An Introduction to MATLAB
See Chapter 1 of Gilat

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Outline
The MATLAB IDE

MATLAB is an acronym for Matrix Laboratory. It was originally a linear algebra package. It has developed into an Integrated Development Environment (IDE). It consists of the following:

1. Desktop Tools – a set of tools such as a command window, text editor, file browser (similar to Windows explorer), command history window, GUI building tool, a tool for creating and editing plots, and debugging tools.

2. Mathematical Function Library – a vast array of mathematical functions that can be executed from the command line or from scripts

3. A Scripting Language
The MATLAB IDE

MATLAB IDE (continued):

4. Graphics – MATLAB offers very powerful two and three dimensional graphics. There is also a tool for editing and creating plots

5. API – you can write C, FORTRAN, and Java routines that use MATLAB functions and you can call C, FORTRAN, and Java routines from MATLAB

6. Numerous **Toolboxes** to extend functionality (more on this in a few slides)
MATLAB is very powerful. Here are a few of the many things you can do with MATLAB.

▶ You can use MATLAB as a calculator. It has a vast library of functions you can use. If you need a function that is not included you can write it using the scripting language.

▶ MATLAB is an extremely powerful linear algebra tool. You can use MATLAB for inverse calculations, $LU$ decomposition, Cholesky factorization, etc.

▶ You can use MATLAB for statistical analysis. There are routines for calculating means, variances, correlations, running regressions, forecasting models, etc.

▶ Do symbolic mathematics, for example symbolic integration and differentiation.

▶ Use MATLAB for mathematical optimization.
The MATLAB IDE

- Use MATLAB for simulation models.
- Use the extensive graphing features for two and three dimensional plots and histograms.
- Use the MATLAB scripting language to create your own functions and programs.
- Use the MATLAB GUI tool to build user interfaces to models.
- Use MATLAB to call routines written in C, C++, FORTRAN, and Java. MATLAB has a very powerful API (Application Program Interface). You can also call MATLAB routines from C and Java.
- MATLAB can import and export data in various formats.
- With MATLAB you can generate compiled applications that do not need MATLAB as a host.
The MATLAB IDE

MATLAB out-of-the-box *does not* have all of the features just described.

There are **Toolboxes** you must purchase to extend the basic functionality of MATLAB.

For example, the Booth PC Lab has the basic MATLAB Toolbox and several others (which seems to change).

There are numerous Toolboxes available. For example, there is a Financial Derivatives Tool Box, a Fixed-Income Toolbox, etc. See [http://www.mathworks.com/products/products/product_listing/index.html](http://www.mathworks.com/products/products/product_listing/index.html).
The MATLAB IDE

There are a number of competing products.

- Similar comprehensive products include Mathematica and Maple

- Competitors in the area of statistics include SAS, R, S, and GAUSS.

- Excel with VBA is a competitor

- There are also programming language IDE’s such as Eclipse and Visual Studio .NET
MATLAB provides a command window/tool. This is the “control center.” When MATLAB opens it puts you in the command window.

<table>
<thead>
<tr>
<th>Command</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>clc</td>
<td>clear the command window</td>
</tr>
<tr>
<td>clear</td>
<td>clear the variables and functions from memory</td>
</tr>
<tr>
<td>pwd</td>
<td>print the current directory</td>
</tr>
<tr>
<td>ls</td>
<td>list all of the files in the current directory</td>
</tr>
<tr>
<td>edit</td>
<td>invoke the editor</td>
</tr>
<tr>
<td>plottools</td>
<td>invoke the GUI for making plots</td>
</tr>
<tr>
<td>cd ..</td>
<td>move up one directory</td>
</tr>
<tr>
<td>cd path_to_directory</td>
<td>cd to the specified directory</td>
</tr>
<tr>
<td>path</td>
<td>list all of the paths that MATLAB looks for</td>
</tr>
<tr>
<td>helpdesk</td>
<td>bring up the MATLAB help system</td>
</tr>
<tr>
<td>edit</td>
<td>bring up the editor</td>
</tr>
</tbody>
</table>
The Command Window/Tool

It is also possible to execute DOS or Unix commands from the MATLAB command window. To do so, put an ! before the command. For example

```
!del filename
```

The command window has command completion – use TAB key.

<table>
<thead>
<tr>
<th>Control Key Sequence</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl+P</td>
<td>Recall the previous command</td>
</tr>
<tr>
<td>Ctrl+N</td>
<td>Recall the next line</td>
</tr>
<tr>
<td>Ctrl+B</td>
<td>Move back one character</td>
</tr>
<tr>
<td>Ctrl+F</td>
<td>Move forward one character</td>
</tr>
<tr>
<td>Ctrl+A</td>
<td>Move to beginning of command line</td>
</tr>
<tr>
<td>Ctrl+E</td>
<td>Move to the end of the command line</td>
</tr>
<tr>
<td>Ctrl+Home</td>
<td>Move to top of command window</td>
</tr>
<tr>
<td>Ctrl+End</td>
<td>Move to end of command window</td>
</tr>
<tr>
<td>Ctrl+U</td>
<td>Clear command line</td>
</tr>
</tbody>
</table>
Path, Directories, and File Explorer

In order for MATLAB to execute these functions and programs they must be on path searched by MATLAB. To see which paths MATLAB searches type in `path` at the command line. To add a new path do either of the following

```matlab
>> addpath('path to file')
```

You can also add a path using the GUI. Select **Set Path** in the **File** menu.

Don’t forget to click **Save** so it will remember the path for future sessions.

Also, you may wish to use the option **Add With Subfolders**.
Path, Directories, and File Explorer

Use the cd command to connect to the desired directory. For example,

```plaintext
>> cd c:\b36104\matlab
```

If there are embedded blanks in the path but the path in single quotes. For example

```plaintext
>> cd ‘c:\Documents and Settings’
```

To move up one directory type

```plaintext
>> cd ..
```
In order to list the files in the current directory type in `ls`. In order to see the current working directory type in `pwd`.

MATLAB comes with a file explorer that is very similar to what you have in Windows. You can:

- navigate through directories
- create new directories
- delete files and directories
The MATLAB Editor

MATLAB also has a text editor. You will use this text editor to create your own programs and functions. There are two ways to invoke the text editor.

You can invoke the text editor from the command line with `edit`.

You can also go to the File menu item, select New, and then M File.

The MATLAB editor is a plain-text editor, not a WYSIWYG editor such as Microsoft Word (thank goodness!!!!).
MATLAB as a Calculator

Matlab can be used as a calculator. Type in any arithmetic expression to get the result.

```matlab
>> 1+10^2/50*10
ans = 21
```

Here is a list of the basic MATLAB operators for arithmetic.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Operation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Addition</td>
<td>2 + 2 = 4</td>
</tr>
<tr>
<td>−</td>
<td>Subtraction</td>
<td>2 - 3 = -1</td>
</tr>
<tr>
<td>*</td>
<td>Multiplication</td>
<td>2*5 = 10</td>
</tr>
<tr>
<td>/</td>
<td>Right Division</td>
<td>4/2 = 2</td>
</tr>
<tr>
<td>\</td>
<td>Left Division</td>
<td>4\2 = 2/4 = .5</td>
</tr>
<tr>
<td>^</td>
<td>Power or exponentiation</td>
<td>2^3 = 8</td>
</tr>
</tbody>
</table>
MATLAB as a Calculator

MATLAB follows the standard precedence rules when evaluating arithmetic expression using *infix notation*. Multiplication and division have higher precedence than addition and subtraction

```
>> 5+4*3+1
ans = 18
```

When there is a tie among operators with the same precedence we follow the left associative rule.

```
>> 35/7/5*1
ans = 1
```

Exponentiation has higher precedence than multiplication and division.

```
>> 100-3*5^2
ans = 25
```
MATLAB as a Calculator

Exponentiation is right associative.

\[ \frac{2}{2^{1^3}} \]

Should behave like

\[ \frac{2}{(2^{(1^3)})} \]

and evaluate to 1. However, both MATLAB and Excel violate this time-held tradition and use left associativity to evaluate exponentiation. That is, in MATLAB (and Excel)

```
>> 2/2^1^3
ans = 0.2500
```
MATLAB as a Calculator

Now, what about unary minus? In MATLAB,

```
>> -1^2
ans = -1
```

However, in Excel $-1^2 = 1$. When ever I write an equation assume that unary minus has low precedence, that is, we follow the MATLAB convention (which is the more common) in written work.

Finally, parenthesis always have the highest precedence. You are **never wrong** to indicate the order of operations by using parenthesis.
MATLAB as a Calculator

Summary for arithmetic:

Table: Precedence order for arithmetic

- parenthesis
- exponentiation: left associative
- multiplication, division: left associative
- addition, subtraction: left associative
MATLAB does not have strong typing of variables. In other words, you do not need to define the variable type as an integer, string, matrix, etc. You just write something such as

\[
\text{>> } x = 34.76
\]

\[
\text{>> } y = \text{‘Mary Smith’}
\]

\[
\text{>> } z = [1.2 \ 3; \ 4, \ 9]
\]

In the first case \( x \) is a real number, in the second case \( y \) is a string variable, in the third case \( z \) is a 2 by 2 matrix.
Variables and Functions

The following rules apply to naming variables.

- Variable names can contain letters, digits, and the underscore character (no other characters).

- Variable names must start with a letter.

- Variable names can have up to 63 characters in MATLAB 7 and above and 31 characters in MATLAB 6.

- MATLAB is case sensitive (Excel is not), \( x \) and \( x \) are distinct variables.

- **Do not** create variable names that will conflict with built-in function names, for example, do not define a variable \( \sin \).
Variables and Functions

Type in `whos` to get a list of all variables, their type, and their dimension. (Type `who` is you just want a list of variables.)

```
>> whos
    Name      Size    Bytes  Class       Type
    x         1x1     8       double
    y         1x10    20      char
    z         2x2     32      double
```

MATLAB also has a phenomenal number of functions, both elementary and specialized. Type in `help elfun` for elementary functions and `help specfun` for more specialized and advanced functions.

A MATLAB expression is any combination of numbers, variables, functions, and operators.
Variables and Functions

Example expressions:

```plaintext
>> x = 50;
>> y = 73;
>> x + sqrt(y)*5
ans = 92.7200
```

Note: if you end an expression with a semicolon (;) MATLAB will not write out the value of the expression. If you wish to continue an expression from one line to the next use ...

```plaintext
>> 5 + 34 ...
+ 65
ans = 104
```

Typing in the command `clear` will clear all functions and variable from memory. Typing in `clear x` will clear the variable `x` from memory. Tying in `clear y*` will clear all variables starting with the letter `y`.

It is also possible to control the formatting of your numbers. Type in `help format` to see your options.
M Files

You can store a sequence of commands and expressions.

Open up the MATLAB editor (edit) and type in the commands and expressions you wish to store. Then save the file. You will notice that the file has a .m extension by default. These are called M-files.

If you save the file in a path that is searched by MATLAB, you can execute the commands in the file by typing in the file name at the command line.

You must begin the name of an M-file with a letter from the alphabet.
MAT Files

MAT files are binary files that store the variables in your workspace. For example, if you type in

```matlab
>> x = 5;
>> save xfile.mat
```

Quit MATLAB and then open it again. Then:

```matlab
>> load xfile.mat
>> whos
```

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Bytes</th>
<th>Class</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>1x1</td>
<td>8</td>
<td>double</td>
<td></td>
</tr>
</tbody>
</table>
MAT Versus M Files

MAT files are binary files that store the variables in your workspace. M Files are text files designed to store a sequence of commands, a program, or a function. More on functions and programs later.

If you do the following:

```matlab
prices = load('ASWch8ex13stockprices.txt')
save test
```

MATLAB will store the prices matrix. However, if you close MATLAB, change the numbers in `ASWch8ex13stockprices.txt` and then

```matlab
load test
```

it will have the old numbers.
### Help Command Result

<table>
<thead>
<tr>
<th>Help Command</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>helpdesk</td>
<td>get entire MATLAB documentation</td>
</tr>
<tr>
<td>help elfun</td>
<td>a list of MATLAB elementary functions</td>
</tr>
<tr>
<td>help specfun</td>
<td>a list of more advanced MATLAB functions</td>
</tr>
<tr>
<td>help elmat</td>
<td>elementary matrices and matrix manipulation</td>
</tr>
<tr>
<td>help matfun</td>
<td>linear algebra and matrix functions</td>
</tr>
<tr>
<td>help iofun</td>
<td>input and output functions</td>
</tr>
<tr>
<td>help “function name”</td>
<td>help for the given function</td>
</tr>
<tr>
<td>help helptools</td>
<td>a list of available help tools</td>
</tr>
<tr>
<td>help general</td>
<td>a list of general purpose commands</td>
</tr>
<tr>
<td>help</td>
<td>a list of all help topics</td>
</tr>
</tbody>
</table>

If you want to look for a command type in lookfor and then a keyword. For example, lookfor variance.
You can change MATLAB’s default directory by creating a file startup.m and putting it in the default startup directory of the MATLAB application.

For example, my startup.m file is

```
cd /Users/kmartin/Documents/files/coursework/36104-2011/matlab
```

In Windows (only) you can also set the startup directory by right clicking on the MATLAB icon and selecting properties. In the Start in: tab, type in the default directory that you want.
If you want to keep track of all the commands and the result (which saving as a MAT file will not do) use the `diary` command.

```
diary logfeb15_2011.txt
```

This will record everything in file `logfeb15_2011.txt`. Use `diary off` to turn off the recording and `diary on` to turn it back on.