Nested Classes in Java

Technion - Israel Institute of Technology

Slides by: Alon Mishne
Edited by: Eran Gilad, Eyal Moscovici April 2013
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236703 - Object-Oriented Programming
In This Tutorial

• Explanation of the nested class concept.
• Access modifiers and nested classes.
• The types of nested classes in Java.
• Inheritance and inner classes.
• Nested classes in the JVM.
• Limits and caveats
• Like C++, Java supports defining classes inside other classes. The general term for these classes is **nested classes**.
• Classes which are not defined inside other classes are called **top-level classes**.
• In Java, there are 4 types of nested classes.
• Nested classes are used extensively in Java.
Access Control

• Reminder: in Java there are 4 access control modifiers. Here’s a more accurate table of their effects:

<table>
<thead>
<tr>
<th>Modifier</th>
<th>Accessible from (in addition to defining class)</th>
</tr>
</thead>
<tbody>
<tr>
<td>public</td>
<td>Any class of any package</td>
</tr>
<tr>
<td>protected</td>
<td>Subclasses + any class of the same package</td>
</tr>
<tr>
<td>private</td>
<td>Only classes that share the same top-level class as the defining class</td>
</tr>
<tr>
<td>default</td>
<td>Any class of the same package</td>
</tr>
</tbody>
</table>

• What does this mean about nested classes?
Access Control Example

- All classes here have access to private variables of all of the others.
  - Though E must have an instance of the other classes to access them.
Type 1 – Static Nested Classes

• Defined as member classes, with the **static** modifier.
• Most similar to nested classes in C++.
• Helps in encapsulation – for example, if B is useful only to A.

A static nested class can have any visibility, just like any other member.

• Cannot access non-static members of enclosing class.

```class A {
    ...
    static class B {
        ...
    }
    ...
}
```
Inner Classes

• Nested classes which are not static are called **inner classes**.
• There are 3 kinds of inner classes:
  – non-static member class, a.k.a. (regular) inner class
  – local class
  – anonymous class
• An instance of an inner classes is associated with an instance of the enclosing class.
• Consequentially, inner classes can access **non-static** members of the enclosing class.
  • Also static members, of course.
More on Inner Classes

• Instances of enclosing / nested classes do not contain each other – they are only associated with each other.
• An instance of an enclosing class may be associated with multiple instances of inner classes.
• An instance of an inner class is associated with exactly one instance of the enclosing class.
Type 2 – Non-Static Member Classes

• Defined as member classes, **without** the static modifier.
• An instance of B is always associated with an instance of A.
• A.B can have any visibility.
• Created with qualified new

```java
class A {
    ...
    class B {
        ...
    }
    ...
}
A a = new A();
A.B ab = a.new B();
// ‘ab’ is associated with ‘a’
```
Access to enclosing class

• If B is an inner class of A, it may access the associated A instance’s `this` pointer via the qualified `A.this`.
• This access is only available for non static nested classes (why?).

```java
class A {
    private void foo() { System.out.println("A"); }
    class B {
        void foo() { System.out.println("B"); }
        void bar() {
            A.this.foo(); //prints A
            foo(); //prints B
        }
    }
}
```
Type 3 – Local Classes

• Defined inside a method, and only visible from the point it is declared to the end of the method.
• If defined inside a non-static method, is considered an inner class and has access to non-static members – otherwise, behaves more like static nested class.
• Can access parameters as well as local variables declared in the same method before the class is declared, but only as long as they are marked `final` (why?).
class Outer {
    private int x;
    void f(final int z) {
        final int y = 4;
        Inner i = new Inner(); // Error.
        class Inner {
            void inc() { x += z + y; } // Legal – y and z are final
        }
        Inner i = new Inner();
    }
    static void g() {
        Inner i = new Inner(); // Illegal – class declaration
        // must appear first
        class Inner { // Legal to use the same name
            void inc() {
                x++; // Illegal – cannot access non-static field x
            }
        }
    }
}
Typically, only one instance of a local class is needed per method invocation.

Anonymous classes are also created inside the body of a method, however
- Defining the class also defines an instance of it
- No more instances can be defined from that class

Probably the most complicated of the nested class types, and probably the most useful.
Anonymous Classes - Syntax

```
new <parent class / interface>(<c’tor arguments>) {
  <anonymous class body>
}
```

- Simple example:

```
interface A {
  void g();
}

class B {
  void f() {
    A a = new A() {
      @Override void g() {}
    };
    a.g();
  }
}
```
Anonymous Classes & Constructors

- Anonymous classes cannot have constructors* (they don’t even have a name).
- Constructors of a parent class can be invoked using the argument list.

```java
class A {
    public A(int x) {...}
    void g() {...}
}
class B {
    A f() {
        return (new A(3){...});
    }
}
```

* They can have instance initializers, though. Outside of our scope.
# Nested Class Types Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Inner (associated with outer instance)</th>
<th>Definition point</th>
<th>Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static nested class</td>
<td>No</td>
<td>As a member of another class.</td>
<td>Depends on access modifier.</td>
</tr>
<tr>
<td>Non-static member class</td>
<td>Yes</td>
<td>As a member of another class.</td>
<td>Depends on access modifier.</td>
</tr>
<tr>
<td>(regular inner class)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local class</td>
<td>Yes (if defined in non-static method)</td>
<td>Inside a method.</td>
<td>From the point it is defined to the end of the method.</td>
</tr>
<tr>
<td>Anonymous class</td>
<td>Yes (if defined in non-static method)</td>
<td>As an expression (since defining it also returns the instance).</td>
<td>None.</td>
</tr>
</tbody>
</table>
• It’s possible to inherit from an inner class, but only as long as the inheriting class can be associated with a subtype of the original outer class.

```java
class BaseOuter {
    class BaseInner {}
    // Legal because BaseOuter is a subtype of BaseOuter:
    class BaseInner2 extends BaseInner {}
}

class DerivedOut extends BaseOuter {
    // Legal because DerivedOuter is a subtype of BaseOuter:
    class DerivedInner extends BaseInner {}
}
```
Inheriting from inner classes 2/2

• What would happen without this limitation?

```java
class Outer {
    int x;
    class Inner {
        void f() { x++; }
    }
}

class Derived extends Outer.Inner {}

void someMethod() {
    new Derived().f(); // What will happen?
}
```
Nested Classes and the JVM

• There is no concept of nested classes in bytecode or in the JVM. The compiler generates a separate .class file for each class.

• Since access modifiers are enforced in the JVM, the compiler sometimes has to work hard to split nested classes into independent classes.

```java
public class Outer {
    class Inner {}
}

> javac Outer.java
> ls
Outer.java
Outer.class
Outer$Inner.class
```
Inner Classes and the JVM

public class Outer {
    class Inner {}
}

Inner actually compiles to something like:

class Outer$Inner {
    Outer $this;
    Inner(Outer $this) {
        this.$this = $this;
    }
}

Likewise, any outer local variables used are passed in the constructor, which is why only final locals are permitted (what would happen otherwise?)
Some Limitations of Nested Classes

- Nested interfaces are always implicitly static.
- Inner classes may not declare static members (with the exception of compile-time constant fields).
Blocks in Java?

- So, how would you create an equivalent to a Smalltalk block?

```java
interface Block {
  Object value();
  Object value(Object o1);
  Object value(Object o1, Object o2);
  ...
}

void foo(Block aBlock) {
  System.out.println(aBlock.value());
}

void bar() {
  final int v = 42;
  foo(new Block() {
      @Override Object value() { return v; }
  });
}
```

What’s missing?
abstract class Block {
    static class NotImplementedException
        extends RuntimeException {}
    Object value() { throw new NotImplementedException(); }
    Object value(Object o1) { throw new NotImplementedException(); }
    Object value(Object o1, Object o2) { throw new ... }
    ...
}

void bar() {
    final int v = 42;
    foo(new Block() {
        @Override Object value() { return v; }
    });
}

• Remember, Squeak’s blocks are instances of a class too... (BlockClosure)
More Information

• Sun’s official tutorial at http://docs.oracle.com/javase/tutorial/java/javaOO/nested.html