

# Lecture 12: 2D Arrays

AP Computer Science Principles

# Semantics

# Value semantics

- **value semantics:** Behavior where values are copied when assigned, passed as parameters, or returned.
  - All primitive types in Java use value semantics.
  - When one variable is assigned to another, its value is copied.
  - Modifying the value of one variable does not affect others.

```
int x = 5;  
int y = x;      // x = 5, y = 5  
y = 17;        // x = 5, y = 17  
x = 8;         // x = 8, y = 17
```

# Reference semantics (objects)

- **reference semantics:** Behavior where variables actually store the address of an object in memory.
  - When one variable is assigned to another, the object is *not* copied; both variables refer to the *same object*.
  - Modifying the value of one variable *will* affect others.

```
int[] a1 = { 4, 15, 8 };
int[] a2 = a1;    // refer to same array as a1
a2[0] = 7;
println(a1); // [7, 15, 8]
```



# Objects as parameters

- Arrays and objects(except String) use reference semantics. Why?
  - *efficiency.* Copying large objects slows down a program.
  - *sharing.* It's useful to share an object's data among methods.
- When an object is passed as a parameter, the object is *not* copied. The parameter refers to the same object.
  - If the parameter is modified, it *will* affect the original object.
- Arrays are passed as parameters by *reference*.
  - Changes made in the method are also seen by the caller.

# Value Semantics

Example:

```
void setup() {  
    int x = 2;  
    triple(x);  
    println(x); // 2  
  
}  
void triple(int number) {  
    number = number * 3; // 6  
}
```

# Value Semantics

**String uses value semantics like primitive types.**

Example:

```
void setup() {  
  
    String str = "hi";  
    twice(str);  
    println(str); // "hi"  
}  
void twice(String str) {  
    str = str + str;  
    println(str); // "hihi"  
}
```

# Reference Semantics

Example:

```
void setup() {  
  
    int[] arr = {0,1,2,3};  
    triple(arr);  
    println(arr);  
    // {0,3,6,9}  
}  
  
void triple(int[] numbers) {  
    for (int i = 0; i < numbers.length; i++) {  
        numbers[i] = numbers[i] * 3;  
    }  
}
```

# Nested Loops

# Nested loops

- **nested loop:** A loop placed inside another loop.

```
for (int i = 1; i <= 5; i++) {  
    for (int j = 1; j <= 10; j++) {  
        print("*");  
    }  
    println(); // to end the line  
}
```

- Output:

```
*****  
*****  
*****  
*****  
*****
```

- The outer loop repeats 5 times; the inner one 10 times.
  - "sets and reps" exercise analogy

# Nested for loop exercise

- What is the output of the following nested for loops?

```
for (int i = 1; i <= 5; i++) {  
    for (int j = 1; j <= i; j++) {  
        print("*");  
    }  
    println();  
}
```

- Output:

```
*  
**  
***  
****  
*****
```

# Nested for loop exercise

- What is the output of the following nested `for` loops?

```
for (int i = 1; i <= 5; i++) {  
    for (int j = 1; j <= i; j++) {  
        print(i);  
    }  
    println();  
}
```

- Output:

1  
22  
333  
4444  
55555

# Nested for loop exercise

- What is the output of the following nested for loops?

```
for (int i = 1; i <= 5; i++) {  
    for (int j = i; j <= 5; j++) {  
        print(i);  
    }  
    println();  
}
```

- Output:

11111  
2222  
333  
44  
5

# Common errors

```
for (int i = 1; i <= 5; i++) {  
    for (int j = 1; i <= 10; j++) {  
        print("*");  
    }  
    println();  
}
```

```
for (int i = 1; i <= 5; i++) {  
    for (int j = 1; j <= 10; i++) {  
        print("*");  
    }  
    println();  
}
```

**Both of the above sets of code produce *infinite loops*.**

# 2-Dimensional Arrays

# 2D Array

0	0	0	0
0	0	0	0
0	0	0	0

```
int[][] matrix=new int[3][4]; //3 rows, 4 columns  
//initialized to 0.
```

# 2D Array

2	0	0	0
0	0	-6	0
0	7	0	0

```
matrix[0][0]=2;
```

```
matrix[1][2]=-6;
```

```
matrix[2][1]=7;
```

# Declare and Initialize

Declaring and initializing 2D arrays.

```
int[][] table; //2D array of ints, null reference
```

//one way to initialize 2D array.

```
float[][] matrix=new float[4][5];
```

//4 rows, 5 columns

//initialized all to 0.0

```
String[][] strs=new String[2][5];
```

//strs reference 2x5 array of

//String objects. Each element is

// null

# Initializer List

//another way to initialize 2D array is through a list.

```
int[] array1={1, 4, 3};
```

```
int[][] mat={{3, 4, 5}, {6, 7, 8}}; //2 rows, 3 columns
```

3	4	5
6	7	8

# Array of Arrays

- A 2D array is implemented as an array of row arrays. Each row is a one-dimensional array of elements. Suppose that mat is the matrix

3	-4	1	2
6	0	8	1
-2	9	1	7

Then mat is an array of three arrays:

mat[0] is the one-dimensional array {3,-4,1,2}.

mat[1] is the one-dimensional array {6,0,8,1}.

mat[2] is the one-dimensional array {-2,9,1,7}.

mat.length is the number of rows.

# Array of Arrays

3	-4	1	2
6	0	8	1
-2	9	1	7

- `mat.length` is the number of rows. In this case, it equals 3 because there are three row-arrays in `mat`.
- For each  $k$ , where  $0 \leq k < \text{mat.length}$ , `mat[k].length` is the number of elements in that row, namely the number of columns. For example `mat[0].length` is the number of elements in row 0. In this case, `mat[k].length=4` for all  $k$ .
- Java allows “jagged arrays” where each row array may have different lengths. However, we won’t used jagged arrays in this class.

# Initializer List

```
int[][] mat={{3,4,5},{1,2},{0,1,-3,5}};
```

```
mat[0]={3,4,5}
```

```
mat[1]={1,2}
```

```
mat[2]={0,1,-3,5}
```

```
mat.length=3
```

```
mat[0].length=3
```

```
mat[1].length=2
```

```
mat[2].length=4
```

# Row-Column Traversal

Suppose that `mat` is a 2D array initialized with integers. Use nested for loop to print out the elements of the array.

```
for(int i=0;i<mat.length;i++) {  
    for(int j=0;j<mat[i].length;j++)  
        print(mat[i][j] + " ");  
    println();  
}
```

# Row-by-Row

Suppose the following method has been implemented.

```
void printArray(int[] array)
{ /*implementation not shown*/ }
```

Use it to print out the 2D array mat.

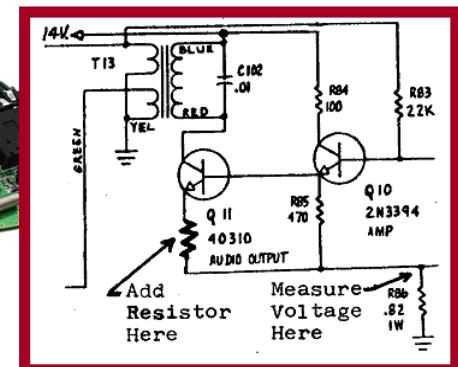
```
for(int i=0;i<mat.length;i++) {
    printArray(mat[i]); //mat[i] is row i of mat
    println();
}
```

# Encapsulation

# Encapsulation

- **encapsulation:** Hiding implementation details from clients.
  - Encapsulation forces **abstraction**.
    - separates external view (behavior) from internal view (state)
    - protects the integrity of an object's data
    - **Abstraction:** You can use something without knowing how it works.

Abstraction is one of the 7 big ideas in AP Computer Science Principles.



# Private fields

*A field that cannot be accessed from outside the class*

**private type name;**

- Examples:

```
private int id;  
private String name;
```

- Client code won't compile if it accesses private fields.

**In Processing, the convention is to AVOID using private variables to keep things simple.**

# Private fields

In the file Student.pde(Object class).

```
class Student{  
    String name;  
    private int ID;  
    Student(String n, int id) {  
        ...  
    }  
    ...  
}
```

# Private fields

In the file Driver.pde(Driver/client class).

```
Student s1;  
void setup() {  
    s1 = new Student("John Smith", 3454);  
}  
void draw() {  
    println(s1.name); //ok  
    println(s1.ID); //error, private  
}
```

# Accessing private state

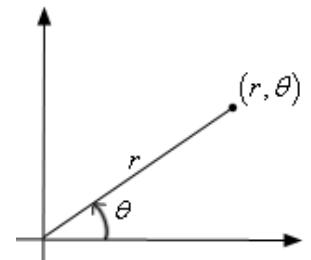
```
// A "read-only" access to the x field
("accessor")
public int getID() {
    return ID;
}
// Allows clients to change the x field
("mutator")
public void setID(int newID) {
    ID = newID;
}
```

- Client code will look more like this:

```
println(s1.getID());
s1.setID(14343);
```

# Benefits of encapsulation

- **Abstraction** between object and clients
- Protects object from unwanted access
  - Example: Can't fraudulently increase an Account's balance.
- Can change the class implementation later
  - Example: Ball could be rewritten in polar coordinates  $(r, \theta)$  with the same methods.
- Can constrain objects' state (**invariants**)
  - Example: Only allow Accounts with non-negative balance.
  - Example: Only allow Dates with a month from 1-12.



# Lab 1

Write the following methods.

**sum:** Write method `sum` which accepts a 2D array of integers and returns the sum of all of the elements. Use row-column traversal method.(Nested for loop)

**rowSum:** `rowSum` accepts two parameters: a 2D array of integers and an integer `row`. `rowSum` returns the sum of the integers of elements in the row given by `row`.

**sum2:** This method is the same as `sum` above but **you must use `rowSum` in your code. (One for loop)**

# Lab 1

Write the following methods.

`largest` accepts a 2D array of integers and returns the largest value. Use row-column traversal method to examine each value.(Nested for loop)

`largestByRow` accepts two parameters: a 2D array of integers and an integer `row`. `largestByRow` returns the largest value in the row given by `row`.

`largest2` accepts a 2D array of integers and returns the largest value. **You must call `largestByRow`. (One for loop)**

# Lab 1

`printTranspose`: Given 2D array of integers, print the transpose of the array.

The transpose of a 2D array is a new array whose rows are the columns of the original array. DO NOT CREATE A NEW ARRAY!

If `mat={{1,2,3},{4,5,6}}`; `printTranspose(mat)` will  
print:

1 4

2 5

3 6

# Lab 1 Outline

Write the setup() method to test your methods.

```
void setup() {  
}  
  
int sum(int[][] mat) {...}  
int rowSum(int[][] mat, int row) {...}  
int sum2(int[][] mat) {...}  
int largest(int[][] mat) {...}  
int largestByRow(int[][] mat, int row) {...}  
int largest2(int[][] mat) {...}  
void printTranspose(int[][] mat) {...}
```

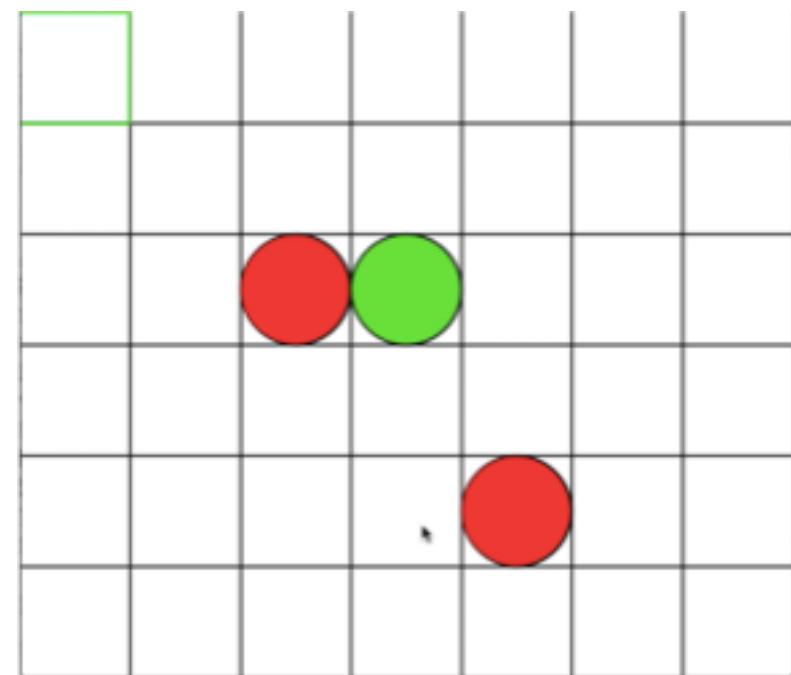
# Lab 2(Grid)

Write a program that creates a 2D(6 rows x 7 cols) grid as shown.

If a mouse is clicked inside of a Cell, a centered circle is drawn. The color of the circle alternates between red and green representing two players.

This program can be converted into Connect 4.

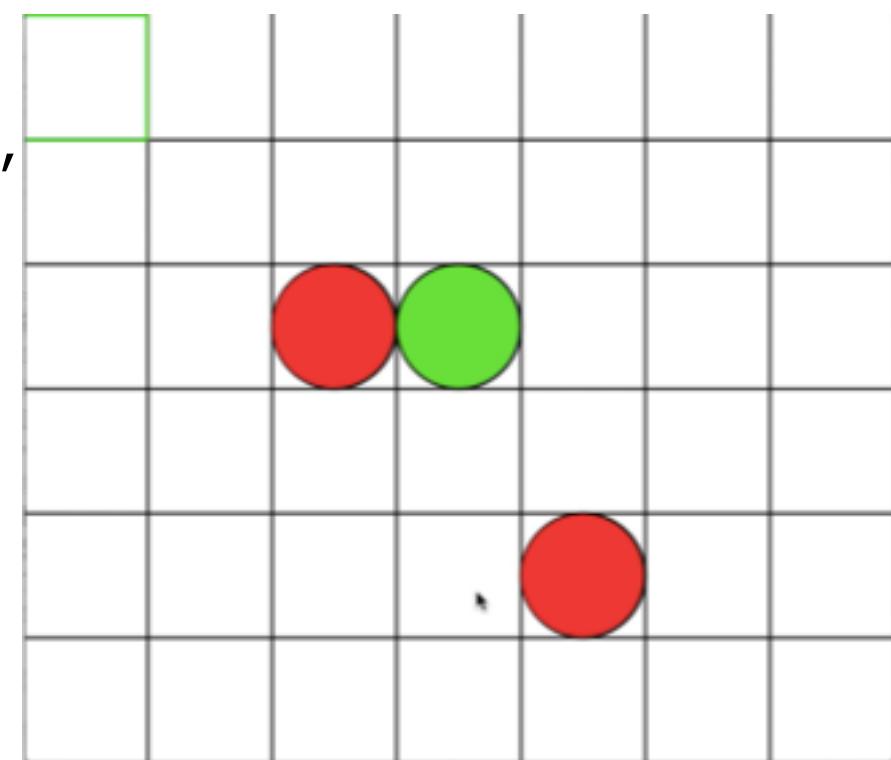
**A template is provided on my website if you wish to get some help.**



# Lab 2

Add a transparent square(green square, top left in image below) to the grid that responds to keyboard inputs.

If a Cell is selected and ENTER is pressed, then that Cell displays the the circle as before.



# Homework

- 1) Read and reread these lecture notes.
- 1) Complete the lab.

# References

Part of this lecture is taken from the following book.

- 1) Stuart Reges and Marty Stepp. Building Java Programs: A Back to Basics Approach. Pearson Education. 2008.