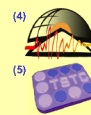


Volcano-Seismic Recognition (VSR) under noisy conditions via waveform reconstruction

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Aims & Proposals

➤ Current automatic VSR at Volcano Observatories (VOs)

i. Actual VSR at VOs:

- ✓ Volcano-Seismic (VS) activity is the **key** to evaluate volcanic risk and forecast eruptions⁽¹⁾
- ✗ VOs need **expert staff** to **manually label** VS events: **detect** (time delimitation) + **classify** (assign them to their physical type or **VS class**)
- ✗ **Manual VSR** is **slow** and **not always reliable**

ii. Automatic VSR:

- ✓ Statistical **modeling** of previously labeled VS events allows **real-time & automatic VSR**

➤ Aims: Unsupervised Volcano-Seismic Recognition (U.VSR)

i. Unsupervised VSR (U.VSR): can

recognize events from any volcano without any prior knowledge by **universal models**

ii. **VULCAN.ears** project⁽²⁾ aims to:

- ✓ Design a **U.VSR system** collecting a **universal DB** with events from more than **15 volcanoes**
- ✓ **Test** the system on a **multi-station⁽³⁾ scenario** at several VOs in **real-time & continuous** mode
- ✓ **Collaborative!**: Free Science ↔ Free World...

➤ Proposal: Waveform reconstruction

i. Reconstruction aims:

- ✓ **Signal denoising** as a prefilter before describing the waveform⁽⁴⁾ to be modeled
- ✓ **Waveform standardization of VS classes** prior to their modeling will enhance the **VSR model portability**, approaching the **U.VSR goal**

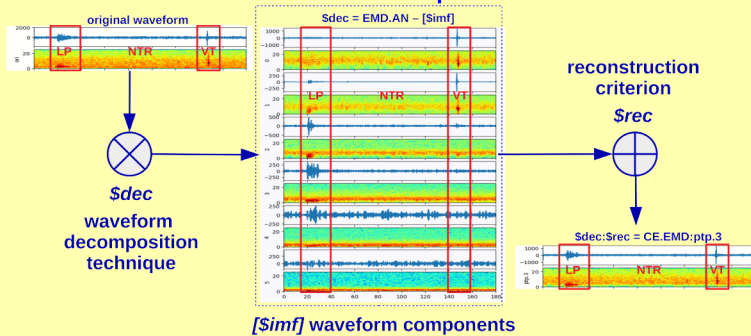
ii. Standardization by reconstruction:

- ✓ Empirical Mode Decomposition (**EMD**) is used to find meaningful waveform components⁽⁵⁾
- ✓ **Standardization** is achieved as **the best mix of components** by a given **reconstruction criteria**

Methodology:

Waveform standardization prior to Volcano-Seismic (VS) modeling

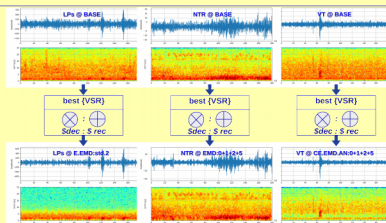
➤ 1. Waveform standardization via decomposition + reconstruction



- 1. Decomposition (\$dec)**: EMD, E.EMD and CE.EMD data-driven techs⁽⁶⁾ are used to decompose the **original waveform** into 6 complementary **\$[Simf]\$** components
- 2. Reconstruction (\$rec)**: static and dynamic criteria will mix some **\$[Simf]\$**s to rebuild the waveform

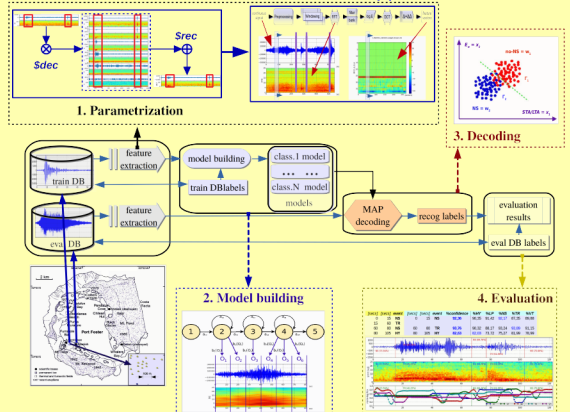
➤ Standardization of noisy events @ Deception Volcano

- ✗ The **\$dec:\$rec\$** standardization approaches which obtain the **highest VSR scores** are **not always the best** expected from the portability & U.VSR point of view!...



➤ 2. VS modeling and their evaluation

A HMM-based VSR system⁽²⁾ will be used to evaluate all waveform standardization **\$dec:\$rec\$** approaches:



VSR system & automatic recognition stages:

- 1. Parametrization**: waveform standardization and posterior description by a stream of feature vectors⁽⁴⁾
- 2. Model building**: of each VS class in the **train DB** using its **labels**
- 3. Decoding**: automatic detection & classification of **eval DB** events
- 4. Evaluation** of results comparing **recog labels** vs. **eval DB labels** via **%cAcc** and **%cPrec** measures

Case studies: Improving VSR results by waveform standardization

➤ 1. VSR improvements using the same stations with **clean** DBs

VSR @ several volcanoes: on continuous streams, averaging VSR results on 3 blind tests in these DBs:

- **Deception.1995(a)**: 2,11 [h] of recordings, 374 events manually labeled into 5 classes
- **Colima.2004**: ~50 [h] of data, 669 events labeled in 11 VS classes
- **Popocatepetl.2002**: ~43 [h] of data, 752 events, 6 classes

BASE results vs. the top 5 \$dec:\$rec\$ standardizations in the same station					
Deception.1995(a)		Colima.2004		Popocatepetl.2002	
\$dec:\$rec\$	%cPrec	\$dec:\$rec\$	%cPrec	\$dec:\$rec\$	%cPrec
BASE	75,32	BASE	76,58	BASE	60,19
EMD.ptp.5	78,17	EMD.ptp.6	78,55	CE.EMD.std.3	65,34
EMD.ptp.6	78,07	EMD:0+1+2+3+4	78,22	EMD:std.2	64,26
E.EMD:0+1+2+3+4	77,25	CE.EMD.ptp.6	78,21	E.EMD:std.3	63,71
E.EMD:0+1+2+4	76,31	EMD:0+1+2+3+5	77,39	CE.EMD:0+1+2+5	62,19
EMD.ptp.4	75,36	EMD:0+1+2+4+5	77,38	CE.EMD:std.4	61,93

✓ The best **\$dec:\$rec\$** standardization approaches depend on the DBs.

✓ Dynamic reconstruction **\$rec** criteria are the best approaches

✓ Moderate VSR improvements in clean DBs

➤ 2. Multistation VSR under noisy conditions

VSR @ Deception Volcano: recognizing VT and LP events overlapped in noisy NTR signals in 2009 by models built with data acquired in 1995 in another location.

BASE recognition results vs. the best CE.EMD.ptp.4 standardization for the ALL (average) class							
ALL		LP		NTR		VT	
\$dec:\$rec\$	%cAcc	\$dec:\$rec\$	%cAcc	\$dec:\$rec\$	%cAcc	\$dec:\$rec\$	%cAcc
BASE	65,76	BASE	67,17	BASE	84,15	BASE	45,95
CE.EMD.ptp.4	76,66	CE.EMD.ptp.4	70,71	CE.EMD.ptp.4	86,31	CE.EMD.ptp.4	72,97

BASE recognition results vs. the top 5 \$dec:\$rec\$ standardizations for each volcano-seismic class							
ALL		LP		NTR		VT	
\$dec:\$rec\$	%cAcc	\$dec:\$rec\$	%cAcc	\$dec:\$rec\$	%cAcc	\$dec:\$rec\$	%cAcc
BASE	65,76	BASE	67,17	BASE	84,15	BASE	45,95
CE.EMD.ptp.4	76,66	E.EMD:std.2	77,27	EMD:0+1+2+5	86,94	CE.EMD.ptp.4	72,97
EMD.ptp.6	68,64	CE.EMD:1+3+4+5	75,25	CE.EMD.ptp.4	86,31	EMD:0+2+3+4+5	72,97
E.EMD:0+2+3+5	68,23	CE.EMD:3+5	74,75	CE.EMD:0+2+3+4	85,22	E.EMD:std.5	67,57
E.EMD:0+1+2+4	67,66	CE.EMD:std.2	73,74	EMD:1+2+4+5	85,01	EMD:0+2+3+4	67,57
E.EMD:0+1+2+4+5	67,35	CE.EMD.ptp.0.3	72,73	EMD:1+2	84,81	EMD:std.3	67,57

- train.DB = **dec.95(b)**: 1,82 [h] of recordings by a short period sensor

- eval.DB = **dec.09**: 12,21 [h] of data obtained by a broadband station

✓ An **improvement of 16%** in the recognition success after standardization!

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