CS2030 Lecture 1

Programming as Communication Across an Abstraction Barrier

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Imperative Programming Concepts

- Imperative — specifies **how** computation proceeds using *statements that change program state*
- Data (Memory)
  - Primitive data-types: numerical, character, boolean
  - Composite data-types:
    - Homogeneous: array (multi-dimensional)
    - Heterogeneous: record (or structure)
- Process (Mechanism)
  - Primitive operations: arithmetic, relational, logical, ...
  - Control structures: sequence, selection, repetition
  - **Modular** programming: functions, procedures, recursion
  - Input and output

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
```

- As Java is a type-safe language, it is very strict when it comes to type checking
- Need to develop a sense of "type awareness" by maintaining type-consistency
- Incompatible typing throws off an error

JShell — Interactive Shell for Java

- Uses REPL to provide an immediate feedback loop

```
jshell> double b = 5.0
b ==> 5.0

jshell> b = "This?";
|  Error:
|  incompatible types: java.lang.String cannot be converted to double
|  b = "This?";
|      ^-----^

jshell> var c = "Hello" /* var has been introduced since java 10.. */
c ==> "Hello"

jshell> /var            /* .. not to be confused with the /var jshell command */
|    double b = 5.0
|    String c = "Hello"

jshell> c = 1
|  Error:
|  incompatible types: int cannot be converted to java.lang.String
|  c = 1
|      ^

jshell> /exit
|  Goodbye
```

- We shall be using JShell as a "testing framework" for unit or integrated (incremental) testing throughout the module

Exercise: Point Within a Circle

"Given a 2D *point*, and a *circle* represented by it's *centre* and *radius*, determine if the circle *contains* the point within it"

- What are the data items?
  - point represented by x and y coordinates
  - circle represented by a centre (i.e. a point) and the radius
- Make use of two **`double`** values to store each point; one **`double`** value to store the radius
- Modularity: design a function `contains` that
  - takes in the point and circle, and
  - returns **`true`** if the point lies within the circle, or **`false`** otherwise

An Imperative (Procedural) Solution

```
jshell> boolean contains(double point_x, double point_y,
   ...> double centre_x, double centre_y, double radius) {
   ...> double dx = point_x - centre_x;
   ...> double dy = point_y - centre_y;
   ...> double distance = Math.sqrt(dx * dx + dy * dy);
   ...> return distance < radius;
   ...> }
|  created method contains(double,double,double,double,double)

jshell> contains(1, 1, 2, 2, 1)
$.. ==> false

jshell> contains(1, 1, 2, 2, 2)
$.. ==> true
```

- Notice that the definition of the `contains` function requires
  - knowledge of the point and circle in terms of five **`double`** variables
  - knowledge of computing the distance between two points, in order to determine containment

Abstraction

- Ideally the function should take in a point and a circle, i.e.

```
boolean contains(Point point, Circle circle) {
```

  - **Data abstraction**: abstract away lower level data

- The implementation of the function can be as simple as

```
    return distanceBetween(point, circle.centre) < circle.radius;
}
```

  - **Functional abstraction**: abstract away lower level computation

- `Point` and `Circle` are different types of objects
- Use a **`class`** to define each individual type of object

Data Abstraction

- `Point` object has properties of `x` and `y`

```
jshell> class Point {
   ...> double x;
   ...> double y;
   ...> }
|  created class Point
```

- `Circle` object has properties of `centre` and `radius`

```
jshell> class Circle {
   ...> Point centre;
   ...> double radius;
   ...> }
|  created class Circle
```

- Creating a point and circle (*though not the desirable way..*)

```
jshell> Point p = new Point()
p ==> Point@6fc6f14e

jshell> p.x = 1; p.y = 1
$.. ==> 1.0
$.. ==> 1.0
```

```
jshell> Circle c = new Circle()
c ==> Circle@2286778

jshell> c.centre = new Point()
$.. ==> Point@6d7b4f4c

jshell> c.centre.x = 2; c.centre.y = 2; c.radius = 1
$.. ==> 2.0
$.. ==> 2.0
$.. ==> 1.0
```

Functional Abstraction

- Include `distanceBetween` function

```
jshell> double distanceBetween(Point p, Point q) {
   ...> double dx = p.x - q.x;
   ...> double dy = p.y - q.y;
   ...> return Math.sqrt(dx * dx + dy * dy);
   ...> }
|  created method distanceBetween(Point,Point)

jshell> distanceBetween(c.centre, p)
$.. ==> 1.4142135623730951
```

- Redefine `contains` function

```
jshell> boolean contains(Circle circle, Point p) {
   ...> return distanceBetween(circle.centre, point) < circle.radius;
   ...> }
|  created method contains(Circle,Point)

jshell> contains(c, p)
$.. ==> false

jshell> c.radius = 2
$.. ==> 2.0

jshell> contains(c, p)
$.. ==> true
```

Encapsulation: Packaging

- There are two aspects of encapsulation – **packaging** and **information hiding**; let's focus on the first aspect
- Classes provide a way to package low level data
- In addition, low level functionality should also be packaged
- With `Point` and `Circle` objects,
  - where should `distanceBetween` be packaged?
    - Distance is a computation over two points; it should be packaged within the `Point` class
    - Let the function be invoked through a `Point` object, i.e. if `p` and `q` are points, then `p.distanceTo(q)` or `q.distanceTo(p)` should give the same result
  - where should `contains` be packaged? *Think dependency..*

Modeling an Object-Oriented (OO) Solution

- Object — an abstraction of *closely-related data and behavior*
- An object-oriented model is a programming solution based on interacting objects:
  - a point has two `double` attributes representing the x- and y-coordinates of the point
  - a circle has a point as it's centre and a radiuas
  - these are **properties** / **attributes** / **fields** of the object
- To determine if a circle contains a point,
  - a circle takes in a point to check for containment
  - a circle's centre (i.e. a point) takes in another point to get its distance with respect to this other point
  - there are **methods** of the object

`Point` Class

- The **properties** and **methods** of a specific type of object is specified within a **`class`** — a blue-print of the object

```
class Point {
    /* properties */
    double x;
    double y;

    /* constructor */
    Point(double x, double y) {
        this.x = x;
        this.y = y;
    }

    /* method */
    double distanceTo(Point otherpoint) {
        double dispX = this.x - otherpoint.x;
        double dispY = this.y - otherpoint.y;
        return Math.sqrt(dispX * dispX + dispY * dispY);
    }
}
```

`Point` Class

- **Properties**:
  - a `Point` comprises two **`double`** values `x` and `y`
  - every `Point` object has the same set of properties, but different property values
- **Constructor**:
  - a method to create or **instantiate** a point
  - the `Point` constructor takes in two **`double`** values as arguments and assigns them to its properties
- **Method**:
  - a method `distanceTo` that returns the distance between a given `Point` and **itself**

`Circle` Class

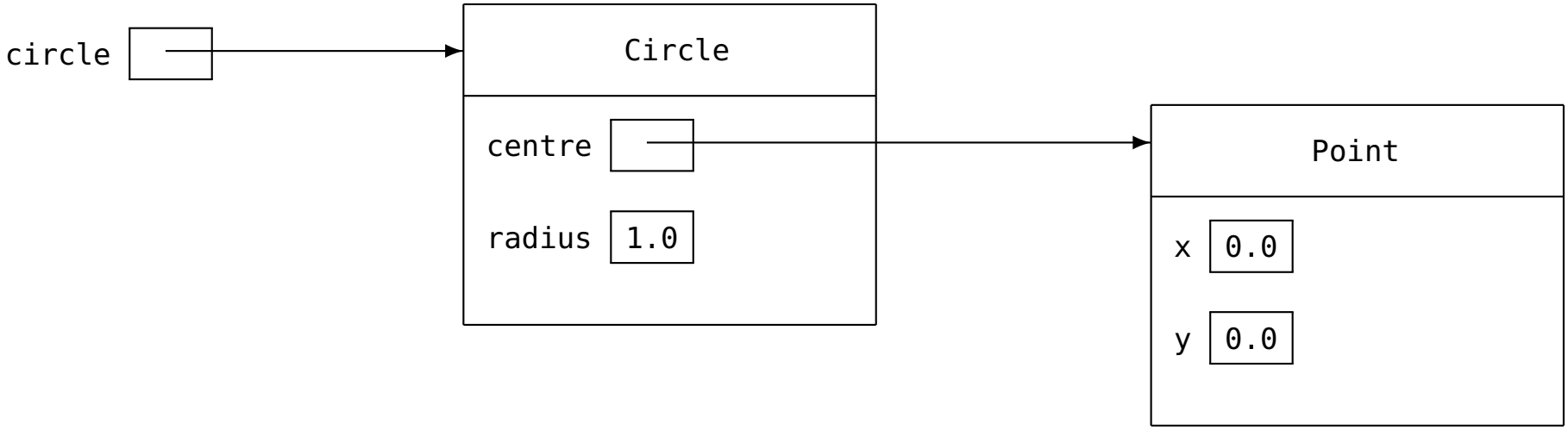
```
class Circle {
```

```
jshell> Point p = new Point(1, 1)
p ==> Point@604eb137

jshell> Point centre = new Point(2, 2)
centre ==> Point@7cd62f43

jshell> Circle c = new Circle(centre, 1)
c ==> Circle@5622fdf

jshell> c.contains(p)
$.. ==> false

jshell> c.radius = 2
$.. ==> 2.0

jshell> c.contains(p)
$.. ==> true
```

Modeling the Association between Objects

- Learn to develop a mental model that is **correct**, **consistent** and **complete**
- Consider modeling the following statement:

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



- Notice the use of **references** that refers (points) to objects

Reference

- When an object is created using **new**, a **reference** to the instantiated object is returned
- What happens in the following?

```
Point p = new Point(1, 1);
Point q = p;
p.x = 2;
```

- How about this?

```
Point p = new Point(1, 1);
void foo(Point p) {
    p.x = 3;
}
```

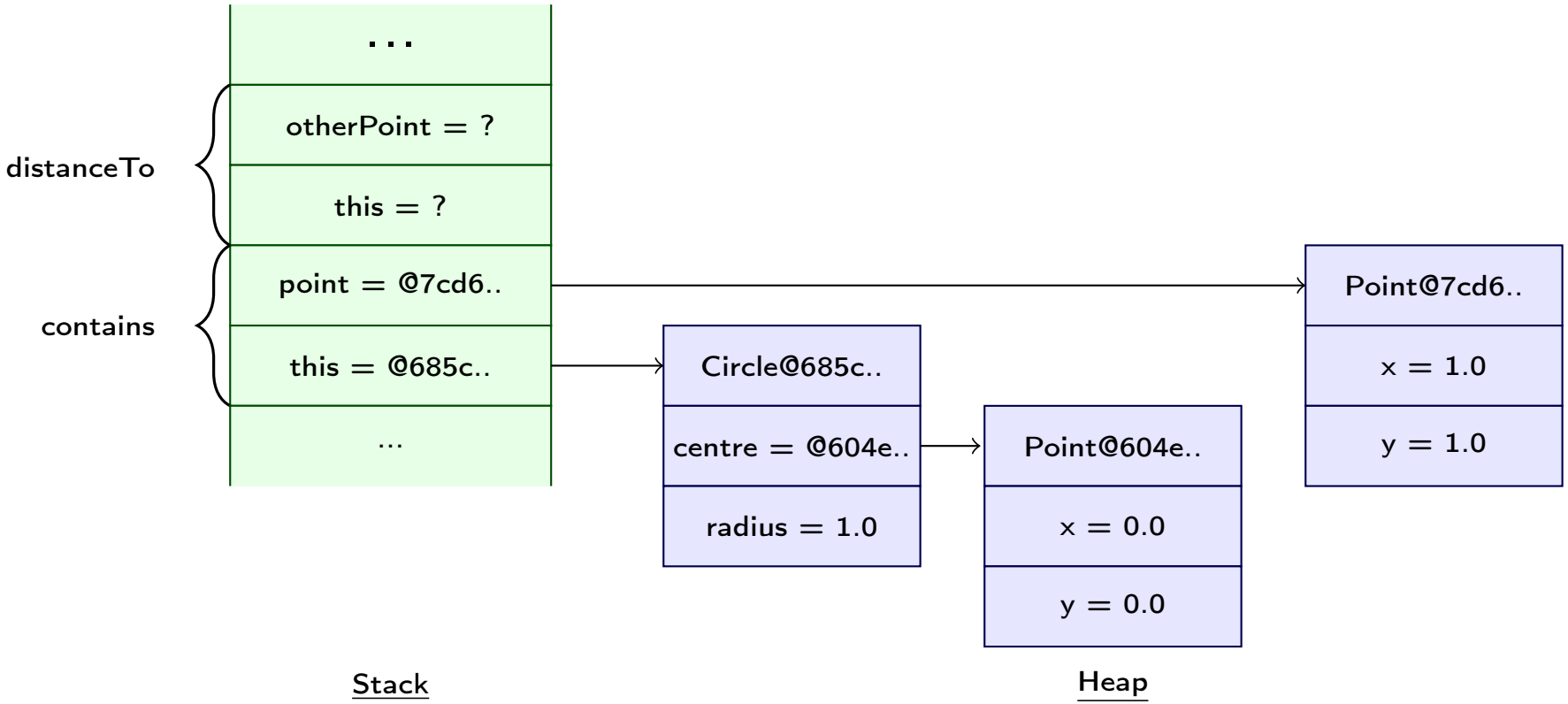
- What if the parameter name in method `foo` is changed to `r`?
- References are passed **as a value** to a function

Modeling Object Behavior

- Modeling behaviour requires knowledge on the mechanism of Java method calls and activations
- The Java **memory model** comprises three areas:
  - Stack
    - LIFO stack for storing activation records of method calls
    - method local variables are stored here
  - Heap
    - for storing Java objects upon invoking `new`
    - *garbage collection* is done here
  - Non-heap (*Metaspace* since Java 8)
    - for storing loaded classes, and other meta data
    - *we shall revisit this when we discuss* `static` *fields*

Java Memory Model

```
jshell> Point centre = new Point(0, 0)
centre ==> Point@604eb137

jshell> Circle circle = new Circle(centre, 1)
circle ==> Circle@685c2f43

jshell> Point point = new Point(1, 1)
point ==> Point@7cd62f43

jshell> circle.contains(point)
$.. ==> false
```



Encapsulation: Information Hiding

- Consider an alternative implementation of the `Point` class

```
class Point {
    double[] coord;

    Point(double x, double y) {
        coord = new double[]{x, y};
    }

    double distanceTo(Point otherpoint) {
        double dispX = coord[0] - otherpoint.coord[0];
        double dispY = coord[1] - otherpoint.coord[1];
        return Math.sqrt(dispX * dispX + dispY * dispY);
    }
}
```

- Not knowing the lower level data of `Point`, `Circle` still works!
- However, the following *know-too-much* implementation fails

```
    boolean contains(Point point) {
        double dx = centre.x - point.x;
        double dy = centre.y - point.y;
        return Math.sqrt(dx * dx + dy * dy) < radius;
    }
```

Access Modifiers

- Prevent access to lower level details by another object using **`private`** access modifiers

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

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

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

- This prevents the `contains` method from accessing `point.x` (`point.y`) or `centre.x` (`centre.y`) directly

Abstraction Barrier

- Interaction between two objects is viewed as communication across an **abstraction barrier**
- Provides a separation between the implementation an object, and how it's used by a client
- OOP Principle #1: **Abstraction**
  - *Implementer defines* the data/functional abstractions using lower-level data and processes
  - *Client uses* the high-level data-type and methods
- OOP Principle #2: **Encapsulation**
  - *Package* related data and behaviour in a self-contained unit
  - *Hide* information/data from the client and allowing access only through methods provided

Tell–Don't–Ask

- Encapsulation isn't merely about restricting access to properties and providing *getters* (possible even *setters*), e.g.

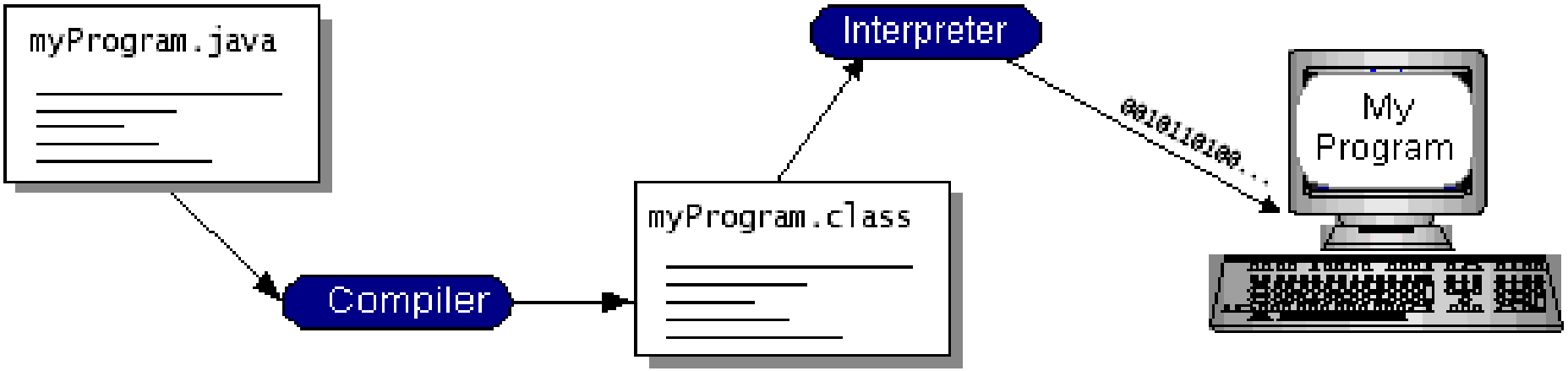
```
class Point {
    private double x;
    private double y;

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

    public double getX() {
        return x;
    }

    public double getY() {
        return y;
    }
}
```

```
class Circle {
    Point centre;
    double radius;

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

    boolean contains(Point point) {
        double dx = centre.getX() - point.getX();
        double dy = centre.getY() - point.getY();
        return Math.sqrt(dx * dx + dy * dy) < radius;
    }
}
```

- Although implementation details of `Point` is hidden away from `Circle` via *getters*, it violates the **Tell–Don't–Ask** principle
  - Tell an object what to do, rather than asking an object for data and acting on it

Java Compilation and Interpretation

- So far, we have been using the JShell as an interpreter to test our programs
- Java programs are typically compiled to **bytecode** first, and subsequently interpreted by the JVM residing on the machine



- We shall take a closer look at compiling and running Java programs in the next lecture

Lecture Summary

- Develop a sense of type awareness when writing Java programs
- Employ object-oriented modeling to convert a process-oriented solution to one that involves the interaction between objects
- Understand memory management using Java Memory Model
- Understand the OO principles of abstraction and encapsulation
- Appreciate the importance of maintaining an abstraction barrier when writing object-oriented programs
- Appreciate java compilation and interpretation

Difference between **CS2030** and **CS2040**

While CS2040 trains you to be efficient,
CS2030 trains you to be human.. ☺