Introduction to MATLAB

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

violeta@mit.edu
http://web.mit.edu/violeta/www/IAP2006

IST Information Services and Technology

Topics

- ✓ MATLAB Interface and Basics
- ➢ Linear Algebra and Calculus
- Graphics
- Programming
- Graphical User Interface
- Math On the Web (optional)

Class Materials

- On laptops download from:

  http://web.mit.edu/acmath/matlab/IntroMATLAB
- On Athena copy from locker acmath

```
athena% add acmath
athena% cp
   /afs/athena.mit.edu/astaff/project/acmath/
   matlab/IntroMATLAB/LA_Calculus.tar .
```

Help in MATLAB

- Command line help

  `>> help` *`command`*

  e.g. `help eig`

  `>> lookfor` *`keyword`*

  e.g. `lookfor eigenvalue`

  `>> helpwin or helpdesk or doc`

- Desktop menu
  - Help->Help MATLAB

MATLAB Help Browser

- MATLAB
  - + Mathematics
    - + Matrices and Linear Algebra
      - Function Summary
      - + Matrices in MATLAB
      - + Solving Linear Systems of Equations
      - Eigenvalues
    - + Differential Equations
      - + Initial Value Problems for ODEs
      - ODE Function Summary
- Other Toolboxes

MATLAB Linear Algebra

Matrices

Linear Equations

Curve Fitting

Scalar-Vector Math

- `A + 2`: element-wise addition
- `A * 2`: element-wise multiplication
- `A + A`: element-wise addition
- `A .^2`: element-wise exponentiation
- `A ./2`: element-wise division

Matrix Math

- Operators + and -

```
>> X=[x1 x2 x3]'; Y=[y1 y2 y3]'; X+Y
ans =
    x1+y1
    x2+y2
    x3+y3
```

Matrix Math (continued)

- Operators .*, ./, and .^

```
>> A = [X.^2   X  ones(3,1)]
ans =
```

$$\begin{matrix} x_1^2 & x_1 & 1 \\ x_2^2 & x_2 & 1 \\ x_3^2 & x_3 & 1 \end{matrix}$$

Matrix Math (continued)

- Operators *, ^, /, and \ on matrices

```
>> Ainv = A^(-1)
>> C = Ainv * Y
>> B = A \ Y
```

Solving Linear Equations

- Example:

  Find the quadratic that passes through three points (x_1,y_1), (x_2,y_2), and (x_3,y_3), i.e. find (c_1, c_2, c_3) such that:

$$y_1 = c_1 x_1^2 + c_2 x_1 + c_3$$

$$y_2 = c_1 x_2^2 + c_2 x_2 + c_3$$

$$y_3 = c_1 x_3^2 + c_2 x_3 + c_3$$

Solving Linear Equations (continued)

- Matrix form: Y = AC
- Solution:
  - Define matrix A

```
>> A = [X.^2  X.^1  X.^0];
```

  - Solve matrix equation

```
>> C = A \ Y
```

Curve Fitting

- Example:

  Fit a polynomial through points (x_i,y_i).
- Solution using `polyfit`

```
>> C1 = polyfit(X, Y, 1);
>> C2 = polyfit(X, Y, 2);
>> Cn = polyfit(X, Y, n);
```

- Solution using matrix math

```
>> Cn = An \ Y
```

Built-In Operators & Functions

- Polynomials
  ```
  >> polyfit
  >> polyval
  ```
- Matrix math
  ```
  >> \
  >> ones
  >> diag
  >> eig
  >> rref
  ```

More Built-In Functions

- Matrix analysis

```
>> det(A)
>> rank(A)
>> trace(A)
```

- Solving linear equations

```
>> inv(A)
>> linsolve(A,B)
```

- Eigenvalues and singular values

```
>> poly(A)
```

MATLAB Calculus

Differential Equations

Function Handles

Integration

Differential Equations

- Ordinary Differential Equations (ODE)
  $$y' = f(t, y)$$
- Differential-Algebraic Expressions (DAE)
  $$M(t, y)y' = f(t, y)$$
- MATLAB solvers for ODEs and DAEs

  `>> ode45; ode23; ode113; ode23s …`

ODE and DAE Solvers

- Syntax

```
>> [T,Y] = solver(odefun,tspan,y0)
```

- `solver: ode45, ode23`, etc.
- `odefun:` Function Handle
- `tspan:` interval of integration vector
- `Y0:` vector of initial conditions
- `[T, Y]:` numerical solution in two vectors

ODE Example

- Problem: $\frac{dq(t)}{dt} = -\frac{1}{RC}q(t)$
- Solution:

```
C = 0.002; R = 150; q0 = -0.001;
tspan = [0 : 0.01 : 100];
[t,q] = ode45(@ode, tspan, q0)
% --------------------
function Dq = ode(t,q)
Dq = -1/(R*C)*q
```

PDE Solver

- Partial Differential Equations (PDEs)
  - Elliptic and parabolic
    e.g. Laplace's equation: $\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = 0$
- Numerical PDE solver: `pdepe`
  - Syntax:

    ```
    >> solution = pdepe(m, pdefun, icfun, bcfun, xmesh, tspan)
    ```
  - Function handles: `pdefun`, `icfun`, `bcfun`

Integration

- Polynomial integration

$$\int p_1 x^n + \ldots + p_n x + p_{n+1} dx = P_1 x^{n+1} + \ldots + P_{n+1} x + C$$

- Analytical solution
  - Built-in function `polyint`

```
>> P = polyint(p); assumes C=k
>> P = polyint(p, k); assumes C=k
```

More Polynomial Integration

- Area under a curve

$$\int_a^b p_1 x^n + p_2 x^{n-1} \ldots + p_{n-1} x^2 + p_n x + p_{n+1} dx$$

- Built-in function `polyval`

```
>> P = polyint(p)
>> area = polyval(P, b) - …
                  polyval(P, a)
```

Differentiation

- Polynomial differentiation

$$\frac{d}{dx}(P_1 x^n + \ldots + P_n x + C) = p_1 x^{n-1} + \ldots + p_n$$

- Built-in function `polyder`

```
>> P = [P1 P2 … Pn C]
>> p = polyder(P)
```

Algebra and Calculus Exercises

- Exercise One: `example1.m`
  - Matrices, vectors, and matrix operators
  - Systems of linear equations
  - Eigenvalues and eigenvectors
- Exercise Two: `example2.m`
  - Polynomials
  - Curve fitting
- Exercise Three: `example3.m`
  - Ordinary differential equations
  - Function handles and function M-files