Fonction anonymes

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Génériques (1)

Types génériques

En Scala, les types génériques se notent avec des crochets:

```
//Classe Générique
case class Pair[T]( first: T, snd: T )

//Fonction générique
def flat[A,B,C]( x: (A,(B,C)) ): (A,B,C) = {
  val (a,(b,c)) = x
  (a,b,c)
}
```

Rien à voir avec les tableaux

- En Java

```
java.util.ArrayList<String>
java.util.HashMap<String,Date>
int[]
```

- Mêmes types, en scala

```
java.util.ArrayList[String]
java.util.HashMap[String,Date]
Array[Int]
```

Fonctionne par *type erasure*

```scala
case class Box[T]( value: T )
def toInt( b: Box[Int] ): Int = b.value
def toInt( b: Box[String] ): Int = b.value.size

/* ERREUR COMPILATION
  |Double definition:
  |def toInt(b: Box[Int]): Int at line 2 and
  |def toInt(b: Box[String]): Int  at line 3
  |have the same type after erasure.
*/
```

Petites questions

Combien d'implémentations possibles pour cette fonction, supposée pure:

```
def foo( a: Boolean, b: Boolean ): Bool
```

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```
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et celle-ci ?

```
def foo( a: Int, b: Int ): Int
```

et celle-là ?

Petites questions

Combien d'implémentations possibles pour cette fonction, supposée pure:

```
def foo( a: Boolean, b: Boolean ): Bool
```

et celle-ci ?

```
def foo( a: Int, b: Int ): Int
```

et celle-là ? et celle-ci ?

```
def foo[T]( a: T, b: T ): T
```

Un peu d’OOP: Singletons et traits

Traits

- Interfaces en Java

```java
interface Iterator<T> {
  T next();
  boolean hasNext();
}
```

- traits en scala

```scala
trait Iterator[T] {
  def next: T
  def hasNext: Boolean
}
```

Utilisation de traits

- `implements` en java

```java
class Infinite<T> implements Iterator<T> {
  //...
}
```

- `extends` en scala

```scala
case class Infinite[T]( value: T )
    extends Iterator[T] {
  def hasNext = true
  def next = value
}
```

Classe statique (java)

```java
public class Water {

  public final static double g = 9.81;
  public final static double density = 1000;

  public static double pressure( double h ) {
    return waterDensity * g * h;
  }

}
```

Objet (scala)

Directement une instance, sans classe !

```
object Water {
  val g = 9.81
  val density = 1000.0

  def pressure( h: Double ) = density * g * h
}

//Utilisation
val p = Water.pressure( 16 ) //Pression d'eau à 16m
```

Singleton (java)

```
public class ItemPriceComparator
implements Comparator<Item> {
  public int compareTo( Item i1, Item i2 ) {
    if( i1.getPrice() < i2.getPrice() ){
      return -1;
    }
    if( i1.getPrice() > i2.getPrice() ) {
      return 1;
    }
    return 0;
  }
}
```

Singleton (scala)

```
object ItemPriceComparator extends Comparator[Item] {
  def compareTo( i1: Item, i2: Item ) =
    if( i1.price < i2.price ) -1
    else if( i1.price > i2.price ) 1
    else 0
}
```

Static factory (java)

```
public class Username {
  private String uname;
  private Username( String u ) {
    uname = u;
  }
  public static Username make( String u ) {
    check(u);
    return new Username( u );
  }
  private static void check( u ) { /* ... */ }
}
```

Companion object (scala)

```scala
//Constructeur privé
case class Username private( username: String )

//Si même nom et même fichier, peut accéder
// aux membres private de Username
object Username {
  def make( u: String ): UserName = {
    check(u)
    new Username(u)
  }
  private def check( u: String ): Unit = ???
}

val u1 = Username.make( "foobar85")
```

Fonctions anonymes

Fonctions anonymes en Scala

```scala
(u:User) => u.age >= 18
  //type: (User)=>Boolean
(u: User) => u.emailAddress
  //type: (User)=>Email
(e:Email) => e.tld == "ch"
  //type: (Email)=>Boolean

(i:Int, j:Int) => i + 2*j
  //type: (Int,Int)=>Int
```

Syntax alternative

```
(_:User).age >= 18
(_:Email).tld == "ch"

(_:Int) + 2 * (_:Int)
```

Utilisation

Déclaration

```
val isAdult = (u:User) => u.age >= 18
val mail = (u: User) => u.emailAddress
val isSwiss = (e:Email) => e.tld == "ch"

val f = (i:Int, j:Int) => i + 2*j
```

Utilisation

Déclaration

```
val isAdult = (u:User) => u.age >= 18
val mail = (u: User) => u.emailAddress
val isSwiss = (e:Email) => e.tld == "ch"

val f = (i:Int, j:Int) => i + 2*j
```

Utilisation

```
val alice =  User( "Alice",
                   Email( "alice@a.ch" ), 19 )

isAdult(alice) // true
isSwiss( mail( alice ) ) // true

f( 2, 5 ) // 12
```

Combiner des fonctions

Combinateurs

```
(A)=>B andThen (B)=>C  : (A)=>C
(B)=>C compose (A)=>B  : (A)=>C
```

Exemple

```
val hasSwissMail1 = mail andThen isSwiss
val hasSwissMail2 = isSwiss compose mail
hasSwissMail1( alice ) // true

val g1 = {(i:Int) => i*2} andThen {i => 1.0/i}
val g2 = {(_:Int) * 2} andThen (1.0/_)
```

Closure

- Les fonctions anonymes Scala sont des *closures* (fermetures)
- Elles capturent l'environement local

```scala
def adder(n: Int): Int=>Int =
  i => i + n

val add2 = adder(2)
add2(5)  //=> 7
add2(-2) //=> 0
adder(3)(10) //=> 13
```

Implémentation

- Scala est un vrai langage orienté objet
- Donc les fonctions sont aussi des objets
- Classes dont la seule méthode abstraite est `apply`:
  - `()=>O` : `Function0[+O]`
  - `(A)=>O`: `Function1[-A,+O]`
  - `(A,B)=>O`: `Function2[-A,-B,+O]`
  - ...

Méthode `apply`

```
object f {
  def apply( i: Int ): Double = 1.0 / i
}
f.apply( 100 ) // 0.01
f( 10  )       // 0.1
```

Utilité

Dans presques tous les langages

Javascript

```
var f = function(x) {
  return x*x + 2*x -5;
}
```

Python

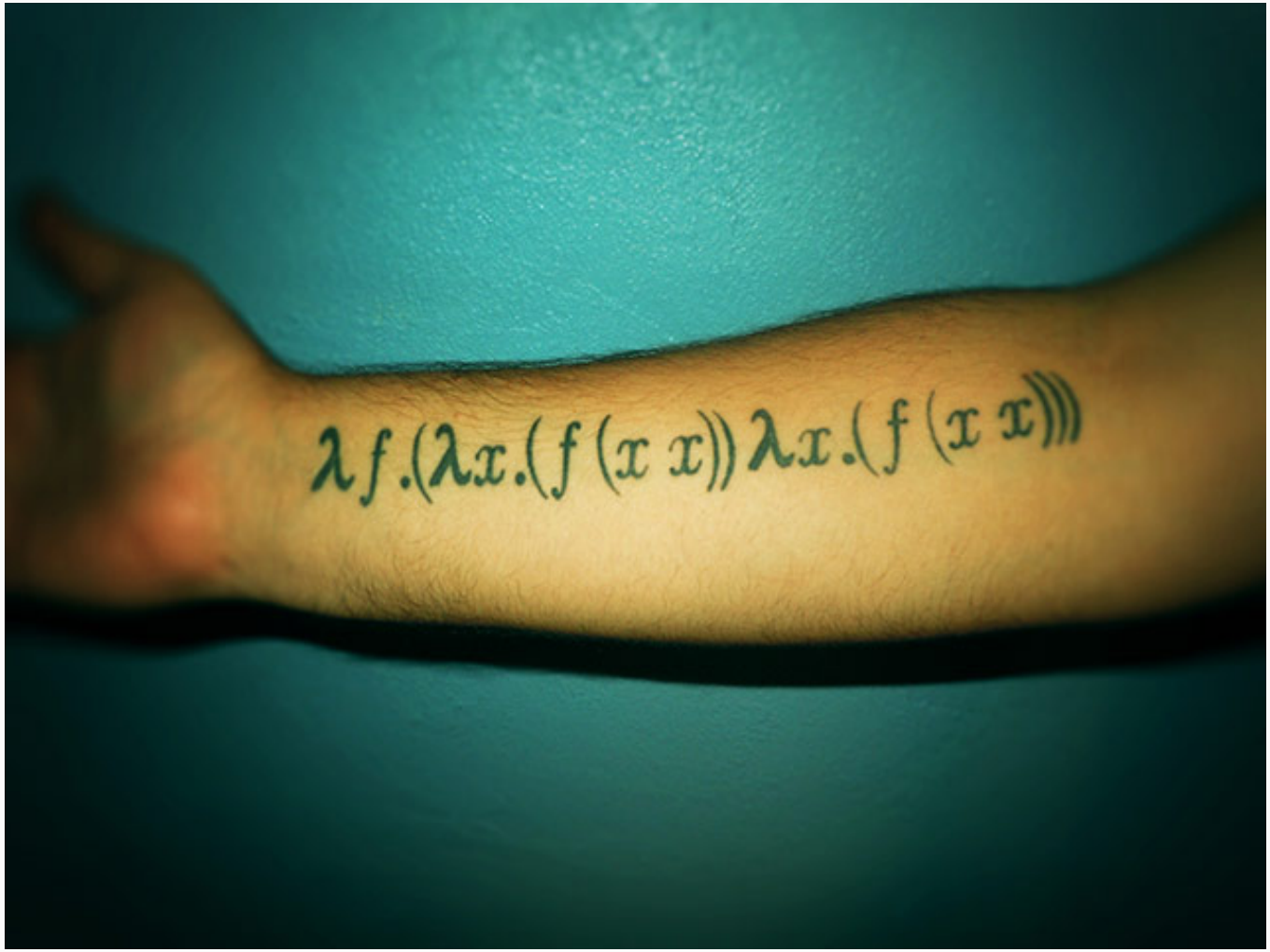
```
f = lambda x: x*x + 2*x - 5
```

C# 3.0

```
Func<int,int> f = x => x*x + 2*x - 5
```

et aussi Java 8, C++11, Perl 5, Matlab, R, etc.

Lambda calcul (Alonzo Church, 1936)



Lambda calcul

- Permet de représenter toutes les fonctions calculables, avec une algèbre très simple, et une évaluation par substitution.

Exemple d'expression (β-reduction)

- $\lambda x.\lambda f.fx$
- $(\lambda x.\lambda f.fx)y = \lambda f.fy$
- $(\lambda f.fy)\lambda x.xx = (\lambda x.xx)y = yy$

Lambda calcul et expressions logiques

Définitions

- `TRUE`: $\lambda x.\lambda y.x$
- `FALSE`: $\lambda x.\lambda y.y$
- `NOT`: $\lambda p.\lambda a.\lambda b.pba$
- `OR`: $\lambda p.\lambda q.ppq$

Exemple (`NOT TRUE`)

$(\lambda p.\lambda a.\lambda b.pba)(\lambda x.\lambda y.x)$

$= \lambda a.\lambda b.(\lambda x.\lambda y.x)ba$

$= \lambda a.\lambda b.(\lambda y.b)a$

$= \lambda a.\lambda b.b$

Fonctions d'ordre supérieur

Fonction dont les arguments et/ou le type de retour est une fonction.

```
val f = (i:Int) => (j:Int) => i*j
val g = f(3)
g(10) // 30
f(2)(5) //10

val checkTLD =
  (tld:String) => (e:Email) => e.tld == tld
val hasFrenchMail = mail andThen checkTLD("fr")
hasFrenchMail( alice ) //false
```

Fonctions d'ordre supérieur (2)

```
val verbose = (f:Int=>Int) => { i:Int =>
  val j = f(i)
  println( s"INPUT: $i OUTPUT: $j" )
  j
}
```

Méthodes d'ordre supérieur

```
def checkTLD( tld: String ): Email => Boolean =
  _.tld == tld

def verbose[A,B]( f: A=>B ): A=>B = { a =>
  val b = f(a)
  println( s"INPUT: $a OUTPUT: $b" )
  b
}
```

Modelisation

Modeliser par des fonctions

- Serveur web: `(HTTPRequest)=>HTTPResponse`
- Client web: `(URL)=>HTTPResponse`
- Transformer une image: `(Image)=>Image`
- Format binaires, par exemple PNG:
  - `(BitVector)=>Image`
  - `(Image)=>BitVector`
- Jeu d'échec (IA): `(Board)=>Move`

Exemple conversion d'images (FP-1)

```
def fromJpeg(bits:BitVector): Image
def resize( heigth: Int, width: Int ): Image=>Image
def blur( radius: Int ): Image=>Image
def rotate( angle: Double ): Image=>Image
def toPng( img: Image ): BitVector
```

Exemple conversion d'images (FP-2)

```
val mod = rotate(90) andThen resize( 1024, 768 )
val pipeline =
    fromJpeg(_) andThen mod andThen toPng

def readBytes( f: File ): BitVector = ???
def writeBytes( f: File, bytes: BitVector ): Unit =
  ???

def convert( in: File, out: File,
    f: (BitVector)=>BitVector ): Unit = {
  val bytesIn = readBytes(in)
  val bytesOut = f( bytesIn )
  writeBytes(out, bytesOut )
}
```

Exemple conversion d'images (OOP-1)

```
trait Transform {
  def apply( img: Image ): Image
}
class Resize( heigth: Int, width: Int )
    extends Transform{
  def apply( img: Image ): Image = ???
}
class Blur( radius: Int ) extends Transform {
  def apply( img: Image ): Image = ???
}
class Rotate( angle: Double ) extends Transform {
  def apply( img: Image ): Image = ???
}
```

Exemple conversion d'images (OOP-2)

```
trait Decoder {
  def apply( bs: BitVector ): Image
}
trait Encoder {
  def apply( img: Image ): BitVector
}
case object FromJpeg extends Decoder {
  def apply( bs: BitVector ): Image = ???
}
case object ToPNG extends Encoder {
  def apply( img: Image ): BitVector = ???
}
```

Exemple conversion d'images (OOP-3)

```
class Combiner( ts: List[Transform] )
    extends Transform {
  def apply( img: Image ): Image = {
    var current = img
    var rem = ts
    while( rem.nonEmpty ) {
      current = rem.head.apply( current )
      rem = rem.tail
    }
    current
  }
}
val mod = new Combiner (
  List( new Rotate(90), new Resize( 1024, 768 ) )
)
```

Exemple conversion d'images (OOP-4)

```
class Pipeline( dec: Decoder, enc: Encoder,
                trans: Transform ) {
  def run( bytes: BitVector ): BitVector =
    enc.apply( trans.apply( dec.apply( bytes ) ) )
}

val pipeline =
  new Pipeline( FromJpeg, mod, ToJpeg )

def convert(in:File,out:File,p:Pipeline):Unit={
  val bytesIn = readBytes(in)
  val bytesOut = p.run( bytesIn )
  writeBytes(out, bytesOut )
}
```

Simplification

D.R.Y.

Gestion des IO (avant)

```
val pw = new PrintWriter( "file1.txt" )
try {
  dumpData( pw )
} finally {
  pw.close()
}
```

Gestion des IO (après- FP)

```
def withPrintWriter( name: String ) =
  ( f: PrintWriter=>Unit ) => {
    val pw = new PrintWriter( name )
    try {
      f( pw )
    } finally {
      pw.close()
    }
  }

withPrintWriter( "file1.txt" )( dumpData )
withPrintWriter( "file2.txt" ){ pw =>
  pw.println( "Hello" )
  pw.println( "world" )
}
```

Gestion des IO (après- FP)

Quel est le type de retour de `withPrintWriter` ?

```
def withPrintWriter( name: String ) =
  ( f: PrintWriter=>Unit ) => {
    val pw = new PrintWriter( name )
    try {
      f( pw )
    } finally {
      pw.close()
    }
  }
```

Gestion des IO (après- FP)

Quel est le type de retour de `withPrintWriter` ?

```
def withPrintWriter( name: String ) =
  ( f: PrintWriter=>Unit ) => {
    val pw = new PrintWriter( name )
    try {
      f( pw )
    } finally {
      pw.close()
    }
  }
```

```
(PrintWriter=>Unit)=>Unit
```

Syntaxe pratique (1)

Scala permet de définir des méthodes qui prennent plusieurs listes d'arguments:

```
def add( i: Int )( j: Int ) = i+j
def foo[A,B,C]( a: A )( f: (A,B)=>C ): B=>C =
  b => f(a,b)

add(1)(2) //=> 3
val twice = foo( 2 )( _ * _ )
twice( 4 ) //=> 8
```

Syntaxe pratique (2)

Scala permet de remplacer les parenthèses par des accolades dans certains cas (1 seul argument):

```
def foo[A,B,C]( a: A )( f: (A,B)=>C ): B=>C =
  b => f(a,b)

val bar = foo(true){ (b:Boolean,s:String) =>
  if(b) s else ""
}
bar("hop") //=> "hop"
```

Gestion des IO (après- FP 2)

```
def withPrintWriter( name: String ) =
  ( f: PrintWriter=>Unit ): Unit = {
  val pw = new PrintWriter( name )
  try {
    f( pw )
  } finally {
    pw.close()
  }
}

withPrintWriter( "file1.txt" )( dumpData )
withPrintWriter( "file2.txt" ){ pw =>
  pw.println( "Hello" )
  pw.println( "world" )
}
```

Gestion des IO (après - OOP 1)

```
trait PWProcessor {
  def process( pw: PrintWriter ): Unit
}

def withPrintWriter( name: String )
  ( pwp: PWProcessor ): Unit = {
  val pw = new PrintWriter( name )
  try {
    pwp.process( pw )
  } finally {
    pw.close()
  }
}
```

Gestion des IO (après - OOP 1)

```
withPrintWriter( "file1.txt" )( new PWProcessor {
  def process( pw: PrintWriter ) = dumpData(pw)
})

withPrintWriter( "file2.txt" )( new PWProcessor {
  def process( pw: PrintWriter ) = {
    pw.println( "Hello" )
    pw.println( "world" )
  }
})
```

Exemple: transactions de bases de données

```
trait Database {
  def transaction: Transaction
  def close: Unit
}
object Database {
  def connect( host: Host ): Database
}
trait Transaction {
  def execute( query: SQL ): List[Result]
  def commit: Unit
}
```

Exemple: Utilisation

```
val db = Database.connect( "machin.org" )

val tx = db.transaction
val res1 = tx.execute( query1 )
val res2 = tx.execute( query2(res1) )
tx.commit
val tx2 = db.transaction
val res3 = tx.execute( query3 )
val res4 = if( res3.isEmpty )
             tx.execute( query4 )
           else
             tx.execute( query5 )
tx2.commit
```

Exemple: Utilisation (debugé !)

```
val db = Database.connect( "machin.org" )

val tx = db.transaction
val res1 = tx.execute( query1 )
val res2 = tx.execute( query2(res1) )
tx.commit
val tx2 = db.transaction
val res3 = tx2.execute( query3 )
val res4 = if( res3.isEmpty )
             tx2.execute( query4 )
           else
             tx2.execute( query5 )
tx2.commit
db.close
```

Exemple: transactions de bases de données (2)

```
object Database {
  private def doConnect( host: Host ): Database
  def connect[A]( host: Host )( body: Database=>A ): A = {
    val db = doConnect( host )
    val a = body( db )
    db.close
    a
}
```

Exemple: transactions de bases de données (2)

```
trait Database {
  protected def start: Transaction
  def transaction[A]( body: Transaction=>A ): A = {
    val tx = start
    val a = body( tx )
    tx.commit
    a
  }
  private def close: Unit
}
```

Exemple: utilisation (2)

```
Database.connect( "machin.org" ){ db =>
  val (r1,r2) = db.transaction { tx =>
    val res1 = tx.execute( query1 )
    val res2 = tx.execute( query2(res1) )
    (res1,res2)
  }
  val r4 = db.transaction { tx =>
    val res3 = tx.execute( query3 )
    val res4 = if( res3.isEmpty )
                 tx.execute( query4 )
               else
                 tx.execute( query5 )
    res4
  }
  (r1,r2,r4)
```