CMSC 341

Inheritance and the Collection classes

Inheritance in Java

- Inheritance is implemented using the keyword `extends`.

```
public class Employee extends Person
{
   //Class definition goes here – only the
   //implementation for the specialized behavior
}
```

- A class may only inherit from only one superclass.
- If a class is not derived from a super class then it is derived from *java.lang.Object*. The following two class declarations are equivalent:

```
public class Person {…}
public class Person extends Object {…}
```

Polymorphism

- If Employee is a class that extends Person, an Employee “is-a” Person and polymorphism can occur.

Creates an array of Person references

```
Person [] p = new Person[2];
p[0] = new Employee();
p[1] = new Person();
```

Polymorphism (cont.)

- However, a Person is not necessarily an Employee. The following will generate a compile-time error.

```
Employee e = new Person();
```

- Like C++, polymorphism requires general class on left of assignment operator, and specialized class on right.
- Casting allows you to make such an assignment provided you are confident that it is ok.

```
public void convertToPerson(Object obj)
{
   Person p = (Person) obj;
}
```

Virtual Method Invocation

- In Java, virtual method invocation is automatic. At runtime, the JVM determines the actual type of object a reference points to. Then, the JVM selects the correct overridden method for it.
- Supposing the *Employee* class overrides the *toString* method inherited from the *Person* class, then the *toString* method of the derived class, *Employee*, is invoked even though the reference is a *Person* reference.

```
Person p = new Employee;
p.toString();
```

Invokes the *toString* method of the *Employee* class

What is inherited by the subclass?

- All fields are inherited. Giving fields in super classes *protected* access allows methods of subclasses to reference the fields.
- All methods are inherited except for constructors.
- Inherited methods may be overloaded or overridden.

Constructors and Inheritance

- The superclass constructors are always called by the constructors of the subclasses, either implicitly or explicitly.
- To explicitly call the superclass constructor, in the first line of the subclass constructor make a call to the *super* method passing the appropriate parameters for the desired constructor.

The super Reference

- All overridden methods in a subclass also contain a reference to their corresponding methods in the superclass named *super*.
- The following code contains the use of the *super* reference to call the super class constructor and to use the implementation of the *toString* method of the superclass.
- Notice it also contains several uses of the *this* reference.

Super Class Example

```
public class Person
{
   protected String name;
   private int age;
   public Person(String name, int age){
        this.name = name;
        this.age = age;
   }
   public Person(String name){
        this(name, 0);
   }
   public String toString(){ return name;}
   public int getAge(){ return age;}
   public void setAge(int age){ this.age = age;}
   public void setName(String name)
   { this.name = name;}
}
```

Call to other constructor

Subclass Example

```
public class Employee extends Person
{
      private double salary;
      public Employee(String name, int age, double sal){
            super(name,age);
            salary = sal;
      }
      public Employee(String name, double salary){
            this(name,18, salary);
      }
      public double getSalary(){ return salary; }
      public void setSalary(double sal){ salary = sal; }
      public String toString()
      {
            return super.toString()
                  + “ has a salary of “ + salary;
      }
}
```

Call to superclass constructor

Call to constructor above

Call to superclass *toString* method

Polymorphism in Action

```
public class Test
{
  public static void main(String []args)
  {
      Person [] people = new Person[3];
      people[0] = new Person("Sam");
      people[1] = new Employee("Jane",45345.63);
      for(Person someone:people)
            System.out.println(someone);
  }
}
```

println invokes the *toString* method of the object the reference is pointing to, as if it were a pointer in C++ and the toString method were virtual.

Output

```
Sam
Jane has a salary of 45345.63
null
```

Abstract Classes and Methods

- Java also has abstract classes and methods like C++. If a class has an abstract method, then it must be declared abstract.

```
public abstract class Node{
    String name;
    public abstract void type();
    public String toString(){ return name;}
    public Node(String name){
        this.name = name;
    }
}
```

Abstract methods have no implementation.

Subclass of Abstract Class

- Subclass of an abstract class must provide implementation for ALL the abstract methods or it must be declared abstract as well.

```
public class NumberNode extends Node{
    int number;
    public void print(){
           System.out.println(“Number node”);
    }
    public NumberNode(String name, int num){
           super(name);
           number = num;
    }
    public String toString(){
           return super.toString() + “ “ + number;
    }
}
```

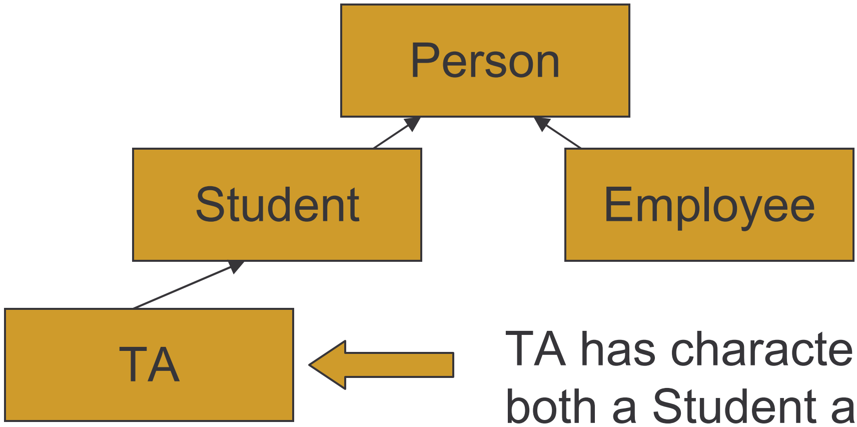
More about Abstract Classes

- Like C++, abstract classes can not be instantiated.

```
// OK because n is only a reference.
  Node n;
// OK because NumberNode is concrete.
  Node n = new NumberNode(“Penta”, 5);
// Not OK. Gives compile error.
  Node n = new Node(“Name”);
```

Multiple Inheritance in Java

- There are always cases where a class appears to have characteristics of more than one class. Consider the following hierarchy.



TA has characteristics of both a Student and an Employee

Interfaces

- Java only allows a class to extend one super class. It does not allow multiple inheritance like C++. However, to cope with the need for multiple inheritance, it created interfaces.
- An interface is like class without the implementation. It contains only
  - public, static and final fields, and
  - public and abstract method headers (no body).

Interface Example

- A public interface, like a public class, must be in a file of the same name.
- The methods and fields are implicitly public and abstract by virtue of being declared in an interface.

```
public interface Employable
{
  void raiseSalary(double d);
  double getSalary();
}
```

Interfaces (cont.)

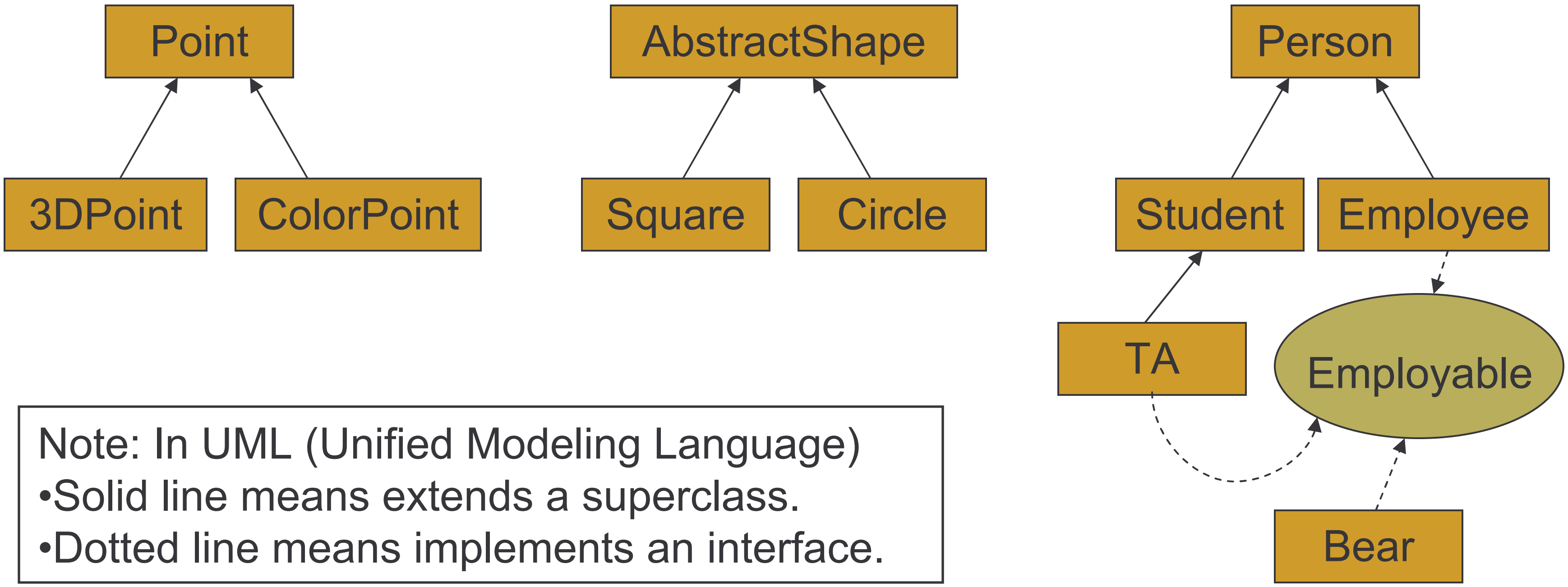
- Many classes may implement the same interface. The classes may be in completely different inheritance hierarchies.
- A class may implement several interfaces.

```
public class TA extends Student implements
Employable
{
    /* Now TA class must implement the getSalary
       and the raiseSalary methods  here */
}
```

Inheritance Progression

Inheritance of Implementation

Inheritance of Interface



Note: In UML (Unified Modeling Language)
•Solid line means extends a superclass.
•Dotted line means implements an interface.

The Collections Framework

- The Java Collections Framework implements a lot of the functionality of the C++ Standard Template Library.
- It is a collection of interfaces, abstract and concrete classes that provide generic implementation for many of the data structures you will be learning about in this course.

The Collections Framework (cont.)

- All of the collection classes contain elements of type Object. Since every object in Java “is-a” Object, then we can create a collection of heterogeneous objects.
- Before we begin examining Collections, let us look at some of the interfaces the framework uses.

The Arrays class

- The java.util.Arrays class is a utility class that contains several static methods to process arrays of primitive and reference data.
  - *binarySearch* – searches sorted array for a specific value
  - *equals* – compares two arrays to see if they contain the same elements in the same order
  - *fill* – fills an array with a specific value
  - *sort* – sorts an array or specific range in array in ascending order according to the natural ordering of elements

Natural Order

- The natural order of primitive data types is known. However, if you create an array of type Object, how does the *sort* method know how to sort the array?
- One way is to pass a Comparator along with the array.
- A Comparator is an object that implements the *java.util.Comparator* interface.

The Comparator Interface

- The *compare* method must behave like C's *strcmp* function. Returns
  - a negative number if o1 precedes o2,
  - a zero if they are equal, and
  - a positive number if o2 precedes o1.

```
public interface java.util.Comparator
{
    int compare(Object o1, Object o2);
}
```

The Comparable Interface

- The other way to define the natural ordering of objects is by having the class implement the *Comparable* interface. The *compareTo* method also behaves like the *strcmp* method in C.

```
public interface java.lang.Comparable
{
    int compareTo(Object o);
}
```

Comparable Example

```
import java.util.*;
public class Fraction implements Comparable
{
        private int n;
        private int d;
        public Fraction(int n, int d){ this.n = n; this.d = d;}
        public int compareTo(Object o)
        {
                Fraction f = (Fraction) o;
                double d1 = (double) n/d;
                double d2 = (double)f.n/f.d;
                if (d1 == d2)
                        return 0;
                else if (d1 < d2)
                        return -1;
                return 1;
        }
        public String toString() { return n + “/” + d; }
}
```

Casting required to access the object data

Casting required for floating point division

Sort Example

```
public class FractionTest
{
   public static void main(String []args)
   {
        Fraction [] array = {new Fraction(2,3),
                new Fraction (4,5), new Fraction(1,6);
        Arrays.sort(array);
        for(Fraction f :array)
                System.out.println(f);
   }
}
```

Collections

- The Collections framework provides two inheritance hierarchies for its containers.
  - Collection
    - Operations for lists and arrays
  - Map
    - Operations for hashes and associative arrays
    - We will not be covering the Map interface in this course, but for more information on this topic, see Sun’s Collections tutorial at http://java.sun.com/docs/books/tutorial/collections/index.html

The Collection Interface

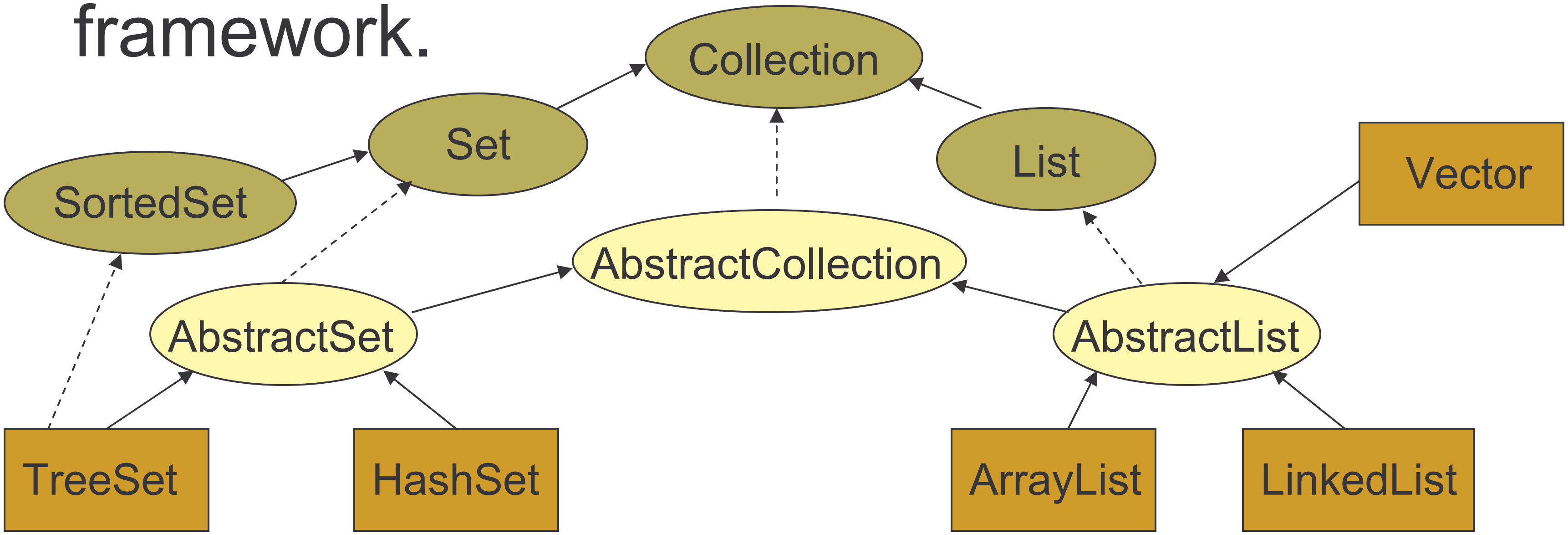
- Some of the most common methods of this interface are:
    - *add* – adds a new element
    - *remove* – removes an element
    - *size* – returns the number of elements
    - *isEmpty* – returns whether collection is empty
    - *contains* – checks whether collection contains an element
    - *iterator* – returns an *Iterator* object to traverse the *Collection*

List and Set Interfaces

- The *Collection* interface has two sub-interfaces.
  - The *Set* interface allows no duplicates to be added to the Collection.
  - The *List* interface allows for an ordered collection. Elements are traversed in the order which they are added to the list. Additional methods include:
    - *get* – returns the element at a specified index
    - *indexOf* –returns the index of a specified element
    - *listIterator* – returns a ListIterator object that traverses the list in both directions

Interface Hierarchy

- Prior to the Collections framework, Java used a Vector class and a Hashtable class. These classes have been incorporated into the new framework.



Collection Example

```
import java.util.*;
public class CollectionExample
{
        public static void main(String args[])
        {
                Collection a = new LinkedList();
                a.add(new Integer(5));
                a.add(new Integer(10));
                a.add(new Integer(3));
                a.add(new Integer(5));
                printAll(a);
        }
        public static void printAll(Collection c)
        {
                Iterator i = c.iterator();
                while(i.hasNext())
                        System.out.println(i.next());
        }
}
```

Substitute with *HashSet* and *TreeSet* to see varying behavior

Thread-safety

- One of the major improvements from the old Vector and Hashtable classes to the Collections framework was the separation of thread-safety from the implementation. The newer Collection classes are not thread-safe, but they can be converted to be thread-safe by using the *Collections.synchronizedList,Set or Map* methods.

```
List list = Collections.synchronizedList(new
  ArrayList());
```

Generics

- Since JDK 1.5 (Java 5), the Collections framework has been parameterized.
- A class that is defined with a parameter for a type is called a generic or a parameterized class. In C++, there were referred to as template classes.
- If you compare the Collection interface in the API for 1.4.2 to the one in version 1.5.0, you will see the interface is now called Collection<E>.

Collection <E> Interface

- The E represents a type and allows the user to create a homogenous collection of objects.
- Using the parameterized collection or type, allows the user to retrieve objects from the collection without having to cast them.

Before:	After:
List c = new ArrayList();	*List<Integer> c = new ArrayList<Integer>();*
c.add(new Integer(34));	*c.add(new Integer(34));*
Integer i = (Integer) c.get(0);	*Integer i = c.get(0);*

Generic Cell Example

```
public class CellDemo
{

   public static void main (String[ ] args)
   {
        // define a cell for Integers
        Cell<Integer> intCell = new Cell<Integer>( new Integer(5) );

        // define a cell for Floats
        Cell<Float> floatCell = new Cell<Float>( new Float(6.7) );

        // compiler error if we remove a Float from Integer Cell
        Float t = (Float)intCell.getPrisoner( );
        System.out.println(t);
   }
}
class Cell< T >
{
   private T prisoner;
   public Cell( T p)
   { prisoner = p; }
   public T getPrisoner(){return prisoner; }
}
```

Dont's of Generic Programming

- Like C++, you CANNOT use a parameter in a constructor.

~~`T obj = new T();`~~

~~`T [] array = new T[5];`~~

- Like C++, you CANNOT create an array of a generic type.

~~`Collection <Integer> c[ ] =`~~
~~`new Collection<Integer>[10];`~~

Do's of Generic Programming

- The type parameter must always represent a reference data type.
- Class name in a parameterized class definition has a type parameter attached.

```
    class Cell<T>
```

- The type parameter is not used in the header of the constructor.

```
    public Cell( )
```

- Angular brackets are not used if the type parameter is the type for a parameter of the constructor.

```
     public Cell3(T prisoner );
```

- However, when a generic class is instantiated, the angular brackets are used

```
    List<Integer> c = new ArrayList<Integer>();
```

Bounding the Type

- You will see in the API a type parameter defined as follows <? extends E>. This restricts the parameter to representing only data types that implement E, i.e. subclasses of E

```
boolean addAll(Collection<? extends E> c)
```

Bounding Type Parameters

- The following restricts the possible types that can be plugged in for a type parameter **`T.`**

```
public class RClass<T extends Comparable>
```

  - "**`extends Comparable`**" serves as a *bound* on the type parameter **`T.`**
  - Any attempt to plug in a type for **`T`** which does not implement the **`Comparable`** interface results in a compiler error message

More Bounding

- In the API, several collection classes contain <? super T> in the constructor. This bounds the parameter type to any class that is a supertype of T.

```
interface Comparator<T>
{ int compare(T fst, T snd); }

TreeSet(Comparator<? super E> c)
```

Generic Sorting

```
public class Sort
{
  public static <T extends Comparable<T>>
  void bubbleSort(T[] a)
  {
      for (int i = 0; i< a.length - 1; i++)
          for (int j = 0; j < a.length -1 - i; j++)
             if (a[j+1].compareTo(a[j]) < 0)
             {
                   T tmp = a[j];
                   a[j] = a[j+1];
                   a[j+1] = tmp;
             }
  }
}
```

Generic Sorting (cont.)

- Given the following:

```
class Animal implements Comparable<Animal> { ...}
class Dog extends Animal { ... }
class Cat extends Animal { ... }
```

- Now we should be able to sort dogs if contains the *compareTo* method which compares animals by weight.
- BUT… bubblesort only sorts objects of type T which extend T. Here the super class implements Comparable.
- New and improved sort on next page can handle sorting Dogs and Cats.

Generic Sorting (cont.)

```
public class Sort
{
  public static <T extends Comparable<? super T>>
  void bubbleSort(T[] a)
  {
      for (int i = 0; i< a.length - 1; i++)
          for (int j = 0; j < a.length -1 - i; j++)
            if (a[j+1].compareTo(a[j]) < 0)
            {
                  T tmp = a[j];
                  a[j] = a[j+1];
                  a[j+1] = tmp;
            }
  }
}
```