ESERCITAZIONI
MATLAB – Nozioni

Programmazione

https://it.mathworks.com/help/matlab/programming-and-data-types.html?s_tid=CRUX_lftnav

Gestione delle eccezioni

Acquisire dati sugli errori

Qualsiasi codice MATLAB® che rileva un errore e lancia un'eccezione costruisce un oggetto `MException`. Il codice MATLAB può lanciare eccezioni predefinite o eccezioni costruite dall'utente.

Funzioni

`try, catch`	Eseguire le dichiarazioni e catturare gli errori risultanti
`MException`	Capture error information
`addCause`	Record additional causes of exception
`addCorrection`	Provide suggested fix for exception
`getReport`	Get error message for exception
`MException.last`	Return last uncaught exception
`rethrow`	Rethrow previously caught exception
`throw`	Throw exception
`throwAsCaller`	Throw exception as if occurs within calling function
`matlab.lang.correction.AppendArgumentsCorrection`	Correct error by appending missing input arguments
`matlab.lang.correction.ConvertToFunctionNotationCorrection`	Correct error by converting to function notation *(Da R2019b)*
`matlab.lang.correction.ReplaceIdentifierCorrection`	Correct error by replacing identifier in function call *(Da R2019b)*

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Programmazione

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Gestione delle eccezioni

Funzioni

try, catch

Eseguire le dichiarazioni e catturare gli errori risultanti

Sintassi

```
try
   statements
catch exception
   statements
end
```

Creare due matrici che non possono essere concatenate verticalmente.

```
A = rand(3);
B = ones(5);

C = [A; B];
```

```
Error using vertcat
Dimensions of matrices being concatenated are not consistent.
```

Utilizzare `try/catch` per visualizzare ulteriori informazioni sulle dimensioni.

```
try
   C = [A; B];
catch ME
   if (strcmp(ME.identifier,'MATLAB:catenate:dimensionMismatch'))
      msg = ['Dimension mismatch occurred: First argument has ', ...
            num2str(size(A,2)),' columns while second has ', ...
            num2str(size(B,2)),' columns.'];
        causeException = MException('MATLAB:myCode:dimensions',msg);
        ME = addCause(ME,causeException);
   end
   rethrow(ME)
end
```

```
Error using vertcat
Dimensions of matrices being concatenated are not consistent.

Caused by:
    Dimension mismatch occurred: First argument has 3 columns while second has 5 columns.
```

Se le dimensioni della matrice non concordano, MATLAB® visualizza ulteriori informazioni sulla mancata corrispondenza. Tutti gli altri errori sono visualizzati come di consueto.

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Programmazione

https://it.mathworks.com/help/matlab/programming-and-data-types.html?s_tid=CRUX_lftnav

tic

Start stopwatch timer

Syntax

```
tic
timerVal = tic
```

Description

`tic` works with the `toc` function to measure elapsed time. The `tic` function records the current time, and the `toc` function uses the recorded value to calculate the elapsed time.

`timerVal = tic` stores the current time in `timerVal` so that you can pass it explicitly to the `toc` function. Passing this value is useful when there are multiple calls to `tic` to time different parts of the same code. `timerVal` is an integer that has meaning only for the `toc` function.

Examples

Measure Time to Create Random Matrices

Measure the time required to create two random matrices.

```
tic
A = rand(12000,4400);
B = rand(12000,4400);
toc
```

```
Elapsed time is 1.538291 seconds.
```

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Importazione dei dati e analisi

Importazione ed esportazione di dati

https://it.mathworks.com/help/matlab/data-import-and-export.html

https://it.mathworks.com/help/matlab/import_export/write-to-delimited-data-files.html#br2ypq2-1

https://it.mathworks.com/help/matlab/import_export/writing-to-text-data-files-with-low-level-io.html#br5_kad-1

https://it.mathworks.com/help/matlab/matlab_prog/formatting-strings.html

https://it.mathworks.com/help/matlab/ref/writelines.html

https://it.mathworks.com/help/matlab/ref/fwrite.html

https://it.mathworks.com/help/matlab/ref/fprintf.html

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Importazione dei dati e analisi

Importazione ed esportazione di dati

fprintf

Write data to text file

Examples

Print Literal Text and Array Values

Print multiple numeric values and literal text to the screen.

```
A1 = [9.9, 9900];
A2 = [8.8,  7.7 ; ...
      8800, 7700];
formatSpec = 'X is %4.2f meters or %8.3f mm\n';
fprintf(formatSpec,A1,A2)
```

```
X is 9.90 meters or 9900.000 mm
X is 8.80 meters or 8800.000 mm
X is 7.70 meters or 7700.000 mm
```

`%4.2f` in the `formatSpec` input specifies that the first value in each line of output is a floating-point number with a field width of four digits, including two digits after the decimal point. `%8.3f` in the `formatSpec` input specifies that the second value in each line of output is a floating-point number with a field width of eight digits, including three digits after the decimal point. `\n` is a control character that starts a new line.

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Importazione dei dati e analisi

Importazione ed esportazione di dati

fprintf

Write data to text file

Examples

Print Literal Text and Array Values

Print multiple numeric values and literal text to the screen.

Write Tabular Data to Text File

Write a short table of the exponential function to a text file called `exp.txt`.

```
x = 0:.1:1;
A = [x; exp(x)];

fileID = fopen('exp.txt','w');
fprintf(fileID,'%6s %12s\n','x','exp(x)');
fprintf(fileID,'%6.2f %12.8f\n',A);
fclose(fileID);
```

The first call to `fprintf` prints header text `x` and `exp(x)`, and the second call prints the values from variable `A`.

If you plan to read the file with Microsoft® Notepad, use `'\r\n'` instead of `'\n'` to move to a new line. For example, replace the calls to `fprintf` with the following:

```
fprintf(fileID,'%6s %12s\r\n','x','exp(x)');
fprintf(fileID,'%6.2f %12.8f\r\n',A);
```

MATLAB® import functions, all UNIX® applications, and Microsoft Word and WordPad recognize `'\n'` as a newline indicator.

View the contents of the file with the `type` command.

```
type exp.txt
```

```
     x          exp(x)
  0.00   1.00000000
  0.10   1.10517092
  0.20   1.22140276
  0.30   1.34985881
  0.40   1.49182470
  0.50   1.64872127
  0.60   1.82211880
  0.70   2.01375271
  0.80   2.22554093
  0.90   2.45960311
  1.00   2.71828183
```

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Importazione dei dati e analisi

Statistiche descrittive

https://it.mathworks.com/help/matlab/descriptive-statistics.html

Funzioni

Statistiche di base

`min`	Minimum elements of array
`mink`	Find k smallest elements of array
`max`	Maximum elements of array
`maxk`	Find k largest elements of array
`bounds`	Minimum and maximum values of an array
`topkrows`	Top rows in sorted order
`mean`	Media aritmetica o valore medio dell'array
`median`	Median value of array
`mode`	Most frequent values in array
`std`	Standard deviation
`var`	Variance
`rms`	Root mean square value

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Importazione dei dati e analisi

Statistiche descrittive

https://it.mathworks.com/help/matlab/descriptive-statistics.html

Funzioni

Covarianza e correlazione

cov	Covariance
corrcoef	Correlation coefficients
xcov	Cross-covariance
xcorr	Correlazione incrociata

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MATLAB – Nozioni

Importazione dei dati e analisi

Statistiche descrittive

Funzioni

mean

Media aritmetica o valore medio dell'array

Esempi

Media

Per un vettore di lunghezza finita A composto da osservazioni scalari N, la media è definita come

$$\mu = \frac{1}{N}\sum_{i=1}^{N} A_i.$$

Media delle colonne della matrice

Creare una matrice e calcolare la media di ciascuna colonna.

```
A = [0 1 1; 2 3 2; 1 3 2; 4 2 2]
```

```
A = 4×3

     0     1     1
     2     3     2
     1     3     2
     4     2     2
```

```
M = mean(A)
```

```
M = 1×3

    1.7500    2.2500    1.7500
```

Media delle righe della matrice

Creare una matrice e calcolare la media di ciascuna riga.

```
A = [0 1 1; 2 3 2; 3 0 1; 1 2 3]
```

```
A = 4×3

     0     1     1
     2     3     2
     3     0     1
     1     2     3
```

```
M = mean(A,2)
```

```
M = 4×1

    0.6667
    2.3333
    1.3333
    2.0000
```

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Importazione dei dati e analisi

Statistiche descrittive

Funzioni

mean

Media aritmetica o valore medio dell'array

Media esclusi i valori mancanti

Creare una matrice contenente valori NaN.

```
A = [1.77 -0.005 NaN -2.95; NaN 0.34 NaN 0.19]
```

```
A = 2×4

    1.7700   -0.0050       NaN   -2.9500
       NaN    0.3400       NaN    0.1900
```

Calcolare i valori medi della matrice, escludendo i valori mancanti. Per le colonne della matrice che contengono qualsiasi valore NaN, mean esegue il calcolo con gli elementi che non sono NaN. Per le colonne della matrice che contengono tutti valori NaN, la media è NaN.

```
M = mean(A,"omitnan")
```

```
M = 1×4

    1.7700    0.1675       NaN   -1.3800
```

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Importazione dei dati e analisi

Statistiche descrittive

Funzioni

std

Standard deviation

Standard Deviation

For a finite-length vector A made up of N scalar observations, the standard deviation is defined as

$$S = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}|A_i - \mu|^2},$$

where μ is the mean of A:

$$\mu = \frac{1}{N}\sum_{i=1}^{N}A_i.$$

The standard deviation is the square root of the variance.

Some definitions of standard deviation use a normalization factor N instead of $N-1$. You can use a normalization factor of N by specifying a weight of 1, producing the square root of the second moment of the sample about its mean.

Regardless of the normalization factor for the standard deviation, the mean is assumed to have the normalization factor N.

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Importazione dei dati e analisi

Statistiche descrittive

Funzioni

std

Standard deviation

Weighted Standard Deviation

For a finite-length vector A made up of N scalar observations and weighting scheme w, the weighted standard deviation is defined as

$$S_w = \sqrt{\frac{\sum_{i=1}^{N} w_i |A_i - \mu_w|^2}{\sum_{i=1}^{N} w_i}}$$

where μ_w is the weighted mean of A.

Weighted Mean

For a random variable vector A made up of N scalar observations and weighting scheme w, the weighted mean is defined as

$$\mu_w = \frac{\sum_{i=1}^{N} w_i A_i}{\sum_{i=1}^{N} w_i}$$

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Importazione dei dati e analisi

Statistiche descrittive

Funzioni

std

Standard deviation

Examples

Standard Deviation of Matrix Columns

Create a matrix and compute the standard deviation of each column.

```
A = [4 -5 1; 2 3 5; -9 1 7];
S = std(A)
```

```
S = 1×3

    7.0000    4.1633    3.0551
```

Specify Standard Deviation Weights

Create a matrix and compute the standard deviation of each column according to a weight vector `w`.

```
A = [1 5; 3 7; -9 2];
w = [1 1 0.5];
S = std(A,w)
```

```
S = 1×2

    4.4900    1.8330
```

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Importazione dei dati e analisi

Statistiche descrittive

Funzioni

corrcoef

Correlation coefficients

Output Arguments

R – Correlation coefficients
matrix

Correlation coefficients, returned as a matrix.

- For one matrix input, `R` has size `[size(A,2) size(A,2)]` based on the number of random variables (columns) represented by `A`. The diagonal entries are set to one by convention, while the off-diagonal entries are correlation coefficients of variable pairs. The values of the coefficients can range from -1 to 1, with -1 representing a direct, negative correlation, 0 representing no correlation, and 1 representing a direct, positive correlation. `R` is symmetric.
- For two input arguments, `R` is a 2-by-2 matrix with ones along the diagonal and the correlation coefficients along the off-diagonal.
- If any random variable is constant, its correlation with all other variables is undefined, and the respective row and column value is `NaN`.

More About

Correlation Coefficient

The correlation coefficient of two random variables is a measure of their linear dependence. If each variable has N scalar observations, then the Pearson correlation coefficient is defined as

$$\rho(A,B) = \frac{1}{N-1}\sum_{i=1}^{N}\left(\frac{A_i-\mu_A}{\sigma_A}\right)\left(\frac{B_i-\mu_B}{\sigma_B}\right),$$

where μ_A and σ_A are the mean and standard deviation of A, respectively, and μ_B and σ_B are the mean and standard deviation of B.

The correlation coefficient *matrix* of two random variables is the matrix of correlation coefficients for each pairwise variable combination,

$$R = \begin{pmatrix} \rho(A,A) & \rho(A,B) \\ \rho(B,A) & \rho(B,B) \end{pmatrix}.$$

Since A and B are always directly correlated to themselves, the diagonal entries are just 1, that is,

$$R = \begin{pmatrix} 1 & \rho(A,B) \\ \rho(B,A) & 1 \end{pmatrix}.$$

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Statistiche descrittive

Funzioni

corrcoef

Correlation coefficients

Examples

Random Columns of Matrix

Compute the correlation coefficients for a matrix with two normally distributed, random columns and one column that is defined in terms of another. Since the third column of `A` is a multiple of the second, these two variables are directly correlated, thus the correlation coefficient in the `(2,3)` and `(3,2)` entries of `R` is `1`.

```
x = randn(6,1);
y = randn(6,1);
A = [x y 2*y+3];
R = corrcoef(A)
```

```
R = 3×3

    1.0000   -0.6237   -0.6237
   -0.6237    1.0000    1.0000
   -0.6237    1.0000    1.0000
```

Two Random Variables

Compute the correlation coefficient matrix between two normally distributed, random vectors of 10 observations each.

```
A = randn(10,1);
B = randn(10,1);
R = corrcoef(A,B)
```

```
R = 2×2

    1.0000    0.4518
    0.4518    1.0000
```

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Importazione dei dati e analisi

Statistiche descrittive

Funzioni

corrcoef

Correlation coefficients

Examples

NaN Values

Create a normally distributed matrix involving `NaN` values, and compute the correlation coefficient matrix, excluding any rows that contain `NaN`.

```
A = randn(5,3);
A(1,3) = NaN;
A(3,2) = NaN;
A
```

```
A = 5×3

    0.5377   -1.3077       NaN
    1.8339   -0.4336    3.0349
   -2.2588       NaN    0.7254
    0.8622    3.5784   -0.0631
    0.3188    2.7694    0.7147
```

```
R = corrcoef(A,'Rows','complete')
```

```
R = 3×3

    1.0000   -0.8506    0.8222
   -0.8506    1.0000   -0.9987
    0.8222   -0.9987    1.0000
```

Use `'all'` to include all `NaN` values in the calculation.

```
R = corrcoef(A,'Rows','all')
```

```
R = 3×3

     1   NaN   NaN
   NaN   NaN   NaN
   NaN   NaN   NaN
```

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Importazione dei dati e analisi

Statistiche descrittive

Argomenti

Computing with Descriptive Statistics

Example 1 — Calculating Maximum, Mean, and Standard Deviation

This example shows how to use MATLAB functions to calculate the maximum, mean, and standard deviation values for a 24-by-3 matrix called `count`. MATLAB computes these statistics independently for each column in the matrix.

```
% Load the sample data
load count.dat
% Find the maximum value in each column
mx = max(count)
% Calculate the mean of each column
mu = mean(count)
% Calculate the standard deviation of each column
sigma = std(count)
```

The results are

```
mx =
         114         145         257

mu =
   32.0000   46.5417   65.5833

sigma =
   25.3703   41.4057   68.0281
```

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Statistiche descrittive

Argomenti

Computing with Descriptive Statistics

Example 1 — Calculating Maximum, Mean, and Standard Deviation

To get the row numbers where the maximum data values occur in each data column, specify a second output parameter `indx` to return the row index. For example:

```
[mx,indx] = max(count)
```

These results are

```
mx =
      114     145     257

indx =
      20    20    20
```

Here, the variable `mx` is a row vector that contains the maximum value in each of the three data columns. The variable `indx` contains the row indices in each column that correspond to the maximum values.

To find the minimum value in the entire `count` matrix, 24-by-3 matrix into a 72-by-1 column vector by using the syntax `count(:)`. Then, to find the minimum value in the single column, use the following syntax:

```
min(count(:))

ans =
      7
```

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Statistiche descrittive

Argomenti

Computing with Descriptive Statistics

Example: Using MATLAB Data Statistics

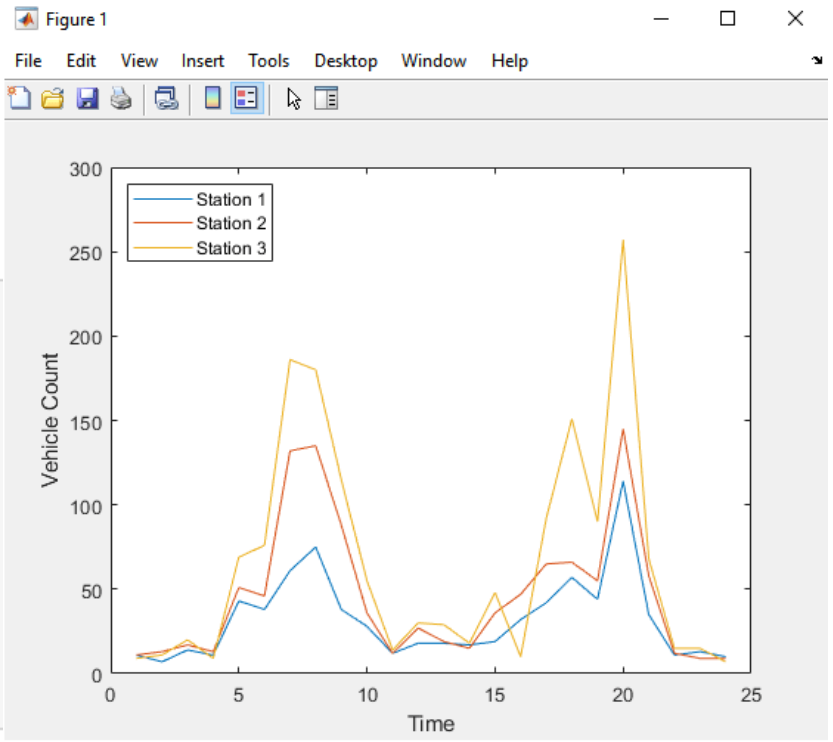
Calculating and Plotting Descriptive Statistics

1. Load and plot the data:

```
load count.dat
[n,p] = size(count);

% Define the x-values
t = 1:n;

% Plot the data and annotate the graph
plot(t,count)
legend('Station 1','Station 2','Station 3','Location','northwest')
xlabel('Time')
ylabel('Vehicle Count')
```



Note

The legend contains the name of each data set, as specified by the `legend` function: `Station 1`, `Station 2`, and `Station 3`. A *data set* refers to each column of data in the array you plotted. If you do not name the data sets, default names are assigned: `data1`, `data2`, and so on.

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Computing with Descriptive Statistics

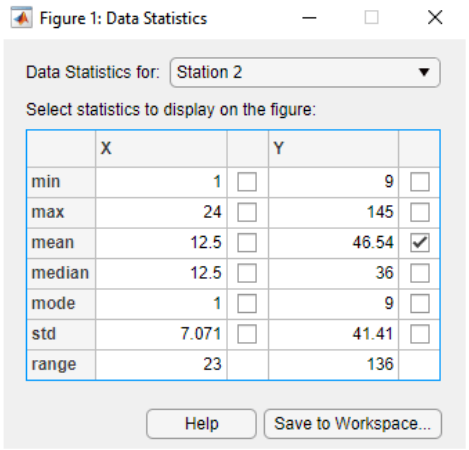
Example: Using MATLAB Data Statistics

Calculating and Plotting Descriptive Statistics

2. In the Figure window, select **Tools > Data Statistics**.
   The Data Statistics dialog box opens and displays descriptive statistics for the X- and Y-data of the `Station 1` data set.

> **Note**
> The Data Statistics dialog box displays a *range*, which is the difference between the minimum and maximum values in the selected data set. The dialog box does not display the range on the plot.

3. Select a different data set in the **Data Statistics for** list: `Station 2`.
   This displays the statistics for the X and Y data of the `Station 2` data set.
4. Select the check box for each statistic you want to display on the plot, and then click **Save to Workspace**.
   For example, to plot the mean of `Station 2`, select the **mean** check box in the **Y** column.



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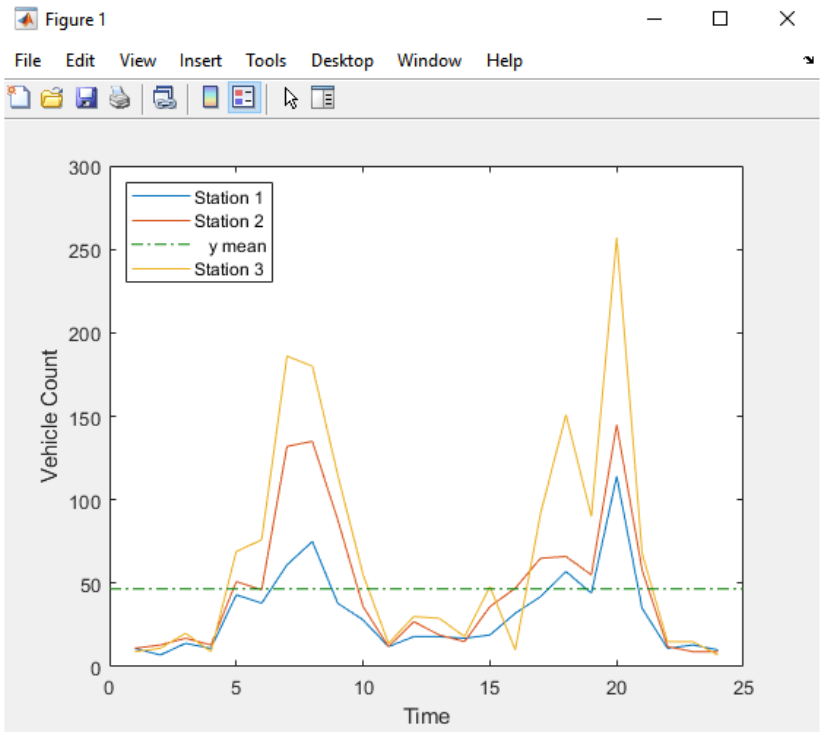
Computing with Descriptive Statistics

Example: Using MATLAB Data Statistics

Calculating and Plotting Descriptive Statistics

This plots a horizontal line to represent the mean of `Station 2` and updates the legend to include this statistic.



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Computing with Descriptive Statistics

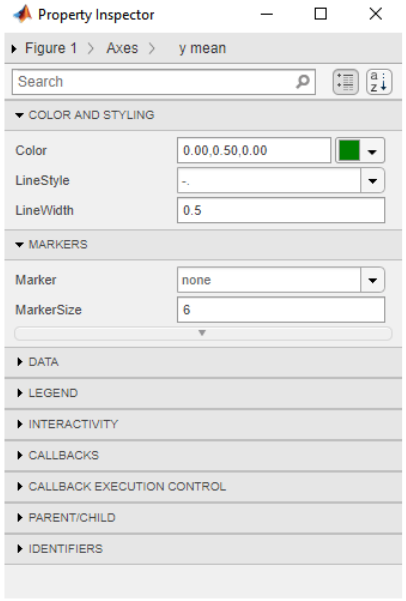
Example: Using MATLAB Data Statistics

Formatting Data Statistics on Plots

The Data Statistics dialog box uses colors and line styles to distinguish statistics from the data on the plot.

To modify the display of data statistics on a plot:

1. In the MATLAB Figure window, click the (**Edit Plot**) button in the toolbar.
   This step enables plot editing.
2. Double-click the statistic on the plot for which you want to edit display properties. For example, double-click the horizontal line representing the mean of `Station 2`.
   This step opens the Property Inspector, where you can modify the appearance of the line used to represent this statistic.



3. In the Property Inspector window, specify the line and marker styles, sizes, and colors.

> **Tip**
>
> Alternatively, right-click the statistic on the plot, and select an option from the shortcut menu.

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Computing with Descriptive Statistics

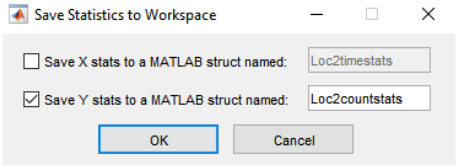
Example: Using MATLAB Data Statistics

Saving Statistics to the MATLAB Workspace

Perform these steps to save the statistics to the MATLAB workspace.

> **Note**
>
> When your plot contains multiple data sets, save statistics for each data set individually. To display statistics for a different data set, select it from the **Data Statistics for** list in the Data Statistics dialog box.

1. In the Data Statistics dialog box, click the **Save to Workspace** button.
2. In the Save Statistics to Workspace dialog box, select options to save statistics for either X data, Y data, or both. Then, enter the corresponding variable names.
   In this example, save only the Y data. Enter the variable name as `Loc2countstats`.



3. Click **OK**.
   This step saves the descriptive statistics to a structure. The new variable is added to the MATLAB workspace.

To view the new structure variable, type the variable name at the MATLAB prompt:

```
Loc2countstats
```

```
Loc2countstats =

  struct with fields:

      min: 9
      max: 145
     mean: 46.5417
   median: 36
     mode: 9
      std: 41.4057
    range: 136
```

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Statistiche descrittive

Argomenti

Computing with Descriptive Statistics

Example: Using MATLAB Data Statistics

Generating Code Files

This portion of the example shows how to generate a file containing MATLAB code that reproduces the format of the plot and the plotted statistics with new data.

1. In the Figure window, select **File > Generate Code**.

   This step creates a function code file and displays it in the MATLAB Editor.

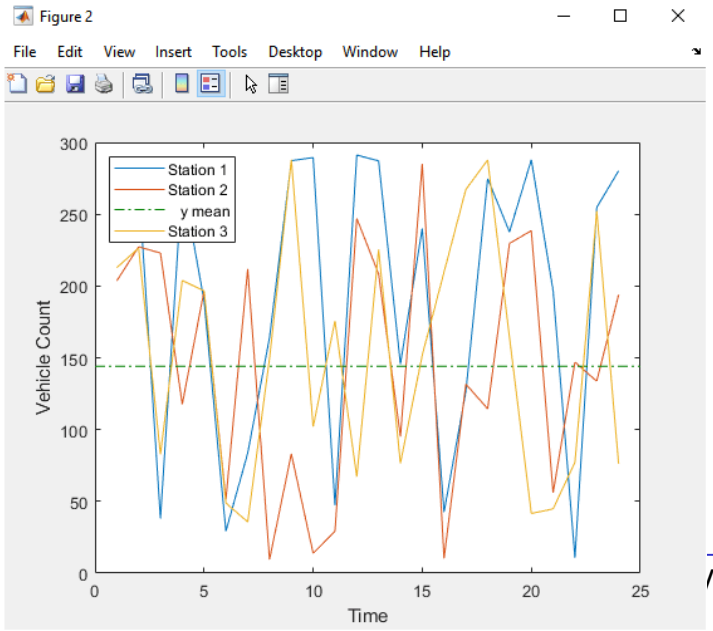
2. Change the name of the function on the first line of the file from `createfigure` to something more specific, like `countplot`. Save the file to your current folder with the file name `countplot.m`.

3. Generate some new, random count data:

```
rng('default')
randcount = 300*rand(24,3);
```

4. Reproduce the plot with the new data and the recomputed statistics:

```
countplot(t,randcount)
```



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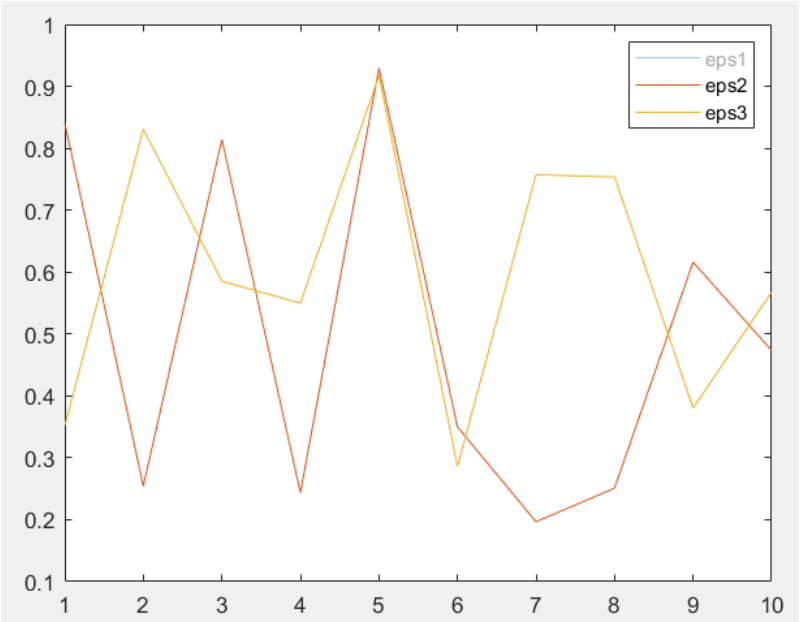
Importazione dei dati e analisi

Esplorazione visiva

https://it.mathworks.com/help/matlab/visual-exploration.html

Examples

```
x = 1:10;
eps1 = rand(10,1);
eps2 = rand(10,1);
eps3 = rand(10,1);
figure
plot(x,eps1);
hold on;
plot(x,eps2);
plot(x,eps3);
legend("eps1","eps2","eps3",'ItemHitFcn',@cb_legend)
function cb_legend(~,evt)
if strcmp(evt.Peer.Visible,'on')
    evt.Peer.Visible = 'off';
else
    evt.Peer.Visible = 'on';
end
end
```



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Importazione dei dati e analisi

Esplorazione visiva

https://it.mathworks.com/help/matlab/visual-exploration.html

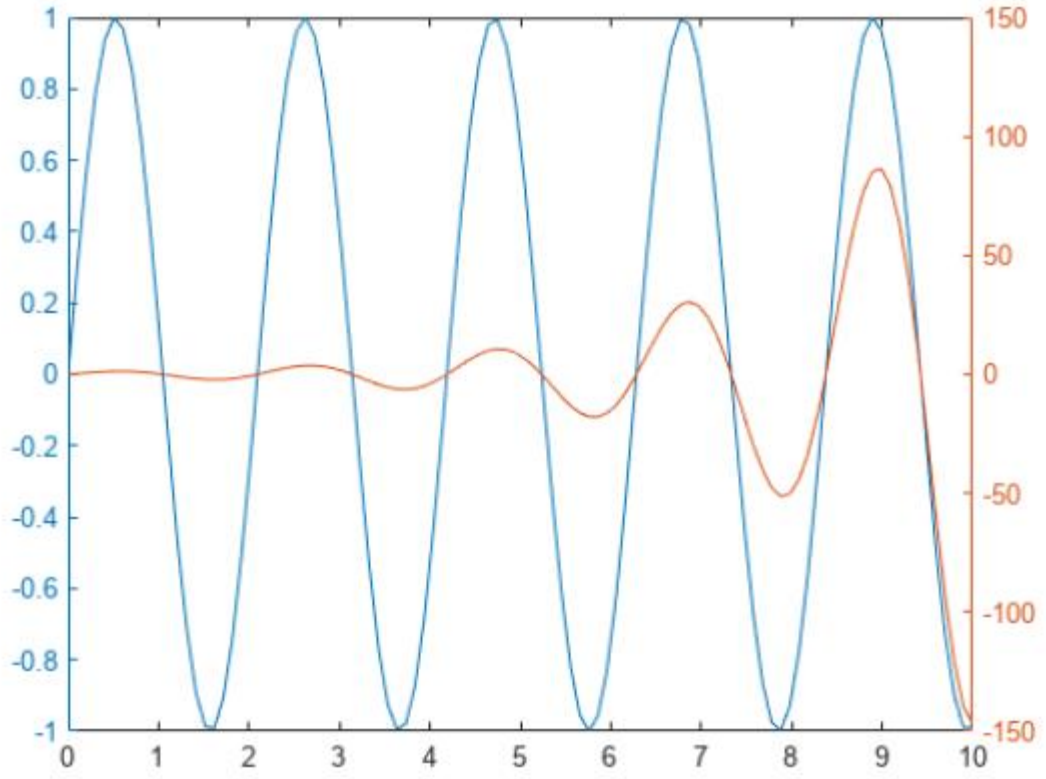
Examples

yyaxis

Create chart with two y-axes

```
x = linspace(0,10);
y = sin(3*x);
yyaxis left
plot(x,y)

z = sin(3*x).*exp(0.5*x);
yyaxis right
plot(x,z)
ylim([-150 150])
```



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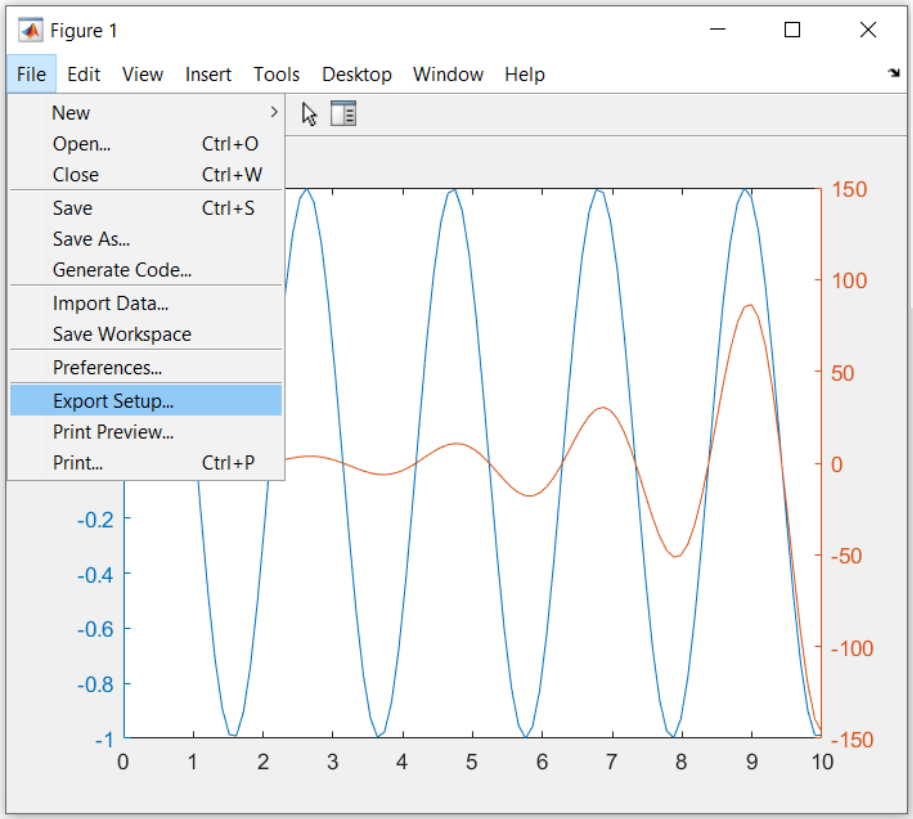

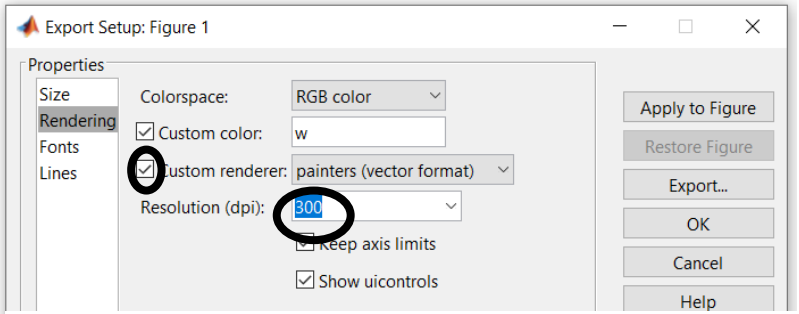

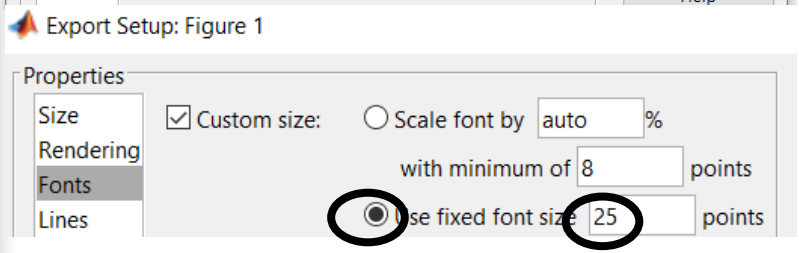

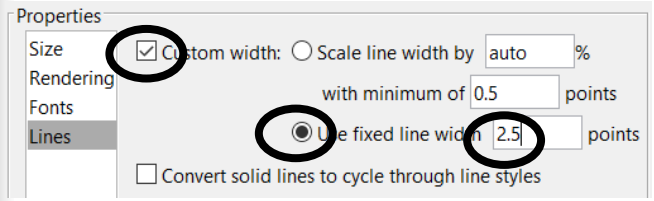

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Importazione dei dati e analisi

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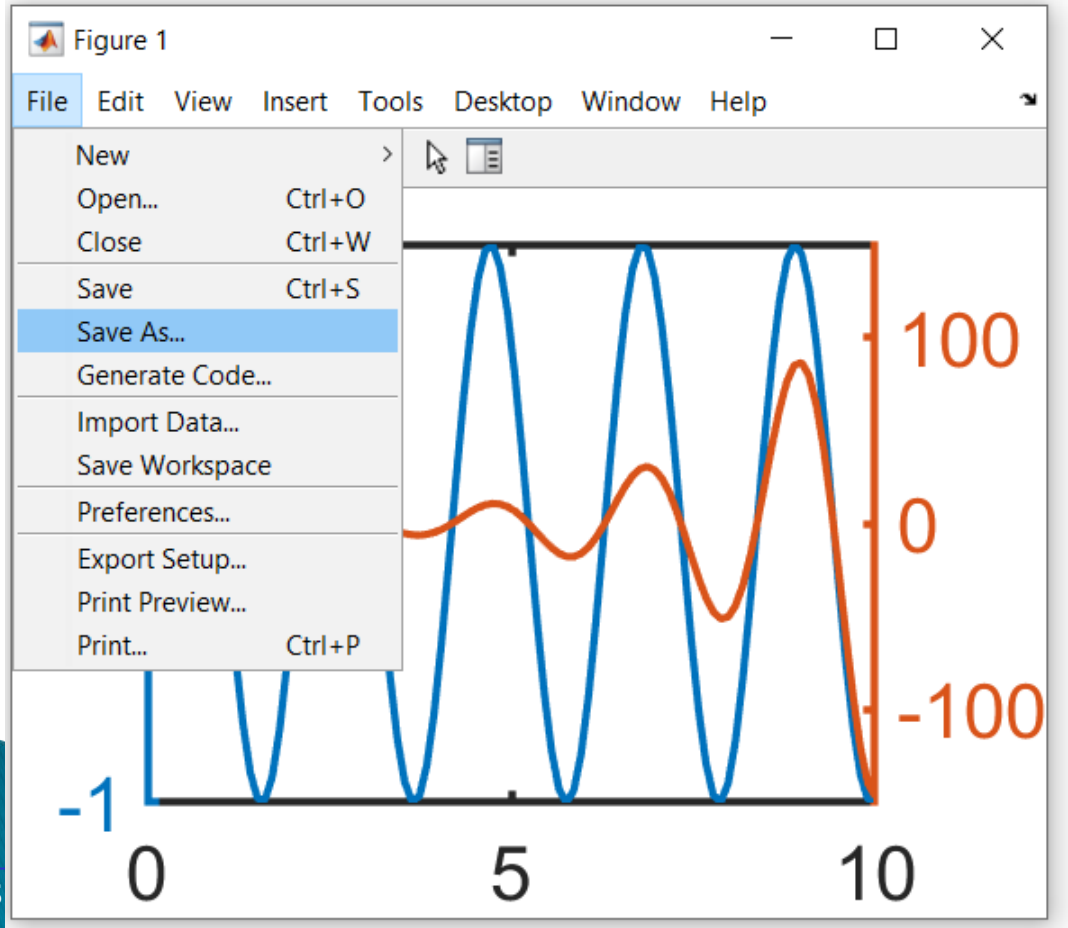

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Analisi Dati

Quando un dato viene acquisito, esso assume un insieme di valori che possono rappresentare condizioni di normale funzionamento oppure di funzionamento anomalo. Nel secondo caso l'anomalia deve essere rilevata e devono essere generati opportuni allarmi da utilizzare in linea e/o fuori linea. Inoltre può essere utile generare report automatici.

Per le misure i tipi di allarme che possono essere generati sono molti. I più comuni sono:

- allarme per superamento limite;
- allarme di velocità di variazione (ROC, Rate Of Change);
- allarme di freezing.

L'allarme per superamento limite viene generato nel momento in cui il valore di una misura supera un certo valore di riferimento definito come limite. Ad esempio si possono definire due valori di limite superiore e due valori di limite inferiore (si veda la figura riportata nella slide seguente). In questo caso, i parametri necessari a generare questi allarmi sono i quattro valori limite.

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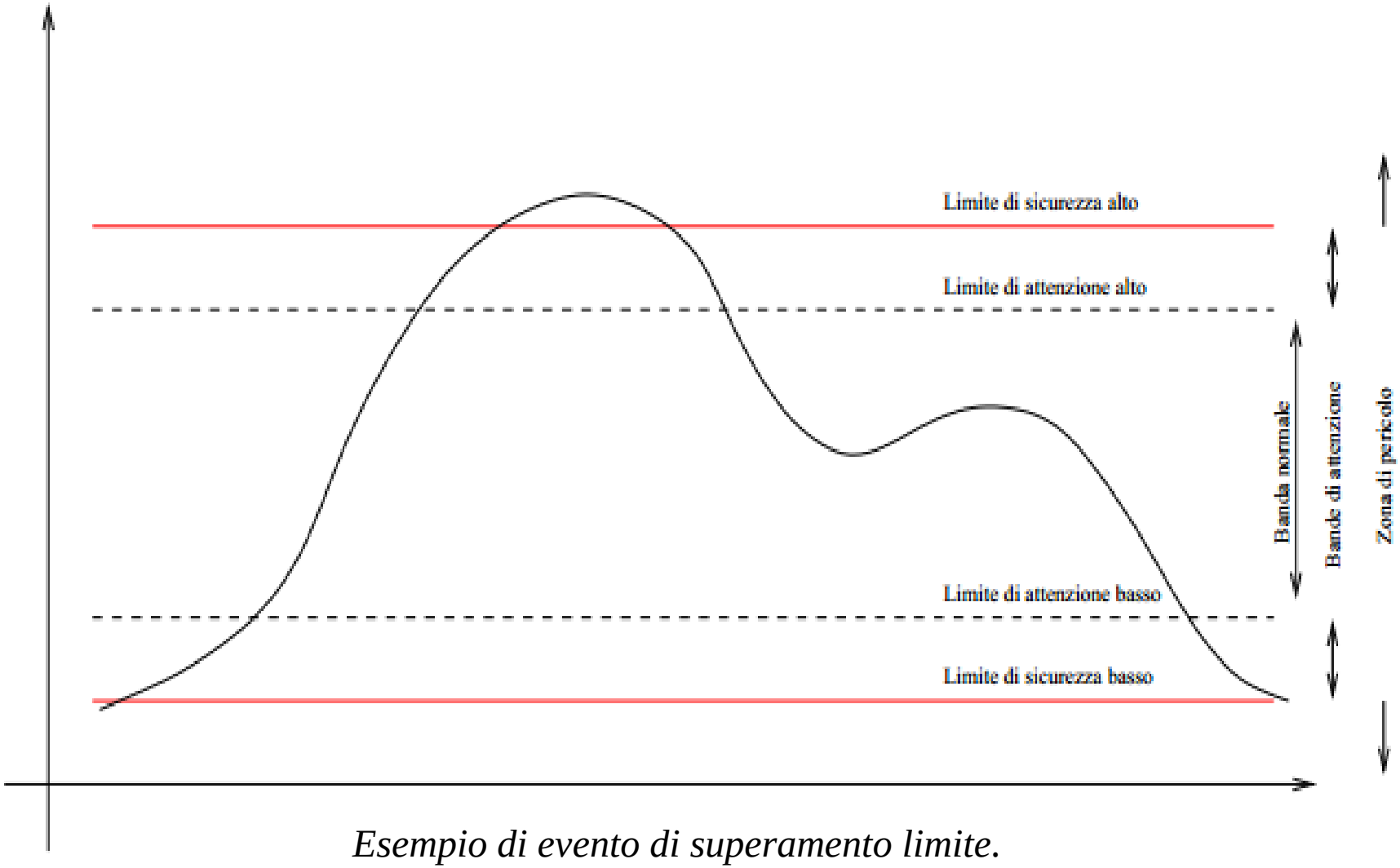
Analisi Dati



Esempio di evento di superamento limite.

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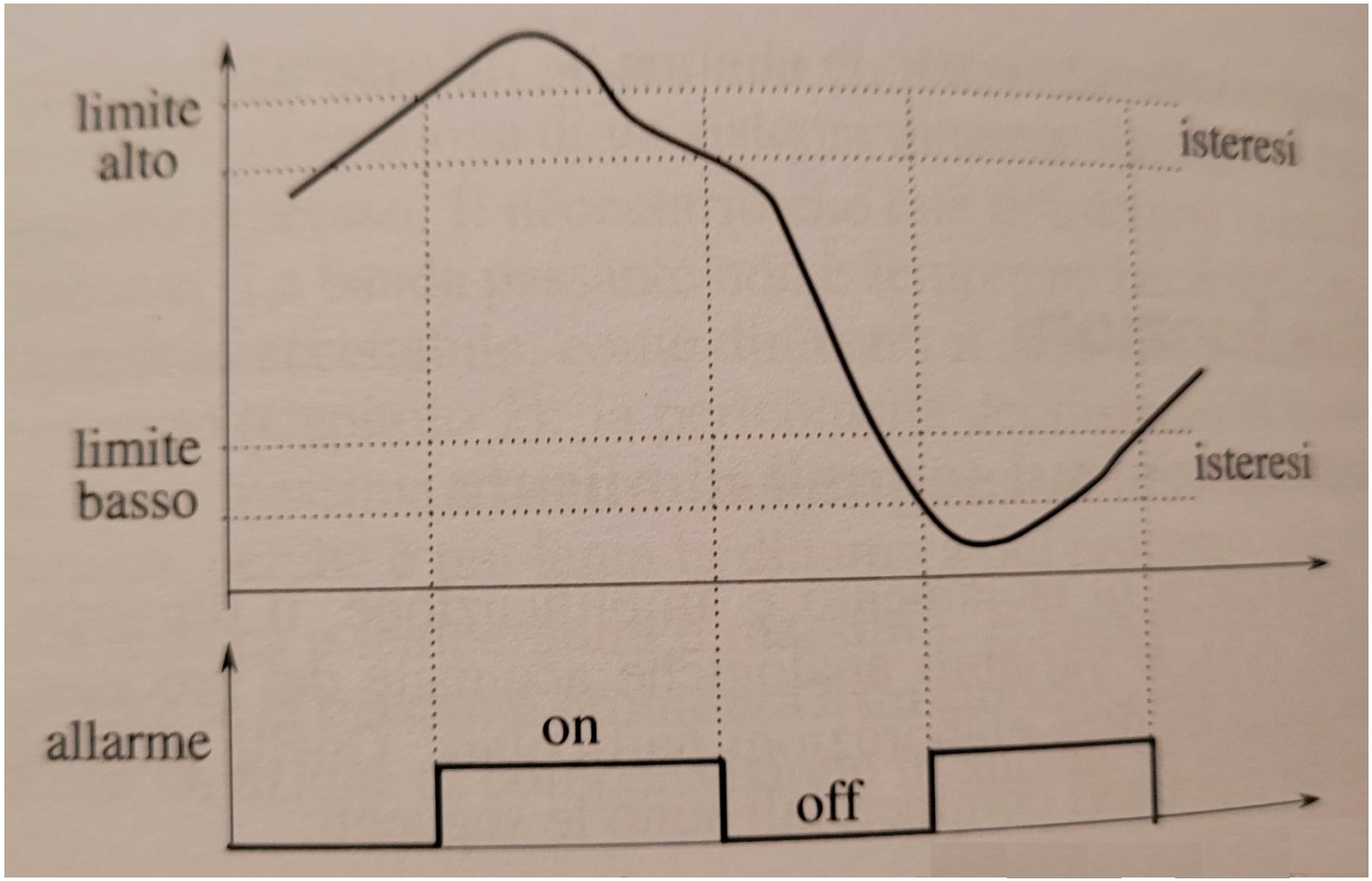
Analisi Dati



Generazione di allarmi per evento di superamento limite.

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Analisi Dati

L’allarme di velocità di variazione, o ROC (Rate Of Change), è un allarme che viene generato quando il valore di un dato subisce una variazione nel tempo superiore a un limite prefissato. Le informazioni necessarie per definire il limite di allarme di velocità di variazione sono il valore massimo di variazione limite ammessa, in unità ingegneristiche o in valore percentuale, e il tempo minimo nel quale essa può compiersi. Se necessario, è possibile definire anche due soglie (una positiva e una negativa).

L’allarme di freezing è un allarme che viene generato quando il valore di un dato non subisce una variazione nel tempo superiore (in valore assoluto) a un limite minimo prefissato (il limite minimo che può essere impostato è 0).

Riferimenti Bibliografici

[1] https://it.mathworks.com

[2] Bimbo, S., Colaiacovo, E. (2006). Sistemi SCADA. APOGEO. ISBN 88-503-1042-0

[3] Magnani, G., Ferretti, G., Rocco, P. (2007). Tecnologie dei sistemi di controllo. McGraw-Hill Education. ISBN-10: 8838663211