OOP Principles

CSI 211: Object Oriented Programming

Tanjina Helaly

3 Principles

- All object-oriented programming languages provide mechanisms that help you implement the object-oriented model.
    - Inheritance
    - Encapsulation
    - Polymorphism

Inheritance

INHERITANCE

- Inheritance is the process by which one object acquires the properties of another object.
- It is a way to form new classes using classes that have already been defined.
- The new classes (child classes), take over (or inherit) **attributes** and **behavior** of the pre-existing classes (parent classes).

Inheritance

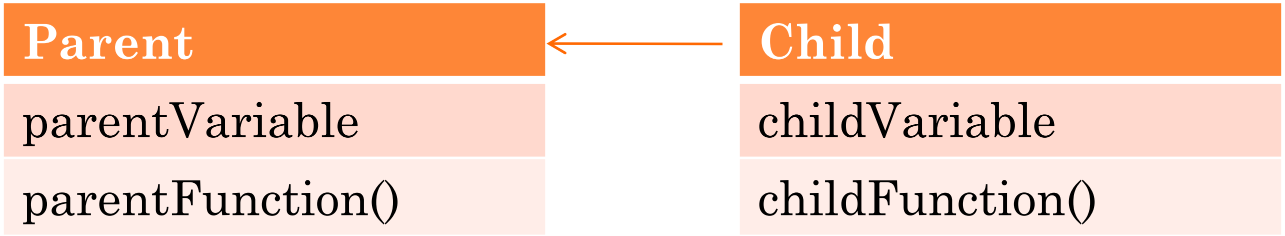
- Java uses “extends” keyword to show inheritance relationship. Example

  class Child **extends** Parent{}
- The class that is extended is a **superclass**
  - Other terms: parent class, base class, ancestor class
- The extended class is a **subclass** of its superclass
  - Other terms: child class, extended class, derived class
- An object created from the subclass has its **own copy** of all the **nonstatic fields** defined in its superclass

INHERITANCE

- This is important because it supports the concept of hierarchical classification.
- Inheritance provides a powerful and natural mechanism for organizing and structuring your software
- It is intended to help reuse existing code with little or no modification.

Inheritance - Example



Parent

parentVariable

parentFunction()

Child

childVariable

childFunction()

Act like

Parent

parentVariable

parentFunction()

Child

parentVariable
childVariable

parentFunction()
childFunction()

INHERITANCE - EXAMPLE

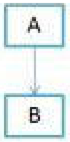
```
class Parent {
    public int parentVariable = 10;
    public void parentFunction() {
        System.out.println( "Parent Function" );
    }
}
class Child extends Parent {
    public int childVariable = 5;
    public void childFunction() {
        parentFunction();
        System.out.printf( "In Child ParentVariable=%d, ChildVariable=%d“,
        parentVariable, childVariable );
    }
}
class Inheritance {
    public static void main( String args[] ) {
        Child example = new Child();
        example.childFunction();
        example.parentFunction();
        System.out.println( example.parentVariable );
    }
}
```

Output

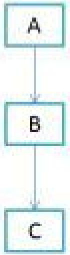
```
Parent Function
In Child ParentVariable=10, ChildVariable=5
Parent Function
10
```

Types of Inheritance

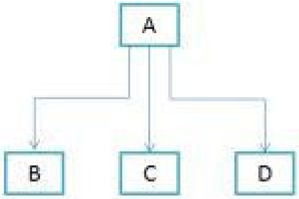
- Single inheritance
  - One parent-> One child



- Multi level inheritance
  - one can inherit from a derived class, thereby making this derived class the base class for the new class.

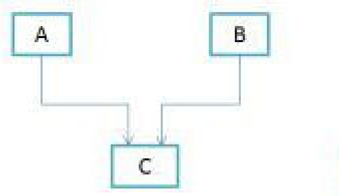


- Hierarchical inheritance
  - One parent – multiple children

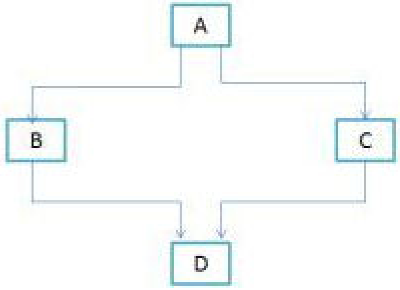


Types of Inheritance

- Multiple inheritance
  - Multiple parents -> one child



- Hybrid inheritance
  - Is a combination of Single and Multiple inheritance



- Java does not support multiple inheritance

INHERITANCE – SUPER KEYWORD

- The **super** keyword in java is a reference variable that is used to refer immediate parent class object.
- Whenever you **create the instance of subclass, an instance of parent class is created implicitly** i.e. referred by super reference variable.
- Usage of java super Keyword
  - super is used to refer immediate parent class member(instance variable & method).
  - super() is used to invoke immediate parent class constructor.

SUPER – PARENT'S INSTANCE VARIABLE/METHOD

- The super keyword can also be used to
  - Access parent class's instance variable if child has an instance variable with same name ().
  - invoke parent class's method. It should be used in case subclass contains the same method as parent class.

SUPER – PARENT'S INSTANCE VARIABLE/METHOD

```
class Parent {
   String name;
   void message(){
        System.out.println("Welcome to Parent class."); }
}
// Create a subclass by extending class parent.
class Child extends Parent {
   String name; // this name hides the name in Parent. Shadowing

   public Child(String a, String b) {
         super.name = a; // name in A
         name = b; // name in B
   }
   void show() {
   System.out.println("superclass's name: " + super.name +"; subclass's name: "+name); }

   //method overriding
   void message(){
        System.out.println("Welcome to Child class."); }

   void display(){
         message();//will invoke current class message() method
         super.message();//will invoke parent class message() method
   }
}
```

SUPER – PARENT'S INSTANCE VARIABLE/METHOD

```
public class TestSuper {
	public static void main(String[] args) {
		Child s=new Child("Parent", "Child");
		s.show();
		s.display();
	}
}
```

- Output:

```
superclass's name: Parent; subclass's name: Child
Welcome to Child class.
Welcome to Parent class.
```

SUPER-TO INVOKE PARENT CONSTRUCTOR.

- The super keyword can also be used to invoke the parent class constructor as given below:

```
class Vehicle{
    Vehicle(){
        System.out.println("Vehicle is created.");
    }
}

class Bike extends Vehicle{
    Bike(){
        super(); //will invoke Parent class's constructor
        System.out.println("Bike is created.");
    }
    public static void main(String[] args){
        Bike b = new Bike();
    }
}
```

Output:

```
Vehicle is created
Bike is created
```

super-To invoke parent constructor.

- What would be the output of the program below:

```
class Vehicle{
    Vehicle(){
        System.out.println("Vehicle is created.");
    }
}

class Bike extends Vehicle{
    Bike(){
        System.out.println("Bike is created.");
    }
    public static void main(String[] args){
        Bike b = new Bike();
    }
}
```

SUPER-TO INVOKE PARENT CONSTRUCTOR.

- What would be the output of the program below:

```
class Vehicle{
    Vehicle(){
        System.out.println("Vehicle is created.");
    }
}

class Bike extends Vehicle{
    Bike(){
        System.out.println("Bike is created.");
    }
    public static void main(String[] args){
        Bike b = new Bike();
    }
}
```

Output:

```
Vehicle is created
Bike is created
```

If the constructor doesn’t have super(), compiler will provide super() as the first statement of the constructor.

SUPER-TO INVOKE PARENT CONSTRUCTOR.

- **Note:**
- super() should be the first statement of your constructor
- If the constructor doesn't have super(), compiler will provide super() as the first statement of the constructor.
  - **It will only work when Parent has no constructor or a parameter less constructor. See the next example.**

SUPER-TO INVOKE PARENT CONSTRUCTOR.

- What would be the output of the program below:

```
class Vehicle{
    Vehicle(String name){
        System.out.printf("Vehicle %s is created.\n", name);
    }
}

class Bike extends Vehicle{
    Bike(){
        System.out.println("Bike is created.");
    }

    public static void main(String[] args){
        Bike b = new Bike();
    }
}
```

SUPER-TO INVOKE PARENT CONSTRUCTOR.

- What would be the output of the program below:

```
class Vehicle{
    Vehicle(String name){
        System.out.printf("Vehicle %s is created.\n", name);
    }
}

class Bike extends Vehicle{
    Bike(){ // Implicit super constructor Vehicle() is undefined. Must explicitly invoke another constructor
        System.out.println("Bike is created.");
    }

    public static void main(String[] args){
        Bike b = new Bike();
    }
}
```

super-To invoke parent constructor.

- So the fix is:

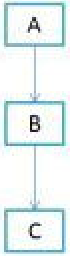
```
class Vehicle{
    Vehicle(String name){
        System.out.printf("Vehicle %s is created.\n", name);
    }
}

class Bike extends Vehicle{
    Bike(){
        super("Bike");
        System.out.println("Bike is created.");
    }

    public static void main(String[] args){
        Bike b = new Bike();
    }
}
```

When Constructors Are Executed

- When a class hierarchy is created, the constructors are executed in the order of the hierarchy.



- For example: for the hierarchy above, constructor of A will be executed first, then B and then C.

When Constructors Are Executed

```
// Create a super class.
class A {
 A() {
    System.out.println("Inside A's constructor."); }
}
// Create a subclass by extending class A.
class B extends A {
 B() {
    System.out.println("Inside B's constructor."); }
}
// Create another subclass by extending B.
class C extends B {
 C() {
    System.out.println("Inside C's constructor."); }
}
class CallingCons {
 public static void main(String args[]) {
    C c = new C();
 }
}
```

Output:

```
Inside A's constructor
Inside B's constructor
Inside C's constructor
```

Object Class

- All classes inherit directly or indirectly from java.lang.Object
  - class Parent { int size; }
  - class Parent extends Object { int size; }
- The child class below is a grandchild of Object
  - class Child extends Parent{ }
- Having a common ancestor class allows java to provide standard members on all objects, like toString()

```
class TestObject {
        public static void main( String args[] ) {
            Parent watchThis = new Parent();
            int myHash = watchThis.hashCode();
            System.out.println( myHash );
            // Where does hashCode come from?
        }
}
```

Object Class - methods

- clone() - Creates a clone of the object.
- equals(Object) - Compares two Objects for equality.
  - Uses "==" to test for equality
  - Note: If a class needs an implementation of equals, which differs from the default "equals", the class should override the method.
- toString() - Returns a String that represents the value of this Object.

ENCAPSULATION

Encapsulation

- *Encapsulation* is the mechanism that binds together code and the data it manipulates and keeps both safe from outside interference and misuse.
- One way to think about encapsulation is as a protective wrapper
  - that prevents the code and data from being arbitrarily accessed by other code defined outside the wrapper.
- the basis of encapsulation is the class.
  - Use access modifier to provide encapsulation

ENCAPSULATION

- Since the **purpose** of a class/encapsulation is to encapsulate complexity, there are mechanisms for hiding the complexity of the implementation inside the class.
  - Use **access modifier** to specify which members should/ shouldn’t be accessed by outside world.
  - the public interface should be carefully designed not to expose too much of the inner workings of a class

Getter/Setter Method

- In encapsulation, the variables of a class will be hidden from other classes, and can be accessed only through the methods of their current class.
- To achieve that in Java –
  - Declare the variables of a class as private.
  - Provide public setter and getter methods to modify and view the variables values.
  - Example:

```
private double balance;

public void setBalance(double b) {
        balance = b;
}
public double getBalance() {
        return balance;
}
```

Benefit of Encapsulation

- Benefit
  - Hide complexity from user.
  - Implement logic while updating field
  - Easy to maintain
  - Make variable read-only or write only

Abstraction vs. encapsulation

- Abstraction represent taking out the behavior from how exactly its implemented,
  - one example of abstraction in Java is interface
- Encapsulation means hiding details of implementation from outside world so that when things change no body gets affected.
  - One example of Encapsulation in Java is private methods; clients don't care about it, You can change, amend or even remove that method if that method is not encapsulated and it were public all your clients would have been affected.

Abstraction vs. encapsulation

- Encapsulation(hiding complexity) implements of abstraction(show what is only necessary)
- https://www.youtube.com/watch?v=1Q4I63-hKcY
- Abstraction is the thought process or model
- Encapsulation is the design

Polymorphism

POLYMORPHISM

- **Poly** means **many** and **morph** means **form**. Thus, polymorphism refers to being able to use many forms of a type without regard to the details.

- More generally, the concept of polymorphism is often expressed by the phrase "one interface, multiple methods."

- *polymorphism* refers to a programming language's ability to process objects differently depending on their data type or class.

Polymorphism

- 3 types
  - Method overriding
  - Method overloading
  - Subclass polymorphism

METHOD OVERRIDING

- Means a **child class** is **re-implementing** a **method of its super class**. Or
- A class replacing an ancestor's implementation of a method with an implementation of it own.
- When overriding a method in child class
  - **Method Signature**(name and argument list) and **return type** must be the same as the parent method.
  - Child method could be equal or more **accessible**.

METHOD OVERRIDING

- When an **overridden method is called** from within its subclass, it will always refer to the version of that **method defined by the subclass**.
  - The version of the method defined by the superclass will be hidden.
- To invoke parent method in child class, need to use "**super**" keyword.
- Static methods can not be overridden
- Dynamic binding

METHOD OVERRIDING - EXAMPLE

```
public class TestOverridding {
    public static void main(String[] args) {
        System.out.println("------Parent-----");
        Parent p = new Parent();
        p.display();

        System.out.println("\n------Child-----");
        Child c = new Child();
        c.display();
    }
}

class Parent {
    public void display() {
        System.out.println( "Display in Parent" );  }
}
class Child extends Parent {
    public void display() {
        System.out.println( "Display in Child" );   }
}
```

Output:

```
------Parent-----
Display in Parent

------Child-----
Display in Child
```

Method overriding - Example(super keyword)

```
public class TestOverridding {
    public static void main(String[] args) {
        System.out.println("------Parent-----");
        Parent p = new Parent();
        p.display();

        System.out.println(“\n------Child-----");
        Child c = new Child();
        c.display();
    }
}

class Parent {
    public void display() {
       System.out.println( "Display in Parent" );  }
}
class Child extends Parent {
    public void display() {
       super.display(); // invoke the parent class’s method
       System.out.println( "Display in Child" );   }
}
```

Output:

```
------Parent-----
Display in Parent

------Child-----
Display in Parent
Display in Child
```

METHOD OVERLOADING

- Two methods in the same class can have the same name with different signature. This is called method overloading and the methods are called overloaded method.
  - The signature of a method is its name with number, type and order of its parameters.
  - The return type is not part of the signature of a method.
- Condition:
  - Methods should be in the same class
  - Same name
  - Must have different argument.
  - Return type could be same or different.

METHOD OVERLOADING

- This called static binding because, which method to be invoked will be decided at the time of compilation

Method overloading - Example

```
class OverloadDemo {
    void test() {
        System.out.println("No parameters"); }

    // Overload test for one integer parameter.
    void test(int a) {
        System.out.println("a: " + a); }

    // Overload test for a double parameter
    double test(double a) {
        System.out.println("double a: " + a);
        return a*a; }
}

class Overload {
    public static void main(String args[]) {
        OverloadDemo ob = new OverloadDemo();
        // call all versions of test()
        ob.test();
        ob.test(10);
        double result = ob.test(123.25);
        System.out.println("Result of ob.test(123.25): " + result);
    }
}
```

Output:

```
No parameters
a: 10
double a: 123.25
Result of ob.test(123.25): 15190.5625
```

Constructor Overloading

- In addition to overloading normal methods, you can also overload constructor methods.
- In fact, for most real-world classes that you create, overloaded constructors will be the norm, not the exception.

Constructor Overloading - Example

```
public class Box {
    double width, height, depth;
    // constructor used when all dimensions specified
    Box(double w, double h, double d) {
        width = w;
        height = h;
        depth = d;
    }
    // constructor used when cube is created
    Box(double len) {
       width = height = depth = len;
    }
    // compute and return volume
    double volume() {
       return width * height * depth;
    }
    public static void main(String[] args){
        Box b = new Box(10, 8, 5);
        System.out.println("Volume of Box: " + b.volume());
        Box b1 = new Box(5);
        System.out.println("Volume of Cube: " + b1.volume());
    }
}
```

Output:

```
Volume of Box: 400.0
Volume of Cube: 125.0
```

Invoking Overloaded Constructors -this( )

- Sometimes it is useful for one constructor to invoke another.
  - this is accomplished by using the **this keyword.**
  - The general form is
    - this(*arg-list)*
- When **this( ) is executed, the overloaded constructor that matches the parameter list** specified by *arg-list is executed.*
- The call to **this( ) must be the first statement within** the constructor.
  - General rule: Constructor call must be the first statement in a constructor.

Constructor Overloading - Example

```
public class Box {
    double width, height, depth;
    // constructor used when all dimensions specified
    Box(double w, double h, double d) {
        width = w;
        height = h;
        depth = d;
    }
    // constructor used when cube is created
    Box(double len) {
        width = height = depth = len;
    }
    // compute and return volume
    double volume() {
       return width * height * depth;
    }
    public static void main(String[] args){
        Box b = new Box(10, 8, 5);
        System.out.println("Volume of Box: " + b.volume());
        Box b1 = new Box(5);
        System.out.println("Volume of Cube: " + b1.volume());
    }
}
```

Output:

```
Volume of Box: 400.0
Volume of Cube: 125.0
```

Constructor Overloading – Example with this()

```
public class Box {
	double width, height, depth;
	// constructor used when all dimensions specified
	Box(double w, double h, double d) {
		width = w;
		height = h;
		depth = d;
	}
	// constructor used when cube is created
	Box(double len) {
	    this(len, len, len);
	}
	// compute and return volume
	double volume() {
	    return width * height * depth;
	}
	public static void main(String[] args){
		Box b = new Box(10, 8, 5);
		System.out.println("Volume of Box: " + b.volume());
		Box b1 = new Box(5);
		System.out.println("Volume of Cube: " + b1.volume());
	}
}
```

Output:

```
Volume of Box: 400.0
Volume of Cube: 125.0
```

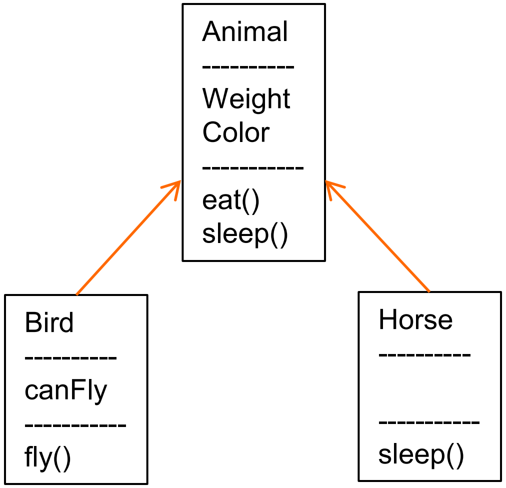
Subclass Polymorphism

- A parent class reference is used to refer to a child class object.
- Couple things to remember:
  - The only possible way to access an object is through a reference variable.
  - The type of the reference variable would determine the methods that it can invoke on the object.
- Using subclass polymorphism we can call or execute the child-class overriding method by the parent-class object.

Subclass Polymorphism - Example

```
public class TestPolymorphism {
    public static void main(String[] args) {
        Animal a = new Bird();
        a.sleep(); // sleep() method of animal class will be executed

        Animal h = new Horse();
        h.sleep(); // sleep() method of Horse class will be executed
    }
}
```



Subclass Polymorphism –Compile/run time

- 2 types of check
  - reference variable would determine the methods that it can invoke on the object. **Compile time check.**
  - object type (NOT reference variable type) determines which overridden method will be used at **runtime.**
  - Consider the code below

```
Animal a = new Bird();
a.sleep();
```

    - Can’t call a.sleep() if the sleep() method is not available in Animal class. Will produce compile error.
    - During runtime the Horse’s sleep() method will be executed not Animal’s.

Subclass Polymorphism – access method not available in parent

```
public class TestPolymorphism {
	public static void main(String[] args) {
		Animal a = new Bird();
		a.fly(); // Compile error: The  method fly() is undefined for the type Animal
	}
}
```

- So what to do if need to call subclass method that is not available in Parent class?
  - Casting

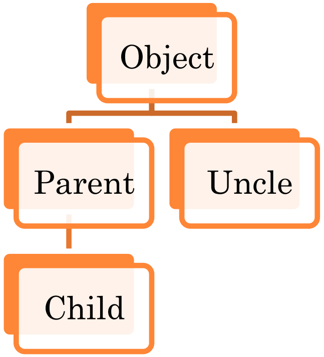
```
public class TestPolymorphism {
	public static void main(String[] args) {
		Animal a = new Bird();
		((Bird)a).fly(); // OK
	}
}
```

Casting and Classes

- An instance of a child class can be assigned to a variable (field) of the parent class.
- variable references an subtype object can be cast down to its subclass type with an **explicit** cast.
- A runtime error occurs when explicitly casting an object to a type that it is not.
  - An object of type Parent cannot be cast to type Child.
- In the code shown in next page, the cast "(Uncle) object" is a runtime error
  - because at that time object holds an instance of the Child class, which is not of type (or subclass) of Uncle.

Casting and Classes

```
class Casting {
        public static void main( String args[] ) {
                Object object;
                Parent parent;
                Child child = new Child();
                Uncle uncle;
                parent = child;
                object = child;
                parent = (Parent) object; // explicit cast down
                child = (Child) object; // explicit cast down
                uncle = (Uncle) object; //Runtime exception
        }
}
```



- **Output**

  java.lang.ClassCastException: Child: cannot cast to Uncle

- the cast "(Uncle) object" is a runtime error - because at that time object holds an instance of the Child class, which is not of type (or subclass) of Uncle.

Precaution while down casting

- We need to first check if the object is of that type.
- How?
  - The **java instanceof operator** is used to test whether the object is an instance of the specified type (class or subclass or interface).
  - getClass() method return the "class [ClassName]"
  - getClass().getName() return the class name.

- Let's revisit example of polymorphism.

```
public class TestPolymorphism {
      public static void main(String[] args) {
            Animal a = new Bird();
            if (a instanceof Bird) // can also use if (a.getClass().getName().equals("Bird"))
               ((Bird)a).fly(); // OK
      }
}
```

Subclass Polymorphism - Benefits

- Process objects differently based on their data type.
  - We can override method in subclasses and which implementation to be used is decided at runtime depending upon the situation (i.e., data type of the real object)
- Can pass parent ref as method argument and handle all subclasses
- Can return parent type and handle all subclasses.

Static & Dynamic Binding

- Association of method definition to the method call is known as binding.
- 2 types:
  - static binding (also known as early binding).
  - dynamic binding (also known as late binding).
- Static Binding:
  - The binding which can be resolved at compile time by compiler is known as static or early binding.
  - All the static, private and final methods have always been bonded at **compile-time** .
  - Why?
    - Compiler knows that all such methods cannot be overridden and will always be accessed by object of local class. Hence compiler doesn’t have any difficulty to determine object of class (local class for sure). That’s the reason binding for

Static Binding

- The binding which can be resolved at compile time by compiler is known as static. Or
- When type of the object is determined at compiled time(by the compiler), it is known as static binding.
- All the static, private and final methods have always been bonded at **compile-time** .
  - Why?
    - Compiler knows that all such methods cannot be overridden and will always be accessed by object of local class.
    - Hence compiler doesn't have any difficulty to determine object of class (local class for sure).
    - That's the reason binding for such methods is static.

Dynamic Binding

- When compiler is not able to resolve the call/binding at compile time, such binding is known as Dynamic or late Binding.
- Example: Overriding
  - in overriding both parent and child classes have same method.
  - Thus while calling the overridden method, the compiler gets confused between parent and child class method.
  - The method is decided during runtime.

Reference

- Java:Complete Reference Chapter 7,8
- Online Reference:
  - http://www.javatpoint.com/super-keyword
  - https://www.tutorialspoint.com/java/
  - https://docs.oracle.com/javase/tutorial/