XIII Einstein Telescope Symposium, Cagliari, 8-12 May, 2023

Seismic waveforms classification in Sardinia

IPGP

Christopher Zerafa, Carlo Giunchi Léonard Seydoux Luca Naticchioni Domenico D'Urso Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa Institut de Physique du Globe, Paris Istituto Nazionale di Fisica Nucleare, Sezione di Roma/UniRoma1 Università degli Studi di Sassari/INFN - LNS













uto Nazionale di Fisica Nucleare

Outline

- Data & location
- Methodology
- Results
 - SOE0, surface station 2022 analysis
 - Multi-window clustering
 - External weather comparison
 - Multi cluster analysis
 - Multi-station analysis
- ScatCluster
- Next steps

Data & Location

Sos Enattos Mine





Data & Location

Borehole locations



BB sensor, 120s, surface











- Consider one year long (2022) time series corresponding to seismic data recorded at each permanent site deployed in Sardinia
- Develop a tool for automatic analysis of seismic time series
- Identification of noise sources
- Study of seasonal effects
- Effects of wind and weather
- Quantification of anthropogenic contributions
- Determination of intrinsic seismic noise of each site

Seismic data are scattered by a cascade of wavelet based filters to provide a compact, time-shift and time warping invariant representation of the input signal.

- Very robust in extracting features from data
- Similar to CNN layers, but requires no training (and no labelled dataset)
- Very computationally efficient
- Wavelet parametrization can be targeted for analysing signals of interest
- Wide range of applications including: music classification, spoken digits recognition, seizure data analysis, image classification
- Geophysical applications: landslides, volcanic and non volcanic tremors, earthquake detection
- First application to date to seismic noise (very challenging)

Methodology background: ScatSeisNet and literature



This package was written and documented by Léonard Seydoux and René Steinmann. Any contributions are very welcomed. We are developing ScatCluster, a new Python based analysis tool based on the core from ScatSeisNet, https://github.com/scatseisnet/

Relevant papers

- R. Steinmann, L. Seydoux, and M. Campillo. (2022b). Al-Based Unmixing of Medium and Source Signatures From Seismograms: Ground Freezing Patterns. Geophysical Research Letters, 49(15). https://doi.org/10.1029/2022GL098854
- R. Steinmann, L. Seydoux, E. Beauce, and M. Campillo. (2022a). Hierarchical Exploration of Continuous Seismo- grams With Unsupervised Learning. Journal of Geophysical Research: Solid Earth, 127(1). <u>https://doi.org/10.1029/2021JB022455</u>
- Anden and Mallat, Deep Scattering spectrum, IEEE Transactions on Signal Processing, 2014 <u>https://doi.org/10.1109/TSP.2014.2326991</u>

Hierarchical exploration of seismic data



Wavelets parametrization

Focus on the 1-20 Hz band

Resolution:

Frequency: 0.2 - 21.02 Hz

Temporal: 0.32 - 20.48 s



	Octaves (J)	Resolution (T)	Quality (Q)
First Order	4	4	2
Second Order	7	1	1

SOE0 - Multi-window clustering





30 min = 17520 windows



1 min = 525600 windows



SOE0 - 30 min windows in 2022, 5 clusters



SOE0 - Waveforms, envelopes and scattering coefficient stacking



SOE0 - Weather Data Comparison



SOE0 - increasing cluster hierarchy



SOE0 - the full picture of detections



Multi-station comparison - 30 min window



ScatCluster workflow

ScatCluster

- Expand from ScatSeisNet from Seydoux et al. (2022)
- Set of notebooks to perform (1) Processing, (2) Visualisation, and (3) Analysis
- Computational efficiency
 - SOME machine [24 COREs, 192GB RAM and 1 NVIDIA A100 GPU]
 - Highly optimized for GPU
 - Full year of 3-channel data
 - 1 hour window: 10 min
 - 30 min window: 15 min
 - 1 min window: 58 min
 - 01_processing_01_set_config.ipynb
 - 01_processing_02_scatseisnet_workflow.ipynb
 - 02_visualisation_01_dendrograms_waveforms.ipynb
 - 03_analysis_01_timewindow_cluster_comparison.ipynb

0

M README md

P requirements tyt

ingv_scatseisnet.py



Next steps and take home message

- Deep scattering spectrum is powerful and efficient
- Interpretation of cluster similarity may be challenging and complex
- Seismic noise data:
 - Data quality control
 - $\circ \quad \ \ \text{Seismic noise sources separation}$
 - Useful for intrinsic noise qualification at sites
- Full analysis of Sardinia sites
- Detailed comparison between noise at surface and in tunnels/boreholes
- Identification of local noise sources
- Release of ScatCluster as open source package

Contact information: carlo.giunchi@ingv.it christopher.zerafa@ingv.it