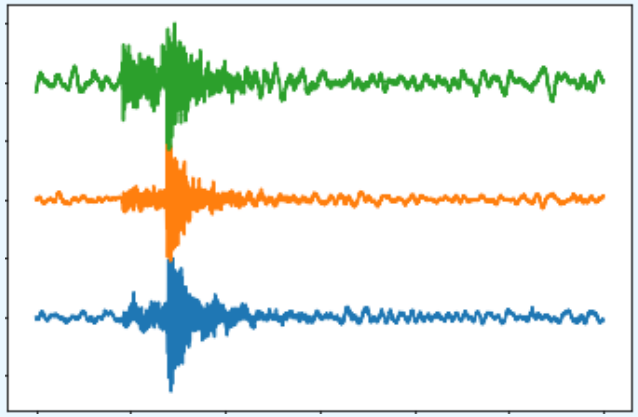
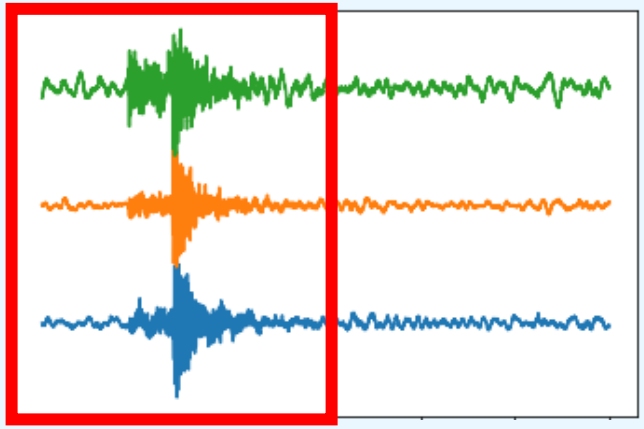
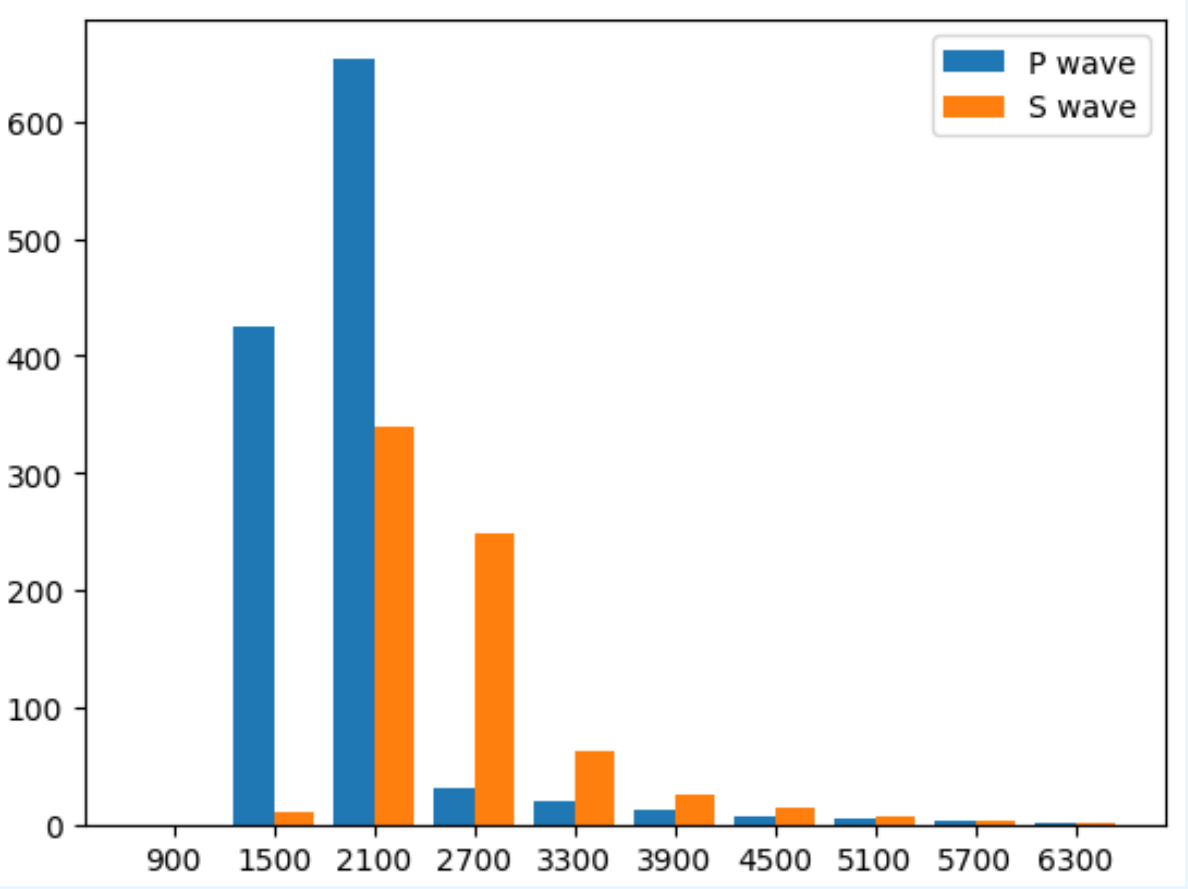
Data ►►► Preprocessing

12,000
Original



6,000
Is Enough





Distribution of arrival times

Data ►►► Preprocessing

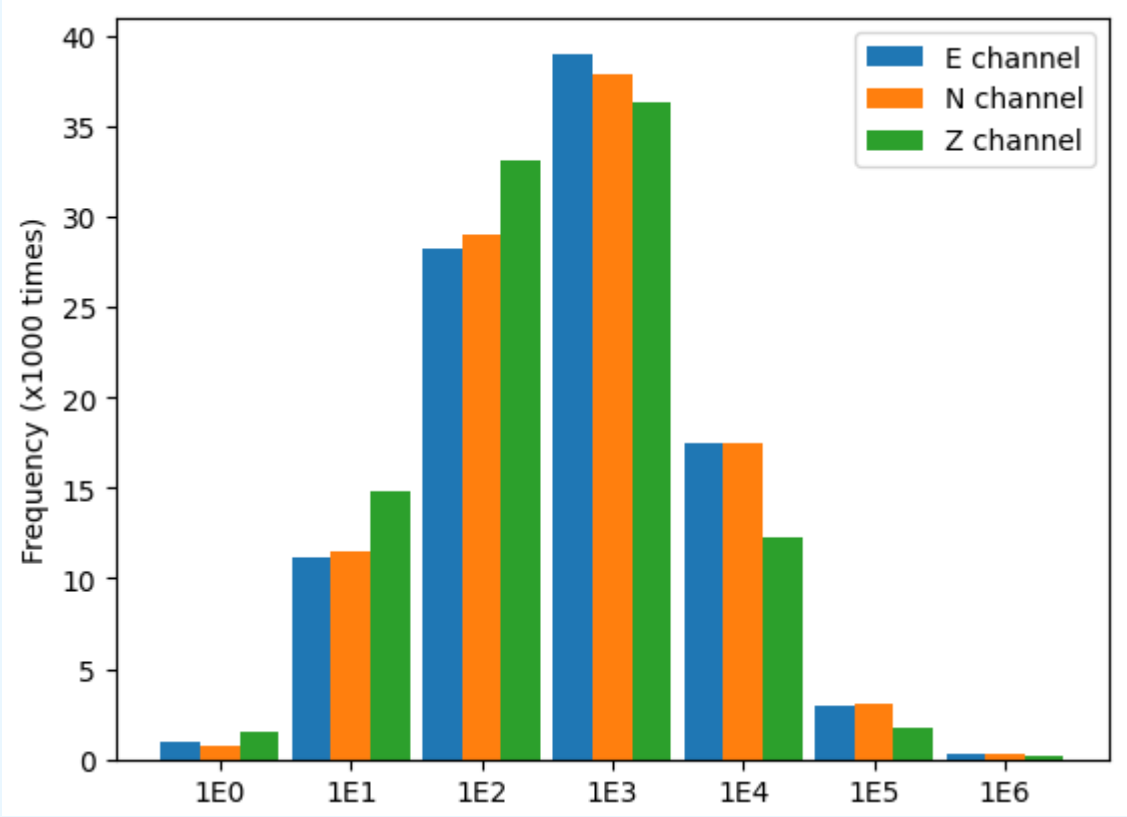
Normalization Needed!

$$\mathrm{Unbiased}_i = x_i - \overline{x_i},$$

$$\mathrm{Normed}_i = \frac{\mathrm{Unbiased}_i}{\max\{|\mathrm{Unbiased}_i|\}}$$

A very wide range

All between [-1, 1]



Distribution of peak values

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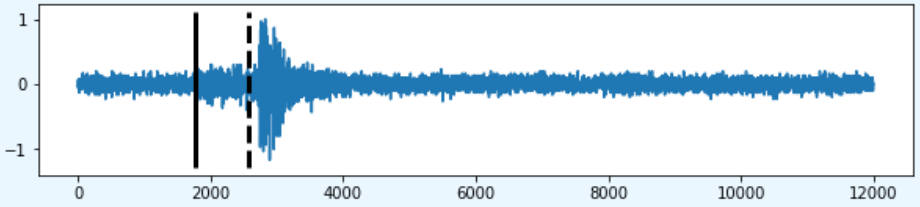
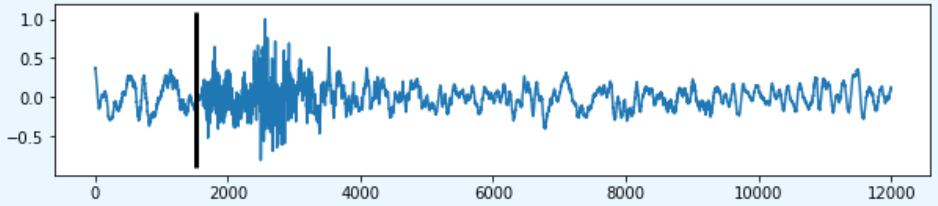
Data ►►► Labeling

Uncertainty



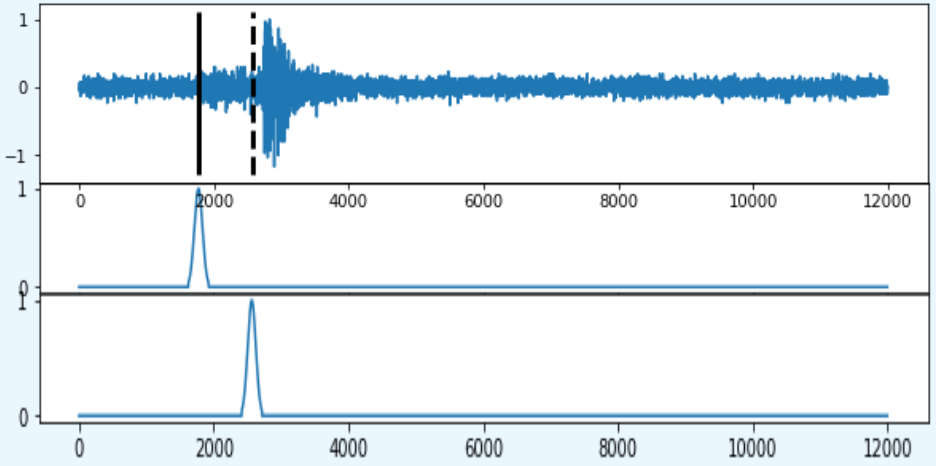
P: 1828 ± σ, S: 2621 ± σ

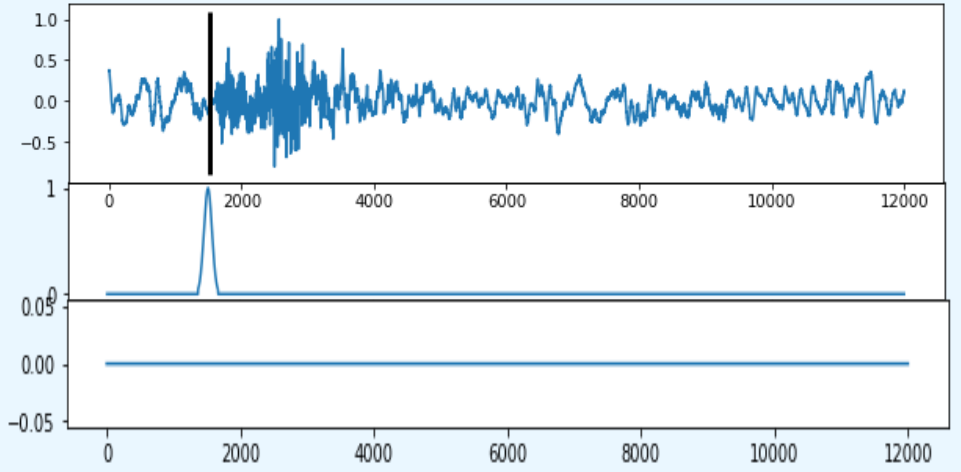
Missing Waves



P: 1518 ± σ, S: None

Numbers





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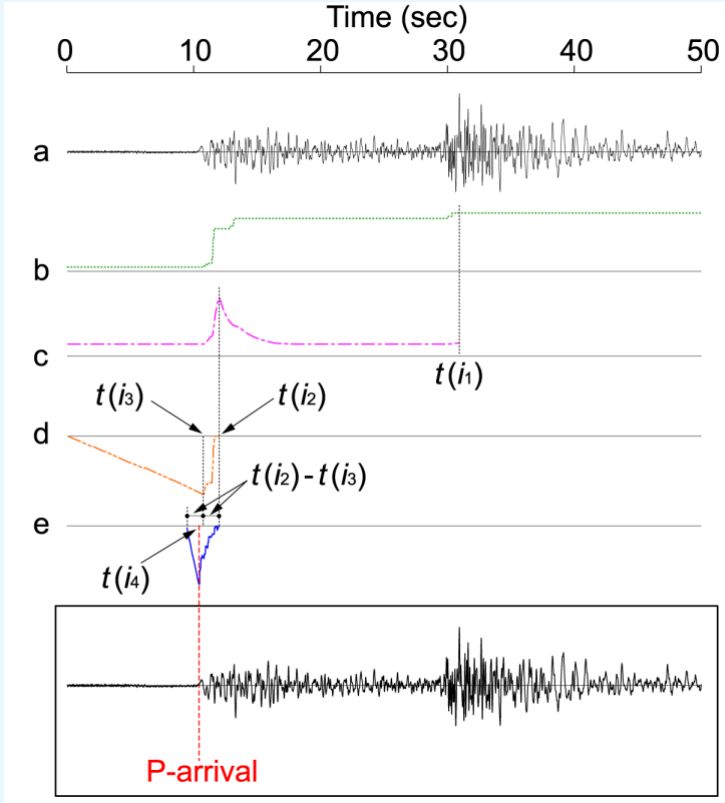
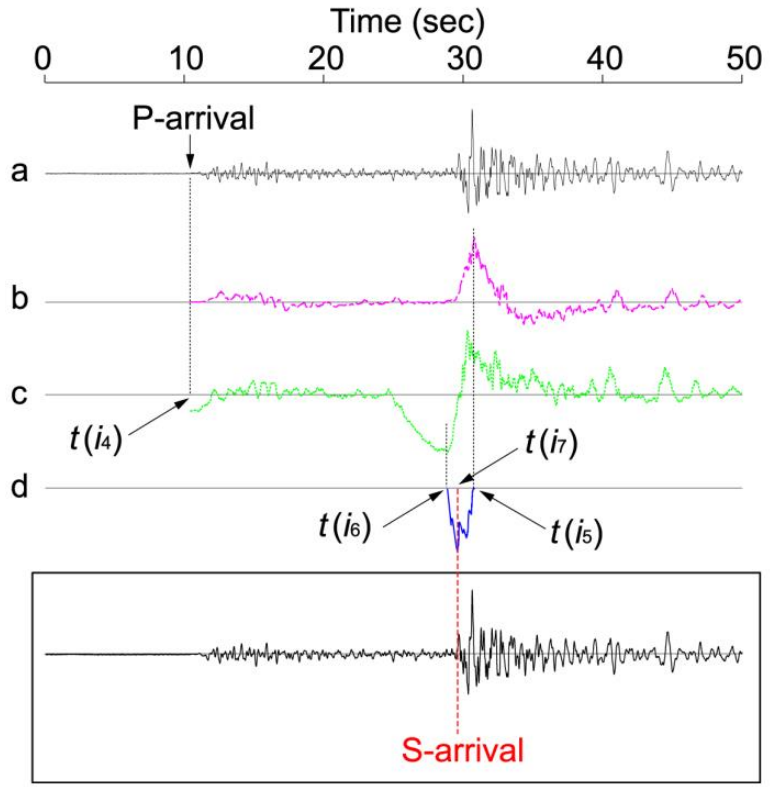
Single-Trace ►►► Traditional Method

AR Pick

- Hard to design
- Complicated
- Not precise enough
- Not robust enough





We'll see from the results (to be presented later .....)

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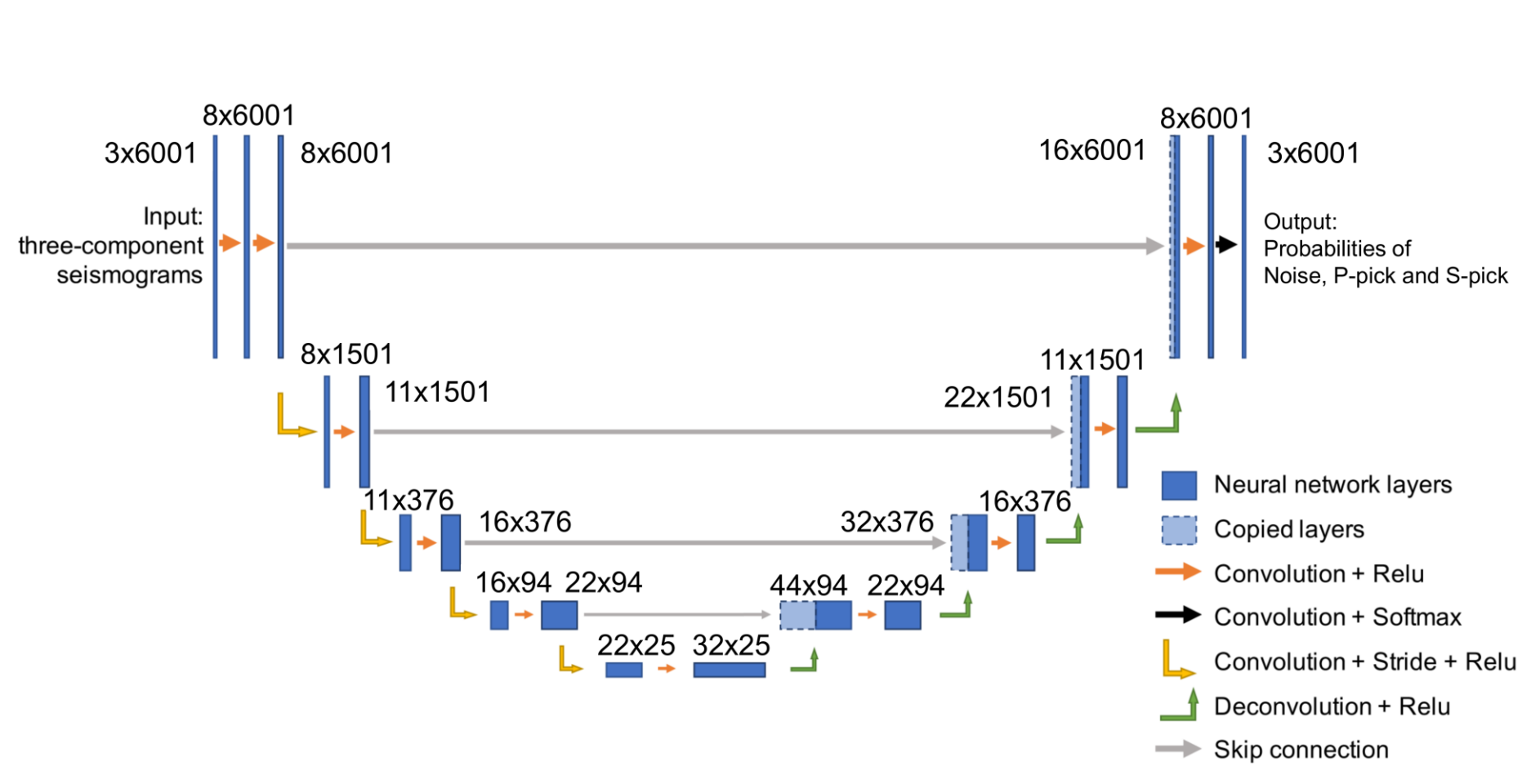
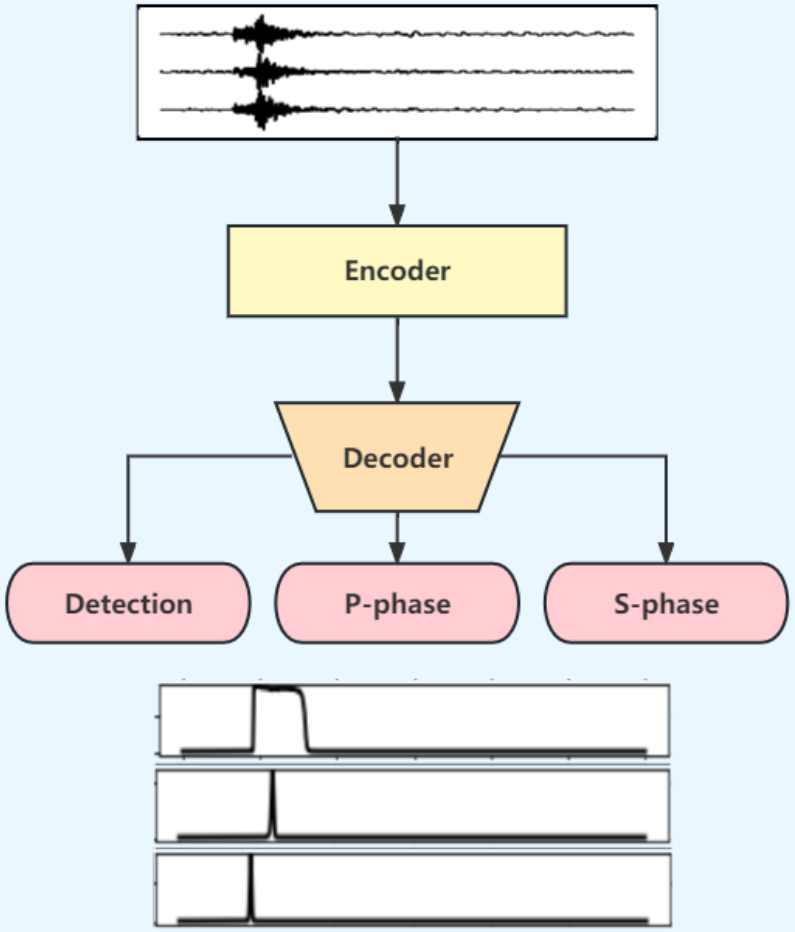
Single-Trace ►►► Learning-Based Method

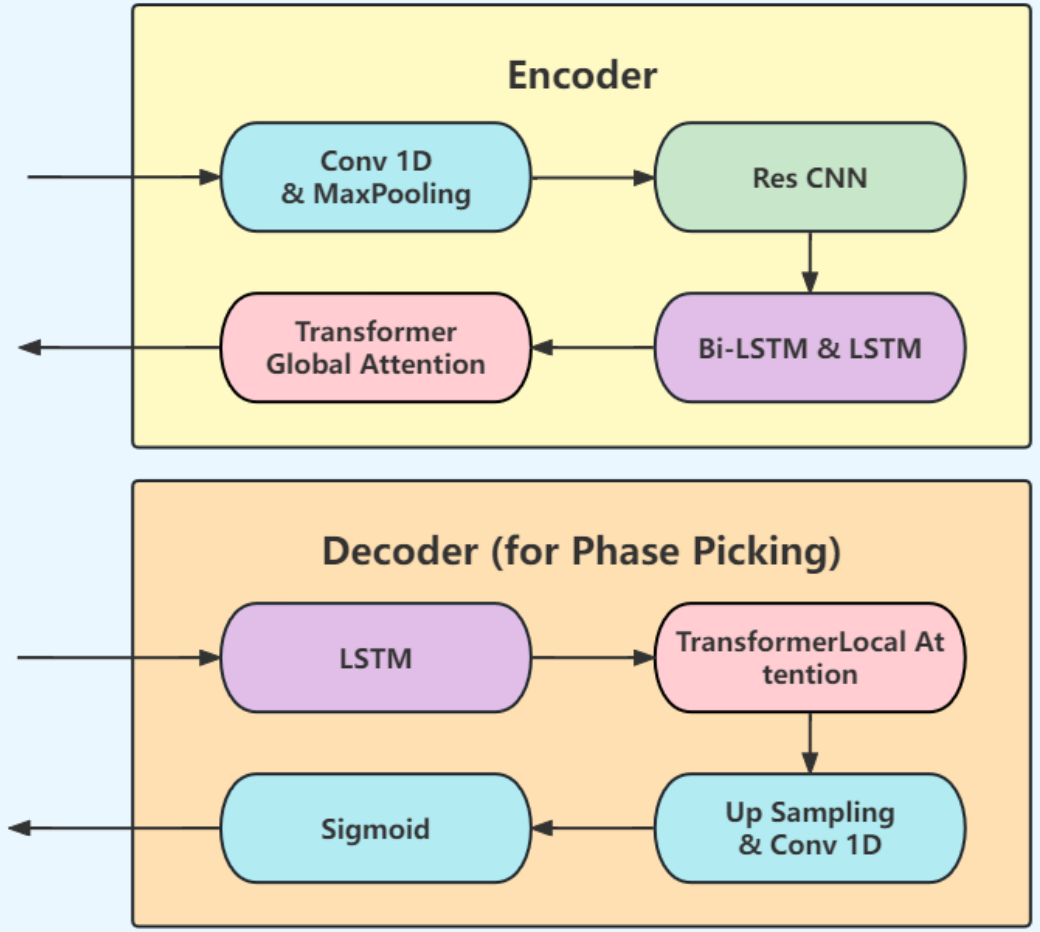
CNN-Based: PhaseNet



Single-Trace ►►► Learning-Based Method

Transformer-Based: EQTransformer





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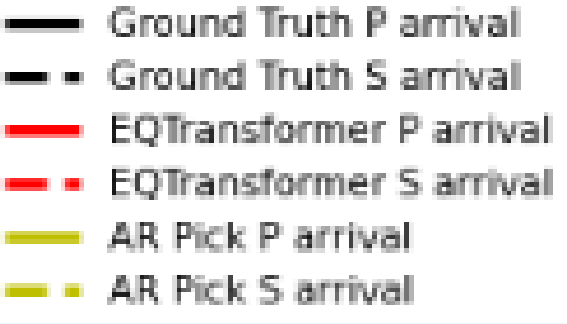
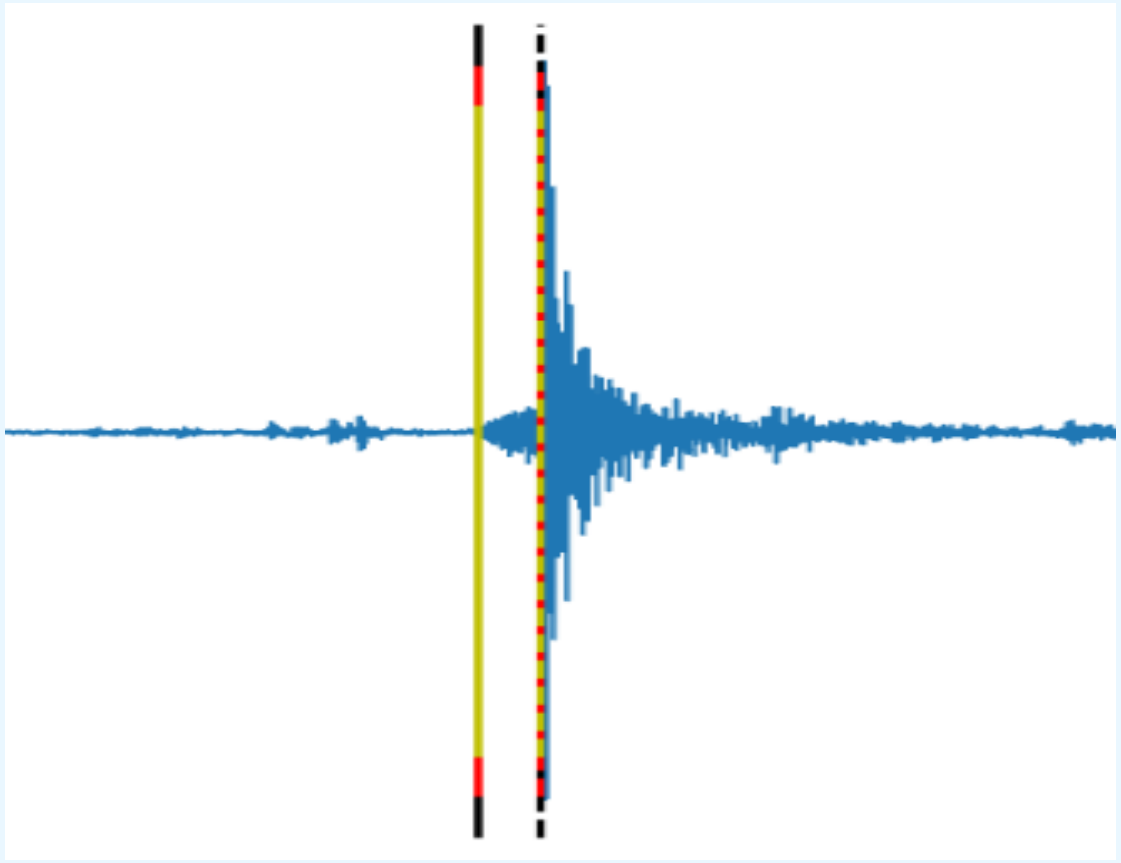
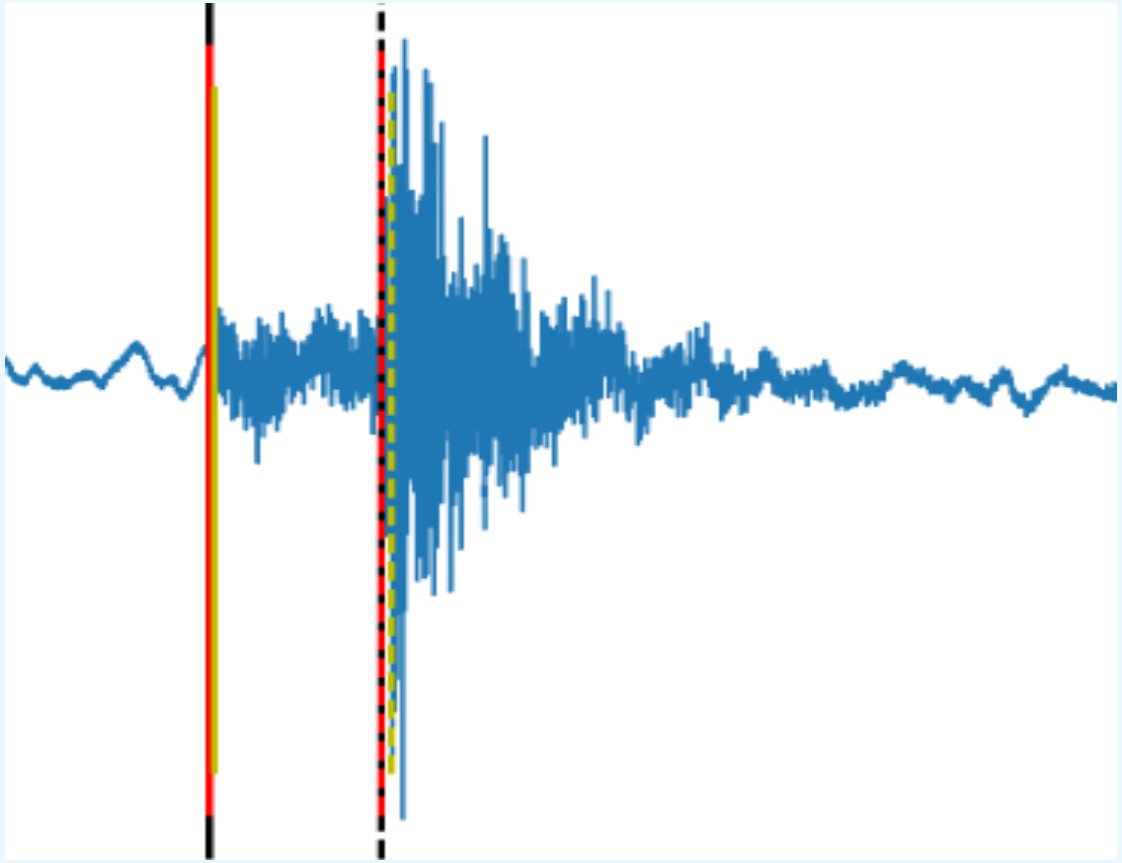
Single-Trace ►►► Results

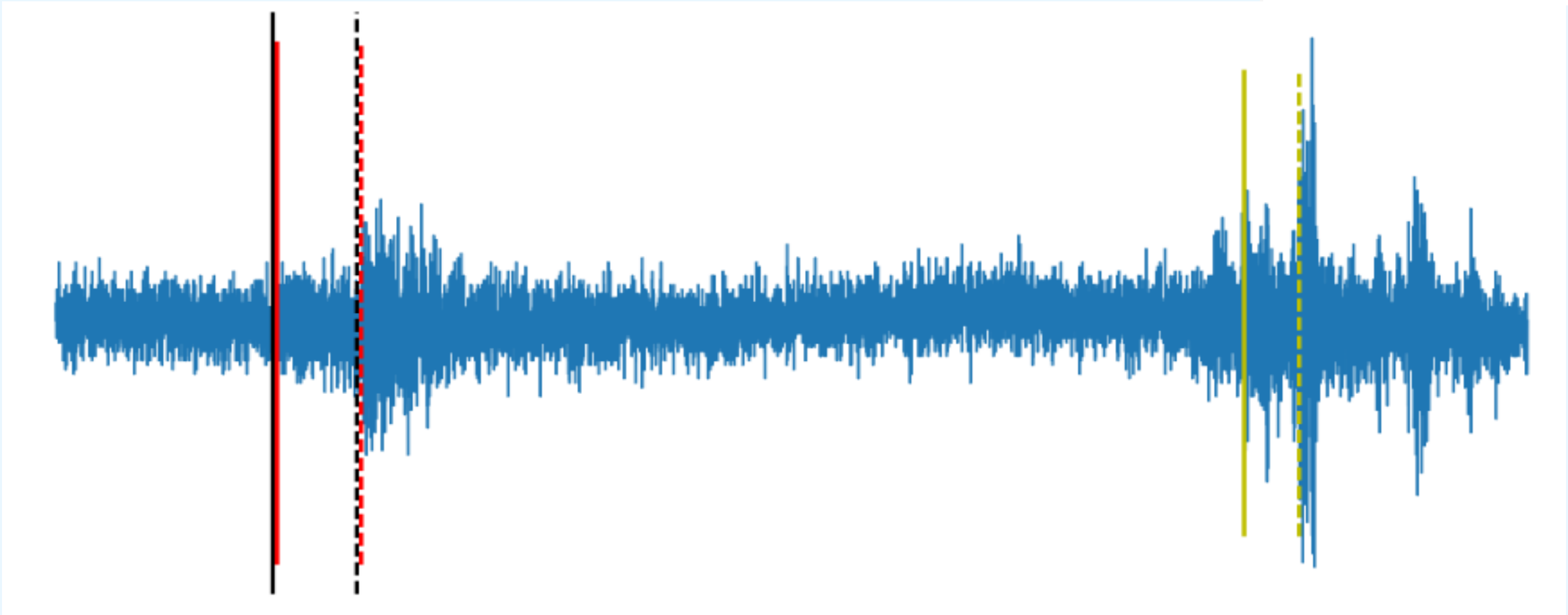






Slight noise, both work well
EQTransformer a bit more precise

Single-Trace ►►► Results



Stronger noise, AR Pick cheated
EQTransformer still works well

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Multiple-Trace

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Single-Trace ►►► Ideas

- AR Pick: Traditional method
- PhaseNet: Convolution Network
- PpkNet: Recurrent Network
- EQTransform: Conv + LSTM + Transformer

Single-Trace ►►► Ideas

- AR Pick: Traditional method
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Attention is ALL you need!

Single-Trace ►►► Ideas

- AR Pick: Traditional method
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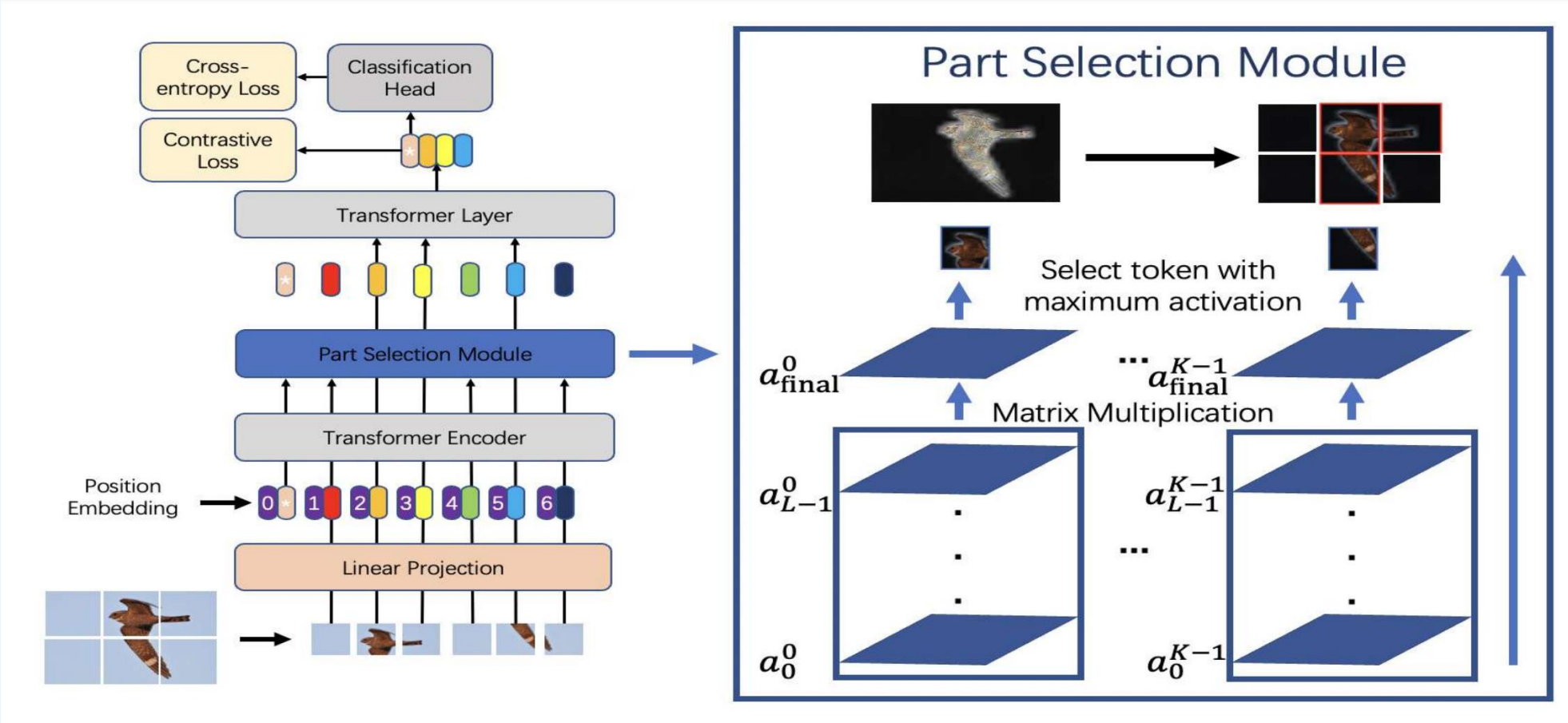
Attention is ALL you need!

What about a PURE Transformer Net?

Single-Trace ►►► Ideas

A Vision Transformer Model: TransFG



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Multiple-Trace

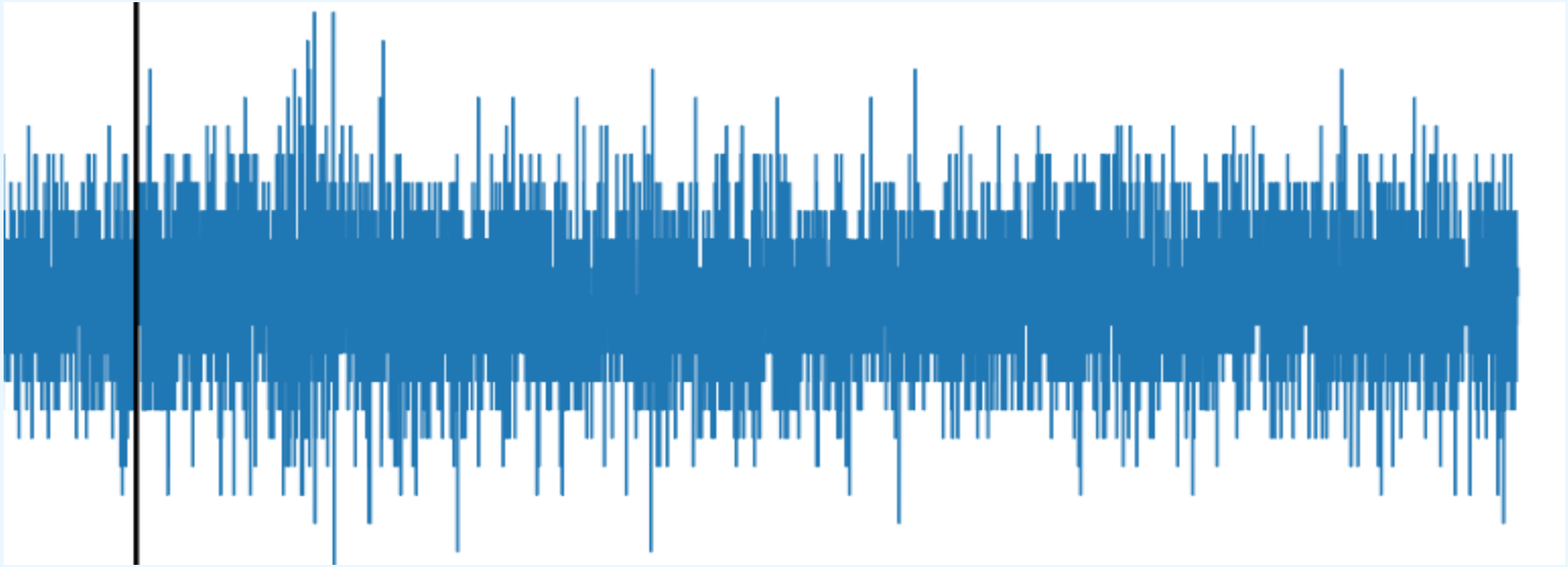
- **Motivation**
- Ideas

Multi-Trace ►►► Motivation

Is EQTransformer good enough?

Multi-Trace ►►► Motivation

Is EQTransformer good enough?



Cannot recognize P-wave at all!

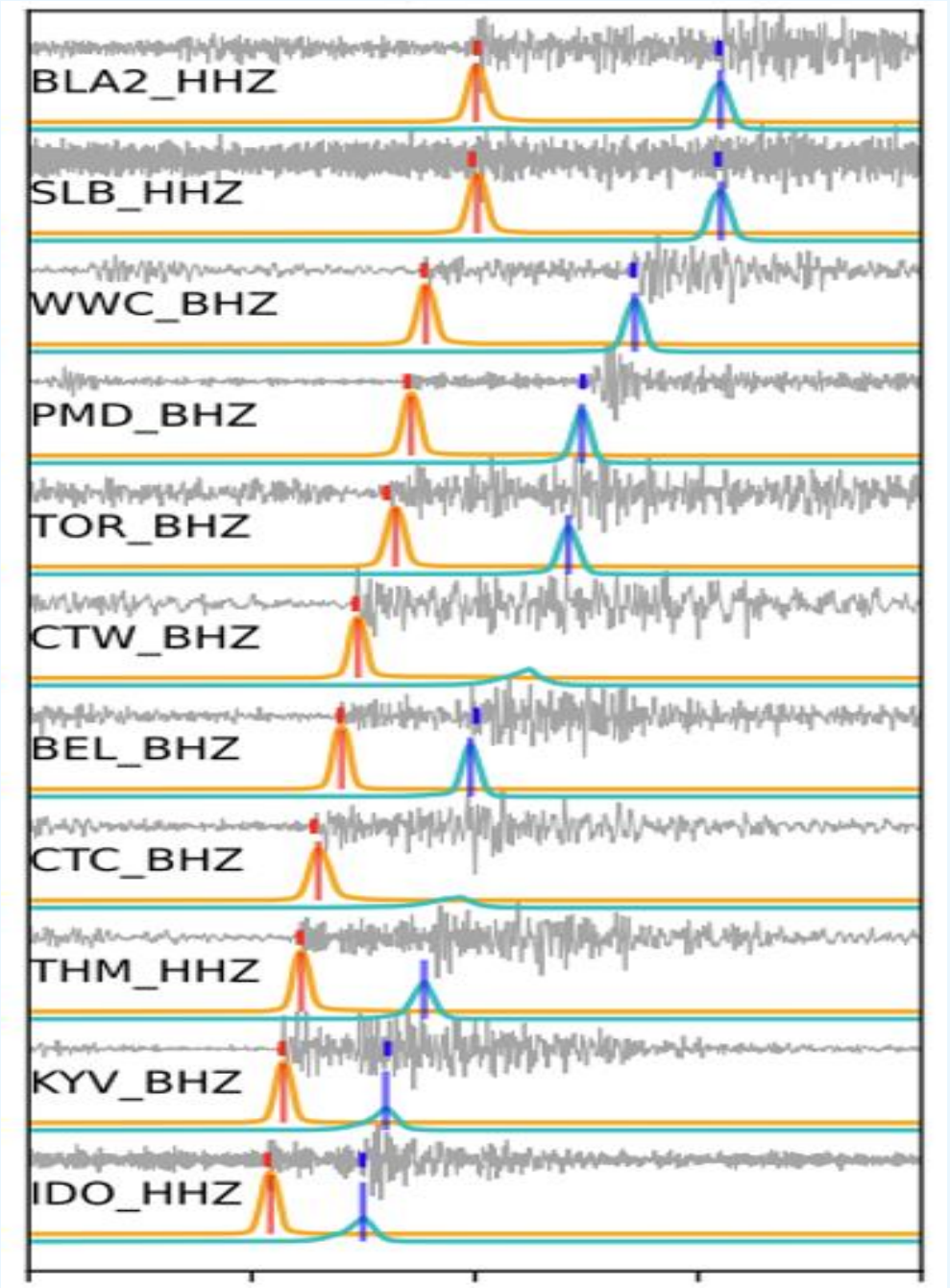
Multi-Trace ►►► Motivation

Different Stations

- More relevant data
- Informational Combination
- Deeper Understanding

Same Earthquake

- More precise
- More robust
- Anti-ambiguous



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Multi-Trace ►►► Ideas

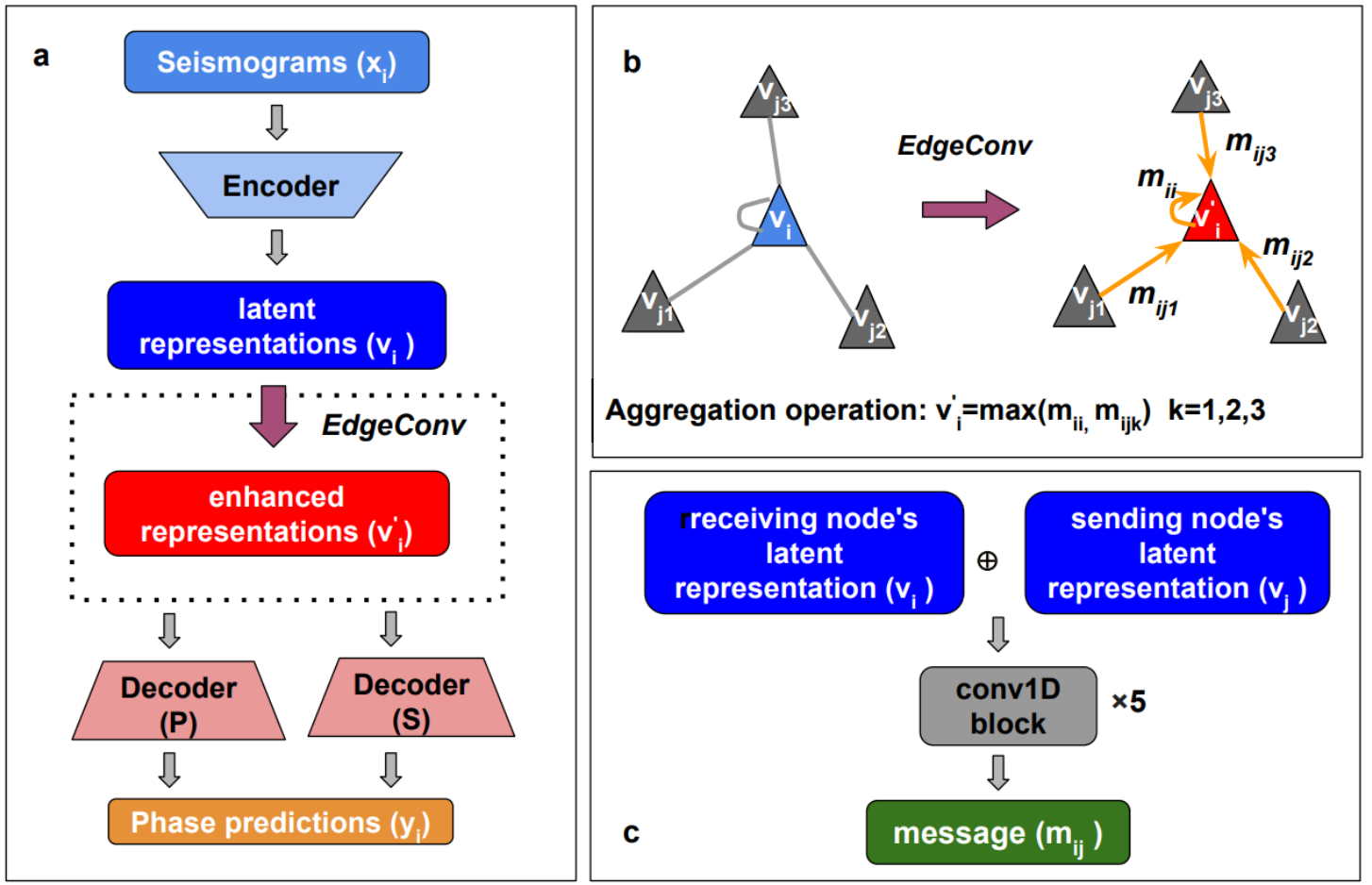

Figure 1. Network architecture. (a) The components of EQTransfromer and inserted Edge Convolution module. (b) The process of collecting messages (m_{ij}) from neighboring nodes, and aggregation to enhanced representations. (c) The neural network in constructing messages (m_{ij}) between two nodes. The operation ⊕ represents concatenation of two latent representations along the channel dimension.

Use Graph to integrate information

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Thanks for listening

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