T3.7-P3

Application of diffusion maps for seismic event characterization in Israel

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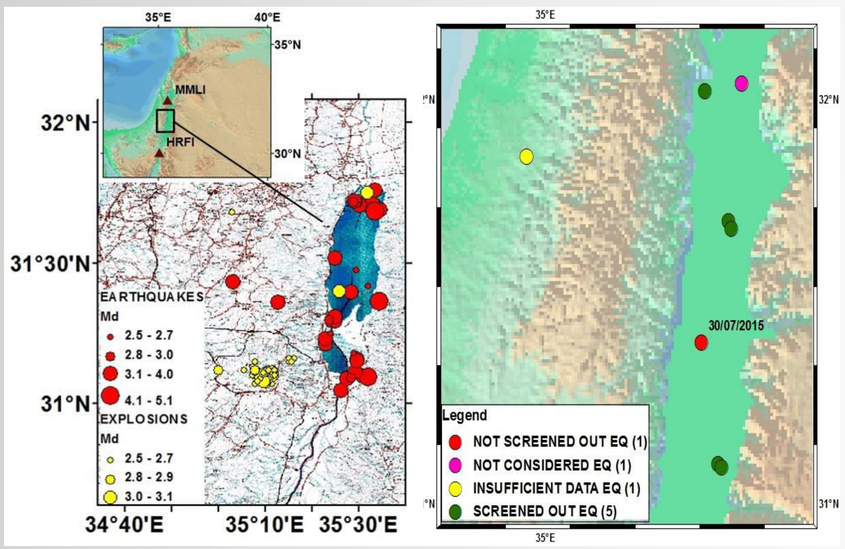
Abstract

In this work, we apply an advanced machine learning technique named diffusion maps for automatic earthquake-explosion discrimination and for explosion classification in Israel. The proposed methods construct a low-dimensional model of the original data. In this new low-dimensional space discrimination and classification analysis is carried out (Rabin, 2016, 2017). In addition, the new construction allows visualizing the pair wise distances between all of the events. The algorithm's performance is demonstrated on several seismic data sets, high accuracy discrimination and classification rates are achieved.

Discrimination in Dead Sea area

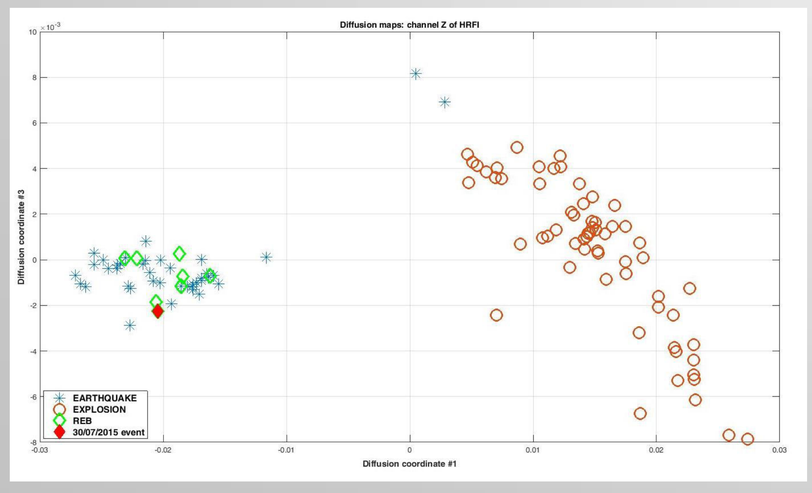
Data set includes 44 earthquakes and 62 explosions that had occurred in the Dead Sea area during 2004-2014. Events were located by the Geophysical Institute of Israel (GII) between latitudes 31°N-32°N and longitudes 34.9°E-35.7°E with duration magnitude Md≥2.5. Event discrimination (earthquakes or explosions) was performed manually by GII analysts. We used data that was recorded at Israel Cooperating National Facility (CNF) stations MMLI and HRFI.



Performance evaluation was carried out by the 1-Fold cross validation (leave-one-out) & average classification scores using 4 leading diffusion coordinates and K-Nearest Neighbors classifier. The results are as follows:

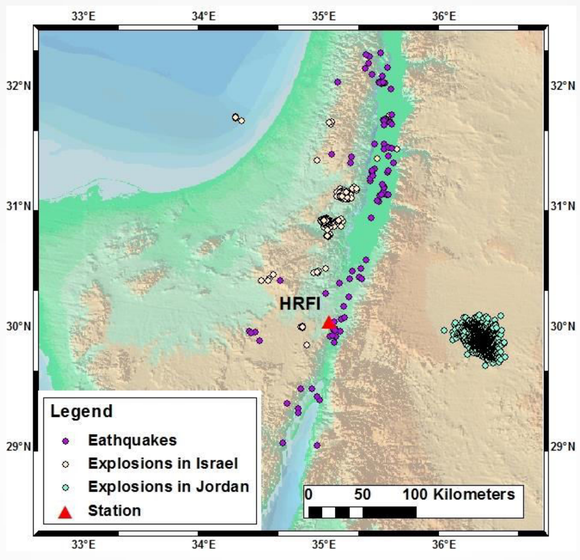
Station	MMLI				HRFI			
Chan	BHZ	BHN	BHE	3C	BHZ	BHN	BHE	3C
Rate %	94.3	91.5	91.5	96.2	96.2	96.2	94.3	98.1

Diffusion representation of the events recorded by the vertical channel of HRFI:



Discrimination using station HRFI

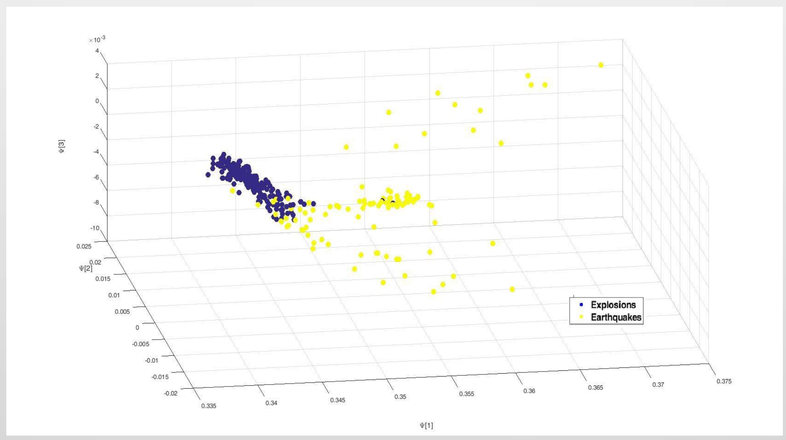
Data set includes 2023 explosions and 105 earthquakes that had occurred during 2004-2015. 1654 of the explosions were reported by the Israel NDC at the Shidiya phosphate quarry in Jordan. The rest of the events have taken from the seismic catalog of the GII located between latitudes 29°N-32.5°N and longitudes 34.2°E-35.7°E with duration magnitude Md ≥ 2.5.



A homogeneous evaluation data set is constructed by using data from 105 earthquakes and a random sample of 210 explosions. The sampling is repeated 200 times, and the results are the average of all trials.

An evaluation is performed using a 1-fold cross-validation procedure. Test points are classified by using a simple K-NN classifier in a d=4 dimensional representation. The optimal dimension (d=4) for classification was found empirically based on our data set by combining all HRFI channels with 95% of correct discrimination.

The next figure is an example of diffusion mapping of HRFI E-channel out of 3 channels.



Quarry Classification

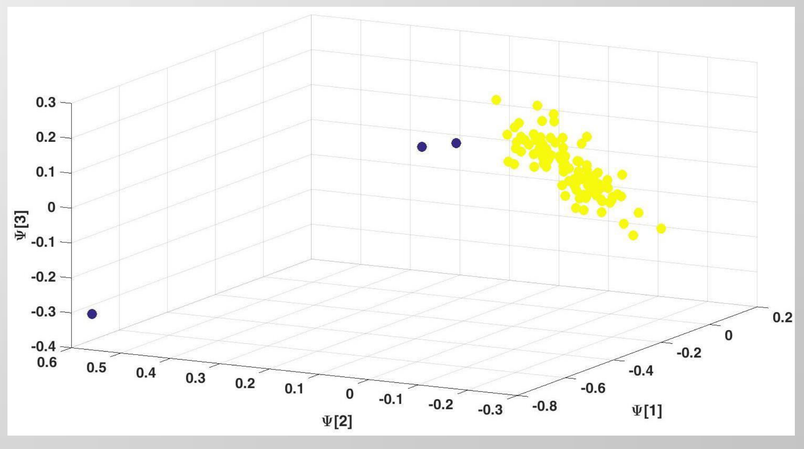
The diffusion map based approach can be utilized for identification and separation of quarries by attributing the explosions to the known sources. For this study we use 602 seismograms of explosions which according to seismic catalogs were performed in 5 quarry clusters. The diffusion mapping is followed by a classification step that is performed based on a 1-fold cross validation using K-NN with K = 3. The next table shows the confusion matrix with total accuracy of 85% .

N	Quarry	Total events	Avg distance to HRFI [km]	Affiliated Quarry				
				1	2	3	4	5
1	Shidiya	250	125	179	44	23	4	0
2	Oron	222	87	5	217	0	0	0
3	Rotem	115	118	7	0	106	0	2
4	M. Ramon	8	47	1	0	0	7	0
5	Har Tuv	7	128	0	0	2	0	5

Detecting Anomalous Events

We show that the diffusion map based algorithm enables to detect anomalous events among set of events at specific site.

Most of quarry blasts in Israel are ripple-fire explosions. Three experimental one shot explosions were carried out by the GII at the Oron phosphate quarry in 2006 (Gitterman, 2009). The figure below presents a diffusion mapping of HRFI Z-channels for 98 events from a small region surrounding the ground truth location of the experimental explosions. The three anomaly points are colored in blue, they are clearly separated from the main cluster.



Acknowledgment

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Gitterman Y., 2009, Source phenomenology experiments with borehole explosions of special design in Israel, Bull. seism. Soc. Am., **99** (3), 1892–1905.