

Object-Oriented Programming

Object Oriented Programming Inheritance

Like father, like son

Acknowledgement

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- We greatly appreciate support from Mr. Aaron Tan Tuck Choy, and Dr. Low Kok Lim for kindly sharing these materials.

Policies for students

- These contents are only used for students PERSONALLY.
- Students are NOT allowed to modify or deliver these contents to anywhere or anyone for any purpose.

Recording of modifications

- Course website address is changed to <http://sakai.it.tdt.edu.vn>
- Slides “Practice Exercises” are eliminated.
- Course codes cs1010, cs1020, cs2010 are placed by 501042, 501043, 502043 respectively.

Objectives

- Introducing inheritance through creating subclasses
 - Improve code reusability
 - Allowing overriding to replace the implementation of an inherited method

References



Textbook

- Chapter 1: Section 1.4 (pg 54 – 56)
- Chapter 9: Section 29.1 (pg 480 – 490)



IT-TDT Sakai → 501043
website → Lessons

- <http://sakai.it.tdt.edu.vn>

Outline

1. Overriding Methods (revisit)
2. Creating a Subclass
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5. “is-a” versus “has-a”
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0. Object-Oriented Programming

- Four fundamental concepts of OOP:
 - Encapsulation
 - Abstraction
 - Inheritance
 - Polymorphism
- Inheritance allows new classes to inherit properties of existing classes
- Main concepts in inheritance
 - Subclassing
 - Overriding

1. Overriding Methods (revisit) (1/2)

- Recall in lecture #3 that a user-defined class automatically inherits some methods – such as `toString()` and `equals()` – from the `Object` class
- The `Object` class is known as the `parent class` (or `superclass`); it specifies some basic behaviours common to all kinds of objects, and hence these behaviours are inherited by all its `subclasses` (`derived classes`)
- However, these inherited methods usually don't work in the subclass as they are not customised

1. Overriding Methods (revisit) (2/2)

- Hence, to make them work, we customised these inherited methods – this is called **overriding**

Lecture #3: MyBall/MyBall.java

```
/****** Overriding methods *****/  
// Overriding toString() method  
public String toString() {  
    return "[" + getColour() + ", " + getRadius() + "];"  
}  
  
// Overriding equals() method  
public boolean equals(Object obj) {  
    if (obj instanceof MyBall) {  
        MyBall ball = (MyBall) obj;  
        return this.getColour().equals(ball.getColour()) &&  
            this.getRadius() == ball.getRadius();  
    }  
    else  
        return false;  
}  
}
```

2. Creating a Subclass (1/6)

- Object-oriented languages allow **inheritance**
 - Declare a new class based on an existing class
 - So that the new class may inherit all of the attributes and methods from the other class
- Terminology
 - If class *B* is derived from class *A*, then class *B* is called a **child** (or **subclass** or **derived class**) of class *A*
 - Class *A* is called a **parent** (or **superclass**) of class *B*


2. Creating a Subclass (2/6)

- Recall the `BankAcct` class in lecture #3

lect3/BankAcct.java

```
class BankAcct {  
    private int acctNum;  
    private double balance;  
  
    public BankAcct() { }  
  
    public BankAcct(int aNum, double bal) { ... }  
  
    public int getAcctNum() { ... }  
  
    public double getBalance() {... }  
  
    public boolean withdraw(double amount) { ... }  
  
    public void deposit(double amount) { ... }  
  
    public void print() { ... }  
}
```

2. Creating a Subclass (3/6)

- Let's define a **SavingAcct** class
 - Basic information:
 - Account number, balance
 - Interest rate
 - Basic functionality:
 - Withdraw, deposit
 - Pay interest
 - Compare with the basic bank account:
 - Differences are highlighted above
 - SavingAcct shares more than 50% of the code with BankAcct
 - So, should we just cut and paste the code from **BankAcct** to create **SavingAcct**?
- 
- A red text label 'New requirements' is positioned to the right of the list. Two red arrows originate from this label: one points to the 'Interest rate' item under 'Basic information', and the other points to the 'Pay interest' item under 'Basic functionality'.

2. Creating a Subclass (4/6)

- Duplicating code is **undesirable** as it is hard to maintain
 - Need to correct all copies if errors are found
 - Need to update all copies if modifications are required
- Since the classes are logically unrelated if the codes are separated:
 - Code that works on one class cannot work on the other
- Compilation errors due to incompatible data types
- Hence, we should create **SavingAcct** as a subclass of **BankAcct**

2. Creating a Subclass (5/6)

BankAcct.java

```
class BankAcct {  
    protected int acctNum;  
    protected double balance;  
  
    //Constructors and methods not shown  
  
}
```

The “protected” keyword allows subclass to access the attributes directly

The “extends” keyword indicates inheritance

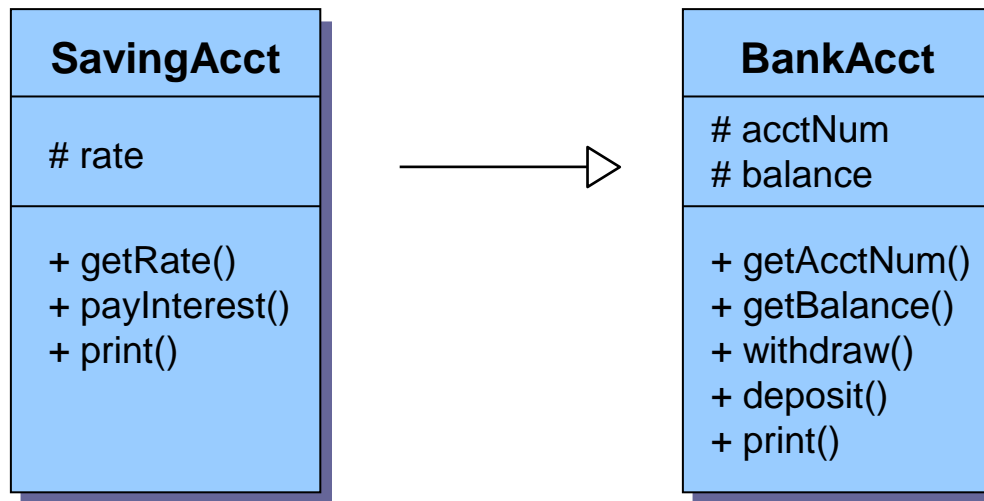
```
class SavingAcct extends BankAcct {  
  
    protected double rate;    // interest rate  
  
    public void payInterest() {  
        balance += balance * rate;  
    }  
  
}
```

This allows subclass of `SavingAcct` to access `rate`. If this is not intended, you may change it to “private”.

SavingAcct.java

2. Creating a Subclass (6/6)

- The subclass-superclass relationship is known as an “**is-a**” relationship, i.e. **SavingAcct is-a BankAcct**
- In the UML diagram, a solid line with a closed unfilled arrowhead is drawn from **SavingAcct** to **BankAcct**
- The symbol **#** is used to denoted protected member



2.1 Observations

- Inheritance greatly reduces the amount of redundant coding
- In `SavingAcct` class,
 - No definition of `acctNum` and `balance`
 - No definition of `withdraw()` and `deposit()`
- Improve maintainability:
 - Eg: If a method is modified in `BankAcct` class, no changes are needed in `SavingAcct` class
- The code in `BankAcct` remains untouched
 - Other programs that depend on `BankAcct` are unaffected ← very important!

2.2 Constructors in Subclass

- Unlike normal methods, constructors are NOT inherited
 - You need to define constructor(s) for the subclass

```
class SavingAcct extends BankAcct {  
    protected double rate;    // interest rate  
  
    public SavingAcct(int aNum, double bal, double rate) {  
        acctNum = aNum;  
        balance = bal;  
        this.rate = rate;  
    }  
  
    //.....payInterest() method not shown  
}
```

SavingAcct.java

2.3 The “super” Keyword

- The “**super**” keyword allows us to use the methods (including constructors) in the superclass directly
- If you make use of superclass’ constructor, it must be the **first statement** in the method body

```
class SavingAcct extends BankAcct {  
    protected double rate;    // interest rate  
    public SavingAcct(int aNum, double bal, double rate) {  
        super(aNum, bal);  
        this.rate = rate;  
    }  
  
    //.....payInterest() method not shown  
}
```

Using the constructor
in **BankAcct** class

SavingAcct.java

2.4 Using SavingAcct

TestSavingAcct.java

```
public class TestSavingAcct {
```

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

```
        SavingAcct sa1 = new SavingAcct(2, 1000.0, 0.03);
```

```
        sa1.print();
```

```
        sa1.withdraw(50.0);
```

Inherited method from **BankAcct**

```
        sa1.payInterest();
```

Method in **SavingAcct**

```
        sa1.print();
```

```
    }
```

```
}
```

How about **print()**?

Should it be the one in **BankAcct** class,
or should **SavingAcct** class override it?

2.5 Method Overriding (1/2)

- Sometimes we need to modify the inherited method:
 - To change/extend the functionality
 - As you already know, this is called **method overriding**
- In the **SavingAcct** class:
 - The **print()** method inherited from **BankAcct** should be modified to include the interest rate in output
- To override an inherited method:
 - Simply recode the method in the subclass using the same method header
 - Method header refers to the name and parameters type of the method (also known as **method signature**)

2.5 Method Overriding (2/2)

SavingAcct.java

```
class SavingAcct extends BankAcct {  
  
    protected double rate;        // interest rate  
  
    public double getRate() { return rate; }  
  
    public void payInterest() { ... }  
  
    public void print() {  
        System.out.println("Account Number: " + getAcctNum());  
        System.out.printf("Balance: $%.2f\n", getBalance());  
        System.out.printf("Interest: %.2f%%\n", getRate());  
    }  
}
```

- The first two lines of code in `print()` are exactly the same as `print()` of `BankAcct`
 - Can we reuse `BankAcct`'s `print()` instead of recoding?

2.6 Using “super” Again

- The `super` keyword can be used to invoke superclass' method
 - Useful when the inherited method is overridden

SavingAcct.java

```
class SavingAcct extends BankAcct {  
  
    . . .  
  
    public void print() {  
        super.print();  
        System.out.printf("Interest: %.2f%%\n", getRate());  
    }  
}
```

To use the `print()` method from `BankAcct`

3. Subclass Substitutability (1/2)

- An added advantage for inheritance is that:
 - Whenever a super class object is expected, a sub class object **is acceptable as substitution!**
 - **Caution:** the **reverse is NOT true** (Eg: A cat is an animal; but an animal may not be a cat.)
 - Hence, all existing functions that works with the super class objects will work on subclass objects with **no modification!**
- Analogy:
 - We can drive a car
 - Honda is a car (Honda is a subclass of car)
 - We can drive a Honda

3. Subclass Substitutability (2/2)

TestAcctSubclass.java

```
public class TestAcctSubclass {  
  
    public static void transfer(BankAcct fromAcct,  
                                BankAcct toAcct, double amt) {  
        fromAcct.withdraw(amt);  
        toAcct.deposit(amt);  
    };  
  
    public static void main(String[] args) {  
  
        BankAcct ba = new BankAcct(1, 234.56);  
        SavingAcct sa = new SavingAcct(2, 1000.0, 0.03);  
  
        transfer(ba, sa, 123.45);  
  
        ba.print();  
        sa.print();  
    }  
}
```

`transfer()` method can work
on the `SavingAcct` object `sa`!

4. The “Object” Class

- In Java, all classes are descendants of a predefined class called **Object**
 - **Object** class specifies some basic behaviors common to all objects
 - Any methods that works with **Object** reference will work on **object of any class**
 - Methods defined in the **Object** class are inherited in all classes
 - Two inherited **Object** methods are
 - **toString()** method
 - **equals()** method
 - However, these inherited methods usually don't work because they are not customised

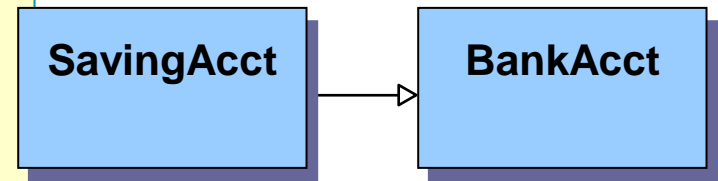
5. “is-a” versus “has-a” (1/2)

- Words of caution:
 - Do not overuse inheritance
 - Do not overuse **protected**
 - Make sure it is something inherent for future subclass
- To determine whether it is correct to inherit:
 - Use the “**is-a**” rules of thumb
 - If “B is-a A” sounds right, then ***B is a subclass of A***
 - Frequently confused with the “**has-a**” rule
 - If “B has-a A” sounds right, then ***B should have an A attribute*** (hence B depends on A)

5. “is-a” versus “has-a” (2/2)

■ UML diagrams

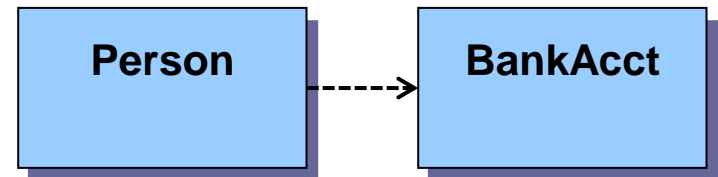
```
class BankAcct {  
    ...  
}  
  
class SavingAcct extends BankAcct {  
    ...  
}
```



Solid arrow

Inheritance: SavingAcct **IS-A** BankAcct

```
class BankAcct {  
    ...  
};  
  
class Person {  
    private BankAcct myAcct;  
};
```



Dotted arrow

Attribute: Person **HAS-A** BankAcct

6. Preventing Inheritance (“final”)

- Sometimes, we want to prevent inheritance by another class (eg: to prevent a subclass from corrupting the behaviour of its superclass)
- Use the **final** keyword
 - Eg: `final class SavingAcct` will prevent a subclass to be created from `SavingAcct`
- Sometimes, we want a class to be inheritable, but want to prevent some of its methods to be overridden by its subclass
 - Use the **final** keyword on the particular method:
`public final void payInterest() { ... }`
will prevent the subclass of `SavingAcct` from overriding `payInterest()`

7. Constraint of Inheritance in Java

- **Single inheritance**: Subclass can only have a single superclass
- **Multiple inheritance**: Subclass may have more than one superclass
- In Java, **only single inheritance is allowed**
- (Side note: Java's alternative to multiple inheritance can be achieved through the use of interfaces – to be covered later. A Java class may implement multiple interfaces.)

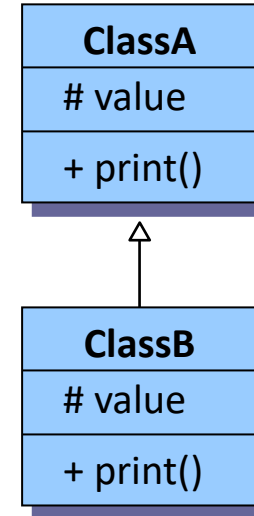
8. Quick Quiz #1 (1/2)

ClassA.java

```
class ClassA {  
    protected int value;  
  
    public ClassA() { }  
  
    public ClassA(int val) { value = val; }  
  
    public void print() {  
        System.out.println("Class A: value = " + value);  
    }  
}
```

```
class ClassB extends ClassA {  
    protected int value;  
  
    public ClassB() { }  
  
    public ClassB(int val) {  
        super.value = val - 1;  
        value = val;  
    }  
  
    public void print() {  
        super.print();  
        System.out.println("Class B: value = " + value);  
    }  
}
```

ClassB.java



8. Quick Quiz #1 (2/2)

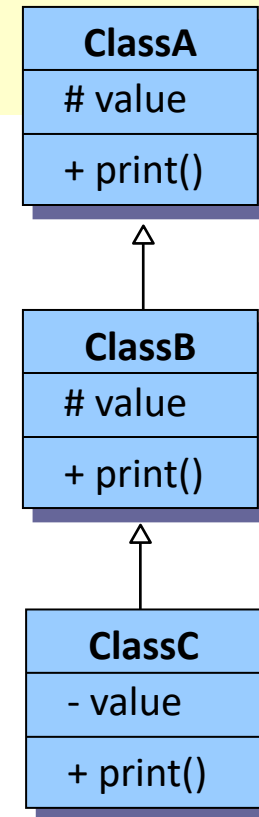
ClassC.java

```
final class ClassC extends ClassB {  
    private int value;  
  
    public ClassC() { }  
  
    public ClassC(int val) {  
        super.value = val - 1;  
        value = val;  
    }  
  
    public void print() {  
        super.print();  
        System.out.println("Class C: value = " + value);  
    }  
}
```

What is the output?

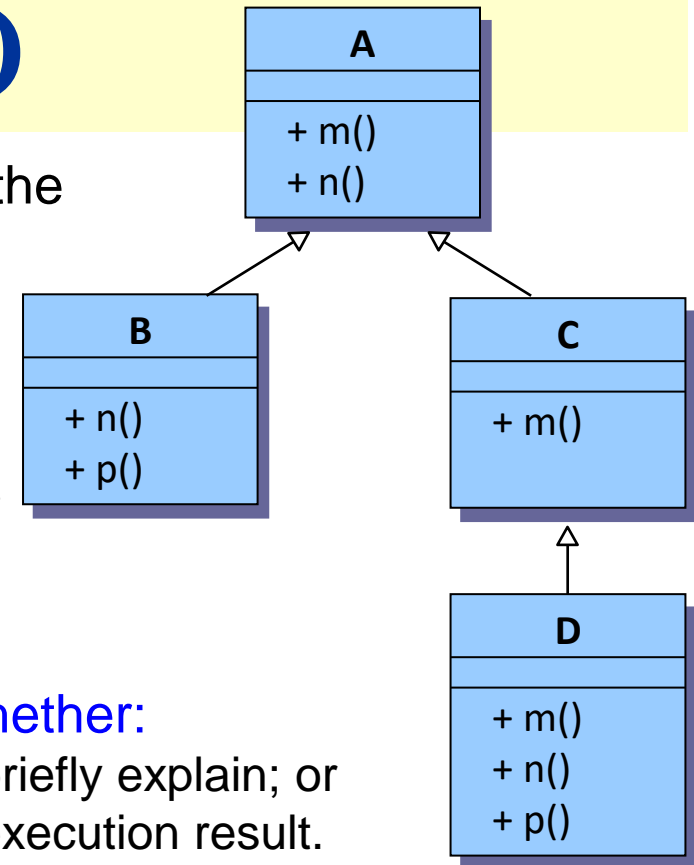
```
public class TestSubclasses {  
    public static void main(String[] args) {  
        ClassA objA = new ClassA(123);  
        ClassB objB = new ClassB(456);  
        ClassC objC = new ClassC(789);  
  
        objA.print(); System.out.println("-----");  
        objB.print(); System.out.println("-----");  
        objC.print();  
    }  
}
```

TestSubclasses.java



8. Quick Quiz #2 (1/2)

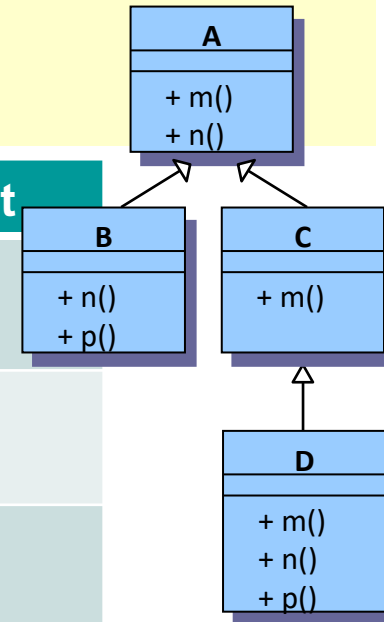
- Assume all methods print out message of the form <class name>,<method name>
- Eg: method m() in class A prints out “A.m”.
- If a class overrides an inherited method, the method’s name will appear in the class icon. Otherwise, the inherited method remains unchanged in the subclass.
- For each code fragment below, indicate whether:
 - ❑ The code will cause compilation error, and briefly explain; or
 - ❑ The code can compile and run. Supply the execution result.



Code fragment (example)	Compilation error? Why?	Execution result
<pre>A a = new A(); a.m();</pre>		A.m
<pre>A a = new A(); a.k();</pre>	Method k() not defined in class A	

8. Quick Quiz #2 (2/2)

Code fragment	Compilation error?	Execution result
A a = new C(); a.m();		
B b = new A(); b.n();		
A a = new B(); a.m();		
A a; C c = new D(); a = c; a.n();		
B b = new D(); b.p();		
C c = new C(); c.n();		
A a = new D(); a.p();		



Summary

- Inheritance:
 - ❑ Creating subclasses
 - ❑ Overriding methods
 - ❑ Using “super” keyword
 - ❑ The “Object” class

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