EECS1022 Winter 2018
Exercises on 2-D Arrays
Implementing Matrix Operations using 2-D Arrays

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1 Background

1.1 Matrix Addition and Subtraction

Consider two x-by-y matrices, where x denotes the number of rows and y the number of columns:

$$m_1 = \underbrace{\overbrace{\begin{pmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1(y-1)} & a_{1y} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2(y-1)} & a_{2y} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3(y-1)} & a_{3y} \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ a_{(x-1)1} & a_{(x-1)2} & a_{(x-1)3} & \cdots & a_{(x-1)(y-1)} & a_{(x-1)y} \\ a_{x1} & a_{x2} & a_{x3} & \cdots & a_{x(y-1)} & a_{xy} \end{pmatrix}}^{y \texttt{ columns}}}_{x \texttt{ rows}}$$

and

$$m_2 = \underbrace{\overbrace{\begin{pmatrix} b_{11} & b_{12} & b_{13} & \cdots & b_{1(y-1)} & b_{1y} \\ b_{21} & b_{22} & b_{23} & \cdots & b_{2(y-1)} & b_{2y} \\ b_{31} & b_{32} & b_{33} & \cdots & b_{3(y-1)} & b_{3y} \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ b_{(x-1)1} & b_{(x-1)2} & b_{(x-1)3} & \cdots & b_{(x-1)(y-1)} & b_{(x-1)y} \\ b_{x1} & b_{x2} & b_{x3} & \cdots & b_{x(y-1)} & b_{xy} \end{pmatrix}}^{y \texttt{ columns}}}_{x \texttt{ rows}}$$

We define $\boxed{m_1 + m_2}$ as another x-by-y matrix, whose entry $c_{ij} = a_{ij} + b_{ij}$, where $1 \leq i \leq x$ and $1 \leq j \leq y$.

$$m_1 + m_2 = \underbrace{\overbrace{\begin{pmatrix} a_{11} + b_{11} & a_{12} + b_{12} & \cdots & a_{1(y-1)} + b_{1(y-1)} & a_{1y} + b_{1y} \\ a_{21} + b_{21} & a_{22} + b_{22} & \cdots & a_{2(y-1)} + b_{2(y-1)} & a_{2y} + b_{2y} \\ a_{31} + b_{31} & a_{32} + b_{32} & \cdots & a_{3(y-1)} + b_{3(y-1)} & a_{3y} + b_{3y} \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ a_{(x-1)1} + b_{(x-1)1} & a_{(x-1)2} + b_{(x-1)2} & \cdots & a_{(x-1)(y-1)} + b_{(x-1)(y-1)} & a_{(x-1)y} + b_{(x-1)y} \\ a_{x1} + b_{x1} & a_{x2} + b_{x2} & \cdots & a_{x(y-1)} + b_{x(y-1)} & a_{xy} + b_{xy} \end{pmatrix}}^{y \texttt{ columns}}}_{x \texttt{ rows}}$$

We define $\boxed{m_1 - m_2}$ as another x-by-y matrix, whose entry $c_{ij} = a_{ij} - b_{ij}$, where $1 \leq i \leq x$ and $1 \leq j \leq y$.

$$m_1 - m_2 = \underbrace{\overbrace{\begin{pmatrix} a_{11} - b_{11} & a_{12} - b_{12} & \cdots & a_{1(y-1)} - b_{1(y-1)} & a_{1y} - b_{1y} \\ a_{21} - b_{21} & a_{22} - b_{22} & \cdots & a_{2(y-1)} - b_{2(y-1)} & a_{2y} - b_{2y} \\ a_{31} - b_{31} & a_{32} - b_{32} & \cdots & a_{3(y-1)} - b_{3(y-1)} & a_{3y} - b_{3y} \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ a_{(x-1)1} - b_{(x-1)1} & a_{(x-1)2} - b_{(x-1)2} & \cdots & a_{(x-1)(y-1)} - b_{(x-1)(y-1)} & a_{(x-1)y} - b_{(x-1)y} \\ a_{x1} - b_{x1} & a_{x2} - b_{x2} & \cdots & a_{x(y-1)} - b_{x(y-1)} & a_{xy} - b_{xy} \end{pmatrix}}^{y \texttt{ columns}}}_{x \texttt{ rows}}$$

1.2 Matrix Multiplication

Consider an x-by-y matrix and a y-by-z matrix

$$m_1 = x\ \texttt{rows} \overset{y\ \texttt{columns}}{\begin{pmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1(y-1)} & a_{1y} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2(y-1)} & a_{2y} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3(y-1)} & a_{3y} \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ a_{(x-1)1} & a_{(x-1)2} & a_{(x-1)3} & \cdots & a_{(x-1)(y-1)} & a_{(x-1)y} \\ a_{x1} & a_{x2} & a_{x3} & \cdots & a_{x(y-1)} & a_{xy} \end{pmatrix}}$$

$$m_2 = y\ \texttt{rows} \overset{z\ \texttt{columns}}{\begin{pmatrix} b_{11} & b_{12} & b_{13} & \cdots & b_{1(z-1)} & b_{1z} \\ b_{21} & b_{22} & b_{23} & \cdots & b_{2(z-1)} & b_{2z} \\ b_{31} & b_{32} & b_{33} & \cdots & b_{3(z-1)} & b_{3z} \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ b_{(y-1)1} & b_{(y-1)2} & b_{(y-1)3} & \cdots & b_{(y-1)(z-1)} & b_{(y-1)z} \\ b_{y1} & b_{y2} & b_{y3} & \cdots & b_{y(z-1)} & b_{yz} \end{pmatrix}}$$

We define $\boxed{m_1 \times m_2}$ as another x-by-z matrix, whose entry $c_{ij} = \sum_{k=1}^{y} a_{ik} \times b_{kj}$, where $1 \leq i \leq x$ and $1 \leq j \leq z$. That is, to calculate c_{ij} in m_3, we select m_1's row i (with y columns) and m_2's column j (with y rows), and sum up the products of entries at the corresponding positions.

$$m_1 \times m_2 = x\ \texttt{rows} \overset{z\ \texttt{columns}}{\begin{pmatrix} \sum_{k=1}^{y} a_{1k} \times b_{k1} & \sum_{k=1}^{y} a_{1k} \times b_{k2} & \cdots & \sum_{k=1}^{y} a_{1k} \times b_{k(z-1)} & \sum_{k=1}^{y} a_{1k} \times b_{kz} \\ \sum_{k=1}^{y} a_{2k} \times b_{k1} & \sum_{k=1}^{y} a_{2k} \times b_{k2} & \cdots & \sum_{k=1}^{y} a_{2k} \times b_{k(z-1)} & \sum_{k=1}^{y} a_{2k} \times b_{kz} \\ \vdots & \vdots & \cdots & \vdots & \vdots \\ \sum_{k=1}^{y} a_{(x-1)k} \times b_{k1} & \sum_{k=1}^{y} a_{(x-1)k} \times b_{k2} & \cdots & \sum_{k=1}^{y} a_{(x-1)k} \times b_{k(z-1)} & \sum_{k=1}^{y} a_{(x-1)k} \times b_{kz} \\ \sum_{k=1}^{y} a_{xk} \times b_{k1} & \sum_{k=1}^{y} a_{xk} \times b_{k2} & \cdots & \sum_{k=1}^{y} a_{xk} \times b_{k(z-1)} & \sum_{k=1}^{y} a_{xk} \times b_{kz} \end{pmatrix}}$$

2 Your Tasks

Create a Java class `MatrixOperations` whose `main` method repeatedly (where you may want to use the `Scanner` class and its methods for reading user inputs):

1. Prompt for the number of rows (say nr_1), then the number of columns (say nc_1), of a first matrix m_1. Initialize a 2-D array of the corresponding dimension sizes.
2. Prompt to enter values of the $nr_1 \times nc_1$ entries in the first matrix m_1, one at a time: $m[0][0]$, $m[0][1]$, $\ldots$, $m[0][nc_1 - 1]$, $m[1][0]$, $m[1][1]$, $\ldots$, $m[1][nc_1 - 1]$, $\ldots$, $m[nr_1 - 1][0]$, $m[nr_1 - 1][1]$, $\ldots$, $m[nr_1 - 1][nc_1 - 1]$.
3. Prompt for the number of rows (say nr_2), then the number of columns (say nc_2), of a second matrix m_2. Initialize a 2-D array of the corresponding dimension sizes.
4. Prompt to enter values of the $nr_2 \times nc_2$ entries in the second matrix m_2, one at a time: $m[0][0]$, $m[0][1]$, $\ldots$, $m[0][nc_2 - 1]$, $m[1][0]$, $m[1][1]$, $\ldots$, $m[1][nc_2 - 1]$, $\ldots$, $m[nr_2 - 1][0]$, $m[nr_2 - 1][1]$, $\ldots$, $m[nr_2 - 1][nc_2 - 1]$.
5. If $nr_1 = nr_2$ and $nc_1 = nc_2$, then compute both $m_1 + m_2$ and $m_1 - m_2$ and print out the two resulting matrices. Otherwise, print an error message: the addition and subtraction operations are not applicable.
6. If $nc_1 = nr_2$, then compute $m_1 \times m_2$ and print out the resulting matrix. Otherwise, print an error message: the multiplication operation is not applicable.

To pretty print a matrix, you may want to separate entries on the same row with a tab (`\t`) rather than a space.

3 Example Runs

3.1 Input Applicable for All Operations

```
Enter the number of rows of m1
2
Enter the number of columns of m1
2
Enter a value for m1[0][0]:
1
Enter a value for m1[0][1]:
2
Enter a value for m1[1][0]:
3
Enter a value for m1[1][1]:
4
m1:
1        2
3        4
Enter the number of rows of m2
2
Enter the number of columns of m2
2
Enter a value for m2[0][0]:
5
Enter a value for m2[0][1]:
6
Enter a value for m2[1][0]:
7
Enter a value for m2[1][1]:
8
m2:
5        6
7        8
m1 + m2:
6        8
10        12
m1 - m2:
-4        -4
-4        -4
m1 * m2:
19        22
43        50
```

3.2 Input Applicable for Multiplication Only

```
Enter the number of rows of m1
2
Enter the number of columns of m1
3
Enter a value for m1[0][0]:
1
Enter a value for m1[0][1]:
2
Enter a value for m1[0][2]:
3
Enter a value for m1[1][0]:
4
Enter a value for m1[1][1]:
5
Enter a value for m1[1][2]:
6
m1:
1        2        3
4        5        6
Enter the number of rows of m2
3
Enter the number of columns of m2
2
Enter a value for m2[0][0]:
7
Enter a value for m2[0][1]:
8
Enter a value for m2[1][0]:
9
Enter a value for m2[1][1]:
10
Enter a value for m2[2][0]:
11
Enter a value for m2[2][1]:
12
m2:
7        8
9        10
11        12
We cannot do addition/substraction.
m1 * m2:
58        64
139        154
```