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Functional Programming in Scala and Further

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Abstract

Scala is one of the modern multi-paradigm programming language. It involves object oriented and functional programming - paradigm possibilities. Scala has an interpreter part and an effective compiler which reduces it to JVM bytecode. Presented article brings the ideology of functional programming in Scala and some parts of its development. Scala has uniform and powerful abstraction concepts for different types and values; to be clear we compare some programs in Scala and Java.

Keywords: Scala, functional programming, higher order functions, traits, monad, functor, futures, streams.

Introduction

Scala is an acronym for "Scalable Language". It means that you can construct additional objects and functions and manipulate with them.

The main feature of the language - scalability is the result of a careful integration of object-oriented and functional language concepts.

Scala has an interpreter part and an effective compiler which reduces it to *JVM bytecode*. That is why you can use **Scala** and **Java** modules in one program. **Scala** compiler contains a subset of a **Java** compiler to make sense of such recursive dependencies.

But what are object-oriented and functional programming concepts?

Object-oriented programming (OOP) is a *programming paradigm* that represents concepts as "*objects*" that have *data fields* (attributes that describe the object) and associated procedures known as *methods*. Objects, which are usually *instances* of *classes*, are used to interact with one another to design applications and computer programs. ***C++, Objective C, Smalltalk, Java*** and ***C#*** are examples of object-oriented programming languages.

The great idea of object-oriented programming is to make these containers fully general, so that they can contain operations as well as data, and that they are themselves values that can be stored in other containers, or passed as parameters to operations. Such containers are called objects.But many languages admit values that are not objects, such as the primitive values, or they allow static fields and methods that are not members of any object. These deviations from the pure idea of object-oriented programming look quite harmless at first, but they have an annoying tendency to complicate things and limit scalability.

OOP makes easy to adapt and extend complex systems, using
subtyping and inheritance,
dynamic configurations, and
classes as partial abstractions.

Functional programming (FP) is a programming paradigm that models computation as the evaluation of expressions. Expressions are built using functions that do not have mutable state and side effects.

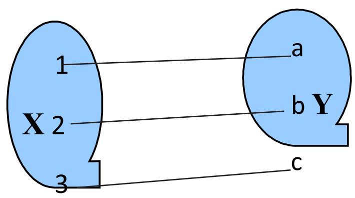
Haskell, Curry, Idry. are examples of functional programming languages.

In math we have no assignment operationand loops, but we have x=sin(a). A function relates every value of type X to exactly one value of Y. A type is associated with a set of values. Here type X represents the set of values (1, 2, 3) and Y represents the set of values (a, b, c).

In **Scala** you could write the signature of such a function as follows:
If function has input type **A** and output type **B**, it is written as: **A** => **B** in **Scala.**

def f: is definition of function **f**

def f: X => Y



The program in FP is constructed with pure functions which means that they do not have side effects. In Scala everything is object, including numbers and functions. This makes pure functions easily testable and less bug prone.
It means that pure function cannot:

- reassign a variable;
- modify data structure in place;
- set a field on an object;
- throw an exception or halt with an error;
- read from or write to a file.

FP has restriction on writing programs, but not on programs what could be written.
FP makes easy to build interesting things from simple parts, using
higher-order functions,

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- algebraic types and pattern matching, and
- parametric polymorphism.

Scala programs tend to be short. Scala programmers have reported reductions in number of lines of up to a factor of ten compared to Java.

```
// this is Java

class MyClass {
private int index;
private String name;
public MyClass (int index, String name) {
this.index = index;
this.name = name;
}
}

//this is Scala
class MyClass(index: Int, name: String)
/* Given this code, the Scala compiler will produce a class that has two private instance variables, an Int named index and a String named name, and a constructor.
In short, you get essentially the same
functionali
*/
```

Scala has uniform and powerful abstraction concepts for different types and values;

· Scala has modular mix incomposition constructs for composing classes and traits.

· There is decomposition possibilities of objects by pattern matching.

Variables

Scala has two types of variables **var and val**.

If we describe in terming of **Java var** is non-final variable which can be reassigned, but val is similar to final variable in **Java**.

```
name; type; value

var x: Double = 5.6
//variable, could be reassigned (mutable)


val  y: Double = 5.6
//value, can not be reassigned (immutable)

val msg1: String = "Hello Scala!"
//with String type

val msg2: java.lang.String =
                         "Hello again Scala!"
//with java.lang.String type

val  lst:List = List(1, 2, 3)
//lst is immutable List

val  lst: List = 1 :: 2 ::  3 :: NULL
//the same output

valnms: Map = Map((1,"Nodar"), (2,"Maria"),(3,"Ann"))
//nms is immutable Map value
```

Functions

Function definition starts with **def name(parameter:type,...):type = {body }**

"def" starts a function definition
function name;
parameter list;

function's result type;
function body

```
def max(x: Int, y: Int): Int =
                 { if (x > y) x else y }
```

A function in Scala is a “first-class value”. You can pass it as a parameter or return as a result.

If functions take other functions as parameters or return as results, they are called **higher-order functions.**

```
val double = (i: Int) => { i * 2 }
//think of symbol "=>" as transformer
```

Scala is high-level

Programmers are constantly grappling with complexity. Scala helps you manage complexity by letting you raise the level of abstraction in the interfaces you design and use.

Assume you have String variable with name. You need to know if there are uppercase characters.

```
// this is Java
boolean nameHasUpperCase = false;
for (int i = 0; i < name.length(); ++i) {
if(Character.isUpperCase(name.charAt(i)))
{
nameHasUpperCase = true;
break;
}
}
// this is Scala
val nameHasUpperCase =
              name.exists(_.isUpperCase)
```

Evaluation Rules

· Call by value: evaluates the function arguments before calling the function.

· Call by name: evaluates the function first, and then evaluates the arguments.

def example = 2

```
// evaluated when called
val example = 2
// evaluated immediately
lazy val example = 2
// evaluated once when needed

def square(x: Double)        // call by value
def square(x: => Double)     // call by name
def bxFct(bindings: Int*) { ... }
// bindings is a sequence of int, containing a // varying # of arguments
```

Higher order functions

Functions in Scala are objects. So you can build functions that take function as a parameter or return functions.Such functions are called Higher order functions.

Assume that we want to build a function which

calculates $\sum_a^b f(k)$ for different values of f.

```
def sum(f: Int => Int, a: Int, b: Int): Int  =   if (a > b) 0 else f(a) + sum(f, a + 1, b)
```

Than for the functions:

```
def id(k: Int): Int = k

def square(k: Int): Int = k * k

def powerOfTwo(k: Int): Int =
if (k == 0) 1 else 2 * powerOfTwo(k - 1)

def sumInts(a: Int, b: Int): Int =
        sum(id, a, b)                         //∑_a^b k

def sumSquares(a: Int, b: Int): Int =        sum(square, a, b)    //∑_a^b k^2

def sumPowersOfTwo(a: Int, b: Int): Int=

sum(powerOfTwo, a, b)        //∑_a^b 2k
```

and print.

```
println( sumInts(1, 10) )
println( sumSquares(1, 10) )
println(sumPowersOfTwo (1, 10) )
```

Methods with collection

Let us create a collection of List type.

```
val lst = List(1, 2, 3, 4, 5, 6, 7, 8)
```

In Scala, there are a lot of methods working with List (map, filter, reduce,...)

```
val sqr = lst.map(x => x * x)
//map applies function to all
//elements of List
val flt = lst.filter(x => x < 6)
//filters lst and creates flt as List(1,2,     val rds = lst.reduce((x,y) => x + y)
//combines the elements of sequence into a //single element and creates rds as //List(3,7,11,15)
```

Classes

In Scala, classes are equivalent to classes in Java or C++. Every class has a primary constructor taken from the class parameters. Class definition fields are generated into needed getters and setters automatically. Auxiliary constructors are optional. They are called as **this.**

```
class Student(name: String,
              scores: Int,
              active: Boolean)
```

Assume that we have class Student. Then, let us create Sequence (List) of Students in val st.

```
val st = Seq(Student("Daviad", 38, true),
Student("Mari", 95, true),
Student("Gio", 51, false))
```

Now, let us transform this Sequence in functional style:

```
val fst = st.filter(_.score <50).filter(_.active)
 sortBy(_.name)    map(_.copy (active = false))
```

In this one-liner we grabbed all students whose scores are lower than 50 and who are still active; then we changed the active status of selected participants to false. map applies given function (copy) to every element.

The final output of the fds is List **(Student("David", 38, true).**

There are dozens of situations where similar one-statements save functional programmers time and dramatically reduce the amount of code in the program.

Traits

Apart from inheriting code from super-class, Scala can import code from one or several traits. Comparing with Java, trait is interface which can contain code.

```
trait Ord {
def < (that: Any): Boolean
def <= (that: Any): Boolean =
            (this<that) || (this == that)
def > (that: Any): Boolean =
                     ! (this<= that)
  def >= (that: Any): Boolean =
                     ! (this < that)
}
```

Closure

A closure is a function, whose return value depends on the value of one or more variables declared outside this function.

```
val  b = 10
val f = (x: Int) => x + b
println(f(5))                //15
```

Monoid, Monadand Functor

A monoid is defined as an algebraic structure (generally, a set) M with a binary operation (multiplication) : $M \times M \rightarrow M$ and an identity element (unit) $\eta : 1 \rightarrow M$, following two axioms:

i. **Associativity**..

$\forall\ a, b, c \in M, (a \cdot b) \cdot c = a \cdot (b \cdot c)$

ii.**Identity**

$\exists\ e \in M\ \forall\ a \in M, e \cdot a = a \cdot e = a$

When specifying an endofunctor $T : X \to X$ (which is a functor that maps a category to itself) as the set M, the Cartesian product of two sets is just the composition of two endofunctors. What you get from here is a monad with these two natural transformations:

1. The binary operation is just a functor composition $\mu : T \times T \to T$
2. The identity element is just an identity endofunctor $\eta : I \to T$

Satisfied the monoid axioms (i. & ii.), amonad can be seen as a monoid which is an endofunctor together with two natural transformations. The name "monad" came from "monoid" and "triad", which indicated that it is a triple (1 functor + 2 trasformations), monoidic algebraic structure.

In other words, monoid is a more general, abstract term. When applying it to the category of endofunctors, we have a monad.

A Functor accepts a function, A ⇒ B, and returns a new function M[A] ⇒ M[B], where M is any kind.

```
trait Monoid[T] {
  def Zero: T
  def Op: (T,T) => T
}

trait Monad[T1] {
  def map[T2] (f: T1 =>T2): Monad[T2]
  def flatMap[T2] (f: T1 => Monad[T2]): Monad[T2]

}
```

$\forall a,b \in C\ f{:}a \Rightarrow b$

$F(a \Rightarrow b) = F(a) \Rightarrow F(b)$

```
trait Functor[M[U]] {
  def map[U,V](m:M[U])(f:U=>V): M[V]
}
```

All these traits are useful for the composition of functions in functional programming.

```
def compose(g: T => T, h: T => T) =
                    (x: T) => g(h(x))
```

Streams

To solve problems sometimes we need n numbers of an infinite sequence, but unfortunately, it is impossible to determinate needed number of elements. Scala has data structure with infinite number of elements which are computed by demand. Such data structure is named streams. Streams are created by using the constant empty and the constructor cons. Streams reduce memory usage by relocating and releasing chunk of data allowing reuse of intermediating results.

```
def numsFrom (n :Int): Stream[Int] =
        Stream.cons(n,numsFrom (n+1))
```

than calculate infinite stream using:

```
lazy val N = numsFrom(0)
N take 10 print
```

The output will be:
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, empty

Stream is a List whose tail is a lazy val. The main benefit of Stream is working with infinite sequence, generally recursive created.

Futures

Futures are convenient abstractions for concurrent programming. Futures give us possibility to execute computations in parallel and receive result at some point of Futures.

```
val fut = future {slowComputation}
  fut.onComplete {
    case Success => useSuccess(result)
    case Failure => useError(exception)
}
```

You can convert futures to list and back.
List (Future(f1), Future(f2), ...Future(fn)
Futures (List(f1,f2,...fn))

or reduce list of futures to new future
Future.reduce (list)(f)

And many other technologies...

Scala comes with a lot of different libraries, which give possibility to construct huge number of computation technologies.

Conclusion

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