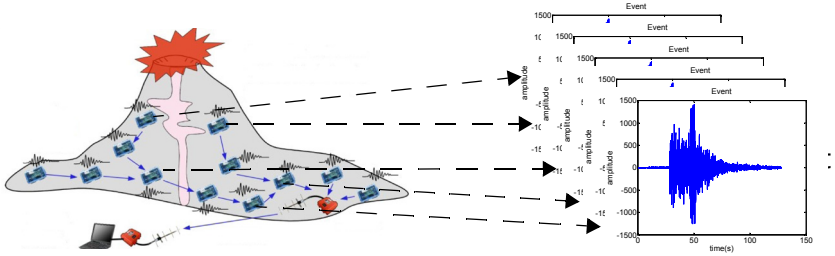
Classification of volcano events observed by multiple seismic stations

Robert P.W. Duin
Pattern Recognition Lab
Delft University of Technology
Netherlands

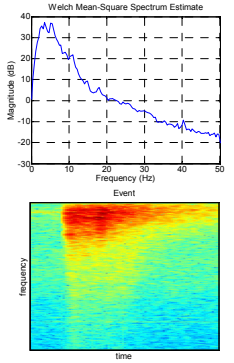
Mauricio Orozco-Alzate
Departamento de Informática y Computación
Universidad Nacional de Colombia Sede Manizales
Colombia

John Makario Londoño-Bonilla
Observatorio Vulcanológico y Sismológico de Manizales
INGEOMINAS
Colombia

Volcano: Nevado del Ruiz (Colombia)



multiple seismic stations observing the same event



spectrum

spectrogram

representation

The problem

Volcano eruptions may be predicted from observations of seismic events like *earthquake*, *long term tremor* and *icequake*. Seismic stations located at different positions on the same volcano may observe the same events in a different ways.

We study the following questions:
- what is a good representations for seismic events?
- are classifiers designed for one station useful for other stations as well?
- how to combine observations from different stations?

The data

3 x 700 events observed by 5 stations on the Nevado del Ruiz in Colombia in 3 classes. Events are automatically detected, sampled with 100.16 Hz and hand labeled. Just events with a duration of 120s (12032) have been used from the period 2002-2006.

The approach

Representations: spectra (6016), spectrograms (128x93), (also HMMs and dissimilarities, but not in this paper). Data split in 50% training, 50% testing, repeated 50 times.

Spectra: PCA to 40 dimensions --> QDA per stations.

Spectrograms:
- represent events by 93 subspectra in a 128-d space.
- compute QDA over all training events.
- classify events by the max-rule over the 93 subspectra.

Classifiers: separate classifiers per station (5), trained by the training set observed by that station

Combining_1: combining the outcomes of 5 the classifiers for every individual signal (horizontal direction in the tables).

Combining_2: combining the outcomes of a single station classifier for the 5 signals obtained from the 5 stations. (vertical direction in the tables).

Combining_3: Combining the classification outcomes of the 5 station classifiers for the corresponding station signals. (diagonal combining in the tables).

Results and conclusions

- One of the stations is non-informative (IRI) as the error is identical to assigning all events to the same class.
- Classification errors of all other stations show a reasonable performance on their own signals.
- Classifiers trained by different station signals than the tested signals, still perform better than random (off-diagonal results).
- Combining_1 deteriorates the result of the single best classifier (right column is worse than bold results).
- Combining_2 shows that combining all signal classifications by a single classifier always helps (bottom row is better than bold results).
- Combining all classifier outcomes for the corresponding signals helps (bottom right result is better than any diagonal result).
- Spectrograms are better than spectra, showing that time variations are informative.

Table 1. Classification errors for the spectral representation.

seismic station signals ↕

	ALF classf	BIS classf	IRI classf	LIS classf	OLL classf	combined
ALF signal	**0.398**(0.001)	0.578(0.002)	0.667(0.000)	0.557(0.002)	0.609(0.003)	0.403(0.001)
BIS signal	0.438(0.002)	**0.271**(0.001)	0.668(0.001)	0.557(0.003)	0.511(0.002)	0.281(0.002)
IRI signal	0.673(0.001)	0.664(0.001)	**0.626**(0.003)	0.667(0.000)	0.670(0.001)	0.626(0.002)
LIS signal	0.642(0.003)	0.679(0.002)	0.669(0.002)	**0.359**(0.002)	0.577(0.004)	0.373(0.002)
OLL signal	0.591(0.001)	0.572(0.001)	0.667(0.000)	0.553(0.002)	**0.362**(0.001)	0.366(0.002)
combined	0.358(0.002)	0.260(0.001)	0.622(0.004)	0.332(0.002)	0.332(0.002)	**0.248**(0.002)

classifiers ↔

Table 2. Classification errors for the spectrogram representation.

seismic station signals ↕

	ALF classf	BIS classf	IRI classf	LIS classf	OLL classf	combined
ALF signal	**0.406**(0.002)	0.544(0.002)	0.662(0.003)	0.522(0.001)	0.609(0.002)	0.417(0.002)
BIS signal	0.509(0.002)	**0.287**(0.002)	0.675(0.004)	0.586(0.003)	0.495(0.003)	0.292(0.002)
IRI signal	0.671(0.001)	0.676(0.001)	**0.627**(0.002)	0.668(0.001)	0.671(0.001)	0.630(0.002)
LIS signal	0.537(0.001)	0.608(0.002)	0.654(0.004)	**0.376**(0.002)	0.547(0.002)	0.375(0.002)
OLL signal	0.556(0.001)	0.469(0.001)	0.655(0.003)	0.640(0.002)	**0.386**(0.002)	0.396(0.002)
combined	0.340(0.002)	0.269(0.002)	0.601(0.005)	0.258(0.002)	0.344(0.002)	**0.238**(0.002)

classifiers ↔