Introduction to MATLAB

Contact Information

- Course website:
  - http://www.ing.unife.it/simani/lessons12.html
  - Information also will be contained on website

Course Overview

- Course Structure
- Meeting Times and Locations
- Coursework

Course Structure

- Spread over 7 weeks
- 3 classes per week
- 2/3 hours per class
  – 3 hours classes in Lab.
  – 2 hours classes in lecture rooms (7, 9)

Course Structure

- Overview of MATLAB
  - – History of MATLAB
  - – Overview of MATLAB environment
  - – Discussion of MATLAB tools
- Basic MATLAB
  - – Simple MATLAB functionality
    - Syntax, Commands
  - – Exercises involving basic MATLAB functionality and its *Toolboxes*

Course Structure

- Advanced MATLAB Functionality
  - – Beyond MATLAB as a calculator
  - – The MATLAB programming language
  - – Project showcasing MATLABs advanced functionality
    - Other *Toolboxes*
    - Dynamic System Simulations
    - Digital Control Design

Meeting Times and Locations

- Class 1
  - Wednesday, 14:00 – 17:00, Laboratory
- Class 2
  - Thursday, 15:00 – 17:00, Room 7
- Class 3
  - Friday, 10:30 – 12:30, Room 9

Meeting Times and Locations

- Miscellaneous
  - Wednesday classes in Laboratory
    - Possible meetings also in Room 9
  - Attendance
    - Attend as many sessions as possible
    - Let me know if you have any conflicts
    - Lecture slides will be posted on the website

Coursework

- Most important part of the course + digital control theory
- Will take place mostly during class sessions:
  - Wednesday: laboratory experiences
  - Thursday & Friday: digital control theory
- Several assignments:
  - the final project is a collection of several exercises

Coursework

- Collection of exercises:
  - Will occur during the laboratory sessions
  - Will involve MATLABs basic functionality
  - Will exploit its Toolboxes for Control System Design
- **Final Examination**:
  - Single practical project @ PCs;
  - Will cover digital control system theory.

MATLAB Overview

- What is MATLAB?
- History of MATLAB
  - Who developed MATLAB
  - Why MATLAB was developed
  - Who currently maintains MATLAB
- Strengths of MATLAB
- Weaknesses of MATLAB

What is MATLAB?

- MATLAB
  - **MATrix LABoratory**
  - Interactive & programming language
    - Will be covered during week 2
  - Control System Design & Programming tool
    - Will be covered during week 3

What is MATLAB con't: 2

- Considering MATLAB at home
  - Standard edition
    - Available for roughly 2 thousand dollars
  - Student edition
    - Available for roughly 1 hundred dollars.
    - Some limitations, such as the allowable size of a matrix

History of MATLAB

- Ancestral software to MATLAB
  - Fortran subroutines for solving linear (LINPACK) and eigenvalue (EISPACK) problems
  - Developed primarily by Cleve Moler in the 1970's

History of MATLAB, con't: 2

- Later, when teaching courses in mathematics, Moler wanted his students to be able to use LINPACK and EISPACK without requiring knowledge of Fortran
- MATLAB developed as an interactive system to access LINPACK and EISPACK

History of MATLAB, con't: 3

- MATLAB gained popularity primarily through word of mouth because it was not officially distributed
- In the 1980's, MATLAB was rewritten in C with more functionality (such as plotting routines)

History of MATLAB, con’t: 4

- The Mathworks, Inc. was created in 1984
- The Mathworks is now responsible for development, sale, and support for MATLAB
- The Mathworks is located in Natick, MA
- The Mathworks is an employer that hires co-ops

Strengths of MATLAB

- MATLAB is relatively easy to learn
- MATLAB code is optimized to be relatively quick when performing matrix operations
- MATLAB may behave like a calculator or as a programming language
- MATLAB is interpreted, errors are easier to fix
- Although primarily procedural, MATLAB does have some object-oriented elements

Weaknesses of MATLAB

- MATLAB is NOT a general purpose programming language
- MATLAB is an interpreted language (making it for the most part slower than a compiled language such as C++)
- MATLAB is designed for scientific computation and is not suitable for some things (such as parsing text)

Overview

- Review of main topics
- Review of the MATLAB environment
- Declaring and manipulating variables
- Useful functions

MATLAB GUI

- Launch Pad / Toolbox
- Workspace
- Current Directory
- Command History
- Command Window

Launch Pad / Toolbox

- Brief details
- Launch Pad allows you to start help/demos
- *Toolbox* is for use with specialized packages (*e.g.,* Signal Processing)

Introduction to Matlab

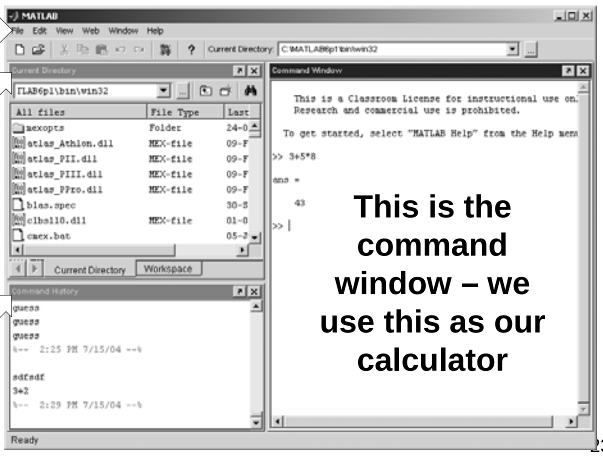
Using MATLAB

- This is the window that appears when you start MATLAB

This is the menu bar

This window shows the current directory or the workspace

This window shows the command history



```
ΓLAB6p1\bin\win32
All files            File Type   Last
mexopts              Folder      24-0
atlas_Athlon.dll     MEX-file    09-F
atlas_PII.dll        MEX-file    09-F
atlas_PIII.dll       MEX-file    09-F
atlas_PPro.dll       MEX-file    09-F
blas.spec                        30-S
clbs110.dll          MEX-file    01-0
cmex.bat                         05-J
```

```
guess
guess
guess
%--  2:25 PM 7/15/04 --%

sdfsdf
3+2
%--  2:29 PM 7/15/04 --%
```

```
  This is a Classroom License for instructional use on.
  Research and commercial use is prohibited.

 To get started, select "MATLAB Help" from the Help menu

>> 3+5*8

ans =

   43

>> |
```

This is the command window – we use this as our calculator

Introduction to Matlab

Workspace

- Allows access to data
- Area of memory managed through the Command Window
- Shows Name, Size (in elements), Number of Bytes and Type of Variable

Current Directory

- MATLAB, like Windows or UNIX, has a current directory
- MATLAB functions can be called from any directory
- Your programs (to be discussed later) are only available if the current directory is the one that they exist in

MATLAB as a Calculator

- You can enter expressions at the command line and evaluate them right away.

previous command

```
>> 3 + 5*8

ans =

        43

>>
```

next command

The '>>' symbols indicate where commands are typed.

Mathematical Operators

Operator	MATLAB	Algebra
+	`+`	`5 + 4 = 9`
–	`-`	`5 - 4 = 1`
×	`*`	`5 * 4 = 20`
÷	`/`	`5 / 4 = 1.25`
a^b	`a^b`	`5^4 = 625`

Command History

- Allows access to the commands used during this session, and possibly previous sessions
- Clicking and dragging to the Command window allows you to re-execute previous commands

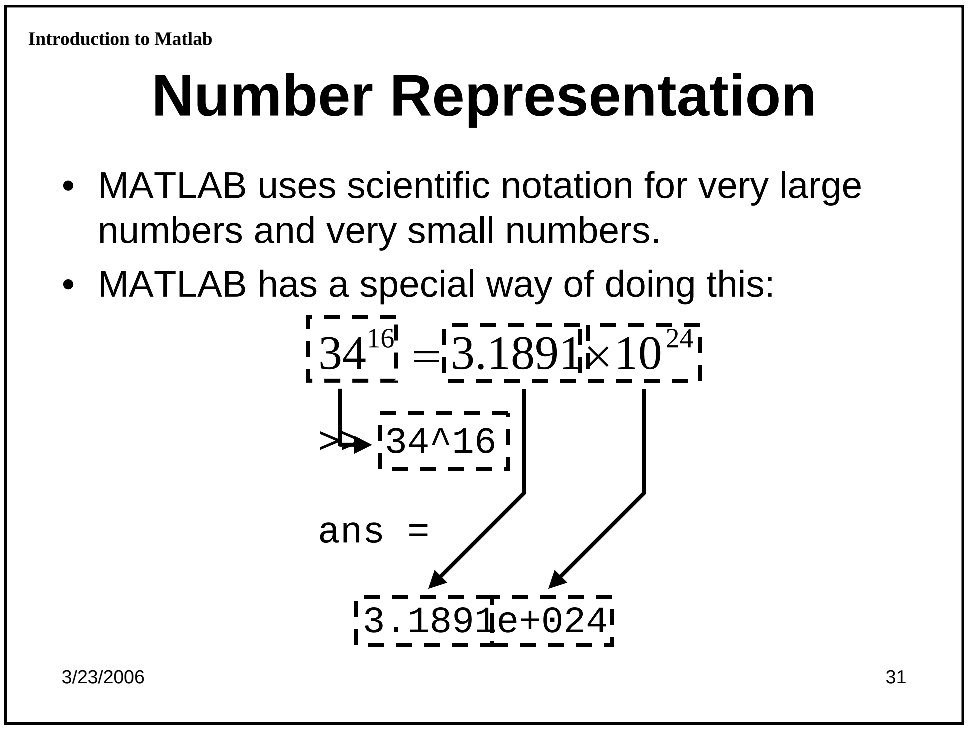
Command Window

- Probably the most important part of the GUI
- Allows you to input the commands that will create variables, modify variables and even (later) execute scripts and functions you program yourself.

Mathematical Operators

```
>> 5+4
ans =
        9
>> 5-4
ans =
        1
>> 5*4
ans =
        20
```

```
>> 5/4
ans =
        1.2500
>> 5^4
ans =
        625
>> 34^16
ans =
        3.1891e+024
```



Number Representation

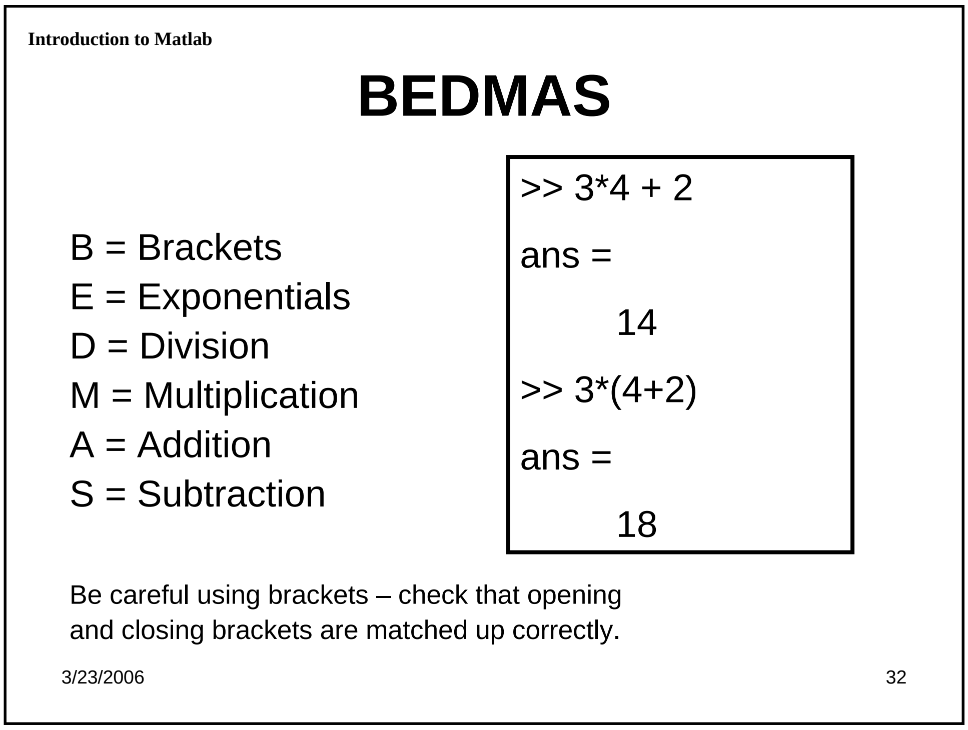
- MATLAB uses scientific notation for very large numbers and very small numbers.
- MATLAB has a special way of doing this:

$$\boxed{34^{16}} = \boxed{3.1891}\boxed{\times 10^{24}}$$

```
>> 34^16

ans =

  3.1891e+024
```



BEDMAS

B = Brackets
E = Exponentials
D = Division
M = Multiplication
A = Addition
S = Subtraction

```
>> 3*4 + 2
ans =
        14
>> 3*(4+2)
ans =
        18
```

Be careful using brackets – check that opening and closing brackets are matched up correctly.

Simple Commands

- who
- whos
- save
- clear
- load

`who`

- **`who`** lists the variables currently in the workspace.
- As we learn more about the data structures available in MATLAB, we will see more uses of “**`who`**”

`whos`

- **`whos`** is similar to who, but also gives size and storage information
- s = **`whos`**(...) returns a structure with these fields name variable name size variable size bytes number of bytes allocated for the array class class of variable and assigns it to the variable s. (We will discuss structures more).

Save

- **`save`** – saves workspace variables on disk
- **`save filename`** stores all workspace variables in the current directory in filename.mat
- **`save filename var1 var2 ...`** saves only the specified workspace variables in **`filename.mat`**. Use the * wildcard to save only those variables that match the specified pattern.

`clear`

- **`clear`** removes items from workspace, freeing up system memory

- Examples of syntax:
  - **`clear`**
  - **`clear name`**
  - **`clear name1 name2 name3 ...`**

`clc`

- Not quite clear

- **`clc`** clears only the command window, and has no effect on variables in the workspace.

`load`

- **`load`** - loads workspace variables from disk
- Examples of Syntax:
  - **`load`**
  - **`load filename`**
  - **`load filename X Y Z`**

Declaring a variable in MATLAB

- Not necessary to specify a type. (Such as integer or float)
- Several kinds of variables:
  - Vector
  - Matrix
  - Structure
  - Cell array

Declaring a variable, con't: 2

- For an integer or floating point number: simply set a variable name equal to some character
- Ex. >> **`A = 5;`**
- Or >> **`A = 5`**
  - Have you seen any difference?

Side note 1

- The presence or lack of a **semi-colon** after a MATLAB command does not generate an error of any kind
- The presence of a **semi-colon** tells MATLAB to suppress the screen output of the command

Side note 1, con't: 2

- The lack of a **semi-colon** will make MATLAB output the result of the command you entered

- One of these options is not necessarily better than the other

Declaring a variable, con't: 3

- You may now use the simple integer or float that you used like a normal number (though internally it is treated like a 1 by 1 matrix)

- Possible operations:
  - +, -, /, *
  - Many functions (round(), ceil(), floor())

Declaring a variable, con't: 4

- You may also make a vector rather simply
- The syntax is to set a variable name equal to some numbers, which are surrounded by brackets and separated by either spaces or commas
- Ex. >>**`A = [1 2 3 4 5];`**
- Or >>**`A = [1,2,3,4,5];`**
  - **Any difference?**

Declaring a variable, con't: 5

- You may also declare a variable in a general fashion much more quickly
- Ex. >> **`A = 1:1:10`**
- The first 1 would indicate the number to begin counting at
- The second 1 would be the increase each time
- And the count would end at 10

Declaring a variable, con’t: 6

- Matrices are the primary variable type for MATLAB
- Matrices are declared similar to the declaration of a vector
- Begin with a variable name, and set it equal to a set of numbers, surrounded by brackets. Each number should be separated by a comma or semi-colon

Declaring a variable, con’t: 7

- The semi-colons in a matrix declaration indicate where the row would end
- Ex. **`A = [ 1,2;3,4]`** would create a matrix that looks like

```
[ 1 2
  3 4 ]
```

Declaring a variable, con’t: 7

- Matrices may be used as normal variables now. Multiplying is already defined for matrices, and additional code does not need to be written.

Declaring a variable, con’t: 8

- The final type of variable we will discuss today will be a “struct”.
- The command **`struct`** is used to create a structure
- Syntax:
  - **`s = struct('field1',{},'field2',{},...)`**
  - **`s = struct('field1',values1,'field2',values2,...)`**

Declaring a variable, con’t 9

- A simple declaration of a structure is as follows:

```
Student.name = ‘Joe’;
Student.age = 23;
Student.major = ‘Computer Science’;
```

Declaring a variable, con’t: 10

- Arrays of structures are possible.
- Taking the previous example, if one were to write:

```
Student(2).name = ‘Bill’
```

…etc

Then the **array** would be created for you.

Declaring a variable, con't: 11

- Structures can group information, but methods are not written for them.

Built-In Functions

- Like a calculator, MATLAB has many built-in mathematical functions.

```
>> sqrt(4)
ans =
        2
>> abs(-3)
ans =
        3
```

- To find out more about MATLAB's functions use MATLAB's help (from command window).

Variables

- We use variables so calculations are easily represented.

$$C = (F - 32) \times \frac{5}{9}$$

$$F = 100 \Rightarrow C = 37.8$$

$$F = 32 \Rightarrow C = 0$$

- You can think of variables as *named locations in the computer memory in which a number can be stored.*

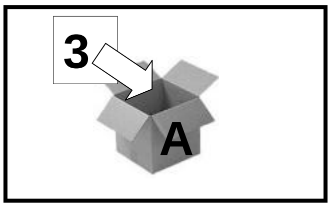
MATLAB Variables

```
>> F=100
F =
        100
>> C=(F-32)*5/9
C =
        37.7778
>> F = 32
        F = 32
>> C=(F-32)*5/9
C =
        0
```

Memory as a Filing System

- You can think of computer memory as a large set of “boxes” in which numbers can be stored. The values can be inspected and changed.
- Boxes can be labelled with a variable name.

```
>> A=3
A =
    3
```



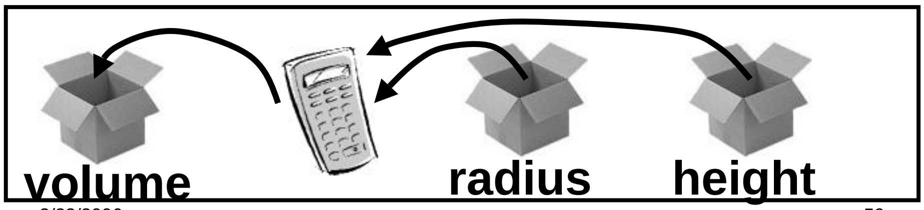
Special Variables

- MATLAB has some special variables:
  - **`ans`** is the result of the last calculation.
  - **`pi`** represents π.
  - **`Inf`** represents infinity.
  - **`NaN`** stands for not-a-number and occurs when an expression is undefined e.g. division by zero.
  - **`i`**, **`j`** represent the square root of –1 (necessary for complex numbers)

Calculations with Variables

- Suppose we want to calculate the volume of a cylinder.
- It's **`radius`** and **`height`** are stored as variables in memory.

```
>> volume = pi*radius^2*height
```



Another satisfied MATLAB user!

Overview

- Brief review of topics covered until now
- Exercises involving creation and manipulation of variables
- More functions!
- Story time – MATLAB Experience

Simple Commands, con’t: 2

- **`who`** and **`whos`** are similar, they allow you to see the variables in your workspace
- **`save`** saves the variables in your workspace to a binary file readable by MATLAB
- **`clear`** removes the variables from your workspace
- **`load`** loads the binary file created by the save command and restores the variables to your workspace

Simple Commands, con’t: 3

- For any of these commands (and many others) you can get a more in depth explanation by typing help followed by the name of the command
- Ex. >>**`help clear`**
- Online documentation for all of these commands is also available on the Mathworks website

Declaring variables in MATLAB

- Learned how to declare several types of variables:
  - Normal floats and int(eger)s
  - Vectors
  - Matrices
  - Structures

Declaring variables in MATLAB, con’t: 2

- Regular int/floats
- Variable name followed by an equals sign and the value you wish to assign
- Ex. **`A = 5;`**

Declaring variables in MATLAB, con’t: 3

- Vectors
- Variable name followed by an equals sign and one or more numbers separated by either spaces or commas and surrounded by brackets
- Ex. **`A = [ 1 2 3 4 5 ];`**

Declaring variables in MATLAB, con't: 4

- Matrices
- Like vector – variable name followed by an equals sign and one or more numbers separated by either spaces or commas and surrounded by brackets. Use semi-colons to indicate a change in row.
- Ex. **`A = [ 1 2; 3 4 ];`**

Declaring variables in MATLAB, con't: 5

- Structures
- Like a struct in C or C++, similar to a class in C++ or Java, but lacking class specific functions or methods
- Declared using a point operator

Declaring variables in MATLAB, con't: 6

- Structures, con't
- Ex.

```
A.name = 'Joe';
A.age = 23;
A.occupation = 'student';
```

Declaring variables in MATLAB, con't: 7

- Structures, con't: 2
- Can have an array of structures
- Ex.

```
A(2).name = 'Bob';
…
```

Sample MATLAB functions

- `Min`
- `Max`
- `Median`
- `Mean`
- `Sum`
- `Diff`

MATLAB Functions: `min`

- `min`
- Will find the minimum element of the array
- Works slightly different on vectors and matrices

MATLAB Functions: `max`

- **`max`**
- Will find the maximum element of the array
- Also works slightly different on vectors and matrices

MATLAB Functions: `median`

- **`median`**
- Will find the median value of the array
- Also works slightly different on vectors and matrices

MATLAB Functions: `mean`

- **`mean`**
- Returns the average value of the array
- Works slightly different on vectors and matrices

MATLAB Functions: `sum`

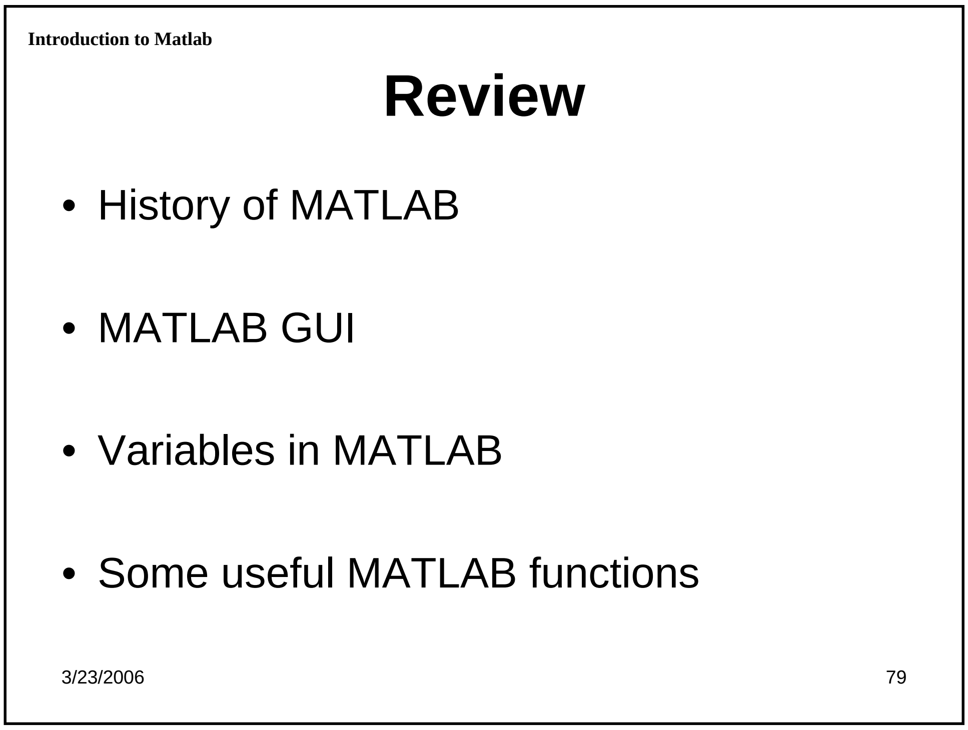
- **`sum`**
- Will return a sum of the array elements
- Also works slightly different on vectors and matrices

`diff`

- **`diff`**
- Will return the difference between adjacent elements in an array
- This is an approximate derivative

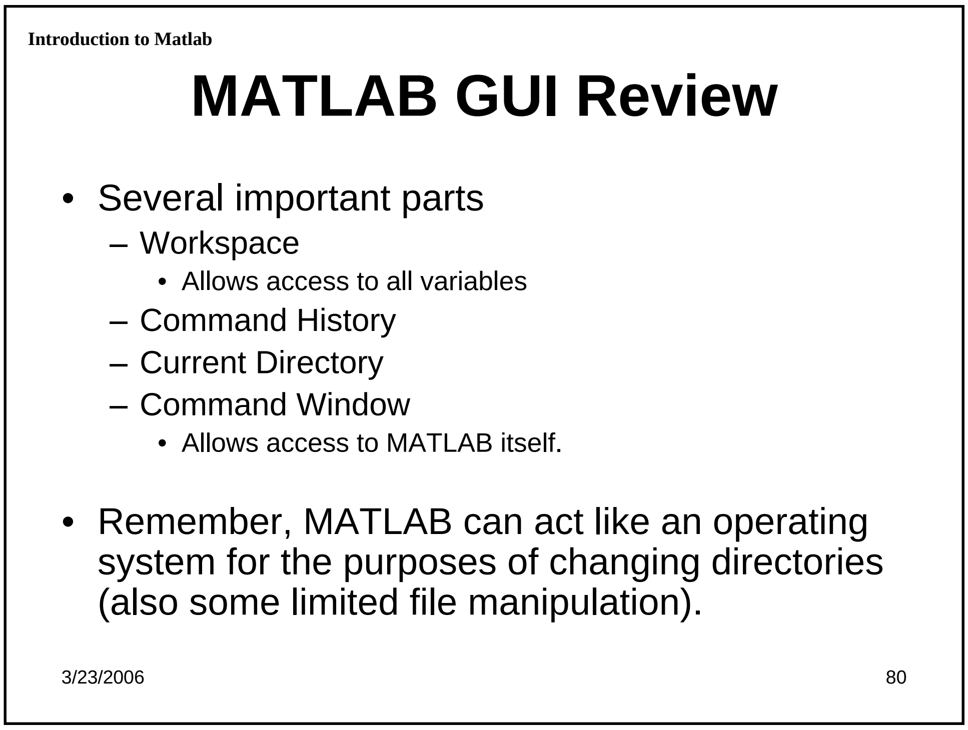
Story time!

- More in depth discussion of MATLAB in the workplace



Review

- History of MATLAB
- MATLAB GUI
- Variables in MATLAB
- Some useful MATLAB functions



MATLAB GUI Review

- Several important parts
  - Workspace
    - Allows access to all variables
  - Command History
  - Current Directory
  - Command Window
    - Allows access to MATLAB itself.
- Remember, MATLAB can act like an operating system for the purposes of changing directories (also some limited file manipulation).

Variables in MATLAB

- Several major types
  - Int/Floats
  - Vectors
  - Matrices
  - Structures

He’s still here.

Overview

- Brief review
- Plotting – in depth
- File I/O – few details

New MATLAB Function

- **`rand()`** - Uniformly distributed random numbers and arrays
- Example of syntax:
  - **`A = rand(n)`**
  - **`A = rand(m,n)`**
- Where **`m`** and **`n`** are dimensions of the matrix

`rand()` con’t: 2

- Scalars may be generated
  - Ex. **`A = rand(1,1);`**

- Vectors may be generated
  - Ex. **`A = rand(10,1);`**

`rand()` con’t: 3

- Generated random numbers will be between 0 and 1.

- Scaling can be done by multiplying the resulting matrix or vector by the number you wish to scale with

Plotting

- Several types of plots available

- **`plot`**
- **`polar`**
- **`bar`**
- **`hist`**

`plot()` (from *MATLAB help*)

- Linear 2-D plot

- Syntax:
  - **`plot(Y)`**
  - **`plot(X1,Y1,...)`**
  - **`plot(X1,Y1,LineSpec,...)`**
  - **`plot(...,'PropertyName',PropertyValue,...)`**
  - **`h = plot(...)`**

`plot()` con’t: 2

- MATLAB defaults to plotting a blue line between points
- Other options exist:
  - Different color lines
  - Different types of lines
  - No line at all!

`plot()` con’t: 3 – Color options

- Color options:
  - Yellow - **‘y’**
  - Magenta - ***‘m’***
  - Cyan - **‘c’**
  - Red - **‘r’**
  - Green - **‘g’**
  - Blue - **‘b’**
  - White - **‘w’**
  - Black - **‘k’**
- Example:

```
– >> temp=1:1:10;
– >> plot(temp, ‘y’);
```

`plot()` con’t: 4 – Line options

- Line styles:
  - **`‘-’:`** solid line (default)
  - **`‘--’:`** dashed line
  - **`‘:’:`** dotted line
  - **`‘-.’:`** dash-dot line

`plot()` con’t: 5 – Line Markings

- **+** - plus sign
- **o** - circle
- **`*`** - asterisk
- **`.`** - Point
- **x** - cross
- **s** - square
- **d** - diamond
- **^** - upward pointing triangle
- **v** - downward pointing triangle
- **>** - right pointing triangle
- **<** - left pointing triangle
- **p** - five-pointed star (pentagram)
- **h** - six-pointed star (hexagram)

`polar()`

- Plot polar coordinates
- Syntax:
  - **`polar(theta,rho)`**
  - **`polar(theta,rho,LineSpec)`**
- **`theta`** – Angle counterclockwise from the 3 o'clock position
- **`rho`** – Distance from the origin

`polar()` con't: 2

- Line color, style and markings apply as they did in the example with **`plot()`** .

`bar()`

- Creates a bar graph

- Syntax
  - **`bar(Y)`**
  - **`bar(x,Y)`**
  - **`bar(...,width)`**
  - **`bar(...,'`*`style`*`')`**
  - **`bar(...,LineSpec)`**

`hist()`

- Creates a histogram plot

- Syntax:
  - **`n = hist(Y)`**
  - **`n = hist(Y,x)`**
  - **`n = hist(Y,nbins)`**

File I/O

- Both high-level and low-level file I/O
- High-level covered here

High-Level File I/O

- I/O = input/output; 3 important commands for input:
  - **`csvread`**: **`M = CSVREAD('FILENAME')`** reads a comma separated value formatted file **`FILENAME`**. The result is returned in **`M`**. The file can only contain numeric values.
  - **`dlmread`**: **`RESULT= dlmread(FILENAME,DELIMITER)`** reads numeric data from the ASCII delimited file **`FILENAME`** using the delimiter **`DELIMITER`**. The result is returned in **`RESULT`**. Use **`'\t'`** to specify a tab.
  - **`textread`**: **`A = textread('FILENAME')`** read formatted data from text file. It reads also numeric data from the file **`FILENAME`** into a single variable. If the file contains any text data, an error is produced.

`csvread`

- Read a comma-separated value file
- Syntax:
  - **`a = csvread('filename')`**
  - **`a = csvread('filename',row,col)`**
  - **`a = csvread('filename',row,col,range)`**
- Note – **`csvread`** does not like to read in text!

`dlmread`

- Like **`csvread`**, only instead of a comma, you specify the delimiter
- Syntax:
  - **`a = dlmread(filename,delimiter)`**
  - **`a = dlmread(filename,delimiter,R,C)`**
  - **`a = dlmread(filename,delimiter,range)`**
- Treat this like a generalized form of **`csvread`**.

`textread`

- Reads formatted data from a text file
- Syntax:
  - `[A,B,C,...] = textread('filename','format')`
  - `[A,B,C,...] = textread('filename','format',N)`
  - `[...] = textread(...,'param','value',...)`
- Useful, but try to do without it, MATLAB is somewhat slower when dealing with text data

Overview

- Brief review
- File Output
- MATLAB Scripts and Functions

Delimiters

- Delimiter: A character or sequence of characters marking the beginning or end of a unit of data.
- Ex. **`1,2,3`** (the delimiter would be **`,`**)
- Also **`1:2:3`** (the delimiter would be **`:`**)

Delimiters, con't: 2

- The most common delimiter is a comma: hence the term csv (CSV, *i.e.* Comma Separated Value) or comma separated values.
- Microsoft Excel can read csv formatted files

High Level File Output

- Some of the input commands have corresponding high-level output commands
- **`csvwrite`**
- **`dlmwrite`**

csvwrite

- Write a matrix to a comma-separated value file
- Syntax:
  - **`csvwrite('filename',M)`**
  - **`csvwrite('filename',M,row,col)`**

    writes matrix `M` starting at offset **`row`** , and column **`col`** in the file. **`row`** and **`col`** are zero-based, that is **`row=col=0`** specifies first number in the file.
- Ex. **`csvwrite(‘blah.csv’,a);`**

`dlmwrite`

- Writes a matrix **`M`** to a delimited file (using the delimiter you specify)
- Syntax:
  - **`dlmwrite(filename,M,delimiter)`**
  - **`dlmwrite(filename,M,delimiter,row,col)`**
- Ex. **`dlmwrite('blah.txt',a,':');`**

Low-Level file I/O

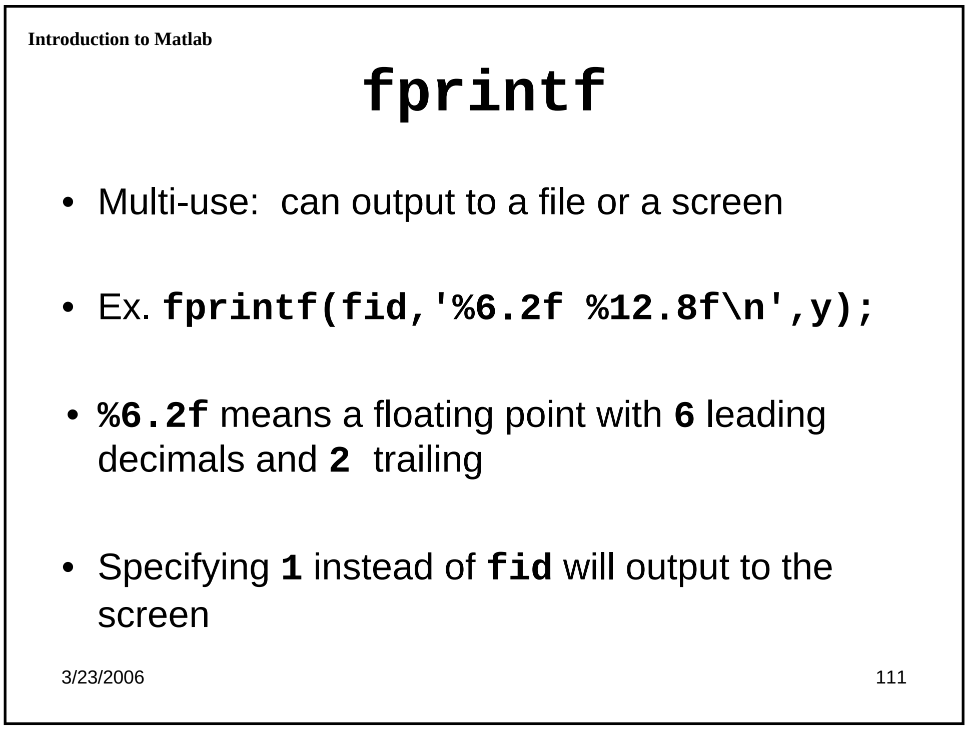
- **`fopen`**
- **`fclose`**
- **`fprintf`**
- **`fgetl / fgets`**

fopen

- Opens a file and returns the handle to the file object
- `File_ID = fopen('blah.txt')`
- Capturing the file handle is necessary to write or read to/from the file

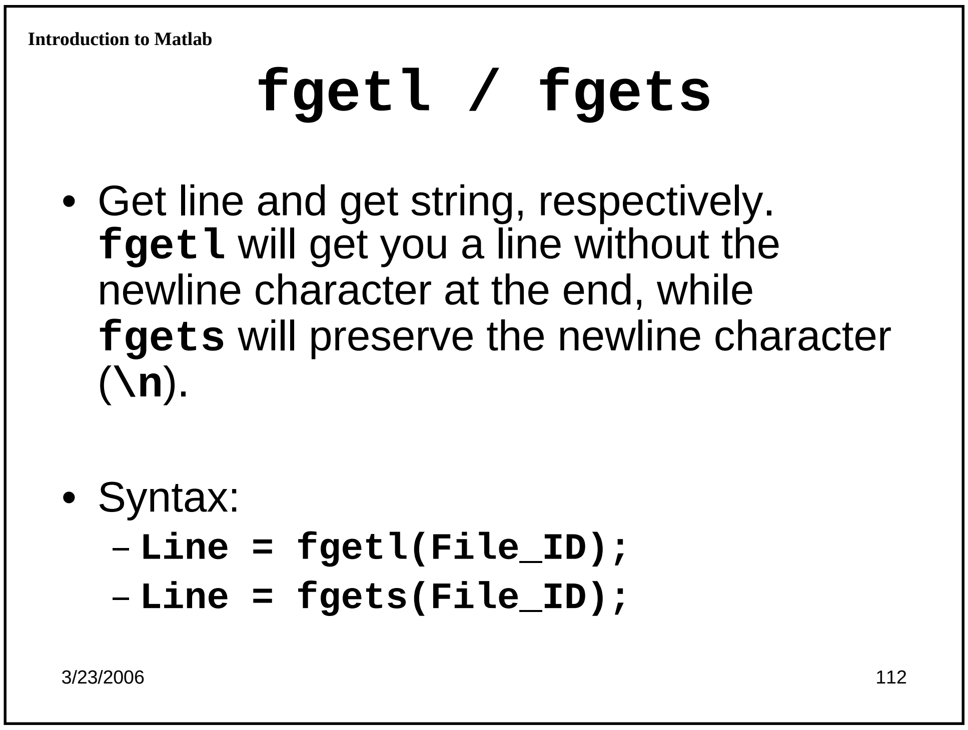
fclose

- Closes a file associated with a specific file identification handle
- Ex. `fclose(File_ID);`
- Ex. `fclose('all');`



`fprintf`

- Multi-use: can output to a file or a screen
- Ex. **`fprintf(fid,'%6.2f %12.8f\n',y);`**
- **`%6.2f`** means a floating point with **`6`** leading decimals and **`2`** trailing
- Specifying **`1`** instead of **`fid`** will output to the screen



`fgetl / fgets`

- Get line and get string, respectively. **`fgetl`** will get you a line without the newline character at the end, while **`fgets`** will preserve the newline character (**`\n`**).
- Syntax:
  - **`Line = fgetl(File_ID);`**
  - **`Line = fgets(File_ID);`**

Programming in MATLAB

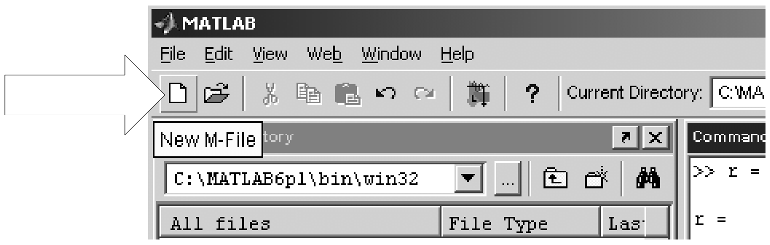
- Two types of files:
  - **Scripts**
  - **Functions**

MATLAB Scripts

- Scripts are MATLAB commands stored in text files. When you type the name of the script file at the MATLAB prompt the commands in the script file are executed as if you had typed them in from the keyboard. Scripts end with the extension `.m`
- Referred to as **M-Files**

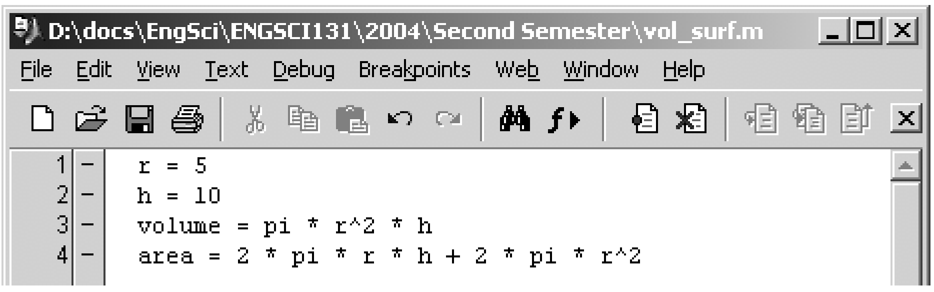
Script Files

- You can save a sequence of commands for reuse later
- Create a new M-File (script file)



Script Files

- Each line is the same as typing a command in the command window
- Save the file as ***`filename`*** `.m`


D:\docs\EngSci\ENGSCI131\2004\Second Semester\vol_surf.m
File Edit View Text Debug Breakpoints Web Window Help

```
r = 5
h = 10
volume = pi * r^2 * h
area = 2 * pi * r * h + 2 * pi * r^2
```

Script Files

- Run the sequence of commands by typing the **`filename`** in the command window

```
>> vol_surf
r =
         5
h =
         10
volume =
         785.3982
area =
         471.2389
>>
```

MATLAB functions

- Have input and output parameters
- MATLAB can return more than one variable at the end of a function
- Variables in scope in the MATLAB function go out of scope and are eliminated when the MATLAB function ceases to exist.

Overview

- Brief review of related topics
- MATLAB Functions
- Looping!
- Optimization
- Review of topics covered thus far

Low-Level file I/O

- `fopen`
- `fclose`
- `fprintf`
- `fgetl / fgets`

Programming in MATLAB

- Two types of files:
  - **Scripts**
  - **Functions**

MATLAB Scripts

- Scripts are MATLAB commands stored in text files. When you type the name of the script file at the MATLAB prompt the commands in the script file are executed as if you had typed them in from the keyboard. Scripts end with the extension **`.m`**
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MATLAB Functions

- Functions are similar to scripts
- Functions may take arguments
- Functions may return one or more values

MATLAB Functions, con’t: 2

- **`function [`*`output`*`] = `*`function_name`*`(`*`input_arguments`*`)`**
- The above is a **function header** and should be the first non-comment line in the function file
- Comments may be placed **below** the function header

MATLAB Functions, con't: 3

- Example function

```
function [output] = square(input)
%
% The function [output] = square(input)
% computes the square of its input
%
  output = input*input;
  return
```

- Body of functions can contain code just like scripts could
- Comment line will be the output of the command
  - `>> help square`

MATLAB Functions, con't: 4

- Another example function

```
function r = rank(A,tol)
%RANK   Matrix rank.
%   RANK(A) provides an estimate of the number of linearly
%   independent rows or columns of a matrix A.
%   RANK(A,tol) is the number of singular values of A
%   that are larger than tol.
%   RANK(A) uses the default tol = max(size(A)) * norm(A) * eps.

%   Copyright 1984-2001 The MathWorks, Inc.
%   $Revision: 5.10 $  $Date: 2001/04/15 12:01:33 $

s = svd(A);
if nargin==1
   tol = max(size(A)') * max(s) * eps;
end
r = sum(s > tol);
```

MATLAB Functions, con't: 5

- Help of the main functions…
  - **SVD   Singular value decomposition.**

```
[U,S,V] = SVD(X) produces a diagonal matrix S,
of the same dimension as X and with
nonnegative diagonal elements in decreasing
order, and unitary matrices U and V so that X
= U*S*V'.

S = SVD(X) returns a vector containing the
singular values.
```

  - **NARGIN Number of function input arguments.**

```
Inside the body of a user-defined function,
NARGIN returns the number of input arguments
that were used to call the function.
```

Looping!

- Scripts and functions also allow the ability to loop using conventional `for` and `while` loops.

- Note that the interpreter also lets you do it, it is simply less easy to grasp

for Loops

- Common to other programming languages

```
for variable = expression
   statement
   ...
   statement
end
```

For Loops, con’t: 2

- Example: (taken from MATLAB help)

```
• a = zeros(k,k) % Pre-allocate matrix
  for m = 1:k
     for n = 1:k
         a(m,n) = 1/(m+n -1);
     end
  end
```

For Loops, con’t: 3

- The looping variable is defined in much the same way that we defined arrays/vectors.
- Ex. **`m = 1:k`**
- Or, **`m = 1:10`**

For Loops, con’t: 4

- Loops are shown to end by the keyword “**end**”
- Curly braces are not present to subdivide packets of code
- Make use of adequate white-space and tabbing to improve code readability

`while` Loops

- Similar to **`while`** loops in other languages

```
while expression
 statement
 …
end
```

`while` Loops, con’t: 2

- Ex. (taken from help while)

```
while (1+eps) > 1
 eps = eps/2;
end
```

`while` Loops, con’t: 3

- Same notes apply to while loops.
- Code is separated by the keyword “**end**”

Looping conclusion

- Some other aspects of looping exist
- Use

  ```
  >> help while
  ```

  and

  ```
  >> help for
  ```

  to see them

MATLAB Code Optimization

- Two ways to optimize MATLAB code
- Vectorise code
- Pre-allocate matrices

Look Ahead

- Review of topics (when requested) or use Matlab **`help` and its `helpdesk`**
- Code generation for **Digital Control System CAD**
- Each laboratory class will introduce more information about **Matlab** and its **Toolboxes**

Overview

- Brief review of topics covered in last slides
- Some more plotting
- Low-level file I/O and handles
- The profiler and **`tic`**-**`toc`**
- Some ui commands

Review

- MATLAB Functions
- Looping!
- Optimization

Case statements

- **Syntax**
  - `switch` *`switch_expr`*

```
case case_expr
 statement,...,statement
case …
{case_expr1,case_expr2,case_expr3,
...} statement,...,statement ...
otherwise
 statement,...,statement end
```

Case statements, con't: 2

- **Ex. (taken from help case)**

```
method = 'Bilinear';
switch lower(method)
    case {'linear','bilinear'}
          disp('Method is linear')
    case 'cubic'
          disp('Method is cubic')
    case 'nearest'
          disp('Method is nearest')
    otherwise disp('Unknown method.')
end
```

```
Method is linear
```

NOTE – when case matches it will not execute all following cases. (Break not necessary).

`if` statements

- Ex. (taken from Matlab help)

```
if expression
     statements
elseif expression
     statements
else
     statements
end
```

`if` statements, con’t: 2

- Ex. (taken again from Matlab help)

```
if I == J
     A(I,J) = 2;
elseif abs(I-J) == 1
     A(I,J) = -1;
else
     A(I,J) = 0;
end
```

MATLAB Code Optimization

- Two ways to optimize MATLAB code
- Vectorise code
- Pre-allocate matrices

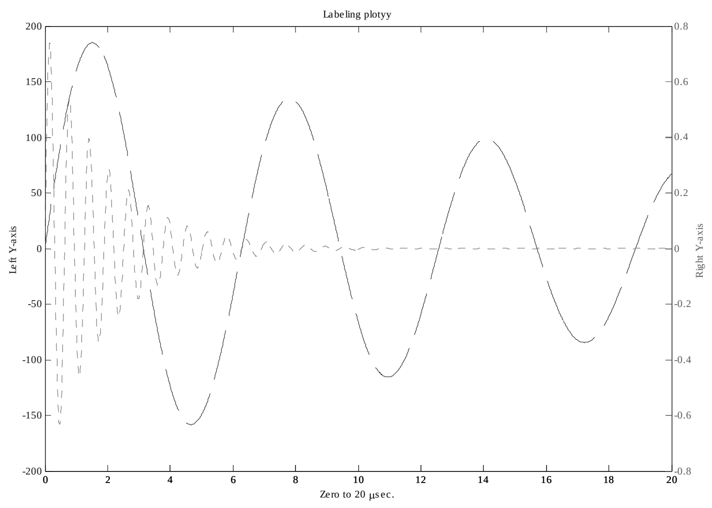
More plotting

- **`plotyy`: example**

```
x = 0:0.01:20;
y1 = 200*exp(-0.05*x).*sin(x);
y2 = 0.8*exp(-0.5*x).*sin(10*x);
[AX,H1,H2] = plotyy(x,y1,x,y2,'plot');
set(get(AX(1),'Ylabel'),'String','Left Y-axis')
set(get(AX(2),'Ylabel'),'String','Right Y-axis')
xlabel('Zero to 20 \musec.')
title('Labeling plotyy')
set(H1,'LineStyle','--')
set(H2,'LineStyle',':')
```

More plotting

- `plotyy`: example



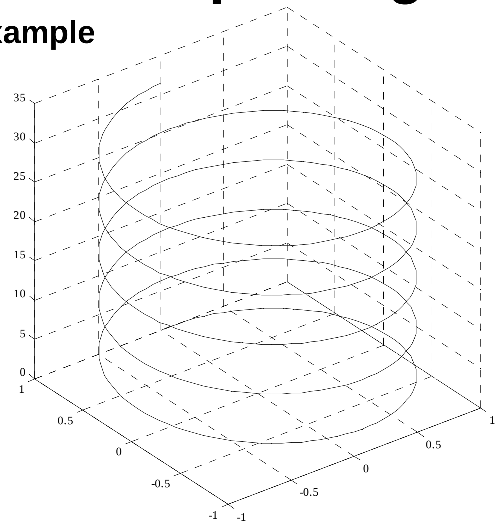
More plotting

- `plot3`: example

```
t = 0:pi/50:10*pi;
plot3(sin(t),cos(t),t)
grid on
axis square
```

More plotting

- `plot3`: example



More plotting

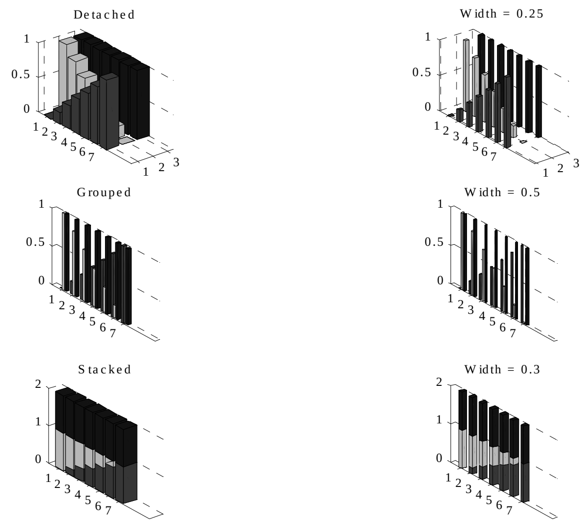
- **`bar3` example**

```
Y = cool(7);

subplot(3,2,1)
bar3(Y,'detached')
title(‘Detached')

subplot(3,2,2)
bar3(Y,0.25,'detached')
title(‘Width = 0.25')

subplot(3,2,3)
bar3(Y,'grouped')
title(‘Grouped')
```

```
subplot(3,2,4)
bar3(Y,0.5,'grouped')
title(‘Width = 0.5')

subplot(3,2,5)
bar3(Y,'stacked')
title(‘Stacked')

subplot(3,2,6)
bar3(Y,0.3,'stacked')
title(‘Width = 0.3')

colormap([1 0 0;0 1 0;0 0 1])
```

More plotting

- `bar3` example



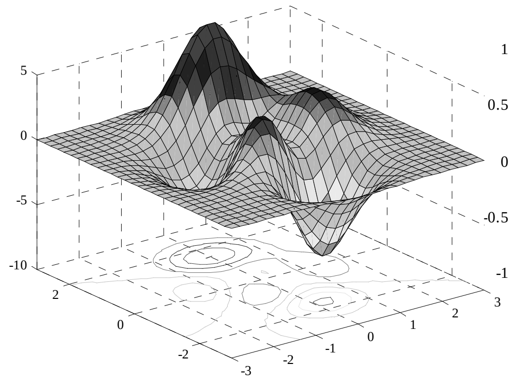
More plotting

- `surf`: 2 examples

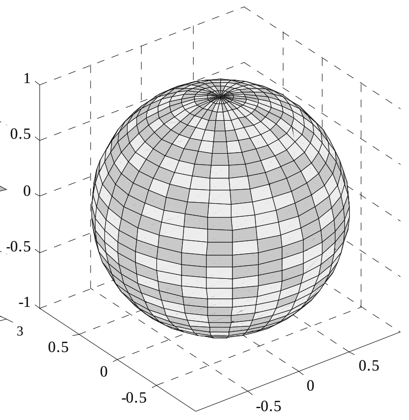
```
% Example 1
[X,Y,Z] = peaks(30);
surfc(X,Y,Z)
colormap hsv
axis([-3 3 -3 3 -10 5])

%Example 2
k = 5;
n = 2^k-1;
[x,y,z] = sphere(n);
c = hadamard(2^k);
surf(x,y,z,c);
colormap([1  1  0; 0  1  1])
axis equal
```

More plotting

- **`surf`: 2 examples**



2 dimensional Gaussian



Sphere

Low level File I/O

- Notes – must open a file and obtain a handle before the commands are used
- Reading accomplished with **`fgetl`** or **`fgets`**
- Writing accomplished with **`fprintf`**

`tic` and `toc`

- **`tic`** and **`toc`** are built in timing mechanisms for code
- Less information than a profile report will generate
- Start the timer by typing **`‘tic’`**
- End the timer and return the elapsed time by typing **`‘toc’`**

Matlab and its Toolboxes

Direct application examples in laboratory room