Computer Science Introductory Course MSc - Introduction to Java

Lecture 2: Object Oriented Programming

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ENST

Outline

1. References
2. Inheritance
3. Encapsulation
4. Polymorphism
5. Interfaces
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Introduction : Object Oriented Programming

- In the last lecture we learned that we can structure programs using objects of many classes.
- In this lecture we will examine OOP concepts in more detail :

constructors :	creating new objects.
references :	designating objects.
inheritance :	creating families of classes.
encapsulation :	hiding implementation.
polymorphism :	factorizing common behaviours.
interfaces :	behavioral contracts.

Constructors : creating a new object

Definition

Constructors are special methods that are called to create a new instance of their class.

```
class BankAccount {
  int balance;
  BankAccount () {
    balance = 0;
  }
  BankAccount (int initialDeposit){
    balance = initialDeposit;
  }
}

account1 = new BankAcconut();
account2 = new BankAccount(100);
```

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References

- When a variable is assigned a primitive type it contains a value.
- When assigned an object, array or string, it contains a reference to the data.
- If a is copied or passed, old and new references point to the same original object.

```
static void changeValues (int anArray[], int value){
   anArray[0] = 42;
   value = 42;
}
public static void main (String args[]){
   int v = 0; int[] a = {0,0};
   System.out.println(v + "␣" + a[0] + "␣" + a[1]);
   changeValues(a,v);
   System.out.println(v + "␣" + a[0] + "␣" + a[1]);
}
output :
0 0 0
0 42 0
```

Immutability

- String are a special case, because they are immutable (cannot be changed).
- When you change a String a new different String is created and the characters of the orignal one are copied.
- For performance : do not build a string with concatenation, use StringBuilder.

```
public static void main (String args[]) {
  String s1 = "hello";
  String s2 = s1;
  s1 = s1 + "!";
  System.out.println(s1 + "␣" + s2);
}

output :
hello! hello
```

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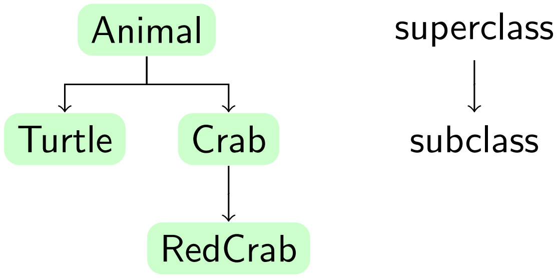
Inheritance

Q : Remember our turtle ? It could turn and advance. But we want a new class Crab that advances sideways ...

- We could write a new class Crab, but there would a lot of code in common with Turtle (which makes the code base difficult to maintain).
- We are going to use inheritance.
- Inheritance makes it possible to create a subclass that inherits the properties of its ancestor or superclass.



Inheritance

```
class Animal {
  Color color;
  Position position;
  double rotation;

  void turn(double angle) {};
  void advance() {};
}

class Crab extends Animal{
  void advance() {
    /* code for moving sideways */
  }
}

Crab crab = new Crab();
crab.color =  Color.BLUE;
crab.advance();
```

overriding and hiding

What we just did with method advance is called overriding.

- When we call `crab.advance()` the crab's advance is called !
- The animal's advance has been overrided.
- If a method is not overriden, the superclass' is used (here `crab.turn(10);` would call Animal's turn implementation.
- the `final` keyword in a method declaration indicates that the method cannot be overridden.

overriding a static method or a variable is called hiding, because the new static implementation or variable *hides* the old one, doing this is usually a bad idea.

this and super

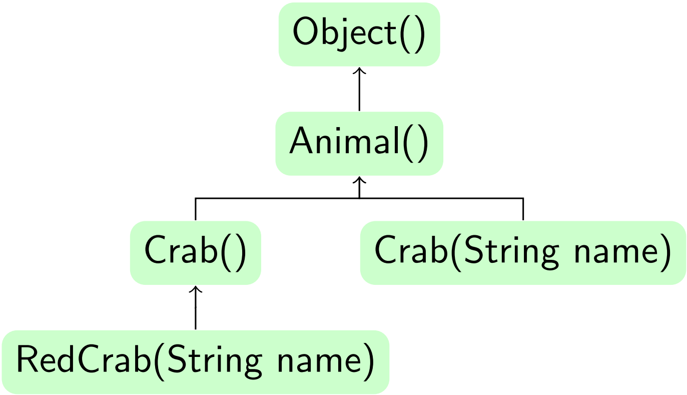
- for a given class `this` represents the current class and `super` the superclass.
- super is used to call overriden superclass' methods.

```
class Animal {
  void advance();
}

class Crab extends Animal{
  String name;
  advance() {
    this.turn(90);
    super.advance();
    this.turn(-90);
  }
}
```

Inheritance and Constructors

- In java all the classes are subclasses of the Object class.
- A subclass constructor will always call a superclass constructor.
- If a class possess no constructor, an empty one with no parameters is implicit.
- Every constructor of a subclass call the no-parameters superclass constructor.
- But we can control this with `super` and `this` keywords.



```
class Animal {
  Position position;
  double rotation;

  Animal(Position position, double rotation) {
    this.position = position;
    this.rotation = rotation;
  }
}

class Crab extends Animal{
  String name;
  Crab(Position position) {
    super(position, 90);
  }
  Crab(Position position, String name) {
    this(position);
    this.name = name;
  }
}
```

abstract methods

Suppose we add birds to our class hierarchy.

- birds and crabs do not move the same way... there is no common implementation for advance that we can put in Animals.
- we could create an empty `advance()` in the `Animal` class and override it in `Bird` and `Crab`.
- Yet, another programer could add a new subclass and forget to implement the `advance()` method.
- Thus, we use abstract methods.

Definition

- An abstract method is a method which has no implementation.
- An abstract class is a class with abstract methods.
- It is mandatory for all the non-abstract subclasses to override all the abstract methods.
- An abstract class cannot be instantiated.

```
abstract class Animal {
  Position position;
  double rotation;

  abstract void advance();

}

class Crab extends Animal{
  String name;
  void advance() {
    /* crab moves */
  }
}

Animal a = new Animal(); // COMPILATION ERROR
Crab   c = new Crab();   // Works!
```

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Encapsulation

Definition

Encapsulation is the act of hiding properties and methods inside a class.

- This allows to protect classes from unexpected side-effects from the outside.
- It also enforces implementation agnostic programming, which is a good idea.

Packages

Definition

- A package is a group of classes.
- Packages define a namespace.
- Classes in the same package share the same namespace.

```
package Animals;
class Animal{}
class Crab{}

import Animals.Crab;
import Animals.*;
class MyProgram{}
```

Acces modifiers

In java encapsultation is obtained through acces/visibility modifiers.

- Classes can be `public`, visible by everyone
  or without modifier in which case they are only visible inside their package (a group of classes).
- Class members (variables and methods) can have 4 modifiers with different degrees of visibility.

Modifier	Class	Package	Subclass	World
public	Y	Y	Y	Y
protected	Y	Y	Y	N
no modifier	Y	Y	N	N
private	Y	N	N	N

```
packages animals;
class Animal {
  private double rotation;
  public void turn(double angle)
    {position += angle;}
}
class Crab extends Animal {
  public void turnBack() {
    turn(180);       // legal
    rotation += 180; // illegal
  }
}
```

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Q : How to make a group of animals advance ?

- We want to make a group of animals (crabs and turtles) advance at the same time.
- We need a container for all of them, what is the container type ?
- Nightmare

```
int numberCrabs; int numberTurtles;
Crab[] crabs;
Turtle[] turtles;

moveAllAnimals () {
  for(int i=0; i < numberCrabs; i++)
    crabs[i].advance();
  for(int i=0; i < numberTurtles; i++)
    turtles[i].advance();
}
void addCrab (Crab c) {crabs[numberCrabs++]=c;}
void addTurtle (Turtle t)
  {turtles[numberTurtles++]=t;}

addCrab(new Crab());
addTurtle(new Turtle());
```

Polymorphism

Use Polymorphism, or the capacity to treat an instance as one of its super classes

```
int numberAnimals;
Animal[] animals;
void moveAllAnimals(){
  for (int i=0; i < numberAnimals; i++)
    animals[i].advance();
}
void addAnimal(Animal a)
  {animals[numberAnimals++] = a;}

addAnimal(new Crab());
addAnimal(new Turtle());
```

- Better

Dynamic and Static type : Casts

```
Animal animal;
animal = new Crab();
```

static type Animal

dynamic type Crab

- when calling an instance method the dynamic type is used.
- when calling a static method the static type is used.
- you can force the static type (only to super-classes of the dynamic type, or to the dynamic type) using casts :

```
Crab c = (Crab) animal; // OK
Turtle t = (Turtle) animal; // Runtime ERROR
```

Dynamic dispatching

- When you call an instance method, the method used is the one provided by the dynamic class, this is called dynamic dispatching.
- It is the really powerful idea behind polymorphism :
  - You can treat a group of objects the same way
  - When you do an operation on one of the objects, the adequate operation will be chosen depending on the dynamic type of the object.

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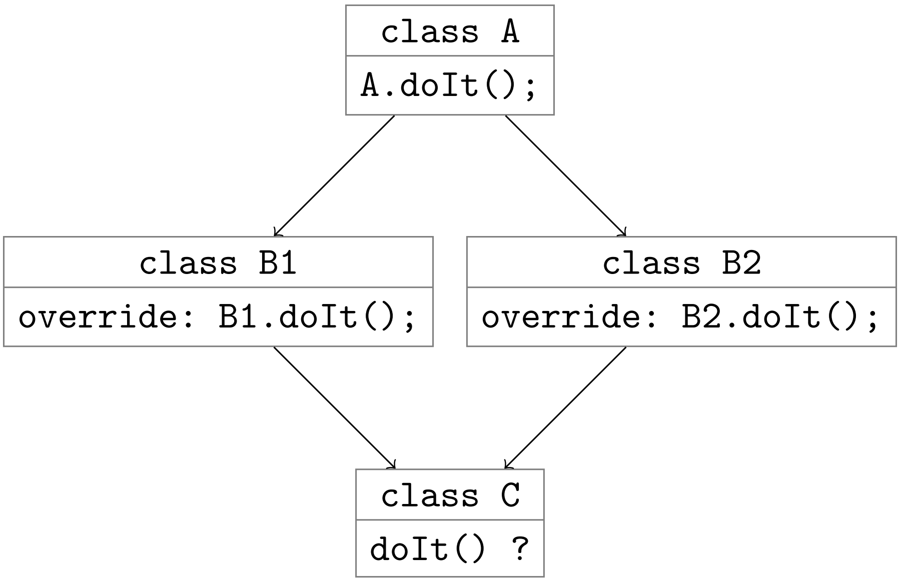
Multiple inheritance ?

- We have added further classes to our animal class hierarchy : Swimming with method `swim()`, Walking with method `walk()`.
- As our turtle can both swim and walk we would like it to inherit from both classes.
- But in java this is forbidden.

Multiple inheritance : problem



When we call `doIt()` on C, do we call $B1$ or $B2$ implementation ?
Multiple answers to this problem (see for example Eiffel's nice solution),
Java Answer : Interfaces.

Interfaces

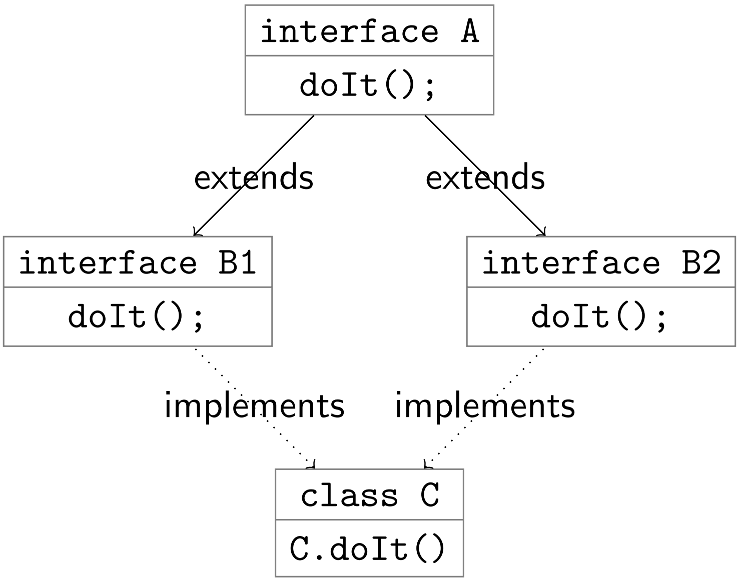
Definition

An interface is a behavioural contract that a class decides to honor.

- Concretely, an interface is a collection of method signatures.
- If a class `implements` an interface, it has to provide a body for each of those methods.
- A class can implement multiple interfaces.
- An interface can extend another (single) interface.

Q : Why does it solves the multiple inheritance problem ? A : We multiply interface, we do not multiply implementation...

Multiple inheritance with interfaces



interface A
doIt();
extends
extends
interface B1
doIt();
interface B2
doIt();
implements
implements
class C
C.doIt()

B2 and B1 asked for a method `doIt`, C provides it, no ambiguity

```
public interface Swimming {
  void swim();
}
public interface Walking {
  void walk();
}
class Turtle extends Animal
             implements Swimming,Walking{
  void swim() { /* swim implementation */}
  void walk() { /* walk implementation */}
}
```

Summary

- To factorize code, creating classes hierarchies is important.
- Each class should hide its implementation to make code robust and maintainable.
- With polymorphism one can design elegant, factorised code.
- When an object implements different behaviours, one should use interfaces.