Volcano-Independent Seismic Recognition (VI.VSR): detecting and classifying events of a given volcano using data from others

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0. Aims & Proposals

➢ Volcano-Seismic Recognition (VSR) at Volcano Observatories (VOs)

- ✔ Volcano-Seismic *(VS) activity* is the most used indicator to evaluate volcanic hazard and forecast eruptions[(1)]
- ✗ VOs require 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
- ✗ C*urrently, automatic VSR* is only deployed in few VOs

➢ Aims: automatic Volcano-Independent Volcano-Seismic Recognition (VI.VSR)

i. automatic Volcano-Seismic Recognition (VSR): statistical modelling of *previously labelled* VS classes to achieve:

- ✔ *Real-time VSR* to detect and classify events *on continuous data streams*
- ✔ *easy VO integration* into most popular data acquisition systems (Earthworm & WebObs)

ii. Volcano-Independent VSR aims to *recognise events from any volcano* without any prior knowledge of its VS classes by means of *universal VSR,* allowing*:*

- ✔ *Fast VSR deploy for awakening volcanoes* and for *new appearing classes* in active volcanoes

➢ Proposal: portable & universal VSR systems

i. portable VSR solutions, relying on:

- ✔ *Easy-to-use* (Python-based) user interfaces to facilitate the VSR integration at VOs
- ✔ Structured *Hidden Markov models* (HMMs) to perform real-time, continuous VSR[(2)]

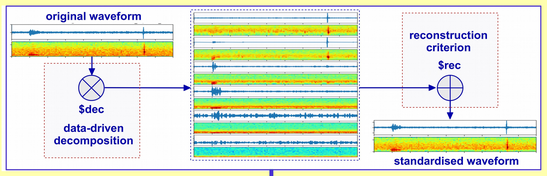
ii. universal VSR, based on ***VULCAN.ears*** project[(3)] approaches:

- ✔ *Universal DBs* collected from more than 15 volcanoes to build *universal* VSR models
- ✔ *Efficient waveform description* will enhance the volcano-independence of models
- ✔ *Parallel VSR channels* focused on each VS class, increasing reliability and precision

I. Methodology: *Efficient* waveform description to build *universal, Volcano-Independent* VSR systems

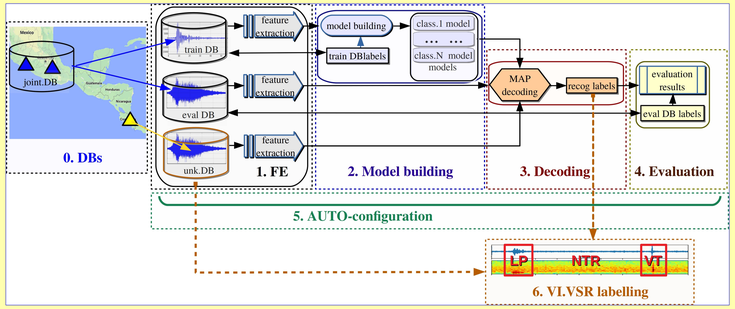
1. *Efficient* waveform description as *a sequence of feature vectors*

(1.1) standardisation (STAND)[(4)] via decomposition + reconstruction ($dec:$rec)
(1.2) parameterisation (param.#feats) of overlapped waveform segments as *feature vectors*
(1.3) feature selection (DFS)[(5)] in the given (param.#feats) parameterisation scheme



2. *Universal*-VI.VSR system setup & recognition of unknown data

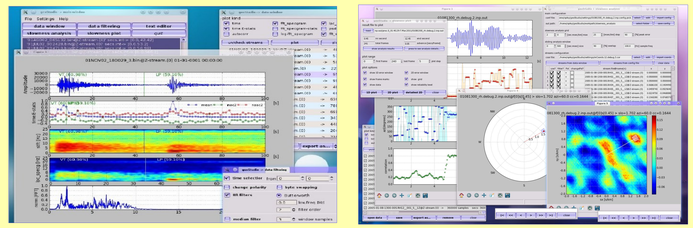
(0) DBs: a universal, *joint.DB* is used to build *universal VSR models*
(1) Feature Extraction (FE): *efficient waveform description* by a stream of feature vectors[(6)]
(2) Model building: of each VS class in the *train DB* using its *labels*
(3) Decoding: automatic detection & classification of *eval DB* events
(4) Evaluation of results comparing *recog labels* vs. *eval DB labels* via VSR precision (*cPrec)*
(5) AUTO-configuration by (re)evaluation **(4)** of the **(1+2+3)** stages
(6) Volcano-independent labelling of VS events of an *unk.DB* acquired at *another volcano*



3. *Easy* VSR integration at VOs via *easy-to-use* interfaces linking VSR & VOs

i. *geoStudio*[(3)] multi-platform**, graphical user interface** for seismic analysis:

- ✔ *Built-in VSR models* of standalone & joint DBs to perform VI.VSR
- ✔ Slowness maps by Zero-Lag correlation method
- ✔ I/O by *ObsPy*® builtin libs. Filtering and advancing plotting features



ii. *pyVSR* command-line interface as a Python wrapper for the VSR system:

- ✔ Ready-to-use scripts to *build* VSR models given a labelled DB
- ✔ Tools to run, define and evaluate whole VSR-tests
- ✔ *Online VSR* of data received from VO data servers

II. Station & volcano-independent VSR results

1. Robust & station-independent VSR at Deception Island

➢ **Station-independent VSR under *noisy* conditions VSR @ Deception Volcano**[(4)]**:** recognizing VT and LP events overlapped on noise/tremor signals in 2009 by models built with data acquired in 1995 at another location:

system	recog type	train.DB = dec.1995 events / classes @ duration	eval.DB = dec.2009 events / classes @ duration	param.#feats	*cPrec%*
SSA-VSR	continuous	288 / 3 @ 1,8 [h]	707 / 3 @ 12,2 [h]	mix.D.16	*66*
				mix.D.16[STAND]	*76*

✔ *VSR precision **increases 16%** using waveform standardisation (STAND)*

➢ **Parallel (PSA) vs. serial (SSA) VSR @ Deception**[(3)]**:** class-focused PSA.VSR channels allow a more efficient AUTO configuration than SSA.

system	recog type	train.DB = dec.1995 events / classes @ dur.	eval.DB = dec.1998 events / classes @ dur.	param.#feats	*cPrec%*
SSA	continuous	288 / 3 @ 1,8 [h]	445 / 3 @ 4,2 [h]	AUTO(mix.D.30)	*52*
PSA.chans	continuous	288 / 3 @ 1,8 [h]	445 / 3 @ 4,2 [h]	AUTO(mix.D.30)	*72*
joint.PSA					*70*

✔ *An **improvement of 38%** achieved by dedicated VSR channels (PSA.chans)*

2. VI.VSR: recognising Popocatépetl events using Colima models

➢ **continuous VI.VSR @ Popocatépetl by Colima:** waveform standardisation (STAND) + efficient feature selection (DFS[(5)]) + system auto.configuration (AUTO) empowers volcano-independent VSR:

system	recog type	train.DB = col.2004 events / classes @ dur.	eval.DB = pop.2002 events / classes @ dur.	param.#feats	*cPrec%*
SSA-VSR	continuous	345 / 6 @ 17 [h]	814 / 6 @ 37 [h]	MFCC.D.A.33	*59*
				AUTO(MFCC.D.A.33)	*65*

✔ *An **enhancement of 10%** via system AUTO-configuration*

3. VI.VSR: recognising Arenal events by Colima and Popocatépetl

➢ **VI.VSR models built by a joint.DB:** complex Arenal events can be successfully classified using *universal* models of a *universal* (joint) training DB

system	recog type	train.DB = col.2004+pop.2002 events / classes @ duration	eval.DB = are.2007 events / classes @ duration	param.#feats	*cPrec%*
SSA-VSR	isolated	813 / 7 @ 41 [h]	552 / 7 @ 14 [h]	mix.D.30	*50*
				AUTO(mix.D.30)	*71*

✔ *A **71% of precision classifying complex events** thanks to universal DBs*

III. VI.VSR highlights

(!) Remarks:

➢ **Volcano-Independent VSR becomes operational!** thanks to state-of-the-art ***VULCAN.ears*** technologies

➢ **Complex volcanoes require joint.DBs in order to build efficient VI.VSR models** (as Arenal volcano with 7 classes and its 3 types of tremors)

(+) Pros:

✔ **Promising early results!:** good precision in both, isolated (>71%) and continuous VI.VSR (>65%)

✔ ***geoStudio* and *pyVSR* interfaces allow a *fast & easy deployment* of VI.VSR systems**

(-) Cons:

✗ **A *universal* waveform description doesn't yet exist**, as it still depends on the training DB

✗ **VSR precision highly depends on the manual labelling of the training DBs**

References & Acknowledgments

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