CS2030 Lecture 1

Getting Started –
Programming with Java

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Programming Paradigms

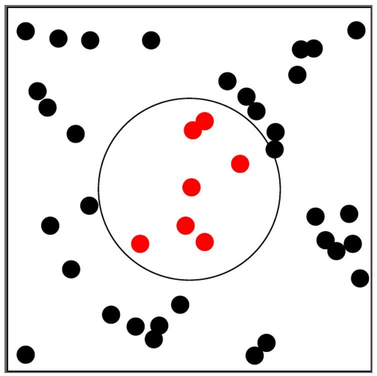
- **Imperative (procedural)**
  - Specifies *how* computation proceeds using statements that change program state
- **Declarative**
  - Specifies *what* should be computed, rather than how to compute it
- **Functional**
  - A form of declarative programming and treats computation like *evaluating mathematical functions*
- **Object-oriented**
  - Supports imperative programming but *organizes programs as interacting objects*, following the real-world

Refresher on common programming concepts

- Data (Memory)
  - Primitive data-type: numerical, character, boolean
  - Composite data-type:
    - Homogeneous: array (multi-dimensional)
    - Heterogeneous: record (or structure)
- Process (Mechanism)
  - Input and output
  - Primitive operations: arithmetic, relational, logical, ...
  - Control structures: sequence, selection, repetition
  - Modular programming: functions, procedures
  - Recursion

Exercise: Disc Coverage Problem

- Given a set of points on the 2D Cartesian plane, find the number of points covering a unit disc (i.e. a circle of radius 1) **centred at each point**

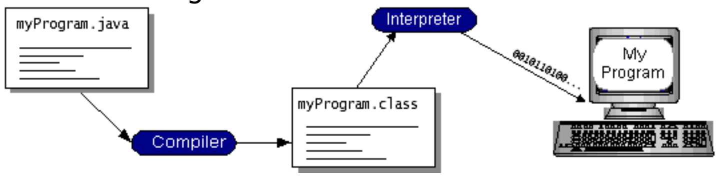


Java Compilation and Interpretation

- A class encompasses tasks common to a specific problem, e.g.

```
class DiscCoverage {
    public static void main(String[] args) {
    }
}
```

- To compile (assuming saved in `DiscCoverage.java`:
  `$ javac DiscCoverage.java`
- The above creates bytecode `DiscCoverage.class` which can be translated and executed on the java virtual machine using:
  `$ java DiscCoverage`



Input and Output

- Input/output via APIs (application programming interfaces):
  `https://docs.oracle.com/javase/9/docs/api`
- Import the necessary packages
  - Input: `java.util.Scanner`
  - Output: `java.lang.System`
    (`java.lang.*` imported by default)

```
import java.util.Scanner;
class DiscCoverage {
    public static void main(String[] args) {
        Scanner scanner = new Scanner(System.in);
        System.out.println(scanner.next());
    }
}
```


Static Typing vs Dynamic Typing

- Dynamic (e.g. JavaScript):

```
var a;
var b = 5.0;
var c = "Hello";

b = "This?"; // ok
```

- Static (e.g. Java):

```
int a;
double b = 5.0;
String c = "Hello";

b = "This?"; // error
```

- Need to develop a sense of "type awareness" by maintaining type-consistency
- During compilation, incompatible typing throws off a compile-time error

Static Typing vs Dynamic Typing

```
import java.util.Scanner;
class DiscCoverage {
    public static void main(String[] args) {
        Scanner scanner = new Scanner(System.in);
        double x;
        double y;

        x = scanner.nextDouble();
        y = scanner.nextDouble();

        System.out.println("(" + x + ", " + y + ")");
    }
}
```

- Another example of type sensitivity: + operator
  `https://docs.oracle.com/javase/specs/jls/se9/html/jls-15.html#jls-15.18.1`

Input via File Re-direction

```java
import java.util.Scanner;

class DiscCoverage {

    public static void main(String[] args) {
        Scanner scanner;
        int numOfPoints;

        scanner = new Scanner(System.in);
        numOfPoints = scanner.nextInt();
        for (int i = 1; i <= numOfPoints; i++) {
            double x = scanner.nextDouble();
            double y = scanner.nextDouble();

            System.out.println("Point #" + i +
                    ": (" + x + ", " + y + ")");
        }
    }
}
```

- Read input from `data.in` using the following command:

```
$ java DiscCoverage < data.in
```


Composite Data — Arrays

```java
import java.util.Scanner;

class DiscCoverage {

    public static void main(String[] args) {
        Scanner scanner;
        double[][] points;

        scanner = new Scanner(System.in);
        points = new double[scanner.nextInt()][2];
        for (int i = 0; i < points.length; i++) {
            points[i][0] = scanner.nextDouble();
            points[i][1] = scanner.nextDouble();

            System.out.println("Point #" + (i + 1) + ": (" +
                    points[i][0] + ", " +
                    points[i][1] + ")");
        }
    }
}
```

- Number of elements defined in the array is given by `length`

Modularity

- Taking a complex program and breaking it up into dedicated sub-tasks to be solved
- The `main` method (object-oriented equivalent of function/procedure) describes the solution in terms of higher-level *abstractions*

```java
import java.util.Scanner;

class DiscCoverage {

    public static void main(String[] args) {
        double[][] points;

        points = readPoints();
        printPoints(points);
    }
```

- Abstractions can then be solved *individually* and *incrementally*

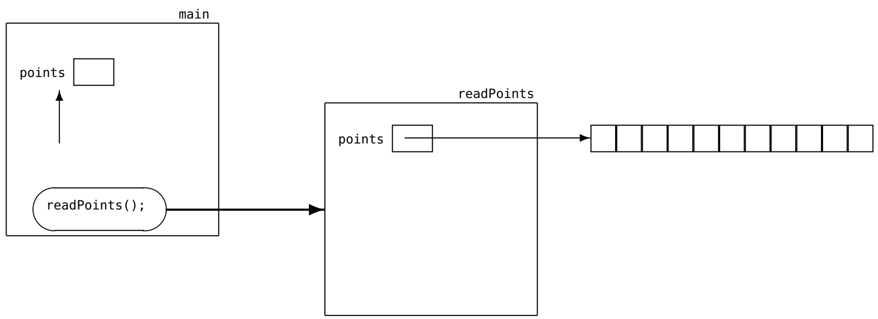
Modularity

```java
    static double[][] readPoints() {
        Scanner scanner;
        double[][] points;

        scanner = new Scanner(System.in);
        points = new double[scanner.nextInt()][2];
        for (double[] point : points) {
            point[0] = scanner.nextDouble();
            point[1] = scanner.nextDouble();
        }
        return points;
    }

    static void printPoints(double[][] points) {
        int i = 0;

        for (double[] point : points) {
            System.out.println("Point #" + (i + 1) + ": (" +
                    point[0] + ", " + point[1] + ")");
            i++;
        }
    }
}
```

Mental Modeling

- Establish a mental model of program execution that is **correct**, **consistent** and **complete**
- Consider modeling the following statement:

  `points = readPoints()`



Mental Modeling

- Method `readPoints` with return type **double** `[][]` returns, the reference to the array is assigned to `points` in `main`

- While **stack** memory allocated for the `readPoint` method is flushed (together with the local variable `point`) upon return, the **heap** memory associated with the array remains intact

Imperative Solution for Disc Coverage

```java
/**
 * Determines if <code>point</code> is contained within the unit
 * disc centred at <code>centre</code>.
 *
 * @param centre is the centre of the unit disc
 * @param point is the other point
 * @return true if <code>point</code> is contained within the unit
 *     disc centred at <code>centre</code>; false otherwise
 */
static boolean isInside(double[] centre, double [] point) {
```


Imperative Solution for Disc Coverage

```java
/**
 * Determines the number of points within the <code>points</code>
 * array that is covered by a unit disc centred at <code>centre</code>
 *
 * @param centre is the centre of the unit disc
 * @param points is the array of points
 * @return the number of points covered
 */
static int discCover(double[] centre, double[][] points) {
```

Imperative Solution for Disc Coverage

```java
    /**
     * Outputs the unit disc coverages centred at each point.
     *
     * @param points list of points
     */
    static void printCoverage(double[][] points) {
        for (double[] point : points) {
            int numOfPoints = discCover(point, points);

            System.out.println("Disc centred at (" +
                    point[0] + ", " + point[1] +
                    ") contains " + numOfPoints + " points.");
        }
    }

    public static void main(String[] args) {
        double[][] points;

        points = readPoints();
        printCoverage(points);
    }
}
```


Modeling an Object-Oriented (OO) Solution

- An object-oriented model based on interacting objects:
  - What are the different types of object in the problem?
    - Circle (or unit disc)
    - Point
  - A circle has a point as it's centre and a radius; these are **attributes** / **properties** / **fields** of the circle
  - Likewise a point has two `double` attributes representing the x- and y-coordinates of the point
  - To determine if a circle contains a point,
    - the circle takes a point to check for containment; this is a **method** (or behaviour)
    - the circle's centre (i.e. a point) needs a method to check its distance with respect to another point

OOP Principle #1: Abstraction

- Establish an abstraction level relevant to the task at hand and ignore lower level details
  - Data abstraction: abstract away low level data items
  - Functional abstraction: abstract away control flow details

```java
public class Circle {
    private Point centre;
    private double radius;

    public Circle(Point centre) {
        this.centre = centre;
        this.radius = 1.0;
    }

    public Circle(Point centre, double radius) {
        this.centre = centre;
        this.radius = radius;
    }

    public boolean contains(Point point) {
        return centre.distance(point) <= radius;
    }
}
```


OOP Principle #1: Abstraction

```java
public class Point {
    private double x;
    private double y;

    public Point(double x, double y) {
        this.x = x;
        this.y = y;
    }

    public double distance(Point otherpoint) {
        double dispX = this.x - otherpoint.x;
        double dispY = this.y - otherpoint.y;
        return Math.sqrt(dispX * dispX + dispY * dispY);
    }

    @Override
    public String toString() {
        return "(" + this.x + ", " + this.y + ")";
    }
}
```

How should the `Main` driver class be adapted?

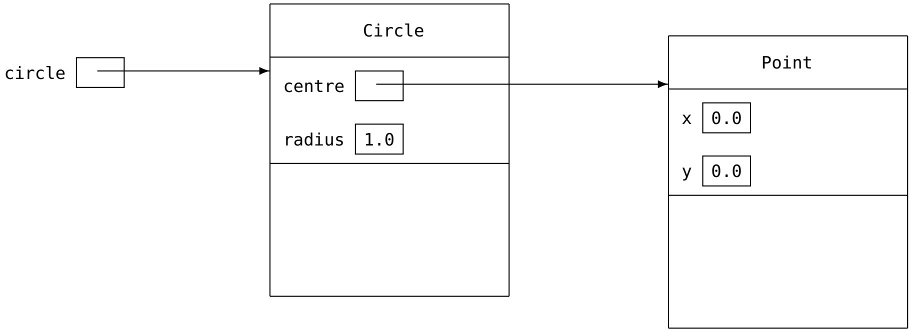
OOP Principle #2: Encapsulation

- **Abstraction barrier**
  - Separation between implementer and client
- Having established a particular high-level abstraction,
  - Implementer **defines** the data/functional abstractions using lower-level data items and control flow
  - Client **uses** the high-level data-type and methods
- **Encapsulation**
  - To protect implementation against inadvertent use
  - Packaging data and related behaviour together into a self-contained unit
  - Hiding information/data from the client, restricting access using methods/interfaces

Object-Oriented Mental Model

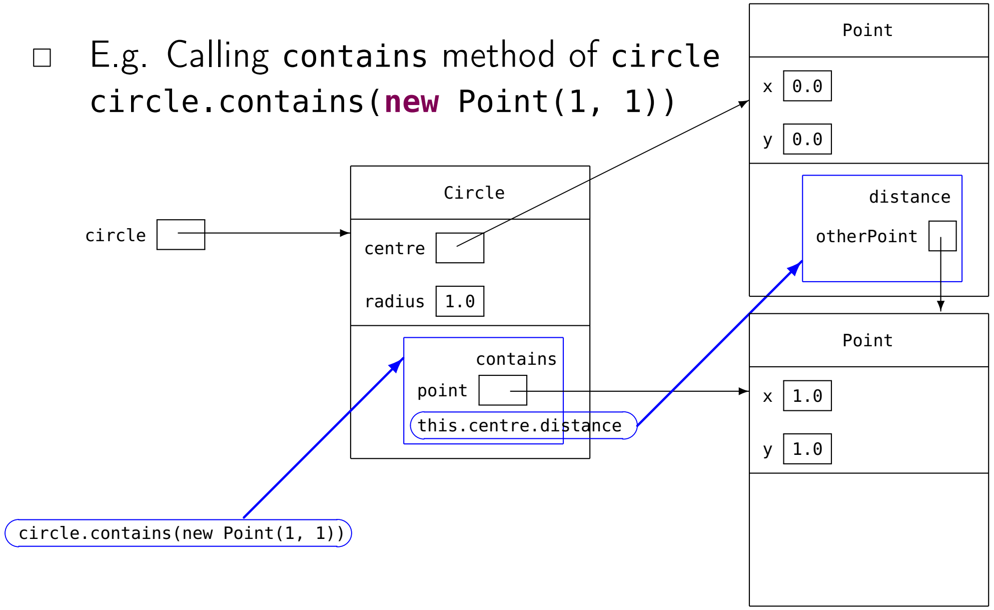
- Extending our mental model to include objects
- Example, when instantiating a `Circle` object

```
Circle circle = new Circle(new Point(0, 0), 1);
```



Object-Oriented Mental Model

- E.g. Calling `contains` method of `circle`
  `circle.contains(new Point(1, 1))`



Lecture Summary

- Appreciate the different programming paradigms
- Appreciate java compilation and interpretation
- Develop a sense of type awareness when developing programs
- Able to employ object-oriented modeling to convert an imperative solution to OO
- Understand the OO principles of abstraction and encapsulation
- Develop and apply a mental model of program execution