RICKER LYMAN
ROBOTIC

Parallel Functional & Streaming Programming with Scala

Week 1: Scala Language Pt. 1

Hello!

Main topics

Part 1. Intro to Big Data & parallel processing

Part 2. Scala

Part 3. Infrastructure & Cloud

Part 4. Kafka & Kafka Streams

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Architect

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Assistant

Let’s get acquainted with each other

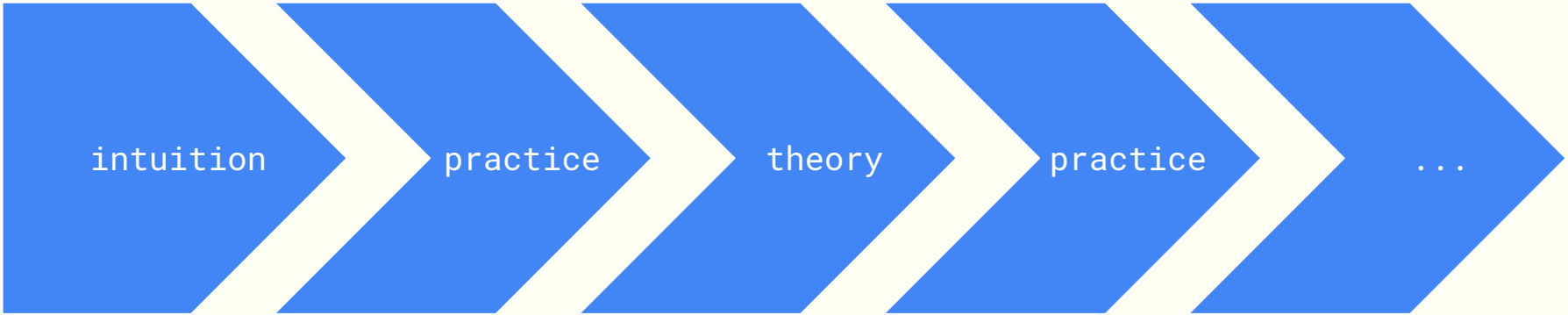
Goal

Get proficient in Scala to build streaming solution on Kafka, be able to deploy it locally and in the Cloud

Scala Part

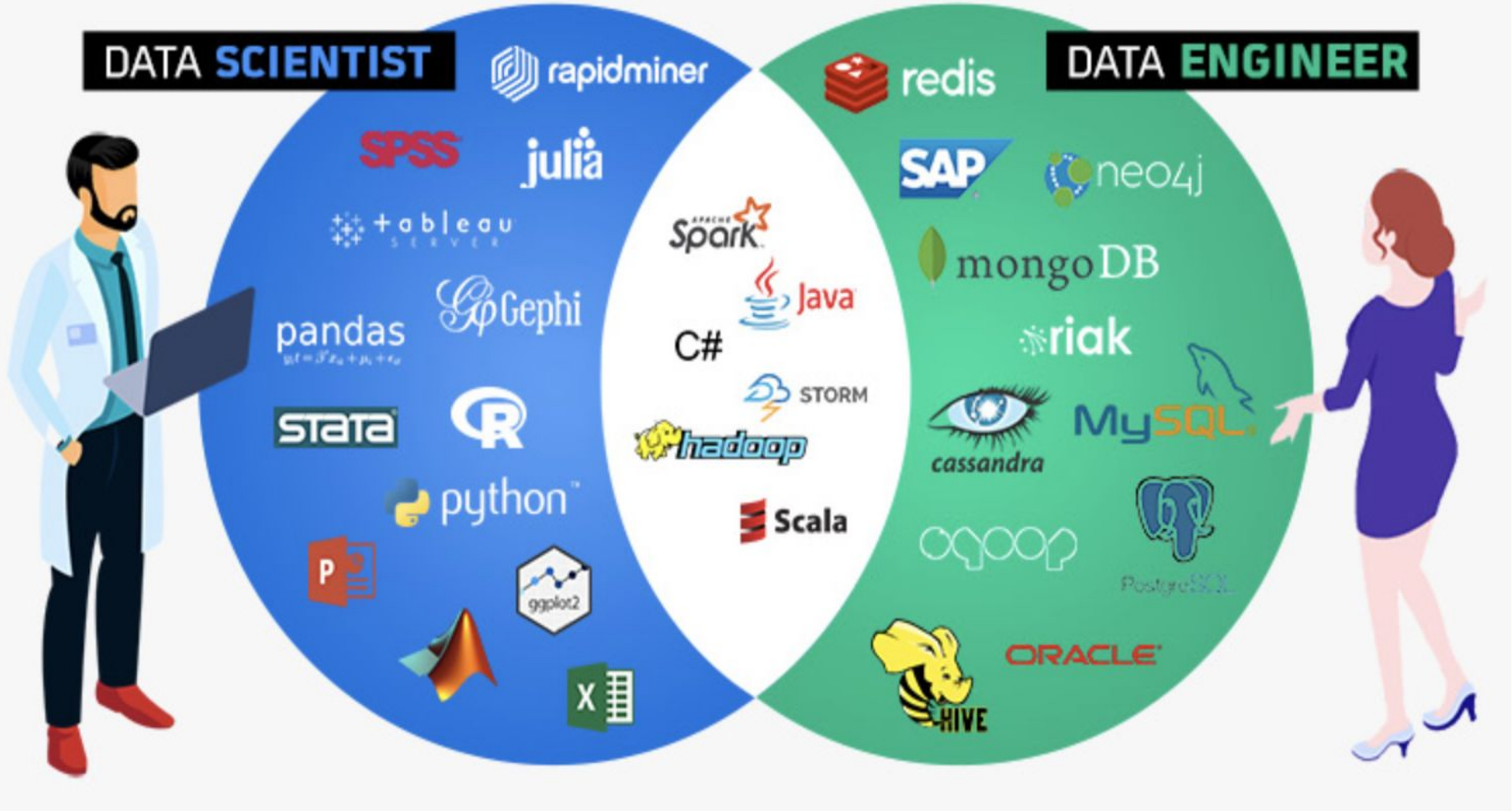
- Scala language
- Functional programming in Scala
- Parallel, Concurrent and Distributed programming in Scala
- Akka
- Practice, practice, practice

Learn



Today’s outline

- Why Scala?
- What is it?
- Language design
- What makes it special?
- Syntax
- Get our hands dirty


DATA SCIENTIST
rapidminer
SPSS
julia
+ableau SERVER
pandas
Gephi
STATA
R
python
P
ggplot2
X
Spark
Java
C#
STORM
hadoop
Scala
DATA ENGINEER
redis
SAP
neo4j
mongoDB
riak
cassandra
MySQL
HIVE
ORACLE

Scala can be scary / beautiful

```
trait ~>[F[_], G[_]] extends Poly1 {
 def apply[T](f : F[T]) : G[T]
 implicit def caseUniv[T]: Case.Aux[F[T], G[T]] = at[F[T]](apply(_))
}
object ~> {
 implicit def inst1[F[_], G[_], T](f : F ~> G) : F[T] => G[T] = f(_)
 implicit def inst2[G[_], T](f : Id ~> G) : T => G[T] = f(_)
 implicit def inst3[F[_], T](f : F ~> Id) : F[T] => T = f(_)
 }
type ~>>[F[_], R] = ~>[F, Const[R]#λ]
object identity extends (Id ~> Id) {
 def apply[T](t : T) = t
}
implicit def hconsSomeHelper[K <: Symbol, H, T <: HList, LabT <: HList, OutT <: HList]
(implicit tailHelper: Aux[T, LabT, OutT]): Aux[Some[H] :: T, K :: LabT, FieldType[K, H] :: OutT] =
 new Helper[Some[H] :: T, K :: LabT] {
   type Out = FieldType[K, H] :: OutT
   def apply(l: Some[H] :: T) = field[K](l.head.get) :: tailHelper(l.tail)
 }
```

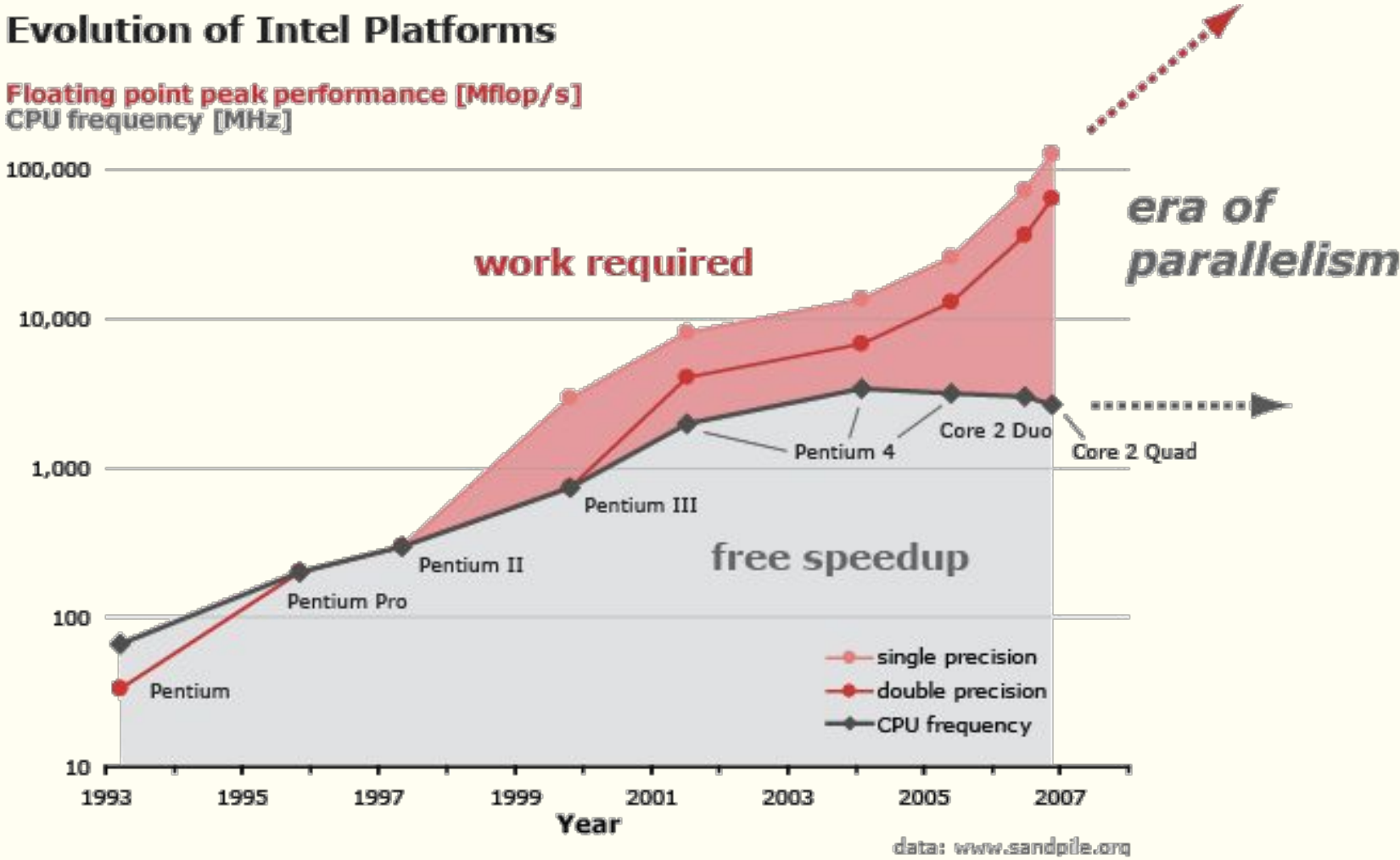
Scala

Scalable language

History

- Designed in 2004
- by Martin Odersky, a professor at the Ecole Polytechnique Federale de Lausanne, in Switzerland
- formerly worked on javac compiler, and Java generics

Moor's law


Evolution of Intel Platforms
Floating point peak performance [Mflop/s]
CPU frequency [MHz]
100,000
10,000
1,000
100
10
work required
era of parallelism
free speedup
Pentium
Pentium Pro
Pentium II
Pentium III
Pentium 4
Core 2 Duo
Core 2 Quad
single precision
double precision
CPU frequency
1993
1995
1997
1999
2001
2003
2005
2007
Year
data: www.sandpile.org

Scala is **Functional language**

Scala is also **Object-oriented** language

Scala is **statically typed** language

Runs on **JVM**, compiles to **bytecode**

Special features

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Special features

Programming Paradigms

Paradigm: In science, a paradigm describes distinct concepts or thought patterns in some scientific discipline.

Programming Paradigms

More intuitive:

Programming style

Language is an **instrument**

Programming Paradigms

Main programming paradigms:

- Imperative programming
  - Procedural
  - Object oriented
- Declarative programming
  - Functional programming
  - Logic programming
  - Dataflow
  - …
- Event-driven
- Parallel computing
- Metaprogramming
- Dynamic/scripting
- ...

Programming paradigms

- Imperative
  - Java, Python, C++, C#
- Declarative
  - SQL, HTML, XML, CSS

Imperative

How?

Declarative

What?

liberties constrain, constraints liberate

Programming paradigms

- Imperative
  - Java, Python, C++, C#
- Functional
  - Lisp, Haskell, F#, Clojure, Scala, Erlang

Imperative programming

is about

▶️ modifying mutable variables, -> (memory cells)

▶️ reference variables -> (load instructions)

▶️ using assignments -> (store instructions)

▶️ and control structures such as if-then-else, loops, break, continue, return. -> (jump instructions)

Imperative programming

Problem: Scaling up.

“How can we avoid conceptualizing programs word by word?”

Reference: John Backus, Can Programming Be Liberated from the von. Neumann Style?, Turing Award Lecture 1978.

Scaling Up

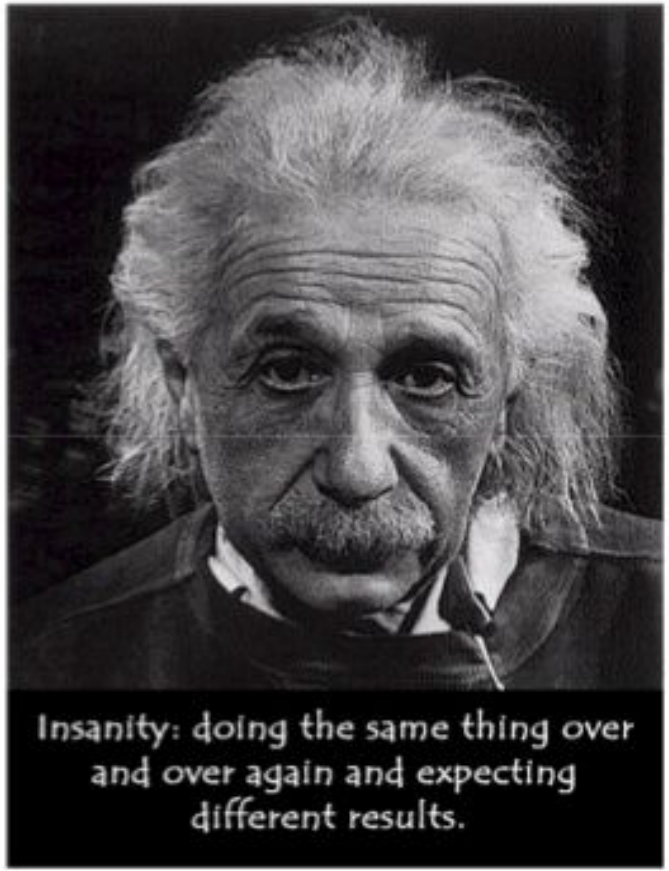
- Vertical scaling
- Horizontal scaling

Questions:

- Where the execution should happen?
- How shared state has to be managed?
- ..

The need for higher level of programming abstractions rises

The cause of the problem …



Mutable state +
Parallel processing =
Non-determinism

Define some variables

- Scala has two kinds of variables, **val**ues and **var**iables

```
// Variable

var greeting = "Hello, world!"

greeting = "Leave me alone, world!" // OK

// Value

val msg = "Hello, world!"

msg = "Goodbye cruel world!" // error: reassignment to val
```

Functional programming

Simplified:

- **No mutable** shared state
- Functions as a **values** (first-class citizens)
- Program composed of functions (**composition**)
- Program satisfy particular **laws**

Function definition

```
def square(x: Int): Int = x * x
```

Object-oriented

- Encapsulation & Inheritance & Polymorphism
- Everything is an object
- Every function call is also a method call
- Functions ⇔ Methods

Functional and Object Oriented are orthogonal

In other words

Both styles can be used simultaneously

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Special features

Static vs Dynamic

```
var numb = 1

numb = "1"// you cannot do that in statically typed
language
```

It’s all about contract between components. Exposing it and maintaining it

Which leads to better **scalability** as well

Static vs Dynamic, Compiled vs Interpreted

```
var numb = 1

numb = "1"// you cannot do that in statically typed
language
```

It’s all about contract between components. Exposing it and maintaining it

Which leads to better **scalability** as well

Static vs Dynamic, Compiled vs Interpreted

- **Statically typed** – the type of names (variables, fields etc.) is known at compile time.
- **Dynamically typed** – the type is associated with values at runtime.

Explicit Types

```scala
val sum: Int = 1 + 2 + 3

val nums: List[Int] = List(1, 2, 3)

val map: Map[String, List[Int]] = ...
```

Type Inference

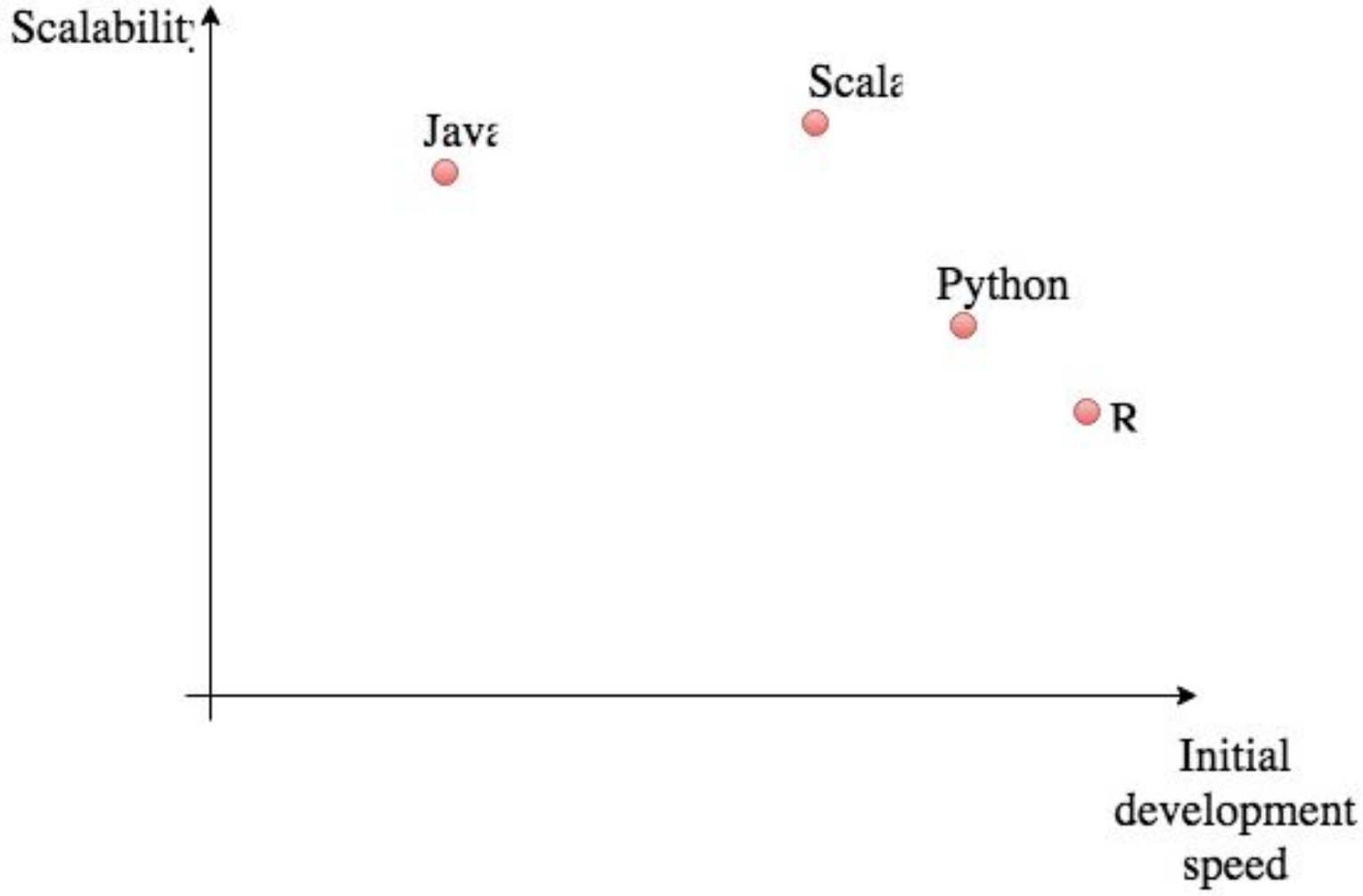
```
val sum = 1 + 2 + 3

val nums = List(1, 2, 3)

val map = Map("abc" -> List(1,2,3))
```

Statically-typed programming language

- The compiler as validity check
  - Verifies types of objects
  - Application compiles => ready for production (almost)
  - First level of defence against errors
- Type inference
  - Scala compiler infers the types
  - You don't need to type type declarations, but the program is type-checked
  - Safer applications with less typing


Scalabilit
Java
Scala
Python
R
Initial
development
speed

Everything is an Expression (almost everything)

In programming language terminology, an "**expression**" is a combination of values and functions that are combined and interpreted by the compiler to create a new value, as opposed to a "**statement**" which is just a standalone unit of execution and doesn't return anything.

The process of combining and interpreting, as for mathematical expressions, is called evaluation.

In scala, many constructs like code-blocks, if-else, method bodies are expressions

```
val ifThenElseExpression = if (aBool) 42 else 0
```

Expression vs Statement

- What is difference in between:

```
val isEven = if (number > 0) "true" else "false"
```

vs

```
var isEven: String
if(number > 0)
  isEven = "true"
else isEven = "false"
```

- Or difference in between (Java):

```
List<Integer> ls = new ArrayList<Integer>();
ls.add(1);
ls.add(2);
```

Vs

```
List<Integer> ls = Arrays.asList(1,2);
```

Value definition

```
val <name>: <Type> = <expression>
```

Example:

```
val positive: Int = {
 if (numb > 0) 1 else -1
}
```

If - Else

Structure:

```
if (<boolean expression>) <expression>
else <expression>
```

Example:

```
val num = 23
val ans2 = if(num > 0) {
  val i = 1
  val j = 2
  i + j
} else {
  val i = 1
  val j = 2
  i - j
}
```

if-else is itself also an expression

Code blocks

- In blocks, the last statement of the code-block becomes the return value

```
val c = {
    val i = 1
    val j = math.pow(2, 10)
    i - j
}
```

Above i-j is the last statement, so it becomes the value of c

- The type of the last statement becomes the type of the target variable

```
val sqr: Boolean = {
      val a = 1
      val b:Long = 23L
      val hi = "hi"
      true
  }
```

Function bodies

```
def <name>(<arg1>: <Type1>, <arg2>: <Type2>,..): <TypeR> =
<expression>
```

Function bodies

```
def square(x: Int): Int = {
 val result = x * x
 return result
}
```

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Special features

Runs on JVM

- Java interoperability
  - Jython, Clojure, Groovy, Kotlin..
- Java Ecosystem & Tooling
  - Big Data ecosystem
- Cross-platform
  - You just need to install Java
  - Simple containerized deployment

Scala is **Functional language**

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Special features

What makes it really special

- REPL (Read Evaluate Print Loop)
- Implicits
- Macro
- Advanced type-level programming
  - Shapeless
- Duck typing (structural typing)
- scala.language.dynamics
- string interpolation
  - sql”select * from user where age > 20”
- XML Literals
- Type Specialization

Not enforced, but very powerful (FP purity as an option - as well)

Syntax

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Get your hands dirty with Scala

REPL

- Supports tab completing, imports
- Type **>scala** to start
- Special commands
  - Commands with : at the front

    :help to get started

    :quit to quit

    :save

Imports

```
import scala.util.Random

// method

import scala.util.Random.nextInt

// wildcard

import scala.util._

// named

import scala.util.Random.{nextInt => next}
```

Imports

```
scala> import scala.util.Random.{nextInt => next}

import scala.util.Random.{nextInt=>next}


scala> next

res0: Int = -859814294
```

println

Output the result of computing the expression

```
> println(expression)
```

Worksheet

AKA Jupyter notebooks

Syntax

- Primitives
- Control Flow
  - if-else
  - loops
- Functions
- Lists
- Tuples
- Pattern matching
- Recursion

Primitive data types

Data Type	Definition
Boolean	true or false
Byte	8-bit signed two's complement integer (-2^7 to 2^7-1, inclusive) -128 to 127
Short	16-bit signed two's complement integer (-2^15 to 2^15-1, inclusive) 32,768 to 32,767
Int	32-bit two's complement integer (-2^31 to 2^31-1, inclusive) 2,147,483,648 to 2,147,483,647
Long	64-bit two's complement integer (-2^63 to 2^63-1, inclusive) -9,223,372,036,854,775,808 to +9,223,372,036,854,775,807
Float	32-bit IEEE 754 single-precision float 1.40129846432481707e-45 to 3.40282346638528860e+38 (positive or negative)
Double	64-bit IEEE 754 double-precision float 4.94065645841246544e-324d to 1.79769313486231570e+308d (positive or negative)
Char	16-bit unsigned Unicode character (0 to 2^16-1, inclusive) 0 to 65,535
String	a sequence of Chars

Recap: Values

Value definitions

```
val a = 1

var b = 2

b = -2

val c, d, e = "wow"
```

Recap: Values

Value definitions

```
val a = 1L

val b: Double = 1d

val c = 1f

val hex = 0x5

val hex2 = 0x00FF

val magic = 0xcafebabe
```

Recap: Inference

Inference

```
val result = if (true) 1D else 1L

res0: Double = 1.0
```

You can also cast

```
1: Long

1.asInstanceOf[Long]
```

But:

```
"1".asInstanceOf[Long]

    java.lang.ClassCastException

"1": Long

    error: type mismatch;
```

Instead:

```
"1".toInt
```

Recap: If-Else

- `if (a > 0) b = 2 else b = -2`

- ```
  if (a > -1 & a <= 4 && a != 0 | (1 == 2 || "1" != "2")) {
      println("b = 2")
      b = 2
  } else {
      b = -2
  }
  ```

- & and | are strict while && and || are short-circuiting
  ```

List

- List definition (with type inference)

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

- Adding an element to the head of a list

```
val list1 = 0 :: list
```

- Adding an element to the tail of a list

```
val list2 = list1 :+ 6
```

- Concatenating lists

```
val list3 = list1 ++ list2
```

for loops

```
for ( <i> <- <s> ) <expression>
```

Remark: <s> has to be a subtype of Traversable (Arrays, Collections, Tables, Lists, Sets, Ranges, . . .)

Ranges for for-loops can be built using **.to(...)**

```
(1).to(5)
```

```
1 to 5
```

Equals to:

```
Range(1, 2, 3, 4, 5)
```

for loops

Example:

```
for (
   i <- 1 to 5
) println(i)
```

for yield

for (seq;) **yield** expr

You can ‘yield’ an expression to produce an output sequence

```
for {
   i <- 1 to 10
   j <- 1 to 100
   if j == i * i
} yield j
```

Exercise:
Given **val** *lb*=*List*(1,2,3,4,5) and using **for**, build the list of squares of *lb*.

while

```
var i: Int = 0

while(i < 10) {

 print(i)

 i += 1

}
```

Function definition

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Function definition

```
def <fName>(<arg1>: <Type1>,..., <argn>:<Typen>): <Typef> = { <expr> }
```

- Remark 1: type of <expr> (the type of the last expression of <expr>) is Typef
- Remark 2: Typef can be inferred for non recursive functions
- Remark 3: The type of **fName** is : (Type1,. . . ,Typen) => Typef

Function definition

```
def getFullName(firstName: String, lastName: String): String = {
   firstName + " " + lastName
}
```

A type of this function:

```
(String, String) => String
```

Default Arguments

```
def getUser(
            firstName: String = "John",
            lastName: String = "Smith",
            age: Int = -1
            ): Unit = {
 // ...
}
```

Named Arguments

```
createUser(user, true, false, false, true, false, false)
```

Better?

```
createUser(
 user = user,
 encryptPassword = true,
 admin = false,
 ldapAuth = false,
 suspicious = true,
 blocked = false,
 visible = false)
```

Infix/Dot notation

```
1 + 2

(1).+(2)

result.append(a).append(b).append(c)

result append a append b append c
```

Anonymous functions

```
(x: Int) => x + 2 // full version
```

Anonymous functions

```
(x: Int) => x + 2 // full version

x => x + 2 // type inferred
```

Anonymous functions

```
(x: Int) => x + 2 // full version

x => x + 2 // type inferred

_ + 2 // placeholder syntax (each argument must be used
                                                exactly once)
```

Anonymous functions

```
(x: Int) => x + 2 // full version

x => x + 2 // type inferred

_ + 2 // placeholder syntax (each argument must be used
                                        exactly once)

x => { // body is an expression
   val numberToAdd = 2
   x + numberToAdd
}
```

Operations with List

```
val list = List(1, 2, 3)
list.foreach(x => println(x)) // prints 1, 2, 3
list.foreach(println) // same
list.map(x => x + 2) // returns a new List(3, 4, 5)
list.map(_ + 2) // same
list.filter(x => x % 2 == 1)// returns a new List(1, 3)
list.filter(_ % 2 == 1) // same
list.reduce((x, y) => x + y) // => 6
list.reduce(_ + _) // same
list.sorted // sorted
list.sortWith((x, y) => x < y)
```

Functions

```
// Regular function definition
def addTwo(x: Int): Int = x + 2
// Value definition
val addTwo = (x: Int) => x + 2
// In these cases a type of the value is
// Int => Int
val addTwo: Int => Int = _ + 2
```

Closures

- An anonymous function is just a function that has no name; nothing more.
- A closure is a function that captures the state of the surrounding environment.

Nested functions

You can nest function definitions. As well as code blocks - as any other kind of expression.

```
// Can nest multiple levels of functions
def outer() {
 var msg = "foo"
 val f = (x: Int) => {
   println(msg)
 }
 def one() {
   def two() {
     def three() {
       println(msg)
     }
     three()
   }
   two()
 }
 one()
}
```

Lexical scoping

In a Scala program, an inner variable is said to shadow a like-named outer variable, because the outer variable becomes invisible in the inner scope.

Local Definitions → Explicits imports → Wild card imports → Packages

Pattern matching

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Pattern matching

match - case expressions (like switch-case):

```
<expr> match {
 case <pattern1> => <r1> //patterns can be constants
 case <pattern2> if <bool_expr> => <r2> //or terms with variables
   ... //or terms with holes: '_'
 case _ => <rn> // default case
}
```

- A series of cases
- Cases checked until first one matches
- First match wins
- No other cases checked
- No matching case leads to scala.MatchError

Pattern matching

match - case expressions (like switch-case):

```
<expr> match {
 case <pattern1> => <r1> //patterns can be constants
 case <pattern2> if <bool_expr> => <r2> //or terms with variables
   ... //or terms with holes: '_'
 case _ => <rn> // default case
}
```

Example:

```
x match {
 case "bonjour" => "hello"
 case "au revoir" => "goodbye"
 case _ => "don't know"
}
```

Remark: the type of this expression is the supertype of r1, r2, . . . rn

Pattern matching List

Doing pattern-matching over lists

```
val list = List(1,2,3,4,5)
val head = list match {
  case Nil => 0
  case head :: tail => head
}
```

Pattern matching on assignment (unapply)

```
val (x, y) = (3, 5)

val x :: xs = List(1, 2, 3, 4)

val List(a, b, c) = List(1, 2, 3)
```

Tuple

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Tuples

Tuples are immutable containers of values

```
val t = (1, "toto", 18.3)
// t: (Int, String, Double) = (1,toto,18.3)
```

Tuple getters: t. 1, t. 2, etc.

```
t._1 // 1: Int
t._2 // toto: String
```

... or with match - case:

```
t match {
   case (2, "toto", _) => "found!"
   case ( _, x, _) => x
}
```

The above expression evaluates in "toto"

Tail Recursion

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Recursion

```
// basic recursive factorial method
def factorial(n: Int): Int = {
 if (n == 0) 1 else n * factorial(n-1)
}

factorial(4)
if (4 == 0) 1 else 4 * factorial(4 - 1)
4 * factorial(3)
4 * (3 * factorial(2))
4 * (3 * (2 * factorial(1)))
4 * (3 * (2 * (1 * factorial(0))))
4 * (3 * (2 * (1 * 1)))
24
```

Recursion

```
def gcd(a: Int, b: Int): Int =
 if (b == 0) a else gcd(b, a % b)
```

This is how it expands:

```
gcd(14, 21)
if (21 == 0) 14 else gcd(21, 14 % 21)
if (false) 14 else gcd(21, 14 % 21)
gcd(21, 14 % 21)
gcd(21, 14)
if (14 == 0) 21 else gcd(14, 21 % 14)
if (false) 21 else gcd(14, 21 % 14)
gcd(14, 7)
gcd(7, 14 % 7)
gcd(7, 0)
if (0 == 0) 7 else gcd(0, 7 % 0)
if (true) 7 else gcd(0, 7 % 0)
7
```

Tail recursion

```scala
import scala.annotation.tailrec

// tail-recursive gcd method
 @tailrec
def gcd(a: Int, b: Int): Int =
 if (b == 0) a else gcd(b, a % b)
```

Various

- ; is usually omitted

  but if you write multiple statements into one line - ; acts like a separator

  val one = 1; val two = 2
- ??? - useful placeholder for non-implemented-yet methods/values
- scala.Predef

Questions

THANK YOU!