Inheritance

Objectives

- Identify the concept of inheritance
- Create a subclass and override methods from a superclass
- Recognize the importance of the superclass Object and the inheritance hierarchy
- Use the instanceof operator to determine the class of an object

Inheritance

- ***Inheritance***: a mechanism for deriving a new class from an existing one
- ***Motivation***:
  - Can ***reuse*** existing classes
    - Faster and cheaper than writing new classes from scratch

Example of Inheritance

- Suppose we have a class called Rectangle that is to be used by a program that draws geometric shapes on the screen.
  - Each object of this class stores the height and length of the rectangle that they represent.
  - There are also getter methods, the constructor for the class, a method to compute the area, and a method to give a String representation of a rectangle.

Java Example of Inheritance

```
/* Rectangle.java: a class that represents a
    rectangle */

public class Rectangle {
    private int length;
    private int width;
    public Rectangle(int rLength, int rWidth) {
            length = rLength;
            width = rWidth;
    }
    public int getLength( ) {
            return length;
    }
    public int getWidth( ) {
            return width;
    }
    public int area( ) {
            return length*width;
    }
    public String toString( ) {
            return "Rectangle: " +
                        "Length(" + length + ") " +
                        "Width(" + width + ")";
    }
}
```

Derived Class Square

- We want to write a class that represents squares. Squares are special rectangles for which the length and width are the same. Hence we want a square to also have some of the methods of the class rectangle, like the method to compute the area.
- We also want additional attributes and methods specific to squares, like a method to get the side of a square.

```
/ * Square.java: class that represents a square */

public class Square extends Rectangle {
  // Length of the diagonal
  private double diagonal;

  public Square(int side) {
       // calls the constructor of the superclass
       super(side, side);
       diagonal = (double) side * 1.4142;
  }
  public int getSide( ) {
        return getWidth( );
  }
  public String toString( ) {
       return "Square: Side(" + getSide( ) + ")";
  }
}
```

Inheritance Terminology

- The derived new class is called the ***subclass,*** *or* the ***child*** class or the ***derived*** class.
- It inherits the attributes and methods of the ***superclass*** (also called the ***parent*** class or ***base*** class)
- It can add new attributes or methods, ***i.e.*** it can ***extend*** the parent class
  - Java keyword to make a subclass is **extends**

Inheriting Visibility

- ***public*** variables and methods: children classes can access them directly
- ***private*** variables and methods: children classes ***cannot*** access them directly
  - Why not? this would violate information hiding
- ***protected*** = may be accessed directly by any class in the same package, or by any subclass
  - So, children classes *can* access protected variables and methods of a parent class

The **super** Reference

- super is a reserved word used in a derived class to refer to its parent class
- Allows us to access those members of the parent class
- ***Invoking the parent's constructor***: the first line of a child's constructor should be

  super(….);

- ***Invoking other parent methods***:

  super.methodName(…);

Is-a Relationship

- The derived class ***is a*** more specific version of the original class
- So, subclass object is of type ***subclass***, but also it is an instance of ***superclass***
  - ***Example***: A Square object ***is a*** Rectangle
  - Can we say that a Rectangle object ***is a*** Square? Is this sometimes true? Is it always true?

Discussion

- Why extend an existing class, ***i.e.*** why not just change the existing class by adding the new attributes and methods?
- Can you think of more examples of classes we can model with an inheritance relationship?

Example: BankAccount class

- Suppose we have a class BankAccount with attributes

  private String accountNumber;

  private double balance;

  and public methods **deposit, withdraw, printBalance, getBalance, toString**

- What attributes and methods of the BankAccount class can be accessed *directly* by code in its subclasses?

Example: BankAccount class

- What new attributes might we have in subclasses SavingsAccount and CheckingAccount?
  - Examples:

    in SavingsAccount : **interestRate**

    in CheckingAccount : **transactionCount**

Example: BankAccount class

Example: BankAccount constructor:

```
public BankAccount(double initialAmount,
                                        String accountNumber) {
    this.balance = initialAmount;
    this.accountNumber = accountNumber; }
```

CheckingAccount constructor:

```
public CheckingAccount(double initialAmount,
                                        String accountNumber) {
    super(initialAmount, accountNumber);
    transactionCount = 0;    }
```

Example: BankAccount Class

- What new methods might we then have in subclasses SavingsAccount and CheckingAccount?
  - In SavingsAccount:
    - addInterest
    - getInterestRate
  - In CheckingAccount:
    - deductFees
    - deposit
    - withdraw

Overriding Methods

- A derived class can define a method with the *same signature* (same name and number and types of parameters) as a method in the parent class
  - The child's method ***overrides*** the parent's method
  - Example: methods deposit and withdraw in CheckingAccount override deposit and withdraw of BankAccount
  - Example: method toString in Square overrides toString of Rectangle

Overriding Methods

- Which method is actually executed at run time?
  - It depends on *which object is used to invoke the method*
  - Example:

    ```
    Rectangle r = new Rectangle(4,5);
    Square s = new Square(5);
    System.out.println(r.toString( ));
    System.out.println(s.toString( ));
    ```

- Note that a method defined with the **final** modifier cannot be overridden

Review the **super** Reference

- Allows us to invoke a method of the parent class that was overridden in the child class
  - Example:

```
public void deposit (double amount) {
    balance = balance + amount;
}
```

Method deposit in BankAccount

```
public void deposit (double amount) {
        transactionCount++;
        super.deposit (amount);
}
```

Method deposit in CheckingAccount

What would happen if we did not have the **super** reference here?

Superclass Variables

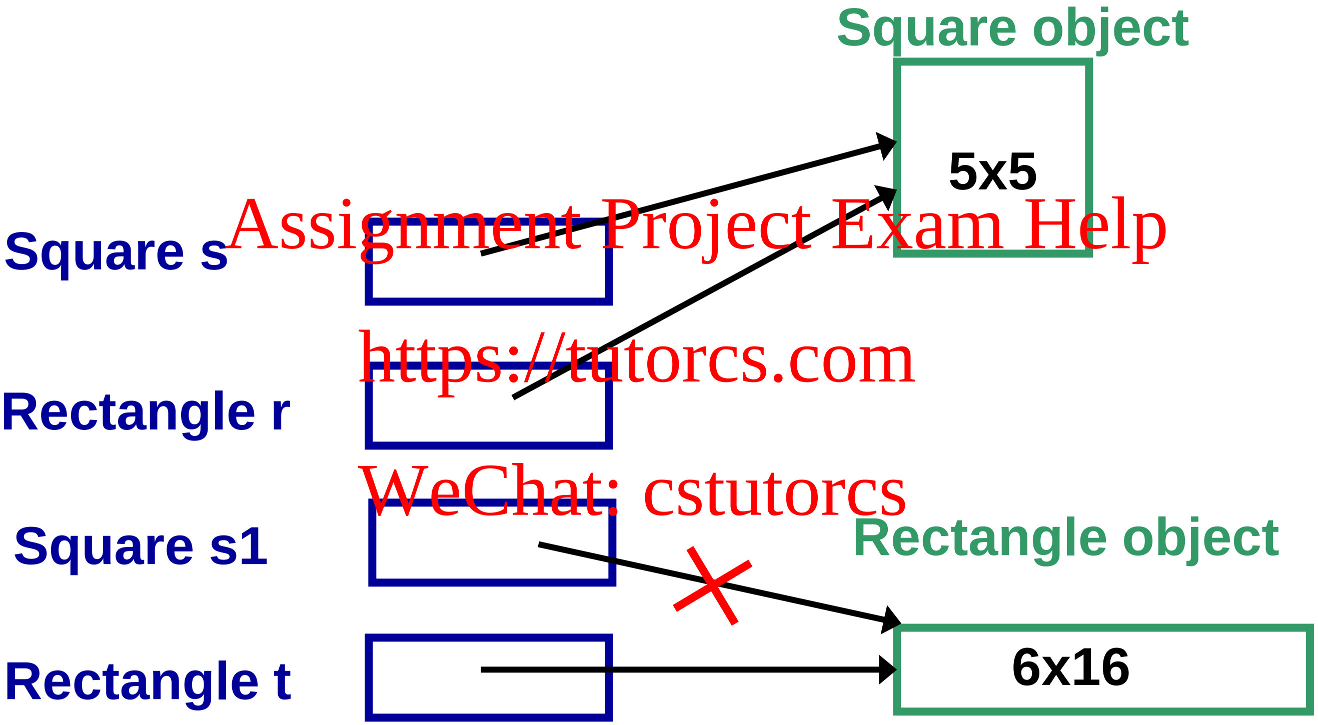
- A variable of the ***superclass*** type may ***reference*** an object of a ***subclass*** type
  - ***Examples*** *(see diagrams next page)*:

```
Square s = new Square(5);
Rectangle r = s;

Rectangle t = new Square(6);
```

- A variable of the *subclass* type ***cannot*** reference an object of the *superclass* type
  - Why not?

Superclass Variables



Type of an Object

- Note that the ***type of an object*** is determined when it is created, and does not change

- Examples:

```
… = new Rectangle(2,5);
… = new BankAccount(45.65, “12345”);
```

- Notice that we are *not* talking about the *type of a variable* here

Polymorphism

- ***Polymorphism***: the principle that behavior of a method can vary depending on the ***type of the object*** being referenced
  - With inheritance, a *variable* can refer to objects of ***different*** types during its lifetime
  - ***Example***:

```
Rectangle r;
r = new Rectangle(2,5);
System.out.println(r.toString( ));
…
r = new Square(2);
System.out.println(r.toString( ));
```

What’s printed depends on the actual type of the object (*not* the type of the variable)

Polymorphism

- When is it known which method should be invoked? ***Not until run time!***
  - This is called ***dynamic binding*** or ***late binding*** of the *variable* to the *type of the object*
  - Why is this not known at compile time?

Example:

```
 if ( … )
      r = new Rectangle(2,5);
  else
      r = new Square(2);
  System.out.println(r.toString( ));
```

Dynamic (Late) Binding

- What happens when a ***superclass*** variable references an object of a ***subclass*** type, and a method is invoked on that object?

Example:
Rectangle r = new Square(5);

- The method *must* exist in the superclass (or one of its ancestors) or there will be a compiler error

Example:
System.out.println(r.getSide( ));

Not legal: r may not always reference a Square object

Dynamic (Late) Binding

- If the method also exists in the subclass, the method from the subclass is invoked (this is called ***overriding***)

  Example: what will be printed by
  System.out.println(r.toString( ));

- If the method does *not* exist in the subclass, the method from the superclass is invoked

  Example: is this legal?
  System.out.println(r.getWidth( ));

Casting Reference Variables

- Go back to the example:

```
Rectangle r = new Square(5);
System.out.println( r.getSide( ) );
```

- This will generate a compiler error (why?)
- How could we fix it?
  - We can let the compiler know that we *intend* our variable **r** to reference a Square object, by casting it to type Square

Review: Casting Primitive Types

- ***Recall***: we have used casting to convert one primitive type to another
  - ***Examples***: why are we casting here?

```
int i, j, n;
```

```
n = (int) Math.random( );
double q = (double) i / (double) j;
```

  - Note that this actually changes the *representation* from integer to double or vice versa

Casting Reference Variables

- We can also cast from *one class type to another* *within an inheritance hierarchy*
- Fix our previous example by casting:

```
Rectangle r = new Square(5);
System.out.println( ( (Square) r).getSide( ));
```

- The ***compiler*** is now happy with our *intention* that r references a Square object!
  - Casting does not change the object being referenced

Casting Reference Variables

- But, what if r did ***not*** reference a Square object when casting took place?

```
Rectangle r = new Rectangle(2,5);
…
System.out.println(( (Square) r).getSide( ));
```

- The compiler is happy, but we would get a *runtime error* (why?)

instanceof Operator

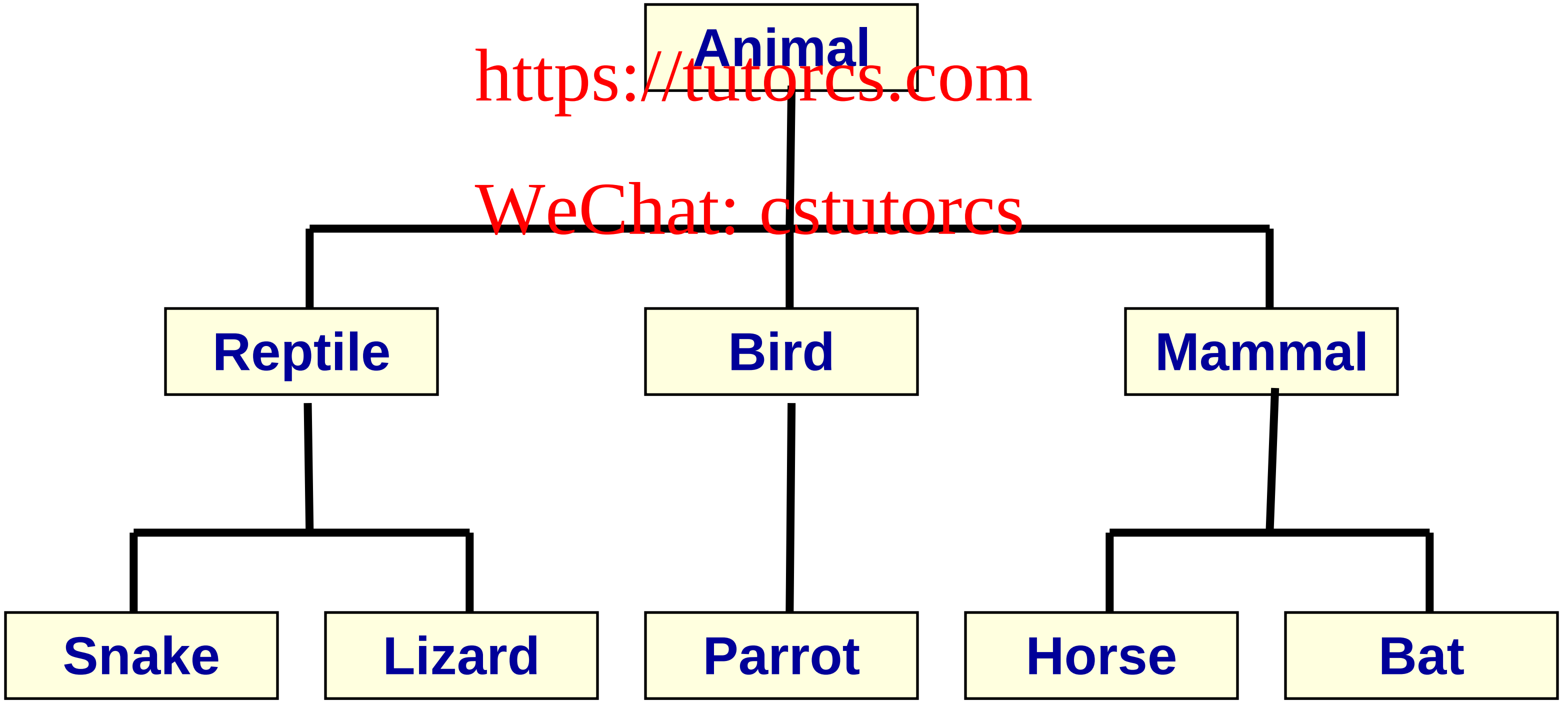
A safer fix: use the instanceof operator

```
if (r instanceof Square)
 {
   System.out.println(((Square)r).getSide( ));
 }
```

- Note that instanceof is an ***operator***, not a method
- It tests whether the referenced object is an instance of a particular class, and gives the expression the value true or false

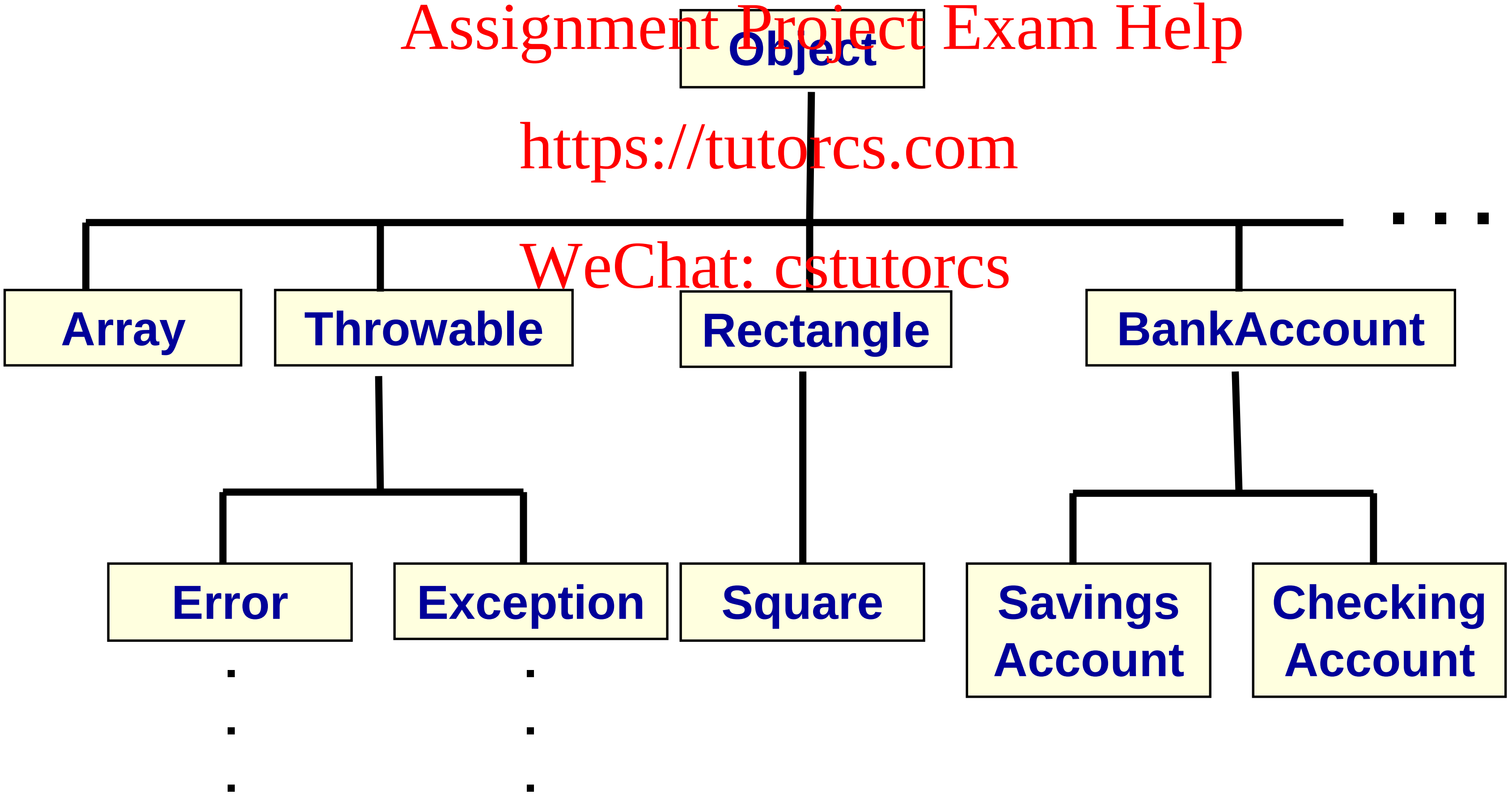
Class Hierarchies

- A derived class can be the parent of several classes derived from it
- A single parent class can have many child classes
- *Siblings*: children of the same parent



Java's Class Hierarchy

- A class called Object is at the top of the class hierarchy so, by default, *any and every* class extends Object.



Java’s Class Hierarchy

- Some methods defined in the Object class are:
  - public boolean equals(Object obj);
  - public String toString( );
- So, will these methods exist in all classes?

Object methods

- toString method: returns a string containing the object’s class name followed by a unique numeric value (the “*hash code*” of the object, or address that says where it is stored)

- Example: Suppose we had *not* defined a toString in the Person class. Then the code

```
Person friend = new Person("Snoopy", "Dog", "");
System.out.println(friend);
```

would print:

```
Person@10b62c9
```

- Not very meaningful to us, so we usually ***override*** this method in the classes we write.

Object methods

- equals method: returns true if the two object references refer to the *same object*
  - Does this compare object addresses or their content?
  - We often override this method in classes we write, for example if we want *equality* to mean that the objects *hold equal data*.

Using the Object class

- A variable of type Object can reference an object of any type! (why?)
  - ***Example***:
    Object obj = new Rectangle(5,6);

- So, an array whose elements are of type **Object** can store *any* type of object

- It can even store a ***mix*** of object types
  - ***Example***:
    Object[] stuff = new Object[10];
    stuff[0] = new Rectangle(5,6);
    stuff[1] = new Integer(25);
    ...

Using the Object class

- When an element of the array is obtained, it can be ***cast*** to its particular (sub)class type, for example:

```
System.out.println(( (Rectangle)stuff[0] ).area( ));
```

- We can create a general collection of objects of type Object