Session 1: Basics

Environment

Functions (areaOfCircle; falling object)

Vectorization (falling object)

Scripts (TempC2F)

Electives: Plotting (any); File operations (TempC2F); Programming concepts (areaOfEllipse addition); Matrix equations (truss)

Environment

Welcome to MATLAB. When you first open the program, you will see several areas on your screen. There is a file browser which shows the scripts available in your current directory. There is a history area which will contain a log of commands you'll enter into the third and largest area, the interactive command window. Think of this as a graphing calculator interface.

The toolstrip will not be on your workstations due to a version difference; instead, the same functionality is available through the traditional menu system.

Variables, operators (elementwise as well), colon range operator, workspace, scripts, functions, for and if statements, vectorization

MATLAB acts basically as a powerful graphing calculator, which you should already be familiar with. It has a few quirks, but for the most part the notation should be the same.

```
2+2
sin(pi/4)
2^3
```

That's well and good, but typically you need to construct more complicated expressions to do anything interesting. The first pieces we need to do that are variables and expressions.

```
x=4;
y=x^2+2*x
x^3+sin(x)/y
ans*5
exp(i*pi)
```

The output you saw a moment ago, `ans`, is the default output of the last expression. You can reuse it in the next expression as well. You can hide the output by using a semicolon.

The next piece we need is what MATLAB is known for: arrays. An array is like a spreadsheet or a matrix: it's a collection of numbers in a grid. Arrays are what allow MATLAB to efficiently consolidate operations and store results, as well as carry out linear algebraic operations like matrix multiplication. We'll spend a few minutes doing some examples so you're familiar with the basic behavior and syntax of MATLAB.

```
1:5
1:0.2:5
x=0:0.1*pi:2*pi;
y=sin(x);
plot(x,y)

3^(1:5)
3.^(1:5)

% This is a comment. It's not run.
% Basic matrix definition and
multiplication
A=[1 2 3; 4 5 6];
B=[7 8; 9 10; 11 12];
A*B
```

```
v = [1 3 4 2];
v(5) = 1;
v'
M = [1 2 6; 0 4 3]
M'

eye(3,3)
eye(3)
ones(3)*ones(3,1)

A=ones(3)
C=rand(3)
A*C
A.*C
A^2
A.^2
```

Functions

The final fundamental piece of using interactive MATLAB is one we've already been using: what is `sin`? Functions can be built-in or downloaded or written by you. They allow you to capture complex actions and store them in a repeatable way.

- Demonstrate how to find a variable to *start* the *clock* when timing an operation. Have the students use the function browser to find out how to *stop* the *clock*. Who was the quickest?

No matter your field, much of your computational work in MATLAB will consist of writing out scripts and functions to contain the ideas and methods you develop. You will also extensively utilize existing functions, both built-in and provided by other people, so you need to become accustomed to reading and understanding m-files.

Example: Area of a circle & of an ellipse (functions) • Mathematics • 5min

Given the radius r, what is the area A of a circle? The classic formula is written

$$A(r)=\pi r^2$$

- To make this reproducible, let us create a function to store it. Open a new file and enter the following:

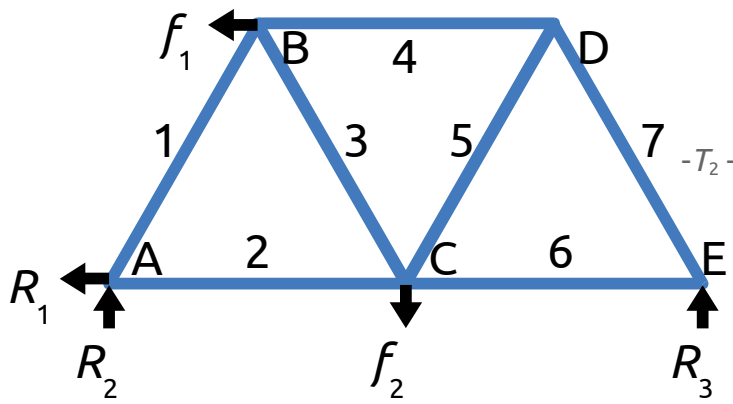
```
function [A] = areaOfCircle(r)
A = pi * r^2;
```

- Save this file as areaOfCircle.m. Test it on a few values. Now try it on `1:1:5`. What do you need to fix for this to work properly?
- Now compose a new function, `areaOfEllipse(a,b)`, and make it work for two inputs.

$$A(a,b)=\pi a b$$

Example: Truss forces (Elementwise & matrix operators) • Mathematics • 5min

A common problem in mechanics is the solution of forces in a truss. This is solved statically by the method of joints, in which you write an equation for each node of the truss and solve the linear set of equations which results.



$$0.5\ T_1 + T_2 = R_1 = f_1$$
$$0.866\ T_1 = -R_2 = -0.433\ f_1 - 0.5\ f_1$$
$$-0.5\ T_1 + 0.5\ T_3 + T_4 = -f_1$$
$$0.866\ T_1 + 0.866\ T_3 = 0$$
$$-T_2 - 0.5\ T_3 + 0.5\ T_5 + T_6 = 0$$
$$0.866\ T_3 + 0.866\ T_5 = f_2$$
$$-T_4 - 0.5\ T_5 + 0.5\ T_7 = 0$$

Let us write the matrix form of this equation as $\mathbf{M}x = f$. You could write the solution to this formally as $x = \mathbf{M}^{-1}f$. While attractive formally, it is often far too expensive to calculate and store an inverse matrix in memory for large problems (even if $\mathbf{M}$ is sparse, $\mathbf{M}^{-1}$ is in general dense).

In practice, matrix inversion is a brute-force solution to a linear algebra problem. MATLAB has a number of clever ways to solve matrices built into it. The most frequent is not to invert the matrix, but instead to use what is called *left division*, written $x = \mathbf{M}\backslash f$.

- Let $f_1 = 1000$ and $f_2 = 2000$. Write the governing equations in matrix form.

$$\begin{pmatrix} 0.5 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0.866 & 0 & 0 & 0 & 0 & 0 & 0 \\ -0.5 & 0 & 0.5 & 1 & 0 & 0 & 0 \\ 0.866 & 0 & 0.866 & 0 & 0 & 0 & 0 \\ 0 & -1 & -0.5 & 0 & 0.5 & 1 & 0 \\ 0 & 0 & 0.866 & 0 & 0.866 & 0 & 0 \\ 0 & 0 & 0 & -1 & -0.5 & 0 & 0.5 \end{pmatrix} x = \begin{pmatrix} f_1 \\ -0.433 f_1 - 0.5 f_2 \\ -f_1 \\ 0 \\ 0 \\ f_2 \\ 0 \end{pmatrix}$$

- Define the matrix using the MATLAB *New Variable...* interface.
- Write the solution vector and call it *f*.
- Solve the matrix in MATLAB using left division:

```
x = M\f;
```

Vectorization

Example: Falling ballistic object (vectorization, control flow) • Physics • 15min

You are familiar with the equation for an object moving in a gravitational field (a.k.a. falling). The formula for vertical position y as a function of time t may be written

$$y(t) = y_0 + v\,t + a\,t^2$$

where y_0 is the initial position (typically ground level, $y_0 = 0$); v is the initial y-velocity; and a is the acceleration (in this case due to gravity, a = -9.8 m/s^2). The classic ballistics example would be an object fired into the air such that a bullet or shell has a high initial velocity. Let's update this by using a railgun, with a projectile velocity of 2.52km/s.

- We will first calculate the values directly.

```
a=-9.8; %m/s^2
v=2520; %m/s
x0=0;
t=1;
y=a*t^2+v*t+x0;
```

- Now let's vectorize the formula, or allow it to work on many values simultaneously (or at least, in one statement).

```
t=linspace(0,5,101);
y=a*t^2+v*t+x0;      % comment on this error or ask for input
y=a*t.^2+v*t+x0;
```

- Plot the vectorized formula: `plot(t,y);`
- Finally, abstract the formula out into its own function. This which will allow us to reuse it over and over again as necessary. Open a new blank file and write the function definition:

```
function y = calcFall(t,v,x0)
      % Physical values
      a=-9.8; %m/s^2

      % Calculation
      y=a*t^2+v*t+x0;
```

- Test the function. What happens after t > 260s? How can we keep our results physical? Modify the function to not yield y-values less than zero.

```
      % Test for physical cases.
      y = y.*(y>0);
```

- Where is the maximum?

```
t(find(y==max(y)))
```

Example: Dam rate of flow (plotting, vectorization) • Civil Eng. • 10min

One equation for the volume rate of flow of water Q over the spillway of a dam is the formula

$$Q = C\sqrt{2g}B\left(H + \frac{v^2}{2g}\right)^{3/2}$$

where C is the discharge coefficient; B is the spillway width; and H is the depth of water passing over the spillway.

- Open the file `computedamrateofflow.m`. This has skeleton code for a function you will define.
- Define a discharge coefficient of 1.946 and the acceleration due to gravity in SI units.
- Calculate the value of Q. This should be in the form `Q = <something>`.
- Plot your function for B = 1m, v = 0.536m/s (the flow rate of the Mississippi river) against a vector H ranging from 1 to 10 at increments of 0.1.
- What would you change to make this also a function of discharge coefficient C?

Scripts and File I/O

Example: Fahrenheit/Celsius (Scripts, file operations) • Mathematics • 25min

You are familiar with the conversion formula from Fahrenheit to Celsius:

$$T_F(T_C) = T_C \frac{180}{100} + 32$$

- Write a function which performs this conversion and save it in an appropriate file.

```
function Tf = TempC2F(Tc)
... your code here ...
```

- Write a script templist.m which generates a table of conversions for the range 0℃ to 200℃ and then writes that table to a file templist.txt.

```
cList = linspace(0,200,101);
fList = TempC2F(cList);

fileID = fopen('templist.txt','w');
fprintf(fileID,'%6s %12s\n','Tc','Tf');
fprintf(fileID,'%6.2f %6.2f\n',cList,fList);
fclose(fileID);
```

- Examine templist.txt. Is the output what you expect? Change the output line to the following:

```
tList = [cList; fList];
fprintf(fileID,'%6.2f %6.2f\n',tList);
```

(Note that the row-major order of MATLAB translates into a transposed column-major order in the output.)

- Next, let's read the data in and plot them.

```
tData = importdata('templist.txt')
plot(tData.data(:,1),tData.data(:,2))
```

Programming Concepts

Modify areaOfEllipse to include a flag (second output) if the calculation is for a circle (`a==b`).