CS/ENGRD 2110
FALL 2017

Lecture 7: Interfaces and Abstract Classes
http://courses.cs.cornell.edu/cs2110

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Announcements

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- A2 is due Sunday night (16 September)
- Prelim 1 is two weeks away! **GO TO THE WEBPAGE:**
  http://www.cs.cornell.edu/courses/cs2110/2018fa/exams.html
- Study Guide
- When you take the exam (where comes later)
  - Half of you will take the exam at 5:30!
  - The other half at 7:30!
- Whom to contact about conflicts

READ CAREFULLY & THOROUGHLY

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- Go back to Lecture 6 & talk about equals

Operator instanceof and function getClass

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s ..@54

..@54
Object
Shape
Rect
Square

What is `s instanceof Rect` ?

What is `s.getClass()` ?

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Where are we?

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You watched 15 minutes of videos in preparation for this lecture. You learned about abstract classes and interfaces.

Reason for asking you to watch it:

You now have seen the technical details and have a basic understanding. We can now give examples and discuss things at greater depth than if you had not watched the videos.

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A Little Geometry!

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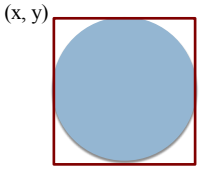
Position of a rectangle in the plane is given by its upper-left corner



Position of a circle in the plane is given by the upper-left corner of its bounding box

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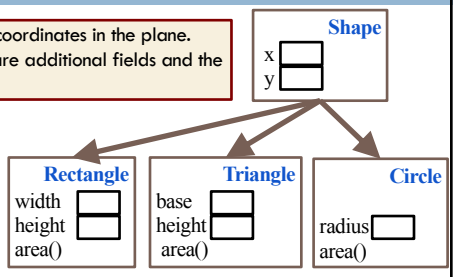
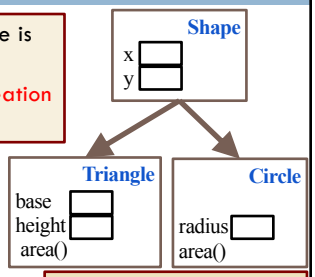
A Little Geometry!

Shape contains coordinates in the plane. Subclasses declare additional fields and the method **area**.



What is "only" a **Shape**, anyway??

Notice: An object of Shape is not really a shape.
→ Don't want to allow creation of objects of class Shape!



Make the class abstract!

```
public abstract class Shape {
    …
}
```

Syntactic rule: if class C is abstract, the new-expression new C(…) cannot be used!

Writing **sumAreas** in class Shape


```
/** Return sum of areas of shapes in s */
public static double sumAreas(Shape[] s) {
    double sum= 0;
    for (int k= 0; k < s.length; k= k+1)
        sum= sum + s[k].area();
    return sum;
}
```

Does this work?

Compile-time reference rule says **no**!

Solutions?

1. Use **instanceof** and cast down to make the call? (next slide)
2. Make **area** a method of Shape?

Approach 1: Cast down to make the call


```
double sum= 0;
for (int k= 0; k < s.length; k= k+1)  {
    if (sh[k] instanceof Circle)
            sum= sum + ((Circle) sh[k]).area();
    else if (sh[k] instanceof  Rectangle)
            sum= sum + ((Rectangle) sh[k]).area();
}
return sum;
```

👍 or 👎?

1. Code is ugly
2. Code doesn't age well

Approach 2: define area in Shape

Add method area to class Shape:

```
public double area() {
    return 0;
}
```

Problem: a subclass might forget to override area().

Use this instead?

```
public double area() {
    throw new RuntimeException(
            "area not overridden");
}
```

Problem: a subclass might still forget to override area().

Approach 3: Make area abstract! (Yay!)

In abstract class Shape, an abstract function area is required of all subclasses:

```
public abstract class Shape {
    …
    /** Return the area of this shape */
    public abstract double area() ;
}
```

Syntax:
If a method has keyword abstract in its declaration, use a semicolon instead of a method body.

Abstract Summary

1. To make it impossible to create an instance of a class C, make C abstract:

```
public abstract C { …}
```

Syntax: the program cannot be compiled if C is abstract and program contains a new-expression new C(…)

2. In an abstract class, to require each subclass to override method m(…), make m abstract:

```
public abstract int m(…) ;
```

Syntax: the program cannot be compiled if a subclass of an abstract class does not override an abstract method.

Abstract class used to "define" a type (abstract data type, or ADT)

Type: set of values together with operations on them

Define type Stack (of ints). Its operations are:

```
isEmpty()   --return true iff the stack is empty
push(k)     --push integer k onto the Stack
pop()       --pop the top stack element
```

```
public abstract class Stack {
    public abstract boolean isEmpty();
    public abstract void push(int k);
    public abstract int pop();
}
```

Naturally, need specifications

Example of Stack subclass: ArrayStack

```
public abstract class Stack {
    public abstract boolean isEmpty();
    public abstract void push(int k);
    public abstract int pop();
}
```

```
public class ArrayStack extends Stack {
    private int n;    // stack elements are in
    private int[] b; // b[0..n-1]. b[0] is bottom

    /** Constructor: An empty stack of max size s. */
    public ArrayStack(int s) {b= new int[s];}

    public boolean isEmpty() {return n == 0;}

    public void push(int v) { b[n]= v; n= n+1;}

    public int pop() {n= n-1; return b[n]; }
}
```

Missing tests for errors! Missing specs!

Example of Stack subclass: LinkedListStack

```
public abstract class Stack {
    public abstract boolean isEmpty();
    public abstract void push(int k);
    public abstract int pop();
}
```

```
public class LinkedListStack extends Stack{
    private int n;    // number of elements in stack
    private Node first; // top node on stack

    /** Constructor: An empty stack */
    public LinkedListStack() {}

    public boolean isEmpty() {return n == 0;}

    public void push(int v) { prepend v to list}

    public int pop() { …}
}
```

Missing tests for errors! Missing specs!

Flexibility!

```
public abstract class Stack { … }
public class LinkedListStack extends Stack { … }
public class ArrayStack extends Stack { … }
```

```
/** A class that needs a stack */
public class C {
    Stack st= new ArrayStack(20);
    …
    public void m() {
        …
    }   st.push(5);
        …
}
```

Store the ptr in a variable of type Stack!

Choose an array implementation, max of 20 values

Use only methods available in abstract class Stack

Flexibility!

```
public abstract class Stack { … }
public class LinkedListStack extends Stack { … }
public class ArrayStack extends Stack { … }
```

```
/** A class that needs a stack */
public class C {      LinkedListStack();
    Stack st= new ArrayStack(20);
    …
    public void m() {
        …
    }   st.push(5);
        …
}
```

Want to use a linked list instead of an array? Just change the new-expression!

Interfaces

An interface is like an abstract class all of whose components are public abstract methods. Just have a different syntax

We don't tell you immediately WHY Java has this feature, this construct. First let us define the interface and see how it is used. The why will become clear as more and more examples are shown.

(an interface can have a few other kinds of components, but they are limited. For now, it is easiest to introduce the interface by assuming it can have only public abstract methods and nothing else. Go with that for now!)

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Interfaces

An interface is like an abstract class all of whose components are public abstract methods. Just have a different syntax

```
public abstract class Stack {
    public abstract boolean isEmpty();
    public abstract void push(int k);
    public abstract int pop();
}
```

Here is an abstract class. Contains only public abstract methods

```
public interface Stack {
    public abstract boolean isEmpty();
    public abstract void push(int k);
    public abstract int pop();
}
```

Here is how we declare it as an interface

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Interfaces

```
public abstract class Stack {
  public abstract boolean isEmpty();
  public abstract void push(int k);
  public abstract int pop();
}
```

```
public interface Stack {
     boolean isEmpty();
     void push(int k);
     int pop();
}
```

Methods must be public and abstract, so we can leave off those keywords.

Extend a class:

```
class StackArray extends Stack {
   …
}
```

Implement an interface:

```
class StackArray implements Stack {
   …
}
```

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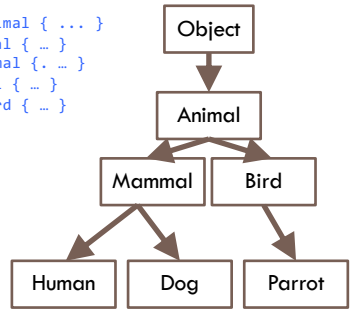
A start at understanding use of interfaces

Have this class hierarchy:

```
class Animal { … }
class Mammal extends Animal { ... }
class Bird extends Animal { … }
class Human extends Mammal {. … }
class Dog extends Mammal { … }
class Parrot extends Bird { … }
```



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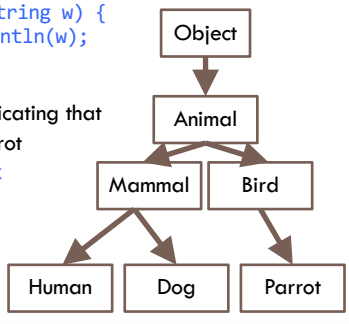
A start at understanding use of interfaces

Humans and Parrots can speak. Other Animals cannot.

```
public void speak(String w) {
     System.out.println(w);
}
```

We need a way of indicating that classes Human and Parrot have this method speak



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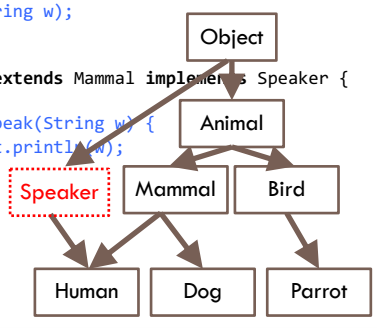
A start at understanding use of interfaces

```
public interface Speaker {
     void speak(String w);
}

public class Human extends Mammal implements Speaker {
     …
     public void speak(String w) {
         System.out.println(w);
     }
}
```

(similarly for Parrot)



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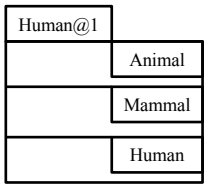
Here's what an object of class Human looks like

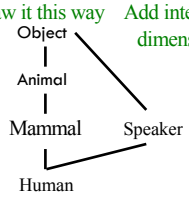
```
public interface Speaker {void speak(String w); }

public class Human extends Mammal implements Speaker {…
  public void speak(String w) { System.out.println(w); }
}
```

Usual drawing of object



Draw it this way Add interface dimension



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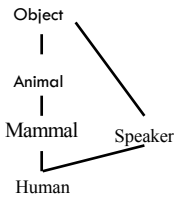
Here's what an object of class Human looks like

```
Human h= new Human();
Object ob= h;
Animal a= (Animal) ob;
Mammal m=  h;
Speaker s= h;
```



h, ob, a, m, and w all point to the same object.

The object can be (and is) cast to any "partition" in it: h, ob, a, m, and w.

Upward casts: can be implicit; inserted by Java

Downward casts: must be explicit

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A real use of interface: sorting

Consider an array of Shapes: want to sort by increasing area

Consider an array of **int**s: want to sort them in increasing order

Consider an array of Dates: want to put in chronological order

We don't want to write three different sorting procedures!

The sorting procedure should be the same in all cases.
What differs is how elements of the array are compared.

So, write ONE sort procedure, tell it the function to be used to compare elements. To do that, we will use an interface.

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Interface **Comparable**

Package java.lang contains this interface

```
public interface Comparable {
  /** = a negative integer if this object < c,
      = 0 if this object = c,
      = a positive integer if this object > c.
      Throw a ClassCastException if c can't
           be cast to the class of this object. */
  int compareTo(Object c);
}
```

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Real example: Comparable

We implement Comparable in class Shape

```
public abstract class Shape implements Comparable {
    …
   /** Return area of this shape */
   public abstract double area() ;

   /** See previous slide*/
   public int compareTo(Object c) {
        Shape s= (Shape) c;
        double diff= area() – s.area();
        return  diff == 0 ? 0 : (diff < 0 ? -1 : 1);
   }
}
```

If c can't be cast of Shape, a ClassCastException is thrown

Arrays.sort has this method

```
/** Sort array b. Elements of b must implement
interface Comparable. Its method compareTo is
used to determine ordering of elements of b. */
Arrays.sort(Object[] b)
```

Shape implements Comparable, so we can write:

```
// Store an array of values in shapes
Shape[] shapes= ...;
...
Arrays.sort(shapes);
```

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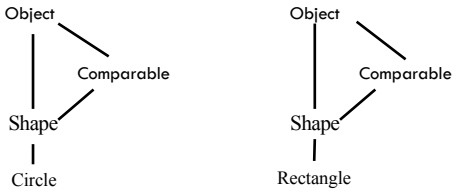
What an object of subclasses look like

```
public abstract class Shape implements Comparable { … }
public class Circle extends Shape { … }
public class Rectangle extends Shape { … }
```

When sort procedure is comparing elements of a Shape array, each element is a Shape. Sort procedure views it from Comparable perspective!



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Abstract Classes vs. Interfaces

- Abstract class represents something
- Share common code between subclasses

- Interface is what something can do. Defines an "abstract data type"
- A contract to fulfill
- Software engineering purpose

Similarities:

- Can't instantiate
- Must implement abstract methods
- Later we'll use interfaces to define "abstract data types"
  - (e.g. List, Set, Stack, Queue, etc)

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