Worksheet 1. Hello Matlab

This worksheet gives a quick introduction to Matlab. Start Matlab from the START
– PROGRAMS – MATLAB6.5 – MATLAB6.5 menu. You should now be faced
by a terminal window awaiting instruction.

Hello World

It is traditional to begin your acquaintance with a new programming language with
the 'Hello World' program. We will begin with some variations on that theme. To
begin with type

```
fprintf('Hello World.\n')
```

To which matlab should respond with

```
Hello World.
```

fprintf is short for 'file print formatted'. If a file is not specified it prints to
standard output (Unix terminology for the terminal screen). The single quotes ''
indicate that their contents is a string. \n is a formatting character indicating a
newline.

   Formatting characters within the string can also be used as placeholders for
matlab numbers and other strings. For instance

```
fprintf('Hello World.\n')
fprintf('The square root of 2 is %f\n',sqrt(2))
```

gives

```
Hello World.
The square root of 2 is 1.414214
```

%f is a format code indicating a placeholder for a floating point number in this
case $\sqrt{2}$.

- *Persuade matlab to say "Hi Ireland!".*

Vectors and Matrices

Matlab was originally designed as a tool for working with matrices as its name—
*Mat*rix *Lab*oratory—suggests. A matrix can be entered by hand, for example

```
 mat=[1 2; 3 4]
```

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Elements on a row are separated by spaces (or commas), rows are separated by semicolons. The result is

```
mat =
    1    2
    3    4
```

Individual elements can be accessed by giving their indices in brackets

```
mat(2,1)
```

Gives

```
ans =  3
```

`ans` is a matlab variable holding the result of the previous calculation not explicitly assigned its own variable.

There are a number of commands for generating special matrices. Try

```
zeros(4,3)
ones(2,2)
eye(3,3)
```

The results should be self explanatory, but if not use the matlab help function

```
help eye
```

to visit matlab's internal documentation on the subject.

- *Create the matrix* $\begin{pmatrix} 9 & 8 \\ 7 & 6 \end{pmatrix}$ *by hand.*

- *Create a* 10×2 *matrix of* 1*'s.*

Data types

Matlabs numerical data types are real numbers (double precision) and complex numbers. For example

```
x=3.6  % Real
z=2+3i % Complex
```

% is the matlab comment character. Convince yourself that operators like `+`,`-`,`*`,`/`,`^` behave the way you expect for these variables. N.B. To matlab `1/2=0.5` unlike fortran.

Logical variables and strings are also important in scientific programming, but we shall usually generate them on the fly rather than assigning them to variables.

- *Calculate $(1 + 2i) \times (2 - 3i)$.*

- *Calculate $(1 - 9i)^2$.*

Graphics

Matlab excels at producing graphs. For instance

```
x=1:100;
y=x.^2;
plot(x,y)
```

x is a 100 element vector whose elements are $1, 2, \ldots 100$. y is a vector the same size as y whose elements are the elements of x squared. The dot in the operator `.^` means to apply the operation in an element by element sense rather than a matrix sense. Ending lines with a semicolon prevents matlab echoing the output to the screen (convenient when working with large matrices).

Matlab can also produce contour plots

```
x=1:20;
y=1:20;
z=rand(20);
contourf(x,y,z)
```

`rand(20)` produces a 20×20 matrix of random numbers (uniform variates distributed between 0 and 1).

- *Set x to the numbers 1 to 10 and calculate the square (without the dot). What is matlab doing?*

- *Produce a contour plot of $x^2 + y^2$.*

M-files

Serious scientific programmers spend relatively little time working with interactively with matlab and instead spend most of their time working with scripts. Matlab scripts have a '.m' extension and so are known as M-files. Open the matlab M-file editor and type in the following

```
% HELLO:  m-file version of 'hello world'
fprintf('Hello world\n')
```

Save the file as hello.m in the directory of your choice. Change the active directory for matlab to the same directory and type `hello` at the command prompt. This will run the script. It is good practise to include one or more comment lines at the start of scripts explaining what they do. These comments will be printed by matlab if you type `help hello`.

The Mandelbrot Set

We can put all these ideas together (and introduce some more) to produce an M-file that draws the Mandelbrot set. The Mandelbrot set is the set of complex numbers c which remain finite on repeated application of the mapping $z \to z^2 + c$ starting with $z = c$.

Make an M-file with the contents

```
% MANDELBROT Draw the Mandelbrot set
tic    % Start timer
% 100 evenly spaced points between -2.1 and 0.6
x = linspace(-2.1,0.6,100);
% 100 evenly spaced points between -1.1 and 1.1
y = linspace(-1.1,1.1,100);
% Convert the x and y vectors
% to matrices X(i,j)=x(j), Y(i,j)=y(i)
[X,Y] = meshgrid(x,y);
% Make a complex matrix: C(i,j)=X(i,j)+iY(i,j)
C = complex(X,Y);

Z_max = 1e6;       % Numerical approximation to infinity
it_max = 50;       % Number of iterations:
                   % again approximately infinity
Z = C;             % Initialise
for k = 1:it_max   % Perform it_max iterations
  Z = Z.^2 + C;
```

```
end
contourf(x,y,double(abs(Z)<Z_max))    % Contour plot
title('Mandelbrot Set','FontSize',16) % Title
toc    % End timer and print time
```

- *The Mandelbrot set is self similar: if you zoom in on part of it you will find it looks the same. Find a mini-Mandelbrot set inside the Mandelbrot set.*

- *No one has found a practical application of the Mandelbrot set. Try to invent one.*

- *Does anything interesting happen if you change the power in $z^2 + c$ to some other number?*