1. Performance
2. Security
3. Productivity

New PL in Industry

PL	Company	Predecessor	Domain	Concepts
Go	Google	C	Systems	Channels Type Inference ML modules GC
Dart	Google	Javascript	Web	Types
Rust		C++	System Browser	Type Inference Ownership Linear Types
Hack	facebook	PHP	Social Network	Gradual Types

The Scala Programming Language

Mooly Sagiv

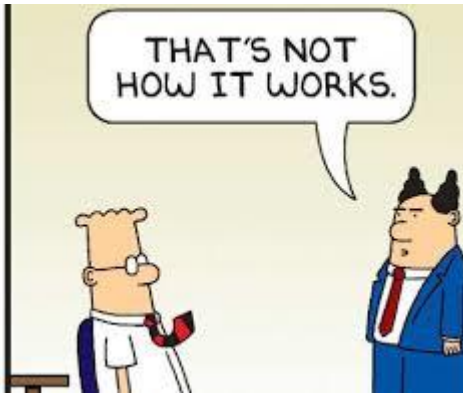
Slides taken from
Martin Odersky (EPFL)
Donna Malayeri (CMU)
Hila Peleg (Technion)

Modern Functional Programming

- Higher order
- Modules
- Pattern matching
- Statically typed with type inference
- Two viable alternatives
  - Haskel
    - Pure lazy evaluation and higher order programming leads to Concise programming
    - Support for domain specific languages
    - I/O Monads
    - Type classes
  - ML/Ocaml/F#
    - Eager call by value evaluation
    - Encapsulated side-effects via references
    - [Object orientation]

Then Why aren't FP adapted?

- Education
- Lack of OO support
  - Subtyping increases the complexity of type inference
- Programmers seeks control on the exact implementation
- Imperative programming is natural in situations



Why Scala?
(Coming from OCaml)

- Runs on the JVM/.NET
  - Can use any Java code in Scala
- Combines functional and imperative programming in a smooth way
- Effective libraries
- Inheritance
- General modularity mechanisms

The Java Programming Language

- Designed by Sun 1991-95
- Statically typed and type safe
- Clean and Powerful libraries
- Clean references and arrays
- Object Oriented with single inheritance
- Interfaces with multiple inheritance
- Portable with JVM
- Effective JIT compilers
- Support for concurrency
- Useful for Internet

Java Critique

- Downcasting reduces the effectiveness of static type checking
  - Many of the interesting errors caught at runtime
    - Still better than C, C++
- Huge code blowouts
  - Hard to define domain specific knowledge
  - A lot of boilerplate code
  - Sometimes OO stands in our way
  - Generics only partially helps
  - Array subtype does not work

Why Scala?
(Coming from Java/C++)

- Runs on the JVM/.NET
  - Can use any Java code in Scala
  - Almost as fast as Java (within 10%)
- Much shorter code
  - Odersky reports 50% reduction in most code over Java
  - Local type inference
- Fewer errors
  - No Null Pointer problems
- More flexibility
  - As many public classes per source file as you want
  - Operator overloading

Scala

- Designed and implemented by Martin Odersky [2001-]
- Motivated towards “ordinary” programmers
- Scalable version of software
  - Focused on abstractions, composition, decomposition
- Unifies OOP and FP
  - Exploit FP on a mainstream platform
  - Higher order functions
  - Pattern matching
  - Lazy evaluation
- Interoperates with JVM and .NET
- Better support for component software
- Much smaller code

Scala

- Scala is an object-oriented and functional language which is completely interoperable with Java (.NET)
- Remove some of the more arcane constructs of these environments and adds instead:

  (1) a uniform object model,

  (2) pattern matching and higher-order functions,

  (3) novel ways to abstract and compose programs

Getting Started in Scala

- scala
  - Runs compiled scala code
  - Or without arguments, as an interpreter!
- scalac - compiles
- fsc - compiles faster! (uses a background server to minimize startup time)
- Go to scala-lang.org for downloads/documentation
- Read Scala: A Scalable Language (see http://www.artima.com/scalazine/articles/scalable-language.html)

Plan

- ✓ Motivation
- Scala vs. Java
- Modularity
- Discussion

Features of Scala

- Scala is both functional and object-oriented
  - every value is an object
  - every function is a value--including methods
- Scala is statically typed
  - includes a local type inference system:
  - **in Java 1.5:**

```
Pair<Integer, String> p =
        new Pair<Integer, String>(1, "Scala");
```

  - **in Scala:**

```
val p = new MyPair(1, "scala");
```

Basic Scala

OCaml

```
let x = ref 3 in

x := !x  + 4
```

- **Use var to declare variables:**

  var x = 3;

  x += 4;

- **Use val to declare values (final vars)**

  val y = 3;

  y += 4; // error

- **Notice no types, but it is statically typed**

  var x = 3;

  x = “hello world”; // error

- **Type annotations:**

  var x : Int = 3;

Scala is interoperable

Scala programs interoperate seamlessly with Java class libraries:

- Method calls
- Field accesses
- Class inheritance
- Interface implementation

all work as in Java

Scala programs compile to JVM bytecodes

Scala's syntax resembles Java's, but there are also some differences

var: Type instead of Type var

```
object Example1
  def main(args: Array[String]) {
    val b = new StringBuilder()
    for (i ← 0 until args.length) {
      if (i > 0) b.append(" ")
      b.append(args(i).toUpperCase)
    }
    Console.println(b.toString)
  }
}
```

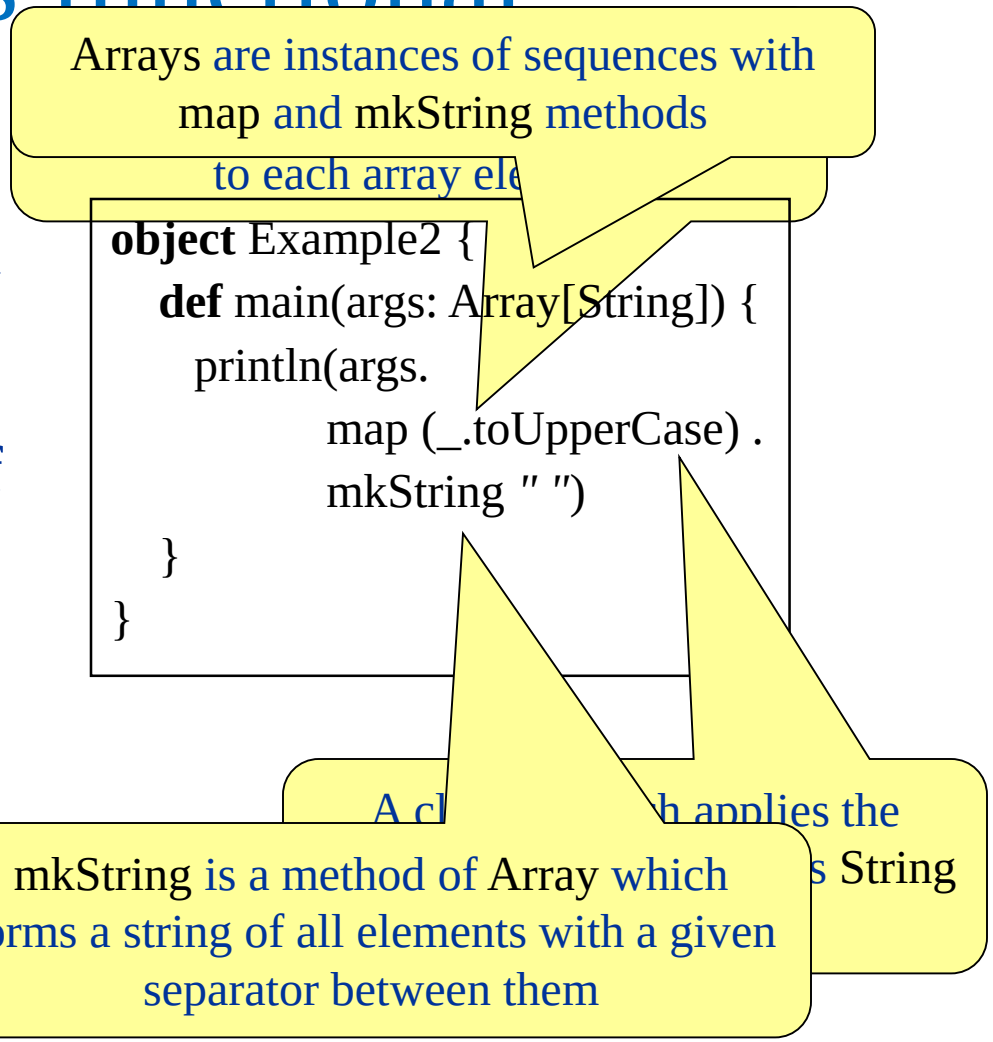
Scala's version of the extended **for** loop
(use <- as an alias for ←)

Arrays are indexed args(i) instead of args[i]

Scala is functional

The last program can also be written in a completely different style:

- Treat arrays as instances of general sequence abstractions
- Use higher-order functions instead of loops




```
mk_string map (fun x -> toUpperCase(x), args), " "
```

Functions, Mapping, Filtering

- Defining lambdas – nameless functions (types sometimes needed)

  val f = x :Int => x + 42; ***f is now a mapping int-> int***

- Closures! ***A way to haul around state***

  var y = 3;

  val g = {x : Int => y += 1; x+y; }

- Maps (and a cool way to do some functions)

  List(1,2,3).map(_+10).foreach(println)

- Filtering (and ranges!)

  (1 to 100). filter (_ % 7 == 3). foreach (println)

  - (Feels a bit like doing unix pipes?)

Scala is concise

Scala's syntax is lightweight and concise

Contributors:

- type inference
- lightweight classes
- extensible API's
- closures as control abstractions

```
var capital = Map( "US" → "Washington",
                   "France" → "paris",
                   "Japan" → "tokyo" )

capital += ( "Russia" → "Moskow" )

for ( (country, city) ← capital )
    capital += ( country → city.capitalize )

assert ( capital("Japan") == "Tokyo" )
```

Average reduction in LOC wrt Java: ≥ 2

due to concise syntax and better abstraction capabilities

Big or small?

Every language design faces the tension whether it should be big or small:

- Big is good: expressive, easy to use
- Small is good: elegant, easy to learn

Can a language be both big and small?

Scala's approach: concentrate on abstraction and composition capabilities instead of basic language constructs

Scala adds	Scala removes
+ a pure object system	- static members
+ operator overloading	- special treatment of primitive types
+ closures as control abstractions	- break, continue
+ mixin composition with traits	- special treatment of interfaces
+ abstract type members	- wildcards
+ pattern matching	

The Scala design

Scala strives for the tightest possible integration of OOP and FP in a statically typed language

This continues to have unexpected consequences

Scala unifies

- algebraic data types with class hierarchies,
- functions with objects

Has some benefits with concurrency

ADTs are class hierarchies

Many functional languages have algebraic data types and pattern matching

$\Rightarrow$

Concise and canonical manipulation of data structures

Object-oriented programmers object:

- *ADTs are not extensible,*
- *ADTs violate the purity of the OO data model*
- *Pattern matching breaks encapsulation*
- *and it violates representation independence!*

Pattern matching in Scala

The **case** modifier of an object or class means you can pattern match on it

Here's a a set of definitions describing binary trees:

```
class Tree[T]

case object Empty extends Tree

case class Binary(elem: T, left: Tree[T], right: Tree[T])
        extends Tree
```

And here's an inorder traversal of binary trees:

```
def inOrder [T] ( t: Tree[T] ): List[T] = t match {
 case Empty              => List()
 case Binary(e, l, r) => inOrder(l) ::: List(e) ::: inOrder(r)
}
```

This design keeps

- purity: all cases are classes or objects
- extensibility: you can define more cases elsewhere
- encapsulation: only parameters of case classes are revealed
- representation independence using extractors [Beyond the scope of the course]

Pattern Scala vs. OCaml

```
abstract class Tree[T]

case object Empty extends Tree

case class Binary(elem: T, left: Tree[T], right: Tree[T])
        extends Tree
```

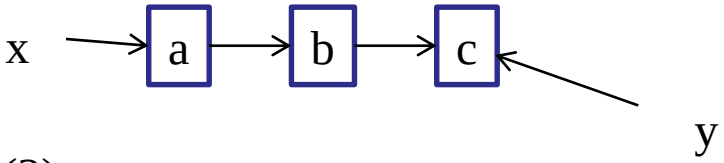
```
def inOrder [T] ( t: Tree[T] ): List[T] = t match {
 case Empty              => List()
 case Binary(e, l, r) => inOrder(l) ::: List(e) ::: inOrder(r)
}
```

```
type Tree = Empty | Binary of Element * Tree * Tree
```

```
let rec InOrder (t : tree)   =   match t with

  | Empty -> []

  | Binary (element, left, right) -> List.append(

              List.append(inOrder(left),  [element]),  InOrder(right))
```

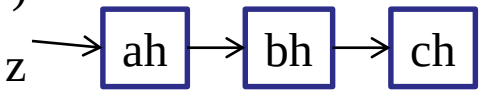
Mutable vs. Immutable Data Structures

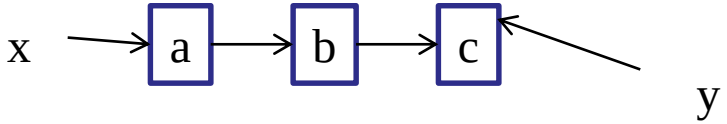
- Basic data structures in Scala are immutable
- Operations will copy (if they must)



y = x.drop(2)

z = x.map(_ + "h")



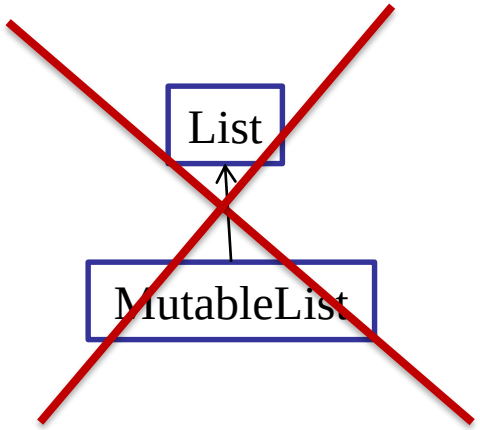


- Many positive consequences

Mutable vs. Immutable

- Mutable and immutable collections are not the same type hierarchy!
- Have to copy the collection to change back and forth, can't cast

x.toList



More features

- Supports lightweight syntax for anonymous functions, higher-order functions, nested functions, currying
- ML-style pattern matching
- Integration with XML
  - can write XML directly in Scala program
  - can convert XML DTD into Scala class definitions
- Support for regular expression patterns

Other features

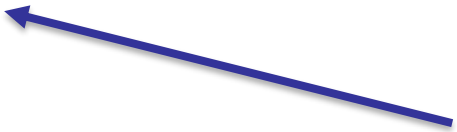
- Allows defining new control structures without using macros, and while maintaining static typing
- Any function can be used as an infix or postfix operator
- Semicolon inference
- Can define methods named +, <= or ::

Automatic Closure Construction

- Allows programmers to make their own control structures
- Can tag the parameters of methods with the modifier def
- When method is called, the actual def parameters are not evaluated and a no-argument function is passed

While loop example

```
object TargetTest1  {
  def loopWhile(def cond: Boolean)(def body: Unit): Unit =
    if (cond) {
      body;
      loopWhile(cond)(body);
    }

  var i = 10;
  loopWhile (i > 0) {
   Console.println(i);
    i = i – 1

  }
}
```



Define loopWhile method

Use it with nice syntax

Scala object system

- Class-based
- Single inheritance
- Can define singleton objects easily (no need for static which is not really OO)
- Traits, compound types, and views allow for more flexibility

Covariance vs. Contravariance

- Enforcing type safety in the presence of subtyping
- If a function expects a formal argument of type T1 → T2 and the actual argument has a type S1 → S2 then
  - what do have to require?
- If a function assumes a precondition T1 and ensures a postcondition T2
  - If the caller satisfies a precondition S1 and requires that S2 holds after the call
  - What do we have to require?

Variance annotations

```
class Array[a] {
  def get(index: int): a
  def set(index: int, elem: a): unit;
}
```

- Array[String] is not a subtype of Array[Any]
- If it were, we could do this:

```
val x = new Array[String](1);
val y : Array[Any] = x;
y.set(0, new FooBar());
// just stored a FooBar in a String array!
```

Variance Annotations

- **Covariance is ok with immutable data structures**

```
trait GenList[+T] {
  def isEmpty: boolean;
  def head: T;
  def tail: GenList[T]
}
object Empty extends GenList[All] {
  def isEmpty: boolean = true;
  def head: All = throw new Error("Empty.head");
  def tail: List[All] = throw new Error("Empty.tail");
}
class Cons[+T](x: T, xs: GenList[T]) extends GenList[T] {
  def isEmpty: boolean = false;
  def head: T = x;
  def tail: GenList[T] = xs
}
```

Variance Annotations

- Can also have contravariant type parameters
  - Useful for an object that can only be written to
- Scala checks that variance annotations are sound
  - covariant positions: immutable field types, method results
  - contravariant: method argument types
  - Type system ensures that covariant parameters are only used covariant positions
    (similar for contravariant)

Missing

- Compound types
- Types as members
- Actors and concurrency
- Libraries

Resources

- The Scala programming language home page (see http://www.scala-lang.org/)
- The Scala mailing list (see http://listes.epfl.ch/cgi-bin/doc_en?liste=scala)
- The Scala wiki (see http://scala.sygneca.com/)
- A Scala plug-in for Eclipse (see http://www.scala-lang.org/downloads/eclipse/index.html)
- A Scala plug-in for IntelliJ (see http://plugins.intellij.net/plugin/?id=1347)

References

- The Scala Programming Language as presented by Donna Malayeri (see http://www.cs.cmu.edu/~aldrich/courses/819/slides/scala.ppt)
- The Scala Language Specification 2.7
- (seehttp://www.scala-lang.org/docu/files/ScalaReference.pdf)
- The busy Java developer's guide to Scala: Of traits and behaviorsUsing Scala's version of Java interfaces(see http://www.ibm.com/developerworks/java/library/j-scala04298.html)
- First Steps to Scala (in Scalazine) by Bill Venners, Martin Odersky, and Lex Spoon, May 9, 2007 (see http://www.artima.com/scalazine/articles/steps.html)

Summing Up [Odersky]

- Scala blends functional and object-oriented programming.
- This has worked well in the past: for instance in Smalltalk, Python, or Ruby
- However, Scala is goes farthest in unifying FP and OOP in a statically typed language
- This leads to pleasant and concise programs
- Scala feels similar to a modern scripting language, but without giving up static typing

Lessons Learned[Odersky]

1. Don’t start from scratch
2. Don’t be overly afraid to be different
3. Pick your battles
4. Think of a “killer-app”, but expect that in the end it may well turn out to be something else
5. Provide a path from here to there

Scala Adaptation

- Twitter
- Gilt
- Foursquare
- Coursera
- Guardian
- UBS
- Bitgold
- Linkin
- Verizen
- Yammer

Summary

- An integration of OO and FP
  - Also available in Javascript/Ruby but with dynamic typing
- Static typing
- Concise
- Efficient
- Support for concurrency
- Already adapted
- But requires extensive knowledge