Matlab Tutorial

Based on Matlab tutorial by IPLab@SUT

Motivation: powerful *and* easy!

- Matlab: a high-performance software and a programming language
- Powerful
  - Mathematics and visualization
  - Toolboxes in statistics, signal processing, vision...
  - Widely used in AI-related fields
- Easy
  - Prototyping, testing, debugging, finding helps...

Motivation: the 80/20 rule

- "Remember the 80/20 rule. Hence 80% of your code should be in some high level language like Matlab... Your time is more valuable than the computer's time."
  - Prof. Kevin P. Murphy

Outline

- Environment
- Matrices
- Elementary math
- Data types
  - String
  - Cell arrays
  - Multidimensional arrays
- Programming part next week!
  - Plot, flow control, functions, debug, ...

Calculations at the Command Line

MATLAB as a calculator

```
» -5/(4.8+5.32)^2
ans =
   -0.0488
» (3+4i)*(3-4i)
ans =
    25
» cos(pi/2)
ans =
  6.1230e-017
» exp(acos(0.3))
ans =
    3.5470
```

Assigning Variables

```
» a = 2;
» b = 5;
» a^b
ans =
    32
» x = 5/2*pi;
» y = sin(x)
y =
     1
» z = asin(y)
z =
    1.5708
```

Semicolon suppresses screen output

Results assigned to "ans" if name not specified

() parentheses for function inputs

A Note about Workspace:
Numbers stored in double-precision floating point format

9

General Functions

- whos: List current variables
- clear: Clear variables and functions from memory
- cd: Change current working directory
- ls: List files in directory

10

Getting help

- *help* command (>>help)
- *lookfor* command (>>lookfor)
- Printable Documents
  - "Matlabroot\help\pdf_doc\"

11

Matrices

- Entering and Generating Matrices
- Subscripts
- Scalar Expansion
- Concatenation
- Deleting Rows and Columns
- Array Extraction
- Matrix and Array Multiplication

12

Entering Numeric Arrays

$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

```
» a=[1 2;3 4]
a =
     1     2
     3     4
» b=[-2.8, sqrt(-7), (3+5+6)*3/4]
b =
  -2.8000   0 + 2.6458i   10.5000
» b(2,5) = 23
b =
  -2.8000   0 + 2.6458i   10.5000         0         0
         0             0         0         0   23.0000
```

Use square brackets [ ]

Row separator semicolon (;)

Column separator space / comma (,)

- Any MATLAB expression can be entered as a matrix element
- Matrices must be rectangular. (Set undefined elements to zero)

13

The Matrix in MATLAB

Columns (n)

A =

Rows (m)	1	2	3	4	5
1	4	10	1	6	2
2	8	1.2	9	4	25
3	7.2	5	7	1	11
4	0	0.5	4	5	56
5	23	83	13	0	10

A (2,4)

A (17)

Rectangular Matrix:
Scalar: 1-by-1 array
Vector: m-by-1 array
1-by-n array
Matrix: m-by-n array

14

Entering Numeric Arrays

Scalar expansion

```
» w=[1 2;3 4] + 5
w =
     6     7
     8     9
```

Creating sequences: colon operator (:)

```
» x = 1:5
x =
     1     2     3     4     5
» y = 2:-0.5:0
y =
    2.0000    1.5000    1.0000    0.5000         0
```

Utility functions for creating matrices.

```
» z = rand(2,4)
z =
    0.9501    0.6068    0.8913    0.4565
    0.2311    0.4860    0.7621    0.0185
```

15

Numerical Array Concatenation

Use [ ] to combine existing arrays as matrix "elements"

```
» a=[1 2;3 4]
a =
     1     2
     3     4
» cat_a=[a, 2*a; 3*a, 4*a; 5*a, 6*a]
cat_a =
     1     2     2     4
     3     4     6     8
     3     6     4     8
     9    12    12    16
     5    10     6    12
    15    20    18    24
```

Use square brackets [ ]

Row separator: semicolon (;)

Column separator: space / comma (,)

4*a

Note:
The resulting matrix must be rectangular

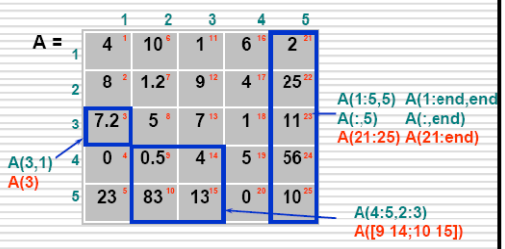
16

Deleting Rows and Columns

```
» A=[1 5 9;4 3 2.5; 0.1 10 3i+1]
A =
    1.0000             5.0000             9.0000
    4.0000             3.0000             2.5000
    0.1000            10.0000             1.0000+3.0000i
» A(:,2)=[]
A =
    1.0000             9.0000
    4.0000             2.5000
    0.1000             1.0000 + 3.0000i
» A(2,2)=[]
???  Indexed empty matrix assignment is not allowed.
```

17

Array Subscripting / Indexing



18

Matrix Multiplication

```
» a = [1 2 3 4; 5 6 7 8];          [2x4]
» b = ones(4,3);                   [4x3]
» c = a*b                  [2x4]*[4x3]→ [2x3]
c =
    10    10    10
    26    26    26  ← a(2nd row).b(3rd column)
```

Array Multiplication

```
» a = [1 2 3 4; 5 6 7 8];
» b = [1:4; 1:4];
» c = a.*b
c =
     1     4     9    16
     5    12    21    32  ← c(2,4) = a(2,4)*b(2,4)
```

19

Matrix Manipulation Functions

- zeros: Create an array of all zeros
- ones: Create an array of all ones
- eye: Identity Matrix
- rand: Uniformly distributed random numbers
- diag: Diagonal matrices and diagonal of a matrix
- size: Return array dimensions
- repmat: Replicate and tile a matrix

20

Matrix Manipulation Functions

- det: Matrix determinant
- inv: Matrix inverse
- eig: Evaluate eigenvalues and eigenvectors
- rank: Rank of matrix

21

Elementary Math

- Logical Operators
- Math Functions
- Polynomial and Interpolation

25

Logical Operations

= = equal to	
> greater than	
< less than	
>= Greater or equa	
<= less or equal	
~ not	
& and	
| or	
isfinite(), etc. . . .	
all(), any()	
find	

```
» Mass = [-2 10 NaN 30 -11 Inf 31];
» each_pos = Mass>=0
each_pos =
     0     1     0     1     0     1     1
» all_pos = all(Mass>=0)
all_pos =
     0
» all_pos = any(Mass>=0)
all_pos =
     1
» pos_fin = (Mass>=0)&(isfinite(Mass))
pos_fin =
     0     1     0     1     0     0     1
```

Note:
- 1 = TRUE
- 0 = FALSE

26

Elementary Math Function

- abs, sign: Absolute value and Signum Function
- sin, cos, asin, acos…: Triangular functions
- exp, log, log10: Exponential, Natural and Common (base 10) logarithm
- ceil, floor: Round toward infinities
- fix: Round toward zero

27

Elementary Math Function

- round: Round to the nearest integer
- sqrt: Square root function
- real, imag: Real and Image part of complex
- rem: Remainder after division

Elementary Math Function

- max, min: Maximum and Minimum of arrays
- mean, median: Average and Median of arrays
- std, var: Standard deviation and variance
- sort: Sort elements in ascending order
- sum, prod: Summation & Product of Elements

28

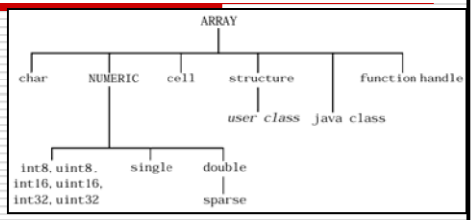
Text strings

- Create a string
  - str = 'hello world'
- disp: display any variable
  - x = [1 2; 3 4]; disp(x);
  - str = 'hello world'; disp(str);
- fprintf: print to stdout or files
  - fprintf('str=%s, one-third=%4.2f', 1/3);
  - Type "help fprintf" for file output
- sprintf: string output as C

Strings are character matrices

- Strings are matrices in which elements are ASCII numbers
  - x = 'hello'; x(2)
    e
  - x = ['ab' 'cd']
    abcd
  - x = ['ab' ; 'cd']
    ab
    cd
- "char" creates a padded character arrays
  - s = char('rolling','stone','momentum.')
    [rolling]
    [stone]
    [momentum]
- String arrays of different length: cell array (later)

Data Types



- Numeric Arrays
- Multidimensional Arrays
- Structures and Cell Arrays

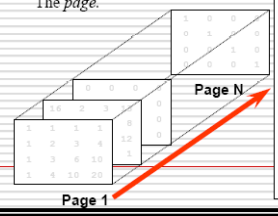
52

Multidimensional Arrays

The first references array dimension 1, the row.

The second references dimension 2, the column.

The third references dimension 3, The *page*.

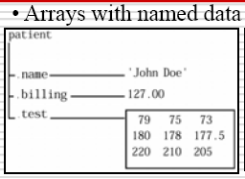



```
» A = pascal(4);
» A(:,:,2) = magic(4)
A(:,:,1) =
     1     1     1     1
     1     2     3     4
     1     3     6    10
     1     4    10    20
A(:,:,2) =
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1
» A(:,:,9) =
  diag(ones(1,4));
```

53

Structures

- Arrays with named data containers called ***fields***.




```
» patient.name='John Doe';
» patient.billing = 127.00;
» patient.test= [79 75 73;
180 178 177.5;
220 210 205];
```

- Also, Build structure arrays using the ***struct*** function.
- Array of *structures*

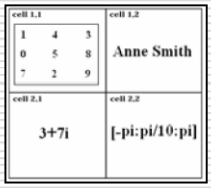
```
» patient(2).name='Katty Thomson';
» Patient(2).billing = 100.00;
» Patient(2).test= [69 25 33; 120 128 177.5; 220
  210 205];
```

54

Cell Arrays

- Array for which the elements are *cell*s and can hold other MATLAB arrays of different types.

```
» A(1,1) = {[1 4 3;
0 5 8;
7 2 9]};
» A(1,2) = {'Anne Smith'};
» A(2,1) = {3+7i};
» A(2,2) = {-pi:pi/10:pi};
```



- Using braces {} to point to elements of cell array
- Using ***celldisp*** function to display cell array

55

Getting more help

- Contact http://www.mathworks.com/support
  - You can find more help and FAQ about mathworks products on this page.
- Getting started with Matlab
  - http://www.indiana.edu/~statmath/math/matlab/gettingstarted/index.html
- Matlab Primer
  - http://math.ucsd.edu/~driver/21d-s99/matlab-primer.html

69

More to come next week!

- Any question?