Lecture 3: Array Applications, Cells, Structures & Script Files

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EE201: Computer Applications. See Textbook Chapter 2 and Chapter 3.

Euclidean Vectors

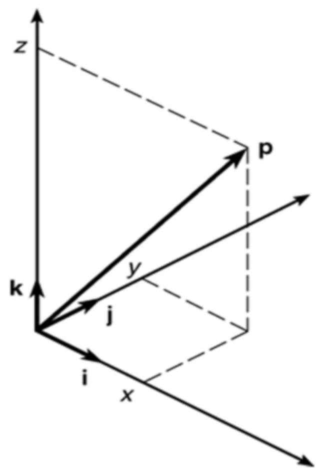
- An Euclidean vector (or geometric vector, or simply a vector) is a geometric entity that has both **magnitude** and **direction**.
- In physics, vectors are used to represent physical quantities that have both magnitude and direction, such as force, acceleration, electric field, etc.
- Vector algebra: adding and subtracting vectors, multiplying vectors, scaling vectors, etc.

Euclidean Vectors in MATLAB

- We specify a vector using its Cartesian coordinates.
- Hence, the vector **p** can be specified by three components: x, y and z, and can be written in MATLAB as:

```
p = [x, y, z];
```

- MATLAB supports 2-D and 3-D vectors, and even higher dimensional ones.



Magnitude, Length, Absolute Value

- In MATLAB, `length()` of a vector is **not** its magnitude. It is the number of elements in the vector.
- The **absolute value** of a vector **a** is a vector whose elements are the absolute values of the elements of **a**.
- The **magnitude** of a vector is its Euclidean norm or geometric length as shown:

$$\mathbf{a} = a_x\mathbf{i} + a_y\mathbf{j} + a_z\mathbf{k}$$

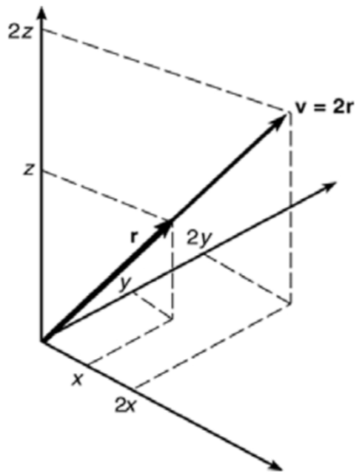
$$\|\mathbf{a}\| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

```
>> a = [2, -4, 5]
a =
     2    -4     5

>> length(a)
ans =
     3

>> abs(a)
ans =
     2     4     5

>> sqrt(a*a') % magnitude
ans =
    6.7082

>> sqrt(sum(a.*a)) %magnitude
ans =
    6.7082
```

$$\|\mathbf{a}\| = \sqrt{2^2 + (-4)^2 + 5^2} = \sqrt{\begin{bmatrix} 2 & -4 & 5 \end{bmatrix}\begin{bmatrix} 2 \\ -4 \\ 5 \end{bmatrix}} = 6.7082$$

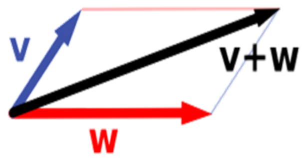
Vector Scaling

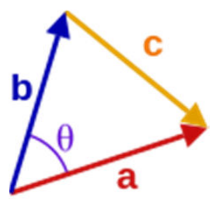
- For vector:
  $\mathbf{a} = a_x\mathbf{i} + a_y\mathbf{j} + a_z\mathbf{k}$
- Scaling this vector by a factor of 2 gives:
- $\mathbf{v} = 2\mathbf{a}$
  $= 2a_x\mathbf{i} + 2a_y\mathbf{j} + 2a_z\mathbf{k}$
- This is just like MATLAB scalar multiplication of a vector:
- `v = 2*[x, y, z];`



Adding and Subtracting Vectors

- Vector addition by geometry: The parallelogram law.
- Or, mathematically:
  $\mathbf{a} = a_x\mathbf{i} + a_y\mathbf{j} + a_z\mathbf{k}$
  $\mathbf{b} = b_x\mathbf{i} + b_y\mathbf{j} + b_z\mathbf{k}$
  $\mathbf{a} + \mathbf{b} = (a_x + b_x)\mathbf{i} + (a_y + b_y)\mathbf{j} + (a_z + b_z)\mathbf{k}$
- Same as vector addition and subtraction in MATLAB.





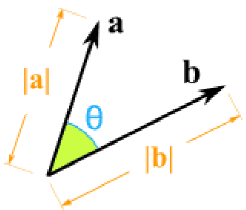
$\mathbf{c} = \mathbf{a} - \mathbf{b}$

Exercise

```
>> a = [2 -4 6]
a =
     2    -4     6

>> b = [3 -1 -1]
b =
     3    -1    -1

>> c = a + b
c =
     5    -5     5

>> d = a - b
d =
    -1    -3     7

>> e = 2*a
e =
     4    -8    12
```

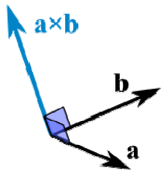

Dot Product

- The dot product of vectors results in a scalar value.
- **a** · **b**
  $= (a_x b_x + a_y b_y + a_z b_z)$
  $= \|\mathbf{a}\| \|\mathbf{b}\| \cos(\theta)$




```
>> a = [2 -4 6];
>> b = [3 -1 -1];
>> c = a * b'
c =
     4

>> c = sum(a .* b)
c =
     4

>> c = dot(a, b)
c =
     4
```

Cross Product

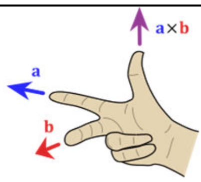


$$\mathbf{a} \times \mathbf{b} = \|\mathbf{a}\|\|\mathbf{b}\| \sin(\theta)\, \mathbf{n}$$

$$\mathbf{a} \times \mathbf{b} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

$$\mathbf{a} \times \mathbf{b} = \begin{vmatrix} a_y & a_z \\ b_y & b_z \end{vmatrix} \mathbf{i} - \begin{vmatrix} a_x & a_z \\ b_x & b_z \end{vmatrix} \mathbf{j} + \begin{vmatrix} a_x & a_y \\ b_x & b_y \end{vmatrix} \mathbf{k}$$

```
>> a = [2 -4 6];
>> b = [3 -1 -1];
>> cross(a, b)
ans =
    10    20    10

>> syms x y z
>> det([x y z; 2 -4 6; 3 -1 -1])
ans =
 10*x + 20*y + 10*z

>> cross([1 0 0], [0 1 0])
ans =
     0     0     1
```



Complex Numbers

```
>> a = 7 + 4j
a =
   7.0000 + 4.0000i

>> [theta, rho] = cart2pol(real(a), imag(a))
theta =
    0.5191
rho =
    8.0623

>> rho = abs(a) % magnitude of complex number
rho =
    8.0623

>> theta = atan2(imag(a), real(a))
theta =
    0.5191
% atan2 is four quadrant inverse tangent

>> b = 3 + 4j
b =
   3.0000 + 4.0000i

>> a+b
ans =
  10.0000 + 8.0000i

>> a*b
ans =
   5.0000 + 40.0000i
```

Polynomials

- A polynomial can be written in the form:
  $a_n x^n + a_{n-1} x^{n-1} + \cdots + a_2 x^2 + a_1 x + a_0$
- Or more concisely:

$$\sum_{i=0}^{n} a_i x^i$$

- We can use MATLAB to find all the roots of the polynomial, i.e., the values of x that makes the polynomial equation equal 0.

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Exercise

- Polynomial Roots:
  $x^3 - 7x^2 + 40x - 34 = 0$
- Roots are $x = 1$, $x = 3 \pm 5i$.
- We can also build polynomial coefficients from its roots.
- We can also multiply (convolution) and divide (deconvolution) two polynomials.

```
>> a = [1 -7 40 -34];

>> roots(a)
ans =
   3.0000 + 5.0000i
   3.0000 - 5.0000i
   1.0000

>> poly([1 3+5i 3-5i])
ans =
     1    -7    40   -34
```

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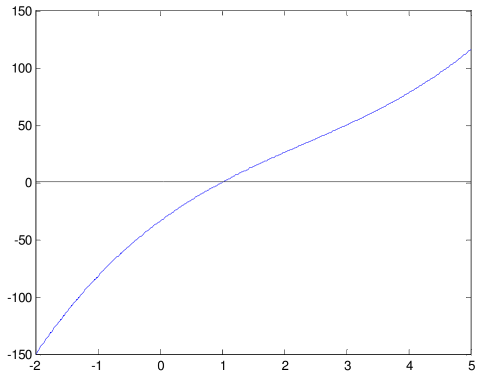
Just for fun… Plot…

```
>> x = -2:0.01:5;
>> f = x.^3 - 7*(x.^2) + 40*x - 34;
>> plot(x, f)
```



Cell Array

- The cell array is an array in which each element is a cell. Each cell can contain an array.
- So, it is an array of different arrays.
- You can store different classes of arrays in each cell, allowing you to group data sets that are related but have different dimensions.
- You access cell arrays using the same indexing operations used with ordinary arrays, but using `{}` not `()`.

Useful functions

`C = cell(n)`	Creates n × n cell array C of empty matrices.
`C = cell(n,m)`	Creates n × m cell array C of empty matrices.
`celldisp(C)`	Displays the contents of cell array C.
`cellplot(C)`	Displays a graphical representation of the cell array C.
`C = num2cell(A)`	Converts a numeric array A into a cell array C.
`iscell(C)`	Returns a 1 if C is a cell array; otherwise, returns a 0.

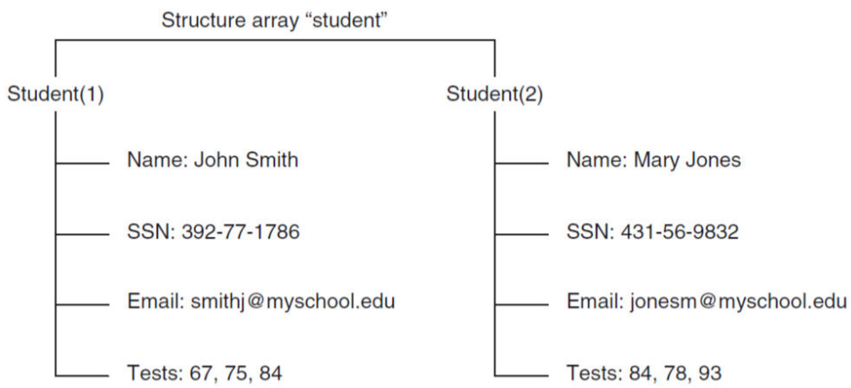
Exercise

```
>> C = cell(3)
C =
    []    []    []
    []    []    []
    []    []    []

>> D = cell(1, 3)
D =
    []    []    []

>> A(1,1) = {'Walden Pond'};
>> A(1,2) = {[1+2i 5+9i]};
>> A(2,1) = {[60,72,65]};
>> A(2,2) = {[55,57,56;54,56,55;52,55,53]};

>> A
A =
    'Walden Pond'    [1x2 double]
     [1x3 double]    [3x3 double]
```

Exercise (Continue)

```
>> celldisp(A)
A{1,1} =
Walden Pond

A{2,1} =
    60    72    65

A{1,2} =
   1.0000 + 2.0000i   5.0000 + 9.0000i

A{2,2} =
    55    57    56
    54    56    55
    52    55    53

>> B = {[2,4], [6,-9;3,5]; [7;2], 10}
B =
    [1x2 double]    [2x2 double]
    [2x1 double]    [         10]

>> B{1,2}
ans =
     6    -9
     3     5
```


Structures (*strcut.memebr*)



Create and Add to Structure

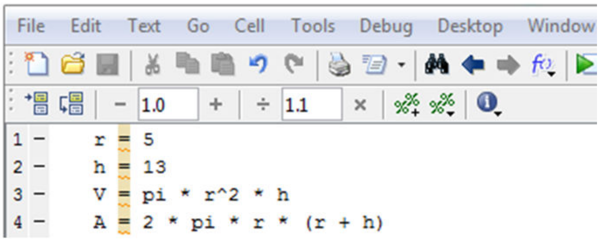
```
>> student.name = 'John Smith';
>> student.SSN = '392-77-1786';
>> student.email = 'smithj@myschool.edu';
>> student.exam_scores = [67,75,84];

>> student
student =
           name: 'John Smith'
            SSN: '392-77-1786'
          email: 'smithj@myschool.edu'
    exam_scores: [67 75 84]

>> student(2).name = 'Mary Jones';
>> student(2).SSN = '431-56-9832';
>> student(2).email = 'jonesm@myschool.edu';
>> student(2).exam_scores = [84,78,93];

>> student
student =
1x2 struct array with fields:
    name
    SSN
    email
    exam_scores
```


Investigate Structure

```
>> student(2)
ans =
           name: 'Mary Jones'
            SSN: '431-56-9832'
          email: 'jonesm@myschool.edu'
    exam_scores: [84 78 93]

>> fieldnames(student)
ans =
    'name'
    'SSN'
    'email'
    'exam_scores'

>> max(student(2).exam_scores)
ans =
    93

>> isstruct(student)
ans =
     1
```

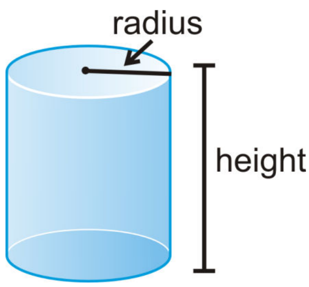
Script files

- You can save a particular sequence of MATLAB commands for reuse later in a script file (.m file)
- Each line is the same as typing a command in the command window.
- From the main menu, select File | New | Script, then save the file as `mycylinder.m`



Remember Example?

- Develop MATLAB code to find Cylinder volume and surface area.
- Assume radius of 5 m and height of 13 m.



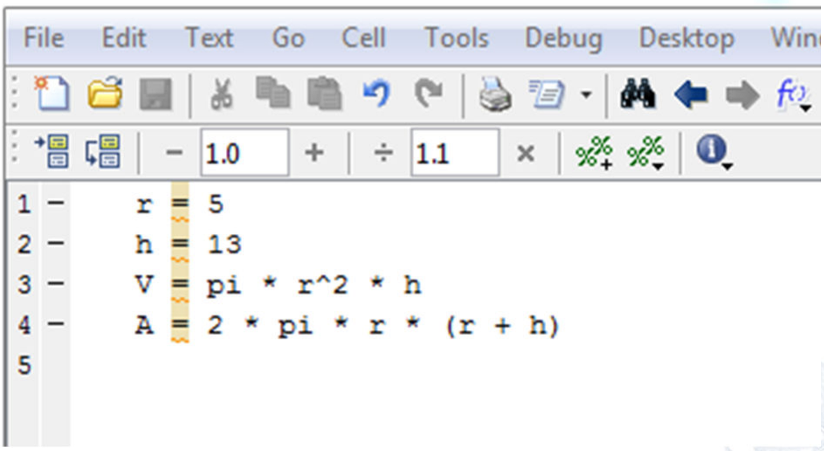
$$V = \pi r^2 h$$

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

Solution

```
>> r = 5
r =
     5

>> h = 13
h =
    13

>> V = pi * r^2 * h
V =
  1.0210e+003

>> A = 2 * pi * r * (r + h)
A =
  565.4867
```


Exercise



Be ware…

- Script File names MUST begin with a letter, and may include digits and the underscore character.
- Script File names should NOT:
  - include spaces
  - start with a number
  - use the same name as a variable or an existing command
- If you do any of the above you will get unusual errors when you try to run your script.
- You can check to see if a command, function or file name already exists by using the `exist` command.

Running .m files

- Run sequence of commands by typing

  `mycylinder`

  in the command window
- Make sure the current folder is set properly

```
>> mycylinder
r =
     5

h =
    13

V =
  1.0210e+003

A =
  565.4867
```

When you type `mycylinder`

When multiple commands have the same name in the current scope (scope includes current file, optional private subfolder, current folder, and the MATLAB path), MATLAB uses this precedence order:

1. **Variables** in current workspace: Hence, if you create a variable with the same name as a function, MATLAB cannot run that function until you clear the variable from memory.
2. **Nested functions** within current function
3. **Local functions** within current file
4. **Functions** in current folder
5. **Functions** elsewhere on the path, in order of appearance

Precedence of functions within the same folder depends on file type:

1. MATLAB **built-in** functions have precedence
2. Then **Simulink** models
3. Then program files with **.m extension**

Comments in MATLAB

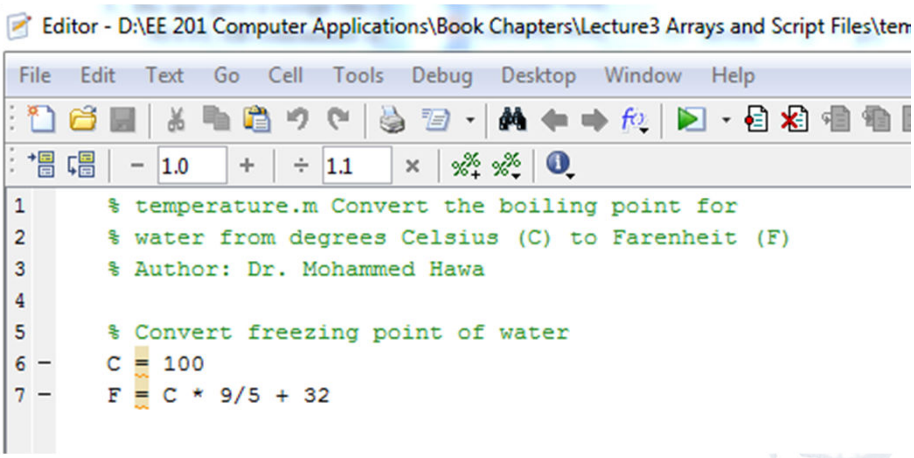
- Comment lines start with a `%` not `//`
- Comments are not executed by MATLAB; it is there for people reading the code.
- Helps people understand what the code is doing and why!
- Comments are VERY IMPORTANT.
- Comment anything that is not easy to understand.
- Good commenting is a huge help when maintaining/fixing/extending code.
- Header comments show up when typing the `help` command.

Bad vs. Good Comments/Code

```
% set x to zero
x = 0
% calculate y
y = x * 9/5 + 32
```

```
% Convert freezing point of
% water from celsius to
% farenheit
c = 0
f = c * 9/5 + 32
```


Exercise



Header comments

```
>> help temperature
  temperature.m Convert the boiling point for
  water from degrees Celsius (C) to Farenheit (F)
  Author: Dr. Mohammed Hawa

>> temperature

C =
   100

F =
   212
```


Simple User Interaction: I/O

- Use `input` command to get input from the user and store it in a variable:

```
h = input('Enter the height:')
```

- MATLAB will display the message enclosed in quotes, wait for input and then store the entered value in the variable

Simple User Interaction: I/O

- Use `disp` command to show something to a user

```
disp('The area of the cylinder is: ')
disp(A)
```

- MATLAB will display any message enclosed in quotes and then the value of the variable.

Exercise

```
r = input('Enter the radius:');
h = input('Enter the height:');

V = pi * r^2 * h;
A = 2 * pi * r * (r + h);

disp('The volume of the cylinder is: ');
disp(V);
disp('The area of the cylinder is: ');
disp(A);
```

```
>> mycylinder
Enter the radius:5
Enter the height:13
The volume of the cylinder is:
  1.0210e+003

The area of the cylinder is:
  565.4867
```

Summary

`disp(A)`	**Displays the contents, but not the name, of the array A.**
`disp('text')`	**Displays the text string enclosed within quotes.**
`x = input('text')`	**Displays the text in quotes, waits for user input from the keyboard, and stores the *value* in x.**
`x = input('text','s')`	**Displays the text in quotes, waits for user input from the keyboard, and stores the input as a *string* in x.**

Homework

- The speed v of a falling object dropped with zero initial velocity is given as a function of time t by $v = gt$, where g is the gravitational acceleration.
- Plot v as a function of t for $0 \ll t \ll t_f$, where t_f is the final time entered by the user.
- Use a script file with proper comments.

Solution

```
% Plot speed of a falling object
% Author: Dr. Mohammed Hawa

g = 9.81; % Acceleration in SI units

tf = input('Enter final time in seconds:');

t = [0:tf/500:tf]; % array of 501 time instants
v = g*t; % speed

plot(t,v);
xlabel('t (sseconds)');
ylabel('v m/s)');
```


Homework

- Solve as many problems from Chapter 2 as you can
- Suggested problems:
- 2.33, 2.34, 2.35, 2.36, 2.39, 2.41, 2.45, 2.48