CS 3101-2 - Programming Languages: Scala

Lecture 3: Fun with Functions

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Functions and Methods

- Functions that are members of some object (class instance or singleton) are called methods.
- `private` keyword makes method visible only within this object.

```
import scala.io.Source

object LongLines {

  def processFile(filename: String, width: Int) {
    val source = Source.fromFile(filename)
    for (l <- source.getLines)
      procLine(filename, width, l)
  }

  private def procLine(filename: String, l: String) {
    if (l.length > 79)
      println(filename +": "+ l.trim)
  }
}
```

Local Functions

- Functions can be defined within other functions.
- Functions are only visible in surrounding scope.
- Inner function can access namespace of surrounding function.

```scala
import scala.io.Source

object LongLines {
  def processFile(filename: String, width: Int) {

    def procLine(l: String) {
      if (l.length > 79) println(filename +": "+ l.trim)
    }

    val source = Source.fromFile(filename)
    for (l <- source.getLines)
      procLine(filename, width, l)
  }
}
```

Repeated Parameters

- The last parameter of a function may be repeated.
- Repeat parameter is denoted with `* following the type`.

```
scala> def echo(args: String*) =
          for (arg <- args) println(arg)
echo: (args: String*)Unit

scala> echo("Hello")

scala> echo("Hello","World")
Hello
World
```

Can operate on args like on an `Array`

```
scala> def echo2(args: String*) =
    print(args.slice(1,args.size))
echo2: (args: String*)Unit

scala> echo2("Scala","is","awesome")
WrappedArray(is, awesome)
```

Named Parameters

Can refer to parameter by name.

```
scala> def speed(distance: Double, time: Double): Double =
          distance / time
speed: (distance: Double, time: Double)Double

scala> speed(100, 20)
res0: Double = 5.0
scala> speed(time = 20, distance = 100)
res1: Double = 5.0
```

Default Parameters

- Can assign a default value to parameters in the function definition.
- Can ommit default parameters when calling the function.

```
def printTime(out: java.io.PrintStream = Console.out) =
          out.println("time = " + System.currentTimeMillis())

scala> printTime()
time = 1415144428335

scala> printTime(Console.err)
time = 1415144437279
```

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First Class Functions

- Functions are values
  - Can be passed as arguments to `higher order functions`.
  - Can be returned by other functions.
  - Can be assigned to a variable.

Higher Order Functions

- Higher order functions are functions that take function values as parameters.
- Provide a powerful abstraction over functions.

```
def my_map(lst : List[Int], fun : Int => Int) : List[Int] =
    for (l <- lst) yield fun(l)

val numbers = List(2,3,4,5)

def addone(n : Int) = n + 1

scala> my_map(numbers, addone)
res0: List[Int] = List(3, 4, 5, 6)
```

Mapping lists

- Lists have methods that accept functions as arguments (sorting, filtering, mapping...)
  foreach, filter, map, fold

```
def addone(x : Int) : Int = x + 1

val numbers = List(-11,-10,5,0,5,10)

scala> numbers.map(addone)
res0: List[Int] = List(-10, -9, 6, 1, 6, 11)
```

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Function Literals

- use => to define a small function in place.
- called 'lambdas' in other languages.

```
scala> (x: Int) => x + 1
res0: Int => Int = <function1>

scala> val numbers = List(-11,-10,5,0,5,10)
numbers: List[Int] = List(-11, -10, 5, 0, 5, 10)

scala> numbers.map((x: Int) => x + 1)
res1: List[Int] = List(-10, -9, 6, 1, 6, 11)
```

Functions objects are values

Functions can be stored in a variable.

```
scala> val numbers = List(-11,-10,5,0,5,10)
numbers: List[Int] = List(-11, -10, 5, 0, 5, 10)

scala> var addfun = (x: Int) => x + 1
addfun: Int => Int = <function1>

scala> numbers.map(addfun)
res1: List[Int] = List(-10, -9, 6, 1, 6, 11)

scala> var addfun = (x: Int) => x * 2
addfun: Int => Int = <function1>

scala> numbers.map(addfun)
res1: List[Int] = List(-22, -20, 10, 0, 10, 20)
```

Short forms of function literals

- Target typing: If a function literal is used immediately the compiler can do type inference.

```
scala> numbers.map(x => x+1)
res1: List[Int] = List(-22, -20, 10, 0, 10, 20)

scala> var addfun = x => x+1
<console>:7: error: missing parameter type
       var addfun = x => x+1
```

Placeholder Syntax

- Can skip parameter names if each parameter is used only once.

```
scala> numbers.map(x => x+1)
res1: List[Int] = List(-22, -20, 10, 0, 10, 20)

scala> numbers.map(_ + 1)
res0: List[Int] = List(-10, -9, 6, 1, 6, 11)

scala> val fun = _ + _  // can't do type inference here
<console>:7: error: missing parameter type for expanded
    function ((x$1, x$2) => x$1.$plus(x$2))
       val fun = _ + _

scala> val fun = (_ : Int) + (_ : Int)
fun: (Int, Int) => Int = <function2>
```

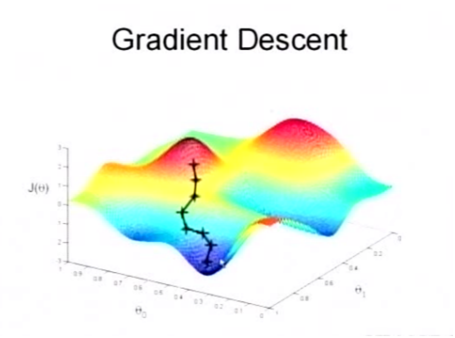
Partially Applied Functions

Only function literals can be assigned to a variable directly.

```
scala> val square = (x:Int) => x*x
foo: Int => Int = <function1>

scala> val squareToo = square
x: Int => Int = <function1>

scala> def squareDef(x:Int) = x*x
squareDef (x: Int)Int

scala> val squareDefToo = squareDef
<console>:13: error: missing arguments for method squareDef;
follow this method with ‘_’ if you want to treat it as a parti
       val  squareDefToo = squareDef

scala> val squareDefToo = squareDef _
squareDefToo: Int => Int = <function1>
```

Example: Gradient Decent

- Goal find local minimum of a function f.
- Move closer to the minimum by taking small steps according to the gradient of f at each point.
- Important in machine learning: find model parameters that minimize some loss/error function.
- Evaluate first derivative f' of f to get gradient.



Example: Gradient Decent (Toy example in 1D)

Try to find the minimum of $\text{fun}(x) = x^4 - 3x^3 + 2$.
Derivative is $\text{fun}'(x) = 4x^3 + 9x^2$.

```
def funDeriv(x : Double) = math.pow(x,4) + 9 * math.pow(x,2)
def gradientDescent(f : Double => Double,
                    init : Double,
                    rate : Double) = {

  def rec(next : Double, old : Double) : Double =
    if (math.abs(next - old) <= 0.00001) next
      else rec(next - rate * f(next), next)

  gradientDescentInner(init, 0)
}

scala> gradientDescent(funDeriv, 1, 0.001)
res0: Double = 0.03331591669117074
```

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Closures

- *Bound variables* are defined as part of a function itself (`vars`, `vals`, parameters).
- *Free variables* are not defined within the function.
- Functions that contains free variables defined in the surrounding context are called *closures*.

```
scala> var more = 1
more: Int = 1

scala> def addMode(x : Int) = x + more
addMode: (x: Int)Int

scala> addMore(1)
res3: Int = 2
```

Closures capture variables not values

```
scala> var more = 1
more: Int = 1

scala> def addMode(x: Int) = x + more
addMode: (x: Int)Int

scala> addMore(1)
res4: Int = 1000
```

Changing captured vars

```
scala> var sum = 0;
sum: Int = 0

scala> def addToSum(x: Int) { sum += x}
addToSum: (x: Int)Unit

scala> addToSum(42)

scala> addToSum(23)

scala> sum
res7: Int = 65
```

Creating and Returning Closures

- Closure references the variable defined when the outer function runs.
- Can return the closure with the argument bound.

```
def makeIncreaser(more : Int) = (x: Int) => x + more

scala> val inc9999 = makeIncreaser(9999)
inc9999: Int => Int = <function1>

scala> inc9999(1)
res0: Int = 1000
```

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Only function literals can be assigned to a variable

```
scala> val square = (x:Int) => x*x
foo: Int => Int = <function1>

scala> val squareToo = square
x: Int => Int = <function1>

scala> def squareDef(x:Int) = x*x
squareDef (x: Int)Int

scala> val squareDefToo = squareDef // Tries to evaluate squar
<console>:13: error: missing arguments for method squareDef;
follow this method with ‘_’ if you want to treat it as a parti

scala> val squareDefToo = squareDef _
squareDefToo: Int => Int = <function1>
```

Partially applied functions

```
scala> val squareDefToo = squareDef _
squareDefToo: Int => Int = <function1>

scala> val squareDefToo = (x: Int) squareDef(x) // equivalent
squareDefToo: Int => Int = <function1>
```

- trailing _ can be a placeholder for the entire argument list.

```
scala> def sumThree(a: Int, b: Int, c: Int) = a+b+c
sumThree: (a: Int, b: Int, c: Int)Int

scala> val sumThreeToo = sumThree _
sumThreeToo: (Int, Int, Int) => Int = <function3>
```

Currying

Currying (a.k.a Schönfinkeling): Define a function that is applied to multiple parameter lists (one at a time).

```
scala> def curriedSum(x: Int)(y: Int) = x + y
curriedSum: (x: Int)(y: Int)Int

scala> curriedSum(1)(2)
res0: Int = 3

scala> curriedSum(1)
<console>:14: error: missing arguments for method curriedSum;
follow this method with ‘_’ if you want to treat it as a
partially applied function
```

Currying and Partially Applied Functions

```
scala> def curriedSum2(x: Int) = (y: Int) => x + y
curriedSum2: (x: Int)Int => Int

scala> curriedSum2(1)
res1: Int => Int = <function1>

scala> def curriedSum(x: Int)(y: Int) = x + y
curriedSum: (x: Int)(y: Int)Int

scala> curriedSum(1)_
res2: Int => Int = <function1>
```

New Control Structures

Higher order functions allow you to write new control structures

```
scala> def twice(op: Double => Double)(x: Double) = op(op(x))
twice: (op: Double => Double)(x: Double)Double

scala> twice( _ + 2)(3)
res16: Double = 7.0

scala> scala twice {
            x => x+ 2
       } (3)
res16: Double = 7.0
```

Currying functions

```
def curry2[A,B,C](f:(A,B) => C) : A => B => C =
    { (a: A) =>
        { (b: B) => f(a,b) }
    }

scala> val add = (x: Int, y: Int) => x + y
add: (Int, Int) => Int = <function2>

scala> val a = curry2(add)
a: Int => (Int => Int) = <function1>

scala> a(1)(2)
res1: Int = 3
```

Currying functions

```
def curry2[A,B,C](f:(A,B) => C) : A => B => C =
    { (a: A) =>
        { (b: B) => f(a,b) }
    }

scala> val add = (x: Int, y: Int) => x + y
add: (Int, Int) => Int = <function2>

scala> val a = curry2(add)
a: Int => (Int => Int) = <function1>

scala> a(1)(2)
res1: Int = 3
```

This is actually already implemented as a method on function objects.

```
scala> val a = add.curried
a: Int => (Int => Int) = <function1>

scala> a(1)(2)
res2: Int = 3
```

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By-Name Parameters

- By default Scala is call-by-value:
  - Any expression is evaluated before it is passed as a function parameter.
- Can force call-by-name by prefixing parameter types with =>.
- Expression passed to parameter is evaluated every time it is used.

```
scala> def add(x : Int, y: Int) =
         { println("normal add: "+ x + "+" + y); x+y }
add: (x: Int, y: Int)Int


scala> def lazyAdd(x: =>Int, y: =>Int) =
         { println("lazy add"); x+y }
```

By-Name Parameters

- By default Scala is call-by-value:
  - Any expression is evaluated before it is passed as a function parameter.
- Can force call-by-name by prefixing parameter types with =>.
- Expression passed to parameter is evaluated every time it is used.

```
scala> def add(x : Int, y: Int) =
         { println("normal add: "+ x + "+" + y); x+y }
add: (x: Int, y: Int)Int


scala> def lazyAdd(x: =>Int, y: =>Int) =
         { println("lazy add"); x+y }

scala> add(add(1,2),add(2,3))
normal add: 1+2
normal add: 2+3
normal add: 3+5
res0: Int = 8
```

By-Name Parameters

- By default Scala is call-by-value:
  - Any expression is evaluated before it is passed as a function parameter.
- Can force call-by-name by prefixing parameter types with =>.
- Expression passed to parameter is evaluated every time it is used.

```
scala> def add(x : Int, y: Int) =
         { println("normal add: "+ x + "+" + y); x+y }
add: (x: Int, y: Int)Int


scala> def lazyAdd(x: =>Int, y: =>Int) =
         { println("lazy add"); x+y }

scala> add(add(1,2),add(2,3))
normal add: 1+2
normal add: 2+3
normal add: 3+5
res0: Int = 8

scala> lazyAdd(add(1,2),add(2,3))
lazy add
normal add: 1+2
normal add: 2+3
res1: Int = 8
```

By-Name Parameters

- We often want to evaluate the passed expression only once.

```
scala> def lazyAdd(x: =>Int, y: =>Int) =
    { println("lazy add:" + x + "+" + y); x+y }

scala> lazyAdd(add(1,2),add(2,3))
normal add: 1+2
normal add: 2+3
lazy add 3 + 5
normal add: 1+2
normal add: 2+3
res1: Int = 8
```

By-Name Parameters

- We often want to evaluate the passed expression only once.

```
scala> def lazyAdd(x: =>Int, y: =>Int) =
    { println("lazy add:" + x + "+" + y); x+y }

scala> lazyAdd(add(1,2),add(2,3))
normal add: 1+2
normal add: 2+3
lazy add 3 + 5
normal add: 1+2
normal add: 2+3
res1: Int = 8

scala> def lazyAdd(x: =>Int, y: =>Int) =
    { val a = x; val b = y;
      println("lazy add:" + a + "+" + b); a+b }
scala> lazyAdd(add(1,2),add(2,3))
normal add: 1+2
normal add: 2+3
lazy add 3 + 5
res2: Int = 8
```

Control Structures with By-Name Parameters

Can use By-Name parameters to build control structures that look like built-in control structures.

```
var assertionsEnabled = true

def myAssert(predicate: () => Boolean) =
    if (assertionsEnabled && !predicate())
        throw new AssertionError

scala> myAssert(() => 5 > 3)

def myAssert2(predicate: => Boolean) =
    if (assertionsEnabled && !predicate)
        throw new AssertionError

scala> myAssert2(5 > 3)
```

Lazy vals

```
def makeString =
  {println("in makeString"); "hello "+"world";}

def printString = {
  lazy val s = makeString
  print("in printString")
  println(s)
  println(s)
}

scala> printString
in printString
in makeString
hello world
hello world
```