Chapter 17
Control and Iteration

17.1 Introduction

This chapter introduces control and iteration in Scala. In Scala, as in many other languages, the mainstay of the control and iteration processes are the `if` and `switch` statements and the `for` and `while` loops.

17.2 Control Structures

17.2.1 The if Statement

The basic format of an `if` statement in Scala is the same as that in languages such as C, Pascal and java. A test is performed and, depending on the result of the test, a statement is performed. A set of statements to be executed can be grouped together in curly brackets {}. For example:

```
if (a == 5)
 println("true")
else
 println("false")


if (a == 5) {
 print("a = 5")
 println("The answer is therefore true")
} else {
 print("a != 5")
 println("The answer is therefore false")
}
```

Of course, the `if` statement need not include the optional `else` construct:

```
if (a == 5) {
 print("a = 5")
 println("The answer is therefore true")
}
```

You must have a *Boolean* in a condition expression, so you cannot make the same equality mistake as in C. The following code always generates a compile time error:

```
if (a = 1) {
 ...
}
```

Unfortunately, assigning a Boolean to a variable results in a boolean (all expressions return a result) and thus the following code is legal, but does not result in the intended behaviour (the string "Hello" is always printed on the console):

```
var a = false
if (a = true)
  println("Hello")
```

You can construct nested `if` statements, as in any other language:

```
if (count < 100)
 if (index < 10)
      {...}
 else
      {...}
else
 {...}
```

However, it is easy to get confused. Scala does not provide an explicit if-then-elseif-else type of structure. In some languages, you can write:

```
if (n < 10)
 print ("less than 10");
else if (n < 100)
 print ("greater than 10 but less than 100");
else if (n < 1000)
 print ("greater than 100 but less then 1000");
else
 print ("greater than 1000");
```

This code is intended to be read as laid out above. However if we write it in Scala, it should be laid out as below:

```
if (n < 10)
 print ("less than 10")
else if (n < 100)
  print ("greater than 10 but less than 100")
 else if (n < 1000)
    print ("> than 100 but < 1000")
  else
    print ("> than 1000")
```

This code clearly has a very different meaning (although it may have the same effect). This can lead to the infamous “dangling else” problem. Another solution is the `switch` statement. However, as you will see the switch statement has significant limitations.

17.2.2 If Returns a Value

Almost all statements in Scala return a result and the if statement is no different. This means that you can use an if statement to determine the value to assign to a value (or pass to a method etc). For example the following code assigns either the string “Dad” or the String “No Data” to the value role defining the the current string referenced by the variable name:

```
val role =
  if (name == "John")
    "Dad"
  else
    "No Data"

println(role)
```

This is a very useful feature of the if statement can be used effectively in many situations.

17.3 Iteration

Iteration in Scala is accomplished using the `for, while` and `do-while` statements. Just like their counterparts in other languages, these statements repeat a sequence of instructions a given number of times.

17.3.1 For Loops

A `for` loop in Scala is very similar to a `for` loop in other languages. It is used to step a *variable* through a series of values until a given test is met. Many languages have a very simple for loop, for example:

```
for i = 0 to 10 do
  ...
endfor;
```

In this case a variable I would take the values 0, 1, 2, 3 etc. up to 10. The long hand from of this in Scala is:

```
for (i <- (0).to(10)) {
      print(i)
}
```

Note that in he above *to* is a method call on the Int (integer) type. In practice this is a lower level implementation issue and it would be far more common to write:

```
for (i <- 0 to 10) print(i)
```

This can be done as Scala can infer the brackets and the dot which has the benefit that it will look far more familiar as a language construct to those used to programming languages such as C and Pascal.

One thing to note is that the to operator here includes the value 10 where as in languages such as C and Java it would mean up to but not including 10.

Multiple indexes can be used with a for loop. For example, we could increment I from 1 to 3 and j from 5 to 7:

```
object MultipleForLoopTest extends App {
  for (i <- 1 to 3; j <-5 to 7) {
    print("Value of i: " + i);
    println(" / Value of j: " + j);
  }
}
```

This may not have the effect you expect. This equates to loop the value of I through 1 to 3 for each of the values of j, thus the output is:

```
Value of i: 1 / Value of j: 5
Value of i: 1 / Value of j: 6
Value of i: 1 / Value of j: 7
Value of i: 2 / Value of j: 5
Value of i: 2 / Value of j: 6
Value of i: 2 / Value of j: 7
Value of i: 3 / Value of j: 5
Value of i: 3 / Value of j: 6
Value of i: 3 / Value of j: 7
```

As you can see from this, the value of I remains constant for all values of j and is then incremented for a repeated for the values of j.

17.3.2 For Until

An alternative to the *to* operator is the *until* operator which indicates that a variable i should loop unto but not including the higher bound, thus:

```
for (i <- 1 until 4) println(i)
```

Producers the output:

```
1
2
3
```

But does not include the value 4.

17.3.3 For Loop with a Filter

Another option with the for loop is to include a filter into the looping process. This can be used to *filter* out those elements within a loop that you do not ant to process. A filter is an additional logical test added to the for loop following the iteration values already presented. For example, assuming that the variable files contains some from of list of files, then we can add an extra test to check so that we only print out files where the file name ends with ".txt":

```
for (f <- files if f.getName.endsWith(".txt"))
  println(f)
```

With this loop each file in the list of files is tested such that the name is first obtained (getName) and then the string method endsWith, tests to see if the filename ends with ".txt", if it does then the file is processed by the loop—which in this case involving printing out the file. If the filename does not end with ".txt" then the loop immediately moves onto the name file in the list.

The complete program for this example is shown below:

```
import java.io.File

object FileLoopTest extends App {
   val files = (new File(".")).listFiles
   for (f <- files if f.getName.endsWith(".txt"))
      println(f)
 }
```

Note that any number of if conditions can be added to provide multiple filters on a for loop. Each if condition is separated by a ';', for example:

```
import java.io.File

object FileLoopTest extends App {
   val files = (new File(".")).listFiles
   for (f <- files if f.getName.startsWith("Help");
                    if f.getName.endsWith(".txt"))
      println(f)
 }
```

17.3.4 Long Hand for Loop

Although we have looked at a number of different for loops in the preceding sections, they are all subsets of the full for loop which is made up of a generator, an optional definition and a filter. Thus you could write:

```
for (
   p <- persons      ;       // a generator
   n = p.name ;       // a definition
   if (n startsWith "To")     // a filter
) println(n)
```

With the definition being reset each time round a loop

17.3.5 For-Yield Loop

A special for loop is a for-yield loop. It is particular useful for collecting together a set of results from a for loop that can be processed by other code rather then performing the processing directly within the for loop.

That is, the value of the all the previous for loops (from the point of view of the expression being evaluated when the for loop executes) is Unit or nothing. However, using a yield then each time round the loop a *yield* expression can be evaluated and the results of the expression collected together and made available to subsequent lines of code once the for loop has completed.

The general syntax for a for yield loop is:
for (sequence) yield expression
Examples of the use of the for-yield loop are shown below:
val data = for (i <- 1 to 5) yield 10 * i
produces a sequence of values (10, 20, 30, 40, 50) held in the val data
val info = for (n <- List (“one”, “two”, “three”)) yield n.substring (0, 2)
produces a list of values (on, tw, th) held in info

In both cases subsequent code could process either the data variable or the info variable. This is a very powerful construct for creating a collection of data items to be further processed from some loop-based operations.

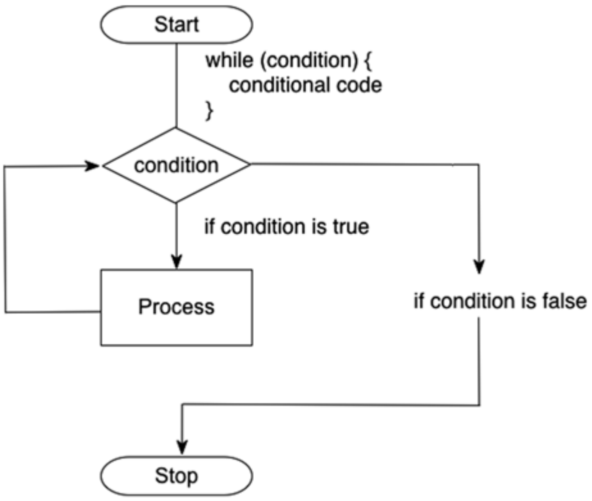


Fig. 17.1 Behaviour of a While loop

17.3.6 *While Loops*

The while loop exists in almost all programming languages. In most cases, it has a basic form such as:

```
while (test expression)
 statement
```

This is also true for Scala. The `while` expression controls the execution of one or more statements. If more than one statement is to be executed then the statements must be enclosed in curly brackets {}:

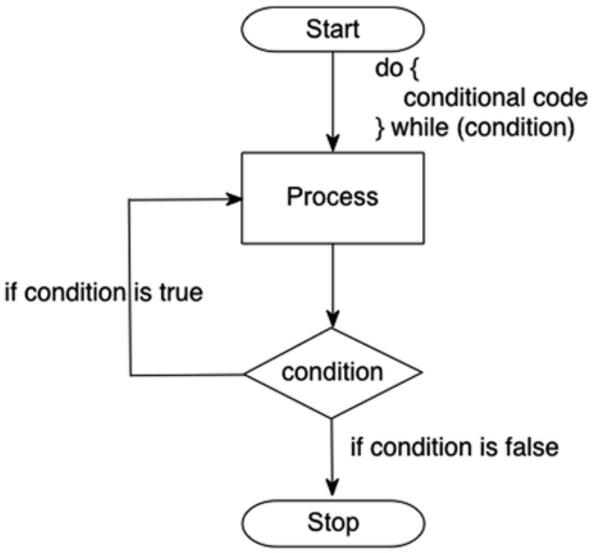
```
var i=0;
while (i < 10) {
   println(i)
   i += 1
}
```

The above loop tests to see if the value of *i* is less than or equal to 10, and then prints the current value of *i* before incrementing it by one. This is repeated until the test expression returns false (i.e. `i = 11`).

You must assign *i* an initial value before the condition expression. If you do not provide an initial value for *i,* it defaults to none value and the comparison with a numeric value raises an exception.

The behaviour of the while loop is illustrated in Fig. 17.1.

Fig. 17.2 Behaviour of a Do loop



17.3.7 Do Loops

In some cases, we want to execute the body of statements at least once; you can accomplish this with the `do` loop construct:

```
do
 statement
while (test expression);
```

This loop is guaranteed to execute at least once, as the test is only performed after the statement has been evaluated. As with the `while` loop, the `do` loop repeats until the condition is false. You can repeat more than one statement by bracketing a series of statements into a block using curly brackets {}:

```
var n = 10
do {
 println(n)
 n= n - 1
} while (n > 0)
```

The above `do` loop prints the numbers from 10 down to 1 and terminates when n = 0. The logic of the while loop is illustrated in Fig. 17.2.

17.3.8 An Example of Loops

As a concrete example of the `for` and `while` loops, consider the following class. It possesses a method that prints numbers from 0 to the `MaxValue` variable:

```
case class Counter {
  var MaxValue = 10
  def count() = {
    var i = 0
    println("----- For -------------");
    for (i <- 0 to MaxValue) {
      print(" " + i)
    }
    println(" ")
    println("----- While -----------")
    i = 0
    while (i <= MaxValue) {
      print(" " + i)
      i = i + 1
    }
    println(" ")
    println("-----------------------")

  }
}

object Counter extends App {
  val c = Counter()
  c.count
}
```

The result of running this application will be:

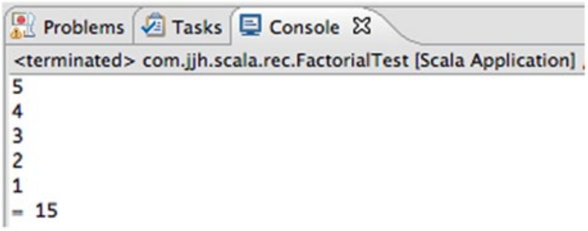
```
----- For -------------
 0 1 2 3 4 5 6 7 8 9 10
----- While -----------
 0 1 2 3 4 5 6 7 8 9 10
-----------------------
```

17.4 Equality

Two instances may be considered equivalent if their contents is the same. This equivalence is defined by the equals method on a class and is used by the '==' and '!=' operators, where:

== tests for equality
!= tests for not equals

Fig. 17.3 Running the FactorialTest application



```
<terminated> com.jjh.scala.rec.FactorialTest [Scala Application]
5
4
3
2
1
= 15
```

The equality operators are actually invoked on the left hand operand with the right hand operand being passed to the operator as a parameter.

You can compare two instances using == and !=, for example:

- 1 == 2 // false
- 1 != 2 // true
- 1 == 1.0 // true
- List(1, 2, 3) == List(1, 2, 3) // true
- List(1, 2, 3) == "John" // false

Not that there is also a *referential* equality operator in Scala. This is provided by 'eq' method. This method tests that the two instances being compared are literally the same instance rather than just equivalent in value.

17.5 Recursion

Recursion is a very powerful programming idiom found in many languages. Scala is no exception. The following class illustrates how to use recursion to generate the factorial of a number:

```
case class Factorial {
  def factorial(number: Int): Int = {
    println(number)
    if (number == 1)
      return 1
    else
      return { number + factorial(number - 1) }
  }
}

object FactorialTest extends App {
  val f = Factorial()
  println("= " + f.factorial(5))
}
```

The result of running this application is illustrated in Fig. 17.3.

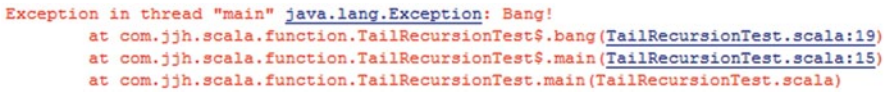
One problem for recursion is that although it is elegant to program it may not be the most efficient rutime solution. However Scala can optimize tail recursive methods such that it can be expressed via recursion in terms of theprogram but optimized into an iterative loop at runtime. Since Scala 2.8 you can now mark a method that you expect to use tail recursion with the annotation @tailrec. An annotation is a piece of metadata that the runtime can use to perform additional processing etc. This allows you to indicate that the method should be optimizable for tail recursion by the compiler. It thus allows the compiler to provide a wanring if the method does not succeed in being tail recursive. For example:

```
package com.jeh.scala.tail

import scala.annotation.tailrec

object Util {
  def factorial(n: Int): Int = {
    @tailrec
    def factorialAcc(acc: Int, n: Int): Int = {
      if (n <= 1) acc
      else factorialAcc(n * acc, n - 1)
    }
    factorialAcc(1, n)
  }
}
```

To understand why this makes a difference consider the following method:

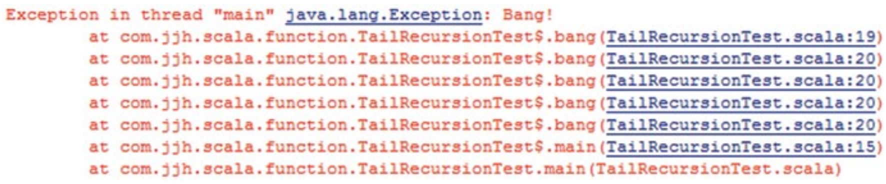
```
package com.jeh.scala.tail

object TailRecursionTest {

  def main(args: Array[String]): Unit = {
    bang(4)
  }

  def bang(x: Int): Int = {
    if (x == 0) throw new Exception("Bang!")
    else bang(x - 1) // +1
  }

}
```

The method bang intentionally throws an Exception (causes an error to occur) when x is Zero. This allows you to see what the compiler has done with the runtime version of the code. With the + 1 element of the else part of the if statement commented out this is a tail recursive method. When we run this program the output is as shown below:



```
Exception in thread "main" java.lang.Exception: Bang!
	at com.jjh.scala.function.TailRecursionTest$.bang(TailRecursionTest.scala:19)
	at com.jjh.scala.function.TailRecursionTest$.main(TailRecursionTest.scala:15)
	at com.jjh.scala.function.TailRecursionTest.main(TailRecursionTest.scala)
```

If we now uncomment the + 1 at the end of the 'if' statement, and rerun this program we now get:



```
Exception in thread "main" java.lang.Exception: Bang!
	at com.jjh.scala.function.TailRecursionTest$.bang(TailRecursionTest.scala:19)
	at com.jjh.scala.function.TailRecursionTest$.bang(TailRecursionTest.scala:20)
	at com.jjh.scala.function.TailRecursionTest$.bang(TailRecursionTest.scala:20)
	at com.jjh.scala.function.TailRecursionTest$.bang(TailRecursionTest.scala:20)
	at com.jjh.scala.function.TailRecursionTest$.bang(TailRecursionTest.scala:20)
	at com.jjh.scala.function.TailRecursionTest$.main(TailRecursionTest.scala:15)
	at com.jjh.scala.function.TailRecursionTest.main(TailRecursionTest.scala)
```

What you can see is that the first version has been converted into a iterative loop which does not need to keep calling itself (which is inefficient at runtime). However, with the second example we have called the same bang method multiple times which has resulted in the need to handle each call separated (set up the call stack for each method invocation) which is far less efficient. Thus knowing whether the recursive method is tail recursive or not is an important consideration.

17.5.1 The Match Expression

Scala's match expression allows for a selection to be made between a number of alternative tests and as such is similar in nature to the case statement in Pascal and C or the Switch statement in java. However, compared to the switch statement in Java is allows much wider pattern matching capability in the case clause of the expression this provides for a far more powerful and flexible construct. Also note that the match expression is an expression (and not just a statement) thus it returns a value and can be used as part of an assignment clause.

The pattern element of the match expression is much more flexible than in languages such as C and Java and can be any one of

- Can be a literal,
- a wildcard (to match anything),
- a type,
- a variable which will be populated,
- of different types,
- tuple patterns etc.

As an example, consider the following simple literal match test:

```
object MatchTest extends App {
    val arg = "John"
    val relationship =
      arg match {
        case "John" => "Dad"
        case "Denise" => "Mum"
        case "Phoebe" => "Daughter"
        case "Adam" => "Son"
          // Default / wildcard
        case _ => "WhoAreYou?"
      }
    println(relationship)
}
```

This example compares the arg varl with the String literals “John”, “Denise”, “Phoebe” and “Adam”. If it is one of these values it returns the string associated with that literal. Thus if arg holds the string “John” then the match expression will return the String “Dad”. The result of the match expression is then saved into the relationship val and printed out. If the value held in arg is not one of the strings explicitly mentioned that it will use the default (wildcard) case test. Thus any other string in arg will result in “WhoAreYou?” being returned by the match expression. Note in match expression “_” is being used a s a wildcard that will match any string not mentioned above in the case tests.

However, unlike many other languages the literals used in the individual case tests do not need to be of the same type. For example, the following uses four different types of literal from an Int, to a Boolean, to a String and a empty list (Nil):

```
object MatchTest2 {

  def main(args: Array[String]): Unit = {
    println(describe(5))
    println(describe(true))
    println(describe("hello"))
    println(describe(Nil))
    println(describe(List(1,2,3)))
  }

  def describe(x: Any) = x match {
    case 5 => "five"
    case true => "truth"
    case "hello" => "welcome message"
    case Nil => "The empty list"
    case _ => "something else"
  }

}
```

The type of the parameter x is Any which is the root of everything in Scala and thus x can indeed hold any type of value. We can now use the method *describe* to produce a printed string for any type of value in Scala—although unless it is the value 5, true, "hello" or Nil it will print the description as "something else".

A variable on the last example allows us to use a variable in the case test of the wild card to obtain the actual value passed in and to use that in the expression being evaluated:

```
object MatchTest3 {

 def main(args: Array[String]): Unit = {
    println(describe(5))
    println(describe(true))
    println(describe("hello"))
    println(describe(Nil))
    println(describe(List(1,2,3)))
  }

  def describe(x: Any) = x match {
    case 5 => "five"
    case true => "truth"
    case "hello" => "welcome message"
    case Nil => "The empty list"
    case somethingElseVariable => "something else: " +
somethingElseVariable
  }

}
```

Now when something other than he value 5, true, "hello" or Nil is passed in then the result will be that the string "something else: " concatenated with that thing in string format will be returned by the describe method.

We can also match by type rather than by specific value. For example, in the following example if the type of data passed in is a String then the first case test will pass and the string will be *bound* to the variable s and thus available for processing in the resultant operation associated with that test. In turn if the instance passed in to getSize is a List then it will pass the second test and be bound to the variable l and be available to the operation following this test. If the instance passed to getSize is actually a Map then it will meet the criteria specified by the third case test. The result in each case is that an appropriate method is called to determine the size of the instance passed to getSize. If the instance is not a String, a List or a Map then −1 is returned by default:

```
object MatchTest4 {
  def main(args: Array[String]): Unit = {
    val name = "John"
    println(getSize(name))
    val xxx = List(1, 2, 3)
    println(getSize(xxx))
    val myMap = Map("London" -> 01, "Cardiff" -> 020)
    println(getSize(myMap))
    val otherMap = Map(1 -> "a", 2 -> "b", 3->"c")
    println(getSize(otherMap))
    val lectureMap =
           Map("John" -> "Scala", "Fed" -> "PHP")
    println(getSize(lectureMap))
    val info = (1, 2, 3)
    println(getSize(info))
  }

  def getSize(x: Any) = x match {
    case s: String => s.length()
    case l: List[_] => l.size
    case m: Map[_,_] => m.size
    case _ => -1
  }

}
```