INTRODUCTION TO MATLAB PROGRAMMING
Lec 1.1: MATLAB Basics

Dr. Niket Kaisare
Department of Chemical Engineering
IIT–Madras

NPTEL Course: MATLAB Programming for Numerical Computations — Week-1

About this Module

- We will cover the following topics
  - MATLAB basics
  - Arrays: Unlocking potential of MATLAB
  - Loops and Execution Control
  - MATLAB files: Scripts and Functions
  - Program Output and Plotting

Starting and Exiting MATLAB

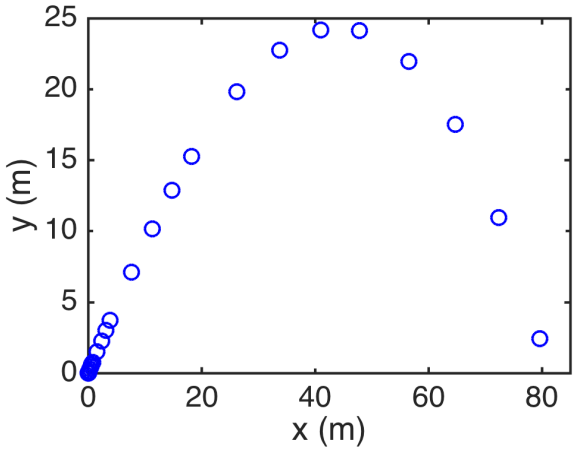
- We will go over starting a MATLAB session, layout of MATLAB window, MATLAB editor, etc.
- Also see video "Getting Started with MATLAB" on MATLAB site http://in.mathworks.com/videos/getting-started-with-matlab-68985.html

MATLAB Programming Example

Indian captain, Mahendra Singh Dhoni, hits a ball with initial velocity of 35 m/s and angle of 45°. If the boundary is at a distance of 75 m, will he score a six?

- Setting up the problem:
  - $v_{net} = 35;\ u_0 = v_{net}\cos(\pi/4);\ v_0 = v_{net}\sin(\pi/4)$
  - $x' = u;\ y' = v$
  - $u' = -\kappa u;\ \ v' = -g;$

Result



MATLAB Code

```
%% Define Parameters and Initial Conditions
param.g      = 9.81;      % gravitational acceleration
param.kappa  = 0.006;     % air drag coefficient
u0 = 35*cos(pi/4);
v0 = 35*sin(pi/4);

%% Setting up and Solving the problem
X0 = [0; 0;               % starting position is the origin
    u0; v0];              % starting velocity is given
tSpan = [0 20];           % simulation time
[tOut, XOut] = ode45(@ballTrajectoryFun,tSpan,X0, [], param);

%% Displaying the results
figure(1);
plot(XOut(:,1),XOut(:,2),'bo');
xlabel('x (m)'); ylabel('y (m)');

%% Animating results
exitCode = ballAnimation(tOut,XOut);
```

MATLAB Code: Main Code Blocks

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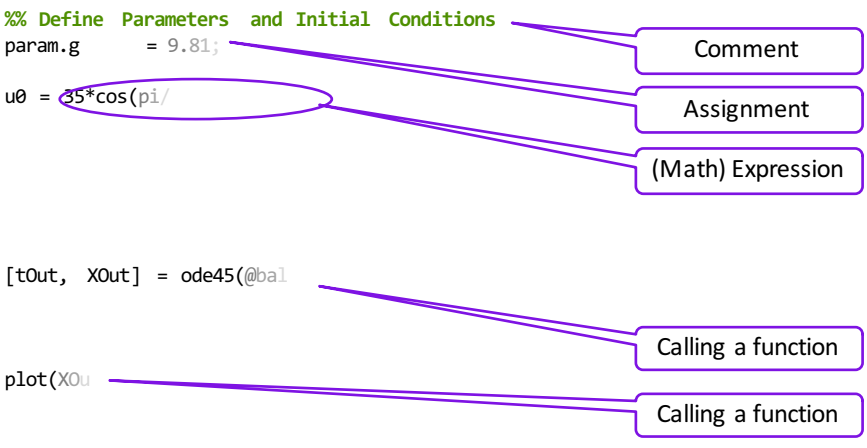
Input block

Computation

Output block

MATLAB Code: Key Parts



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Basic Data Types

- Matlab easily works with arrays
  - Scalars, vectors and arrays
  - Assigning variables
  - Row vs. column vectors
  - Arrays / Matrices
- Suppress "echo"
- Variables are case-sensitive

Command Window

```
>> a = 4

a =

     4

>> b = [1:5]

b =

     1     2     3     4     5

>> c = [1, 2; 7 4]

c =

     1     2
     7     4

>> d = [1; 2; 3; 4]

d =

     1
     2
     3
     4

fx >>
```

Basic Mathematical Expressions

Scalar Operations

- `+ - * / ^`
- `log, exp`
- `pow, sqrt`
- `sin, cos, tan`
- `asin, acos, atan`
- `rem, round, ceil, floor`

Special Variables

Variable	Meaning
`pi`	Number π
`eps`	Machine precision
`i`	Imaginary unit
`inf`	Infinity
`NaN`	Not a Number (e.g., 0/0)
`ans`	Last displayed result
`end`	Last element of array
`realmax`	Largest real number
`intmax`	Largest integer

End of Lecture 1-1

INTRODUCTION TO MATLAB PROGRAMMING
Lec 1.2: Array Operations

Dr. Niket Kaisare
Department of Chemical Engineering
IIT–Madras

NPTEL Course: MATLAB Programming for Numerical Computations — Week-1

Arrays are the most powerful aspect of MATLAB

- We will learn
  - Building arrays
  - Colon notations
  - Array operations and functions
- Also view "Working with Arrays in MATLAB" on MATLAB website:
  http://in.mathworks.com/videos/working-with-arrays-in-matlab-69022.html

Building Arrays

- Recall that we can build arrays as:

```
>> A = [1, 2; 3 4];
```

- We can also build arrays from existing arrays (if correct size):

```
>> B = [b, c];
```

Array Building Functions

Command	Meaning
`ones(m,n)`	Build m×n matrix of 1's
`zeros(m,n)`	Build m×n matrix of 0's
`eye(n)`	Identity matrix
`diag(vec)`	Create diagonal matrix
`diag(A)`	Diagonal elements of A
`rand(m,n)`	Uniform random number array
`randn(m,n)`	Gaussian Random number array
`magic(m)`	Magic square matrix
`hilb`	Hilbert matrix

Basic Mathematical Expressions

"Scalar" Operations

- `log, exp`
- `power, sqrt`
- `sin, cos, tan`
- `asin, acos, atan`
- `rem, round, ceil, floor`

Matrix Operations

- `+ - * / ^`
- `logm, expm`
- `mpower, sqrtm`
- `sum,prod,cumsum,cumprod`
- `min, max, mean, std`
- `length, size, eig`

Basic Mathematical Expressions

"Scalar" Operations

- + - .* ./ .^
- log, exp
- power, sqrt
- sin, cos, tan
- asin, acos, atan
- rem, round, ceil, floor

Matrix Operations

- + - * / ^
- logm, expm
- mpower, sqrtm
- sum,prod,cumsum,cumprod
- min, max, mean, std
- length, size, eig

End of Lecture 1-2

INTRODUCTION TO MATLAB PROGRAMMING
Lec 1.2b: Array Operations Revisited

Dr. Niket Kaisare
Department of Chemical Engineering
IIT–Madras

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Tapping some Array Operations in MATLAB

- Also view "Working with Arrays in MATLAB" on MATLAB website:
  http://in.mathworks.com/videos/working-with-arrays-in-matlab-69022.html
- Consider the following example (Marks earned by students)

Name	Math	Programming	Thermodynamics	Mechanics
Amit	24	44	36	36
Bhavna	52	57	68	76
Chetan	66	53	69	73
Deepak	85	40	86	72
Elizabeth	15	47	25	28
Farah	79	72	82	91

Some things to try

- Create a 6×3 matrix `allMarks` to contain marks for first three courses
- Append marks for the Mechanics course to `allMarks` when received
- Do the following computations
  - Mechanics course was out of 50. Scale the marks to half
  - Extract row 3 and give the m… arks
  - Extract marks of our best stu… ourses
  - Calculate average marks obt…
  - Scale all the marks out of 10…

We will use matrix fundaes for this:

$$\begin{bmatrix} a & b \\ c & d \\ e & f \end{bmatrix} \begin{bmatrix} 2 & 0 \\ 0 & 0.1 \end{bmatrix} = \begin{bmatrix} 2a & 0.1b \\ 2c & 0.1d \\ 2e & 0.1f \end{bmatrix}$$

End of Lecture 1-2b

INTRODUCTION TO MATLAB PROGRAMMING
Lec 1.3: Loops and Execution Control

Dr. Niket Kaisare
Department of Chemical Engineering
IIT–Madras

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Various Loops in MATLAB

- For Loop (commands below will execute 10 times)

```
for i=1:10
    <statement 1>;
    ⋮
    <statement n>;
end
```

- While Loop (commands below will execute if the condition is true)

```
while i<10
    <statement 1>;
    ⋮
    <statement n>;
    i=i+1;
end
```

When to use For Loop

- For loop is used when a set of operations are to be repeated a specific number of times
- Examples
  - Find first 10 terms of Fibonacci series
  - Find factorial of a number n
  - …

When to use While Loop

- While loop is used when a set of operations is to be repeated if a certain condition is met
  - Find all terms of Fibonacci series less than value 200
  - Location of a ball thrown upwards is given by $y = v_0 t - \frac{1}{2} g t^2$. Calculate the location of the ball for every 0.1 seconds until it reaches the ground (i.e., $y > 0$)

MacLaurin Series

- Calculate approximate value of $e^{0.5}$ using the infinite series:

$$e^a = 1 + a + \frac{a^2}{2!} + \frac{a^3}{3!} + \frac{a^4}{4!} + \cdots$$

These calculations are to be performed with 2 to 7 terms in the series

End of Lecture 1-3

INTRODUCTION TO MATLAB PROGRAMMING
Lec 1.4: Working with Files – Scripts & Functions

Dr. Niket Kaisare
Department of Chemical Engineering
IIT–Madras

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Working with MATLAB files

- Type "`edit <fileName>`" at the command prompt to open MATLAB code editor with the file `fileName.m`.
- MATLAB files are of two types: Scripts and Functions
- More help from MATLAB website on "Writing a MATLAB Program": http://in.mathworks.com/videos/writing-a-matlab-program-69023.html

MATLAB Files: Scripts vs. Functions

- **Scripts**
  Files containing sequence of MATLAB commands
- MATLAB statements are executed as if typed on command prompt

- **Functions**
  Files that take certain input(s), executes sequence of steps, and returns output(s) at the end
- MATLAB statements are executed in function's own variable space

Scope of Variables

- `script` shares the variables with workspace from where it was called
- Typically, that means MATLAB workspace

- `function` has its own workspace
- Variables used in a function have local scope
- Functions "talk" through input and output variables:

```
[out1,out2,...] = function fcnName(in1,in2,...)
```

Script and Function Examples:

- Write a script to calculate factorial

$$n! = 1 \times 2 \times \cdots \times n$$

- Write a function to calculate

$$f = c_0 + c_1 x + c_2 x^2 + \cdots + c_n x^n$$

Note: Such functions are commonly used to calculate physical properties of fluids.
Today, we will consider a simple case of:

$$c_0 = 1, \qquad c_m = 1/m$$

When to use Scripts vs. Functions (beginners)

- Use scripts when you want to…
  - Make small calculations (e.g., factorial, plotting, basic computing etc.)
- Use functions when you want to…
  - Calculate values (r) as a function of variables (t,y,…): $r = f(t, y, \ldots)$
  - Pass on the function values to MATLAB function for solving something; e.g.,:

$\frac{dy}{dt} = f(t, y)$ → `function dy = myODEfun(t,y)`

`<...>ode45(@myOdefun, <...>)`

  - Calculate properties as a function of temperature, concentration, current, etc.
- All other purposes, you are likely to use scripts (instead of functions)

INTRODUCTION TO MATLAB PROGRAMMING
Lec 1.5: Plotting and Output

Dr. Niket Kaisare
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Various forms of output

- Display on the screen
  - Variables will `echo` if command ends without semicolon
  - Other options…
- Plotting data
  - Using `plot` command
  - Other options…
- More help from MATLAB website on "Using Basic Plotting Functions"
  http://in.mathworks.com/videos/using-basic-plotting-functions-69018.html

Displaying on the screen

- Recall various methods we used in this module:
  - `Echo` result on screen: `>> b = [1, 2; 7 1];`
  - Using `disp` command: `disp(b)`
  - `disp` some text: `disp('Hello world')`
  - More "beautiful" output:

```
disp(['Factorial value is ', num2str(factValue)])
```

  - More advanced output using `fprintf`:

```
fprintf('Factorial Value is: %4i\n',factValue)
```

Plotting

- Consider the example of a ball thrown vertically upwards
  - Plot location vs. time
  - `Label`ing the axes
  - Other plotting options
- `Plot`-ting multiple lines
- `Log-Log` plot

End of Lecture 1.5

MODULE – 1
INTRODUCTION TO MATLAB PROGRAMMING

Dr. Niket Kaisare
Department of Chemical Engineering
IIT–Madras

Summary of Module-1

- MATLAB basics
  - Familiarized with MATLAB command window and editor
  - Variables: scalars, vectors and arrays
  - Mathematical operations: both scalar and matrix operations
- Arrays: Unlocking potential of MATLAB
  - Array operations vs. elemental operations
  - Using arrays for more efficient use of MATLAB

Summary of Module-1

- Execution control
  - `for` and `while` loops
  - `if-then` statements
- MATLAB files
  - Scripts and Functions
  - When to use scripts vs. functions
- Plotting in MATLAB