Software Components

Inheritance

Introducing inheritance through creating subclasses

- Improve code reusability
- Allowing overriding to replace the implementation of an inherited method

Outline

1. Overriding Methods (revisit)
2. Creating a Subclass
   - 2.1 Observations
   - 2.2 Constructors in Subclass
   - 2.3 The “super” Keyword
   - 2.4 Using SavingAcct
   - 2.5 Method Overriding
   - 2.6 Using “super” Again
3. Subclass Substitutability
4. The “Object” Class
5. “is-a” versus “has-a”
6. Preventing Inheritance (“final”)
7. Constraint of Inheritance in Java
8. Quick Quizzes

- 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 previous lectures 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 <u>don’t work</u> 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

MyBall/MyBall.java

```
  // 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 BankAccount class in previous lecture

BankAccount.java

```
class BankAccount {

  private int accountNumber;
  private double balance;

  public BankAccount() { }
  public BankAccount(int number, double aBalance) { ... }

  public int getAccountNumber() { ... }
  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 SavingAccount class
- Basic information:
  - Account number, balance
  - Interest rate
- Basic functionality:
  - Withdraw, deposit
  - Pay interest

New requirements

- Compare with the basic bank account:
  - Differences are highlighted above
  - SavingAccount shares more than 50% of the code with BankAccount
- So, should we just cut and paste the code from BankAccount to create SavingAccount?

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 SavingAccount as a subclass of BankAccount

2. Creating a Subclass

BankAccount.java

```
class BankAccount {

  protected int accountNumber;
  protected double balance;

  //Constructors and methods not shown

}
```

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

2. Creating a Subclass (5/6)

SavingAccount.java

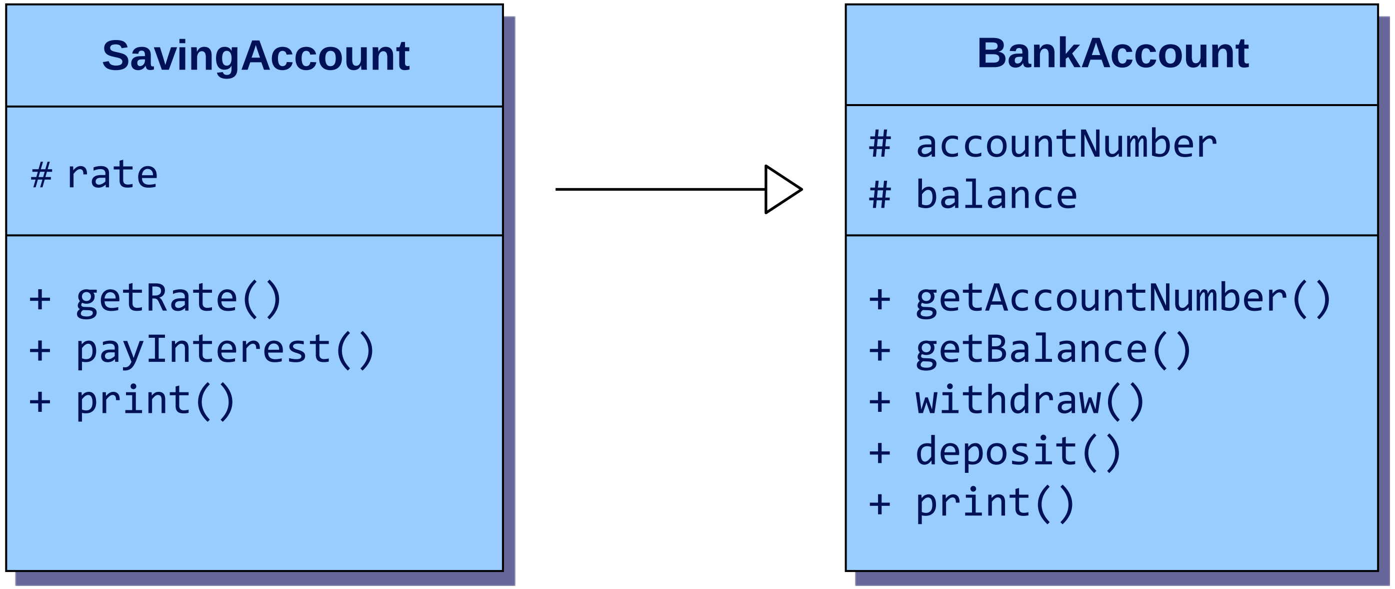
```
class SavingAccount extends BankAccount {

  // interest rate
  protected double rate;

  public void payInterest() {
      balance += balance * rate;
  }

}
```

The “extends” keyword indicates inheritance

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

2. Creating a Subclass (6/6)

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



2.1 Observations

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

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

SavingAccount.java

```java
class SavingAccount extends BankAccount {

  protected double rate;    // interest rate

  public SavingAccount(int number, double aBalance, double rate) {
      accountNumber = number;
      balance = aBalance;
      this.rate = rate;
  }

  //......payInterest() method not shown

}
```

- 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

SavingAccount.java

```
class SavingAccount extends BankAccount {

  protected double rate;    // interest rate

  public SavingAccount(int number, double aBalance, double rate) {
      super(number, aBalance);
      this.rate = rate;
  }

  //......payInterest() method not shown
}
```

Using the constructor in BankAccount class

TestSavingAccount.java

```
public class TestSavingAccount {

  public static void main(String[] args) {

      SavingAccount savingAccount = new SavingAccount(2, 1000.0, 0.03);

      savingAccount.print();
      savingAccount.withdraw(50.0);

      savingAccount.payInterest();
      savingAccount.print();
  }
}
```

Inherited method from BankAccount

Method in SavingAccount

How about print()?
Should it be the one in BankAccount class, or should SavingAccount 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 SavingAccount class:
  - The print() method inherited from BankAccount 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)

SavingAccount.java

```
class SavingAccount extends BankAccount {

  protected double rate;    // interest rate

  public double getRate() {
      return rate;
  }

  public void payInterest() { ... }

  public void print() {
      System.out.println("Account Number: " + getAccountNumber());
      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 BankAccount
  - Can we reuse BankAccount’s print() instead of recoding?

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

SavingAccount.java

```
class SavingAccount extends BankAccount {

  . . .

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

To use the print() method from BankAccount

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)

TestAccountSubclass.java

```java
public class TestAccountSubclass {

  public static void transfer(BankAccount fromAccount,
                              BankAccount toAccount,
                              double amount) {
     fromAccount.withdraw(amount);
     toAccount.deposit(amount);
  };

  public static void main(String[] args) {
     BankAccount bankAccount = new BankAccount(1, 234.56);
     SavingAccount savingAccount = new SavingAccount(2, 1000.0, 0.03);
     transfer(bankAccount, savingAccount, 123.45);

     bankAccount.print();
     savingAccount.print();
  }
}
```

transfer() method can work on the SavingAccount object savingAccount!

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)

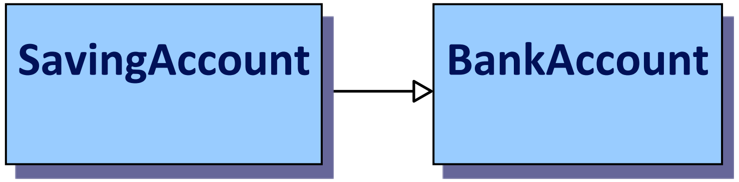
- Words of caution:
  - Do not overuse inheritance
  - Do not overuse **protected**
    - Make sure it is something inherent for future subclass
- To determine whether it is correct to inherit:
  - Use the “**is-a**” rules of thumb
    - If “B is-a A” sounds right, then ***B is a subclass of A***
  - 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”

5. “is-a” versus “has-a” (2/2)

UML diagrams

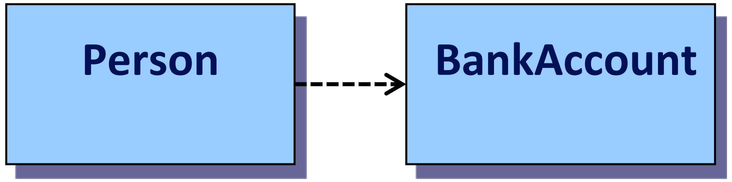
```
class BankAccount {
    ...
}

class SavingAccount extends BankAccount {
     ...
}
```



Solid arrow

Inheritance: SavingAccount IS-A BankAccount

```
class BankAccount {
    ...
};

class Person {
    private BankAccount myAccount;
};
```



Dotted arrow

Attribute: Person HAS-A BankAccount

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 SavingAccount will prevent a subclass to be created from SavingAccount
- 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 SavingAccount 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

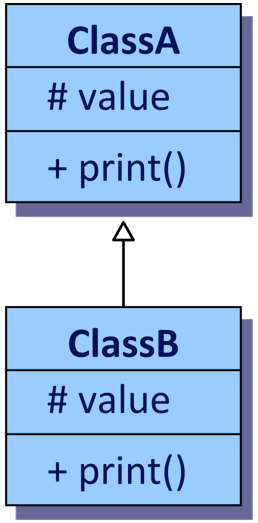
8. Quick Quiz #1 (1/2)

ClassA.java

```java
class ClassA {
  protected int value;

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

ClassB.java

```java
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);
  }
}
```



8. Quick Quiz #1

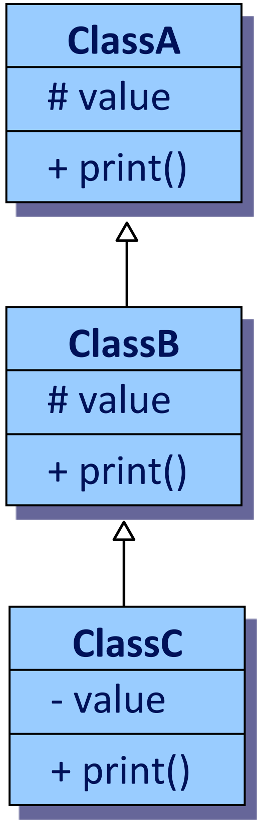
8. Quick Quiz #1 (2/2)

ClassC.java

```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);
  }
}
```

TestSubclasses.java

```java
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();
   }
}
```



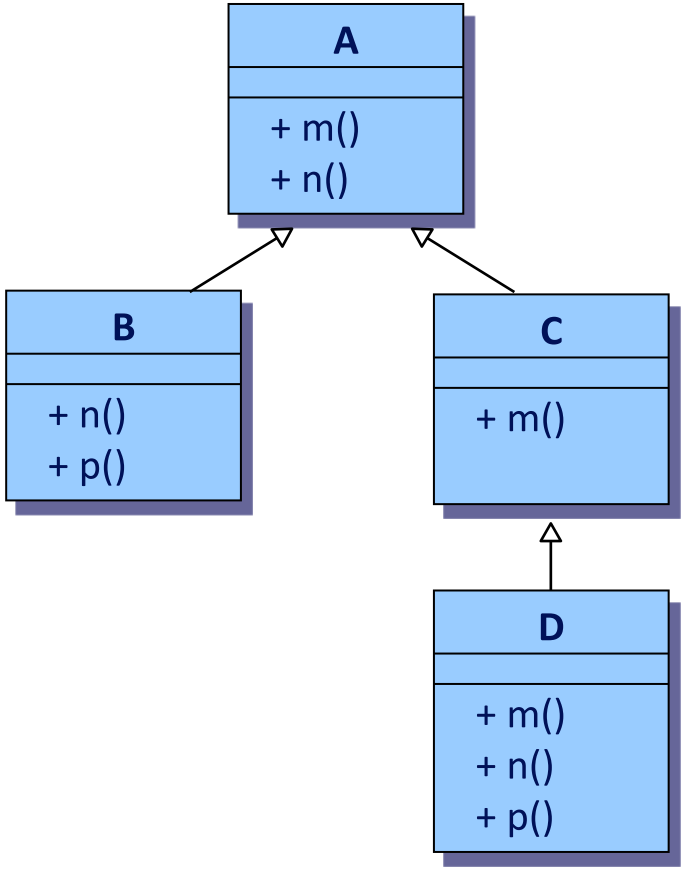
8. Quick Quiz #2 (1/2)

- 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

A a = new A();
a.m();
		A.m

A a = new A();
a.k();
	Method k() not defined in class A	



8. Quick Quiz #2

8. Quick Quiz #2 (2/2)

Code fragment	Compilation error?	Execution result

A a = new C();
a.m();		

B b = new A();
b.n();		

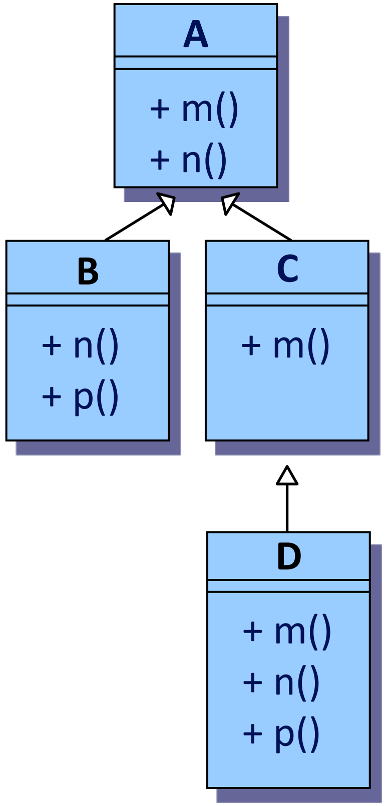
A a = new B();
a.m();		

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

Thank you!

HUS
VNU UNIVERSITY OF SCIENCE