MATLAB Tutorials

16.62x Experimental Projects

Violeta Ivanova, Ph.D.
Educational Technology Consultant
MIT Academic Computing

violeta@mit.edu
This Tutorial

- Class materials
  web.mit.edu/acmath/matlab/16.62x

- Topics
  - MATLAB Basics Review
  - Data Analysis
  - Statistics Toolbox
  - Curve Fitting Toolbox
Other References

- Mathematical Tools at MIT
  web.mit.edu/ist/topics/math

- Course16 Tutorials
  - Unified MATLAB:
    web.mit.edu/acmath/matlab/unified
  - 16.06 & 16.07 MATLAB & Simulink:
    web.mit.edu/acmath/matlab/course16
MATLAB Basics Review

Toolboxes & Help
Matrices & Vectors
Built-In Functions
Graphics
Help in MATLAB

- Command line help
  >> `help <command>`
  e.g. `help regress`
  >> `lookfor <keyword>`
  e.g. `lookfor regression`

- Help Browser
  - Help->Help MATLAB
MATLAB Help Browser

- MATLAB
  - Mathematics
  - Data Analysis
  - Programming
  - Graphics
- Curve Fitting Toolbox
- Statistics Toolbox
  - Linear Models
  - Hypothesis Tests
  - Statistical Plots
Vectors

- **Row vector**
  
  ```matlab
  >> R1 = [1 6 3 8 5]
  >> R2 = [1 : 5]
  >> R3 = [-pi : pi/3 : pi]
  ```

- **Column vector**
  
  ```matlab
  >> C1 = [1; 2; 3; 4; 5]
  >> C2 = R2'
  ```
Matrices

- Creating a matrix
  
  ```matlab
  >> A = [1 2.5 5 0; 1 1.3 pi 4]
  >> A = [R1; R2]
  ```

- Accessing elements
  
  ```matlab
  >> A(1,1)
  >> A(1:2, 2:4)
  >> A(:,2)
  ```
Matrix Operations

- **Operators + and -**
  
  ```matlab
  >> X = [x1 x2]; Y = [y1 y2]; A = X+Y
  A =
      x1+y1   x2+y2
  ```

- **Operators *, /, and ^**
  
  ```matlab
  >> Ainv = A^-1    % Matrix math is default!
  ```

- **Operators .*, ./, and .^**
  
  ```matlab
  >> Z = [z1 z2]; B = [Z.^2  Z.^0]
  B =
      z1^2  z2^2  1   1
  ```
Matrices & vectors

\[
\begin{align*}
\text{>> } [n, m] &= \text{size}(A) \\
\text{>> } n &= \text{length}(X) \\
\text{>> } M1 &= \text{ones}(n, m) \\
\text{>> } M0 &= \text{zeros}(n, m) \\
\text{>> } En &= \text{eye}(n) \\
\text{>> } N1 &= \text{diag}(En)
\end{align*}
\]

And many others ...

\[
\text{>> } y &= \exp(\sin(x) + \cos(t))
\]
Graphics

- 2D linear plots: `plot`
  
  ```
  >> plot (t, z, 'r-')
  ```

  Colors: `b`, `r`, `g`, `y`, `m`, `c`, `k`, `w`
  Markers: `o`, `*`, `.`, `+`, `x`, `d`
  Line styles: `-`, `--`, `-.`, `:`

- Annotating graphs
  
  ```
  >> legend ('z = f(t)')
  >> title ('Position vs. Time')
  >> xlabel ('Time')
  >> ylabel ('Position')
  ```
Multiple Plots

- Multiple datasets on a plot
  
  ```matlab
  >> p1 = plot(xcurve, ycurve)
  >> hold on
  >> p2 = plot(Xpoints, Ypoints, 'ro')
  >> hold off
  ```

- Subplots on a figure
  
  ```matlab
  >> s1 = subplot(1, 2, 1)
  >> p1 = plot(time, velocity)
  >> s2 = subplot(1, 2, 2)
  >> p2 = plot(time, acceleration)
  ```
MATLAB Data Analysis

Preparing Data
Basic Fitting
Correlation
Data Input / Output

- **Import Wizard** for data import
  File->Import Data ...
- **File input with** `load`
  \[ B = \texttt{load}('datain.txt') \]
- **File output with** `save`\[ \texttt{save}('dataout', 'A', '-ascii') \]
Missing Data

- Removing missing data
  - Removing NaN elements from vectors
    ```matlab
    >> x = x(~isnan(x))
    ```
  - Removing rows with NaN from matrices
    ```matlab
    >> X(any(isnan(X),2),:) = []
    ```
- Interpolating missing data
  ```matlab
  YI = interp1(X, Y, XI, 'method')
  ```
Data Statistics

Figure window: Tools->Data Statistics
Correlation

- Correlation coefficient & confidence interval

```matlab
>> [R, P, Rlo, Rup, alpha] = corrcoef(X);
>> [i, j] = find(P < 0.05);
```

```
X =
18.2000 17.0500  6.1500
25.8200 19.8000  6.6100
18.2400 15.9800  6.9400
28.6000 22.0700  7.0600
31.1000 22.8300  7.2000
33.6000 24.5500  7.4500
40.4600 27.2700  7.0800
28.2700 23.5700  6.0700
20.1000 13.5800  6.6200
27.9100 22.8000  7.2700
26.1800 20.3000  7.0000
22.1200 16.5900  7.6900
21.8400 16.8400  7.4200
10.8400 17.7100  6.4100
  \ 4500
```

```matlab
>> [r, p] = corrcoef(X)
```

```
r =
    1.0000  0.6974 -0.0685
  0.6974  1.0000 -0.1516
-0.0685 -0.1516  1.0000
```

```
p =
    1.0000  0.0000  0.6587
  0.0000  1.0000  0.3260
  0.6587  0.3260  1.0000
```
Basic Fitting

Figure window: Tools->Basic Fitting ...

![Graph showing the relationship between cancer rates and smoking habits. The equation $y = 3x + 20$ is displayed, indicating a linear relationship. The graph includes data points for bladder cancer, lung cancer, and leukemia.](image)
Polynomials

- Evaluating polynomials
  \[ y = p_1 x^n + p_2 x^{n-1} + \cdots + p_n x + p_{n+1} \]
  ```matlab
  >> p = [p1 p2 ... ]
  >> t = [-3 : 0.1 : 3]
  >> z = polyval(p, t)
  ```

- Fitting a polynomial
  ```matlab
  >> X = [x1 x2 ... xn]; Y = [y1 y2 ... yn]
  >> Pm = polyfit(X, Y, m)
  ```
Statistics Toolbox

- Probability Distributions
- Descriptive Statistics
- Linear & Nonlinear Models
- Hypothesis Tests
- Statistical Plots
Descriptive Statistics

■ Central tendency
  >> m = mean(X)
  >> gm = geomean(X)
  >> med = median(X)
  >> mod = mode(X)

■ Dispersion
  >> s = std(X)
  >> v = var(X)
Probability Distributions

- **Probability density functions**
  
  \[
  Y = \text{exppdf}(X, \mu) \\
  Y = \text{normpdf}(X, \mu, \sigma)
  \]

- **Cumulative density functions**
  
  \[
  Y = \text{expcdf}(X, \mu) \\
  Y = \text{normcdf}(X, \mu, \sigma)
  \]

- **Parameter estimation**
  
  \[
  m = \text{expfit}(data) \\
  [m, s] = \text{normfit}(data)
  \]
Distribution Fitting Tool

- Start from command line window

```matlab
>> dfittool
```
Linear Models

Definition:

\[ y = X\beta + \varepsilon \]

- **y**: \( n \times 1 \) vector of observations
- **X**: \( n \times p \) matrix of predictors
- **\( \beta \)**: \( p \times 1 \) vector of parameters
- **\( \varepsilon \)**: \( n \times 1 \) vector of random disturbances
Linear Regression

- Multiple linear regression
  
  ```matlab
  >> [B, Bint, R, Rint, stats] = regress(y, X)
  ```

  - **B**: vector of regression coefficients
  - **Bint**: matrix of 95% confidence intervals for B
  - **R**: vector of residuals
  - **Rint**: intervals for diagnosing outliers
  - **stats**: vector containing $R^2$ statistic etc.

- Residuals plot
  
  ```matlab
  >> rcoplot(R, Rint)
  ```
Polynomial Fitting Tool

>> polytool(X, Y)
Analysis of Variance (ANOVA)

- One-way ANOVA
  \[ \text{>> anova1}(X, \text{group}) \]
Multiple Comparisons

>> [p, tbl, stats] = \texttt{anova1}(X, \text{group})
>> [c, m] = \texttt{multcompare}(\text{stats})
More Built-In Functions

- Two-way ANOVA
  \[
  \text{>> } [P, \text{tbl, stats}] = \text{anova2}(X, \text{reps})
  \]

- Statistical plots
  \[
  \text{>> } \text{boxplot}(X, \text{group})
  \]

- Other hypothesis tests
  \[
  \text{>> } H = \text{ttest}(X)
  \]
  \[
  \text{>> } H = \text{lillietest}(X)
  \]
Exercise 1: Data Analysis

- RFID and Barcode Scanning Tests
  - Script m-file: dataanalysis.m

Follow instructions in the m-file …

Questions?
Curve Fitting Toolbox

Curve Fitting Tool
Goodness of Fit
Analyzing a Fit
Fourier Series Fit
Curve Fitting Tool

>> cftool

![Graph showing world population vs. year with an exponential fit](image-url)
Goodness of Fit Statistics

Table of Fits

<table>
<thead>
<tr>
<th>Name</th>
<th>Data set</th>
<th>Type</th>
<th>SSE</th>
<th>R-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>exponential fit</td>
<td>Nbil vs. year</td>
<td>Exponential</td>
<td>0.1572972880...</td>
<td>0.9973106593...</td>
</tr>
<tr>
<td>gaussian fit</td>
<td>Nbil vs. year</td>
<td>Gaussian</td>
<td>0.0263778905...</td>
<td>0.9995490123...</td>
</tr>
</tbody>
</table>

Table Options

Check to view column in Table of Fits:

- Name
- Data set
- Type
- SSE
- R-square

Table options...

Close  Help
Analyzing a Fit
Fourier Series Fit
Exercise 2: Regression

- Linear regression & other line fitting
  - Script m-file: regression.m

Follow instructions in the m-file …

Questions?