Inner Classes

Inner Classes

- In Java (and C++), a class can be **nested within** another class.
- Each object in the inner class exists relative to an object of the outer class.
- Objects of the inner class have available instance variables and methods of the outer class.

Ways to Construct ClosedList

- ```
  class Cell {…}
  class ClosedList {…}
  ```

  Separate Classes

- ```
  class ClosedList
  {
    class Cell {…}
    ...
  }
  ```

  Inner Class

Interpretation of Identifiers

- In an inner class, the innermost meaning of an identifier applies.

```
class ClosedList
{
  String identity;
  class Cell
   {
   String identity;
   ...
   }
  ...
}
```

Inner identity is used.

Outer identity is used.

Usage

- Normally one or more objects of the inner class are created for a given object of the outer class.
- Objects of the inner class only make sense in the context of a supporting object of the outer class.

Exporting Inner Objects

- Inner objects *can* be used outside, understanding that they are always *relative* to the *object* in which they were created.

Example: List Iterator

- We want to define an Iterator for a ClosedList.
- For read-only Iteration, the Iterator class can be defined outside the ClosedList class.
- For **modification**, such as `remove()`, it is sometimes necessary for the Iterator to ***change*** variables in the **container**, such as the head or tail.

Example: List Iterator (2)

- By making the `ListIterator` an inner class, we can:
  - Use data elements defined in the `ClosedList`.
  - Avoid exposing those data elements to the world at large.
  - Use Iterators outside `ClosedList`.

ClosedList.Iterator

```
class ClosedList
{
private Cell head;
private Cell tail;
...
public Iterator getIterator()
  {
  return new Iterator(head);
  }

public class Iterator // inner class to ClosedList
  {
  private Cell current;
  private Cell previous;      // keep track of previous

  public Iterator(Cell head)
    {
    current = head;
    previous = null;
    }
    ...
```

Can export Iterator to outside!

ClosedList.Iterator: remove()

Defined to remove the value just produced by next().

```
public void remove()
   {
   if( previous == null )
     {
     head = head.getNext();
     }
   else
     {
     previous.setData(current.getData());  // reuse
     previous.setNext(current.getNext());  // previous
     current = previous;                   // lose current
     }
   }
```

`head` is defined in the outer class!

Test Program

```
class TestClosedList
{
public static void main(String arg[])
  {
  int numItems = 10;
  ClosedList L = new ClosedList();

  for( int i = 0; i < numItems; i++ )
    {
    L.enqueue(new Integer(i));
    }

  ClosedList.Iterator it = L.getIterator();

  System.out.println("removing " + it.next());
  it.remove();  // remove first item
}
```

Test Program

```
class TestClosedList {
public static void main(String arg[])
  {
  int numItems = 10;
  ClosedList L = new ClosedList();

  // add 10 items to L

  for( int i = 0; i < numItems; i++ )
    {
    L.enqueue(new Integer(i));
    }

  System.out.println("Initial list contents: " + L);

  // starting from the beginning, skip 3 items

  ClosedList.Iterator it = L.getIterator();

  for( int i = 0; i < 3; i++ )
    {
    System.out.println("skipping " + it.next());
    }

  // remove 2 items

  System.out.println("removing " + it.next());
  it.remove();

  System.out.println("removing " + it.next());
  it.remove();

  System.out.println("List contents after removing two: " + L);

  for( int i = 0; i < 3; i++ )
    {
    System.out.println("skipping " +it.next());  // ignore value
    }

  // insert 3 items

  for( int i = 0; i < 3; i++ )
    {
    int value = 10*(i+1);
    System.out.println("inserting " + value);
    it.insert(new Integer(value));
    }

  System.out.println("List contents after inserting three: " + L);
  }
}
```

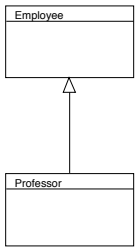
Test Program Output

```
Initial list contents: 0 1 2 3 4 5 6 7 8 9
skipping 0
skipping 1
skipping 2
removing 3
removing 4
List contents after removing two: 0 1 2 5 6 7 8 9
skipping 5
skipping 6
skipping 7
inserting 10
inserting 20
inserting 30
List contents after inserting three: 0 1 2 5 6 7 10 20 30 8 9
```

Inheritance

- "Inheritance" is a way of building one class on top of another
  - The original class is called the **base class**, or **parent class**.
  - The new class is called the **derived class**, or **child class**.

Diagrammatic Notation (UML)



class Professor
extends
class Employee

UML = Unified Modeling Language

Inherited Capabilities

- **Extension**:
  The derived class can potentially use all data components and methods from the base class, and add more of its own.
- **Over-Riding:**
  It can also selectively re-define or "over-ride" methods of the same name. (It is a good idea to keep the same approximate meaning.)

Purposes of Inheritence

- Use the *same* concepts and code for *many* classes (base-class concepts and code shared by derived classes):
  - Work economy
  - Intellectual economy
- Tie together similar classes:
  - Increases the utility of methods that **use** such classes.

Extension = Java Inheritance

- In Java, the keyword for "inherits from" is
  extends
- The derived class *extends* the base class.
- Extension allows over-riding as well; there is no separate keyword for over-riding.

Extension Example

- class **Account** defines a basic bank account
- class **CheckingAccount** defines a special account for check-writing

```
class Account
{
Money balance;

Account(Money initialBalance)
  {
  balance = initialBalance;
  }

void deposit(Money amount)
  {
  balance = balance.add(amount);
  }

boolean withdraw(Money amount)
  {
  if( balance.lessThan(amount) )
    return false;
  balance = balance.subtract(amount);
  return true;
  }

void showBalance(PrintStream out)
  {
  out.println("Balance: " + balance);
  }
```

Only allow withdrawal if sufficient funds; return boolean to indicate success or failure.

```
class CheckingAccount extends Account
{
Money serviceCharge;

CheckingAccount(Money initialBalance, Money serviceCharge)
  {
  super(initialBalance);
  this.serviceCharge = serviceCharge;
  }

boolean cashCheck(Money amount)
  {
  return withdraw(amount.add(serviceCharge));
  }

(continued next page)
```

Additional variable for the derived class.

"super" means "the constructor of the base class".

Added service charge

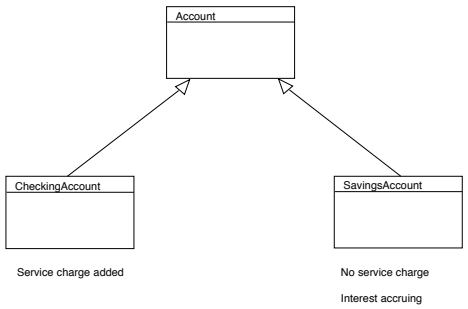
```
(program continued)

 public static void main(String arg[])
 {
 CheckingAccount myCheckingAccount =
   new CheckingAccount(new Money(10000),
                       new Money(100));

 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.deposit(new Money(5000));
 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.cashCheck(new Money(2000));
 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.cashCheck(new Money(1000));
 myCheckingAccount.showBalance(System.out);

 myCheckingAccount.withdraw(new Money(1000));
 myCheckingAccount.showBalance(System.out);
 }
}
```

Program Output

```
Balance: $100.0

Balance: $150.0

Balance: $129.0

Balance: $118.0

Balance: $108.0
```

(Link to the complete program: **Bank**)

Multiple derived classes

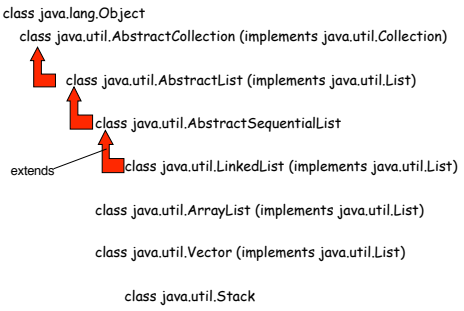


Which methods can be over-ridden?

- In order to be over-ridden, a method must be declared either:
  - **public**
  - **protected**

in the base class.

Inheritance Examples abound in Java Libraries



Implications of Inheritance

- The preceding diagram means, for example, that to find all methods for class java.util.Stack, you may wish to look at:
  - java.util.Vector
  - java.util.AbstractList
  - java.util.AbstractCollection
  - java.lang.Object

Methods of java.util.Stack

- Methods of Stack proper:
  - Object push(Object item)
  - Object pop()
  - boolean empty()
  - Object peek()
  - int search(Object o)
- Methods of Vector:
  - add, add, addAll, addAll, addElement, capacity, clear, clone, contains, containsAll, copyInto, elementAt, elements, ensureCapacity, equals, firstElement, get, hashCode, indexOf, insertElementAt, isEmpty, lastElement, lastIndexOf, remove, removeAll, removeAllElements, removeElement, removeElementAt, removeRange, retainAll, set, setElementAt, setSize, size, subList, toArray, toString, trimToSize
- Methods of AbstractList:
  - iterator, listIterator
- Methods of Object (not otherwise over-ridden)
  - finalize, getClass, notify, notifyAll, wait

Testing where Object is in Hierarchy

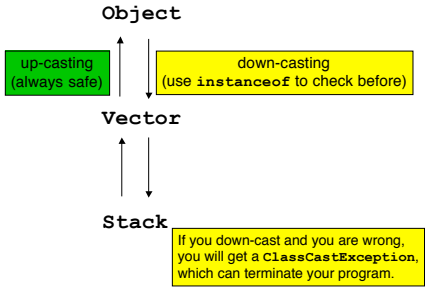
- *instanceof* operator

  Object ob = …;

  if(ob instanceof Vector) …
  if(ob instanceof Stack) …

More than one can be true!

Casting



class *Object*

- Object is the ancestor of all classes
- Some methods of Object:
  - boolean equals(Object)
  - Class getClass(): returns the "most derived" *Class object*
  - String toString()
- Method of class Class:
  - String getName()
  - So Ob.getClass().getName() will get you the class name of the object.

Implementing an Interface is similar to Inheritance

- Interface ≈ Base Class
- Implementor ≈ Derived Class
- By declaring methods to use the Interface rather than the Implementor class as an argument, more **generality** is afforded to that method.

Example

- `java.util.Iterator` is standard
- Make `ClosedList.Iterator` implement `java.util.Iterator`
- Any other code accepting a `java.util.Iterator` can now use our:
  `ClosedList.Iterator`
- We can *still* do everything we did before.

Abstract Classes

- A class is **abstract** if it is not intended to be instantiated directly; rather, objects in derived classes are instantiated.
- Each derived-class object **implicitly** entails an underlying base-class object.
- In Java, an abstract class is so-declared:
  abstract class MyClass {. . .}

Abstract Classes in Java

- An abstract class is so-declared:
  abstract class MyClass {. . .}
- A class declared abstract cannot be instantiated directly.

Abstract Methods

- A **method** is **abstract** if there is no code for it in the abstract class; instead the meaning of the method is obtained from over-riding in derived classes.
- Only abstract classes can contain abstract methods.

Abstract Class Example: Tree

- Consider the following type of Tree:
  - A Tree can be an Atom
  - A Tree can be a Composite: a pair of Sub-Trees (each of which is a tree in its own right).
- Type Tree is abstract:
  - We never create a tree directly.
  - We only create an Atom or a Composite.

Tree in Java

```
abstract class Tree
{
}

class Leaf extends Tree
{
Object value;

Leaf(Object value)
 {
 this.value = value;
 }
}
```

```
class Composite extends Tree
{
Tree left;
Tree right;

Composite(Tree left, Tree right)
 {
 this.left = left;
 this.right = right;
 }
```

Adding a Method to Tree

- Add method

  int leafCount();

  to Tree

leafCount in the base class

```
abstract class Tree
{
public abstract int leafCount();
}
```

leafCount in the Derived Classes

```
class Leaf extends Tree
{
Object value;

Leaf(Object value)
 {
 this.value = value;
 }

int leafCount()
 {
 return 1;
 }
}
```

```
class Composite extends Tree
{
Tree left;
Tree right;

Composite(Tree left, Tree right)
 {
 this.left = left;
 this.right = right;
 }

int leafCount()
 {
 return left.leafCount() + right.leafCount();
 }
}
```

Abstract Class vs. Interface

- An abstract class can still contain data and methods; an interface cannot.
- It is common for an abstract class to define methods with the intention that they be over-ridden differently by each derived class.

Multiple Inheritance

- Some languages allow one class to derive from multiple base classes; Java does not.
- The nearest thing would be a class deriving from a single basic class and implementing an interface at the same time.