Scala programming language

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Scala on JVM

- scalac compiles Scala to Java bytecode
  - (regular .class files)
- **Any Java class can be used from Scala**

Origin

- Started at 2001 by Martin Odersky at EPFL Lausanne, Switzerland
- Scala 2.0 released in 2006
- Current version 2.7

- Twitter backend runs on Scala

Scala properties

- Object oriented
- Statically typed
- Functional & imperative

Static typing

- Type checking done at compile time
- Type associated with variable, not value
- Better tools possible
- More verbose code compared to dynamic language
- Can’t add methods to class at runtime
- No duck typing – really?

Functional programming

- Functions are first class citizens
- Immutability
- Tuples
- Currying
- Recursion
- Monads

Introduction

Demo of Scala interpreter

Variables & values, type inference

```
var msg = "Hello“      // msg is mutable
msg += " world"
msg = 5;               // compiler error
```

Variables & values, type inference

```
val msg = "Hello world“     // msg is immutable
msg += " world“             // compiler error
```

```
val n : Int = 3     // explicit type declaration
var n2 : Int = 3
```

Immutability

- Why?
  - Immutable objects are automatically thread-safe

    (you don't have to worry about object being changed by another thread)
  - Compiler can reason better about immutable values -> optimization

  - Steve Jenson from Twitter: *"Start with immutability, then use mutability where you find appropriate."*

Calling Java from Scala

- Any Java class can be used seamlessly

```
import java.io._
val url = new URL("http://www.scala-lang.org")
```

demo

Methods

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


// equivalent:
def neg(x : Int) : Int = -x
def neg(x : Int) : Int = { return -x; }
```

Types

- Int, Double, String, Char, Byte, BigInt, …
  - wrappers around Java types

Lists

- Lists are immutable (= contents cannot be changed)
- List**[String]** contains Strings

```
val lst = List("b", "c", "d")
lst.head                    // “b”
lst.tail                    // List(“c”, “d”)
val lst2 = "a" :: lst       // cons operator
```

Lists

- Nil = synonym for empty list

```
val l = 1 :: 2 :: 3 :: Nil
```

- List concatenation

```
val l2 = List(1, 2, 3) ::: List(4, 5)
```

Foreach

```
val list3 = List("mff", "cuni", "cz")
```

- Following 3 calls are equivalent

```
list.foreach((s : String) => println(s))
list.foreach(s => println(s))
list.foreach(println)
```

For comprehensions

```
for (s <- list)
  println(s)

for (s <- list if s.length() == 4)
  println(s)
```

- for just calls foreach

Arrays

- Lists are immutable, arrays are mutable

```
val a = Array("Java", "rocks")
a(0) = "Scala";
```

Covariance

- Lists are covariant, arrays are invariant

```
// compiler error
val array : Array[Any] = Array(1, 2, 3);

// ok
val list : List[Any] = List(1, 2, 3);
```

Arrays

```
val greets = new Array[String](2)
greets(0) = "Hello"
greets(1) = "world!\n"
for (i <- 0 to 1)
  print(greets(i))
```

Arrays are no special type

greets(i) === greets.apply(i)

greets(i) = "Hi" === greets.update(i, "Hi")

- Any class that defines apply / update can be used like this

Every operation is a method call

- “to” is not a keyword
  - for (i <- 0 **to** 2) print(greets(i))
  - 0 to 2 === 0.to(2)
- x – 1 === x.-(1)
- map containsKey ‘a’ === map.containsKey(‘a’)

Associativity

- If method name ends with colon, the method is invoked on the right operand

```
val list = List("b", "c")
"a" :: list     ===    list.::("a")
```

Performance

- Scala treats everything as objects
  - no primitive types, no arrays
- So this comes with a cost, right?
  - Usually not, the scalac compiler uses Java primitive types and arrays where possible

Anonymous functions

```
val l = new List("mff", "cuni", "cz")
l.filter(s => s.length == 4)
```

```
val l = List[Person](new Person(…), …)
l.sort((p1, p2) => p1.lastName < p2.lastName)
```

Currying

- Function with only some arguments specified = function expecting the rest of the arguments

- Common concept in functional languages

Currying

```
// Does n divide m?
def nDividesM(m : Int)(n : Int) = (n % m == 0)

// Currying,
// isEven is of type (Int) => Boolean
val isEven = nDividesM(2)_

println(isEven(4))
println(isEven(5))
```

Tuples

- Sequence of elements with different types

```
(10, List('c', 'm'), "cache");
```

  - type of this expression is Tuple3[Int, List[Char], String]

Tuples

```
def divMod(x : Int, y : Int) = (x / y, x % y)

val dm = divMod(10, 3)    // Tuple2[Int, Int]
dm._1      // 3
dm._2      // 1

val (d, m) = divMod(10, 3);
println(d + " " + m);      // 3 1
```

Pattern matching

- Like switch statement
  - But much more powerful

Pattern matching

```
def flatten(list: List[Any]) : List[Any] =
list match {
    case (x: List[Any]) :: xs =>
                            flatten(x) ::: flatten(xs)
    case x :: xs => x :: flatten(xs)
    case Nil => Nil
}

val nested = List(1, List(2, 3), 4);
val flat = flatten(nested); // List(1, 2, 3, 4)
```

Classes

```
/** A Person class.
 * Constructor parameters become
 * public members of the class.*/
class Person(val name: String, var age: Int) {
  if (age < 0) {
      throw …
  }
}

var p = new Person(“Peter", 21);
p.age += 1;
```

Objects

- Scala's way for "statics"
  - not quite – see next slide
  - (in Scala, there is no *static* keyword)

- "Companion object" for a class
  - = object with same name as the class

demo

Objects

```
// we declare singleton object "Person"
// this is a companion object of class Person
object Person {
  def defaultName() = "nobody"
}
class Person(val name: String, var age: Int) {
  def getName() : String = name
}

// surprise, Person is really an object
val singleton : Person = Person;
```

Case classes

- Implicitely override toString, equals, hashCode
  - take object's structure into account

```
abstract class Expr
case class Number(n: Int) extends Expr
case class Sum(e1: Expr, e2: Expr) extends Expr

// true thanks to overriden equals
Sum(Number(1), Number(2)) ==
Sum(Number(1), Number(2))
```

Case classes

- Needed if we want to pattern match on class hiearchies

```
def eval(e: Expr): Int = e match {
  case Number(n) => n
  case Sum(l, r) => eval(l) + eval(r)
}
```

Exceptions

```
object Main {
  def main(args: Array[String]) {
    try {
      val elems = args.map(Integer.parseInt)
      println("Sum is: " + elems.foldRight(0) (_ + _)) }
    catch {
      case e: NumberFormatException =>
        println("Usage: scala Main <n1> <n2> ... ")
    }
  }
}
```

Traits

Traits

- Like Java interfaces
- But can contain implementations and fields

```
trait Pet {
  var age: Int = 0
  def greet(): String = {
    return "Hi"
  }
}
```

Extending traits

```
class Dog extends Pet {
  override def greet() = "Woof"
}

trait ExclamatoryGreeter extends Pet {
  override def greet() = super.greet() + " !"
}
```

Traits - mixins

- Traits can be “mixed in” at instation time

```
trait ExclamatoryGreeter extends Pet {
  override def greet() = super.greet() + " !"
}

val pet = new Dog with ExclamatoryGreeter
println(pet.greet())          // Woof !
```

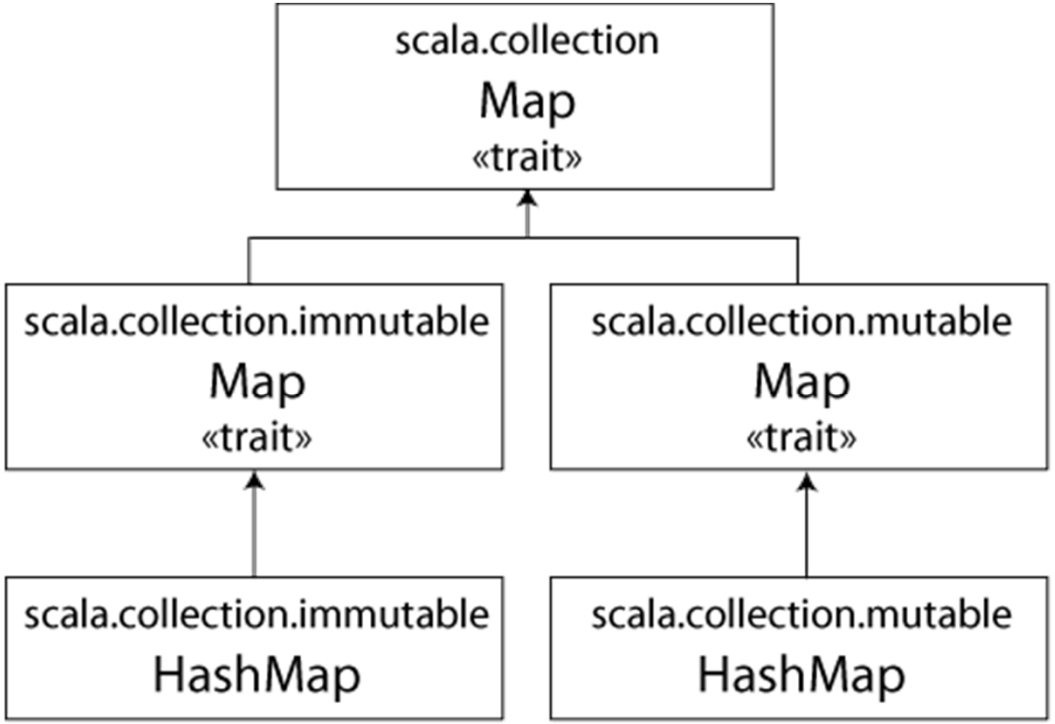
Traits – common use

```
trait Ordered[A] {
  def compare(that: A): Int       // abstract method

  def <  (that: A): Boolean = (this compare that) <  0
  def >  (that: A): Boolean = (this compare that) >  0
}

class Health(val value : Int) extends Ordered[Health]
{
  override def compare(other : Health) = {
       this.value - other.value; }
  def isCritical() = …
}
```

Maps and Sets



Map – simple example

```
import scala.collection._

val cache = new mutable.HashMap[String,String];
cache += "foo" -> "bar";

val c = cache("foo");
```

- The rest of Map and Set interface looks as you would expect

ListBuffer

- ListBuffer[T] is a mutable List
  - Like Java's ArrayList<T>

```
import scala.collection.mutable._

val list = new ListBuffer[String]
list += "Vicky"
list += "Christina"

val str = list(0)
```

Option

- Like “Maybe” in Haskell

- Example – 3 state Boolean

```
var sure : Option[Boolean] = Some(false);
sure = Some(true);
sure = None;
```

Actors

Actors

- Concurrency using threads is hard
  - Shared state – locks, race conditions, deadlocks
- Solution – **message passing + no shared state**
  - Inspired by Erlang language
    - Erlang used at Ericsson since 1987, open source since 1998
    - Facebook chat backend runs on Erlang

What is an actor

- Actor is an object that receives messages
- Actor has a *mailbox* – queue of incoming messages
- Message send is by default *asynchronous*
  - Sending a message to an actor immediately returns

Actors – trivial example

- We define messages

```
case object MsgPing
case object MsgPong
case object MsgStop
```

Actors – trivial example

```
class Ping(count: Int, pong: Actor) extends Actor {
  def act() {
    var pingsSent = 0
    println("Ping: sending ping " + pingsSent)
    pong ! MsgPing; pingsSent += 1
    while(true) {
      receive {
        case MsgPong =>
          if (pingsSent < count) {
            if (pingsSent % 1000 == 0)
              println("Ping: sending ping " + pingsSent)
            pong ! MsgPing; pingsSent += 1
          } else {
            println("Ping: sending stop")
            pong ! MsgStop
            exit()
          }
      }}}}
```

Actors – trivial example

```
class Pong extends Actor {
  def act() {
    var pongCount = 0
    while(true) {
      receive {
        case MsgPing =>
          if (pongCount % 1000 == 0)
            println("Pong: replying " + pongCount)
          sender ! MsgPong
          pongCount += 1
        case MsgStop =>
          println("Pong: stop")
          exit()
      }
    }
  }
}
```

Actors – trivial example

```
val pong = new Pong
val ping = new Ping(100000, pong)
ping.start
pong.start

// any following code here is not
  blocked by the actors, each Actor
  (Ping, Pong) runs in his own thread
```

Actors – what else is available?

- actor ! message - asynchronous send
- actor !? message - synchronous send (awaits reply)

- actor !! message - asynchronous, returs *future* object
  - future object can be used later to get the result

Creating “keywords”

- From actors example, it seems that Scala has built-in keywords like *receive { }* or *!*
- Not true – actors are implemented as a library
- We already know that

  pong ! MsgPing is equivalent to

  pong.!(MsgPing) *// ! is a method of Actor class*

Creating “keywords”

- Moreover, receive is just a method of Actor class
- Method **arguments can be passed in curly braces**
  - Ability to create DSL-like languages

```
receive {
        case MsgPong =>
    …
}
```

Creating keywords - lock in Java

```
String x = "No"

l.lock();
try {
  x = "Yes"
} finally {
  l.unlock();
}
```

Creating keywords - lock in Scala

```
var x = "No"

lock(l) {
   x = "Yes“
}
```

Lock “keyword” implemetation

- Lock “keyword” is really an ordinary method

```
// f is a function (piece of code) returning
// Unit (ie. void)
def lock(l : Lock)(f : => Unit) = {
  l.lock();
  try {
    f       // call f
  } finally {
    l.unlock();
  }
}
```

Parallelism

Parallelism

- What about parallelMap, parallelReduce etc. ?
- Not present in Scala library yet ☹
  - Have to implement own versions

Little more advanced

What exactly is the List?

- List is an abstract class with 2 descendant case classes:
  - Nil
  - ::

- What gets called for List(1, 2, 3) ?

```
object List {
// * means variable arguments
def apply[A](xs: A*): List[A] = xs.toList
```

scala.Seq

- scala.Seq is the supertype that defines methods like:
  - filter, fold, map, reduce, take, contains, …
- List, Array, Maps… descend from Seq

Yield, iterators

- Syntax sugar for returning iterator object
- Iterators allow to iterate over a sequence of elements. They have hasNext() and next() methods.
- Lazy evaluation
  - when olderThan21 is called, the for loop is **not** executed

```
def olderThan21(xs: Iterator[Person]): Iterator[String] =
{
  for (p <- xs if p.age > 21) yield p.getName()
}
```

Matching generic arguments?

- Will this compile?

```
def genMatch(list: List[Any]) : String =
list match {
    case (x: List[Int]) => "ints"
    case (x: List[String]) => "strings"
}
```

Matching generic arguments?

- JVM has no runtime support for generics (compiler uses erasure)

```
def genMatch(list: List[Any]) : String =
list match {
    // warning: type argument is unchecked
    case (x: List[Int]) => "ints"
    // error: unreachable code
    case (x: List[String]) => "strings"
}
```

Adding methods to classes

- Possible in dynamic languages (even at runtime)
- Possible using Extension methods in C#
  - (just syntax sugar for static methods)

- How to do it in Scala?

“Adding methods” to classes

- ScalaTest test framework

  map should have value 7 // legal scala code

- We want to be able to call map.should
  - map does not have a “should” method

- Solution – wrapper object

```
class Wrapper(wrappedObject : Any) {
   def should() …
}
```

“Adding methods” to classes

```
class Wrapper(wrappedObject : Any) {
   def added() { …}
}
```

- Define implicit conversion method Any -> Wrapper

```
implicit def wrap(o : Any) = new Wrapper(o)
```

object.added() compiles as wrap(object).added()

“Adding methods” - demo

```
class CollectionWrapper[T](wrappedCollection : java.util.Collection[T]) {
def join(delim : String) : String = {
    val iter = wrappedCollection.iterator();
     val buffer = new StringBuffer(iter.next().toString());
     while (iter.hasNext()) buffer.append(delim).append(iter.next().toString());
     return buffer.toString();
   }
}

implicit def wrapCollection[T](o : java.util.Collection[T]) = new CollectionWrapper(o)

var javaList = new java.util.ArrayList[String]();
println(javaList.join("-"));                    // same as wrapCollection(javaList).join(“-“)
```

Structural types

- { val length : Int }
  - any object that has length field
- { def length() : Int }
  - any object that has length() method

- Duck typing
- Invoking methods on the object uses reflection - slower

Traits – diamond inheritance?

XML

```
import scala.xml._

val df = java.text.DateFormat.getDateInstance()
val dateString = df.format(new java.util.Date())

def theDate(name: String) =
  <dateMsg addressedTo={ name }>
    Hello, { name }! Today is { dateString }
  </dateMsg>;


println(theDate("John Doe").toString())
```

Happy coding

Slides + demos at
http://coding-time.blogspot.com