Object-Oriented Programming

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08, 2016

Outline

Object-Oriented Programming Goals

- Programs as collections of collaborating objects
- Object has public interface, hidden implementation
- Objects are classfied according to their behavior
- Objects may represent real-world entities or entities that produce services for a program
- Objects may be reusable across programs

Introduction To OOP Languages

There are many object-oriented programming (OOP) languages

- Some are pure OOP language (e.g., Smalltalk).
- Newer languages do not support other paradigms but use their imperative structures (e.g., Java and C♯).
- Some support procedural and data-oriented programming (e.g., Ada and C++).
- Some support functional program (e.g., Scala)

Some Important Features of OOP

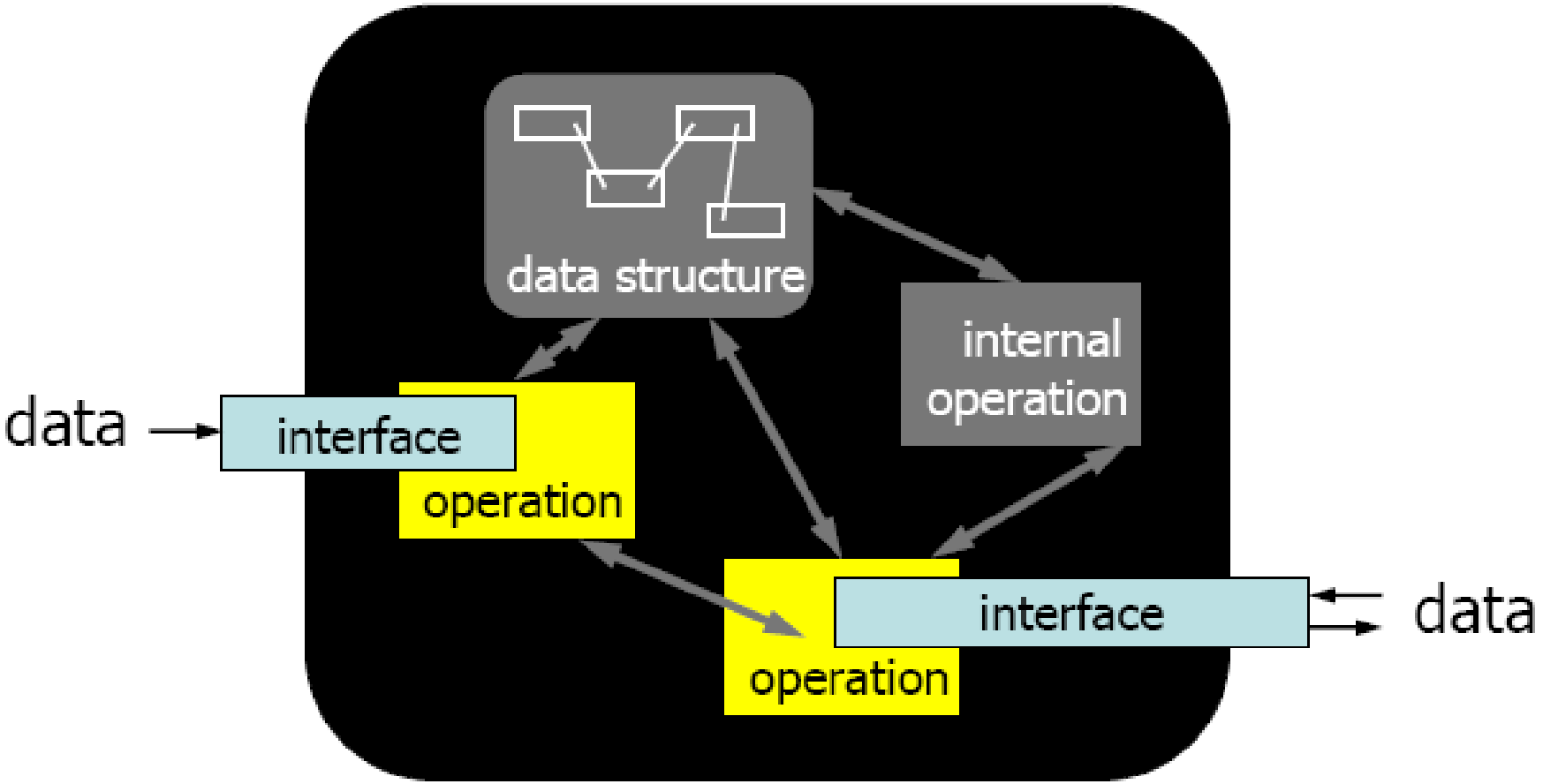
- Abstract data types
  - Encapsulation
  - Information Hiding
- Class Hierarchy
- Inheritance
- Polymorphism - Dynamic Binding

Data Abstraction

An abstract data type is data type that satisfies the following two conditions:

- **Encapsulation:**
  - Attributes and operations are combined in a single syntactic unit
  - compiled separately
- **Information Hiding:**
  - The access to members are controlled
  - Reliability increased

Information Hiding



ADT Example

Operations on a stack:

- create(stack)
- destroy(stack)
- empty(stack)
- push(stack,element)
- pop(stack)
- top(stack)

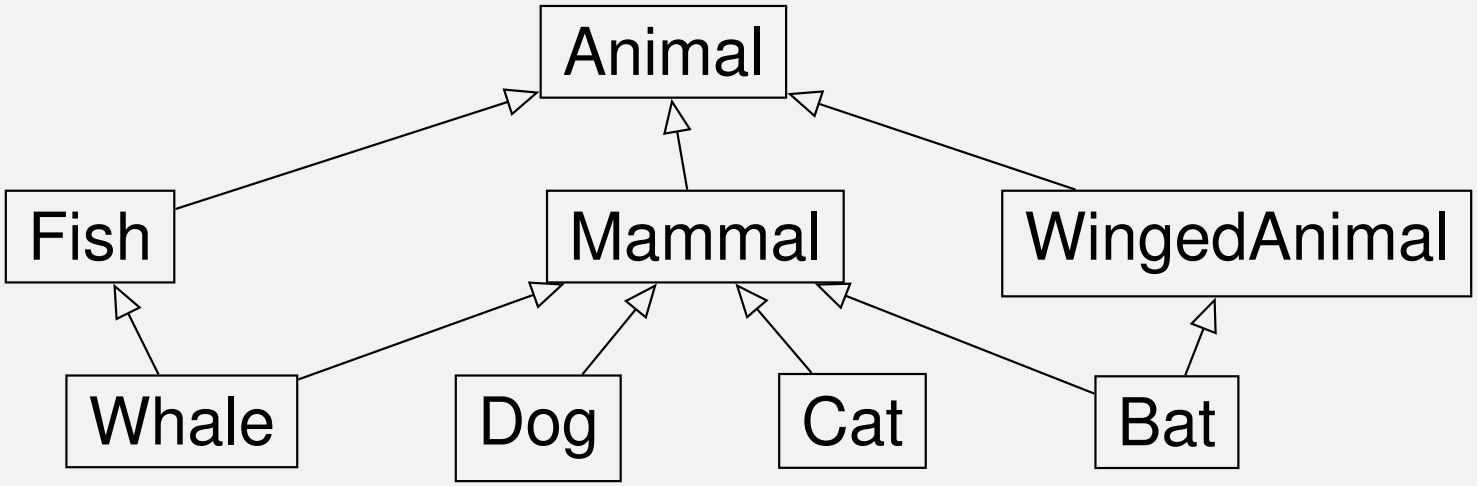
Client code:

```
...
create(stk1);
push(stk1, color1);
push(stk1, color2);
if (! empty(stk1))
    temp = top(stk1);
...
```

Implementation can be adjacent or linked list. Client: don't care!

Class Hierarchy

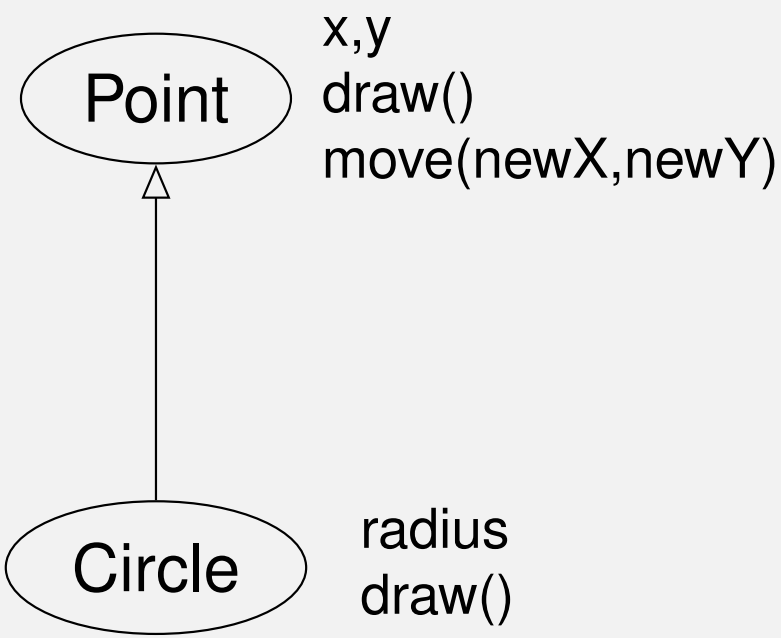
- A class may have some Subclasses
- A class may have one/many Superclass(es)



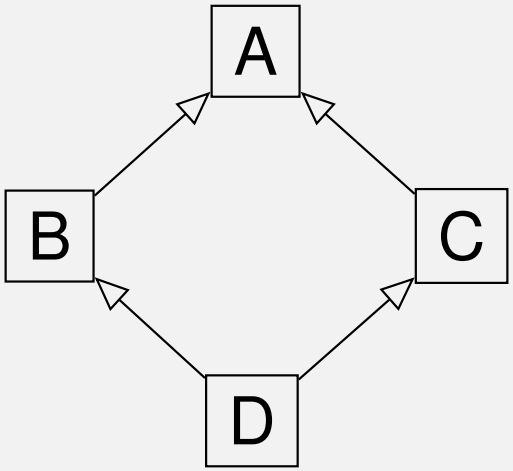
Inheritance

- A subclass is able to inherit **non-private** members of its superclasses
- A subclass can add its own members and **override** its inherited members
- Single vs. multiple inheritance
- Inheritance increases the reusability in OOP

Example of Inheritance



Diamond Problem in Multiple Inheritance



- if D inherits from B and C different versions of the same behaviour, which version will be effective in D?
- this problem, called diamond problem, is solved differently in different OO language
- is there the diamond problem in Java?

Class vs. Object

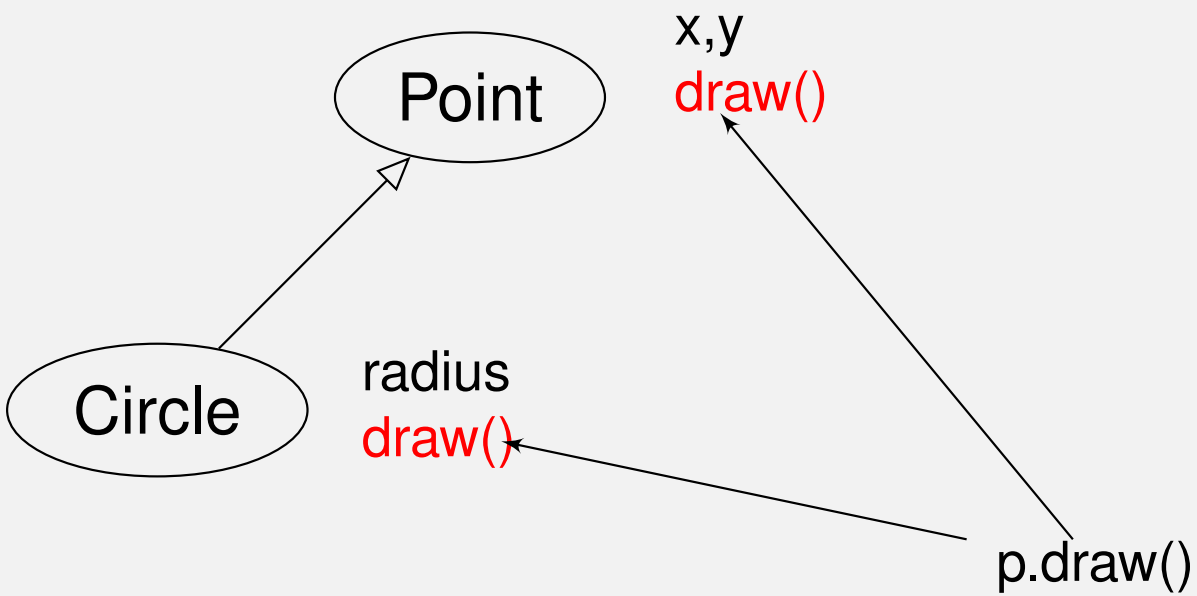
- A class defines the abstract characteristics of a thing
  - its attributes or properties and
  - its behaviors or methods or features.
    A Dog has *fur* and is able *to bark*
- An object is a particular instance of a class.
  Lassie is a dog

Method vs. Message

- A method describes a behavior of an object.
  A dog can bark
- A message is a process at which a method of an object is invoked.
  Lassie barks

Polymorphism

- Polymorphism: different objects can respond to the same message in different ways.



- Dynamic binding

Other Concepts

- There are two kinds of variables in a class:
  - Class variables
  - Instance variables
- There are two kinds of methods in a class:
  - Class methods – accept messages to the class
  - Instance methods – accept messages to objects
- Abstract class vs. Concrete class:
  - Abstract Class – no instance
  - Concrete Class - able to have its instances

Scala Programming Language

- Invented by Martin Ordesky at EPFL, Lausanne, Switzerland.

- Similar to Java
- Work smoothly with Java
- Run on Java Virtual Machine
- OOP + FP
- Include lexer and parser generator

Classes and Objects in Scala

Class

- class [1]
- abstract class [5]
- trait [2]
- case class [3]

Object

- new <class name>
- <case class name>
- object

Example [7]

```
class Rational(n:Int, d:Int){
    require(d != 0)

    private val g = gcd(n.abs, d.abs)
    private def gcd(a: Int, b: Int): Int =
                    if (b == 0) a else gcd(b, a % b)
    val numer = n / g
    val denom = d / g

    def this(n: Int) = this(n, 1)

    def + (that: Rational): Rational =
        new Rational(
              numer * that.denom + that.numer * denom,
              denom * that.denom
        )

    override def toString = numer +"/"+ denom
}
```

Example on Abstract class [4]

```
abstract class Element {
    def contents: Array[String] //no body: abstract
    val height = contents.length
    val width =
      if (height == 0) 0 else contents(0).length
}
class ArrayElement(conts: Array[String])
                    extends Element {
    def contents: Array[String] = conts
}
class LineElement(s: String)
                    extends ArrayElement(Array(s)) {
    override def width = s.length
    override def height = 1
}
```

Example on Object [1]

```
object Element {

    def elem(contents: Array[String]): Element =
        new ArrayElement(contents)

    def elem(line: String): Element =
        new LineElement(line)
}

val space = Element.elem(" ")
val hello = Element.elem(Array("hello","world"))
```

Which kind of Element will be assigned to *space* and *hello*?

Example on Case Class [3]

```
abstract class Expr

case class Var(name: String) extends Expr
case class Number(num: Double) extends Expr
case class UnOp(operator: String, arg: Expr)
                                        extends Expr
case class BinOp(operator: String,
        left: Expr, right: Expr) extends Expr

val v = Var("x")
val op = BinOp("+", Number(1), v)
v.name
op.left
```

Example 1 on Traits [9]

Reusability:



```
abstract class Bird

trait Flying {
    def flyMess: String
    def fly() = println(flyMess)
}
trait Swimming {
    def swim() = println("I'm swimming")
}

class Penguin extends Bird with Swimming

class Hawk extends Bird with Swimming with Flying {
    val flyMess = "I'm a good flyer"
}
class Frigatebird extends Bird with Flying {
    val flyMess = "I'm an excellent flyer"
}
```

Example 2 on Traits [2]

Stackable Modifications:

```
abstract class IntQueue {
    def get(): Int
    def put(x: Int):Unit}
class BasicIntQueue extends IntQueue {
    private val buf = new ArrayBuffer[Int]
    def get() = buf.remove(0)
    def put(x: Int):Unit= { buf += x }}
trait Doubling extends IntQueue {
    abstract override def put(x:Int) {super.put(2*x)}}
trait Incrementing extends IntQueue {
    abstract override def put(x:Int) {super.put(x+1)}}
val queue =
    new BasicIntQueue with Incrementing with Doubling
queue.put(10)
queue.get() //???
```

Trait Linearization: Doubling-> Incrementing-> BasicIntQueue-> IntQueue-> AnyRef-> Any

Trait Linearization: Resolving Diamond Problem in Scala

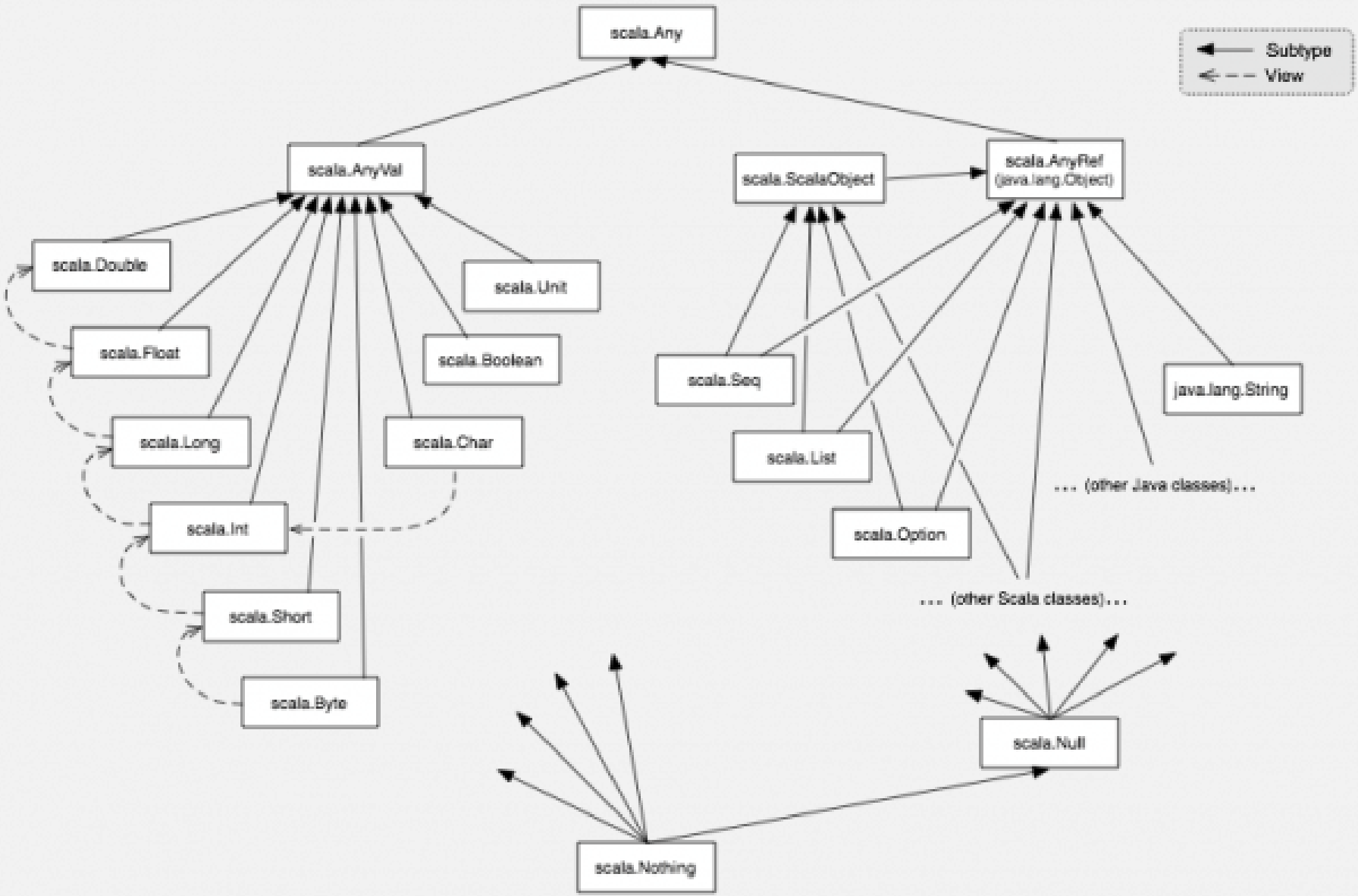
- A class extends just a single class but is able to have many "with" traits
- If these traits have the same method, which method is inherited
- Solution in Scala: Trait linearization
  1. Take the first extended trait/class and write its complete inherited hierarchy in vertical form, store this hierarchy as X
  2. Take the next trait/class after the with clause, write its complete hierarchy and cancel the classes or traits that are repeated in hierarchy X. Add the remaining traits/classes to the front of the hierarchy X.
  3. Go to step 2 and repeat the process, until no trait/class is left out.
  4. Place the class itself in front of hierarchy as head for which the hierarchy is being written.

Example on Trait Linearization

```
trait A {
    def name: String
}
trait B extends A {
    override def name: String ="class b"
}
trait C extends A {
    override def name: String ="class c"
}
class D extends B with C {}
var class_d = new D
println(class_d.name)
```

- B: B->A->AnyRef->Any
- C: C->A->AnyRef->Any
- C->B->A->AnyRef->Any
- D: D->C->B->A->AnyRef->Any

Scala Hierarchy [8]



Access Modifiers [6] in Scala

- protected
- private
- protected[<name>]
- private[<name>]

Example,

```
package Assignment
...
protected[Assignment] val field1 = 100
private[this] val field2 = 2;
```

OOP in Python

- Class vs. Object
- Instance vs. static fields
- Instance, Class, Static methods
- Encapsulation
- Inheritance
- Polymorphism

Class vs. Object

- Class is a user-defined prototype for an object

```
class <Clsname>:  => Clsname: name of the class
    'Optional class documentation string'
    <class_suite>   => fields, methods
```

- Object: an instance of the class

```
class Employee:
    'Common base class for all employees'
    empCount = 0     => empCount: static field
    def __init__(self,n,s):=>constructor
        self.name = n              =>name: instance field
        self.salary = s            =>salary: instance field
        Employee.empCount += 1
obj = Employee("Nam",30)  => create object
```

Instance Methods

- Instance Method: method belongs to the instance

```
class Employee:
    def displayEmployee(self):  => first parameter for instance
        print("Name : ", self.name,
                        ", Salary: ", self.salary)
obj = Employee("Nam",30)
obj.displayEmployee()  =>obj is passed to self
```

- able to access to instance fields through first parameter and '.' => self.name
- able to access to static field through class name and '.' => Employee.empCount

Class and Static Methods

```
class Employee:
    @classmethod                    =>to define class method
    def create(cls,n,s):            =>first parameter for class
        print(cls.empCount)         =>access to static fields
        return cls(n,s)
    @staticmethod                   =>to define static method
    def isHighSal(s):               =>no parameter for class
        if s > 8:                   =>unable to access any fields
            print("High Salary")
obj = Employee.create("Nam",30)  =>Employee is passed to cls
Employee.isHighSal(30)  =>Employee is used to resolve
```

Information Hiding

- to hide fields and methods
- based on name of fields and methods
  - Protected: prefix by a single underscore (_example)
  - Private: prefix by a double underscores (__example)
  - Public: begin with a letter

Class Hierarchy

- Python 3: root is **object**
- Multiple Inheritance

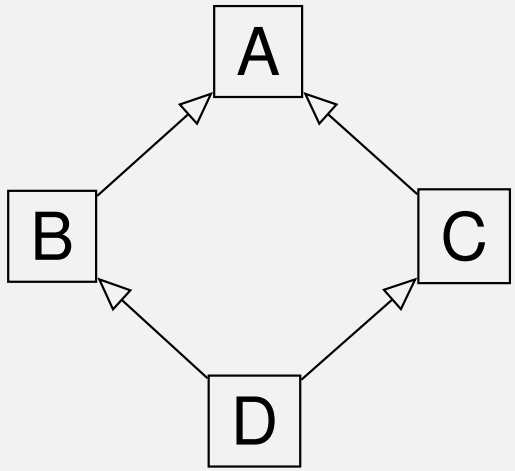
  class <clsname>(<parent>(,<parent>)*)?:

- For example,

  class A: => superclass is **object**
  class Rectangle(Parallelogram):
  => superclass is Parallelogram
  class Square(Rhombus, Rectangle):
  => superclasses are Rhombus and Rectangle

Inheritance

- Subclass inherits non-private fields and methods from super-classes
- Diamond problem

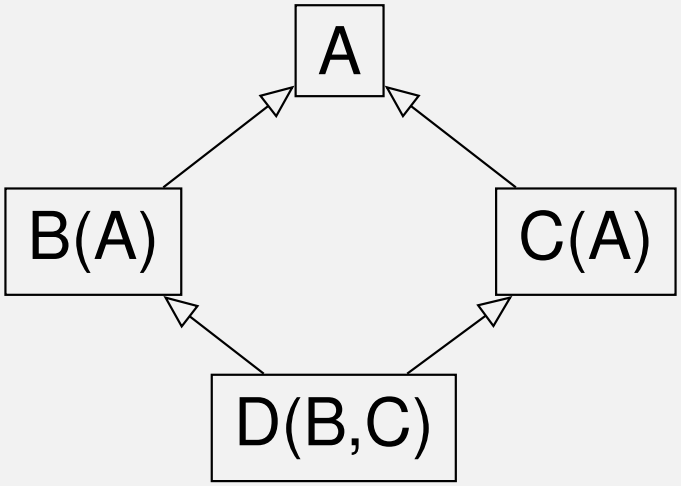


- Method Resolution Order: determine search sequence of a class

Method Resolution Order (MRO)

- MRO is used to determine search sequence L(M) of class M
  - L(object) = [object]
  - L(M(A,B,C)) = [M] + merge(L(A),L(B),L(C),[A,B,C])
- merge($[H_1|T_1]$,$[H_2|T_2]$,$[H_3|T_3]$)
  - Step 1: if H_1 is a **good** head which is NOT in the tail of other lists, take H_1 out as an output, remove H_1 out of all lists, back to Step 1.
  - Step 2: if H_1 is not a good head, check if H_2 is a good head. If it is, apply Step1 for H_2. If it is not, check for H_3 and so on. If there is no good head, give an error.

Example



- L(A) = [A,object]
- L(B) = [B] + merge(L(A),[A]) = [B,A,object]
- L(C) = [C] + merge(L(A),[A]) = [C,A,object]
- L(D) = [D]+merge(L(B),L(C),[B,C]) = [D,B,C,A,object]
- merge([B,A,o],[C,A,o],[B,C]) =>
  - B is a good head => [B]+merge([A,o],[C,A,o],[C])
  - A is NOT a good head, check C, and C is a good head => [B,C] + merge([A,o],[A,o],[])
  - A is a good head => [B,C,A] + merge([o],[o],[])
  - o is a good head => [B,C,A,o]

super, isinstance, type

- **super()** => refer to the superclass

```
1 class A:
2     def foo(self,x):
3         print(x)
4 class B(A):
5     def foo(self,x):
6         super().foo(x)
7 B().foo(3)  => 3
```

- **isinstance(o,T)** => check if object **o** is of type **T**

```
class A: pass
class B(A): pass
x = B()
```

isinstance(x,B) => Trueisinstance(x,A) => Truetype(x) is B => Truetype(x) is A => False

- **type(o)** => return the type of object **o**

- **Overloading**:

```
def func(param1,param2=0): pass
func(1,2)
func("asbc")
```

- **Universal Polymorphism**:

Parametric Polymorphism

```
class A:
  def func1(self):
    print("A")
  def func2(self): pass
class B:
  def func1(self):
    print("B")
for x in [A(),B()]:
  x.func1()
  x.func2()
```

Subtyping Polymorphism

```
class A:
  def func1(self):
    print("A")
  def func2(self): pass
class B(A):
  def func1(self):
    print("B")
for x in [A(),B()]:
  x.func1()
  x.func2()
```

Some other issues

- **id()**: address of the specified object

  x,y,z = 3,3,4
  id(x) => address of object 3 which x points to
  id(y) => same above address => x, y -> same object
  id(z) => z points to different object

- **is** vs. **==**
  - **is**: True just when they are same object
  - **==**: True even when they are different objects but their attributes are equal

  x,y = [1,2,3],[1,2,3]
  x **is** y => False
  id(x) == **id**(y) => False
  x == y => True

Some other issues

- Context manager by **with** statement

  with <expression> **as** <variable>:
  <stmt−**list**>

  - **<expression>** must return an object which has **__enter__** and **__exit__** methods
  - The **with** statement is executed like:

    <variable> = <expression>
    <variable>.__enter__()
    <stmt_list>
    <variable>.__exit__()

  - **__exit__** method is always executed before the control goes out of the **<stmt_list>**
  - used for managing resources: file, database,...

    with open('abc.txt','r') **as** f:
        print(f.read())
    f.closed => True

Summary

What are still in your mind?

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