

# Classes, objects, Java

Madhavan Mukund, S P Suresh

Programming Language Concepts

Lecture 2, 10 January 2023

# Programming with objects

- Object are like abstract datatypes
  - Hidden data with set of public operations
  - All interaction through operations — **messages, methods, member-functions, ...**
- **Class**
  - Template for a data type
  - How data is stored
  - How public functions manipulate data
- **Object**
  - Concrete instance of template
  - Each object maintains a separate copy of local data
  - Invoke methods on objects — send a message to the object

## Example: 2D points, in Python

- A point has coordinates  $(x, y)$ 
  - Each point object stores its own internal values `x` and `y` — instance variables
  - For a point `p`, the local values are `p.x` and `p.y`
  - `self` is a special name referring to the current object — `self.x`, `self.y`
- When we create an object, we need to set it up
  - Implicitly call a **constructor** function with a fixed name
  - In Python, constructor is called `__init__()`
  - Parameters are used to set up internal values
  - In Python, the first parameter is always `self`

```
class Point:  
    def __init__(self, a=0, b=0):  
        self.x = a  
        self.y = b
```

# Adding methods to a class

- Translation: shift a point by  $(\Delta x, \Delta y)$ 
  - $(x, y) \mapsto (x + \Delta x, y + \Delta y)$
  - Update instance variables
- Distance from the origin
  - $d = \sqrt{x^2 + y^2}$
  - Does not update instance variables
  - **state** of object is unchanged

```
class Point:
    def __init__(self, a=0, b=0):
        self.x = a
        self.y = b

    def translate(self, dx, dy):
        self.x += dx
        self.y += dy

    def odistance(self):
        import math
        d = math.sqrt(self.x*self.x +
                      self.y*self.y)
        return(d)
```

# Changing the internal implementation

- **Polar coordinates:**  $(r, \theta)$ , not  $(x, y)$ 
  - $r = \sqrt{x^2 + y^2}$
  - $\theta = \tan^{-1}(y/x)$
- Distance from origin is just  $r$
- Translation
  - Convert  $(r, \theta)$  to  $(x, y)$
  - $x = r \cos \theta$ ,  $y = r \sin \theta$
  - Recompute  $r, \theta$  from  $(x + \Delta x, y + \Delta y)$
- Interface has not changed
  - User need not be aware whether representation is  $(x, y)$  or  $(r, \theta)$

```
import math
class Point:
    def __init__(self, a=0, b=0):
        self.r = math.sqrt(a*a + b*b)
        if a == 0:
            self.theta = math.pi/2
        else:
            self.theta = math.atan(b/a)

    def odistance(self):
        return(self.r)

    def translate(self, dx, dy):
        x = self.r*math.cos(self.theta)
        y = self.r*math.sin(self.theta)
        x += dx
        y += dy
```

# Abstraction

- User should not know whether `Point` uses `(x,y)` or `(r,theta)`
  - Interface remains identical
  - Even constructor is the same

- Python allows direct access to instance variables from outside the class

```
p = Point(5,7)
p.x = 4 # Point is now (4,7)
```

- Breaks the abstraction
  - Changing the internal implementation of `Point` can have impact on other code
- Rely on programmer discipline

```
class Point:
    def __init__(self,a=0,b=0):
        self.x = a
        self.y = b
```

```
class Point:
    def __init__(self,a=0,b=0):
        self.r = math.sqrt(a*a + b*b)
        if a == 0:
            self.theta = math.pi/2
        else:
            self.theta = math.atan(b/a)
```

# Subtyping and inheritance

- Define `Square` to be a subtype of `Rectangle`

- Different constructor
- Same instance variables

- The following is legal

```
s = Square(5)
a = s.area()
p = s.perimeter()
```

- `Square` inherits definitions of `area()` and `perimeter()` from `Rectangle`

```
class Rectangle:
    def __init__(self,w=0,h=0):
        self.width = w
        self.height = h

    def area(self):
        return(self.width*self.height)

    def perimeter(self):
        return(2*(self.width+self.height))

class Square(Rectangle):
    def __init__(self,s=0):
        self.width = s
        self.height = s
```

# Subtyping and inheritance ...

- Can change the instance variable in `Square`
  - `self.side`
- The following gives a run-time error

```
s = Square(5)
a = s.area()
p = s.perimeter()
```

  - `Square` inherits definitions of `area()` and `perimeter()` from `Rectangle`
  - But `s.width` and `s.height` have not been defined!
  - Subtype is not forced to be an extension of the parent type

```
class Rectangle:
    def __init__(self,w=0,h=0):
        self.width = w
        self.height = h

    def area(self):
        return(self.width*self.height)

    def perimeter(self):
        return(2*(self.width+self.height))

class Square(Rectangle):
    def __init__(self,s=0):
        self.side = s
```



# Subtyping and inheritance ...

- Subclass and parent class are usually developed separately
- Implementor of `Rectangle` changes the instance variables
- The following gives a run-time error

```
s = Square(5)
a = s.area()
p = s.perimeter()
```

- `Square` constructor sets `s.width` and `s.height`
- But the instance variable names have changed!
- Why should `Square` be affected by this?

```
class Rectangle:
    def __init__(self,w=0,h=0):
        self.width = w
        self.height = h

    def area(self):
        return(self.width*self.height)

    def perimeter(self):
        return(2*(self.width+self.height))
```

```
class Rectangle:
    def __init__(self,w=0,h=0):
        self.wd = w
        self.ht = h

    def area(self):
```

# Subtyping and inheritance ...

- Need a mechanism to hide private implementation details
  - **Declare** component private or public
- Working within privacy constraints
  - Instance variables `wd` and `ht` of `Rectangle` are private
  - How can the constructor for `Square` set these private variables?
  - `Square` doesn't (and shouldn't) know the names of the private instance variables
- Need to have elaborate declarations
  - Type and visibility of variables
- Static type checking catches errors early

```
class Rectangle:
    def __init__(self,w=0,h=0):
        self.wd = w
        self.ht = h

    def area(self):
        return(self.wd*self.ht)

    def perimeter(self):
        return(2*(self.wd+self.ht))

class Square(Rectangle):
    def __init__(self,s=0):
        self.width = s
        self.height = s
```

# Getting started with Java

The C Programming Language,  
Brian W Kernighan, Dennis M Ritchie

The only way to learn a new programming language is by writing programs in it. The first program is the same for all languages.

*Print the words*

`hello, world`

This is a big hurdle; to leap over it you have to create the program text somewhere, compile it successfully, load it, run it, and find out where your output went. With these mechanical details mastered, everything else is comparatively easy

## ■ In Python

```
print("hello, world")
```

## ■ ...C

```
#include <stdio.h>
main()
{
    printf("hello, world\n");
}
```

## ■ ...and Java

```
public class helloworld{
    public static void main(String[] args)
    {
        System.out.println("hello, world");
    }
}
```

# Why so complicated?

- Let's unpack the syntax
- All code in Java lives within a class
  - No free floating functions, unlike Python and other languages
  - Modifier `public` specifies visibility
- How does the program start?
  - Fix a function name that will be called by default
  - From C, the convention is to call this function `main()`

```
public class helloworld{  
    public static void main(String[] args)  
    {  
        System.out.println("hello, world");  
    }  
}
```

```
public class helloworld{  
    public static void main(String[] args)  
    {  
        System.out.println("hello, world");  
    }  
}
```

```
public class helloworld{
```

# Why so complicated ...

- Need to specify input and output types for `main()`
  - The **signature** of `main()`
  - Input parameter is an array of strings; command line arguments
  - No output, so return type is `void`
- Visibility
  - Function has to be available to run from outside the class
  - Modifier `public`

```
public class helloworld{  
    public static void main(String[] args)  
    public static void main(String[] args)  
  
    {  
        System.out.println("hello, world");  
    }  
}
```

# Why so complicated ...

## ■ Availability

- Functions defined inside classes are attached to objects
- How can we create an object before starting?
- Modifier `static` — function that exists independent of dynamic creation of objects

```
public class helloworld{  
    public static void main(String[] args)  
    {  
        System.out.println("hello, world");  
    }  
}
```

# Why so complicated ...

- The actual operation
  - `System` is a public class
  - `out` is a `stream` object defined in `System`
    - Like a file handle
    - Note that `out` must also be `static`
  - `println()` is a method associated with streams
    - Prints argument with a newline, like Python `print()`
- Punctuation `{`, `}`, `;` to delimit blocks, statements
  - Unlike layout and indentation in Python

```
public class helloworld{
    public static void main(String[] args)
    {
        System.out.println("hello; world");
        System.out.println("hello; world");
    }
}
```

# Compiling and running Java code

- A Java program is a collection of classes
- Each class is defined in a separate file with the same name, with extension `java`

- Class `helloworld` in `helloworld.java`

```
public class helloworld{  
    public static void main(String[] args)  
    {  
        System.out.println("hello, world");  
    }  
}
```

- Java programs are usually interpreted on **Java Virtual Machine (JVM)**
  - JVM provides a uniform execution environment across operating systems
  - Semantics of Java is defined in terms of JVM, OS-independent
  - **"Write once, run anywhere"**



# Compiling and running Java code

- `javac` compiles into JVM `bytecode`
  - `javac helloworld.java` creates bytecode file `helloworld.class`
- `java helloworld` interprets and runs bytecode in `helloworld.class`

- **Note:**

- `javac` requires file extension `.java`
- `java` should not be provided file extension `.class`
- `javac` automatically follows dependencies and compiles all classes required
  - Sufficient to trigger compilation for class containing `main()`

```
public class helloworld{
    public static void main(String[] args)
    {
        System.out.println("hello, world");
    }
}
```

# Scalar types

- In an object-oriented language, all data should be encapsulated as objects
- However, this is cumbersome
  - Useful to manipulate numeric values like conventional languages
- Java has eight primitive scalar types
  - `int`, `long`, `short`, `byte`
  - `float`, `double`
  - `char`
  - `boolean`
- Size of each type is fixed by JVM
  - Does not depend on native architecture

Type	Size in bytes
<code>int</code>	4
<code>long</code>	8
<code>short</code>	2
<code>byte</code>	1
<code>float</code>	4
<code>double</code>	8
<code>char</code>	2
<code>boolean</code>	1

- 2-byte `char` for Unicode

# Declarations, assigning values

- We **declare** variables before we use them

```
int x, y;  
double y;  
char c;  
boolean b1, b2;
```

- Note the semicolons after each statement

- The assignment statement works as usual

```
int x,y;  
x = 5;  
y = 7;
```

- Characters are written with single-quotes (only)

```
char c,d;
```

```
c = 'x';
```

```
d = '\u03C0'; // Greek pi, unicode
```

- Double quotes denote **strings**

- Boolean constants are **true**, **false**

```
boolean b1, b2;
```

```
b1 = false;
```

```
b2 = true;
```

# Initialization, constants

- Declarations can come anywhere

```
int x;  
x = 10;  
double y;
```

- Use this judiciously to retain readability

- Initialize at time of declaration

```
int x = 10;  
double y = 5.7;
```

- Can we declare a value to be a constant?

```
float pi = 3.1415927f;
```

```
pi = 22/7; // Disallow?
```

- Note: Append `f` after number for `float`, else interpreted as `double`

- Modifier `final` indicates a constant

```
final float pi = 3.1415927f;
```

```
pi = 22/7; // Flagged as error;
```

# Operators, shortcuts, type casting

- Arithmetic operators are the usual ones
  - `+`, `-`, `*`, `/`, `%`
- No separate integer division operator `//`
- When both arguments are integer, `/` is integer division

```
float f = 22/7;    // Value is 3.0
```

- Note implicit conversion from `int` to `float`
- No exponentiation operator, use `Math.pow()`
- `Math.pow(a,n)` returns  $a^n$

- Special operators for incrementing and decrementing integers

```
int a = 0, b = 10;  
a++;    // Same as a = a+1  
b--;    // Same as b = b-1
```

- Shortcut for updating a variable

```
int a = 0, b = 10;  
a += 7;    // Same as a = a+7  
b *= 12;   // Same as b = b*12
```

# Strings

- `String` is a built in class

```
String s,t;
```

- String constants enclosed in double quotes

```
String s = "Hello", t = "world";
```

- `+` is overloaded for string concatenation

```
String s = "Hello";  
String t = "world";  
String u = s + " " + t;  
// "Hello world"
```

- Strings are **not** arrays of characters

- Cannot write

```
s[3] = 'p';  
s[4] = '!';
```

- Instead, invoke method `substring` in class `String`

- `s = s.substring(0,3) + "p!";`

- If we change a `String`, we get a new object

- After the update, `s` points to a new `String`
- Java does automatic garbage collection

# Arrays

- Arrays are also objects
- Typical declaration

```
int[] a;  
a = new int[100];
```

  - Or `int a[]` instead of `int[] a`
  - Combine as `int[] a = new int[100];`
- `a.length` gives size of `a`
  - Note, for `String`, it is a method `s.length()`!
- Array indices run from `0` to `a.length-1`

- Size of the array can vary
- Array constants: `{v1, v2, v3}`

- For example

```
int[] a;  
int n;
```

```
n = 10;  
a = new int[n];
```

```
n = 20;  
a = new int[n];
```

```
a = {2, 3, 5, 7, 11};
```