Instructor: Paul Alpano March 14, 2017
EEE 11 WLMHWX/WLMFQR

MP 1: Matrix Solver

- Please work **INDIVIDUALY**. Your codes will be run through a software similarity test and a plagiarism checker. Students who submitted substantially similar work or copied their codes online will be investigated for cheating will be filed a case with the College Disciplinary Council.
- Properly **INDENT** and **LABEL** your codes. Points will be deducted on codes with no proper indentation and labels.
- Save your codes in the following format: **MP1_LASTNAME.c** (e.g. MP1_ALPANO.c)
- Codes that does **NOT** compile will be given a grade of 0.
- Submit your .c file on or before 11:55 pm of **April 5, 2017.** Codes not uploaded through UVLE and submitted through my email will be given a grade of 0.
- You will demonstrate your codes **DURING** the laboratory class on **April 6/7, 2017**. Students who failed to let the Lecturer/Student Assistant check their work during class hours will be given a grade of 0.

A Matrix is an array of numbers identified by rows and columns where you could use operations such as transposition and arithmetic. A common notation for matrices is:

Let a, b, c, d, e, f, g, h, i ϵ $\mathbb{R}$. A 3x3 matrix X is defined as

$$X = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix}$$

The notation 3x3 (m x n) represents the "*number of rows (m)* **x** *number of columns (n)*". However, applying the arithmetic operations on matrices is not as simple as applying them on regular equation.

Given two matrices X and Y:

$$X = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix} \qquad Y = \begin{pmatrix} k & l & m \\ n & o & p \\ q & r & s \end{pmatrix}$$

Transpose:

$$X^T = \begin{pmatrix} a & d & g \\ b & e & h \\ c & f & i \end{pmatrix} \qquad Y^T = \begin{pmatrix} k & n & q \\ l & o & r \\ n & p & s \end{pmatrix}$$

Addition:

$$X + Y = \begin{pmatrix} a + k & l + b & c + m \\ d + n & e + o & f + p \\ g + q & h + r & I + s \end{pmatrix}$$

Only applicable if $m_x = m_y$ and $n_x = n_y$

Subtraction:

$$X - Y = \begin{pmatrix} a - k & l - b & c - m \\ d - n & e - o & f - p \\ g - q & h - r & I - s \end{pmatrix}$$

Only applicable if $m_x = m_y$ and $n_x = n_y$

Multiplication:

$$X * Y = \begin{pmatrix} (a*k)+(b*n)+(c+q) & (a*l)+(b*o)+(c+r) & (a*m)+(b*p)+(c+s) \\ (d*k)+(e*n)+(f+q) & (d*l)+(e*o)+(f+r) & (d*m)+(e*p)+(f+s) \\ (g*k)+(h*n)+(i+q) & (g*l)+(h*o)+(i+r) & (g*m)+(h*p)+(i+s) \end{pmatrix}$$

Given Matrix X and Matrix Y, we get Matrix Z where Z = X * Y if and only if $n_x = m_y$. The resulting Matrix Z has rows and columns of m_x x n_y. We get the value of each element of Matrix Z by getting its dot product. Dot product is multiplying each element of the same row number from the first matrix (X) to the corresponding elements of the same column number of the second matrix (Y) and adding them altogether.

Division:

$X/Y = X * Y^{-1}$ where $Y^{-1} = \frac{1}{determinant}(Y_{adjugate})$

$$Y * Y^{-1} = I = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Given Matrix X and Matrix Y, we divide matrices by multiplying the first matrix to the inverse of the second matrix. The inverse of a matrix is treated as the matrix's reciprocal. When we multiply a matrix to its inverse, the product is the identity matrix I. In this Machine Problem, we are to get the inverse of a matrix by multiplying $\frac{1}{determinant}$ to the adjugate of the original matrix. If the determinant is zero, matrix division is not possible.

Given Matrix W to be a 2x2 matrix, the determinant is computed as:

$$W = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \qquad det(W) = (a*d) – (b*c)$$

Given Matrix Y to be a square matrix of order n, the determinant is computed as:

$$\det(Y) = \sum_{i=1}^{i=n} y_{ij}Y_{ij} \quad \text{or} \quad \det(Y) = \sum_{j=1}^{j=n} y_{ij}Y_{ij}$$

Where y_{ij} is the entry on row number I and column number J and Y_{ij} is determinant of the square matrix of order (n-1) obtained from *Y* by removing the row number i and the column number j multiplied by $(-1)^{i+j}$. Therefore, the determinants of 3x3 matrix Y using i = 1 is:

$$Det(Y) = k*det\begin{pmatrix} o & p \\ r & s \end{pmatrix} - l*det\begin{pmatrix} n & p \\ q & s \end{pmatrix} + m*det\begin{pmatrix} n & o \\ q & r \end{pmatrix}$$

$$= k * [(o * s) - (p * r)] – l * [(n * s) – (p * q)] + m * [(n * r) – (o * q)]$$

To get the adjugate of Matrix Y, we first get its matrix of Minors Y_{minor}. Y_{minor} has the same number of rows and columns of Y (mxn) and the element's value $Y_{minor, ij}$ is computed by getting the determinant of the square matrix of order (n-1) by removing the row number i and column number j. We get the cofactor $Y_{cofactor}$ by multiplying each element of Y_{minor} by $(-1)^{i+j}$. Lasty, the adjugate $Y_{adjugate}$ is computed by transposing the cofactor $Y_{cofactor}$.

$$Y_{minor} = \begin{pmatrix} (o*s) - (p*r) & (n*s) - (p*q) & (n*r) - (o*q) \\ (l*s) - (m*r) & (k*s) - (m*q) & (k*r) - (l*q) \\ (l*p) - (m*o) & (k*p) - (m*n) & (k*o) - (l*n) \end{pmatrix}$$

$$Y_{cofactor} = \begin{pmatrix} (o*s) - (p*r) & - [(n*s) - (p*q)] & (n*r) - (o*q) \\ - [(l*s) - (m*r)] & (k*s) - (m*q) & - [(k*r) - (l*q)] \\ (l*p) - (m*o) & - [(k*p) - (m*n)] & (k*o) - (l*n) \end{pmatrix}$$

$$Y_{adjugate} = \begin{pmatrix} (o*s) - (p*r) & - [(l*s) - (m*r)] & (l*p) - (m*o) \\ - [(n*s) - (p*q)] & (k*s) - (m*q) & - [(k*p) - (m*n)] \\ (n*r) - (o*q) & - [(k*r) - (l*q)] & (k*o) - (l*n) \end{pmatrix}$$

For this Machine Problem:

- Your code should only use the header file **STDIO.H.**
- Your code should **NOT** use **GLOBAL VARIABLES, CONSTANTS and MACROS**.

*Codes not complying with these rules above will be given a grade of 0.

- Codes with warnings on compilation will be given a deduction of 10 points PER warning.
- Codes without proper error handling will be given a deduction of 10 points PER instance.
- Codes that does not follow proper display formatting will be deducted 10 points from their final score.
- You have the freedom to implement your own variables and functions with its parameters.
- Always assume all matrices are square matrices. Initialize your Matrices as a 5x5 matrix with all elements having a value of 0.
- The matrix dimensions are assumed as ***int***. The elements of the matrices are assumed as ***float***. Display the elements of the matrix with ***2 decimal places***. Use a ***"tab" (\t) as spaces*** in between numbers of the same row.
- At the start of the program:
  - Prompt the user to input the dimension (value of n) of Matrix A (Min value = 2, Max value = 5). Then, prompt the user to input the values of Matrix A, reading it by rows (e.g. for a 2x2 matrix: row 1 col 1, row 1 col 2, row 2 col 1, row 2 col 2). You have the freedom to choose whether the user would input all the values in a single line or enter them one-by-one, as long as you warn the user on how they should input it. You have the option to display the matrix afterwards with the correct dimension (for debugging). Always assume that the user will input float numbers and the exact number of elements per dimension.
  - Then, prompt the user to input the dimension (value of n) of Matrix B (Min value = 2, Max value = 5). Then, prompt the user to input the values of Matrix B, reading it by rows (e.g. for a 2x2 matrix: row 1 col 1, row 1 col 2, row 2 col 1, row 2 col 2). You have the freedom to choose whether the user would input all the values in a single line or enter them one-by-one, as long as you warn the user on how they should input it. You have the option to display the matrix afterwards with the correct dimension (for debugging). Always assume that the user will input float numbers and the exact number of elements per dimension.

  *Hint: Redirection should work to input BOTH matrix A and matrix B.
- Your code should do the following matrix operations. These operations SHOULD NOT change the original values of Matrix A and Matrix B. Your program should end after you display the last operation:

  a. Display Matrix A and Matrix B
  b. Display Transpose A and Transpose B
  c. A + B
  d. A – B
  e. A * B
  f. Get Determinant A and Determinant B
  g. A / B

a) Display Matrix A and Matrix B (5 pts + 5 pts)

Display the elements of Matrix A in matrix form and its dimension.

b) Display Transpose A and Transpose B (5 pts + 5 pts)

Display the transpose of matrix A and matrix B.

c) A + B (10 pts)

Display the sum of matrix A and matrix B. If the matrix dimensions are not equal, display "Sum not possible. Matrix dimensions are not equal. Matrix A has nxn dimension and Matrix B has mxm dimension" where n is the dimension of matrix A and m is the dimension of matrix B.

d) A – B (10 pts)

Display the difference of matrix A and matrix B. If the matrix dimensions are not equal, display "Difference not possible. Matrix dimensions are not equal. Matrix A has nxn dimension and Matrix B has mxm dimension" where n is the dimension of matrix A and m is the dimension of matrix B.

e) A * B (20 pts)

Display the product of matrix A and matrix B. If the matrix dimensions are not equal, display "Product not possible. Matrix dimensions are not equal. Matrix A has nxn dimension and Matrix B has mxm dimension" where n is the dimension of matrix A and m is the dimension of matrix B.

f) Determinant A and Determinant B (5 pts + 5 pts)

Display the determinants of matrix A and matrix B.

g) A / B (30 pts)

Display the adjugate of matrix B (10 pts), the inverse of matrix B (10 pts), and the quotient of matrix A and matrix B (10 pts). If the matrix dimensions are not equal, display "Quotient not possible. Matrix dimensions are not equal. Matrix A has nxn dimension and Matrix B has mxm dimension" where n is the dimension of matrix A and m is the dimension of matrix B. If determinant of matrix B is zero, display "Quotient not possible. Determinant of Matrix B is zero."

Example:

test.txt:

```
5
9.31 -5.3 6.03 -1.34 3.46 4.3 5.83 -2.84 4.51 8.13 -1.04 8.48 9.03 4.23 7.32 0.32 -7.13 2.54 -6.49 -9.32 7.21 2.23 -4.54 2.34 3.23
5
-2.32 2.57 3.57 -4.65 0.36 -6.43 -9.54 7.21 2.37 6.43 8.72 -7.25 -9.23 3.1 1.23 5.78 -0.35 2.67 1.37 8.36 7.36 -4.21 -9.95 5.67 -7.46
```

```
paul@ubuntu:~/Desktop/MP1_ALPANO$ ./MP1_ALPANO < test.txt
Input the dimension of the First Matrix (2-5 only):
Input the First Matrix:
Input the dimension of the Second Matrix (2-5 only):
Input the Second Matrix:

Displaying Matrix A with 5x5 dimension:
9.31    -5.30   6.03    -1.34   3.46
4.30    5.83    -2.84   4.51    8.13
-1.04   8.48    9.03    4.23    7.32
0.32    -7.13   2.54    -6.49   -9.32
7.21    2.23    -4.54   2.34    3.23

Displaying Matrix B with 5x5 dimension:
-2.32   2.57    3.57    -4.65   0.36
-6.43   -9.54   7.21    2.37    6.43
8.72    -7.25   -9.23   3.10    1.23
5.78    -0.35   2.67    1.37    8.36
7.36    -4.21   -9.95   5.67    -7.46

Displaying Matrix A Transpose:
9.31    4.30    -1.04   0.32    7.21
-5.30   5.83    8.48    -7.13   2.23
6.03    -2.84   9.03    2.54    -4.54
-1.34   4.51    4.23    -6.49   2.34
3.46    8.13    7.32    -9.32   3.23
```

Displaying Matrix B Transpose:

-2.32	-6.43	8.72	5.78	7.36
2.57	-9.54	-7.25	-0.35	-4.21
3.57	7.21	-9.23	2.67	-9.95
-4.65	2.37	3.10	1.37	5.67
0.36	6.43	1.23	8.36	-7.46

Displaying Sum (A + B):

6.99	-2.73	9.60	-5.99	3.82
-2.13	-3.71	4.37	6.88	14.56
7.68	1.23	-0.20	7.33	8.55
6.10	-7.48	5.21	-5.12	-0.96
14.57	-1.98	-14.49	8.01	-4.23

Displaying Difference (A - B):

11.63	-7.87	2.46	3.31	3.10
10.73	15.37	-10.05	2.14	1.70
-9.76	15.73	18.26	1.13	6.09
-5.46	-6.78	-0.13	-7.86	-17.68
-0.15	6.44	5.41	-3.33	10.69

Displaying Product (A * B):

82.78	16.67	-98.64	-19.38	-60.32
13.68	-59.78	14.75	37.29	12.60
104.95	-181.34	-87.46	100.23	46.01
-38.86	91.94	1.70	-72.25	-27.34
-33.36	15.75	57.83	-20.80	6.82

Determinant A = 6937.49
Determinant B = -23598.43

Displaying Adjugate of Matrix B:

-5134.88	-336.19	1022.79	-3127.79	-3874.07
3932.11	1962.98	964.96	-120.49	1905.78
-5311.20	-1750.39	3284.22	-3080.30	-4675.44
6074.31	-23.26	2381.42	-835.68	270.77
4415.66	877.47	-2105.91	455.42	4295.88

Displaying Inverse of Matrix B:

0.22	0.01	-0.04	0.13	0.16
-0.17	-0.08	-0.04	0.01	-0.08
0.23	0.07	-0.14	0.13	0.20
-0.26	0.00	-0.10	0.04	0.01
-0.19	-0.04	0.09	-0.02	-0.18

Displaying Quotient (A / B):

3.96	0.89	-0.58	1.88	2.51
-3.36	-0.93	0.24	0.23	-1.76
-2.07	-0.32	-1.33	1.09	-0.35
5.24	1.13	-0.25	0.29	2.75
-1.03	-0.54	0.28	0.39	-0.46

paul@ubuntu:~/Desktop/MP1_ALPANO$