CSE 21 Intro to Computing II

Lecture 12

Multi-dimensional Arrays (2)

Today

- Multi-dimensional Arrays (2)
- Lab
  - Lab 13 and 14 due this week (4/29 – 5/5)
    - Lab 14 (Final Exam Review): **Attendance MANDATORY** to get full credit
    - **Required** to show work to a TA (or me) for full credit
- Reading Assignment
  - Sections 5.9 (including participation activities)
    - Work on the **Participation Activities** in each section to receive participation grade at the end of semester (based on at least 80% completion)
    - **Each Section must have 80% completion to receive grade. <80% is a ZERO**
    - **Work on Challenge Activities to receive extra credit (Up to 5% of overall grade)**
  - Participation and Challenge activities evaluated at the end of semester
  - **ALL Activities due on May 6th at 11:59pm**
- Course evaluation online
  - Fill out by May 4th
  - Curve the final exam grades for class if more than 70% fill out evaluation

Final Exam

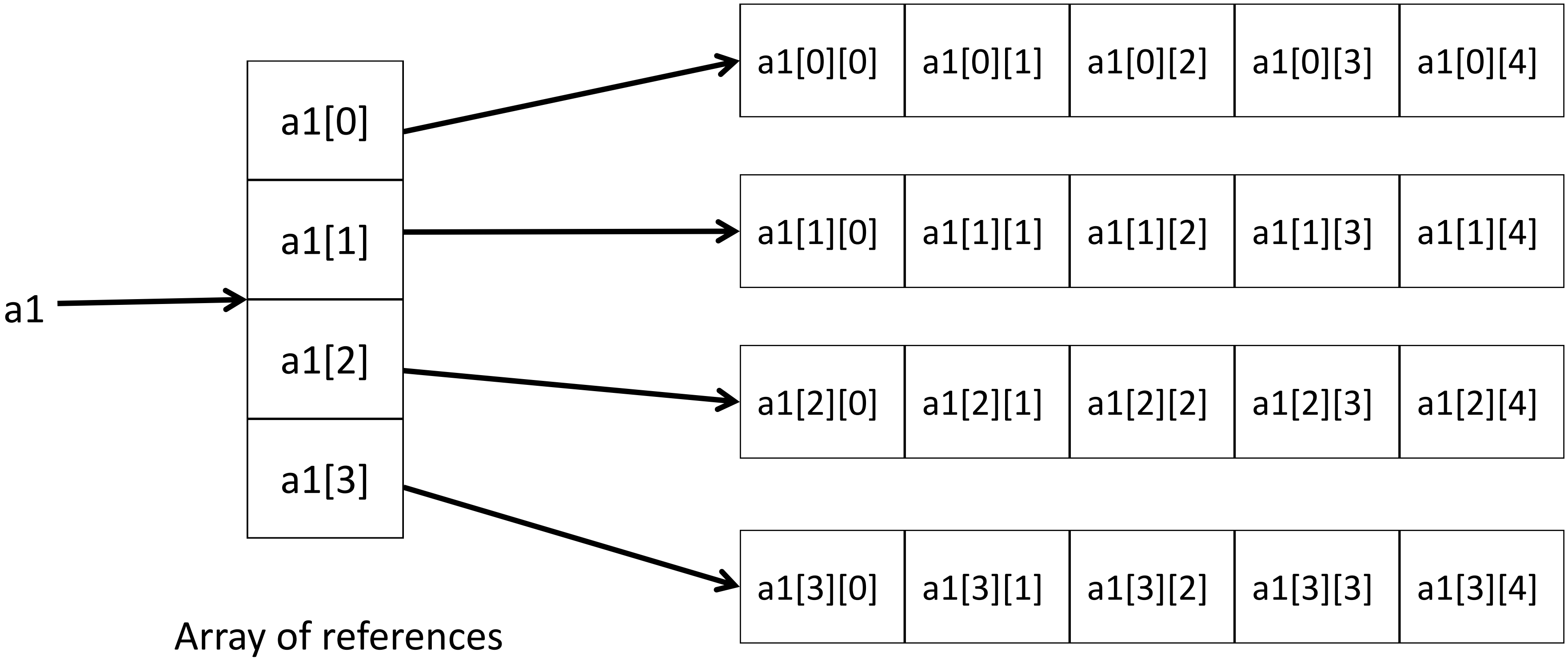
- When and where
  - Date/time: Thursday, May 10th, 2018 @ 11:30am – 2:30pm
  - Location: CLSSRM 102
- Coverage
  - Comprehensive: Lectures 1-12
  - Sections 5.9, 6.1-6.11, 7.1-7.8, 7.11-7.14, 9.1-9.5, 10.1-10.6, 12.1-12.6
- Exam Policies
  - Open book (print-out of chapters) and open notes
  - No electronic devices will be allowed
  - All Students MUST bring their CatCard to the exam

2D Arrays (review)

- A two-dimensional (2D) array is an array of references (or pointers) to other arrays:
  - All arrays must be of the same type
- This creates a 2D data structure
- As matrices (in math), individual elements in the array are addressed with two subscripts, specifying the Row and Column (in that order) of the particular data item. (called row major)
- Memorize RC
  - (Radio Control, Royal Crown, Rice Cracker, RC Cola)

2D Arrays diagram (review)

```
int[][] a1 = new int[4][5];
```



a1

a1[0]
a1[1]
a1[2]
a1[3]

a1[0][0] a1[0][1] a1[0][2] a1[0][3] a1[0][4]
a1[1][0] a1[1][1] a1[1][2] a1[1][3] a1[1][4]
a1[2][0] a1[2][1] a1[2][2] a1[2][3] a1[2][4]
a1[3][0] a1[3][1] a1[3][2] a1[3][3] a1[3][4]

Array of references
to other arrays

Arrays containing data

Declaring 2D Arrays (review)

- We first declare an array of *references to other arrays*, then declare the arrays.
- Example:

```
double[][] a; //the actual array
a = new double[3][5];
```

- These steps can be combined on a single line, just like in 1D:

```
double[][] a = new double[3][5];
```

- 2D arrays may be initialized with nested array initializers

```
int[][] b = { {1,2,3}, {4,5,6} };
```

1st row 2nd row

Using 2D Arrays (review)

- 2D arrays are used to represent data that is a function of two variables (or indices)
- A 2D array element is addressed using the array name followed by a integer subscript in brackets: **a[3][5]**
- Sizes of the arrays
    - a.length is the number of rows
    - a[0].length is the number of elements (cols) in row 0
    - a[1].length is the number of elements (cols) in row 1

Using 2D Arrays

- Example:

```
double[][] a = new double[3][5];
for ( r = 0; r < 3; r++ ) {
   for ( c = 0; c < 5; c++ ){
      a[r][c] = r*c; // Mult table
   }
}
```

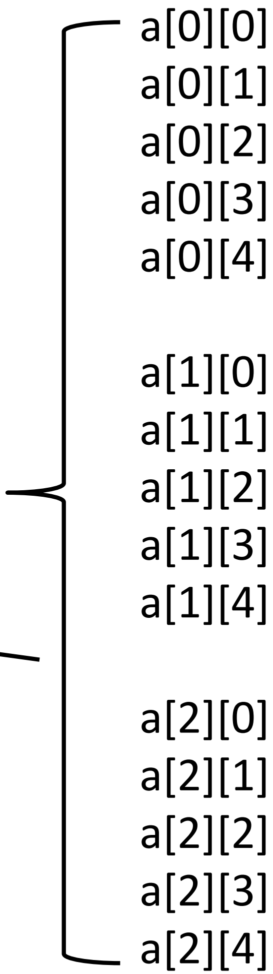
Indices	0	1	2	3	4
0					
1					
2					

Using 2D Arrays

- Example:

```
double[][] a = new double[3][5];
for ( r = 0; r < 3; r++ ) {
   for ( c = 0; c < 5; c++ ){
      a[r][c] = r*c; // Mult table
   }
}
```

Indices	0	1	2	3	4
0					
1					
2					



a[0][0]
a[0][1]
a[0][2]
a[0][3]
a[0][4]

a[1][0]
a[1][1]
a[1][2]
a[1][3]
a[1][4]

a[2][0]
a[2][1]
a[2][2]
a[2][3]
a[2][4]

Using 2D Arrays

- Example:

```
double[][] a = new double[3][5];
for ( r = 0; r < 3; r++ ) {
  for ( c = 0; c < 5; c++ ){
    a[r][c] = r*c; // Mult table
  }
}
```

Indices	0	1	2	3	4
0					
1					
2				?	

a[0][0]
a[0][1]
a[0][2]
a[0][3]
a[0][4]

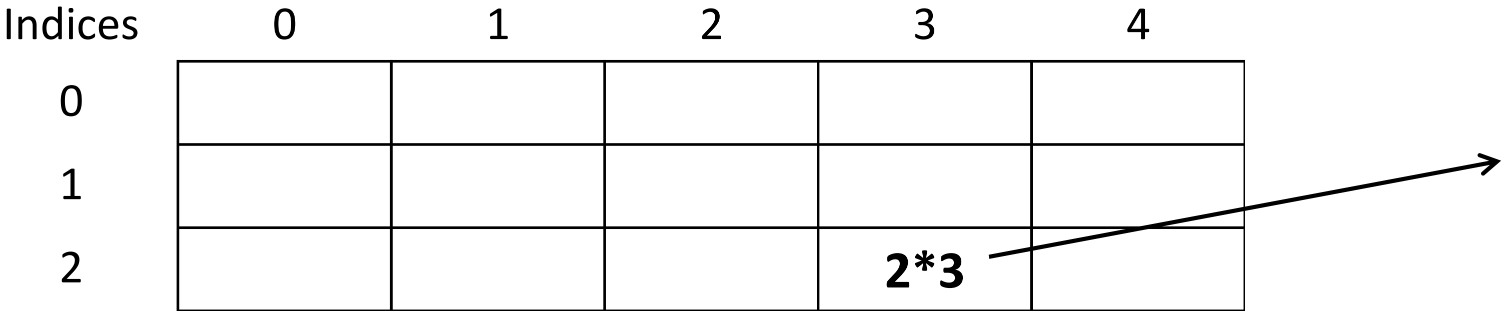
a[1][0]
a[1][1]
a[1][2]
a[1][3]
a[1][4]

a[2][0]
a[2][1]
a[2][2]
a[2][3]
a[2][4]

Using 2D Arrays

- Example:

```
double[][] a = new double[3][5];
for ( r = 0; r < 3; r++ ) {
  for ( c = 0; c < 5; c++ ){
    a[r][c] = r*c; // Mult table
  }
}
```



Indices	0	1	2	3	4
0					
1					
2				2*3	

a[0][0]
a[0][1]
a[0][2]
a[0][3]
a[0][4]

a[1][0]
a[1][1]
a[1][2]
a[1][3]
a[1][4]

a[2][0]
a[2][1]
a[2][2]
a[2][3]
a[2][4]

Using 2D Arrays

- Example:

```
double[][] a = new double[3][5];
for ( r = 0; r < 3; r++ ) {
  for ( c = 0; c < 5; c++ ){
    a[r][c] = r*c; // Mult table
  }
}
```

Indices	0	1	2	3	4
0					
1			**?**		
2				**6**	

a[0][0]
a[0][1]
a[0][2]
a[0][3]
a[0][4]

a[1][0]
a[1][1]
a[1][2]
a[1][3]
a[1][4]

a[2][0]
a[2][1]
a[2][2]
a[2][3]
a[2][4]

Using 2D Arrays

- Example:

```
double[][] a = new double[3][5];
for ( r = 0; r < 3; r++ ) {
  for ( c = 0; c < 5; c++ ){
    a[r][c] = r*c; // Mult table
  }
}
```

Indices	0	1	2	3	4
0					
1			**2**		
2				**6**	

a[0][0]
a[0][1]
a[0][2]
a[0][3]
a[0][4]

a[1][0]
a[1][1]
a[1][2]
a[1][3]
a[1][4]

a[2][0]
a[2][1]
a[2][2]
a[2][3]
a[2][4]

Using 2D Arrays

- Example:

```
double[][] a = new double[3][5];
for ( r = 0; r < 3; r++ ) {
  for ( c = 0; c < 5; c++ ){
    a[r][c] = r*c; // Mult table
  }
}
```

Indices	0	1	2	3	4
0	**0**	**0**	**0**	**0**	**0**
1	**0**	**1**	**2**	**3**	**4**
2	**0**	**2**	**4**	**6**	**8**

a[0][0]
a[0][1]
a[0][2]
a[0][3]
a[0][4]

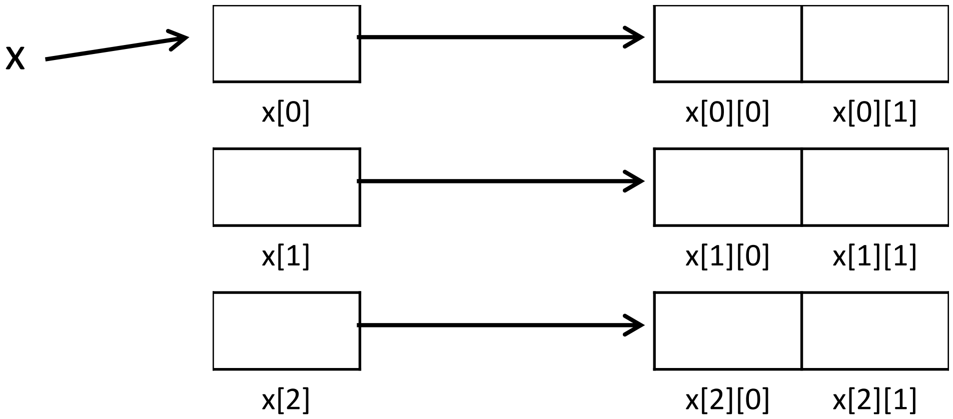
a[1][0]
a[1][1]
a[1][2]
a[1][3]
a[1][4]

a[2][0]
a[2][1]
a[2][2]
a[2][3]
a[2][4]

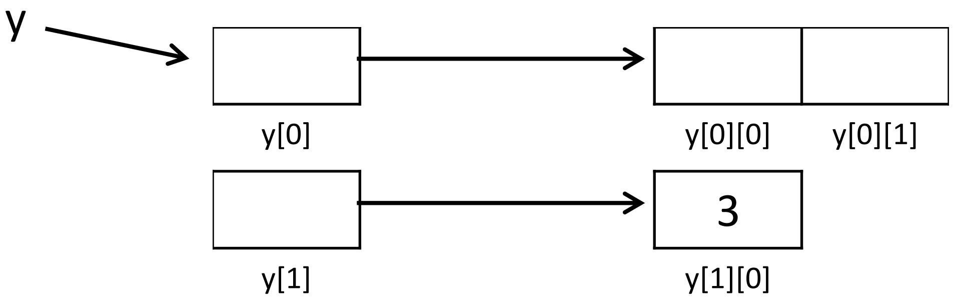
2D Arrays: Rows with diff Columns

- Not all rows have to have the same # of cols:

```
int [][] x =
  new int [3][2];
//3 rows and 2 cols
```



```
int [][] y =
  new int [2][];
y[0] = new int[2];
y[1] = new int[1];
y[1][0] = 3;
//2 rows: 2 and 1 cols!
```



Higher-Order Arrays

- The same ideas that apply to 2D arrays can be extended for arrays of any order
- Example: the following statement creates a 3D array containing a total of 30 elements

```
    double[][][] a = new double[4][5][3];
```

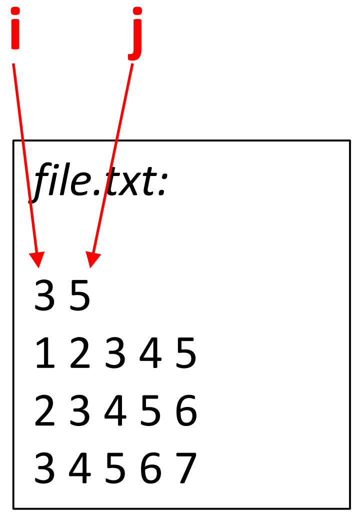
  - The 1st element has the subscript range 0 to 3
  - The 2nd element has the subscript range 0 to 4
  - The 3rd element has the subscript range 0 to 2
- These are used to represent data that is a function of more than two independent variables (or indices)
  - Example: a color image using 3 color spaces (RGB)

File Input + 2D Array

```
public static int[][] getInput(String filename) {
    int [][] arr = null;
    try {
        Scanner sc = new Scanner ( new FileReader(filename) );
        int row = sc.nextInt();
        int column = sc.nextInt();
        arr = new int[row][column];

        for (int i = 0 ; i < row; i++)
            for (int j = 0 ; j < column; j++)
                arr[i][j] = sc.nextInt();
        sc.close();
    } catch ( NoSuchElementException e){
        System.out.println(e);

    } catch (FileNotFoundException e) {
        System.out.println(e);
    }
    return arr;
}
```



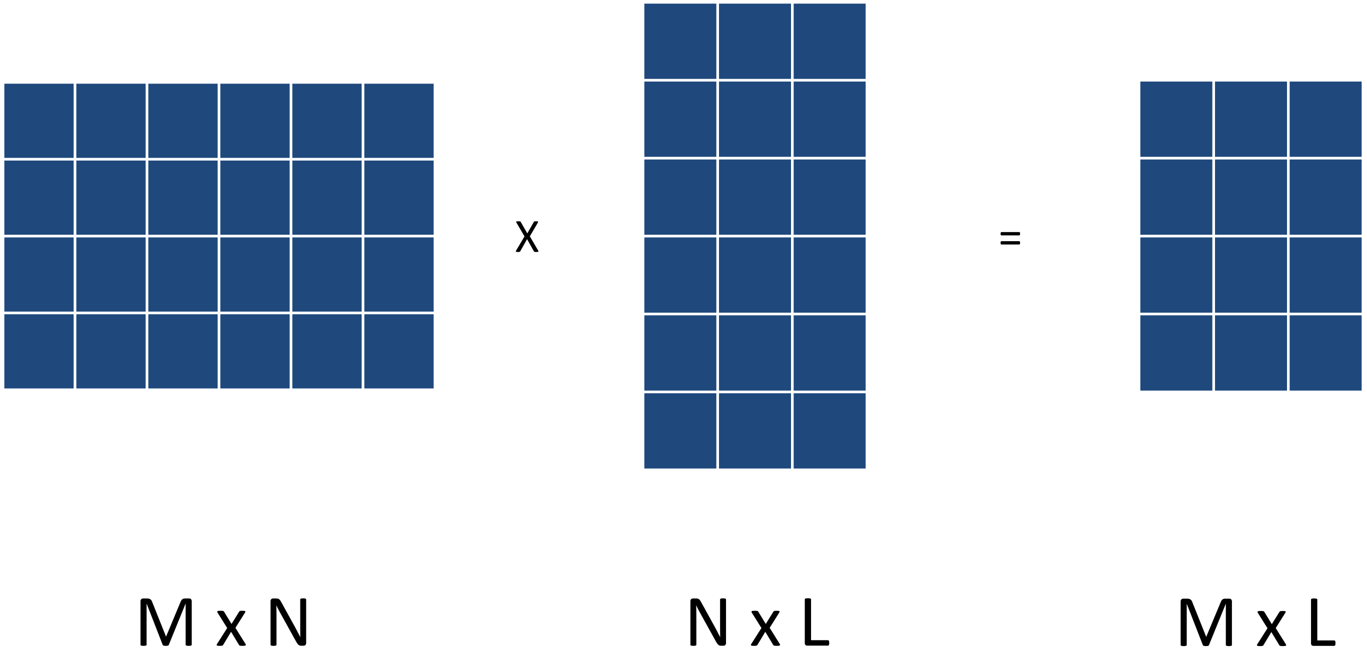
file.txt:

```
3 5
1 2 3 4 5
2 3 4 5 6
3 4 5 6 7
```

Square Matrix Multiplication

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \text{X} \begin{bmatrix} m & n \\ o & p \end{bmatrix} = \begin{bmatrix} am+bo & an+bp \\ cm+do & cn+dp \end{bmatrix}$$

General Matrix Multiplication



X

=

M x N

N x L

M x L

Matrix Multiply

```
public static int[][] multiply(int[][] m1, int[][] m2) {
    int m1rows = m1.length;
    int m1cols = m1[0].length;
    int m2rows = m2.length;
    int m2cols = m2[0].length;
    if (m1cols != m2rows)
      throw new IllegalArgumentException("matrices don't match: " +
m1cols + " != " + m2rows);
    int[][] result = new int[m1rows][m2cols];

    // multiply
    for (int i=0; i<m1rows; i++)
      for (int j=0; j<m2cols; j++)
        for (int k=0; k<m1cols; k++)
         result[i][j] += m1[i][k] * m2[k][j];

    return result;
}
```

Example File Out

```java
String filename = "Result.txt";

try {
   FileWriter output = new FileWriter(filename);

   String ostr = "";
   for (int i = 0; i < arr2D.length; i++) {
      for (int j = 0; j < arr2D[0].length; j++) {
           System.out.print(ostr = (arr2D[i][j] + "\t"));
           output.write(ostr);
      }
      System.out.println();
      output.write("\r\n"); // Carriage return
   }
   output.close();
} catch (Exception e) {
     System.out.println(e);
}
```