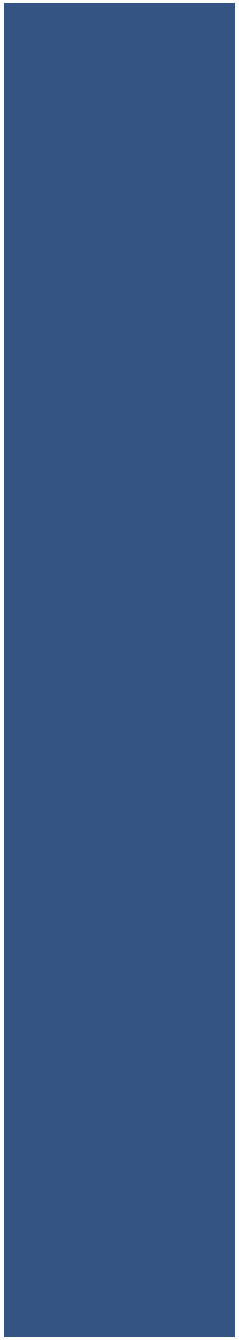
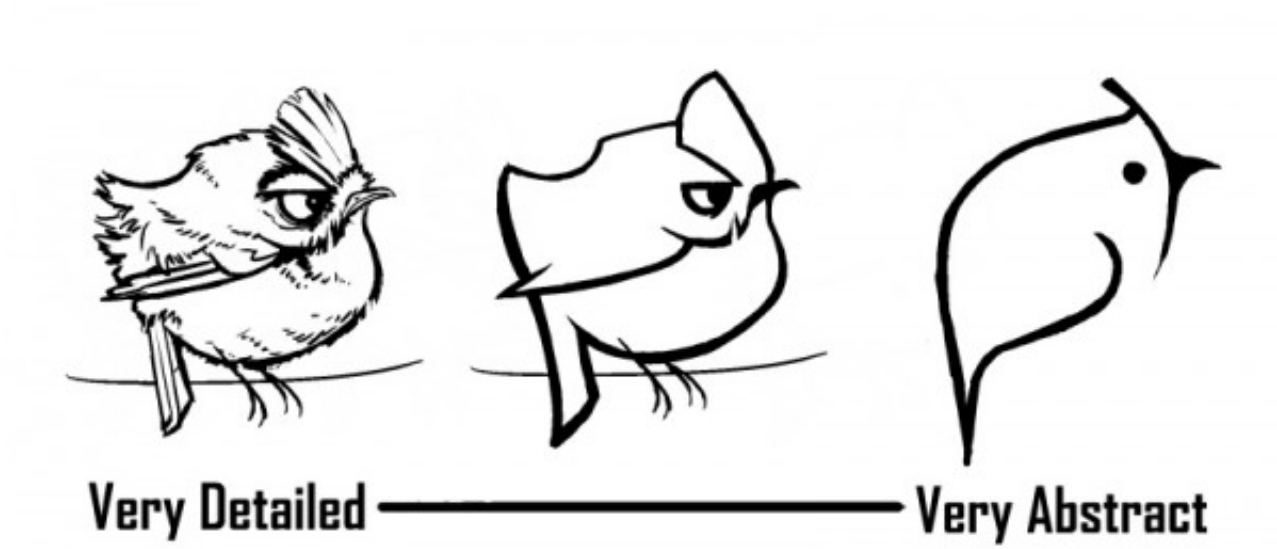
Object-oriented Design

Abstraction, Modularity, and Encapsulation



Abstraction

- Distills a system to its functionality



[source:onanimation.com]

Abstract Data Type

ADT (Abstract Data Type)

- Define ADT before implementation
- Specifies what each operation does, but not how it does (an interface in Java)
  - An interface is a list of method declarations without their method body
- An ADT is realized by a concrete data structure (which is called “a class” in Java)

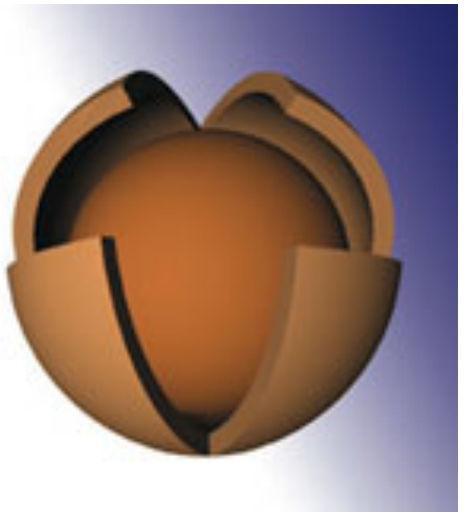
Modularity

- Splits a large program into a number of smaller, **independent** parts to reduce complexity
- Each part (a module) represents a separate functional unit

[Source: php.jglobal.com]

Encapsulation

- Hide the implementation details of a module from its users
- Each module maintains a consistent interface but reveals **no** internal details for outsiders
- Gives the programmers the freedom in implementing the details



[Source: entertainingcode.com]

Goals

Software implementation should be

- Robustness
- Adaptability
- Reusability

Object-oriented Design

An object

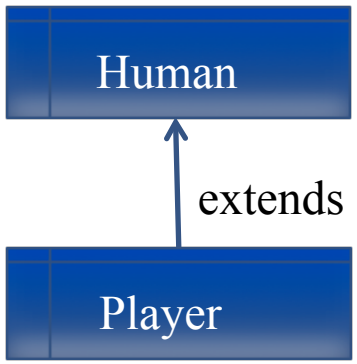
- Is the main actor in the object-oriented paradigm
- is an instance of a class

A Class

- Defines an object
- Consists of fields and methods
- Gives others a consistent and concise view to interact with the object (without knowing details)

Inheritance

- A way to reuse code (based on a hierarchical structure)
- Player (A subclass) extends Human (A superclass)
- A player has his/her own name and record, and can watch, talk, jump, and shoot.

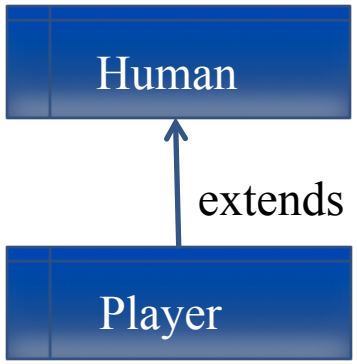


Fields: name
Methods: watch(), talk(), jump()

Fields: record
Methods: shoot()

Overriding

- Redefine a method in the subclass
- A player jumps in a different way
- A player has his/her own name and record, and can watch, talk, **jump**, and shoot.



Fields: name
Methods: watch(), talk(), jump()

Fields: record
Methods: **jump**(), shoot()

Polymorphism

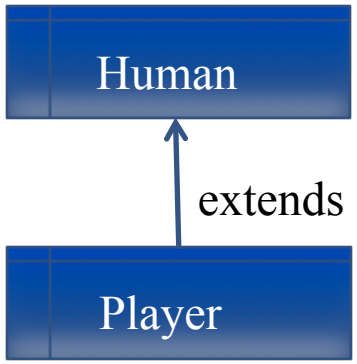
- An object can be polymorphic.
- It may have different forms and behave the same method in different ways depending on which class it refers to

For example,

- An instance of Human (like us) jumps in one way
- An instance of Player (like LeBron James) jumps in a different way
- How do you jump?

Overloading

- In the same class, one can define the same method with different signatures
- The signature of a method is a combination of its name, and the type and number of arguments



Fields: name
Methods: watch(), talk(), jump()

Fields: record
Methods: **shoot(), shoot(int a)**

this

- A keyword in Java
- The reference of the **current instance** of the class

```
public class Example {
    public int dog =2;
    public void clobber() {
        int dog = 5;
        System.out.println("The local dog value = "+dog);
        System.out.println("The field dog value = "+this.dog);
    }
    public static void main(String[] argv) {
        this.clobber();
    }
}
```

```
javac Example.java
java Example

The local dog value  = 5
The field dog value = 2
```

An inheritance example

- Progression
  - 1, 2, 3, …
- Arithmetic Progression
  - f(n) = f(n-1)+d
  - f(0) = 1, d =2, we have 1, 3, 5, 7, …
- Geometric Progression
  - f(n) = f(n-1)*r
  - f(0) = 1, r = 2, we have 1, 2, 4, 8, 16, …
- Fibonacci Progression
  - f(n) = f(n-1)+f(n-2)
  - f(0) =1, f(1) = 2, we have 1, 2, 3, 5, 8, 13, 21, …

Progression

- Fields:
  - first (the first value)
  - cur (the current value)
- Methods:
  - Progression(): Initialize the field values (A Constructor function)
  - firstValue(): Reset the progression to the first value and return that value
  - nextValue(): Step the progression to the next value and return that value
  - printProgression(int n): Reset the progression and print the first n values

Progression

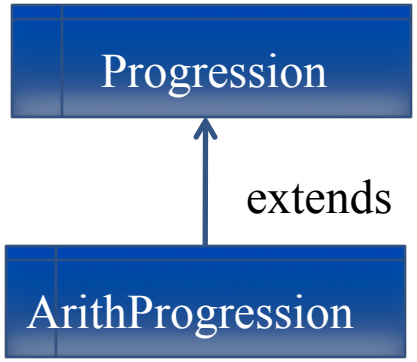
```
//1, 2, 3, …
public class Progression {
        protected long first;
        protected long cur;
        Progression(){  //Constructor
                first = cur = 1;
        }
        protected long firstValue(){ //Reset cur
                cur = first;
                return cur;
        }
        protected long nextValue(){    //cur = cur+1; return cur;
                return ++cur;
        }
        protected long printProgression(int n){ … }
}
```

Progression

```
//Print the first n values
protected long printProgression(int n){
        System.out.print(firstValue());
        for(int i =2; i<=n; i++)
                System.out.print(“ “+ nextValue());
        System.out.println();
}
```

Arithmetic Progression

first, first+d, first+2d, …



Fields: first, cur
Methods: firstValue(), nextValue(),
printProgression()

Fields: d
Methods: nextValue()

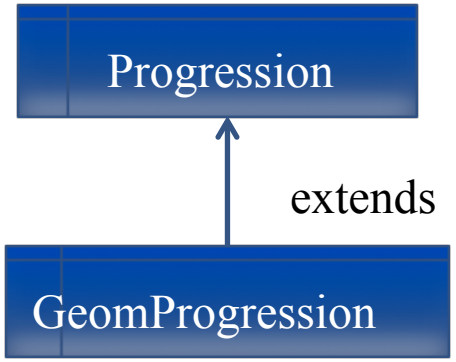
Arithmetic Progression

```
//refines constructor, replaces nextValue(), and
//inherits Progression(), firstValue(), printProgression(int)

class ArithProgression extends Progression{
        protected long d;
        ArithProgression(){  //d =1 by default
                this(1,1); //first=cur=1, d = 1;
        }
        ArithProgression(int a, int increment) { //Set d to increment
                first =cur= a;
                d = increment;
        }
        protected long nextValue(){
                cur += d;     //cur = cur+d;
                return cur;
        }
}
```

Geometric Progression

first, first*r, first*r^2, …



Fields: first, cur
Methods: firstValue(), nextValue(),
printProgression()

Fields: r
Methods: nextValue()

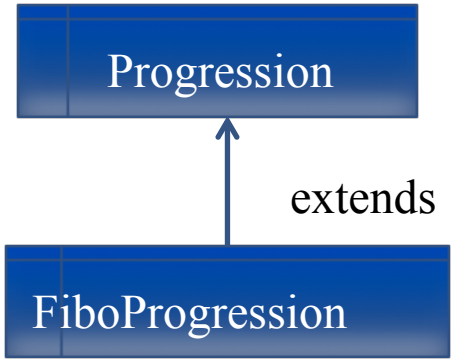
Geometric Progression

```
//refines constructor, replaces nextValue(), and
//inherits Progression(), firstValue(), printProgression(int)

class GeomProgression extends Progression
{
        protected long r;
        GeomProgression(){  //first =1, r =1 by default
                this(1,1); //first = 1; r = 1;
        }
        GeomProgression(int a, int base) { //Set r to base
                first = a;
                r = base;
        }
        protected long nextValue(){
                cur *= r;       //cur = cur*r;
                return cur;
        }
}
```

Fibonacci Progression

$a0, a1, a2, a3, \ldots (a_{n+1} = a_{n-1} + a_n)$



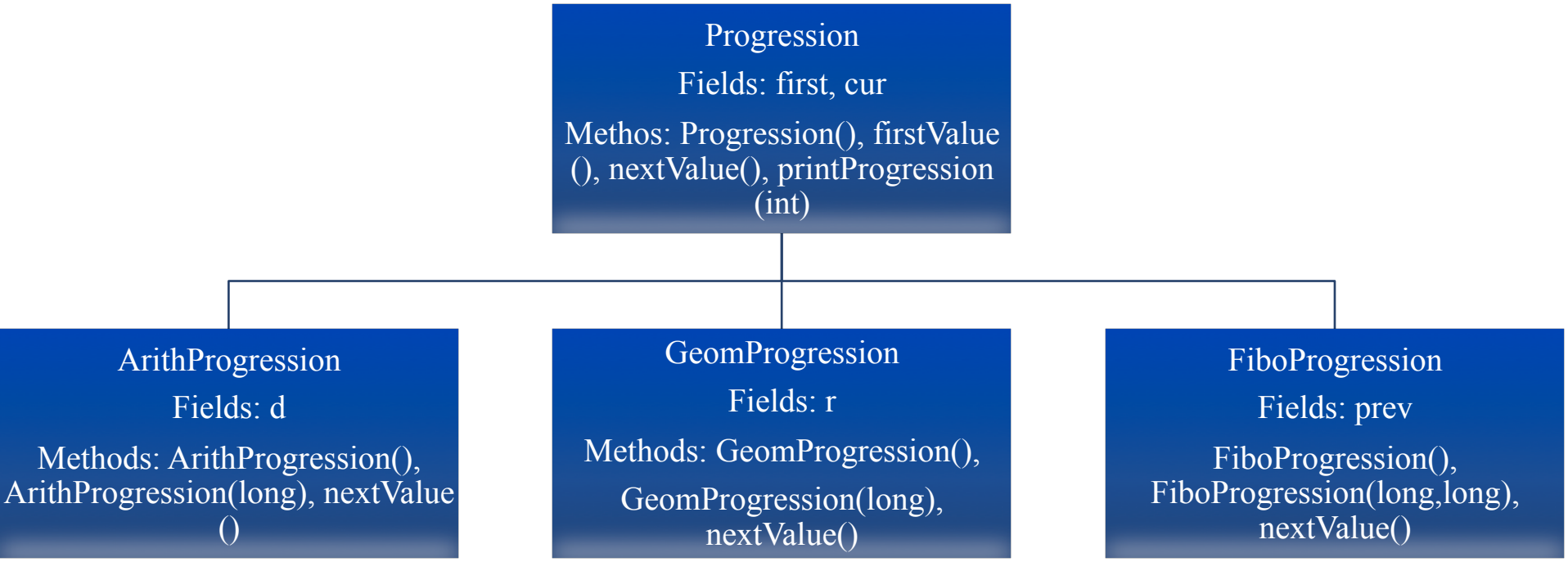
Fields: first, cur
Methods: firstValue(), nextValue(),
printProgression()

Fields: prev
Methods: nextValue()

Fibonacci Progression

```
//inherits Progression(), firstValue(), printProgression(int)
class FiboProgression extends Progression{
        protected long prev;
        FiboProgression(){  //a0=1, a1=2 by default
                this(1,2);
        }
        FiboProgression(long a0, long a1) {
                first = a0; //overwrite the initial value of first (so is cur)
                prev = a1-a0; //fictitious value preceding the first
        }
        protected long nextValue(){   //a_{n+1} = a_{n-1}+a_n
                long temp = prev; //temp = a_{n-1}
                prev = cur; //prev = a_n
                cur+=temp;//cur = a_{n+1} = a_{n-1}+a_n
                return cur;
        }
}
```

Inheritance Diagram



Test Progression

```
class TestProgression{
        public static void main(String[] args){
                Progression prog;
                prog = new ArithProgression(1, 2);
                prog.printProgression(10);
                prog = new GeomProgression(1,3);
                prog.printProgression(10);
                prog = new FiboProgression(3,4);
                prog.printProgression(10);
        }
}
```

```
1 3 5 7 9 11 13 15 17 19
1 3 9 27 81 243 729 2187 6561 19683
3 4 7 11 18 29 47 76 123 199
```

DoubleProgression

```
//1, 2, 3, …
public class DoubleProgression {
        protected double first;
        protected double cur;
        Progression(){  //Constructor
                first = cur = 1;
        }
        protected double firstValue(){ //Reset cur
                cur = first;
                return cur;
        }
        protected double nextValue(){        //cur = cur+1; return cur;
                return ++cur;
        }
        protected double printProgression(int n){ … }
}
```

DoubleProgression

```
//Print the first n values
protected void printProgression(int n){
        System.out.print(firstValue());
        for(int i =2; i<=n; i++)
                System.out.print(“ “+ nextValue());
        System.out.println();
}
```

Geometric Double Progression

```
//refines constructor, replaces nextValue(), and
//inherits Progression(), firstValue(), printProgression(int)

class GeomDoubleProgression extends DoubleProgression
{
        protected double r;
        GeomProgression(){  //first =1, r =1 by default
                this(1,1); //first = 1; r = 1;
        }
        GeomProgression(double a, double base) { //Set r to base
                first = a;
                r = base;
        }
        protected double nextValue(){
                cur *= r;       //cur = cur*r;
                if(cur<0) throw new Exception("negative value!");
                return cur;
        }
}
```

Test Progression

```
class TestProgression{
        public static void main(String[] args){
                Progression prog;
                prog = new ArithProgression(1, 2);
                prog.printProgression(10);
                prog = new GeomProgression(1,3);
                try{
                        prog.printProgression(10);
                }catch(Exception abc){
                        System.out.println(abc.getValue());
                }
                prog = new GeomDoubleProgression(100,0.024);
                prog.printProgression(10);
                prog = new FiboProgression(3,4);
                prog.printProgression(10);
        }
}
```

```
1 3 5 7 9 11 13 15 17 19
1 3 9 27 81 243 729 2187 6561 19683
3 4 7 11 18 29 47 76 123 199
```

Exception Handling

Exceptions are

- unexpected events that occur during the execution of a program (by JRE or programmers)
- Throw an exception in Java

  throw new exception_type (param, …)

- Example:

```
if (insertIndex >= A.length){
        throw new
                BoundaryViolationException("No element at index " + insertIndex);
}
```

Catching Exceptions

- When an exception is thrown, it must be caught
- Otherwise, the program will terminate
- Use try-catch block in Java to catch exceptions

```
int index = Integer.MAX_VALUE;
try{
        String.toBuy = shoppingList[index];
}
catch(ArrayIndexOutOfBoundsException aioobx){
        System.out.println("The index "+index+" is outside the array.");
}
```

Interface

Application Programming Interface (API)

- The methods that each object supports
- A list of method declarations with no data and no bodies

Implementing Interfaces

- An interface enforces the requirements that a class has methods with certain specified signatures
- A class can implement many interfaces (must implement all methods of each interface)

An Interface and Its Implementation

```
public interface Sellable {
        public String description();
        public int listPrice();
        public int lowestPrice();
}
```

```
public class Photo implements Sellable{
        private String descript;
        private int price;
        private boolean color;

        public Photo(String desc, int p, boolean c){
                descript = desc; price = p; color = c;
        }
        public String description(){
                return desc;
        }
        public int listPrice(){
                return price;
        }
        public int lowestPrice(){
                return price/2;
        }
}
```

Multiple Inheritance

- An interface can have multiple inheritance

  (a class cannot)

```
public interface Sellable {
        public String description();
        public int listPrice();
        public int lowestPrice();
}
```

```
public interface Transportable {
        public int weight();
        public int isHazardous();
}
```

```
public interface InsurableItem extends Transportable, Sellable {
        public int insuredValue();
}
```

Generics

- A generic type is not defined at compile time but becomes fully specified at run time
- Define a class with **formal type parameters**
- Instantiate an object of this class by using **actual type parameters** to indicate the concrete types

An Integer Pair Example

```
public class IntPair{
        string key;
        int value;
        public void set(string k, int v){
                key = k;
                value = v;
        }
        public string getKey(){ return key; }
        public int getValue(){ return value;}
        public String toString(){
                return “[”+getKey()+”, ”+getValue()+” ]”;
        }
        public static void main(…){…}
}
```

An Double Pair Example

```
public class DoublePair{
        string key;
        double value;
        public void set(string k, double v){
                key = k;
                value = v;
        }
        public string getKey(){ return key; }
        public double getValue(){ return value;}
        public String toString(){
                return “[”+getKey()+”, ”+getValue()+” ]”;
        }
        public static void main(…){…}
}
```

A Pair Example

```
…
public static void main(String[] args){
        IntPair pair1 = new IntPair();
        pair1.set(“age”, 20);
        System.out.println(pair1.toString());
        DoublePair pair2 = new DoublePair ();
        pair2.set(new String(“grade”), new Double(82.53));
        System.out.println(pair2.toString());
}
…
```

Javac Pair.java
Java Pair

[age, 20]
[grade, 82.53]

A Generic Example

```
public class Pair<K, V>{
        K key;
        V value;
        public void set(K k, V v){
                key = k;
                value = v;
        }
        public K getKey(){ return key; }
        public V getValue(){ return value;}
        public String toString(){
                return “[”+getKey()+”, ”+getValue()+” ]”;
        }
        public static void main(…){…}
}
```

A Generic Example

```
…
public static void main(String[] args){
        Pair<String, Integer> pair1 = new Pair<String, Integer>();
        pair1.set(new String("age"), new Integer(20));
        System.out.println(pair1.toString());
        Pair<String, Double> pair2 = new Pair<String, Double>();
        pair2.set(new String("grade"), new Double(82.53));
        System.out.println(pair2.toString());
}
…
```

Javac Pair.java
Java Pair

[age, 20]
[grade, 82.53]

Generic Progression

```
//1, 2, 3, …
public class Progression <k> {
        protected k first;
        protected k cur;
        Progression(){  //Constructor
                first = cur;
        }
        protected k firstValue(){ //Reset cur
                cur = first;
                return cur;
        }
        protected k nextValue(){        //cur = cur+1; return cur;
                return cur;
        }
        protected k printProgression(int n){ … }
}
```

Geometric Progression

```
//refines constructor, replaces nextValue(), and
//inherits Progression(), firstValue(), printProgression(int)

class GeomProgression extends Progression<Long>{
        protected long r;
        GeomProgression(){  //first =1, r =1 by default
                this(1,1); //first = 1; r = 1;
        }
        GeomProgression(long a, long base) { //Set r to base
                first = a;
                r = base;
        }
        protected long nextValue(){
                cur *= r;       //cur = cur*r;
                return cur;
        }
}
```