Array Operations
ENGR 1187
MATLAB 4
Aerospace Engineers use turbulence data to calculate how close other planes can fly near the wake of a larger plane. These vortices can cause unstable flight conditions for smaller planes approaching the wake of a commercial jetliner. Thus this turbulent flow data is important in airspace management.
Today's Learning Objectives

- Explain meaning of element-by-element operations.

- Identify situations where the standard operators in MATLAB (when used with arrays) are reserved for linear algebra, which is not always element-by-element.

- Apply dot operators for the six cases where linear algebra is not element-by-element and therefore dot operators are needed to produce element-by-element calculations.
Scalar Math Review

For scalar variables \( a \) and \( b \):

\[
\begin{align*}
\text{>> } & \quad a = 6; \\
\text{>> } & \quad b = 2;
\end{align*}
\]

MATLAB has scalar math operations:

\[
\begin{align*}
\text{>> } & \quad a + b \\
\text{>> } & \quad a - b \\
\text{>> } & \quad a * b \\
\text{>> } & \quad a / b \\
\text{>> } & \quad a ^ b
\end{align*}
\]
Scalar–Vector Addition

Define the vector $v$ and the scalar $c$:

$$
\begin{align*}
\texttt{v} & = \ [ \ 10 \ 20 \ 30 \ 40 \ ] \ ; \\
\texttt{c} & = 4 \\
\end{align*}
$$

Add them:

$$
\begin{align*}
\texttt{v} + \texttt{c} \\
\texttt{c} + \texttt{v}
\end{align*}
$$

$$
\text{ans} =
\begin{bmatrix}
14 \\
24 \\
34 \\
44
\end{bmatrix}
$$
Vector–Vector Addition

Define the vector \( v \) and the vector \( c \):

\[
\begin{align*}
\gg v &= [ 10 \ 20 \ 30 \ 40 ] \\
\gg c &= [ 2 \ 4 \ 6 \ 8 ]
\end{align*}
\]

Add them:

\[
\begin{align*}
\gg v + c \\
\gg c + v
\end{align*}
\]

\[
\text{ans} = \\
12 \ 24 \ 36 \ 48
\]

\( v \) and \( c \) must be the same length!
Scalar - Vector Multiplication

For the vector \( x \) and the scalar \( c \):

\[
\begin{align*}
\text{>> } v &= [ \ 10 \quad 20 \quad 30 \quad 40 \ ] ; \\
\text{>> } c &= 4 ; \\
\text{Multiply them:}\\
\text{>> } c * v \\
\text{>> } v * c
\end{align*}
\]

\[
\text{ans =}
\begin{bmatrix}
40 & 80 & 120 & 160
\end{bmatrix}
\]
Vector - Vector Multiplication

\[ x = \begin{bmatrix} 10 & 20 & 30 & 40 \end{bmatrix} \]
\[ y = \begin{bmatrix} 2 & 4 & 6 & 8 \end{bmatrix} \]

Now multiply:

\[ z = x \times y \]

??? Error using ==> mtimes
Inner matrix dimensions must agree!!!
Vector - Vector Multiplication

\[ x = \begin{bmatrix} 10 & 20 & 30 & 40 \end{bmatrix} \]
\[ y = \begin{bmatrix} 2 & 4 & 6 & 8 \end{bmatrix} \]

To multiply two arrays element by element we need to use the following syntax:

\[ z = x .* y \]

\[
\begin{bmatrix}
20 & 80 & 180 & 320
\end{bmatrix}
\]
Scalar - Vector Division

```
>> v = [ 10  20  30  40 ]
>> c = 4

Divide them:
>> v / c

ans =
   2.50   5.00   7.50   10.00
```
Scalar - Vector Division

\[
\begin{align*}
\gg v &= \begin{bmatrix} 10 & 20 & 30 & 40 \end{bmatrix} \\
\gg c &= 4
\end{align*}
\]

Divide them:

\[
\begin{align*}
\gg c / v & \quad \gg c./v \\
\text{Error using} / & \quad \text{ans} = \\
\text{Matrix dimensions} & \quad 0.400 \quad 0.200 \quad 0.133 \\
\text{must agree.} & \quad 0.100
\end{align*}
\]
Vector - Vector Division

\[ x = \begin{bmatrix} 10 & 20 & 30 & 40 \end{bmatrix} \]
\[ y = \begin{bmatrix} 2 & 4 & 6 & 8 \end{bmatrix} \]

Divide them:

\[ \gg \quad x \ . \ / \quad y \]
ans =
\[ \begin{bmatrix} 5 & 5 & 5 & 5 \end{bmatrix} \]

Also, try

\[ \gg \quad y \ . \ / \quad x \]
ans =
\[ \begin{bmatrix} 0.20 & 0.20 & 0.20 & 0.20 \end{bmatrix} \]
Scalar - Vector Exponents

>> v = [ 10  20  30  40 ]
>> c = 4

Try:
>> v ^ c

Try instead:
>> v .^ c

Error using ^
Inputs must be a scalar and a square matrix. To compute elementwise POWER, use POWER (.^) instead.
Vector - Vector Exponents

\[ x = [ 2 \ 2 \ 2 \ 2 \ 2 ] ; \]
\[ y = [ 2 \ 4 \ 6 \ 8 ] ; \]

Try this:
\[ \gg x .^\ y \]
\[ \text{ans} = \]
\[ 4 \ 16 \ 64 \ 256 \]

Also try
\[ \gg y .^\ x \]
\[ \text{ans} = \]
\[ 4 \ 16 \ 36 \ 64 \]
Scalar - Vector Math Summary

For a scalar $c$ and a vector $v$:

- **Addition**: $v + c$ or $c + v$
- **Subtraction**: $v - c$ or $c - v$
- **Multiplication**: $v * c$ or $c * v$ or $v.*c$ or $c.*v$
- **Division**: $v / c$ or $c./v$ or $v ./ c$
- **Exponent**: $v.^c$ or $c.^v$
Vector - Vector Math Summary

For two vectors $x$ and $y$:

- **Addition**: $x + y$ or $y + x$
- **Subtraction**: $x - y$ or $y - x$
- **Multiplication**: $x .* y$ or $y .* x$
- **Division**: $x ./ y$ or $y ./ x$
- **Exponent**: $x .^ y$ or $y .^ x$

You must **always** use the dot operator for **Multiplication**, **Division**, and **Exponent**.
Example 1

Calculate $y = 4x^2$ for $x = 1, 2, 3$ and $4$.

First define $x$

```matlab
>> x = [1 2 3 4];
```

Then calculate $y$

```matlab
>> y = 4.*x.^2
```

Which ‘.’ is required here?

```
y = 
   4 16 36 64
```
Example 2

Calculate \( y = (4a^2 + a)/(2+a) \) for \( a = 1,2,3 \) and \( 4 \).

First define \( a = [ 1 \ 2 \ 3 \ 4 ] \)

\[
\gg a = [1 \ 2 \ 3 \ 4];
\]

\[
a = \begin{bmatrix}
1 \\
2 \\
3 \\
4
\end{bmatrix}
\]

\[
\gg y = ((4*a.^2) + a)./(2+a)
\]

\[
y = \begin{bmatrix}
1.6667 \\
4.5000 \\
7.8000 \\
11.3333
\end{bmatrix}
\]
Built - In Vector Functions

MATLAB has built-in functions for vectors.

When $v$ is a vector:

- $\text{max}(v)$ returns the largest element in $v$.
- $\text{min}(v)$ returns the smallest element in $v$.
- $\text{mean}(v)$ returns the average value of the elements in $v$.
- $\text{sum}(v)$ returns the sum of the elements of $v$.
- $\text{length}(v)$ returns the number of elements in $v$.
- $\text{sort}(v)$ sorts the elements of $v$. 
Important Takeaways

- Know when to use a dot operator for Multiplication, Division, and Exponents.
- Only use a dot operator when appropriate and understand what you are trying to accomplish before you use it.
- Vector functions operate on an entire set of numbers located inside of an array, or matrix.
Preview of Next Class

- Input and Output
  - Inputting data into and out of programs
  - GPA calculator example
    - With and without use of vectors
  - Inputting to a script file
  - Output to command window
What’s Next?

- Review today’s Quiz #04
- Open the in-class activity from the EEIC website and we will go through it together.
- Then, start working on MAT-04 homework.
- Before next class, you will read more detail about script files including global variables. There is also information on input and output (I/O) commands in MATLAB.