ANQDS v1.0

Artificial and Natural Quake Discrimination Software

User Manual

***ANQDS** v1.0 is an open-source and MATLAB-based graphical user interface developed to discriminate the natural and artificial seismic events. The program uses a semi-automatic algorithm based on four different methods to analyze the seismic data:*

- *Amplitude ratio*
- *Complexity*
- *Short-time Fourier transform*
- *Power spectrum density*

It uses two different statistical methods to classify the data:

- *Linear discrimination function*
- *Quadratic discrimination function*

ANQDS has the ability to automatically analyze a selected seismic event using the Amplitude ratio and Complexity methods. The program needs user interpretation for analyzes based on the Short-time Fourier transform and Power spectrum density methods.

This software was developed within the scope of AFAD National Earthquake Research Program (UDAP-Ç-19-13). Click to see the software development team.

1. Quick Tutorial

Installation

ANQDS v1.0 requires Matlab 2015a or later versions.

The code includes several subroutines and user interfaces. Please, download the program files and sub folders from GitHub repository.

GitHub repository: https://github.com/ozkankafadar/ANQDS_v1.0

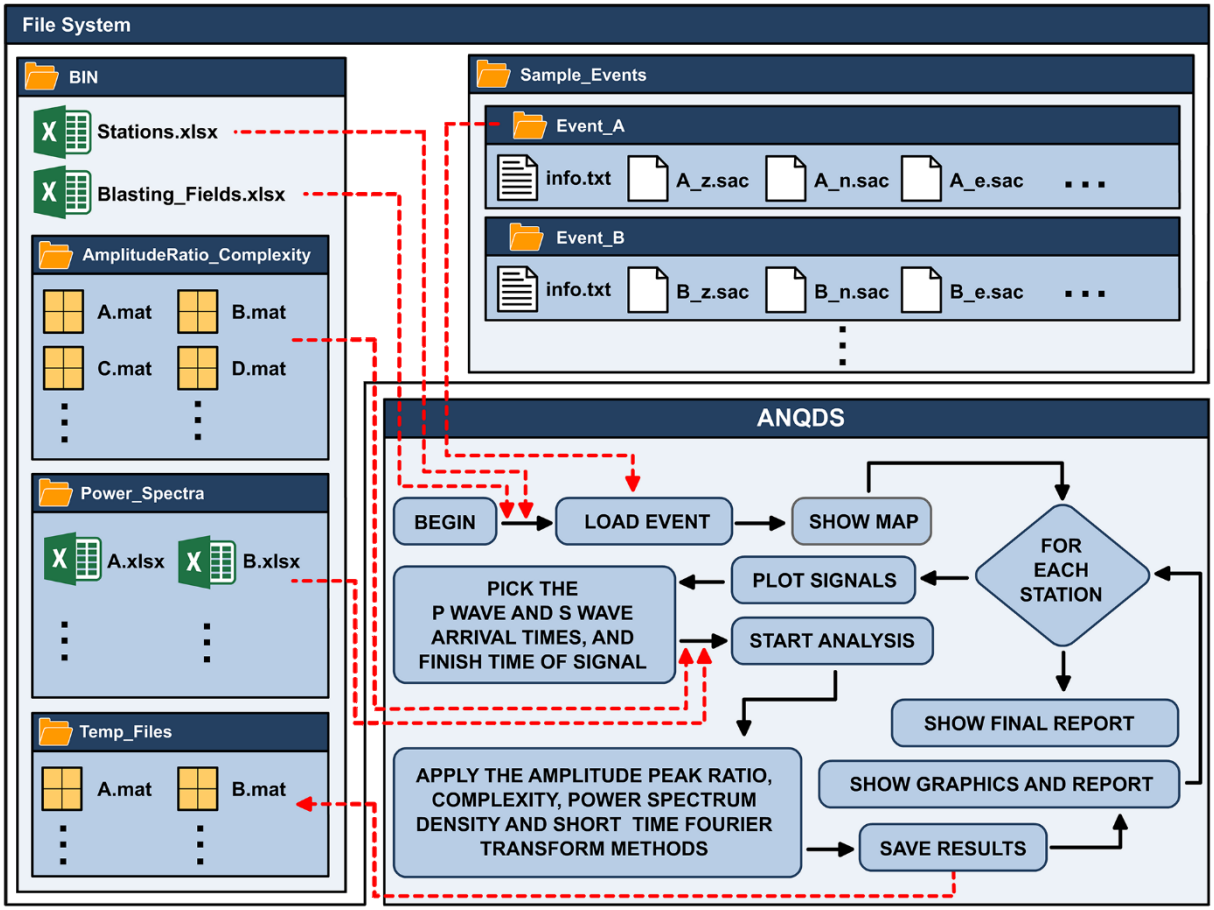
For installation:

- **Option 1:**
  - If your computer has not a full MATLAB R2015a (64-bit) installation, please, install MATLAB Compiler Runtime (MCR), which can be downloaded from MathWorks website (http://www.mathworks.com/products/compiler/mcr).
  - Run **ANQDS** v1.0 executable file (ANQDS.exe).
- **Option 2:**
  - If your computer has a MATLAB R2015a or higher version, **ANQDS** v1.0 can be run using the "*Source Code*" folder without any installation.
  - Please, run MATLAB software and open the "*Start.m*" file in the "*Source Code*" folder.
  - After that, click the "*Run*" button (or press F5) in "*Editor*" panel.

Note: Follow the instruction below to give "write permission" to the Temp_files folder that the program uses for temporary files.

Click the right mouse button on the Temp_files folder. Then click on properties in the drop-down menu, select a user in the security panel and allow "full control" permission.

2. ANQDS v1.0 File System



ANQDS v1.0 needs several input files to decide whether a seismic event is natural or artificial. It uses the Excel spreadsheets called **Stations** and **Blasting_Fields**, located in the **Bin** folder, for information of the stations and quarries in the study area.

2.1. Stations Excel spreadsheet

The **Stations** Excel spreadsheet in **Bin** folder plays a key role for analysis. Because while the program is estimating the source of a seismic event, it uses the weight coefficient of the methods in the Stations Excel spreadsheet.

First of all, the “first estimations” should be performed for each station to obtain the discrimination functions in the amplitude ratio and complexity methods. After that, for each method, the number of events consistent with the “first estimations” are obtained and performed the **Stations** Excel spreadsheet.

The methods used for “first estimation”:

- Times and locations of the seismic events
- Amplitudes of the P-wave and S-wave in the seismograms
- First direction of the movement of P-wave in the seismograms

- Rg phase in the seismograms
- Coda wave attenuation in the seismograms

The **Stations** Excel spreadsheet consists of ten columns including the station name, latitude, longitude, total number of events and the number of events consistent with the “first estimations” for each method. For example; the total number of successful event for amplitude ratio method (LDF) is 99 for ADCV station. So, this value is divided by 2 and 50% ratio were obtained as 49.5 for A-LDF. Similarly, it is calculated as 49.5 for A-QDF.

	A	B	C	D	E	F	G	H	I	J
1	STATION	LATITUDE	LONGITUDE	EVENT	A-LDF	A-QDF	C-LDF	C-QDF	STFT	PS
2	ADCV	38.808	42.7246	101	49.5	49.5	45.5	45.5	72	70
3	AFYN	38.2714	30.5027	100	47.5	49	43.5	45	77	81
4	AFYO	38.7871	30.2988	79	31	32.5	32.5	32	49	38
5	AHAN	41.1639	42.6244	40	0	0	0	0	40	40
6	AKAS	36.2326	29.6052	62	0	0	0	0	61	59
7	AKCA	37.7942	37.6882	100	48.5	48.5	46	45.5	72	68
8	AKCD	38.2956	37.9224	100	43	47	45	47	84	78
9	AKDA	40.1034	41.3636	38	0	0	0	0	38	38
10	AKHS	38.8788	27.8138	100	43	47.5	43	47.5	91	72
11	AKO	37.4615	35.446	114	53	54.5	53	56	83	84
12	AKPI	39.5039	33.9967	100	44	46.5	43	48.5	81	79

A-LDF: Amplitude ratio (LDF), A-QDF: Amplitude ratio (QDF),

C-LDF: Complexity (LDF), C-QDF: Complexity (QDF),

STFT: Short-time Fourier transform,

PS: Power spectrum density

2.2. Blasting_Fields Excel spreadsheet

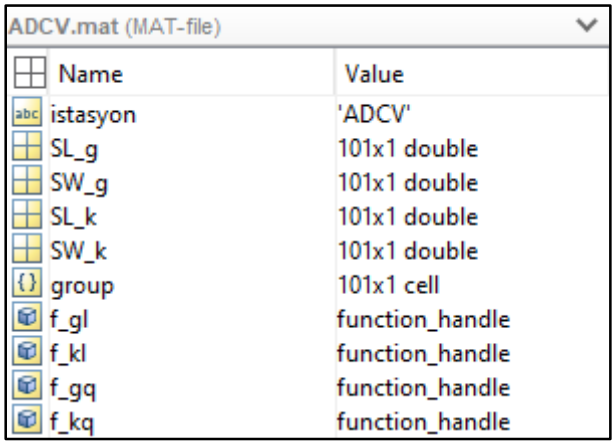
The **Blasting_Fields** Excel spreadsheet in the **Bin** folder includes the latitude and longitude information of the quarries in Turkey.

	A	B	C	D
1	NAME	LATIDUTE	LONGITUDE	LOCATION
2	Noname	28.1285964	41.55989725	Noname
3	Noname	28.23263042	41.51022964	Noname
4	Noname	28.10541597	41.16366208	Noname
5	Noname	28.07613971	41.17181974	Noname
6	Noname	28.09474282	41.18415464	Noname
7	Noname	28.09219686	41.19302745	Noname
8	Noname	28.10004037	41.19983398	Noname
9	Noname	28.11788819	41.20163849	Noname
10	Noname	28.16192188	41.21324321	Noname

2.3. MAT files in the AmplitudeRatio_Complexity

The **AmplitudeRatio_Complexity** folder includes the MAT files comprising the parameters that are required to calculate the amplitude ratio and complexity values based on the LDF and QDF statistical approaches for each station.

For example, the structure of the ADCV.MAT file belonging to ADCV station:



The MATLAB code to be used to create this MAT file is as follows:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

stationName = 'Your Station Name';
[parameters, group, ~] = xlsread('Data.xlsx','Sayfa1');
amp1 = parameters(:,1);
amp2 = parameters(:,2);
comp1 = parameters(:,3);
comp2 = parameters(:,4);
 [Amp_X,Amp_Y] = meshgrid(linspace(min(amp2),max(amp2)),linspace(min(amp1),max(amp1)));
Amp_X = Amp_X(:); Amp_Y = Amp_Y(:);
 [Comp_X,Comp_Y] =
meshgrid(linspace(min(comp2),max(comp2)),linspace(min(comp1),max(comp1)));
Comp_X = Comp_X(:); Comp_Y = Comp_Y(:);
 [~,~,~,~,coef_amp_linear] = classify([Amp_X Amp_Y],[amp2 amp1],group,'linear');
[~,~,~,~,coef_comp_linear] = classify([Comp_X Comp_Y],[comp2 comp1],group,'linear');
[~,~,~,~,coef_amp_quadratic] = classify([Amp_X Amp_Y],[amp2 amp1],group,'quadratic');
[~,~,~,~,coef_comp_quadratic] = classify([Comp_X Comp_Y],[comp2 comp1],group,'quadratic');
% Amplitude ratio (LDF)
K_amp_linear = coef_amp_linear(1,2).const;
L_amp_linear = coef_amp_linear(1,2).linear;
Function_amp_linear = @(x,y) K_amp_linear + L_amp_linear(1)*x + L_amp_linear(2)*y;
% Complexity (LDF)
K_comp_linear = coef_comp_linear(1,2).const;
L_comp_linear = coef_comp_linear(1,2).linear;
Function_comp_linear = @(x,y) K_comp_linear + L_comp_linear(1)*x + L_comp_linear(2)*y;
% Amplitude ratio (QDF)
K_amp_quadratic = coef_amp_quadratic(1,2).const;
L_amp_quadratic = coef_amp_quadratic(1,2).linear;
Q_amp_quadratic = coef_amp_quadratic(1,2).quadratic;
Function_amp_quadratic= @(x,y) K_amp_quadratic + [x y]*L_amp_quadratic + sum(([x
y]*Q_amp_quadratic) .* [x y], 2);
% Complexity (QDF)
K_comp_quadratic = coef_comp_quadratic(1,2).const;
L_comp_quadratic = coef_comp_quadratic(1,2).linear;
Q_comp_quadratic = coef_comp_quadratic(1,2).quadratic;
Function_comp_quadratic= @(x,y) K_comp_quadratic + [x y]*L_comp_quadratic + sum(([x
y]*Q_comp_quadratic) .* [x y], 2);
save([stationName, '.mat'])
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

	A	B	C	D	E
1	1.1542	3.95539	2.17028	1.65574	EQ
2	0.63992	3.81271	1.40252	3.42465	EQ
3	0.52356	3.83589	0.85049	3.8181	QB
4	0.35012	3.64435	0.43323	5.84772	QB
5	1.90686	4.0294	3.63706	1.60306	EQ
6	1.72692	4.09736	1.53317	1.51669	EQ
7	1.64609	4.50571	3.33	3.56124	EQ
8	1.66747	5.12538	4.53214	2.50751	EQ
9	2.40011	5.4061	5.17947	1.57834	EQ
10	0.48828	4.11951	0.66578	2.22343	EQ
11	0.46608	4.21645	0.84875	2.45499	QB
12	3.34153	5.57148	6.91883	2.10648	EQ

An example format is given above for the Data.xlsx file. The file contains the logarithm of the maximum amplitude of S-wave (log(As)), amplitude ratio (As/Ap), complexity (C) and spectral ratio (Sr) obtained from the seismograms recorded by a station (EQ: Natural seismic event, QB: Artificial seismic event).

2.4. Power spectra Excel spreadsheet in the Power_Spectra folder

The **Power_Spectra** folder includes the Excel spreadsheets that consists of the frequency and amplitude values of the maximum and minimum power spectra obtained for each station. For this process, the power spectra of all seismograms for a station are calculated and estimates the maximum and minimum limits of these spectra. In this file, the columns from left to right show x and y coordinates for minimum values of natural events, maximum values of natural events, minimum values of artificial events and maximum values of artificial events, respectively.

	A	B	C	D	E	F	G	H
1	1.03E+00	9.36E+11	1.02E+00	3.78E+05	1.02E+00	1.39E+10	1.01E+00	2.50E+06
2	1.15E+00	1.83E+12	1.14E+00	6.59E+05	1.14E+00	2.66E+10	1.13E+00	3.46E+06
3	1.28E+00	2.28E+12	1.28E+00	1.15E+06	1.27E+00	4.10E+10	1.26E+00	4.78E+06
4	1.43E+00	3.57E+12	1.42E+00	1.61E+06	1.42E+00	7.88E+10	1.41E+00	5.32E+06
5	1.61E+00	4.47E+12	1.59E+00	2.51E+06	1.58E+00	1.09E+11	1.58E+00	8.20E+06
6	1.79E+00	6.25E+12	1.78E+00	3.51E+06	1.77E+00	1.68E+11	1.75E+00	1.02E+07
7	2.00E+00	8.73E+12	1.99E+00	4.40E+06	1.98E+00	2.32E+11	1.96E+00	1.26E+07
8	2.25E+00	9.79E+12	2.22E+00	5.50E+06	2.21E+00	3.21E+11	2.19E+00	1.40E+07
9	2.50E+00	1.37E+13	2.48E+00	6.89E+06	2.45E+00	4.45E+11	2.45E+00	1.56E+07
10	2.80E+00	1.37E+13	2.78E+00	7.72E+06	2.74E+00	6.15E+11	2.73E+00	1.73E+07
11	3.13E+00	1.72E+13	3.10E+00	8.65E+06	3.07E+00	8.50E+11	3.05E+00	1.73E+07
12	3.50E+00	1.93E+13	3.47E+00	9.69E+06	3.43E+00	9.45E+11	3.40E+00	1.72E+07
13	3.91E+00	2.16E+13	3.89E+00	8.70E+06	3.82E+00	1.05E+12	3.80E+00	1.72E+07

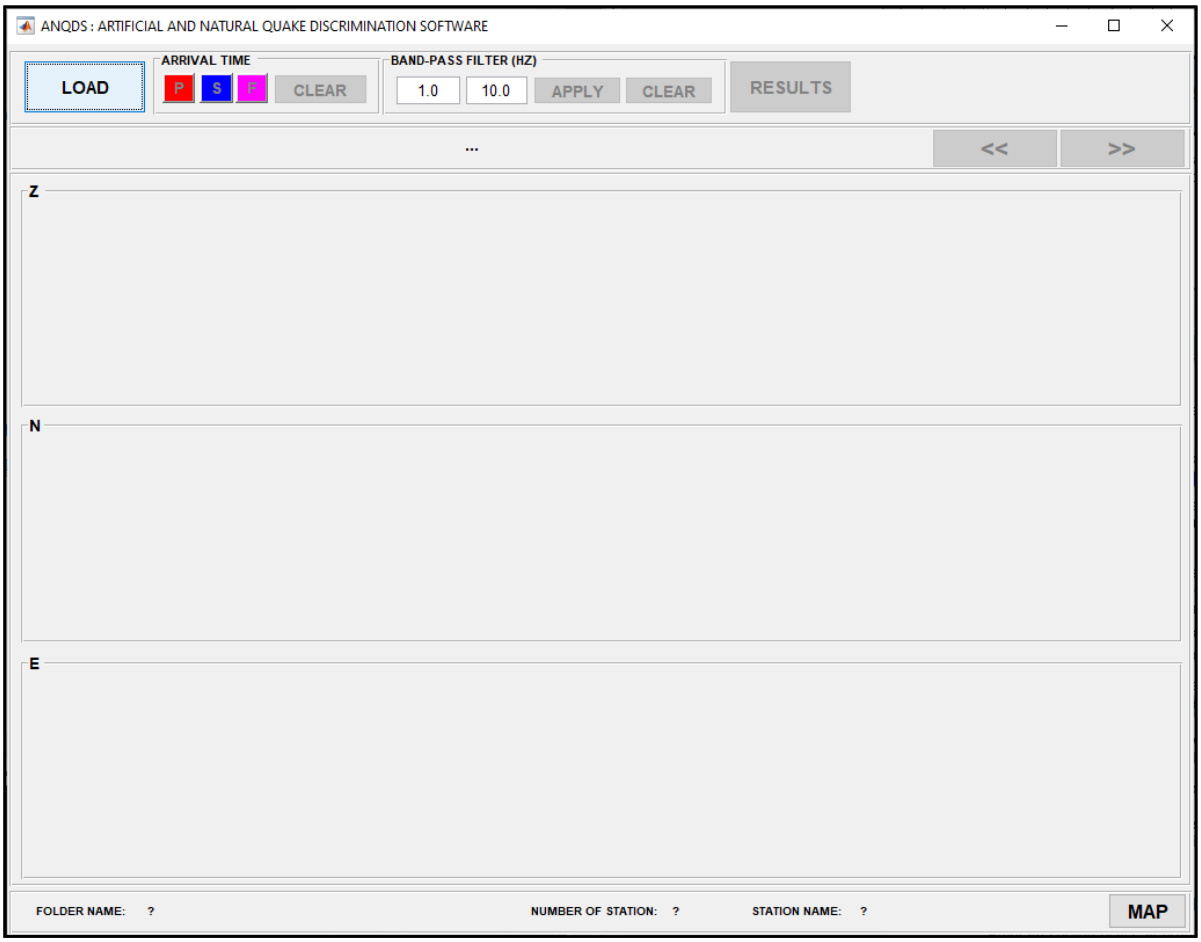
2.5. MAT files in the Temp_Files folder

The program creates automatically the parameters required for analysis to the **Temp_File**s folder for each station. These files are automatically deleted from the **Temp_Files** folder when the program is closed or a different seismic event is selected using the LOAD button.

3. ANQDS v1.0 Graphical User Interface

3.1. Main Window

The **ANQDS** v1.0 main program window is a Windows form with tools to display and analyze seismograms recorded by one or more stations. The detailed descriptions of the tools on the form are given below:



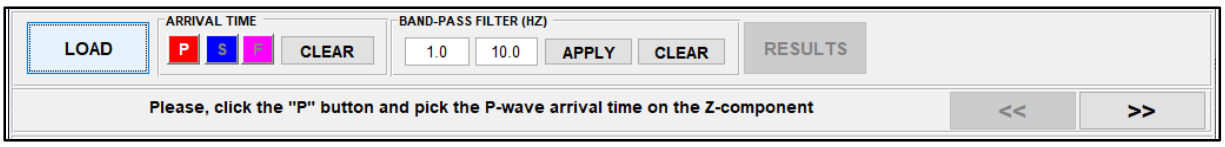
3.1.1. Menu

By clicking the LOAD button, the directory containing the station records of the event to be analyzed is selected. The program is designed to read the SAC data file format.

The ARRIVAL TIME panel is used to select the P-wave arrival time P, S-wave arrival time S and signal finish time F needed for the Amplitude ratio and Complexity methods. The CLEAR button is used to reset the arrival times.

The BAND-PASS FILTER (Hz) panel allows to apply the band-pass filter to the seismograms. Thus, P-wave and S-wave arrival times can be selected more precisely. The default values of the cut-off frequencies of the low-pass and high-pass filters are defined as 1 Hz and 10 Hz and these frequencies can be customized. The APPLY button is used to apply the band-pass filter. Besides, the CLEAR button is used to obtain the raw data.

If the event directory is selected, the main menu will look like as follows:

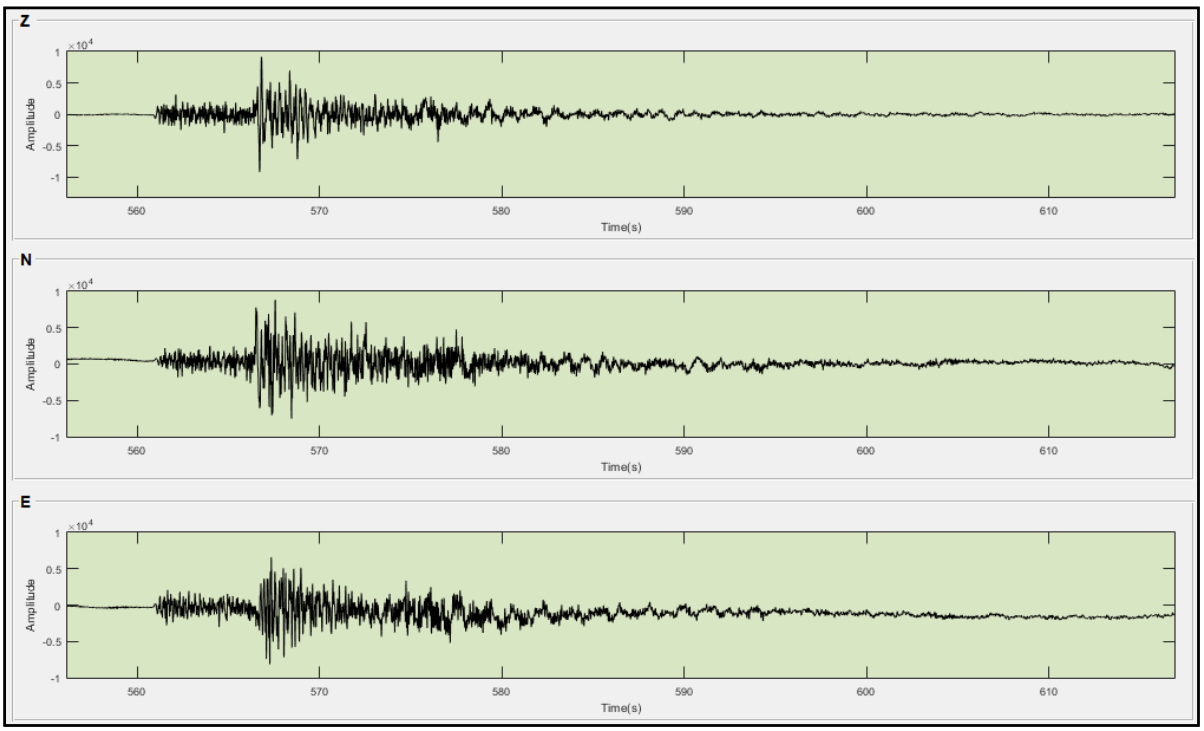


After selecting the P-wave and S-wave arrival times and signal finish time using the P, S and F buttons, the START button is clicked to start the analysis. The << and >> buttons are used to navigate between the stations. Thus, the natural and artificial event discrimination for a seismic event can be performed using multi-station data.

When the user clicks the START button, the RESULTS window is displayed automatically. In case the user closes the RESULTS window, the previous analyses can be displayed again by clicking the RESULTS button.

3.1.2. Seismogram Panels

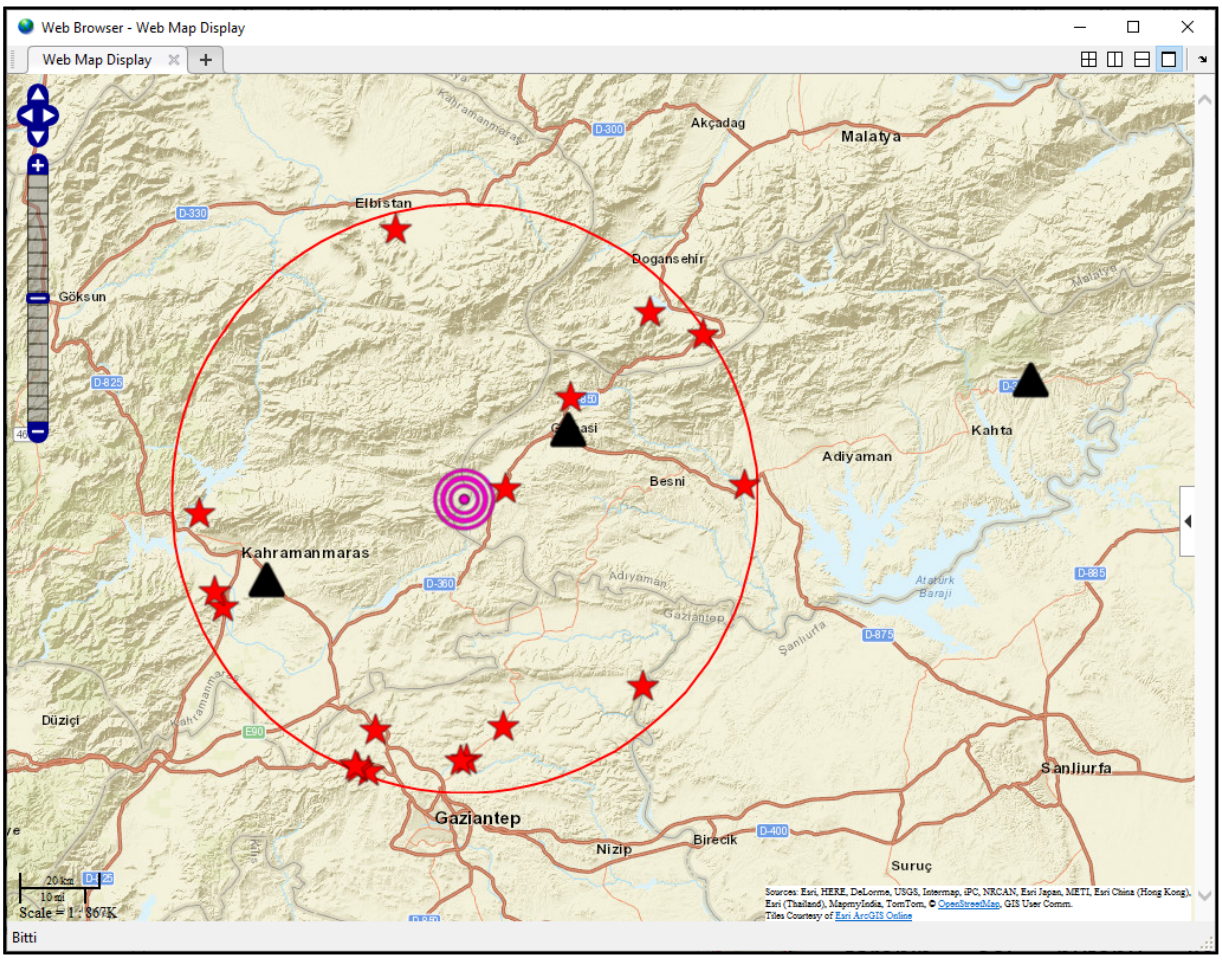
ANQDS v1.0 displays the available components in the directory of the selected event. The vertical component seismogram must be in the event directory. There is no such requirement for horizontal component seismograms. However, it is recommended to select the S wave arrival time over the horizontal components. The selected P-wave and S-wave arrival times are displayed on both vertical and horizontal components. Zoom feature has been activated to allow precise selection of first arrivals. When the zoom feature is active, the icon is displayed while navigating the signal with the mouse.

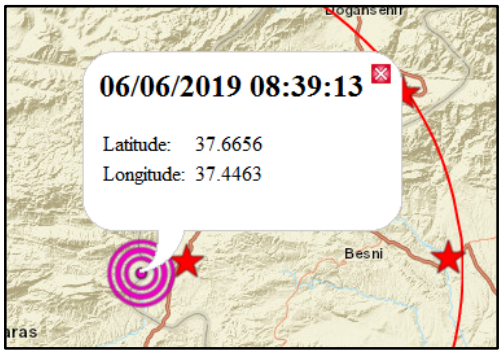


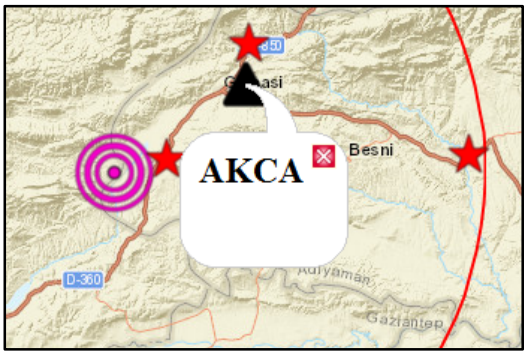
3.1.3. Status Bar

The status bar is an information panel that displays the name of the selected event directory FOLDER NAME: 6.06.2019 08.39.13, the number of stations available in the directory NUMBER OF STATION: 3, and the name of the station STATION NAME: KAHM to be used for the analysis.

In addition, there is a MAP button within the status bar that can be used to display the map designed to display the location of the seismic event, recording stations ▲ and quarries ★ in the region.



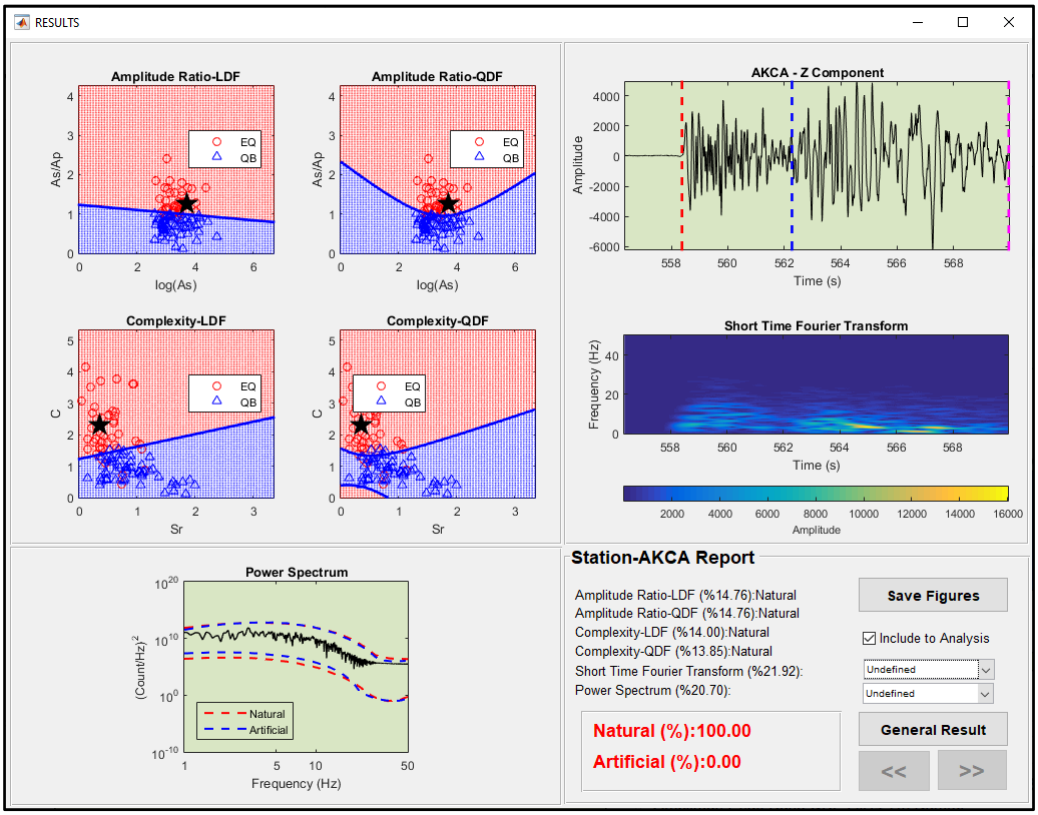




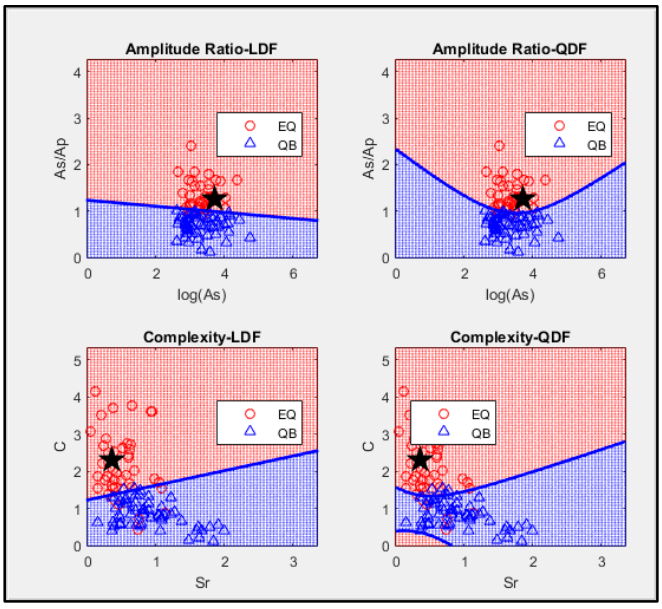
Detailed information can be displayed by clicking the station and quarries icons with the left mouse button.

3.2. "*RESULTS*" Window

The RESULTS window consists of four panels:



3.2.1. Amplitude Ratio and Complexity Analysis Panel

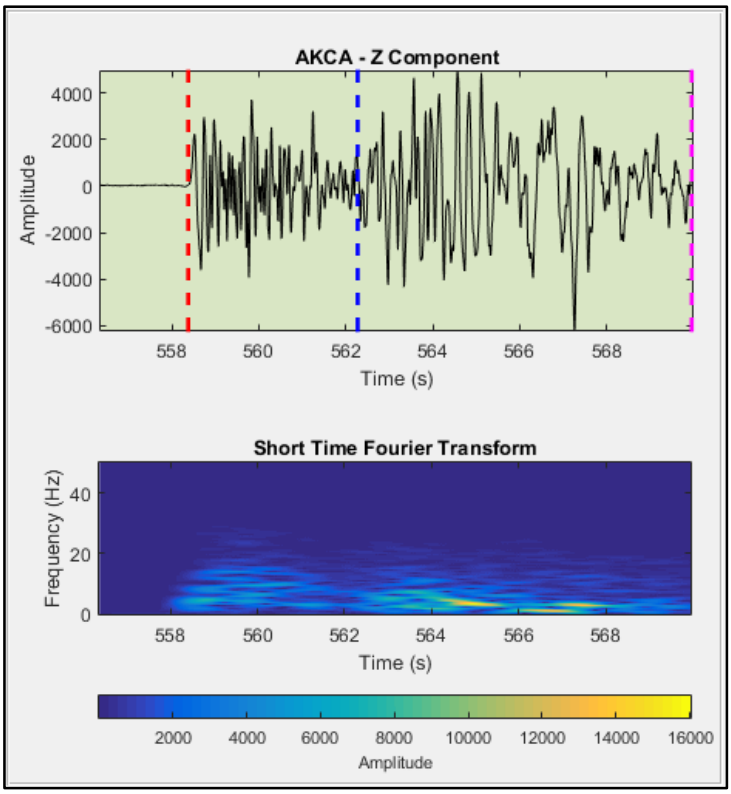


The blue lines in the graphics indicate the discrimination functions, and the black stars show the amplitude ratio and complexity values. For stations that do not have the MAT files required for the amplitude and complexity methods, the message "**No function information**" is displayed.

Amplitude Ratio (LDF and QDF): The black stars show the ratio of the maximum amplitudes of the S- to P-wave versus the logarithm of the maximum amplitude of the S-wave in the vertical component of the seismogram.

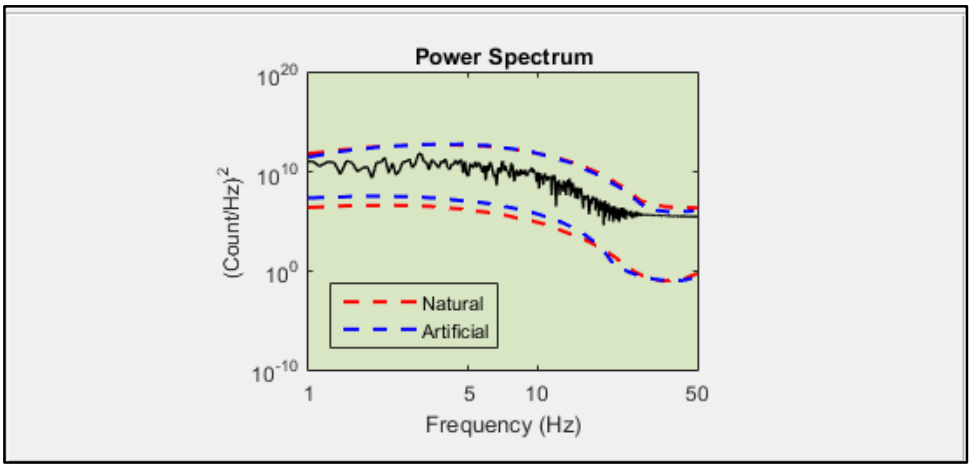
Complexity (LDF and QDF): The black stars show the complexity versus the spectral ratio.

3.2.2. Short-Time Fourier Transform Analysis Panel



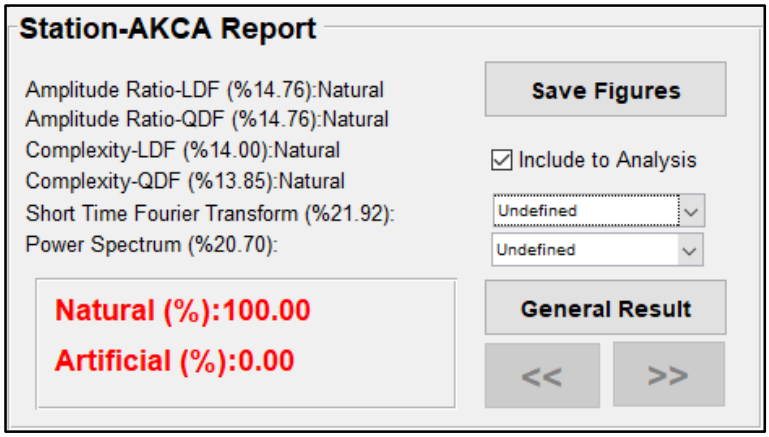
In the panel, the vertical component seismogram and short-time Fourier transform are displayed. So the time-frequency content of the signal can be monitored in details.

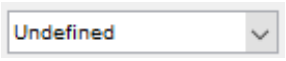
3.2.3. Power Spectrum Density Analysis Panel



The red and blue dashed lines represent the power spectrum density ranges calculated from the natural and artificial events recorded at the station, respectively.

3.2.4. Station Report Panel

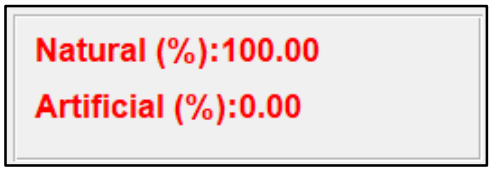


In the panel, the weighting percentages for each method and source types obtained from the analysis are displayed. Analysis results of the short-time Fourier transform and power spectrum density are user-defined, and drop-down lists 

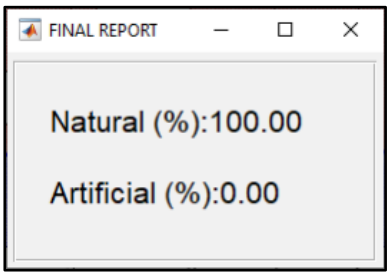
are provided for selection. In the drop-down list; It includes Undefined, Natural and Artificial options. The short-time Fourier transform and power spectrum density should be examined by the user, and the source type of the seismic event should be selected. If the event type is not selected, the results of these two methods are not included in the analysis.

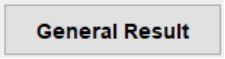
If any station in the event directory is not to be included in the analysis, the 

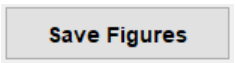
checkbox should be disabled. By default, all stations are assumed to be included in the analysis.



ANQDS v1.0 calculates the success percentages for both station-based and overall analyzes. In the left panel, success percentages are displayed for a station.



Click the 

button to display the overall analysis percentage values calculated based on all stations. In addition, by clicking the 

button, each analysis

graphic can be saved in a selected directory. Previous analysis button << and next analysis button >> are used to navigate through the results of the analyzed stations.

Software Development Team

Assoc. Prof. Dr. Özkan KAFADAR
Kocaeli University
Department of Constructor Technology
okafadar@kocaeli.edu.tr

Assoc. Prof. Dr. Erman ŞENTÜRK
Kocaeli University
Department of Geomatics Engineering
erman.senturk@kocaeli.edu.tr

Dr. Hamdullah LİVAOĞLU
Kocaeli University
hamdullah.livaoglu@kocaeli.edu.tr

Project Team

Prof. Dr. Fadime SERTÇELİK
Assoc. Prof. Dr. Tahir Serkan IRMAK
Assoc. Prof. Dr. Özkan KAFADAR
Dr. Evrim YAVUZ
Dr. Hamdullah LİVAOĞLU
Assoc. Prof. Dr. Erman ŞENTÜRK
Senior Geophysics Engineer Bahar TÜRKYILMAZ
Senior Geophysics Engineer Nalan CEYDİLEK
Senior Geophysics Engineer Gözde MERTER
Senior Geophysics Engineer Seher GÖZSÜZ
Assoc. Prof. Dr. Serpil GERDAN