

Performing calculations with matrices

University of Colorado Boulder

MCDB/BCHM 4312/5312
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Types of arithmetic operations in MATLAB

Matrix operations

- Follow rules of linear algebra
- Operators: * / ^

Array operations

- Element-by-element operations
- Operators: .* ./ .^

Matrix multiplication

$$\begin{array}{c} \text{A} \\ \left[\begin{array}{ccc} 10 & 15 & 21 \\ 1 & 3 & 55 \\ 9 & 18 & 2 \end{array} \right] \end{array} \times \begin{array}{c} \text{B} \\ \left[\begin{array}{c} 2 \\ 5 \\ 6 \end{array} \right] \end{array} = \begin{array}{c} \left[\begin{array}{c} 221 \\ 347 \\ 120 \end{array} \right] \end{array} = 10 * 2 + 15 * 5 + 21 * 6$$

Number of columns in A must match number of rows of B

Matrix vs array multiplication

Matrix multiplication

$$\begin{bmatrix} 10 & 3 \\ 8 & 12 \end{bmatrix} * \begin{bmatrix} 8 & 5 \\ 15 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} (10 \times 8) + (3 \times 15) & (10 \times 5) + (3 \times 1) \\ (8 \times 8) + (12 \times 15) & (8 \times 5) + (12 \times 1) \end{bmatrix}$$

$$= \begin{bmatrix} 125 & 53 \\ 244 & 52 \end{bmatrix}$$

Array multiplication

$$\begin{bmatrix} 10 & 3 \\ 8 & 12 \end{bmatrix} * \begin{bmatrix} 8 & 5 \\ 15 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 10 \times 8 & 3 \times 5 \\ 8 \times 15 & 12 \times 1 \end{bmatrix}$$

$$= \begin{bmatrix} 80 & 15 \\ 120 & 12 \end{bmatrix}$$

There is no `.+` or `.-` operator

Why?

There is no difference between array
sum/subtract vs matrix sum/subtract

Which of the following are true about array operations in MATLAB?

- A. $*$, $/$, $^$ are array operators
- B. Array operations are element-by-element operations
- C. $.+$, $.-$ are array operators
- D. $.*$, $./$, $.^$ are array operators
- E. Array operations follow the rules of linear algebra

What is the missing operator (???)?

```
>> A = [1 2; 3 4]
```

```
>> B = [2 4; 3 1]
```

```
>> A ??? B
```

```
ans =
```

```
    2    8
```

```
    9    4
```

A. *

B. /

C. .*

D. ./

E. ^

What is the output of the following command?

```
>> A = [1 2 3 4];
```

```
>> A = A ^ 2
```

- A. $A = [1 \ 4 \ 9 \ 16]$
- B. $A = [2 \ 4 \ 6 \ 8]$
- C. $A = [10 \ 20 \ 30 \ 40]$
- D. An error occurs

What is the output of the following command?

```
>> A = [1 2 3 4];
```

```
>> A * 2
```

- A. $A = [1 \ 4 \ 9 \ 16]$
- B. $A = [2 \ 4 \ 6 \ 8]$
- C. $A = [10 \ 20 \ 30 \ 40]$
- D. An error occurs

What is the output of the following command?

```
>> A = [1 2 3 4];
```

```
>> 1 / A
```

A. $A = [1 \ 0.50 \ 0.33 \ 0.250]$

B. $A = [2 \ 4 \ 6 \ 8]$

C. $A = [10 \ 20 \ 30 \ 40]$

D. An error occurs

Using functions in MATLAB

Basic syntax of a function

output = function(input, *optional*)

- For this class, I will distinguish functions using fixed-width font

You should keep a list of functions for class – useful for your "cheat sheet"

I might ask you what common functions do in mid-terms and exams

Which command(s) will display documentation about a command?

- A. doc
- B. man
- C. help
- D. ref

Which of the following is not a real function in MATLAB?

A. `sum`

B. `enumerate`

C. `fprintf`

D. `stairs`

E. I don't know how to tell

Which of the following is incorrect syntax for the function min?

A. `M = min(X)`

B. `M = min(X, [], 'all')`

C. `M = min(X, 'all')`

D. `[M, I] = min(X)`

E. `M = min(X, [], 'rows')`

Understanding the help files

- Documentation can use a lot of jargon
- If you are unsure what they mean, please ask
- You can send us an email or create a discussion in the Canvas page

For the syntax shown below, what is in the output I?

$$[M, I] = \min(X)$$

- A. I is the smallest element in X
- B. I is the index of the smallest element of the columns of X
- C. I is the index of the smallest element in X
- D. I is largest element of X
- E. I think therefore I am

Functions with multiple outputs

```
[M, I] = min(X)
```

- Example in MATLAB

```
X = rand(5); %Create a 5x5 matrix of  
            %random numbers
```

```
[M, I] = min(X);
```

What if you only want one of the outputs?

- Use the tilde (~) to get MATLAB to ignore an output

$$[\sim, I] = \max(X)$$

Questions?

Plotting data

**(a.k.a. why we spent so much time on
matrices)**

Task: Plot a Gaussian function

$$y = e^{-x^2/w^2}$$

Plot the equation above over the interval $x[-10, 10]$, with a width w of 4

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Step 1: Create a vector for x

Step 2: Evaluate the equation

Task: Plot a Gaussian function

$$y = e^{-x^2/w^2}$$

Plot the equation above over the interval $x[-10, 10]$, with a width w of 4

Step 1: Create a vector for x

Step 2: Evaluate the equation

Function for exponential is `exp`

Task: Plot a Gaussian function

$$y = e^{-x^2/w^2}$$

Plot the equation above over the interval $x[-10, 10]$, with a width w of 4

Step 1: Create a vector for x

Step 2: Evaluate the equation

Step 3: Plot the curve

```
plot(x, y)
```

What is the value of y at $x = 1.85$?

A. 0.40

B. 0.60

C. 0.80

D. 1.00

What is the full-width at half maximum (FWHM) of the curve?

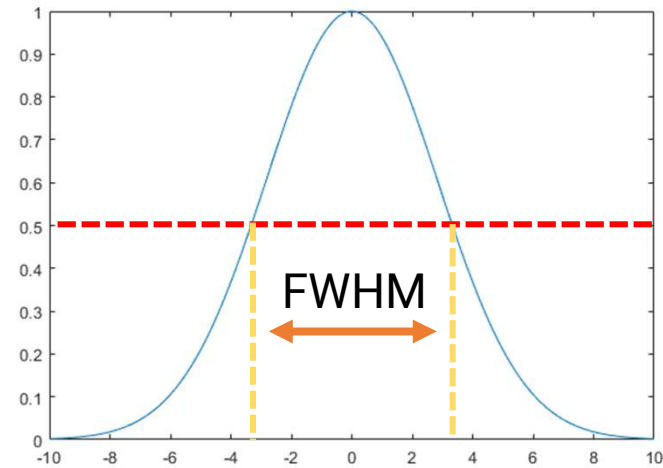
- FWHM = width of curve at $y = 0.5$

A. 6.61

B. 10.51

C. 4.31

D. 3.31



Plot a second plot

$$y = e^{-x^2/w^2}$$

Plot the equation above over the interval $x[-10, 10]$, with a width w of 7

Summary

- Array vs matrix operations
- Array operators `.*`, `./`, `.^`
- Using help and doc to get documentation for a function
- How to plot a function and use the graphical tools to read the graph

Homework Tips: Saving the image

- Save the image for homework – don't forget labels

Homework Tips: Importing data from a CSV file

- Download the CSV file ([beadDiameters.csv](#)) from Canvas and place it in your MATLAB folder
- Double-click the file to open
- Select "Numeric Matrix" in the output type
- Click "Import Selection"