CS2030S

AY24/25 S2 **Problem Set 01** 22-23 January 2025

1. *This question is adapted from the CS2030S midterm test of AY 21/22 Sem 2.*

   Consider the following Java program:

```
class BankAccount {
  double balance;

  BankAccount(double initBalance) {
    this.balance = initBalance;
  }
}

class Customer {
  BankAccount account;

  Customer() {
    this.account = new BankAccount(0);
  }

  public void deposit(double amount) {
    this.account.balance += amount;
  }

  public boolean withdraw(double amount) {
    if (this.account.balance >= amount) {
      this.account.balance -= amount;
      return true;
    }
    return false;
  }
}
```

   (a) Does this program follow the principle of information hiding? Explain.

   Comments:

   No. The balance information in `BankAccount` is publically accessible. So is the `account` information of a `Customer`.

   (b) Does this program follow the principle of "Tell, Don't Ask?" Explain.

   Comments:

   No. `Customer` directly checks the balance of `BankAccount` and modifies the value. It is asking for the balance from the account and then updates it, rather than telling the account to update its own balance.

   (c) If you think the program violates any of the principles in Parts (a) and (b), revise the program so that it adheres to the principles.

   Comments:

```
class BankAccount {
  private double balance; // make this private
  BankAccount(double initBalance) {
    this.balance = initBalance;
  }

  public void deposit(double amount) {
    this.balance += amount;
  }

  public boolean withdraw(double amount) {
    if (this.balance >= amount) {
      this.balance -= amount;
      return true;
    }
    return false;
  }
}

class Customer {
  private BankAccount account; // make this private

  Customer() {
    this.account = new BankAccount(0);
  }

  public void deposit(double amount) {
    this.account.deposit(amount); // tell account to do it
  }

  public boolean withdraw(double amount) {
    return this.account.withdraw(amount); // tell account to do it
  }
}
```

2. Consider the following definition of a `Vector2D` class:

```
class Vector2D {
  private double x;
  private double y;

  public Vector2D(double x, double y) {
    this.x = x;
    this.y = y;
  }

  public void add(Vector2D v) {
    this.x = this.x + v.x;
    this.y = this.y + v.y;
    // line A
  }
}
```

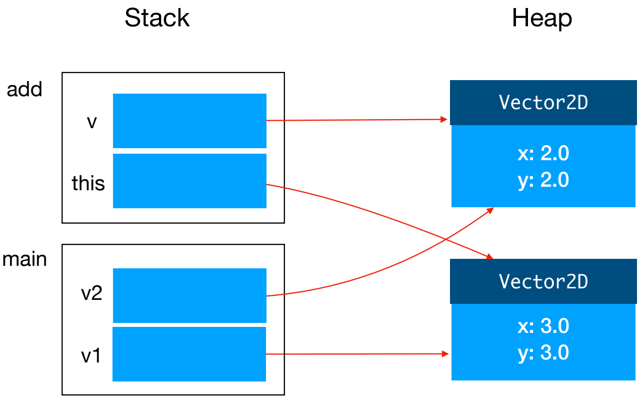
Suppose that the following program fragment is in a `main` method,

```
Vector2D v1 = new Vector2D(1, 1);
Vector2D v2 = new Vector2D(2, 2);
v1.add(v2);
```

(a) Show the content of the stack and the heap when the execution reaches the line labeled `A` above. Label your variables and the values they hold clearly. You can use arrows to indicate object references. Draw boxes around the stack frames of the methods `main` and `add`, and label them.

Comments:

The stack and heap look something like this:



(b) Suppose that the representation of `x` and `y` have been changed to a `double` array:

```
class Vector2D {
  private double[] coord2D;
  :
}
```

What changes do you need for the other parts of class `Vector2D`?

Comments:

We can change it to either:

```
class Vector2D {
  private double[] coord2D;

  public Vector2D(double x, double y) {
    this.coord2D = new double[]{x, y};
  }

  public void add(Vector2D v) {
    coord2D = new double[] {
      this.coord2D[0] + v.coord2D[0],
      this.coord2D[1] + v.coord2D[1]};
  }
}
```

or

```
class Vector2D {
  private double[] coord2D;

  public Vector2D(double x, double y) {
    this.coord2D = new double[]{x, y};
  }
  public void add(Vector2D v) {
    this.coord2D[0] += v.coord2D[0];
    this.coord2D[1] += v.coord2D[1];
  }
}
```

The difference is that the former allocates the new array while the latter just updates the 2D array in place.

Would the program fragment above still be valid?

Comments:

Yes, the program fragment, which is the client of `Vector2D`, is still valid. This is possible because the implementation details (how x and y coordinates are stored and operated on) of `Vector2D` is hidden behind the abstraction barrier and thus one can switch to a different implementation without affecting the existing code written by the clients.

3. Study the following `Point` and `Circle` classes.

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

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

public class Circle {

  private Point centre;
  private int radius;

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

  @Override
  public boolean equals(Object obj) {
    System.out.println("equals(Object) called");
    if (obj == this) {
      return true;
    }
    if (obj instanceof Circle) {
      Circle circle = (Circle) obj;
      return (circle.centre.equals(centre) && circle.radius == radius);
    } else {
      return false;
    }
  }

  public boolean equals(Circle circle) {
    System.out.println("equals(Circle) called");
    return circle.centre.equals(centre) && circle.radius == radius;
  }
}
```

Given the following program fragment,

```
Circle c1 = new Circle(new Point(0, 0), 10);
Circle c2 = new Circle(new Point(0, 0), 10);
Object o1 = c1;
Object o2 = c2;
```

(a) What is the return value of `c1.equals(c2)`? Explain.

Comments:

It returns `false`. Even though both `c1` and `c2` are circles with the same radius and the same center, the `Point` class does not override the `equals` method. As such, when comparing the two centers, `Object::equals` is invoked and the comparison returns `false`.

Without an implementation of `Point::equals`, we need to initialize the circles as follows for `c1.equals(c2)` to return `true`.

```
  Point p = new Point(0, 0);
  Circle c1 = new Circle(p, 10);
  Circle c2 = new Circle(p, 10);
```

(b) For each of the statement below, trace through the two-step dynamic binding process to show which `equals` method is invoked during run-time.

(i) `o1.equals(o2);`

(ii) `o1.equals((Circle) o2);`

(iii) `o1.equals(c2);`

(iv) `c1.equals(o2);`

(v) `c1.equals((Circle) o2);`

(vi) `c1.equals(c2);`

Comments:

For (i) to (iii), the invocation target is `o1`, with a compile-time type of `Object`. The only method named `equals` the compiler can find in the class `Object` is `boolean equals(Object)`. Thus, this method descriptor will be stored in the generated bytecode. During run time, Java determines that the run-time type of `o1` is `Circle`. It thus looks for an accessible method in the class `Circle` with matching method descriptor `boolean equals(Object)`.

In this question, there is an implementation of `boolean Circle::equals(Object)` that overrides `Object::equals`. Thus, `boolean Circle::equals(Object)` is invoked for (i) to (iii).

For (iv) to (vi), the invocation target `c1` has a compile-time type of `Circle`. Now the compiler finds two (overloaded) methods named `equals` in the class `Circle`. In this case, it determines the more specific, invocable, methods between the two.

- For (iv), the parameter has a compile-time type of `Object`. Since we can't pass a `Object` instance into a method expecting a `Circle`, the only correctly invocable method is `boolean Circle::equals(Object)`. Similar to (i) to (iii), the method descriptor `boolean equals(Object)` is stored in the generated binaries. The run-time decision is the same as (i) to (iii) since the run-time type of the target `c1` is also a `Circle`.

- For (v) and (vi), the parameter has a compile-time type of `Circle`. Now, both `boolean Circle::equals(Object)` and `boolean Circle::equals(Circle)` are invocable. Between the two, `boolean Circle::equals(Circle)` is the more specific one and thus the descriptor `boolean equals(Circle)` is stored in the generated binaries. During run-time, `boolean Circle::equals(Circle)` will be invoked.

Homework

4. In this question, your task is to create an abstraction for a single-digit ternary number, that can only store the values 0, 1, or 2.

(a) Write a class called `Ternary` with an `int` field named `value`. The field should not be accessible from outside the class. The class should have a constructor that initializes `value` to 0, and a `toString` method that returns the `value` as a `String`.

Example of how the class can be used:

```
jshell> Ternary t = new Ternary();
t ==> 0
```

Note: You can use the static method `String::valueOf` to convert an `int` to a `String`. See the Java API for `String` for more information.

(b) Add a method called `incr` to the class. `incr` should increment `value` by one but wraps around to 0 when the value exceeds 2. The method should not return anything.

Example of how the class can be used:

```
jshell> Ternary t = new Ternary();
t ==> 0

jshell> t.incr()
jshell> t
t ==> 1

jshell> t.incr()
jshell> t
t ==> 2

jshell> t.incr()
jshell> t
t ==> 0
```

Comments:

```
class Ternary {
  private int value;

  public Ternary() {
    this.value = 0;
```

```java
  }

  public void incr() {
    this.value = (this.value + 1) % 3;
  }

  @Override
  public String toString() {
    return String.valueOf(this.value);
  }
}
```