# Analyse et Conception Formelle

## Lesson 5

## –

## Crash Course on Scala



## Bibliography


- *Programming in Scala*, M. Odersky, L. Spoon, B. Venners. Artima. `http://www.artima.com/pins1ed/index.html`
- *An Overview of the Scala Programming Language*, M. Odersky & al. `http://www.scala-lang.org/docu/files/ScalaOverview.pdf`
- *Scala web site*. `http://www.scala-lang.org`



Acknowledgements

- Many thanks to J. Noyé and J. Richard-Foy for providing material, answering questions and for fruitful discussions.




## Scala in a nutshell

- "Scalable language": small scripts to architecture of systems
- Designed by Martin Odersky at EPFL
  - Programming language expert
  - One of the designers of the current Java compiler

- Pure object model: *only objects and method calls* ($\neq$ Java)
- With functional programming: higher-order, pattern-matching, ...
- Fully interoperable with Java (in both directions)
- Concise smart syntax ($\neq$ Java)
- A compiler and a read-eval-print loop integrated into the IDE (select expression and type CTRL+SHIFT+X)



## Outline

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## Base types and type annotations

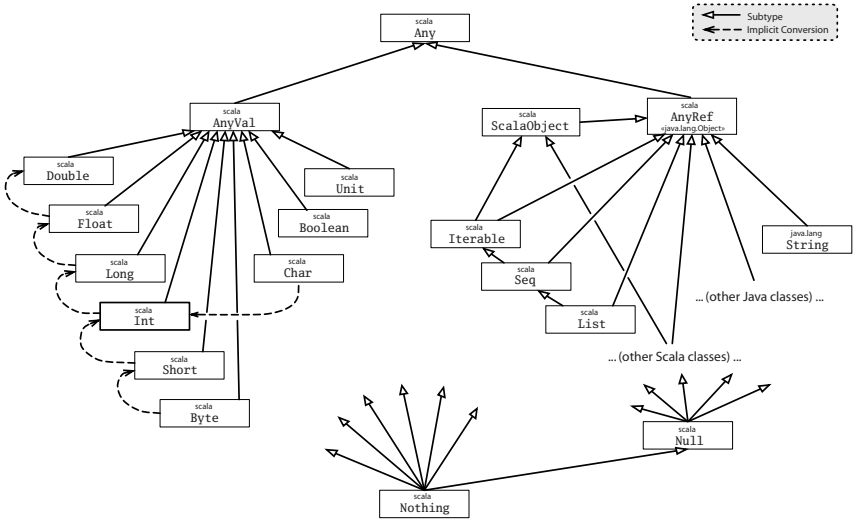
- `1:Int`, `"toto":String`, `'a':Char`, `():Unit`
- Every data is an object, including base types!
  *e.g.* `1` is an object and `Int` is its class
- Every access/operation on an object is a method call!
  *e.g.* `1 + 2` executes: `1.+(2)` (`o.x(y)` is equivalent to `o x y`)

**Exercise 1**

*Use the* `max(Int)` *method of class* `Int` *to compute the maximum of* `1+2` *and* `4`.

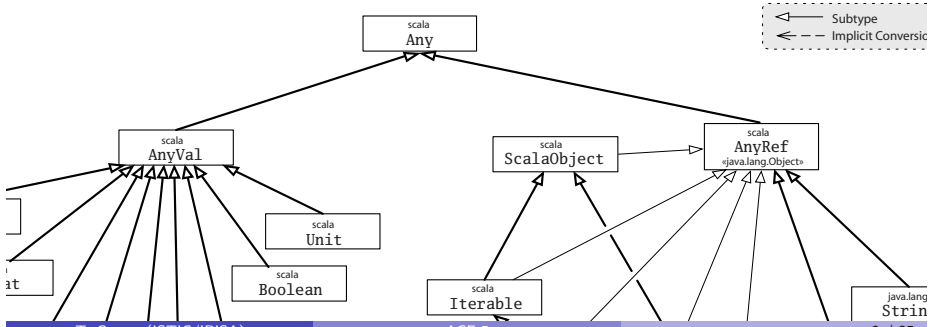


## Class hierarchy






## Class hierarchy



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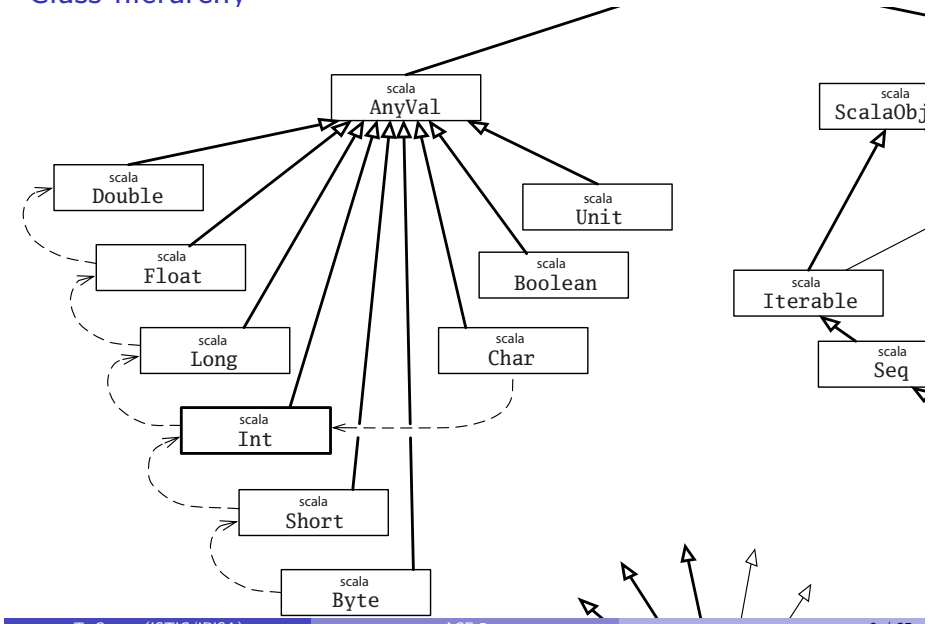




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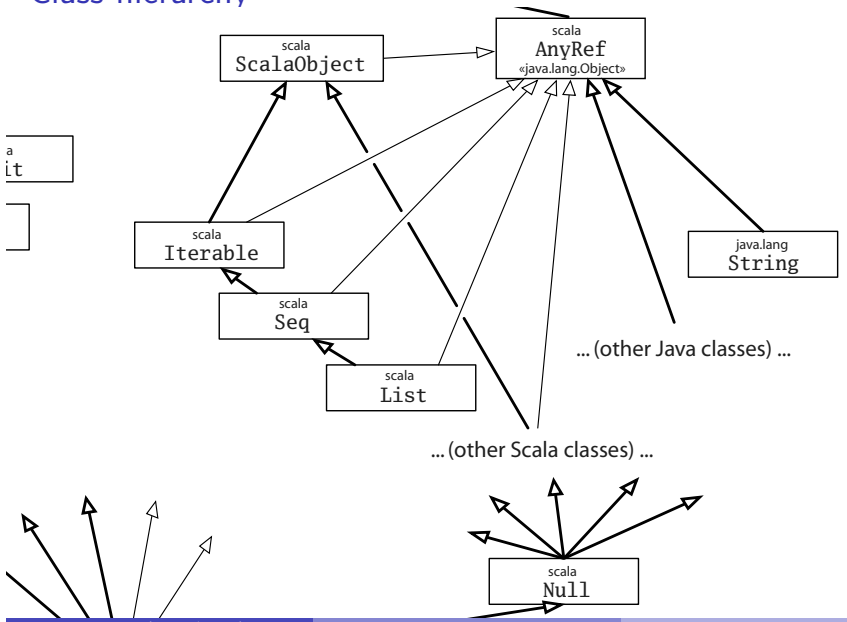




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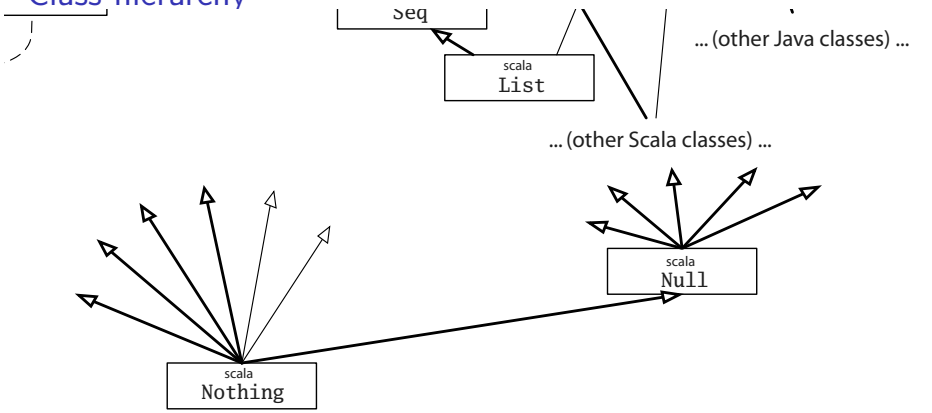




## `val` and `var`

- `val` associates an object to an identifier and *cannot* be reassigned
- `var` associates an object to an identifier and *can* be reassigned
- Scala philosophy is to use `val` instead of `var` whenever possible
- Types are (generally) automatically inferred

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```
scala> val x=1                    // or val x:Int = 1
x: Int = 1

scala> x=2
<console>:8: error: reassignment to val
       x=2
         ^
scala> var y=1
y: Int = 1

scala> y=2
y: Int = 2
```

## if expressions

- Syntax is similar to Java `if` statements ...
  but that they are not statements but typed expressions
- `if ( condition )` e1 `else` e2

  Remark: the type of this expression is the supertype of e1 and e2
- `if ( condition )` e1

  Remark: the type of this expression is the supertype of e1 and `Unit`

### Exercise 2

*What are the results and types of the corresponding `if` expressions:*

- `if (1==2) 1 else 2`
- `if (1==2) 1 else "toto"`
- `if (1==1) 1`
- `if (1==1) println(1)`



## match - case expressions

- Replaces (and extends) the usual switch - case construction
- The syntax is the following:

```
e  match {
     case pattern1  => r1      //patterns can be constants
     case pattern2  => r2      //or terms with variables
    ...                        //or terms with holes: '_'
     case _ => rn
   }
```

- Remark: the type of this expression is the supertype of r1, r2, ... rn

### Example 1 (Match-case expressions)

```
x match {
  case "bonjour" => "hello"
  case "au revoir" => "goodbye"
  case _ => "don't know"
 }
```



## (Immutable) Lists: `List[A]`

- List definition (with type inference)
  `val l= List(1,2,3,4,5)`
- Adding an element to the head of a list
  `val l1= 0::l`
- Adding an element to the queue of a list
  `val l2= l1:+6`
- Concatenating lists
  `val l3= l1++l2`
- Getting the element at a given position
  `val x= l2(2)`
- Doing pattern-matching over lists

```
l2 match {
   case Nil => 0
   case e::_ => e
}
```



## for loops

- `for ( ident <- s )` e
  Remark: s has to be a subtype of `Traversable`
  (Arrays, Collections, Tables, Lists, Sets, Ranges, ...)
- Usual for-loops can be built using `.to(...)`
  "`(1).to(5)`" ≡ "`1 to 5`" results in `Range(1, 2, 3, 4, 5)`

### Exercise 3

*Given `val lb=List(1,2,3,4,5)` and using `for`, build the list of squares of `lb`.*

### Exercise 4

*Using `for` and `println` build a usual* $10 \times 10$ *multiplication table.*

## (Immutable) Tuples : `(A,B,C,...)`

- Tuple definition (with type inference)
  ```
  scala> val t= (1,"toto",18.3)
  t:  (Int, String, Double) = (1,toto,18.3)
  ```
- Tuple getters: `t._1`, `t._2`, etc.
- ... or with `match - case`:
  ```
  t match { case (2,"toto",_) => "found!"
            case (_,x,_) => x
  }
  ```
  The above expression evaluates in `"toto"`



## (Immutable) maps : `Map[A,B]`

- Map definition (with type inference)
  `val m= Map('C' -> "Carbon",'H' -> "Hydrogen")`
  Remark: inferred type of `m` is `Map[Char,String]`
- Finding the element associated to a key in a map, with default value
  `m.getOrElse('K',"Unknown")`
- Adding an association in a map
  `val m1= m+('O' -> "Oxygen")`
- A `Map[A,B]` can be traversed (using `for`) as a `Collection` of pairs of type `Tuple[A,B]`, e.g. `for((k,v) <- m){ ... }`

**Exercise 5**

*Print all the keys of map* `m1`



## Outline





## Basic functions

- `def f ( arg1: Type1, ..., argn:Typen ): Typef = { e }`
  Remark 1: type of e (the type of the last expression of e) is Typef
  Remark 2: Typef can be inferred for *non recursive functions*
  Remark 3: The type of f is : (Type1,...,Typen) => Typef

**Example 2**

```
def plus(x:Int,y:Int):Int={
     println("Sum of "+x+" and "+y+" is equal to "+(x+y))
     x+y  // no return keyword
   }      // the result of the function is the last expression
```

**Exercise 6**

*Using a map, define a phone book and the functions* `addName(name:String,tel:String)`, `getTel(name:String)`, `getUserList:List[String]` *and* `getTelList:List[String]`.

## Anonymous functions and Higher-order functions

- The anonymous Scala function adding one to x is:
  `((x:Int) => x + 1)`
  Remark: it is written $(\lambda x.x+1)$ in Isabelle/HOL
- A higher order function takes a function as a parameter
  *e.g.* method/function `map` called on a List[A] takes a function (A =>B) and results in a List[B]

```
scala>  val l=List(1,2,3)
l: List[Int] = List(1, 2, 3)

scala>  l.map ((x:Int) => x+1)
res1: List[Int] = List(2, 3, 4)
```

**Exercise 7**

*Using* `map` *and the* `capitalize` *method of the class String, define the* `capUserList` *function returning the list of capitalized user names.*



## Partial application

- The '_' symbol permits to *partially* apply a function
  *e.g.* `getTel(_)` returns the function associated to `getTel`

**Example 3 (Other examples of partial application)**

`(_:String).size` `(_:Int) + (_:Int)` `(_:String) == "toto"`

**Exercise 8**

*Using* `map` *and partial application on* `capitalize`*, redefine the function* `capUserList`*.*

**Exercise 9**

*Using the higher order function* `filter` *on Lists, define a function* `above(n:String):List(String)` *returning the list of users having a capitalized name greater to name* `n`*.*



## Outline





## Class definition and constructors

- `class` C(v1: type1, ..., vn:typen) `{ ... }`
  (the primary constructor)

  *e.g.*
```
class Rational(n:Int,d:Int){
  val num=n       // can use var instead
  val den=d       // to have mutable objects
  def isNull:Boolean=(num==0)
}
```

- Objects instances can be created using `new`:
  `val r1= new Rational(3,2)`

**Exercise 10**

*Complete the* `Rational` *class with an* `add(r:Rational):Rational` *function.*

## Overriding, operator definitions and implicit conversions

- Overriding is explicit: `override def f(...)`

**Exercise 11**

*Redefine the* `toString` *method of the* `Rational` *class.*

- All operators '+', '*', '==', '>', ... can be used as function names
  *e.g.* `def +(x:Int):Int= ...`
  Remark: when *using* the operator recall that `x.+(y)` ≡ `x + y`

**Exercise 12**

*Define the '+' and '*' operators for the class* `Rational`.

- It is possible to define implicit (automatic) conversions between types
  *e.g.* `implicit def bool2int(b:Boolean):Int= if b 1 else 0`

**Exercise 13**

*Add an implicit conversion from* `Int` *to* `Rational`.



## Traits

- Traits stands for interfaces (as in Java)

```
trait IntQueue {
      def get:Int
      def put(x:Int)
}
```

- The keyword `extends` defines trait implementation

```
class MyIntQueue extends IntQueue{
      private var b= List[Int]()
      def get= {val h=b(0); b=b.drop(1); h}
      def put(x:Int)= {b=b:+x}
}
```



## Singleton objects

- Singleton objects are defined using the keyword `object`

```
trait IntQueue {
      def get:Int
      def put(x:Int)
}

object InfiniteQueueOfOne extends IntQueue{
      def get=1
      def put(x:Int)={}
 }
```

- A singleton object does not need to be "created" by `new`

```
InfiniteQueueOfOne.put(10)
InfiniteQueueOfOne.put(15)
val x=InfiniteQueueOfOne.get
```



## Type abstraction and Polymorphism

Parameterized function/class/trait can be defined using type parameters

```
trait Queue[T]{       // more generic than IntQueue
     def get:T
     def push(x:T)
}

class MyQueue[T] extends Queue[T]{
     protected var b= List[T]()

     def get={val h=b(0); b=b.drop(1); h}
     def put(x:T)= {b=b:+x}
}

def first[T1,T2](pair:(T1,T2)):T1=
     pair match case (x,y) => x
```

## Case classes

- Case classes provide a natural way to encode Algebraic Data Types
  *e.g.* binary expressions built over rationals: $\frac{18}{27} + -(\frac{1}{2})$

```
trait Expr
case class BinExpr(o:String,l:Expr,r:Expr) extends  Expr
case class Constant(r:Rational) extends Expr
case class Inv(e:Expr) extends Expr
```

- Instances of case classes are built without `new`
  *e.g.* the object corresponding to $\frac{18}{27} + -(\frac{1}{2})$ is built using:

```
BinExpr("+",Constant(new Rational(18,27)),
                Inv(Constant(new Rational(1,2))))
```



## Case classes and pattern-matching

```
trait Expr
case class BinExpr(o:String,l:Expr,r:Expr) extends Expr
case class Constant(r:Rational) extends Expr
case class Inv(e:Expr) extends Expr
```

- `match case` can directly inspect objects built with case classes

```
def getOperator(e:Expr):String= {
     e match {
       case BinExpr(o,_,_) => o
       case _ => "No operator"
     }
}
```

**Exercise 14**

*Define an `eval(e:Expr):Rational` function computing the value of any expression.*



## Outline





## Interoperablity between Java and Scala

- In Scala, it is possible to build objects from Java classes
  *e.g.* `val txt:JTextArea=new JTextArea("")`
- And to define scala classes/objects implementing Java interfaces
  *e.g.* `object Window extends JFrame`
- There exists conversions between Java and Scala data structures

```
import scala.collection.JavaConverters._

val l1:java.util.List[Int]= new java.util.ArrayList[Int]()
l1.add(1); l1.add(2); l1.add(3)  // l1: java.util.List[Int]

val sb1= l1.asScala.toList      // sl1: List[Int]
val sl1= sb1.asJava             // sl1: java.util.List[Int]
}
```

- Remark: it is also possible to use Scala classes and Object into Java

## Outline





## Isabelle/HOL exports Scala case classes and functions...

```
theory tp
[...]
datatype 'a tree= Leaf | Node "'a * 'a tree * 'a tree"
fun member:: "'a ⇒ 'a tree ⇒ bool"
where
"member _ Leaf = False" |
"member x (Node(y,l,r)) = (if x=y then True else ((member x l)
                                                  ∨ (member x r)))"
```

to Scala

```
object tp {
  abstract sealed class tree[+A]       // similar to traits
  case object Leaf extends tree[Nothing]
  case class Node[A](a: (A, (tree[A], tree[A]))) extends tree[A]
  def member[A : HOL.equal](uu: A, x1: tree[A]): Boolean =
    (uu, x1) match {
       case (uu, Leaf) => false
       case (x, Node((y, (l, r)))) => (if (HOL.eq[A](x, y)) true
                          else member[A](x, l) || member[A](x, r))
```



## ... and some more cryptic code for Isabelle/HOL equality

```
object HOL {
   trait equal[A] {
     val `HOL.equal`: (A, A) => Boolean
   }

   def equal[A](a: A, b: A)(implicit A: equal[A]): Boolean =
      A.`HOL.equal`(a, b)

   def eq[A : equal](a: A, b: A): Boolean = equal[A](a, b)

}
```

To link Isabelle/HOL code and Scala code, it can be necessary to add:

```
implicit def equal_t[T]: HOL.equal[T] = new HOL.equal[T] {
    val `HOL.equal` = (a: T, b: T) => a==b
}
```

Which defines `HOL.equal[T]` for all types `T` as the Scala equality `==`