Type

DVAtool

in the Matlab command prompt. It will open the DVAtool GUI shown in Figure 1. Note that all pushbuttons of the GUI except ‘LOAD DATA’ and ‘LOAD TAGNAMES’ are inactive. Once data is loaded to the GUI, all buttons will be active.

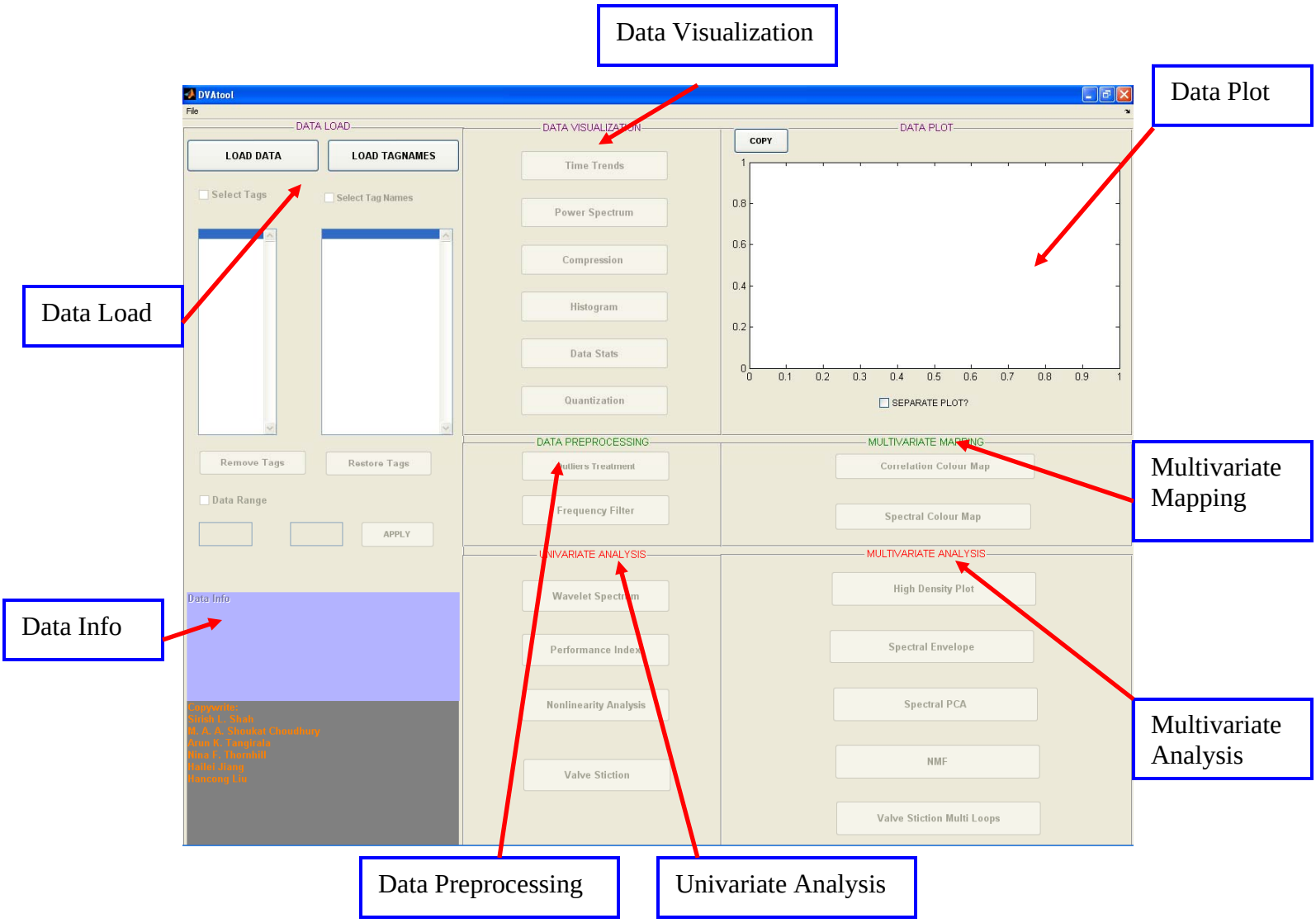


Figure 1: The layout of the DVAtool

The DVAtool GUI contains 8 components or sections. The titles of these sections are shown in the rectangular boxes and their locations are shown with arrows.

1. **DATA LOAD** section: The top-left panel is the data-load section.

1.1 **Load Data**: You can load data to the GUI by clicking the '**LOAD DATA'** push button. Clicking this pushbutton will open an interface for loading the desired data into the GUI. Either a workspace variable or data from any Matlab recognizable file can be loaded.

Ex. 1 Loading an Example:

The GUI is supplied with few example data sets. One of such data sets is a refinery data set. In the Matlab workspace prompt, type
load sear_data
It will load the data into Matlab workspace. To check, type
whos
in the Matlab command prompt. It will show that

```
  Name            Size            Bytes  Class     Attributes

  errmat          512x37         151552  double
  refinery_tags    37x1            2964  cell
```

Now, Click 'LOAD DATA' button of the GUI. It will open up the following Figure Ex-1

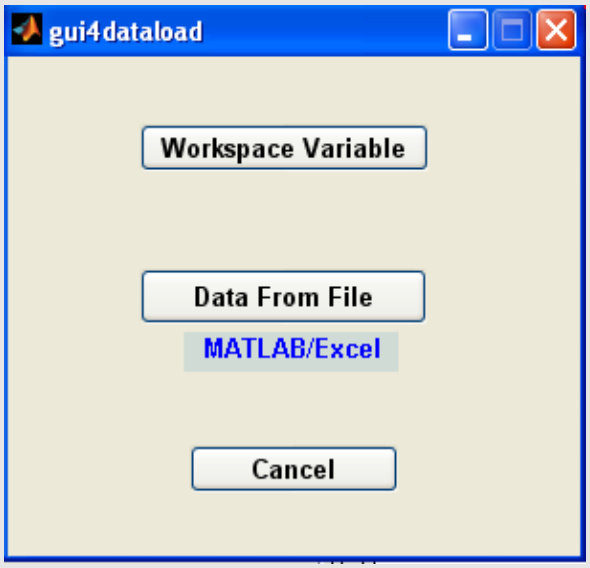


Figure Ex -1: Loading Data in DVAtool

Loading Data from Matlab Workspace

Click the **'Workspace Variable'** button, it will open up the following Figure Ex- 2.

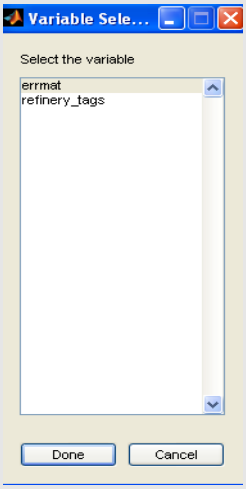
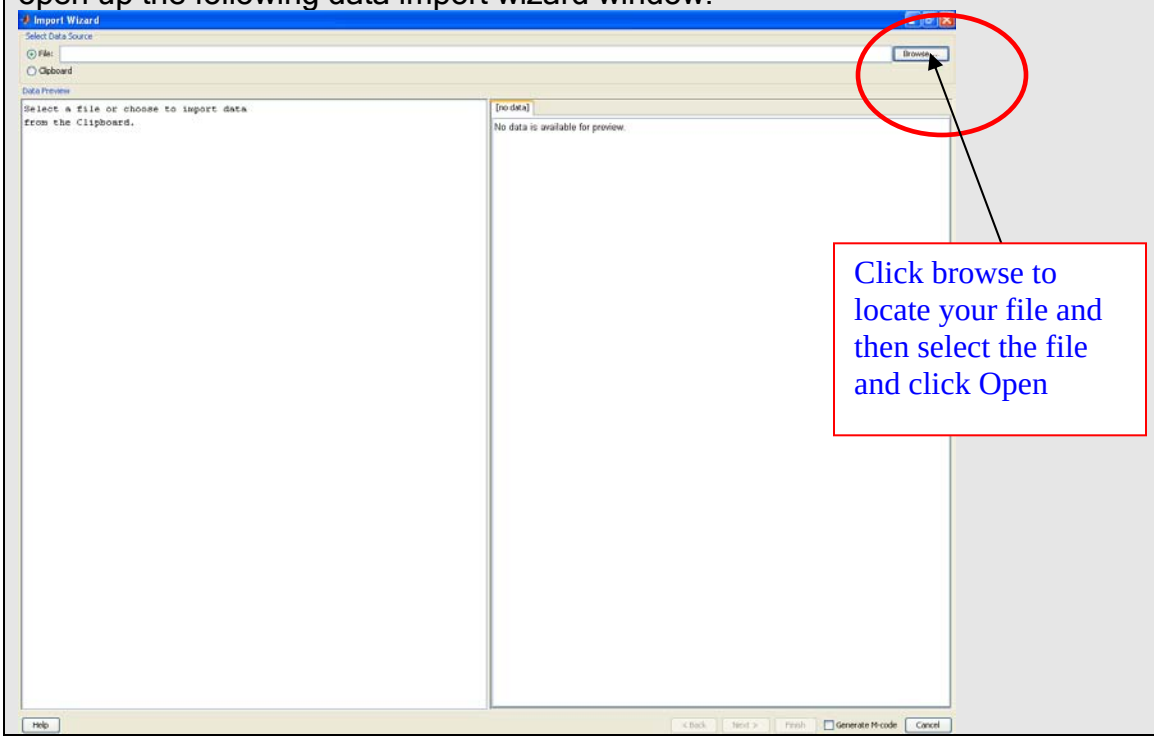


Figure Ex-2: Selection of a variable for loading into DVAtool

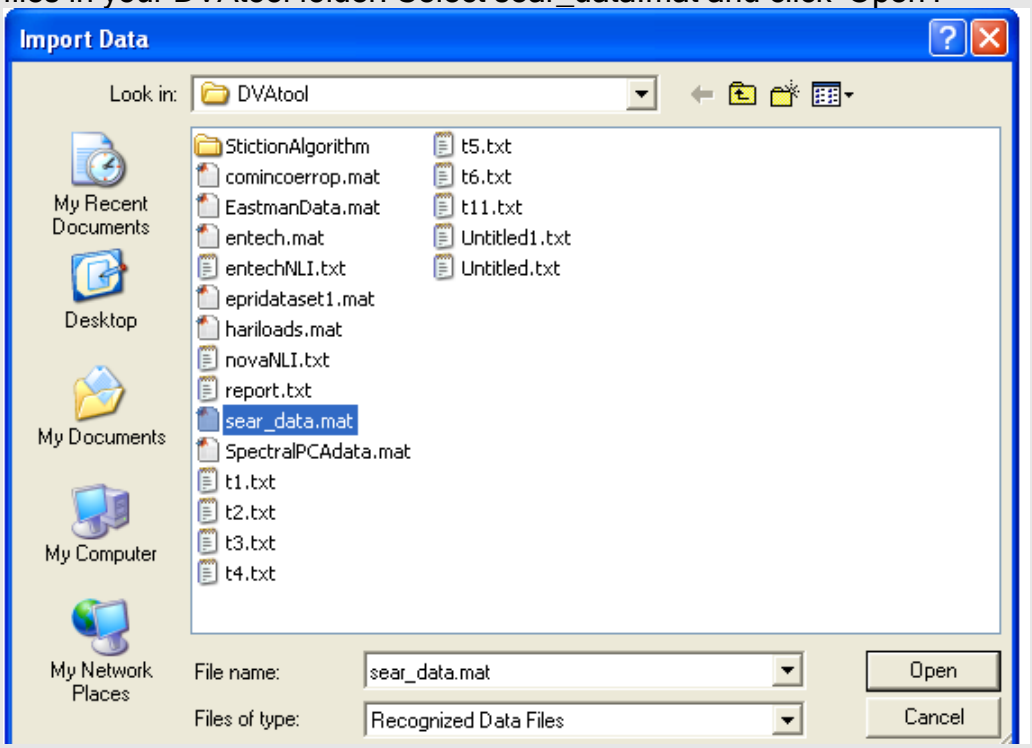
This 'Variable Selection' window shows the available variables in the workspace. Select '**errmat**' using mouse and click 'Done' button at the bottom of the window. This will load the data into the GUI.

Loading Data from a Matlab recognizable File:

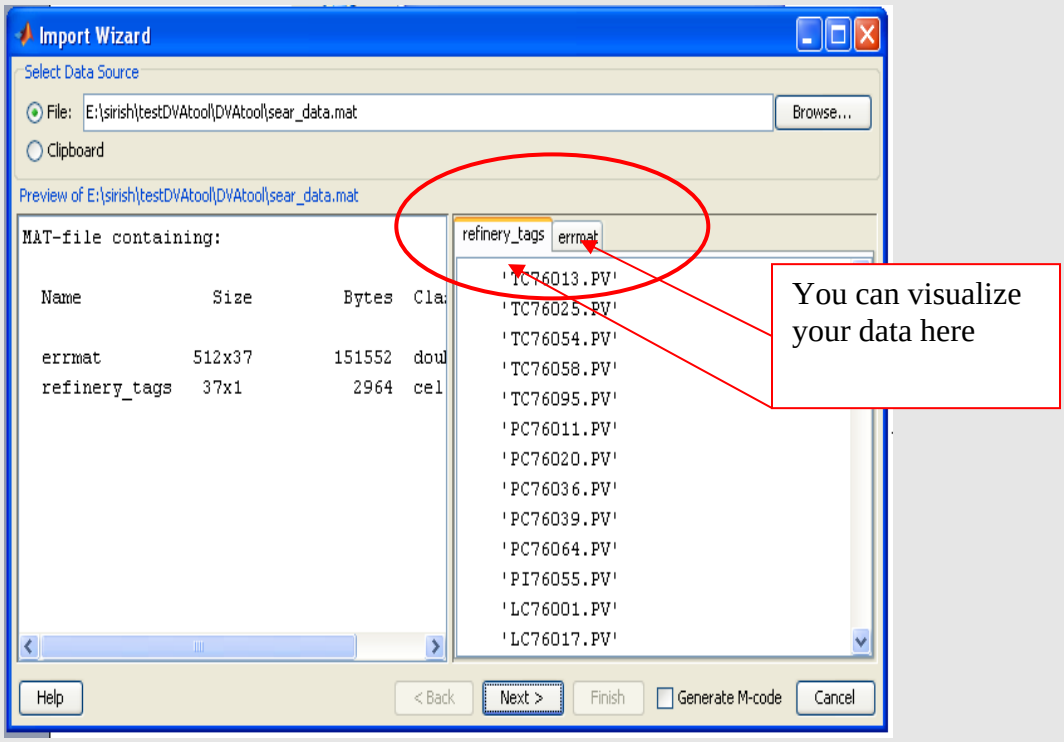
Click '**Data from File'** pushbutton to load data from any Matlab recognizable file. This will open up the following data import wizard window.



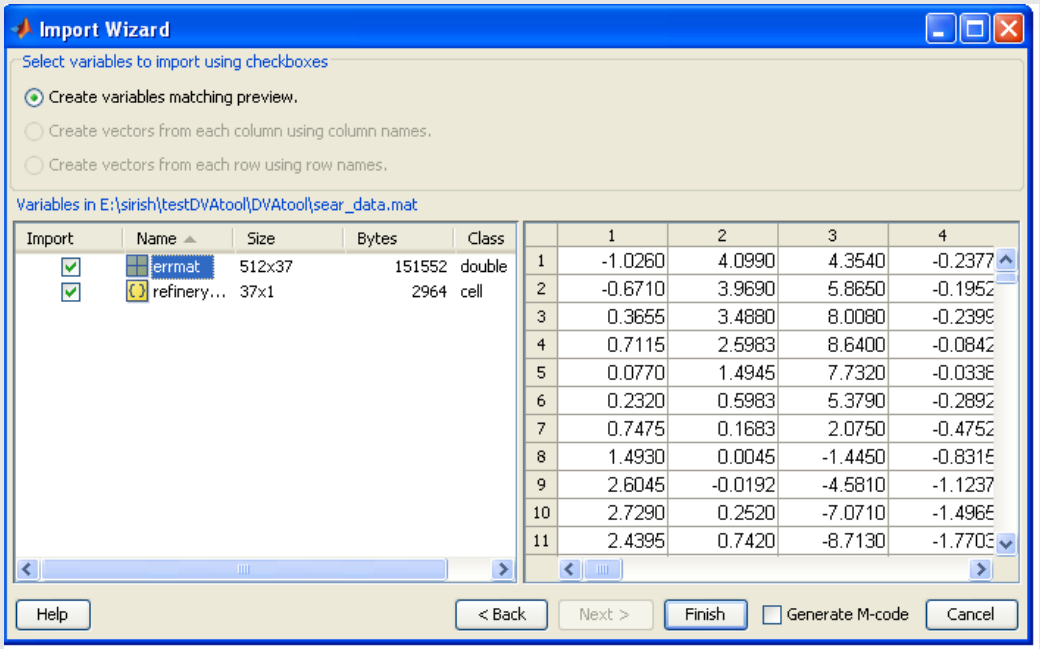
Now, click ‘browse’ to locate your file. For example, you may find the following files in your DVAtool folder. Select sear_data.mat and click ‘Open’.



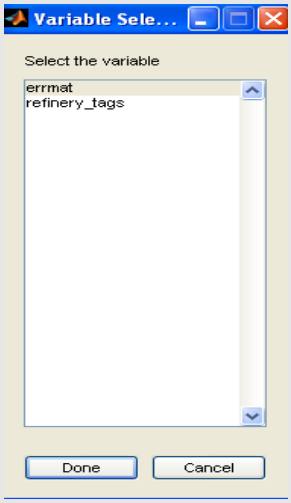
This will load the data into the data import wizard and it will look like the following:



Now you can view your data, tagnames, etc. Then click **next** to select your desired variables.

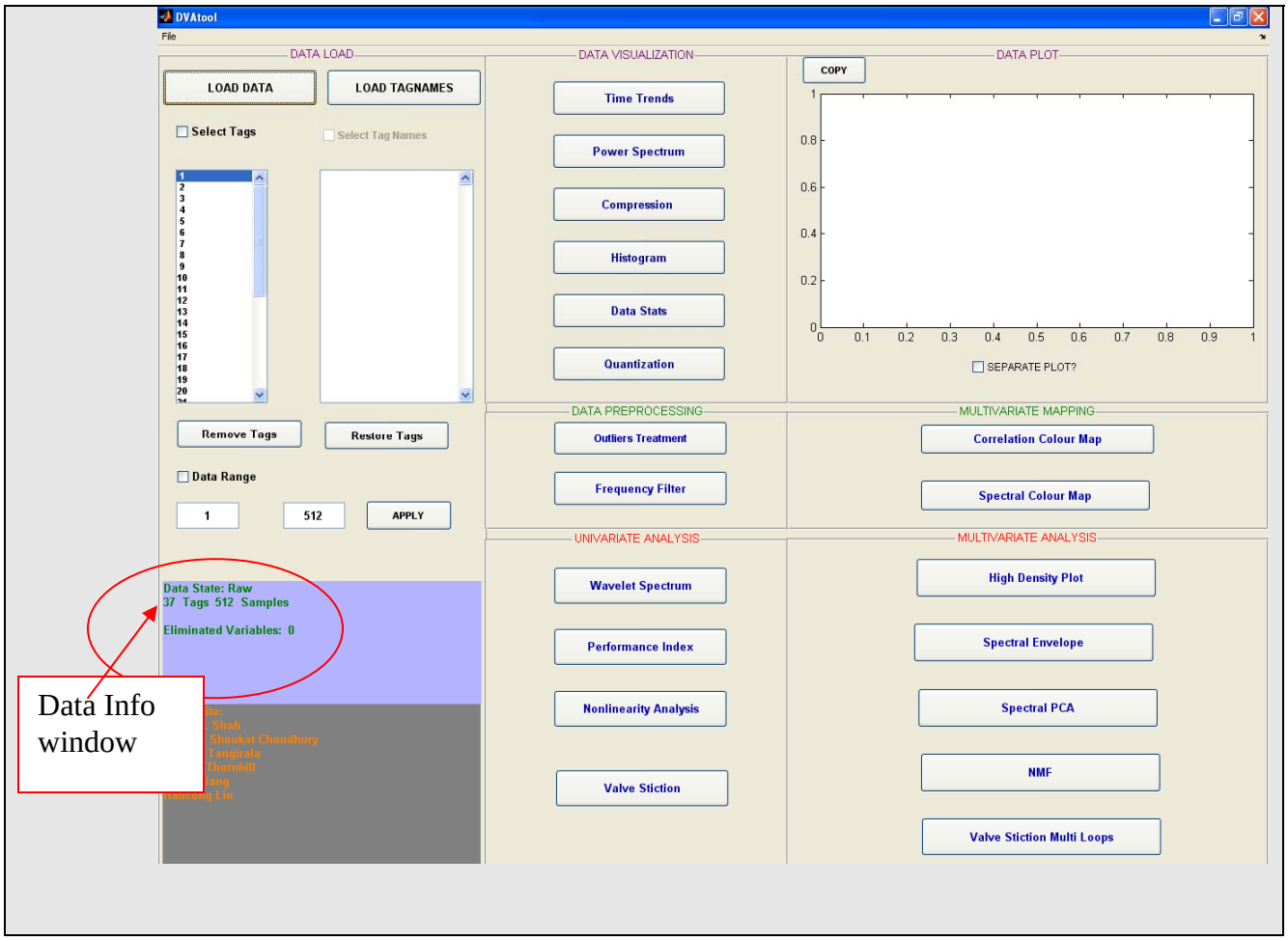


For example, if you select errmat, it shows the data into the right side window. Now, selecting errmat and refinery tags and clicking finish will load both variables into the Matlab workspace and will open up the following window.



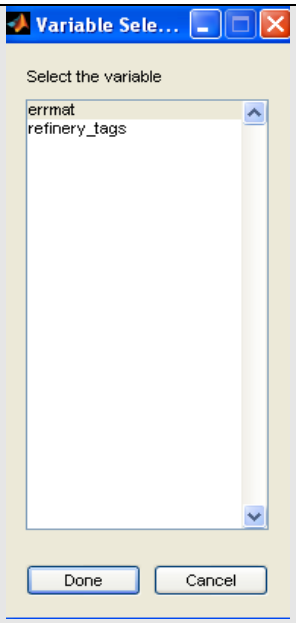
Now, you can choose the variable you like and press ‘Done’ to load it into the DVAtool.

Now the GUI should look like the following:


DVAtool
File
DATA LOAD
LOAD DATA
LOAD TAGNAMES
Select Tags
Select Tag Names
Remove Tags
Restore Tags
Data Range
1
512
APPLY
Data State: Raw
37 Tags 512 Samples
Eliminated Variables: 0
DATA VISUALIZATION
Time Trends
Power Spectrum
Compression
Histogram
Data Stats
Quantization
DATA PLOT
COPY
SEPARATE PLOT?
DATA PREPROCESSING
Outliers Treatment
Frequency Filter
MULTIVARIATE MAPPING
Correlation Colour Map
Spectral Colour Map
UNIVARIATE ANALYSIS
Wavelet Spectrum
Performance Index
Nonlinearity Analysis
Valve Stiction
MULTIVARIATE ANALYSIS
High Density Plot
Spectral Envelope
Spectral PCA
NMF
Valve Stiction Multi Loops
Data Info window

1.2 **Load Tagnames**: This is an optional pushbutton. If tagnames or variable names of the data are available, you can load the tagnames of the data by clicking '**LOAD TAGNAMES**'. Number of tagnames must be equal to the number of tags loaded to the GUI. Once you load the TagNames, the titile of the pushbutton gets changed to **"CLEAR TAGNAMES".**

As soon as you load the data to GUI, 'the Data Info' box located at the left-bottom side will show the information such as how many tags and how many data samples are loaded to the GUI.



load the Tagnames (Example - cont'd)

clicking the 'LOAD TAGNAMES' toggle button will show the 'Variable Selection' window again (shown below):

Select 'refinery_tags' and click 'Done' button to load the tagnames in the GUI.
The 'Data Info' window shows the following information:

It shows that the loaded data in the GUI have 37 tags and each tag has 512 samples.

1.3 Copy right Info

Acknowledgement:

Contributions in various forms from the following people are gratefully acknowledged:

1. Prof. Nina F. Thornhill, Imperial College London, UK
2. Dr. Hancong Liu, former PDF, UofA
3. Hailei Jiang, former graduate student, UofA

1.4 Selecting a subset of variables (tags) for Analysis:

Below the ‘LOAD DATA’ pushbutton, there is a ‘tick box’ called ‘Select Tags’. You can choose a particular Tag or a number of Tags for your analysis. You can also do the same using ‘Select Tagnames’ pushbutton. For example, in the previous example, if it is desired to use only first 10 variables for a particular analysis, one can do it in two ways. 1. First, you check the ‘select tags’ tick box and then simply hold the shift key of your keyboard and select the first 10 variables with mouse click. 2. Alternatively, after checking the ‘select tags’ tick box, you can eliminate all other variables from the GUI using the **‘Remove Tags’** pushbutton at the bottom of the taglist box. You can also restore the eliminated tags using the ‘Restore Tags’ buttons provided at the bottom of the tagnames list box.

1.5 Selecting a particular data window or a range of the data for Analysis:

Above the Data Info panel, there is an option to select data range for your analysis. For example, if you like to use only a certain number of samples of the loaded data, you can specify the lower sample number and the higher sample number in the given box and press ‘Apply’. This will make only the selected range of data available to all functions of the DVAtool. If you change your mind regarding the range selection, simply uncheck the ‘Data range’ checkbox; which will automatically reload the original data to the toolbox and will make it available to all functions of DVAtool again.

2 **DATA VISUALIZATION** section:

The middle-top panel is the **DATA VISUALIZATION** section. The loaded data can be quickly visualized with the advantage of mouse-click using this section.

2.1 Time Trends: Clicking the ‘**Time Trends’** pushbutton will plot the time series data against the sample number in the figure window of ‘DATA PLOT’ panel located on the top-right corner of the GUI. The figure title shows the information regarding the tag or time series. There are two buttons at the left-bottom and right-bottom of the

plot. Clicking the '**Next**' button will plot the next tag and the '**Prev**' button will plot the previous tag.

2.2 Power Spectrum: Clicking the **'Power Spectrum'** button will plot the power spectrum of the plot in the 'Data Plot' window.

2.3 Histogram: Clicking the '**Histogram**' button will pop-up a window asking for 'the number of desired bins' for the histogram. The default value is 20. Once this information is supplied, the histogram of the time series data will appear in the 'Data Plot' window.

2.4 Data Stats: This function gives you the basic statistical information such as mean, median, standard deviation and median absolute deviation of the data. Clicking the **'Data Sats'** will pop-up a window asking to select the desired statistics. Once they are selected, a notepad table consisting of the data information and their statistics will open up.

2.5 Compression: Compression presents a quantitative information regarding the quality of the data. If a compression factor of 3 or more is found for a time series or tag, this particular tag/time series may not be worth for further analysis.

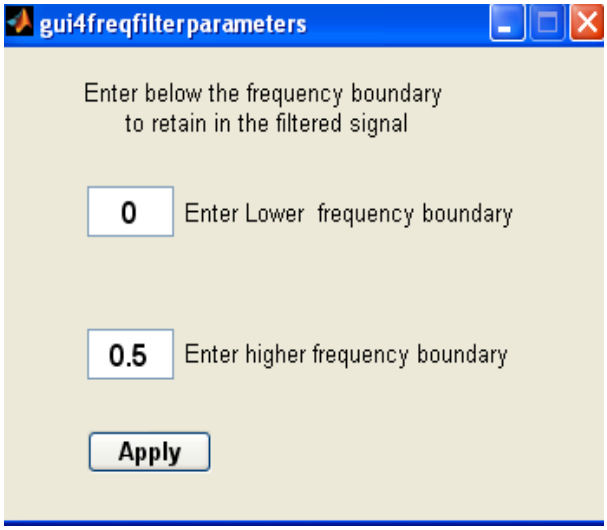
2.6 Quantization: Quantization presents another quantitative information regarding the quality of the data that may be lost during the analog to digital conversion. If a quantization factor of 0.4 or more is found for a time series or tag, this particular tag/time series may not be worth for further analysis.

3.0 Data Preprocessing: The central part of the toolbox shows the "Data Preprocessing" panel. Currently, it can perform two functions – 1. Outliers detection and replacement 2. Data Filtering

3.1 Outliers Treatment: This is a toggle-button. Clicking this will detect outliers in each time series data and will replace them using a suitable statistical technique. The original raw data is now replaced by the outliers-treated data. Data after outlier treatment is only available to all functions of the toolbox now. Notice

that the title of the button is already changed to “Work with original data”. By clicking the button again will restore the original data into the toolbox.

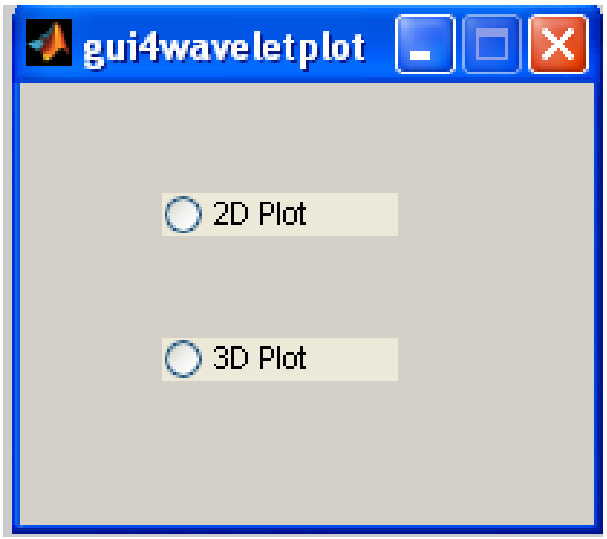
3.2 Frequency Filter: This is a frequency domain notch type bandpass Weiner filter. Clicking this button will pop up the following window asking for the lower and upper boundary of the filter.



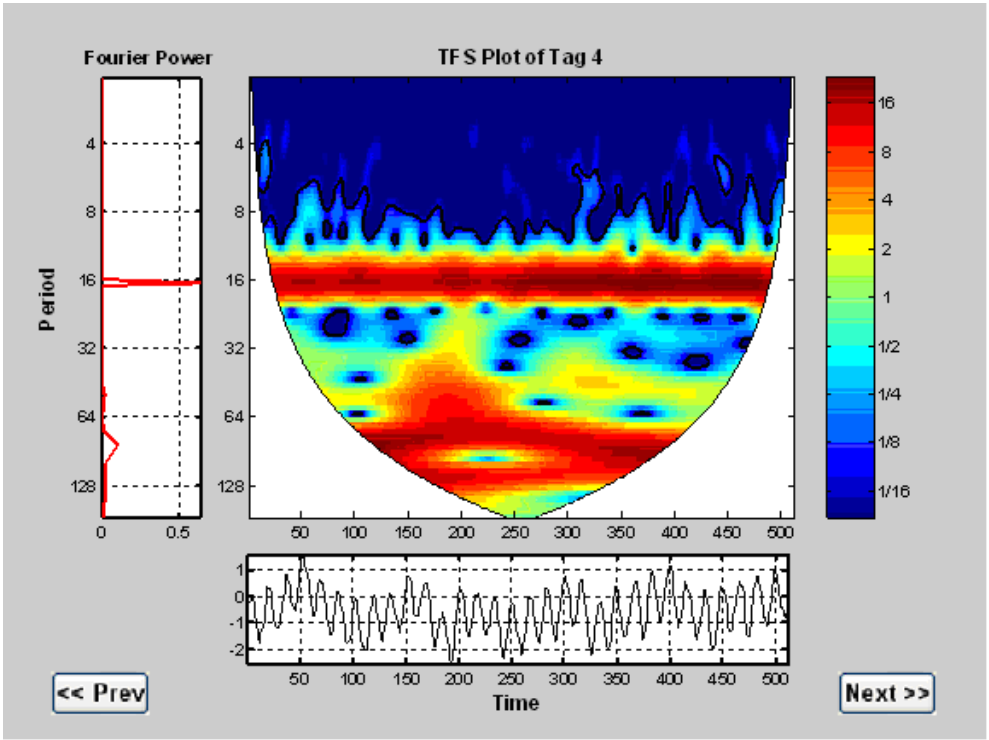
Once boundaries of the filter are specified, press ‘Apply’. It will remove all other frequencies of the signal or time series outside the specified boundary. Notice that the title of the filter pushbutton has now been changed to “Use Unfiltered Data”. By clicking the button again will restore the original data into the toolbox.

4.0 Univariate Analysis: The middle-bottom panel of the DVAtool is the Univariate Analysis section. Most of the analysis of this section is based on the single time series variable.

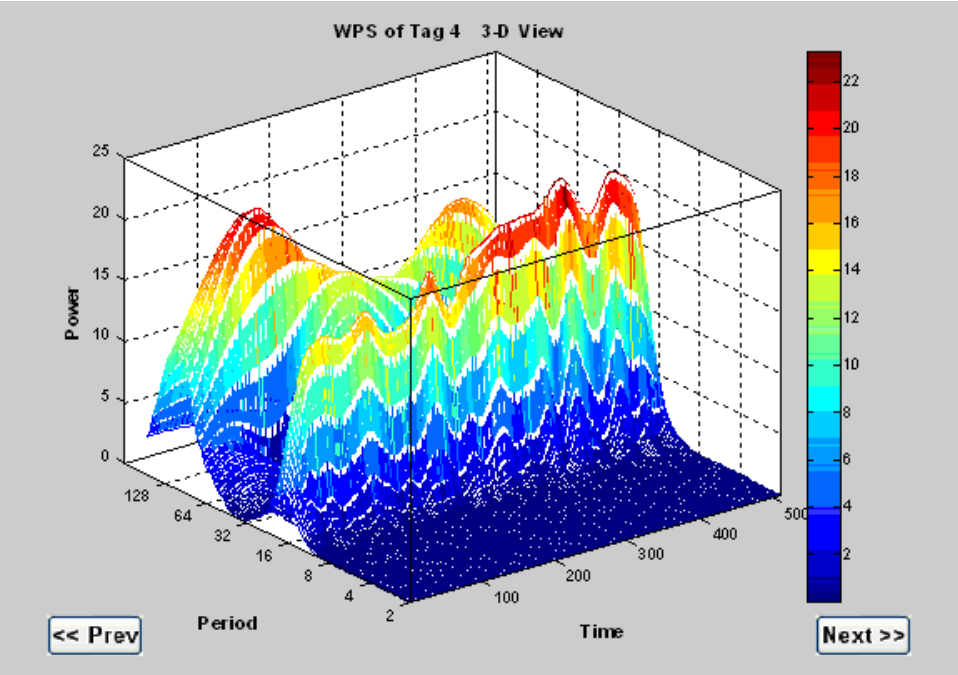
4.1 Wavelet Spectrum: This function plots the wavelet power spectrum either in a 2-D plot or in a 3-D plot. Clicking this button will open up the following pop-up window asking to choose whether to plot a 2-D or a 3-D plot.



4.1.1 **Two Dimensional (2-D) Wavelet Spectrum**: Selecting '2D Plot' plot option will produce a figure containing three subplots in a nice compact way. An example is shown in the following figure. The bottom plot is the time series data; the left shows the Fourier Power spectrum and the center plot shows the contour plot of the wavelet power spectrum. Morlet wavelet is used in the calculation.

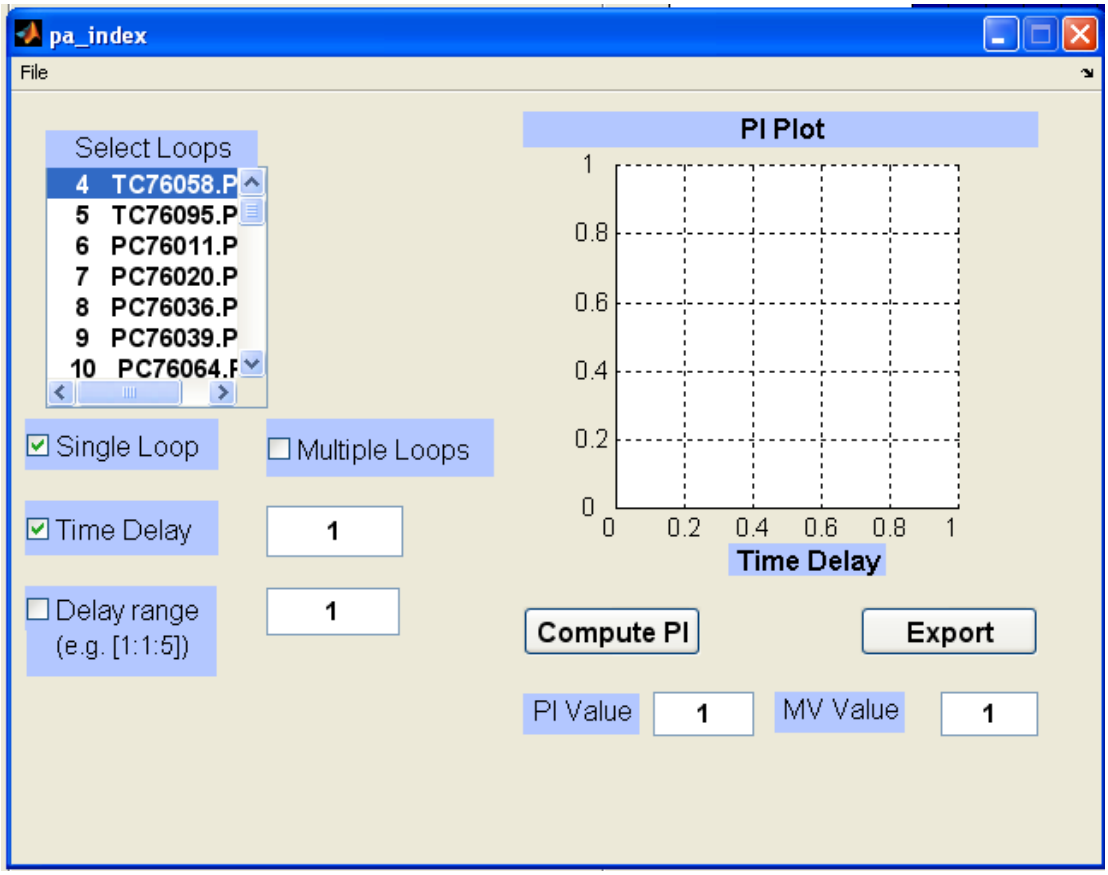


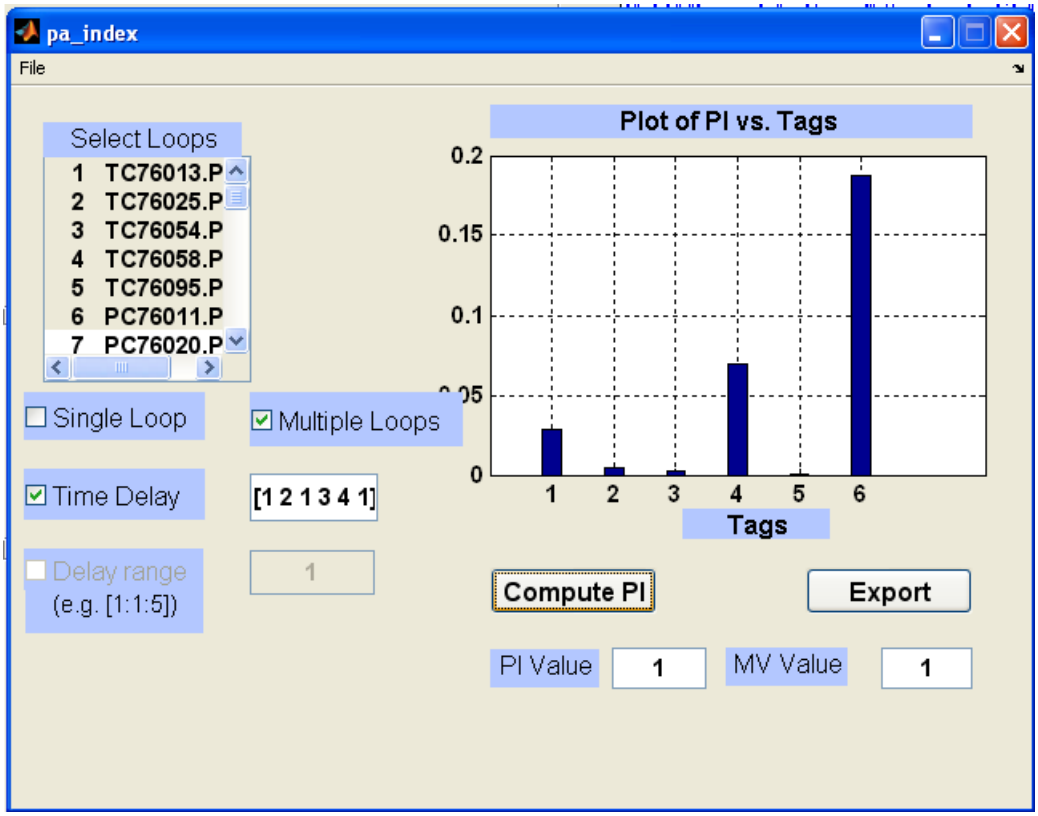
4.1.2 Three Dimensional (3-D) Wavelet Spectrum: Selecting 3D Plot generates a three dimensional wavelet spectra plot as shown in the following figure.



4.2 Performance Index: This function estimates minimum variance performance index for control loop performance assessment. The controller performance index always lie in the range of 0 to 1, where 0 is for the worst performance and 1 is for the best or minimum variance performance. Clicking the 'Performance Index' pushbutton will open up the following figure. This will have all data captured from DVAtool data list box. Select any loop and press 'Compute PI'. This will show the computed performance index in the 'PI Value' box. The 'MV Value' box will show the calculated minimum variance for the specified time delay. Performance index calculation needs the time delay information. If a range of time delay information is provided in the box 'Delay Range', performance indices for all these lags or delays will be calculated and they will be plotted in the 'PI plot' box.

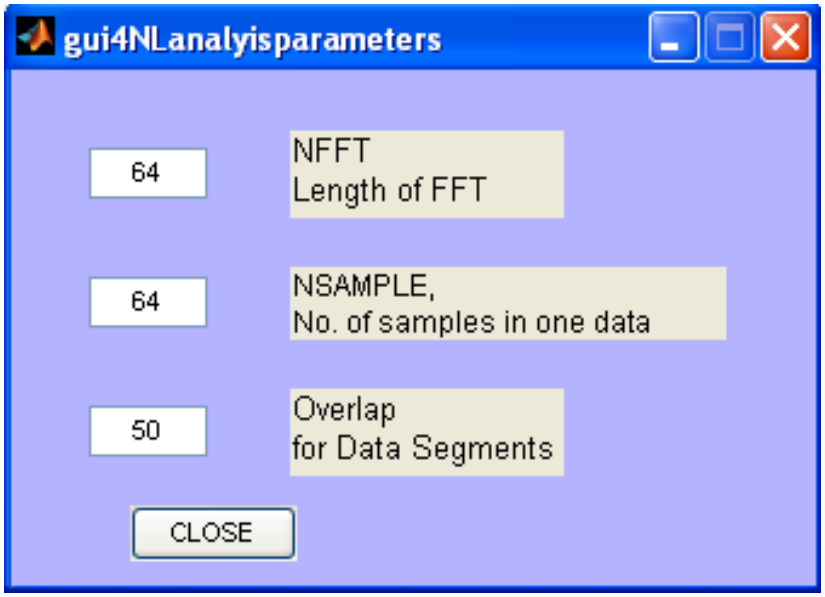
One can also calculate performance indices for multiple loops at a time. Check the ‘Multiple Loops’ check box. Then by holding shift key of your keyboard click the loops for which you like to calculate performance index. Now specify the time delays for them in a vector in the ‘Time Delay’ box. Now, click ‘Compute PI’. This will compute the performance indices and will plot them against the tag number in the PI plot box. An example is shown below. The calculated PI and MV values can be exported to a file by clicking the ‘Export’ button.





4.3 Nonlinearity Analysis:

This function calculates Non-Gaussianity Index (NGI), Nonlinearity Index and Total Nonlinearity Index for each time series data or variable. Clicking the 'Nonlinearity Analysis' button will pop-up a window asking to specify the parameters for nonlinearity calculation.

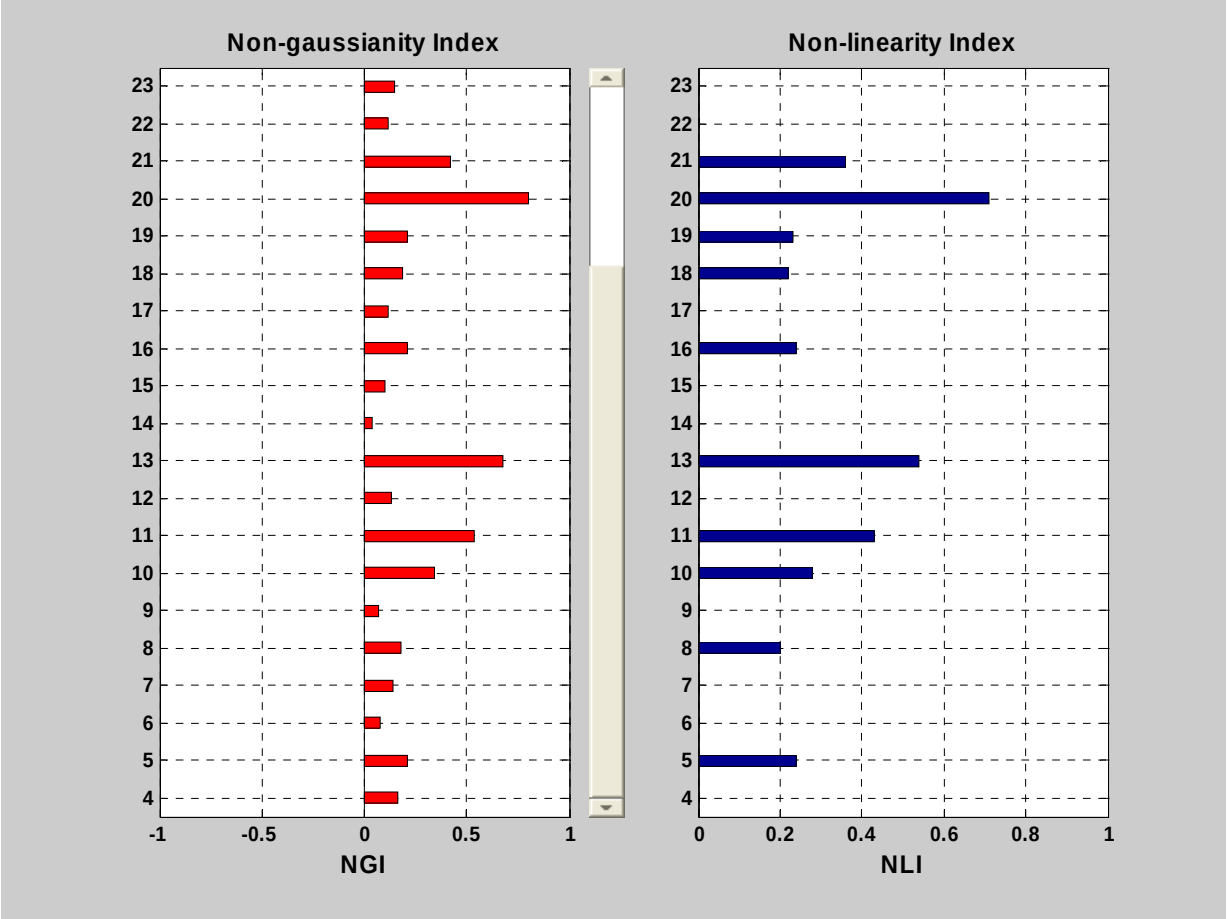


Nsample – The number of data points in one data segment. It should be at least two times of the period of the time series if the data is periodic.

NFFT – Length of Fourier Transform can be chosen as equal to the Nsample

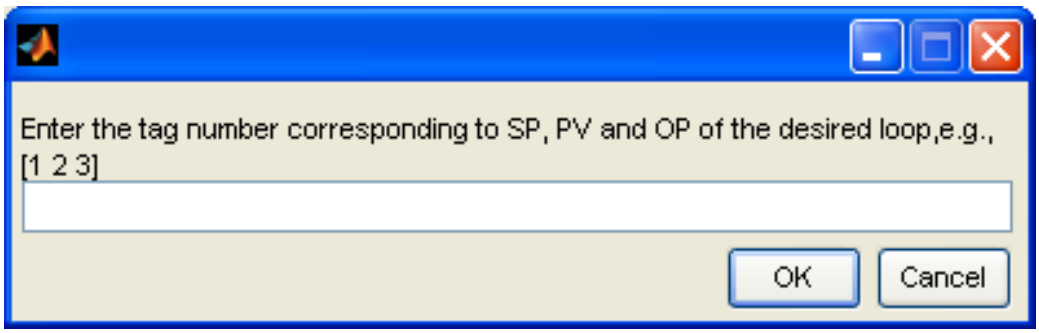
Overlap – If the data length is short say less than 1000 samples, allow some overlapping of the data segments.

Once the parameters are specified, NGI and NLI values are calculated. They are stored in a file as well as they appear in a figure.



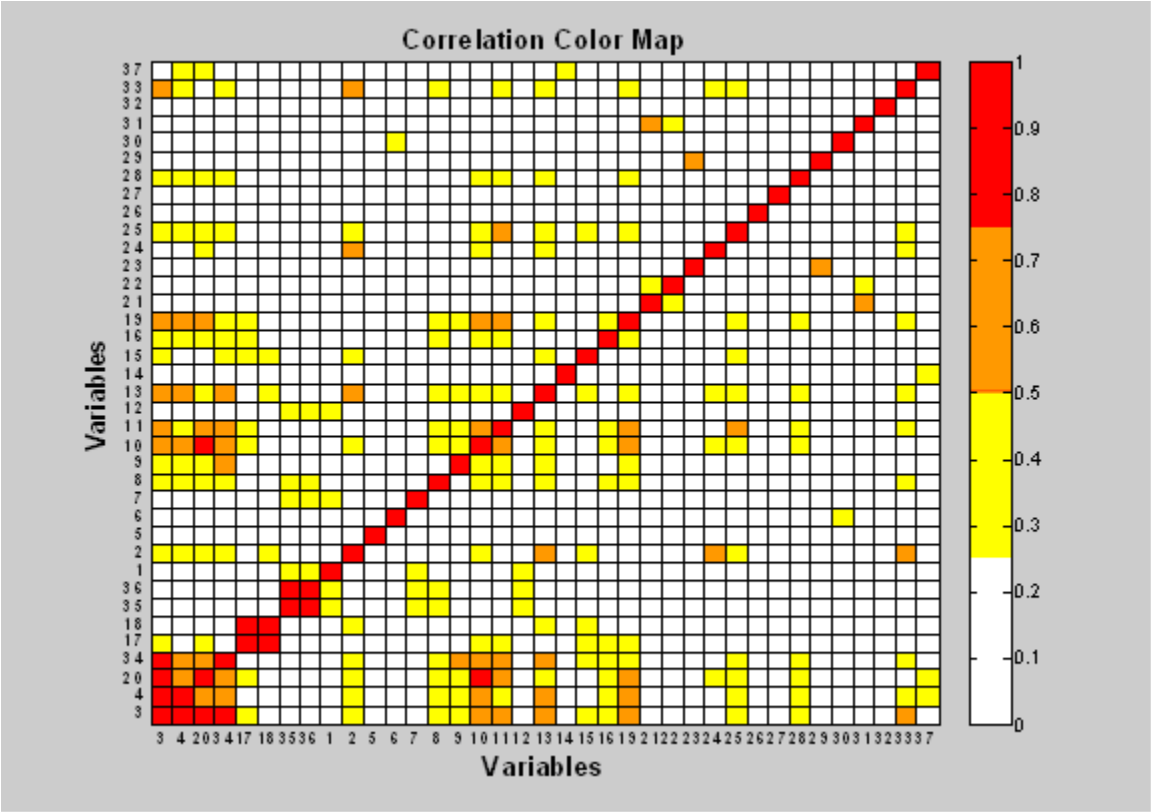
4.4 Valve Stiction:

This function can detect and quantify stiction in a control loop. It needs SP, PV and OP data of a control loop. If SP is not available, the mean of PV is assumed as SP data. Clicking this function will pop a window asking to specify the SP, PV and OP data. Once they are specified, stiction is detected and quantified. The result is returned in the Matlab workspace.



5.0 Multivariate Mapping: This panel is located just below the 'Data Plot' panel in the middle-right part of the toolbox. It has two functions now.

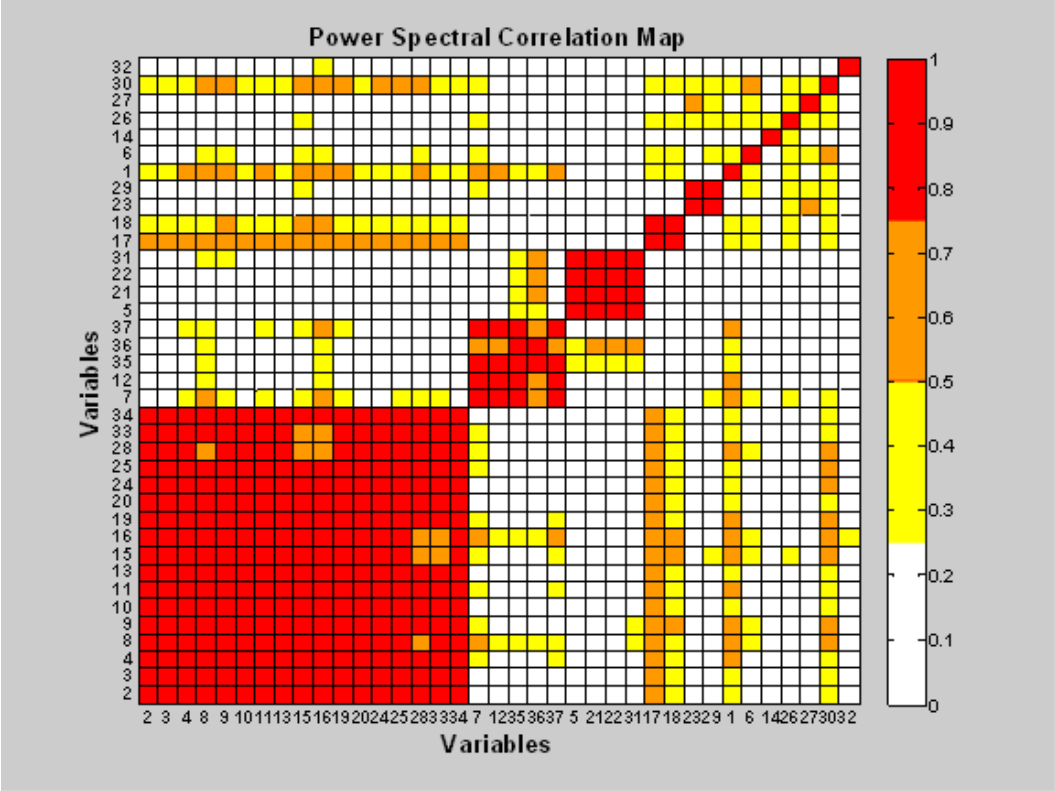
5.1 Correlation Color Map: This function calculates the cross-correlation matrix of the data loaded in the DVAtool and plots the matrix as a Color Map. The most correlated variables are grouped together. This plot is useful to find the set of variables from a data set, which are correlated to each other in the time domain.

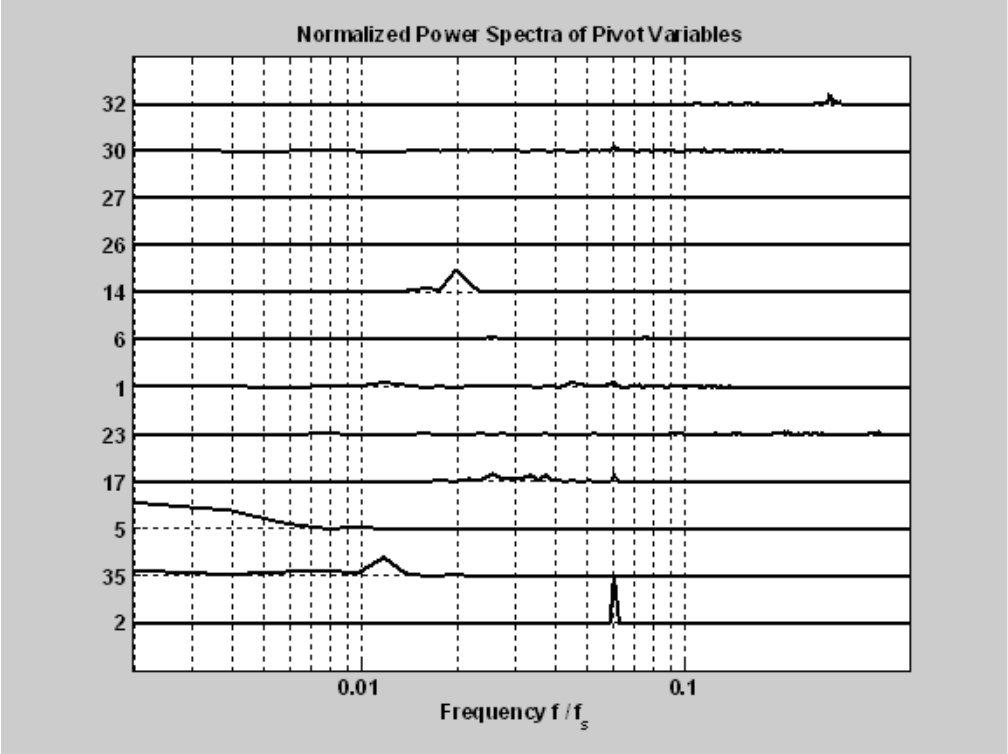


5.2 Spectral Color Map:

This function calculates the spectral correlation present in a data set. First, it calculates the power spectra of each variable and then it finds the power spectral correlation indices (PSCI) of the variables. The power spectral correlation index (PSCI) is defined as the correlation between the power spectra of two different measurements or variables. It is a measure of the similarity of spectral shapes, i.e., measure of the commonness of

frequencies of oscillations. This function is helpful in finding the variables which have common or similar oscillations. The variables with similar power spectral shapes may also be grouped together. Finally, PSCIs are plotted as a color map. Clicking the button, 'Spectral Color Map' will pop-up a window asking for specifying the number of colors you like to have in the color map and whether you like to group the similar oscillations. Once they are specified, it will produce two figures. One is the spectral color map and the other is the Pivot variables for each group present in the color map.

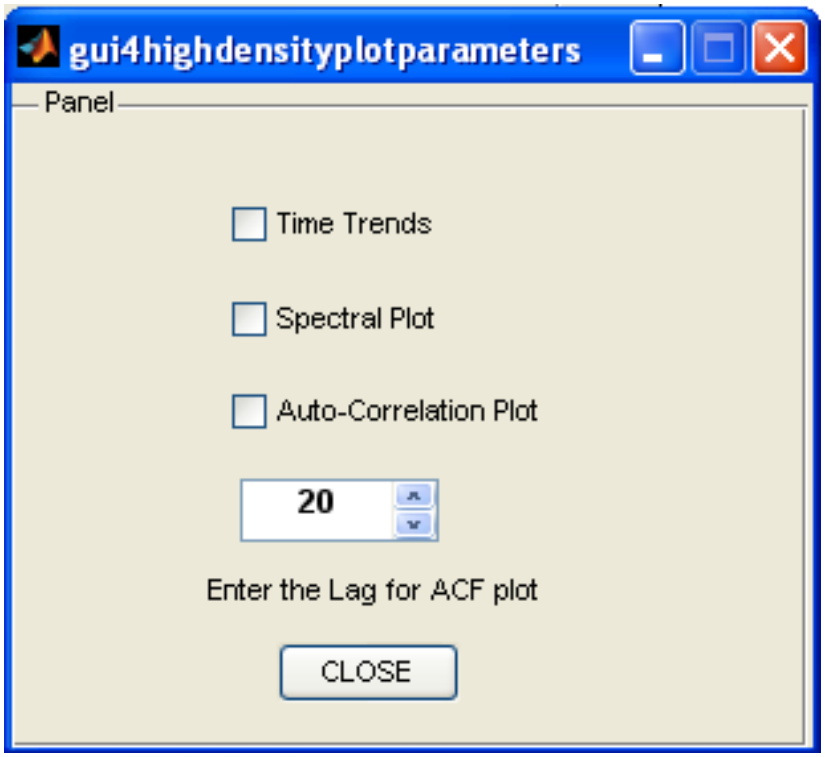



Normalized Power Spectra of Pivot Variables
32
30
27
26
14
6
1
23
17
5
35
2
0.01
0.1
Frequency f / f_s

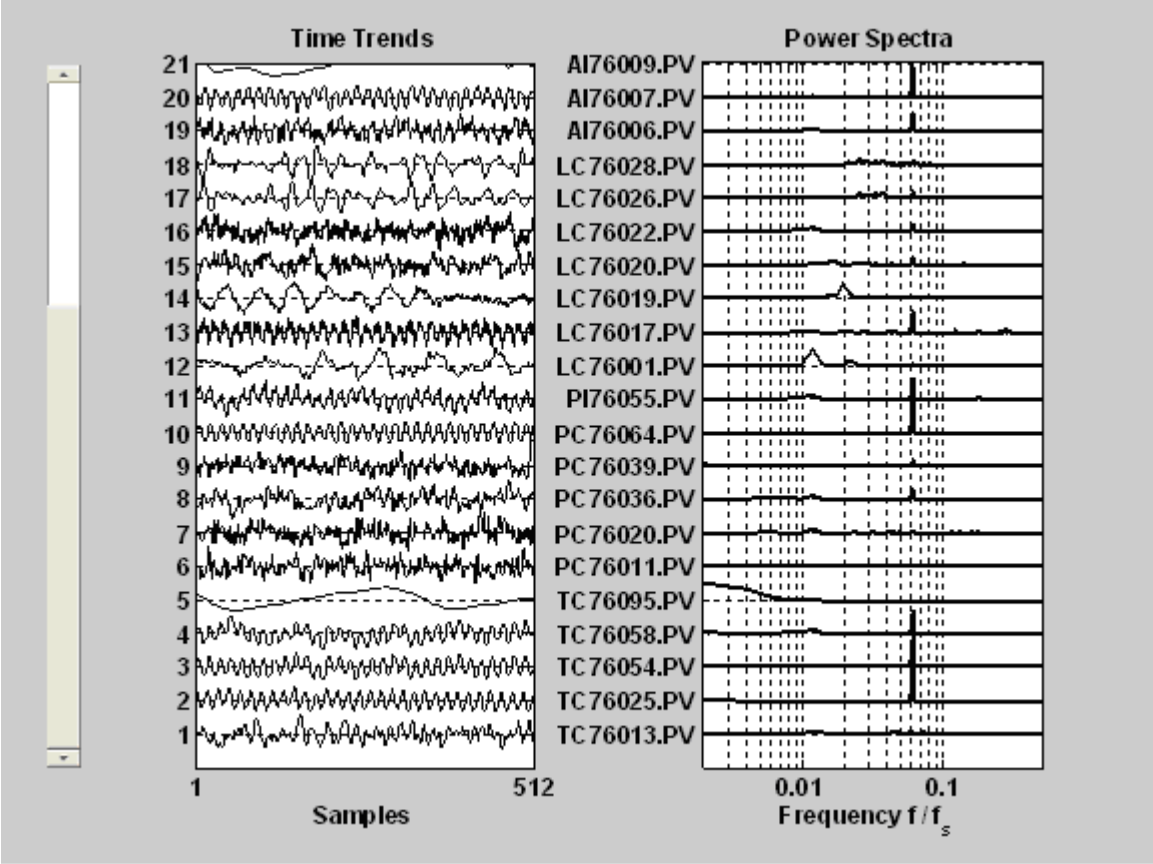
6. Multivariate Analysis:

6.1 High Density Plot

This function can plot all time series data loaded in the GUI, their spectra and/or their auto-correlation function (acf) in one nice compact figure. From this figure, one can easily visualize the time domain and spectral nature of the data. It is also helpful in detecting the presence of common oscillation(s) in the data. Clicking the 'High Density Plot' button will pop-up a subwindow for specifying your options.

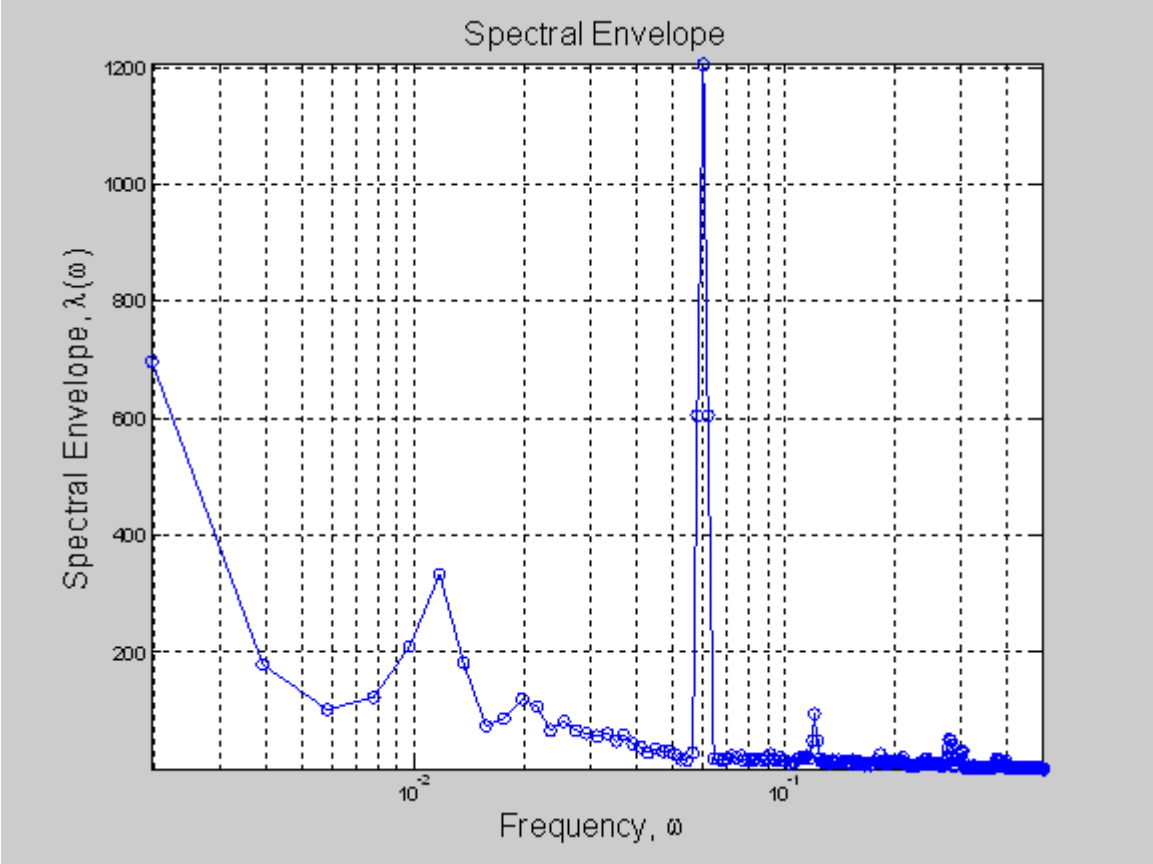


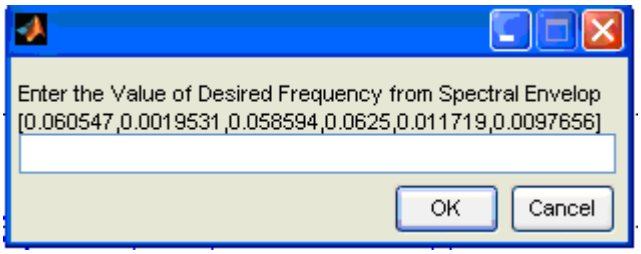
Check the appropriate boxes of your choice. A plot will be generated as per your selected options. For example, if only 'Time Trends' and 'Spectral Plot' are checked, a plot showing all time trends and their power spectra will be produced. If there are more than 20 tags or variables, a scroll bar at the left of the plot will be produced. Once scroll through the variables and their spectra using this scroll bar.

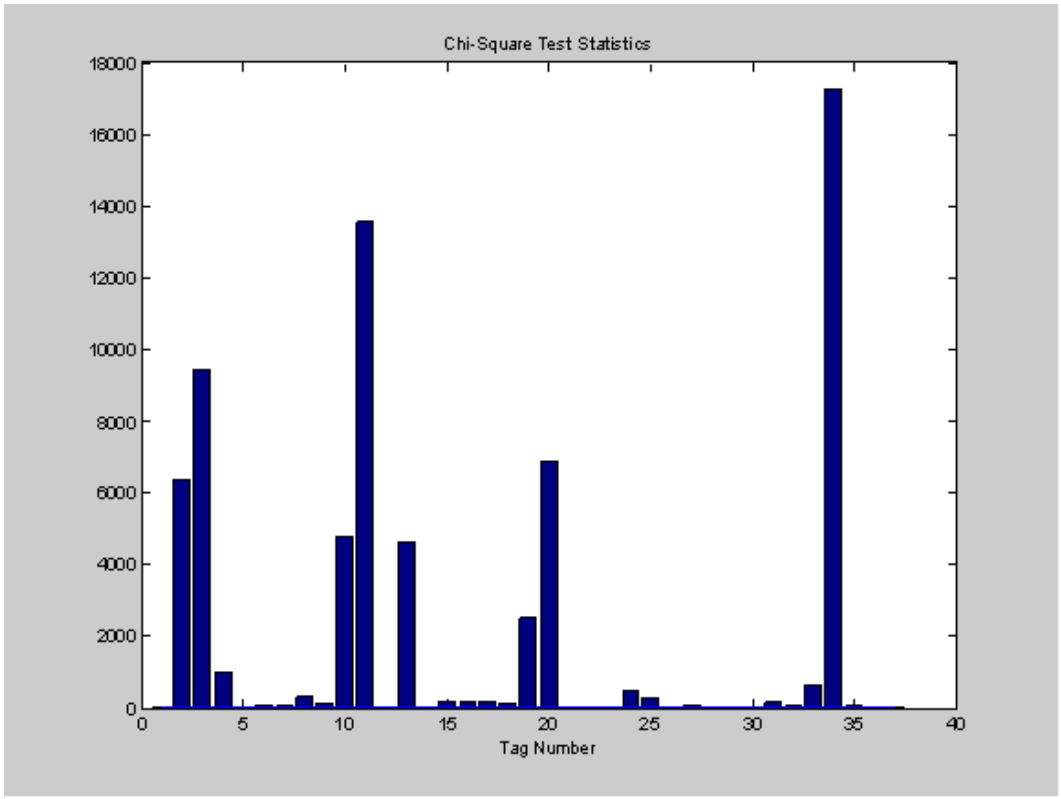


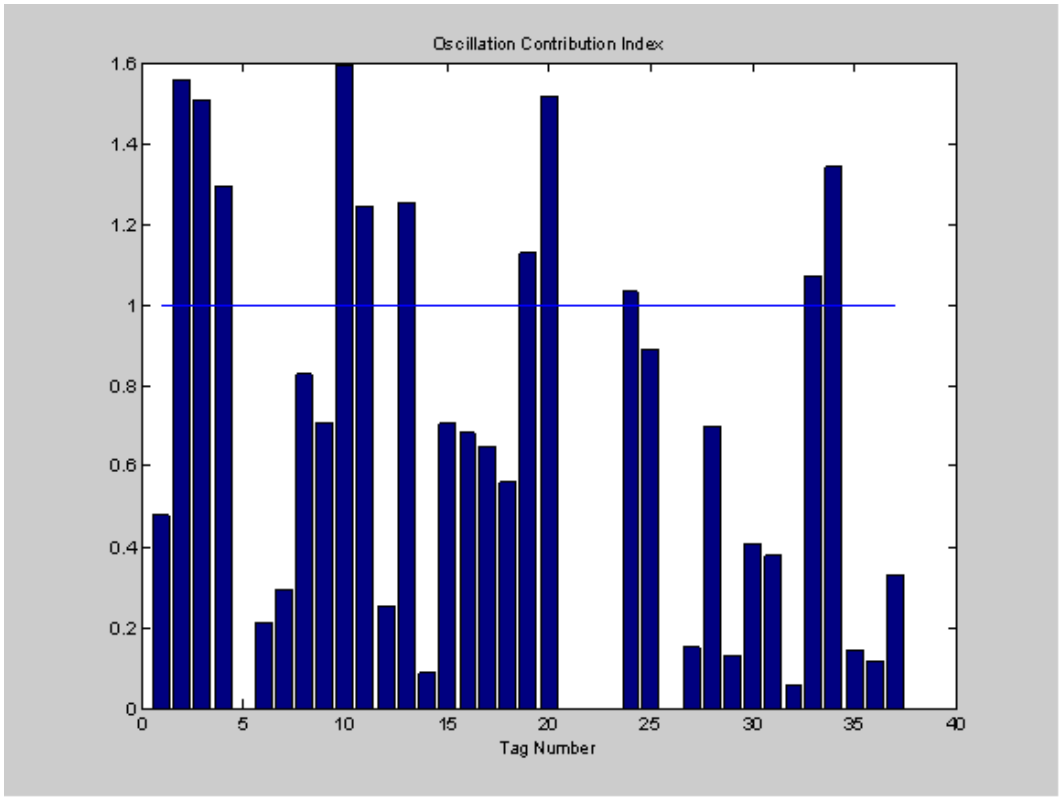
6.2 Spectral Envelope

The spectral envelope is a frequency domain method, which can be used to troubleshoot plantwide oscillations. Clicking the ‘Spectral Envelope’ button will produce the spectral envelop plot indicating the dominant common frequencies in the data set. A pop-window will ask to specify the oscillation, whose root-cause is to be diagnosed. Once the frequency is specified, it will produce two more plots. One is the chi-square test statistics plot and the other is oscillation contribution index. The tag with the highest test statistics or with the highest contribution index is more likely the root-cause of this common oscillation.


Spectral Envelope
Spectral Envelope, λ(ω)
Frequency, ω
1200
1000
800
600
400
200
10^-2
10^-1


Enter the Value of Desired Frequency from Spectral Envelop
[0.060547,0.0019531,0.058594,0.0625,0.011719,0.0097656]
OK
Cancel


Chi-Square Test Statistics
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
30
35
40
Tag Number


Oscillation Contribution Index
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
40
Tag Number

6.3 Spectral PCA: *To be done*

6.4 Nonnegative Matrix Factorization (NMF): *To be done*

6.5 Stiction in Multiloops: *To be done*