Inheritance and subclasses

- **a way to create or describe one class in terms of another**
  - "a D is like a B, with these extra properties..."
  - "a D is a B, plus…"
  - B is the **base** class or **super**class
  - D is the **derived** class or **sub**class
    Perl, C++ use base/derived; Java uses super/sub
- **inheritance is used for classes that model strongly related concepts**
  - objects share some properties, behaviors, etc.
  - and have some properties and behaviors that are different

- **real-world example: GUI "widgets" or "controls"**
  - aspects common to all widgets:
    position, size, background color, caption, …
  - aspects different for different kinds of widgets:
    how to draw, responses to events, …
- **one class is a natural extension of the other**
  - sometimes you care about the difference
    drawing: a button is not a pull-down menu is not a text area
  - sometimes you don't
    set/get caption, set background color, get dimensions

C-style `Widget`

- **a struct to hold the data**
- **functions to create, modify, etc.**
- **a type field & conditional code to distinguish different types**

```
struct Widget {
   int type;         // what kind of widget
   int bgcolor;
   Rect position;
   ...
};

   setbgcolor(int col);
   setcaption(string);
   draw();
   getwidth();
   ...

        Widget *but = new Widget(BUTTON);
        but->setbgcolor(0xFF00FF);
        but->draw(); ...
```

Problems with this approach

- **each function (such as draw()) has to have code for all possible widgets**

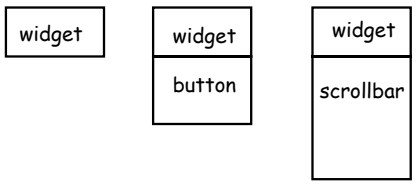
```
void draw(Widget *wp)
{
   switch (wp->type) {
      case BUTTON: ...
      case SCROLLBAR: ...
      case MENU: …
      // etc
   }
}
```

- **code for handling each type is scattered all over**
- **each piece has to be changed when a new kind of widget is added**

Subclasses

```
class Widget {
    int bgcolor;
    // other vars common to all Widgets
}
class Button extends Widget {
   int state;
   // other vars specific to Buttons
}
class Scrollbar extends Widget {
   int min, max, current;
   // other vars specific to Scrollbars
}
```

- **a Button is a subclass (a kind of) Widget**
  - inherits all members of Widget
  - adds its own members
- **a Scrollbar is also a subclass of Widget**



More subclasses

- subclasses can add their own data members
- can add their own member functions
- can override superclass functions with functions of same name and argument types

```
class Scrollbar extends Widget {
    int min, max, current;
    public void draw() {...}  // overrides
    public void setslider(int) {...}
}

class CheckButton extends Widget {
    boolean checked;
    public void draw() {...}  // overrides
    public void setstate(boolean) {...}
}

    CheckButton b;
    Scrollbar s;

    b.draw();  // call CheckButton.draw
    s.draw();  // call Scrollbar.draw
```

Inheritance and subclasses

- example: a PerlRE class derived from RE
- adds Perl RE capabilities like richer REs and matching substrings

```
public class PerlRE extends RE {
  // maybe some internal representation of RE
  String[] matches;  // maybe matched strings

  public int match(String s) {
       // do Perl matching
       return 1;
  }
  public PerlRE(String s) {
       super(s); // invoke parent constructor
       // maybe compile s into internal rep
  }

  public static void main(String[] args) {
       PerlRE pre = new PerlRE("a|b|c");
       pre.match("abc");
       RE re = pre;
       re.match("bcd");
  }
}
```

Object hierarchy

- **all objects are derived from class Object**
  - e.g., an RE is an Object
  - a PerlRE is an RE is an Object

```
Object -> RE -> PerlRE
       -> Math
       -> System
       -> Component -> Container -> Panel -> Applet
                    -> Button
                    -> Label
                    -> etc.
       -> InputStream -> FilterInputStream
                           -> BufferedInputStream
```

- **Object has methods for equals, hashCode, toString, clone, etc.**
  - normally these are extended
- **default RE.equals is Object.equals**
  - tests for same reference, i.e., same object
- **to compare for equal regexp, overload equals**

```
class RE {  // one defn of equality
  public boolean equals(RE r2) {
    return re.equals(r2.re);
}
```

Overriding, dynamic method lookup

- **`PerlRE.equals()` overrides `RE.equals()`**
  - arguments are identical

- **all functions are implicitly *virtual*: a reference to the superclass calls the subclass method for a subclass object**

```
PerlRE pre = new PerlRE("a|b|c");
System.out.println(
     "Perl RE = " + pre.match("a");

RE re = pre;
System.out.println(
     "RE = " + re.match("a"));
                // calls pre.match()
```

Virtual Functions

- **what if we have bunch of different Widgets and want to draw them all in a loop?**
- **virtual function mechanism lets each object carry information about what functions to apply**
- **when a reference to a superclass type is really a reference to a subclass object**
- **and you use that reference to call a function**
- **this calls the subclass function**
- **"polymorphism": proper function to call is determined at run-time**
  - e.g., drawing Widgets in an array:

```
draw_all(Widget[] wa) {
  for (int i = 0; i < wa.length; i++)
     wa[i].draw();
}
```

- **virtual function mechanism automatically calls the right draw() function for each object**
  - "virtual" means that a subclass may provide its own version of this function, which will be called automatically for instances of that subclass
  - superclass can provide a default implementation
- **the loop does not change if more kinds of widgets are added**

Exceptions are objects

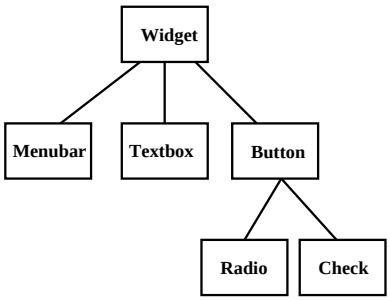
- **all derived from class Exception**
- **multiple catch blocks to catch multiple exceptions**
  - caught in order of most specific first
- **you can define your own exceptions**

```
public void savefile(String s, String f)
            throws EndOfTheWorld
{
  try {
     FileOutputStream out = new FileOutputStream(f);
     out.write(s.getBytes());
     out.close();
  } catch (FileNotFoundException e) {
     System.err.println(e + " can't open " + f);
  } catch (IOException e) {
     System.err.println(e + " savefile error");
  } catch (Exception e) {
    System.err.println(e + " utterly unexpected error");
    throw new EndOfTheWorld("repent!");
  }
}

class EndOfTheWorld extends Exception {
  EndOfTheWorld(String s) {
    System.err.println(s +
                " the end of the world is at hand.");
  }
}
```

Inheritance principles

- **classes are supposed to match the natural objects in the application**
- **derive specific types from a general type**
  - collect common properties in the superclass
  - add special properties in the subclasses
- **distinctions are not always clear**
  - is a radiobutton a button or not?
  - should there be separate classes for horizontal and vertical scrollbars?
  - is a checkbutton a radiobutton or vice versa or neither?



Summary of inheritance

- **a way to describe a family of types**
- **by collecting similarities (superclass)**
- **and separating differences (subclasses)**

- **polymorphism: proper member functions determined at run time**

- **not every class needs inheritance**
  - may complicate without compensating benefit

- **use composition instead of inheritance?**
  - an object contains (has) an object rather than inheriting from it
- **"is-a" versus "has-a"**
  - inheritance describes "is-a" relationships
  - composition describes "has-a" relationships

Interfaces

- **an interface is like a class**
- **declares a type**
- **only declares methods (not implementations)**
  - and constants ("final")
  - methods are implicitly public
  - constants are implicitly public static final
- **any class can implement the interface**
  - i.e., provide implementations of the interface methods
  - and can provide other methods as well
  - and can implement several interfaces
- **the only way to simulate function pointers and function objects**

Comparison interface for sorting

```
interface Cmp {
        int cmpf(Object x, Object y);
}
class Icmp implements Cmp {  // Integer comparison
        public int cmpf(Object o1, Object o2) {
                int i1 = ((Integer) o1).intValue();
                int i2 = ((Integer) o2).intValue();
                if (i1 < i2)
                        return -1;
                else if (i1 == i2)
                        return 0;
                else
                        return 1;
        }
}
class Scmp implements Cmp { // String comparison
        public int cmpf(Object o1, Object o2) {
                String s1 = (String) o1;
                String s2 = (String) o2;
                return s1.compareTo(s2);
        }
}
```

- **whole lot of casting going on**
- **can't do an illegal cast, but don't find out till runtime**

Sort function using an interface

```
void sort(Object[] v, int left, int right, Cmp cmpf) {
        int i, last;

        if (left >= right)  // nothing to do
                return;
        swap(v, left, rand(left,right));
        last = left;
        for (i = left+1; i <= right; i++)
                if (cmpf.cmpf(v[i], v[left]) < 0)
                        swap(v, ++last, i);
        swap(v, left, last);
        sort(v, left, last-1, cmpf);
        sort(v, last+1, right, cmpf);
}

        Integer[] iarr = new Integer[n];
        String[] sarr = new String[n];

        Quicksort.sort(iarr, 0, n-1, new Icmp());
        Quicksort.sort(sarr, 0, n-1, new Scmp());
```

Wrapper types

- **most library routines work on Objects**
  - don't work on basic types like int
- **have to "wrap" basic types in objects to pass to library functions, store in Vectors, etc.**
  - Character, Integer, Float, Double, etc.
- **wrappers also include utility functions and values**

```
Integer I = new Integer(123); // constructor
int i = I.intValue();  // get value
i = Integer.parseInt("123"); // atoi
I = Integer.valueOf("123");
String s = I.toString();

Double D = new Double(123.45);
double d = D.doubleValue();
d = Double.parseDouble("123.45");  // atof
D = Double.valueOf("123.45");
string s = D.toString();

double atof(String str) {
   return Double.parseDouble(str);
}

System.out.println(Double.MAX_VALUE);
```

Collections and collections framework

- **"collection" == container in C++, etc.**
  - Set, List (includes array), Map
- **interfaces for standard data types**
  - abstract data types for collections
  - can do most operations independently of real type
  - include standard interface for
    add, remove, size, member test, …
- **implementations (concrete representations)**
  - HashSet, TreeSet
  - ArrayList, LinkedList
  - HashMap, TreeMap
- **algorithms**
  - standard algorithms like search and sort
  - work on any Collection of any type
    that provides standard operations like comparison
  - "polymorphic"
- **iterators**
  - uniform mechanism for accessing each element

Collection interface

- **Set and List provide (more or less) this interface**

```
public interface Collection {
   int size();
   boolean isEmpty();
   boolean contains(Object elem);
   boolean add(Object elem);
   boolean remove(Object elem);
   Iterator iterator();
   ...
```

- **Map provides**

```
public interface Map {
   int size();
   boolean isEmpty();
   Object put(Object key, Object value);
   Object get(Object key);
   Object remove(Object key);
   boolean containsKey(Object key); // + Value
   ...
```

Collections sort

- **ArrayList is an implementation of List**
  - like Vector but better
  - adds some of its own methods, like get()
- **Collections.sort is a polymorphic algorithm**
  - specific type has to implement Comparable

```
class qsort1 {
  public static void main(String[] argv)
              throws IOException {
    FileReader f1 = new FileReader(argv[0]);
    BufferedReader f2 = new BufferedReader(f1);

    String s;
    List al = new ArrayList(100000);
    while ((s = f2.readLine()) != null)
       al.add(s);
    Collections.sort(al);
    for (int j = 0; j < al.size(); j++)
       System.out.println(al.get(j));
  }
}
```

Interface example: map

- **interface defines methods for something**
- **says nothing about the implementation**

```
interface Map
       void put(String name, String value);
       String get(String name);
       boolean member(String name);
       // ...
}
```

- **classes implement it by defining functions**
- **have to implement all of the interface**

```
class Hashmap implements Map {
       Hashtable h;
       Hashmap() { h = new Hashtable(); }
       void put(String name, String value) {
              h.put(name, value); }
       String get(String name) {
              return h.get(name); }
       boolean member(String name) {
              return h.contains(name); }

class Treemap implements Map {
       RBTree t;
       Treemap() { t = new RBTree(); }
       void put(String name, String value){ … }
       String get(String name) { … }
```

Maps, wrappers, iterators

```
Map hs = new HashMap();

String buf;
while ((buf = f2.readLine()) != null) {
   String nv[] = buf.split("[   ]+");
   Integer oldv = (Integer) hs.get(nv[1]);
   if (oldv == null)
      hs.put(nv[0], new Integer(nv[1]));
   else {
      int v = oldv.intValue() +
                  Integer.parseInt(nv[1]);
      hs.put(nv[0], new Integer(v));
   }
}
for (Iterator i = hs.keySet().iterator();
                           i.hasNext(); ) {
   String n = (String) i.next();
   Integer v = (Integer) hs.get(n);
   System.out.println(n + " " + v);
}
```

Word frequency counter

```
Map hs = new TreeMap(); // or HashMap
String buf;
while ((buf = f2.readLine()) != null) {
   String nv[] = buf.split("[      ]+");
   for (int i = 0; i < nv.length; i++) {
      Integer oldv = (Integer) hs.get(nv[i]);
      if (oldv == null)
         hs.put(nv[i], new Integer(1));
      else
         hs.put(nv[i],
             new Integer(oldv.intValue()+1));
   }
}
for (Iterator it = hs.keySet().iterator();
                           it.hasNext(); ) {
   String n = (String) it.next();
   Integer v = (Integer) hs.get(n);
   System.out.println(v + " " + n);
}
```