

[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 \sim 40x#GT)
 - FP-fewer version: 76% (#FP \sim 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 \sim 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

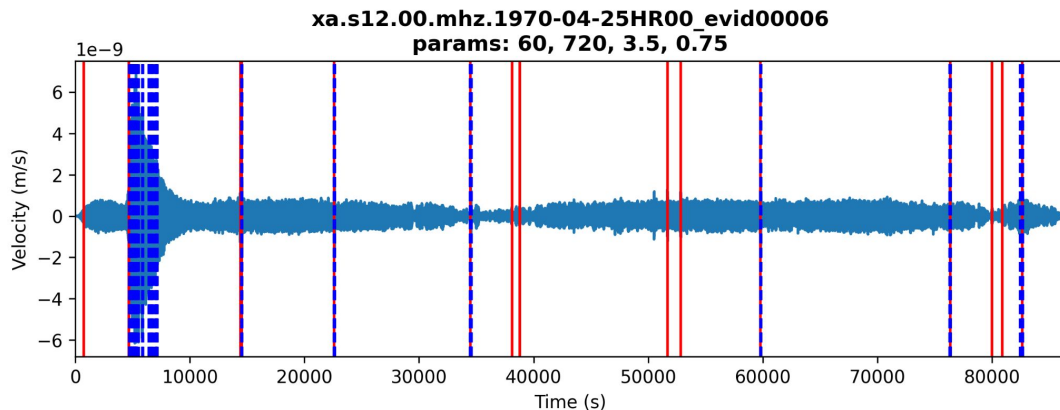
lunar	Recall(train)	FP(train)	Recall(val)	FP(val)	
[120, 600, 4.0, 1.5]	60.53	259	47.37	422	reference setting in ipynb highest recall in train
[60, 720, 3.5, 0.75]	97.37	987	84.21	1352	candidate 1
[160, 680, 3.25, 0.75]	68.42	301	63.16	752	
[100, 760, 3.75, 1.0]	78.95	488	76.32	488	candidate 2

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

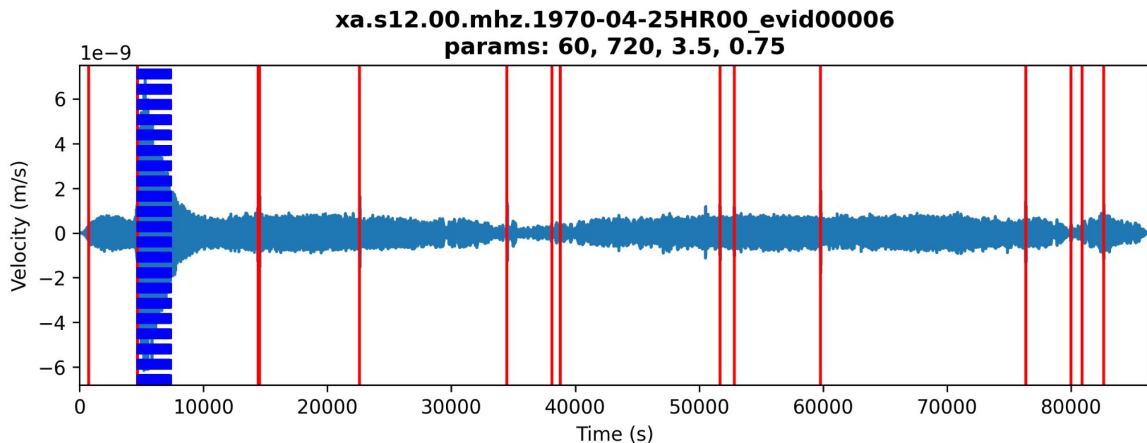
- Based on train part we generate two candidate settings
 - [60, 720, 3.5, 0.75]
 - [100, 760, 3.75, 1.0]
- We would like to further improve candidate 1 by using background modeling to suppress FP
 - We found noise could not be stable, hence need dynamic or static gaussian modeling

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

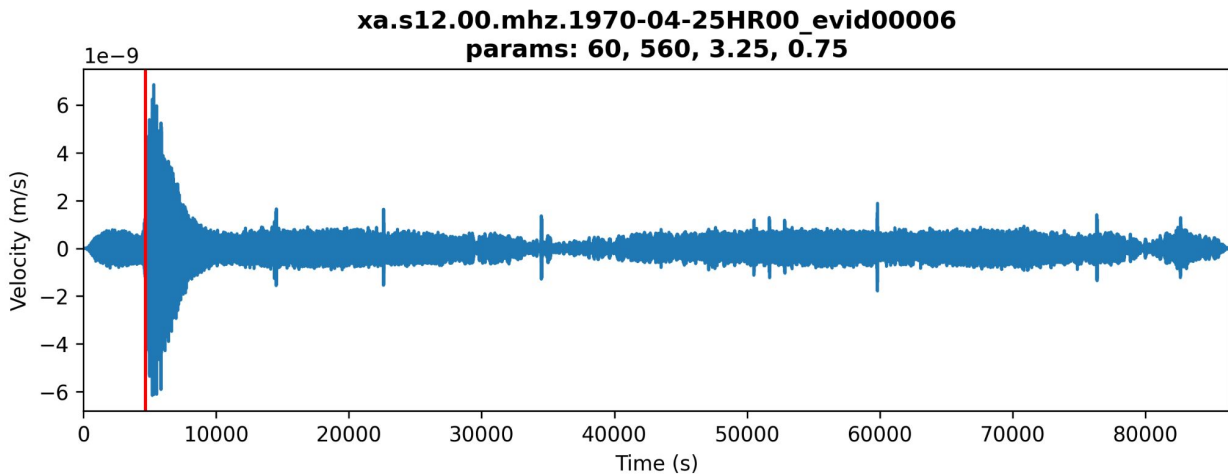


STA/LTA (red solid line)
STGaussian (blue dot line)

STGaussian: only one static
gaussian for background
noise



Final:
STA/LTA+STGaussian



Final val results

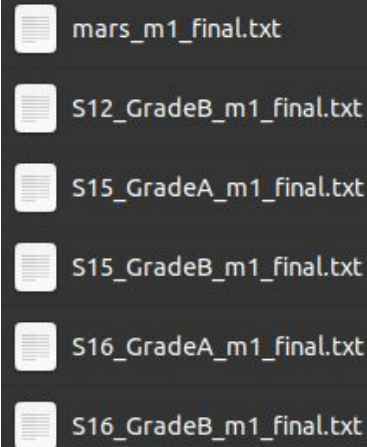
lunar	Recall(train)	FP(train)	Recall(val)	FP(val)	
[120, 600, 4.0, 1.5]	60.53	259	47.37	422	reference setting in ipynb
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[60, 720, 3.5, 0.75]	97.37	987	84.21	1352	candidate 1
[160, 680, 3.25, 0.75]	68.42	301	63.16	752	
[100, 760, 3.75, 1.0]	78.95	488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

Output for test sequences

We put [60, 720, 3.5, 0.75]+STGaussian in github / output

Thanks

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



- mars_m1_final.txt
- S12_GradeB_m1_final.txt
- S15_GradeA_m1_final.txt
- S15_GradeB_m1_final.txt
- S16_GradeA_m1_final.txt
- S16_GradeB_m1_final.txt