CS368 MATLAB Programming

Lecture 2

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Based on lecture slides by Michael O'Neill and Beck Hasti

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Quiz

Admin

- Are you in room 168 Noland or on Zoom?
- A : I don't know
- B : 168 Noland
- C : Zoom
- D : Both

Scalar Operations, Binary

Code

- `x + y` is $x + y$.
- `x - y` is $x - y$.
- `x * y` is xy.
- `x / y` and `y \ x` are $\frac{x}{y}$.
- `x ^ y` is x^y.

Scalar Operations, Unary

Code

- *sqrt(x)* is $\sqrt{x}$.
- *exp(x)* is e^x .
- *log(x)* is natural log or $\ln(x)$, *log10(x)* is $\log_{10}(x)$.
- *sin(x)* with x in radians, *sind(x)* with x in degrees, *asin(y)* is $\arcsin(y)$ in radians, *asind(x)* is $\arcsin(y)$ in degrees.
- *cos(x)*, *cosd(x)*, *acos(y)*, *acosd(y)*.
- *tan(x)*, *tand(x)*, *atan(y)*, *atand(y)*.

Scalar Operations, Unary Integer

Code

- *round(x)* is rounding x to nearest integer.
- *floor (x)* is $\lfloor x \rfloor$, largest integer $\leqslant x$.
- *ceil (x)* is $\lceil x \rceil$, smallest integer $\geqslant x$.
- *mod(x, y)* is $x \mod y$, or x modulo y, the remainder when x is divided by y, integer division, $x \ \% \ y$ does not work in MATLAB.

Scalar Operations, Rounding

Quiz

- $1.00001 + 1$
- B : **2**
- C : **2.00001**
- D : **2.0000**

Scalar Math Operations, Infinity

Quiz

- *10 ^ 309*
- *B* : **1e+309**
- *C* : **1.0000e+309**
- *D* : **Inf**

Scalar Operations, Precision

Quiz

- *10 ^ −309*
- *B* : **1e-309**
- *C* : **1.0000e-309**
- *D* : **0**

Scalar Operations, Numerical Instability

Quiz

- *(1 + 10^−16 − 1) ∗ 10^16*
- B : **0**
- C : **0.0000**
- D : **1**
- E : **1.0000**

Scalar Math Operations, Numerical Instability Again

Quiz

- *(1 − 1 + 10^−16) ∗ 10^16*
- B : **0**
- C : **0.0000**
- D : **1**
- E : **1.0000**

Numerical Instability

Code

- The number of decimal places that is displayed can be changed.
- The number of decimal places that can be stored is fixed.

1. $\pi, e, \sqrt{2}$ etc are approximate values (accurate up to 16 decimal places).
2. Underflow may occur: numbers that are too close to 0 are stored as **0** .
3. Overflow may occur: numbers that are too large are stored as **Inf** .

Vector Multiplication

Math

- $\begin{bmatrix} a \\ b \end{bmatrix} \odot \begin{bmatrix} c \\ d \end{bmatrix} = \begin{bmatrix} ac \\ bd \end{bmatrix}$ is the element-wise product.
- $\begin{bmatrix} a \\ b \end{bmatrix} \cdot \begin{bmatrix} c \\ d \end{bmatrix} = \begin{bmatrix} a & b \end{bmatrix} \begin{bmatrix} c \\ d \end{bmatrix} = ac + bd$ is the inner product, also called the dot product for matrices.
- $\begin{bmatrix} a \\ b \end{bmatrix} \otimes \begin{bmatrix} c \\ d \end{bmatrix} = \begin{bmatrix} a \\ b \end{bmatrix} \begin{bmatrix} c & d \end{bmatrix} = \begin{bmatrix} ac & ad \\ bc & bd \end{bmatrix}$ is the outer product.

Vector Multiplication

Code

- Suppose M and W are two row vectors having the same size.
- $M .* W$ is the element-wise product $M \odot W$.
- $M * W'$ and $dot(M, W)$ are the inner product $M \cdot W = MW^T$.
- $M' * W$ is the outer product $M \otimes W = M^T W$.

General Vector Operations

Code

- Suppose M and W are two row vectors having the same size, and c is a scalar.
- $M + W$ and $M - W$ are element-wise and also vector addition and subtraction.
- M .^ W and M .^ c are element-wise exponentiation.

General Vector Operations, Unary

Code

- Most of the built-in unary operations are element-wise when applied to vectors.
- For example, the square root function can be applied element-wise to vectors directly.

1. *sqrt ([a b c])* is $\begin{bmatrix}\sqrt{a} & \sqrt{b} & \sqrt{c}\end{bmatrix}$.
2. *[a b c] .^ 0.5* is also $\begin{bmatrix}\sqrt{a} & \sqrt{b} & \sqrt{c}\end{bmatrix}$.
3. *[a b c] ^ 0.5* results in an error.

Vector Operations, Multiplication

Quiz

- **2 6 12 20 30 42 56 72**
- A : (1:8)' * (2:9)
- B : (1:8) * (2:9)'
- C : (1:8) * (2:9)
- D : (1:8) .* (2:9)

Vector Operations, Exponentiation

Quiz

- **1 2 4 8 16 32 64 128**
- A : (0:7) ^ 2
- B : (0:7) .^ 2
- C : 2 ^ (0:7)
- D : 2 .^ (0:7)

Vector Operations, Trig Operations

Quiz

- **1 0 -1 0 1 0 -1 0**
- A : $round(sind((0{:}7)\ *\ 180))$
- B : $round(cosd((0{:}7)\ *\ 180))$
- C : $round(sind((0{:}7)\ *\ 90))$
- D : $round(cosd((0{:}7)\ *\ 90))$

Matrix Multiplication

Math

- $\begin{bmatrix} a & b \\ c & d \end{bmatrix} \odot \begin{bmatrix} e & f \\ g & h \end{bmatrix} = \begin{bmatrix} ae & bf \\ cg & dh \end{bmatrix}$ is the element-wise product.
- $\begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} e \\ f \end{bmatrix} = \begin{bmatrix} ae + bf \\ ce + df \end{bmatrix}$ and $\begin{bmatrix} e & f \end{bmatrix} \begin{bmatrix} a & b \\ c & d \end{bmatrix} = \begin{bmatrix} ea + fc & eb + fd \end{bmatrix}$ are matrix products.
- $\begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} e & f \\ g & h \end{bmatrix} = \begin{bmatrix} ae + bg & af + bh \\ ce + dg & cf + dh \end{bmatrix}$ is also the matrix product.

Matrix Multiplication

Code

- Suppose M and W are two matrices.
- $M .* W$, when M and W have the same size, is the element-wise product $M \odot W$.
- $M * W$, when number of columns of M is the same as the number of rows of W, is the matrix product MW.

General Matrix Operations, Binary

Code

- Suppose M and W are two matrices, and c is a scalar.
- $M + W$ and $M - W$ are element-wise and also matrix addition and subtraction.
- $M \;.* \; W$ is element-wise, and $M * W$ is matrix multiplication.
- $M \;./\; W$ and $W \;.\backslash\; M$ are element-wise, and $M \;/\; W$ and $W \backslash M$ find the matrix X such that $MX = W$, the solution of systems of linear equations. More details in a later lecture.
- $M \;.\hat{}\; W$ and $M \;.\hat{}\; c$ are element-wise, and $M \;\hat{}\; c$ is matrix exponentiation.

General Matrix Operations, Unary

Code

- Most of the built-in unary operations are element-wise when applied to matrices.
- For example, the square root function can be applied element-wise to matrices directly.

1. *sqrt ([a b; c d])* is $\begin{bmatrix} \sqrt{a} & \sqrt{b} \\ \sqrt{c} & \sqrt{d} \end{bmatrix}$.
2. *[a b; c d] .^ 0.5* is also $\begin{bmatrix} \sqrt{a} & \sqrt{b} \\ \sqrt{c} & \sqrt{d} \end{bmatrix}$.
3. *[a b; c d] ^ 0.5* is the actual square root of the matrix, it finds a matrix $\begin{bmatrix} e & f \\ g & h \end{bmatrix}$ such that $\begin{bmatrix} e & f \\ g & h \end{bmatrix} \begin{bmatrix} e & f \\ g & h \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$.

Matrix Operations, Multiplication

Quiz

- (What is the second column of $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$?)
- $\begin{matrix} \mathbf{2} \\ \mathbf{5} \\ \mathbf{8} \end{matrix}$

1. $m = [1\ 2\ 3;\ 4\ 5\ 6;\ 7\ 8\ 9]$;

- A : $m * [0\ \ 1\ \ 0]$
- B : $m * [0;\ \ 1;\ \ 0]$
- C : $[0\ \ 1\ \ 0] * m$
- D : $[0;\ \ 1;\ \ 0] * m$

Matrix Operations, Multiplication Again

Quiz

- (What is the row 2, column 3 entry of $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$?)
- **6**

1. m = [1 2 3; 4 5 6; 7 8 9]; ei = [0; 1; 0]; ej = [0; 0; 1];

- A : ei ' * m * ej
- B : ej ' * m * ei
- C : ei ' * ej * m
- D : m * ei * ej '

Matrix Operations, Division

Quiz

- *[1 2; 3 4] .\ [2 4; 6 8]*
- $A: \begin{matrix} \mathbf{2} & \mathbf{0} \\ \mathbf{0} & \mathbf{2} \end{matrix}$ $\quad B: \begin{matrix} \mathbf{0.5} & \mathbf{0} \\ \mathbf{0} & \mathbf{0.5} \end{matrix}$
- $C: \begin{matrix} \mathbf{2} & \mathbf{2} \\ \mathbf{2} & \mathbf{2} \end{matrix}$ $\quad D: \begin{matrix} \mathbf{0.5} & \mathbf{0.5} \\ \mathbf{0.5} & \mathbf{0.5} \end{matrix}$

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