[Team Whitespace 2024]

Seismic Detection Across the Solar System

The Challenge:

- Limited transmission bandwidth demands efficient data selection.
- Real-world seismic data is inherently noisy.
- Classical STA/LTA methods require extensive tuning for different planetary environments.

Our Solution: A Simple Vision-Inspired Seismic Detection and Package

- **Tuning STA/LTA:**
  - Optimizes the STA/LTA method for lunar and mars missions
  - High recall version: 84% (but #FP ~= 40x#GT)
  - FP-fewer version: 76% (#FP ~= 13x#GT)
- If we would like to suppress FP really
  - Method STA/LTA+StaticGaussian
  - Achieves acceptable recall of significant seismic events while minimizing false detections.
  - Recall 55% (#FP ~= 1.5#GT)
- Initial study using NASA data demonstrates the effectiveness of:
  - Tuned STA/LTA, Dynamic Gaussian Modeling, Static Gaussian Modeling
  - Finally suppress 93% FP to obtain acceptable method: STA/LTA+StaticGaussian
- **Open-Source Collaboration:** We provide a complete script to empower amateurs and researchers to explore and contribute to this cutting-edge technology.

Vision-Inspired? Background Subtraction & Object Detection Are Like Seismic Detection

- Similar Approach: In vision, we separate moving objects from the background, just like detecting quakes from background noise in seismic data.

Why Use a Background Model?

- **Object Detection Requires Specific Knowledge**: We'd need to define quake characteristics, which we don't have.
- **General Approach**: Background models allow us to detect anomalies without specific quake properties.
- **Amateurs in Seismology**: We're still learning about quakes, so we prefer a simpler, flexible method.

Why Not Use Deep Learning?

- **Limited Seismology Expertise**: We use DL in vision, but applying it here without enough knowledge could lead to bad results.
- **Noise Modeling**: DL might struggle without proper noise understanding.

Evolution of Background Subtraction

- **Static Gaussian**: Fixed background.
- **Dynamic Gaussian**: Adapts to changes.
- **Mixture of Gaussians**: Handles sudden shifts.

Experimental results show Static Gaussian could help STA/LTA to suppress large amount false positive

Enhancing Seismic Event Detection with STA/LTA

- **STA/LTA: A Classical Approach**
  - Widely used in seismology for detecting events.
  - Relies on comparing short-term averages to long-term averages of signal amplitude.
  - Requires careful tuning of parameters:
    - `sta_len` (Short-Term Average length)
    - `lta_len` (Long-Term Average length)
    - `thr_on` (Threshold for triggering detection)
    - `thr_off` (Threshold for ending detection)
- **Reference Settings:** In NASA packages, a common starting point is:
  - `sta_len = 120`, `lta_len = 600`, `thr_on = 4.0`, `thr_off = 1.5`.

Our Package for Optimized STA/LTA Performance

- **Flexibility:** Separate training and validation datasets.
- **Evaluation:** Function to calculate recall and false positive rate.
- **Parameter Tuning:** Use the training data to explore different parameter settings through grid search (`sta_len`, `lta_len`, `thr_on`, `thr_off`).

- Training data is split into non-overlapping train and val
- We use train part to pick three candidate settings
  - Candidate 1: has too many false positive
  - Candidate 2: is another setting with fewer false positive
- And try to use the same conf for lunar and mars

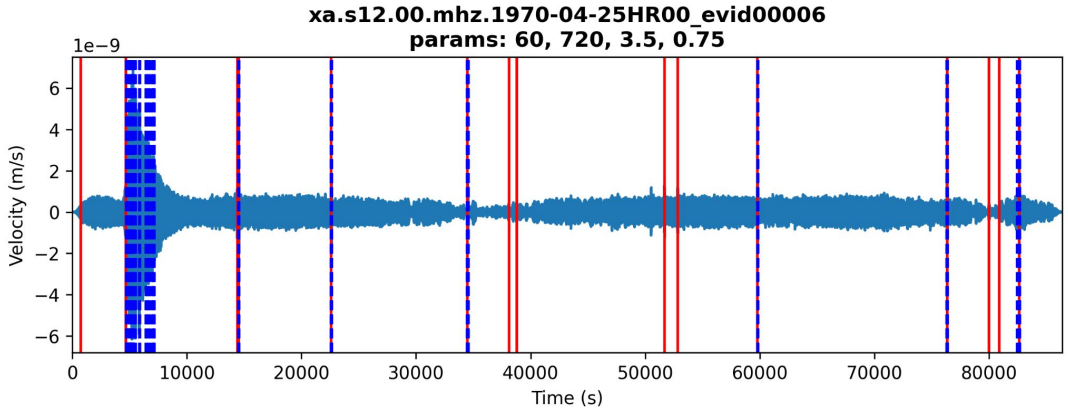
lunar	Recall(train)	FP(train)	Recall(val)	FP(val)	
[120, 600, 4.0, 1.5]	60.53	259	47.37	422	reference setting in ipynb
[60, 720, 3.5, 0.75]	97.37	987	84.21	1352	highest recall in train candidate 1
[160, 680, 3.25, 0.75]	68.42	301	63.16	752	
[100, 760, 3.75, 1.0]	78.95	488	76.32	488	candidate 2

mars	Recall(train)	FP(train)	Recall(val)	FP(val)	
[120, 600, 4.0, 1.5]	0	0	0	0	reference setting in ipynb
~~[60, 400, 3.25, 0.75]~~	~~100~~	~~2~~	~~100~~	~~1~~	~~highest recall in mars train~~
~~[60, 400, 4.75, 0.75]~~	~~100~~	~~0~~	~~0~~	~~0~~	
[60, 720, 3.5, 0.75]	100	1	100	0	highest recall in lunar train
[160, 680, 3.25, 0.75]	100	0	100	0	
[100, 760, 3.75, 1.0]	100	0	100	1	candidate 2 from lunar train

Applying background modeling

- Based on train part we generate two candidate settings
  - [60, 720, 3.5, 0.75]
  - [100, 760, 3.75, 1.0]
- We would like to further improve candidate 1 by using background moding to suppress FP
  - We found noise could not be stable, hence need dynamic or static gaussian modeling

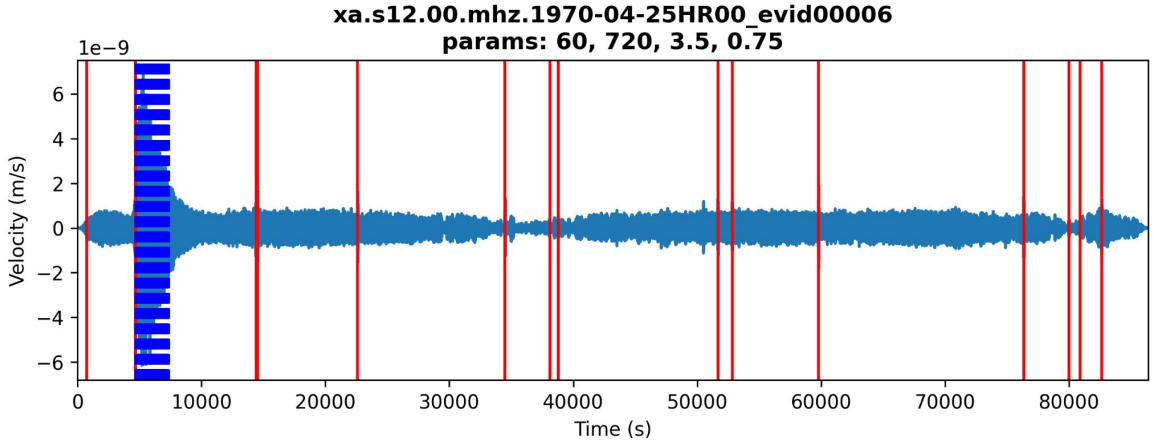
STA/LTA (red solid line)
DynamicGaussian
(blue dot line)

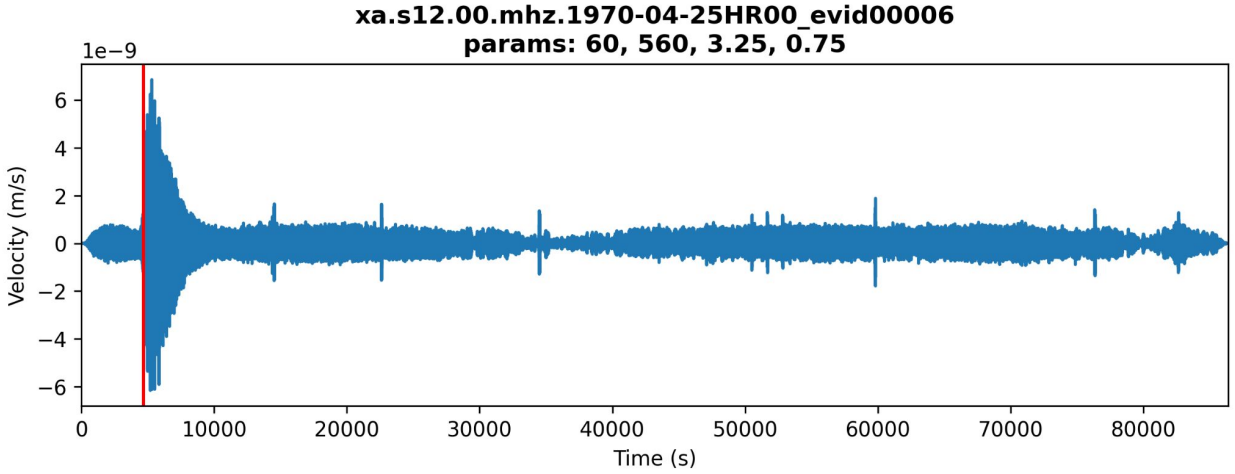


STA/LTA (red solid line)
STGaussian (blue dot line)

STGaussian: only one static gaussian for background noise

Final:
STA/LTA+STGaussian





Final val results

lunar	Recall(train)	FP(train)	Recall(val)	FP(val)	
[120, 600, 4.0, 1.5]	60.53	259	47.37	422	reference setting in ipynb
[60, 720, 3.5, 0.75]	97.37	987	84.21	1352	highest recall in train candidate 1
[160, 680, 3.25, 0.75]	68.42	301	63.16	752	
[100, 760, 3.75, 1.0]	78.95	488	76.32	488	candidate 2
[60, 720, 3.5, 0.75]			55.26	58	FP suppressed

Thanks

https://github.com/tungtylee/seismic-viewer