接口

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reference

- http://bobah.net/book/export/html/55
- http://stackoverflow.com/questions/1504633/what-is-the-point-of-invokeinterface
- http://www.javaworld.com/article/2073649/core-java/why-extends-is-evil.html
- http://www.javaworld.com/article/2076814/core-java/inheritance-versus-composition--which-one-should-you-choose-.html
- http://ebnbin.com/2015/12/20/java-8-default-methods/

Outline

- 接口
- Classes versus Interfaces
- invokevirtual vs invokeinterface
- default method in Java 8

接口

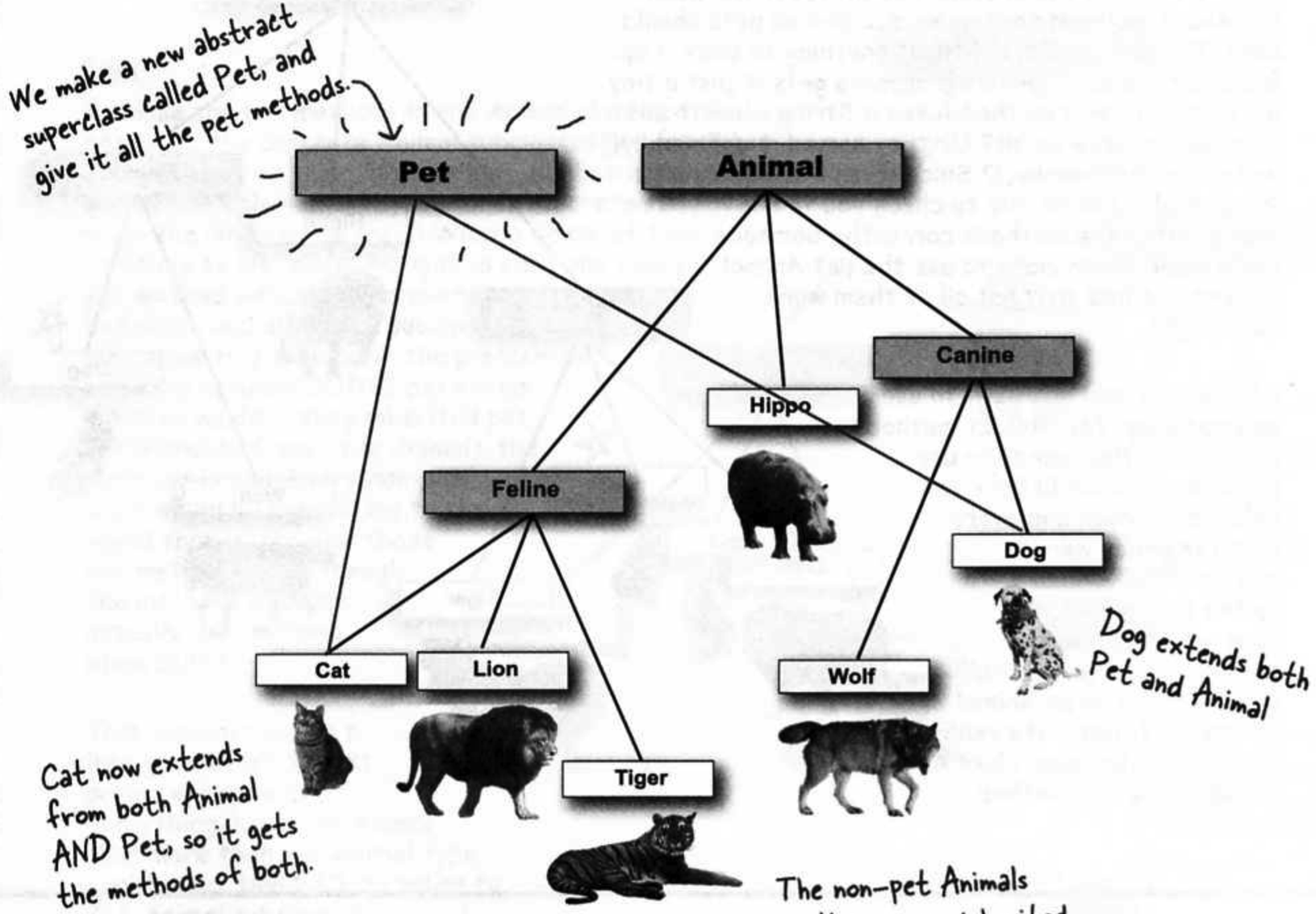
案例

- What if later you want to use Dog for a PetShop program?
  - A Pet needs methods like beFriendly() and Play().
- PetShop program may have many things.

So what we REALLY need is:

- A way to have pet behavior in **just** the pet classes
- A way to guarantee that all pet classes have all of the same methods defined (same name, same arguments, same return types, no missing methods, etc.), without having to cross your fingers and hope all the programmers get it right.
- A way to take advantage of polymorphism so that all pets can have their pet methods called, without having to use arguments, return types, and arrays for each and every pet class.

It looks like we need TWO superclasses at the top



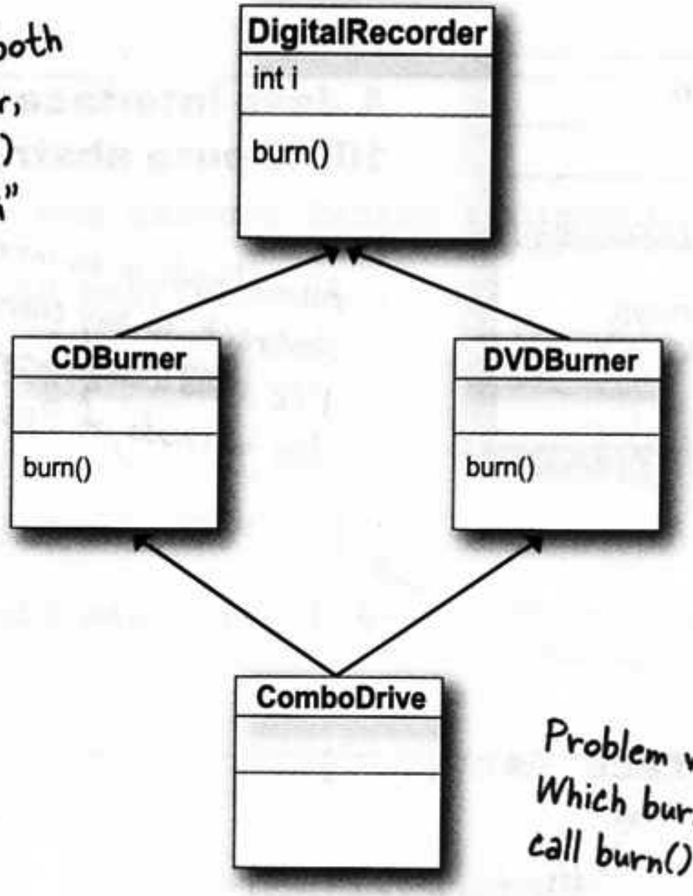
It's called "multiple inheritance" and it can be a Really Bad Thing.

That is, if it were possible to do in Java.

But it isn't, because multiple inheritance has a problem known as The Deadly Diamond of Death.

Deadly Diamond of Death

CDBurner and DVDBurner both inherit from DigitalRecorder, and both override the burn() method. Both inherit the "i" instance variable.



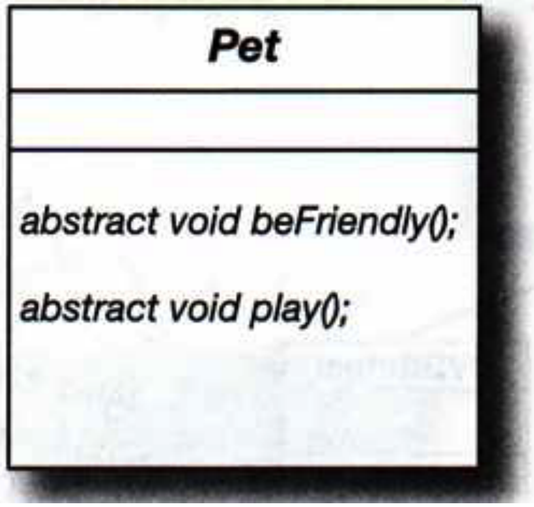
Imagine that the "i" instance variable is used by both CDBurner and DVDBurner, with different values. What happens if ComboDrive needs to use both values of "i"?

Problem with multiple inheritance. Which burn() method runs when you call burn() on the ComboDrive?

Interface

A Java interface solves your multiple inheritance problem by giving you much of the polymorphic *benefits* of multiple inheritance without the pain and suffering from the Deadly Diamond of Death (DDD).

The way in which interfaces side-step the DDD is surprisingly simple: ***make all the methods abstract!*** That way, the subclass ***must*** implement the methods (remember, abstract methods *must* be implemented by the first concrete subclass), so at runtime the JVM isn't confused about *which* of the two inherited versions it's supposed to call.



A Java interface is like a 100% pure abstract class.

All methods in an interface are abstract, so any class that IS-A Pet MUST implement (i.e. override) the methods of Pet.

To DEFINE an interface:

```
public interface Pet {...}
```

Use the keyword "interface" instead of "class"

To IMPLEMENT an interface:

```
public class Dog extends Canine implements Pet {...}
```

Use the keyword "implements" followed by the interface name. Note that when you implement an interface you still get to extend a class

Making and Implementing the Pet interface

interface methods are implicitly public and abstract, so typing in 'public' and 'abstract' is optional (in fact, it's not considered 'good style' to type the words in, but we did here just to reinforce it, and because we've never been slaves to fashion...)

You say 'interface' instead of 'class' here

```
public interface Pet {

    public abstract void beFriendly();

    public abstract void play();

}
```

All interface methods are abstract, so they MUST end in semicolons. Remember, they have no body!

Dog IS-A Animal and Dog IS-A Pet

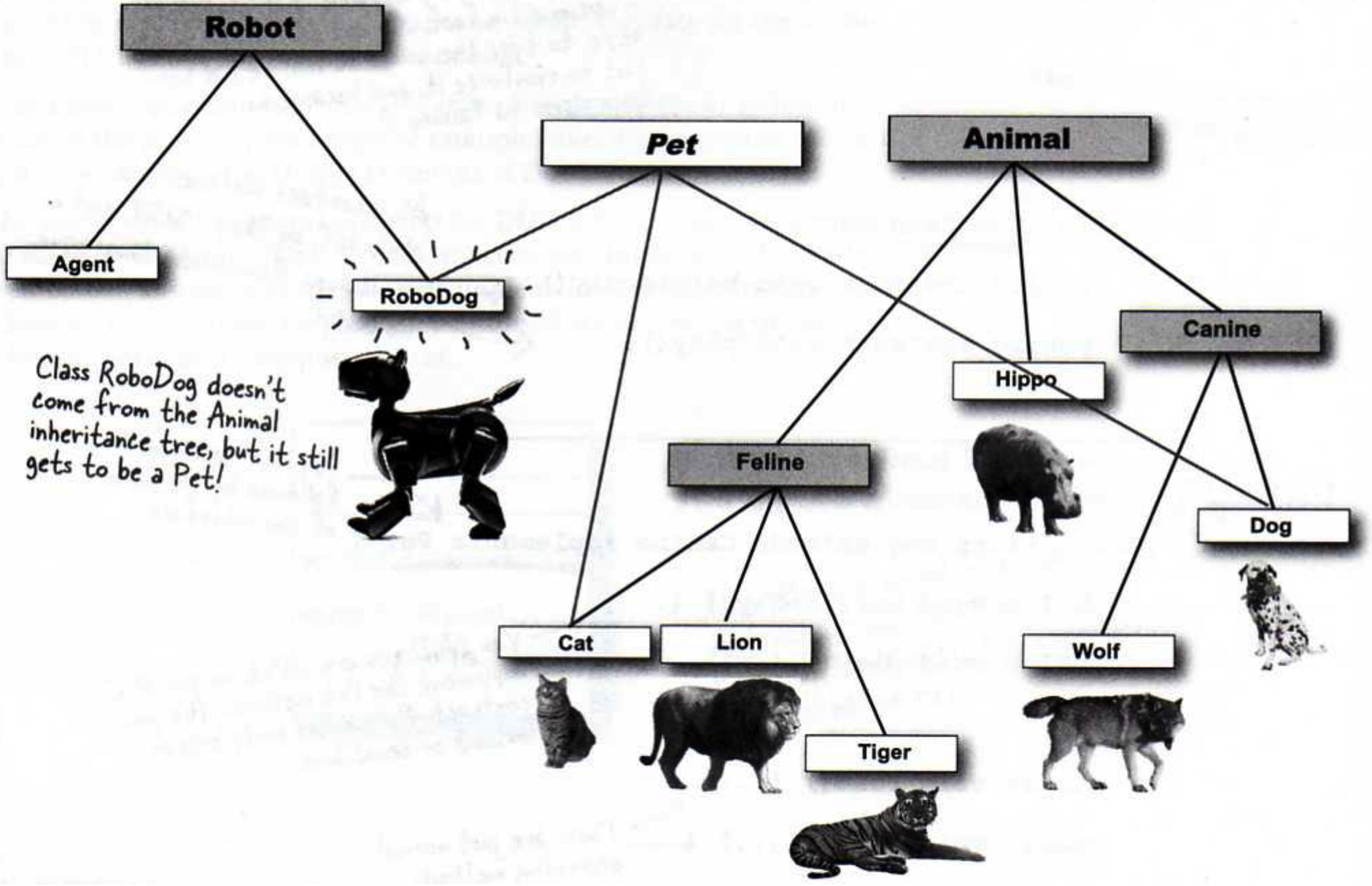
You say 'implements' followed by the name of the interface.

```
public class Dog extends Canine implements Pet {

   public void beFriendly() {...}

   public void play() {..}


   public void roam() {...}

   public void eat() {...}

}
```

You SAID you are a Pet, so you MUST implement the Pet methods. It's your contract. Notice the curly braces instead of semicolons.

These are just normal overriding methods.

Classes from *different* inheritance trees can implement the *same* interface.

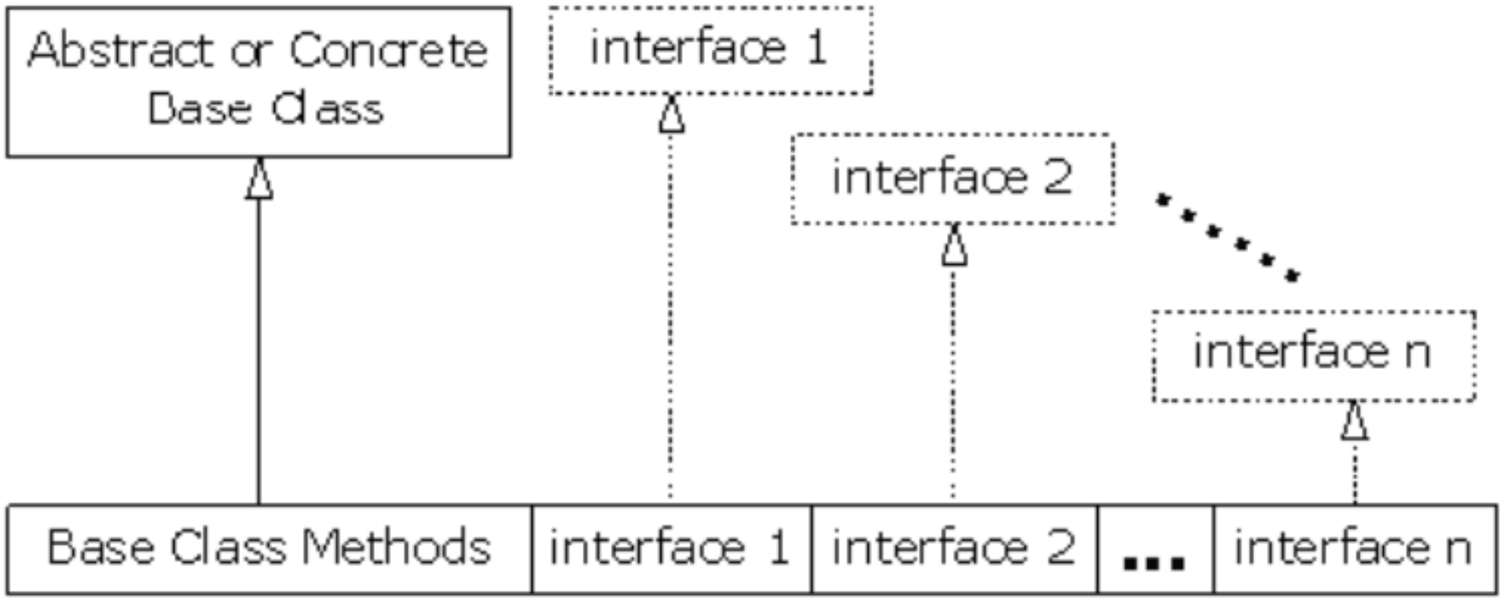


Extends one & Implements more

Better still, a class can implement *multiple* interfaces!

A Dog object IS-A Canine, and IS-A Animal, and IS-A Object, all through inheritance. But a Dog IS-A Pet through interface implementation, and the Dog might implement other interfaces as well. You could say:

```
public class Dog extends Animal implements
Pet, Saveable, Paintable { ... }
```


Abstract or Concrete Base Class
interface 1
interface 2
interface n
Base Class Methods
interface 1
interface 2
...
interface n

How do you know whether to make a class, a subclass, an *abstract* class, or an interface?

- Make a class that doesn't extend anything (other than Object) when your new class doesn't pass the IS-A test for any other type.
- Make a subclass (in other words, *extend* a class) only when you need to make a ***more specific*** version of a class and need to override or add new behaviors.
- Use an abstract class when you want to define a ***template*** for a group of subclasses, and you have at least *some* implementation code that all subclasses could use. Make the class abstract when you want to guarantee that nobody can make objects of that type.
- Use an interface when you want to define a ***role*** that other classes can play, regardless of where those classes are in the inheritance tree.

通过继承扩展接口

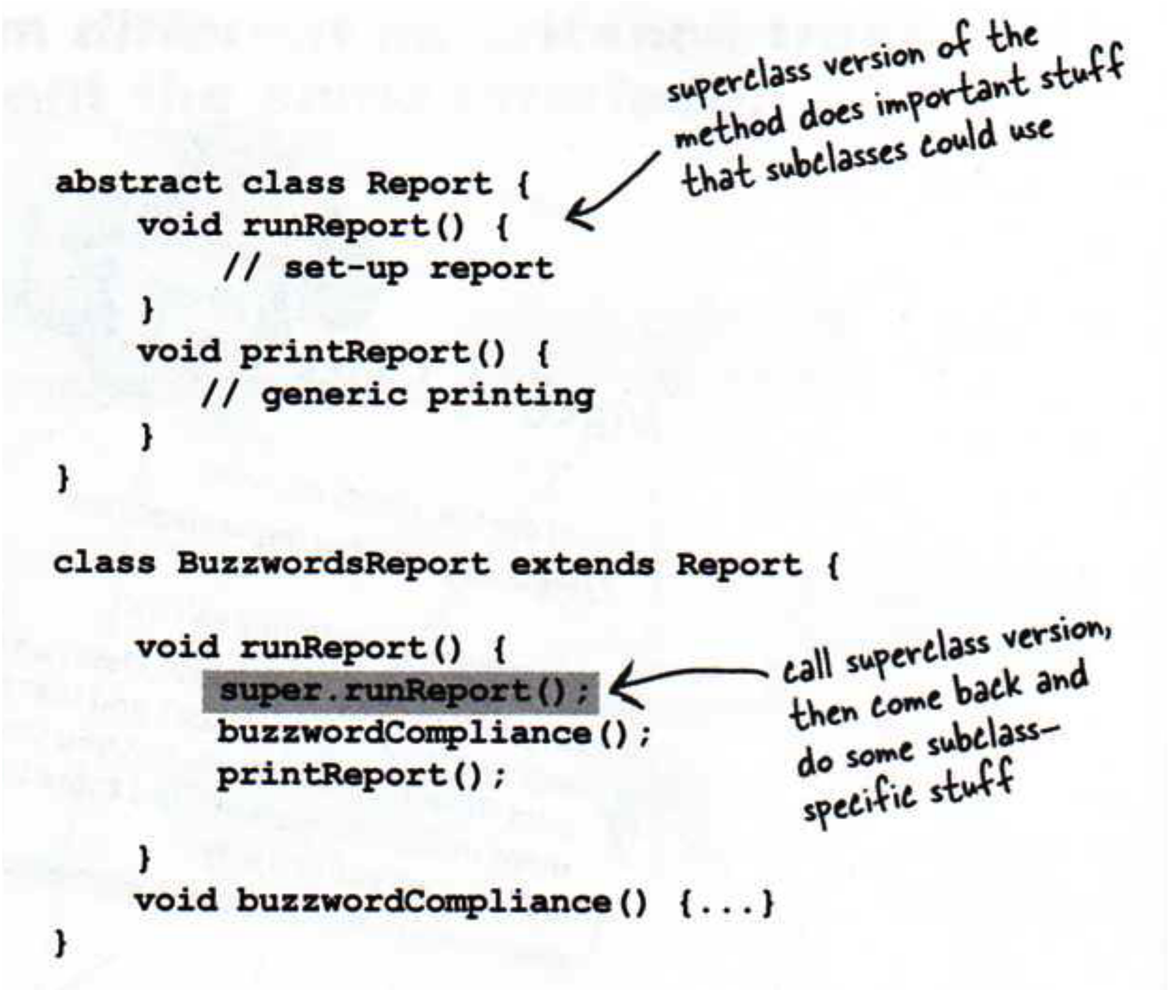
- //: c08:HorrorShow.java
- // Extending an interface with inheritance.
- interface Monster {
- void menace();
- }
- interface DangerousMonster extends Monster {
- void destroy();
- }

```
//: c08:RandVals.java
// Initializing interface fields with
// non-constant initializers.
import java.util.*;
public interface RandVals {
    Random rand = new Random();
    int randomInt = rand.nextInt(10);
    long randomLong = rand.nextLong() * 10;
    float randomFloat = rand.nextLong() * 10;
    double randomDouble = rand.nextDouble() * 10;
} ///:~
```

final关键字可用于变量声明，
一旦该变量被设定，
就不可以再改变该变量的值

- 在接口中定义的数据成员自动是**static** 和**final** 的。它们不能是“空final”，但是可以被非常量表达式初始化。
- 这些数据成员不是接口的一部分，只是被存储在该接口的静态存储区域内。
- 接口可以嵌套在类或其它接口中

Invoking the superclass version of a method



class vs interface

具体类和接口的使用

- 显示地使用具体的类
  - 锁定某个具体的实现
  - 丧失了可扩展性
  - 丧失了灵活性
- 按接口编程
  - 增加开发的可并行性

案例 1： 遍历集合

Design I - 使用具体类

```
f()
{   LinkedList list = new LinkedList();
    //...
    g( list );
}
g( LinkedList list )
{
    list.add( ... );
    g2( list )
}
```

如果我们有这样的需求变更：
我们希望快速的查找

Design II - 使用父类

```
f()
{   Collection list = new LinkedList();
    //...
    g( list );
}
g( Collection list )
{
    list.add( ... );
    g2( list )
}
```

```
f()
{   Collection c = new HashSet();
    //...
    g( c );
}
g( Collection c )
{
    for( Iterator i = c.iterator(); i.hasNext() ;)
        do_something_with( i.next() );
}
```

继承的问题

- 子类必须保持和父类同样的接口
- 子类必须继承了父类的实现
- 一旦父类脆弱发生变化，就会对子类造成很大的麻烦

集合的问题

- 使用集合给的比要的更多
- 增加了耦合性
- 增加了出错的概率

```
f()
{   Collection c = new HashSet();
    //...
    g( c );
}
g( Collection c )
{
    for( Iterator i = c.iterator(); i.hasNext() ;)
        do_something_with( i.next() );
}
```

As another example, compare this code:

```
f()
{   Collection c = new HashSet();
    //...
    g( c );
}
g( Collection c )
{
    for( Iterator i = c.iterator(); i.hasNext() ;)
        do_something_with( i.next() );
}
```

按接口编程

to this:

```
f2()
{   Collection c = new HashSet();
    //...
    g2( c.iterator() );
}
g2( Iterator i )
{   while( i.hasNext() ;)
        do_something_with( i.next() );
}
```

Design III — 使用接口

案例 2：记录最高水位的栈

Design I

```
class Stack extends ArrayList
{   private int stack_pointer = 0;
    public void push( Object article )
    {   add( stack_pointer++, article );
    }
    public Object pop()
    {   return remove( --stack_pointer );
    }
    public void push_many( Object[] articles )
    {   for( int i = 0; i < articles.length; ++i )
            push( articles[i] );
    }
}
```

```
Stack a_stack = new Stack();
a_stack.push("1");
a_stack.push("2");
a_stack.clear();
```

Disadvantage

- First, if you override everything, the base class should really be an interface, not a class. There's no point in implementation inheritance if you don't use any of the inherited methods.

- Second, and more importantly, you don't want a stack to support all ArrayList methods.

Design II

```
class Stack
{   private int stack_pointer = 0;
    private ArrayList the_data = new ArrayList();
    public void push( Object article )
    {   the_data.add( stack_pointer++, article );
    }
    public Object pop()
    {   return the_data.remove( --stack_pointer );
    }
    public void push_many( Object[] articles )
    {   for( int i = 0; i < o.length; ++i )
            push( articles[i] );
    }
}
```

Design III

```
class Monitorable_stack extends Stack
{
    private int high_water_mark = 0;
    private int current_size;
    public void push( Object article )
    {   if( ++current_size > high_water_mark )
            high_water_mark = current_size;
        super.push(article);
    }

    public Object pop()
    {   --current_size;
        return super.pop();
    }
    public int maximum_size_so_far()
    {   return high_water_mark;
    }
}
```

So far so good, but consider the fragile base-class issue. Let's say you want to create a variant on Stack that tracks the maximum stack size over a certain time period. One possible implementation might look like this

- This new class works well, at least for a while. Unfortunately, the code exploits the fact that push_many() does its work by calling push(). At first, this detail doesn't seem like a bad choice. It simplifies the code, and you get the derived class version of push(), even when the Monitorable_stack is accessed through a Stack reference, so the high_water_mark updates correctly.

- One fine day, someone might run a profiler and notice the Stack isn't as fast as it could be and is heavily used. You can rewrite the Stack so it doesn't use an ArrayList and consequently improve the Stack's performance.

Design IV

```
class Stack
{   private int stack_pointer = -1;
    private Object[] stack = new Object[1000];
    public void push( Object article )
    {   assert stack_pointer < stack.length;
        stack[ ++stack_pointer ] = article;
    }
    public Object pop()
    {   assert stack_pointer >= 0;
        return stack[ stack_pointer-- ];
    }
    public void push_many( Object[] articles )
    {   assert (stack_pointer + articles.length) < stack.length;
        System.arraycopy(articles, 0, stack, stack_pointer+1,
                                                articles.length);
        stack_pointer += articles.length;
    }
}
```

- The new version of Stack works fine; in fact, it's better than the previous version. Unfortunately, the Monitorable_stack derived class doesn't work any more, since it won't correctly track stack usage if push_many() is called (the derived-class version of push() is no longer called by the inherited push_many() method, so push_many() no longer updates the high_water_mark). Stack is a fragile base class.

Summary

- In general, it's best to avoid concrete base classes and extends relationships in favor of interfaces and implements relationships.

Listing 0.1. Eliminate fragile base classes using interfaces

```
 1| import java.util.*;
 2|
 3| interface Stack
 4| {
 5|     void push( Object o );
 6|     Object pop();
 7|     void push_many( Object[] source );
 8| }
 9|
10| class Simple_stack implements Stack
11| {   private int stack_pointer = -1;
12|     private Object[] stack = new Object[1000];
13|
14|     public void push( Object o )
15|     {   assert stack_pointer < stack.length;
16|
17|         stack[ ++stack_pointer ] = o;
18|     }
19|
20|     public Object pop()
21|     {   assert stack_pointer >= 0;
22|
23|         return stack[ stack_pointer-- ];
24|     }
25|
26|     public void push_many( Object[] source )
27|     {   assert (stack_pointer + source.length) < stack.length;
28|
29|         System.arraycopy(source,0,stack,stack_pointer+1,source.length);
30|         stack_pointer += source.length;
31|     }
32| }
33|
34|
35| class Monitorable_Stack implements Stack
36| {
37|     private int high_water_mark = 0;
38|     private int current_size;
39|     Simple_stack stack = new Simple_stack();
40|
41|     public void push( Object o )
42|     {   if( ++current_size > high_water_mark )
43|             high_water_mark = current_size;
44|         stack.push(o);
45|     }
46|
47|     public Object pop()
48|     {   --current_size;
49|         return stack.pop();
50|     }
51|
52|     public void push_many( Object[] source )
53|     {
54|         if( current_size + source.length > high_water_mark )
55|             high_water_mark = current_size + source.length;
56|
57|         stack.push_many( source );
58|     }
59|
60|     public int maximum_size()
61|     {   return high_water_mark;
62|     }
63| }
64|
```

Invokevirtual vs invokeinterface

Java

- 编译期
  - 静态
  - 多分派
  - overloading
- 运行期
  - 动态
  - 单分派
  - overridding
- 都是invokevirtual指令

```
public class Dispatch {

    static class QQ{}
    static class _360{}
    public static class Father{

        public void hardChoice(_360 _360) {
            System.out.println("Father choose 360");
        }

        public void hardChoice(QQ qq) {
            System.out.println("Father choose qq");
        }

    }

    public static class Son extends Father{

        public void hardChoice(_360 _360) {
            System.out.println("Son choose 360");
        }

        public void hardChoice(QQ qq) {
            System.out.println("Son choose qq");
        }

    }

    public static void main(String[] args) {
        Father father = new Father();
        Father son = new Son();
        father.hardChoice(new _360());
        son.hardChoice(new QQ());
    }

}
```

```
   Classfile /Users/qinliu/Dispatch.class
  Last modified 2015-5-20; size 569 bytes
  MD5 checksum 04224e8234feafca65ece76dcc3fd6c6
  Compiled from "Dispatch.java"
public class Dispatch
  minor version: 0
  major version: 52
  flags: ACC_PUBLIC, ACC_SUPER
Constant pool:
   #1 = Methodref          #13.#27        // java/lang/Object.”<init>":()V
   #2 = Class              #28            // Dispatch$Father
   #3 = Methodref          #2.#27         // Dispatch$Father."<init>":()V
   #4 = Class              #29            // Dispatch$Son
   #5 = Methodref          #4.#27         // Dispatch$Son."<init>":()V
   #6 = Class              #30            // Dispatch$_360
   #7 = Methodref          #6.#27         // Dispatch$_360."<init>":()V
   #8 = Methodref          #2.#31         // Dispatch$Father.hardChoice:(LDispatch$_360;)V
   #9 = Class              #32            // Dispatch$QQ
  #10 = Methodref          #9.#27         // Dispatch$QQ."<init>":()V
  #11 = Methodref          #2.#33         // Dispatch$Father.hardChoice:(LDispatch$QQ;)V
  #12 = Class              #34            // Dispatch
  #13 = Class              #35            // java/lang/Object
  #14 = Utf8               Son
  #15 = Utf8               InnerClasses
  #16 = Utf8               Father
  #17 = Utf8               _360
  #18 = Utf8               QQ
  #19 = Utf8               <init>
  #20 = Utf8               ()V
  #21 = Utf8               Code
  #22 = Utf8               LineNumberTable
  #23 = Utf8               main
  #24 = Utf8               ([Ljava/lang/String;)V
  #25 = Utf8               SourceFile
  #26 = Utf8               Dispatch.java
  #27 = NameAndType        #19:#20        // "<init>":()V
  #28 = Utf8               Dispatch$Father
  #29 = Utf8               Dispatch$Son
  #30 = Utf8               Dispatch$_360
  #31 = NameAndType        #36:#37        // hardChoice:(LDispatch$_360;)V
  #32 = Utf8               Dispatch$QQ
  #33 = NameAndType        #36:#38        // hardChoice:(LDispatch$QQ;)V
  #34 = Utf8               Dispatch
  #35 = Utf8               java/lang/Object
  #36 = Utf8               hardChoice
  #37 = Utf8               (LDispatch$_360;)V
  #38 = Utf8               (LDispatch$QQ;)V
```

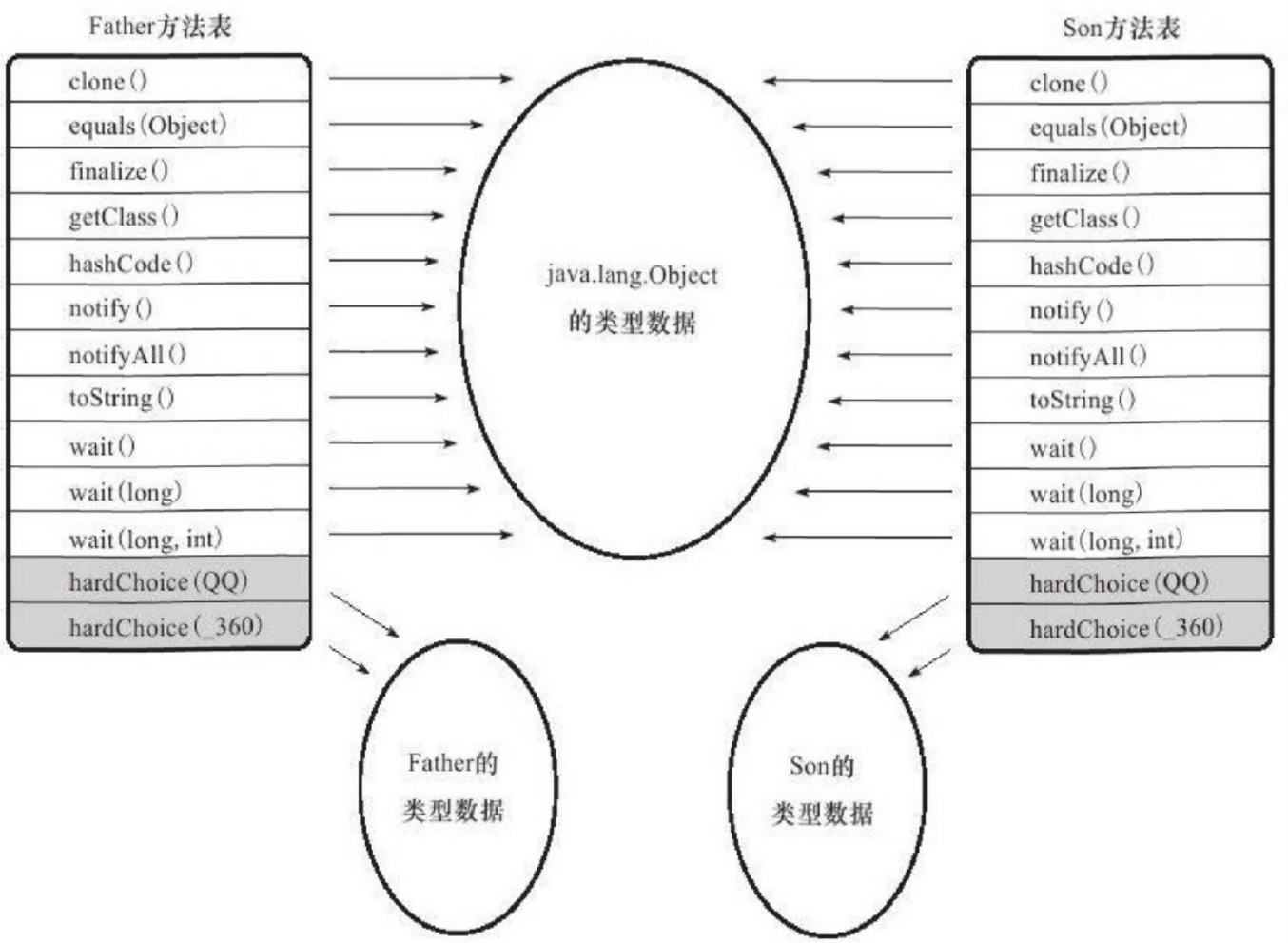
```
{
  public Dispatch();
    descriptor: ()V
    flags: ACC_PUBLIC
    Code:
      stack=1, locals=1, args_size=1
         0: aload_0
         1: invokespecial #1                  // Method java/lang/Object."<init>":()V
         4: return
      LineNumberTable:
        line 1: 0
        line 17: 4

  public static void main(java.lang.String[]);
    descriptor: ([Ljava/lang/String;)V
    flags: ACC_PUBLIC, ACC_STATIC
    Code:
      stack=3, locals=3, args_size=1
         0: new           #2                  // class Dispatch$Father
         3: dup
         4: invokespecial #3                  // Method Dispatch$Father."<init>":()V
         7: astore_1
         8: new           #4                  // class Dispatch$Son
        11: dup
        12: invokespecial #5                  // Method Dispatch$Son."<init>":()V
        15: astore_2
        16: aload_1
        17: new           #6                  // class Dispatch$_360
        20: dup
        21: invokespecial #7                  // Method Dispatch$_360."<init>":()V
        24: invokevirtual #8                  // Method Dispatch$Father.hardChoice:(LDispatch$_360;)V
        27: aload_2
        28: new           #9                  // class Dispatch$QQ
        31: dup
        32: invokespecial #10                 // Method Dispatch$QQ."<init>":()V
        35: invokevirtual #11                 // Method Dispatch$Father.hardChoice:(LDispatch$QQ;)V
        38: return
      LineNumberTable:
        line 30: 0
        line 31: 8
        line 32: 16
        line 33: 27
        line 34: 38
}
SourceFile: "Dispatch.java"
InnerClasses:
     public static #14= #4 of #12; //Son=class Dispatch$Son of class Dispatch
     public static #16= #2 of #12; //Father=class Dispatch$Father of class Dispatch
     static #17= #6 of #12; //_360=class Dispatch$_360 of class Dispatch
     static #18= #9 of #12; //QQ=class Dispatch$QQ of class Dispatch
```

分析

- 输出结果：

- Father choose 360
- Son choose qq

- 分析
- 	Father father = new Father();
- 	Father son = new Son();
-
- 	/**
- 	* Father里面有两个重载的hardChoice方法。所以会根据hardChoice()的实参的【静态类型】来决定调用哪个版本的方法。
- 	*/
- 	father.hardChoice(new _360());
-
- 	/**
- 	* 变量son的静态类型是Father，实际类型是Son。并且类Son重写了父类Father里面的两个重载的hardChoice方法。
- 	* 所以运行的时候首先会确定调用子类Son里面的方法，然后在根据hardChoice()的实参的【静态类型】来决定调用Son里面的哪个版本的方法。
- 	*/
- 	son.hardChoice(new QQ());



实现动态分派时的方法表结构

Each Java class is associated with a virtual method table that contains "links" to the bytecode of each method of a class. That table is inherited from the superclass of a particular class and extended with regard to the new methods of a subclass. E.g.,

```
class BaseClass {
    public void method1() { }
    public void method2() { }
    public void method3() { }
}

class NextClass extends BaseClass {
    public void method2() { } // overridden from BaseClass
    public void method4() { }
}
```

results in the tables

BaseClass
1. BaseClass/method1()
2. BaseClass/method2()
3. BaseClass/method3()

NextClass
1. BaseClass/method1()
2. NextClass/method2()
3. BaseClass/method3()
4. NextClass/method4()

Note, how the virtual method table of NextClass retains the order of entries of the table of BaseClass and just overwrites the "link" of method2() which it overrides.

An implementation of the JVM can thus optimize a call to invokevirtual by remembering that BaseClass/method3() will always be the third entry in the virtual method table of any object this method will ever be invoked on.

With invokeinterface this optimization is not possible. E.g.,

```
interface MyInterface {
    void ifaceMethod();
}

class AnotherClass extends NextClass implements MyInterface {
    public void method4() { } // overridden from NextClass
    public void ifaceMethod() { }
}

class MyClass implements MyInterface {
    public void method5() { }
    public void ifaceMethod() { }
}
```

This class hierarchy results in the virtual method tables

AnotherClass
1. BaseClass/method1()
2. NextClass/method2()
3. BaseClass/method3()
4. AnotherClass/method4()
5. MyInterface/ifaceMethod()

MyClass
1. MyClass/method5()
2. MyInterface/ifaceMethod()

As you can see, AnotherClass contains the interface's method in its fifth entry and MyClass contains it in its second entry. To actually find the correct entry in the virtual method table, a call to a method with invokeinterface will always have to search the complete table without a chance for the style of optimization that invokevirtual does.

```
public class InvokevirtualVsInvokeinterface {
  private static interface I {
    public int getInteger ();
  }

  private static class A implements I {
    public int getInteger () { return 0; }
  }

  private static class B extends A { }

  static volatile I i = new B();
  static volatile A a = new B();

  public static void main(String[] args) {
    {
      long tm1 = System.nanoTime();
      for (int k = 0; k < 100000000; ++k) {
          a.getInteger();
      }
      long tm2 = System.nanoTime();
      System.out.println("invokevirtual took " + (Math.abs(tm2 - tm1) / 1000) + " us");
    }

    {
      long tm1 = System.nanoTime();
      for (int k = 0; k < 100000000; ++k) {
          i.getInteger();
      }
      long tm2 = System.nanoTime();
      System.out.println("invokeinterface took " + (Math.abs(tm2 - tm1) / 1000) + " us");
    }

    // Output on Intel Xeon X5570 @ 2.93GHz:
    // invokevirtual took 41170 us
    // invokeinterface took 66305 us
  }
}
```

```
Compiled from "InvokevirtualVsInvokeinterface.java"
public class InvokevirtualVsInvokeinterface extends java.lang.Object{
static volatile InvokevirtualVsInvokeinterface$I i;

static volatile InvokevirtualVsInvokeinterface$A a;

public InvokevirtualVsInvokeinterface();
  Code:
    0:    aload_0
    1:    invokespecial    #1; //Method java/lang/Object."<init>":()V
    4:    return

public static void main(java.lang.String[]);
  Code:
    0:    invokestatic     #2; //Method java/lang/System.nanoTime:()J
    3:    lstore_1
    4:    iconst_0
    5:    istore_3
    6:    iload_3
    7:    ldc    #3; //int 100000000
    9:    if_icmpge        25
    12:   getstatic        #4; //Field a:LInvokevirtualVsInvokeinterface$A;
    15:   invokevirtual    #5; //Method InvokevirtualVsInvokeinterface$A.getInteger:()I
    18:   pop
    19:   iinc    3, 1
    22:   goto    6
    25:   invokestatic     #2; //Method java/lang/System.nanoTime:()J
    28:   lstore_3
    29:   getstatic        #6; //Field java/lang/System.out:Ljava/io/PrintStream;
    32:   new    #7; //class java/lang/StringBuilder
    35:   dup
    36:   invokespecial    #8; //Method java/lang/StringBuilder."<init>":()V
    39:   ldc    #9; //String invokevirtual took
    41:   invokevirtual    #10; //Method java/lang/StringBuilder.append:(Ljava/lang/String;)Ljava/lang/StringBuilder;
    44:   lload_3
    45:   lload_1
    46:   lsub
    47:   invokestatic     #11; //Method java/lang/Math.abs:(J)J
    50:   ldc2_w  #12; //long 1000l
    53:   ldiv
    54:   invokevirtual    #14; //Method java/lang/StringBuilder.append:(J)Ljava/lang/StringBuilder;
    57:   ldc    #15; //String  us
    59:   invokevirtual    #10; //Method java/lang/StringBuilder.append:(Ljava/lang/String;)Ljava/lang/StringBuilder;
    62:   invokevirtual    #16; //Method java/lang/StringBuilder.toString:()Ljava/lang/String;
    65:   invokevirtual    #17; //Method java/io/PrintStream.println:(Ljava/lang/String;)V
    68:   invokestatic     #2; //Method java/lang/System.nanoTime:()J
```

```
  71:  lstore_1
  72: iconst_0
  73: istore_3
  74: iload_3
  75: ldc    #3; //int 100000000
  77: if_icmpge  95
  80: getstatic    #18; //Field i:LInvokevirtualVsInvokeinterface$I;
  83:       invokeinterface      #19,  1; //InterfaceMethod
InvokevirtualVsInvokeinterface$I.getInteger:()I
  88: pop
  89: iinc   3, 1
  92: goto  74
  95: invokestatic       #2; //Method java/lang/System.nanoTime:()J
  98: lstore_3
  99: getstatic    #6; //Field java/lang/System.out:Ljava/io/PrintStream;
  102:       new   #7; //class java/lang/StringBuilder
  105:       dup
  106:       invokespecial     #8; //Method java/lang/StringBuilder."<init>":
()V
  109:       ldc    #20; //String invokeinterface took
  111:       invokevirtual      #10; //Method java/lang/StringBuilder.append:
(Ljava/lang/String;)Ljava/lang/StringBuilder;
  114:       lload_3
  115:       lload_1
  116:       lsub
  117:       invokestatic       #11; //Method java/lang/Math.abs:(J)J
  120:       ldc2_w      #12; //long 1000l
  123:       ldiv
  124:       invokevirtual      #14; //Method java/lang/StringBuilder.append:
(J)Ljava/lang/StringBuilder;
  127:       ldc    #15; //String  us
  129:       invokevirtual      #10; //Method java/lang/StringBuilder.append:
(Ljava/lang/String;)Ljava/lang/StringBuilder;
  132:       invokevirtual      #16; //Method java/lang/StringBuilder.toString:
()Ljava/lang/String;
  135:       invokevirtual      #17; //Method java/io/PrintStream.println:
(Ljava/lang/String;)V
  138:       return

static {};
  Code:
    0:   new   #21; //class InvokevirtualVsInvokeinterface$B
    3:   dup
    4:   aconst_null
    5:   invokespecial     #22; //Method
InvokevirtualVsInvokeinterface$B."<init>":
(LInvokevirtualVsInvokeinterface$1;)V
    8:   putstatic     #18; //Field i:LInvokevirtualVsInvokeinterface$I;
    11: new   #21; //class InvokevirtualVsInvokeinterface$B
    14: dup
    15: aconst_null
    16: invokespecial     #22; //Method
InvokevirtualVsInvokeinterface$B."<init>":
(LInvokevirtualVsInvokeinterface$1;)V
    19: putstatic     #4; //Field a:LInvokevirtualVsInvokeinterface$A;
    22: return

}
```

- A benchmark code to compare invokevirtual with invokeinterface performance. invokeinterface is 38% slower.

```
class Base {
public:
virtual void f() { cout << "Base::f" << endl; }
virtual void g() { cout << "Base::g" << endl; }
virtual void h() { cout << "Base::h" << endl; }
};
```

按照上面的说法，我们可以通过Base的实例来得到虚函数表。 下面是实际例程：

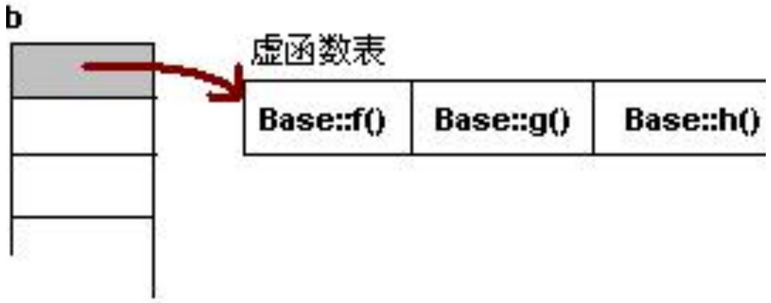
```
typedef void(*Fun)(void);
Base b;
Fun pFun = NULL;
cout << "虚函数表地址：" << (int*)(&b) << endl;
cout << "虚函数表 — 第一个函数地址：" << (int*)*(int*)(&b) << endl;
// Invoke the first virtual function
pFun = (Fun)*((int*)*(int*)(&b));
pFun();
```

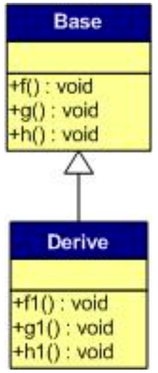
实际运行经果如下：(Windows XP+VS2003, Linux 2.6.22 + GCC 4.1.3)

```
虚函数表地址：0012FED4
虚函数表 — 第一个函数地址：0044F148
Base::f
```

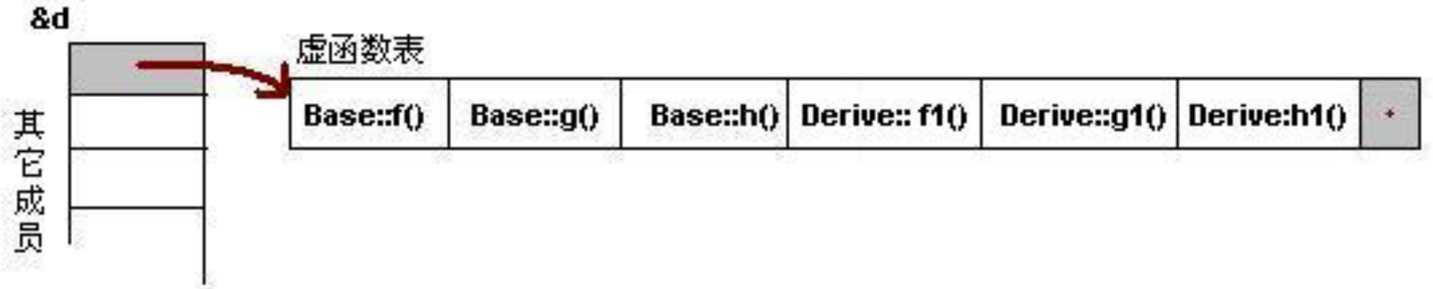
C++虚函数的实现

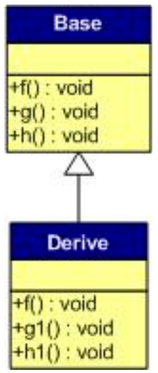
基类



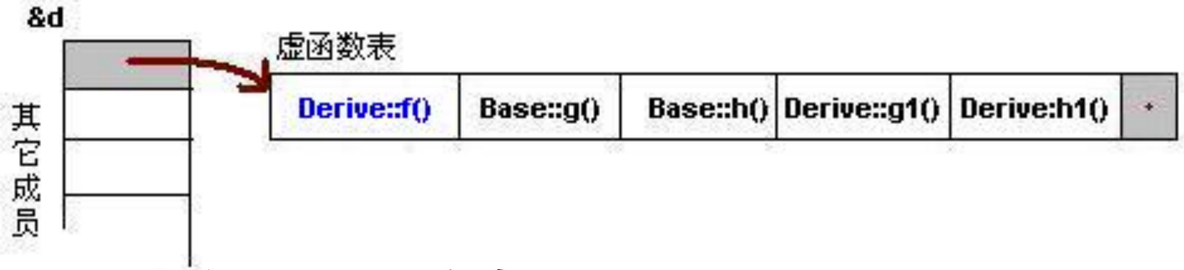


无虚函数覆盖

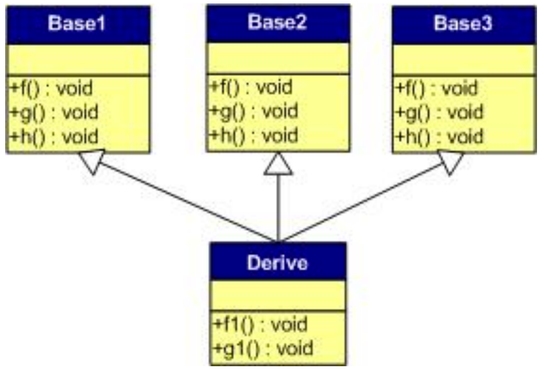




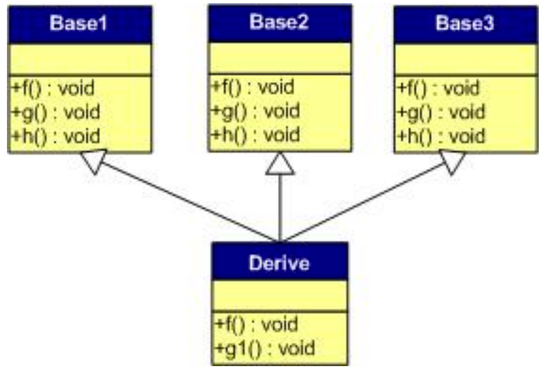
虚函数覆盖



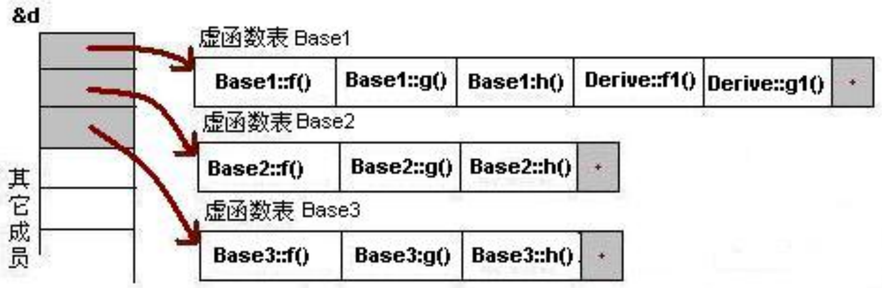
虚函数覆盖



无虚函数覆盖



虚函数覆盖



多重继承

default method
in Java 8

一个简单的例子

```
interface InterfaceA {
    default void foo() {
        System.out.println("InterfaceA foo");
    }
}

class ClassA implements InterfaceA {
}

public class Test {
    public static void main(String[] args) {
        new ClassA().foo(); // 打印：“InterfaceA foo”
    }
}
```

```
promote:Downloads liuqin$ javap -verbose Test
Classfile /Users/liuqin/Downloads/Test.class
  Last modified 2016-5-19; size 300 bytes
  MD5 checksum c5c350a838c93cf66c59d12a8a4a32b0
  Compiled from "Test.java"
public class Test
  minor version: 0
  major version: 52
  flags: ACC_PUBLIC, ACC_SUPER
Constant pool:
   #1 = Methodref          #6.#15         // java/lang/
Object."<init>":()V
   #2 = Class              #16            // ClassA
   #3 = Methodref          #2.#15         //
ClassA."<init>":()V
   #4 = Methodref          #2.#17         // ClassA.foo:()V
   #5 = Class              #18            // Test
   #6 = Class              #19            // java/lang/
Object
   #7 = Utf8               <init>
   #8 = Utf8               ()V
   #9 = Utf8               Code
  #10 = Utf8               LineNumberTable
  #11 = Utf8               main
  #12 = Utf8               ([Ljava/lang/String;)V
  #13 = Utf8               SourceFile
  #14 = Utf8               Test.java
  #15 = NameAndType        #7:#8          // "<init>":()V
  #16 = Utf8               ClassA
  #17 = NameAndType        #20:#8         // foo:()V
  #18 = Utf8               Test
  #19 = Utf8               java/lang/Object
  #20 = Utf8               foo
{
  public Test();
    descriptor: ()V
    flags: ACC_PUBLIC
    Code:
      stack=1, locals=1, args_size=1
         0: aload_0
         1: invokespecial #1                  // Method
java/lang/Object."<init>":()V
         4: return
      LineNumberTable:
        line 10: 0

  public static void main(java.lang.String[]);
    descriptor: ([Ljava/lang/String;)V
    flags: ACC_PUBLIC, ACC_STATIC
    Code:
      stack=2, locals=1, args_size=1
         0: new           #2                  // class
ClassA
         3: dup
         4: invokespecial #3                  // Method
ClassA."<init>":()V
         7: invokevirtual #4                  // Method
ClassA.foo:()V
        10: return
      LineNumberTable:
        line 12: 0
        line 13: 10
}
SourceFile: "Test.java"
```

为什么要有默认方法

- 在 java 8 之前，接口与其实现类之间的 耦合度 太高了（tightly coupled），当需要为一个接口添加方法时，所有的实现类都必须随之修改。默认方法解决了这个问题，它可以为接口添加新的方法，而不会破坏已有的接口的实现。这在 lambda 表达式作为 java 8 语言的重要特性而出现之际，为升级旧接口且保持向后兼容（backward compatibility）提供了途径。

- String[] array = new String[] {
- "hello",
- ", ",
- "world",
- };
- List<String> list = Arrays.asList(array);
- list.forEach(System.out::println); // 这是 jdk 1.8 新增的接口默认方法

jdk 1.8 的 Iterable 接口中的 forEach 默认方法：

- package java.lang;

- import java.util.Objects;
- import java.util.function.Consumer;

- public interface Iterable<T> {
- default void forEach(Consumer<? super T> action) {
- Objects.requireNonNull(action);
- for (T t : this) {
- action.accept(t);
- }
- }
- }

默认方法的继承

```
interface InterfaceA {
    default void foo() {
        System.out.println("InterfaceA foo");
    }
}

interface InterfaceB extends InterfaceA {
}

interface InterfaceC extends InterfaceA {
    @Override
    default void foo() {
        System.out.println("InterfaceC foo");
    }
}

interface InterfaceD extends InterfaceA {
    @Override
    void foo();
}

public class Test {
    public static void main(String[] args) {
        new InterfaceB() {}.foo(); // 打印：“InterfaceA foo”
        new InterfaceC() {}.foo(); // 打印：“InterfaceC foo”
        new InterfaceD() {
            @Override
            public void foo() {
                System.out.println("InterfaceD foo");
            }
        }.foo(); // 打印：“InterfaceD foo”

        // 或者使用 lambda 表达式
        ((InterfaceD) () -> System.out.println("InterfaceD foo")).foo();
    }
}
```

默认方法的多重继承

```
interface InterfaceA {
    default void foo() {
        System.out.println("InterfaceA foo");
    }
}

interface InterfaceB {
    default void bar() {
        System.out.println("InterfaceB bar");
    }
}

interface InterfaceC {
    default void foo() {
        System.out.println("InterfaceC foo");
    }

    default void bar() {
        System.out.println("InterfaceC bar");
    }
}

class ClassA implements InterfaceA, InterfaceB {
}

// 错误
//class ClassB implements InterfaceB, InterfaceC {
//}

class ClassB implements InterfaceB, InterfaceC {
    @Override
    public void bar() {
        InterfaceB.super.bar(); // 调用 InterfaceB 的 bar 方法
        InterfaceC.super.bar(); // 调用 InterfaceC 的 bar 方法
        System.out.println("ClassB bar"); // 做其他的事
    }
}
```

```
promote:Downloads liuqin$ javap -verbose ClassB
Classfile /Users/liuqin/Downloads/ClassB.class
  Last modified 2016-5-19; size 457 bytes
  MD5 checksum 3ce098725d3829e25f1f22f48fbb014a
  Compiled from "ClassB.java"
class ClassB implements InterfaceB,InterfaceC
  minor version: 0
  major version: 52
  flags: ACC_SUPER
Constant pool:
   #1 = Methodref          #8.#18         // java/lang/Object."<init>":()V
   #2 = InterfaceMethodref #9.#19         // InterfaceB.bar:()V
   #3 = InterfaceMethodref #10.#19        // InterfaceC.bar:()V
   #4 = Fieldref           #20.#21        // java/lang/System.out:Ljava/io/
PrintStream;
   #5 = String             #22            // ClassB bar
   #6 = Methodref          #23.#24        // java/io/PrintStream.println:
(Ljava/lang/String;)V
   #7 = Class              #25            // ClassB
   #8 = Class              #26            // java/lang/Object
   #9 = Class              #27            // InterfaceB
  #10 = Class              #28            // InterfaceC
  #11 = Utf8               <init>
  #12 = Utf8               ()V
  #13 = Utf8               Code
  #14 = Utf8               LineNumberTable
  #15 = Utf8               bar
  #16 = Utf8               SourceFile
  #17 = Utf8               ClassB.java
  #18 = NameAndType        #11:#12        // "<init>":()V
  #19 = NameAndType        #15:#12        // bar:()V
  #20 = Class              #29            // java/lang/System
  #21 = NameAndType        #30:#31        // out:Ljava/io/PrintStream;
  #22 = Utf8               ClassB bar
  #23 = Class              #32            // java/io/PrintStream
  #24 = NameAndType        #33:#34        // println:(Ljava/lang/String;)V
  #25 = Utf8               ClassB
  #26 = Utf8               java/lang/Object
  #27 = Utf8               InterfaceB
  #28 = Utf8               InterfaceC
  #29 = Utf8               java/lang/System
  #30 = Utf8               out
  #31 = Utf8               Ljava/io/PrintStream;
  #32 = Utf8               java/io/PrintStream
  #33 = Utf8               println
  #34 = Utf8               (Ljava/lang/String;)V
{
  ClassB();
    descriptor: ()V
    flags:
    Code:
      stack=1, locals=1, args_size=1
         0: aload_0
         1: invokespecial #1                  // Method java/lang/
Object."<init>":()V
         4: return
      LineNumberTable:
        line 30: 0

  public void bar();
    descriptor: ()V
    flags: ACC_PUBLIC
    Code:
      stack=2, locals=1, args_size=1
         0: aload_0
         1: invokespecial #2                  // InterfaceMethod
InterfaceB.bar:()V
         4: aload_0
         5: invokespecial #3                  // InterfaceMethod
InterfaceC.bar:()V
         8: getstatic     #4                  // Field java/lang/
System.out:Ljava/io/PrintStream;
        11: ldc           #5                  // String ClassB bar
        13: invokevirtual #6                  // Method java/io/
PrintStream.println:(Ljava/lang/String;)V
        16: return
      LineNumberTable:
        line 33: 0
        line 34: 4
        line 35: 8
        line 36: 16
}
SourceFile: "ClassB.java"
```

接口继承行为发生冲突时的解决规则

```
interface InterfaceA {
    default void foo() {
        System.out.println("InterfaceA foo");
    }
}

interface InterfaceB extends InterfaceA {
    @Override
    default void foo() {
        System.out.println("InterfaceB foo");
    }
}

// 正确
class ClassA implements InterfaceA, InterfaceB {
}

class ClassB implements InterfaceA, InterfaceB {
    @Override
    public void foo() {
//        InterfaceA.super.foo(); // 错误
        InterfaceB.super.foo();
    }
}
```

如果想要调用 InterfaceA 接口中的 foo 方法

```
interface InterfaceA {
    default void foo() {
        System.out.println("InterfaceA foo");
    }
}

interface InterfaceB extends InterfaceA {
    @Override
    default void foo() {
        System.out.println("InterfaceB foo");
    }
}

interface InterfaceC extends InterfaceA {
    @Override
    default void foo() {
        InterfaceA.super.foo();
    }
}

class ClassA implements InterfaceB, InterfaceC {
    @Override
    public void foo() {
        InterfaceB.super.foo();
        InterfaceC.super.foo();
    }
}
```

接口与抽象类

当接口继承行为发生冲突时的另一个规则是，类的方法声明优先于接口默认方法，无论该方法是具体的还是抽象的。

```
interface InterfaceA {
    default void foo() {
        System.out.println("InterfaceA foo");
    }

    default void bar() {
        System.out.println("InterfaceA bar");
    }
}

abstract class AbstractClassA {
    public abstract void foo();

    public void bar() {
        System.out.println("AbstractClassA bar");
    }
}

class ClassA extends AbstractClassA implements InterfaceA {
    @Override
    public void foo() {
        InterfaceA.super.foo();
    }
}

public class Test {
    public static void main(String[] args) {
        ClassA classA = new ClassA();
        classA.foo(); // 打印：“InterfaceA foo”
        classA.bar(); // 打印：“AbstractClassA bar”
    }
}
```

```
promote:Downloads liuqin$ javap -verbose Test2
Classfile /Users/liuqin/Downloads/Test2.class
  Last modified 2016-5-19; size 332 bytes
  MD5 checksum 502a6670288dd911087660d26e2ff3ad
  Compiled from "Test2.java"
public class Test2
  minor version: 0
  major version: 52
  flags: ACC_PUBLIC, ACC_SUPER
Constant pool:
   #1 = Methodref          #7.#16         // java/lang/Object."<init>":()V
   #2 = Class              #17            // ClassA
   #3 = Methodref          #2.#16         // ClassA."<init>":()V
   #4 = Methodref          #2.#18         // ClassA.foo:()V
   #5 = Methodref          #2.#19         // ClassA.bar:()V
   #6 = Class              #20            // Test2
   #7 = Class              #21            // java/lang/Object
   #8 = Utf8               <init>
   #9 = Utf8               ()V
  #10 = Utf8               Code
  #11 = Utf8               LineNumberTable
  #12 = Utf8               main
  #13 = Utf8               ([Ljava/lang/String;)V
  #14 = Utf8               SourceFile
  #15 = Utf8               Test2.java
  #16 = NameAndType        #8:#9          // "<init>":()V
  #17 = Utf8               ClassA
  #18 = NameAndType        #22:#9         // foo:()V
  #19 = NameAndType        #23:#9         // bar:()V
  #20 = Utf8               Test2
  #21 = Utf8               java/lang/Object
  #22 = Utf8               foo
  #23 = Utf8               bar
{
  public Test2();
    descriptor: ()V
    flags: ACC_PUBLIC
    Code:
      stack=1, locals=1, args_size=1
         0: aload_0
         1: invokespecial #1                  // Method java/lang/
Object."<init>":()V
         4: return
      LineNumberTable:
        line 26: 0

  public static void main(java.lang.String[]);
    descriptor: ([Ljava/lang/String;)V
    flags: ACC_PUBLIC, ACC_STATIC
    Code:
      stack=2, locals=2, args_size=1
         0: new           #2                  // class ClassA
         3: dup
         4: invokespecial #3                  // Method ClassA."<init>":()V
         7: astore_1
         8: aload_1
         9: invokevirtual #4                  // Method ClassA.foo:()V
        12: aload_1
        13: invokevirtual #5                  // Method ClassA.bar:()V
        16: return
      LineNumberTable:
        line 28: 0
        line 29: 8
        line 30: 12
        line 31: 16
}
SourceFile: "Test2.java"
```

接口和抽象方法不可相互替代

- 虽然 Java 8 的接口的默认方法就像抽象类，能提供方法的实现，但是他们俩仍然是 不可相互代替的：
  - 接口可以被类多实现（被其他接口多继承），抽象类只能被单继承。
  - 接口中没有 this 指针，没有构造函数，不能拥有实例字段（实例变量）或实例方法，无法保存 状态（state），抽象方法中可以。
  - 抽象类不能在 java 8 的 lambda 表达式中使用。
  - 从设计理念上，接口反映的是 “like-a” 关系，抽象类反映的是 “is-a” 关系。

接口的静态方法

```
interface InterfaceA {
    default void foo() {
        printHelloWorld();
    }

    static void printHelloWorld() {
        System.out.println("hello, world");
    }
}

public class Test {
    public static void main(String[] args) {
        InterfaceA.printHelloWorld(); // 打印：“hello, world”
    }
}
```

其他注意点

- default 关键字只能在接口中使用（以及用在 switch 语句的 default 分支），不能用在抽象类中。
- 接口默认方法不能覆写 Object 类的 equals、hashCode 和 toString 方法。
- 接口中的静态方法必须是 public 的，public 修饰符可以省略，static 修饰符不能省略。
- 即使使用了 java 8 的环境，一些 IDE 仍然可能在一些代码的实时编译提示时出现异常的提示（例如无法发现 java 8 的语法错误），因此不要过度依赖 IDE。