

Scala's static type system

INTRODUCTION TO SCALA



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More answers to "Why use Scala?"

Scala combines object-oriented and functional programming in one concise, high-level language. Scala's static types help avoid bugs in complex applications, and its JVM and JavaScript runtimes let you build high-performance systems with easy access to huge ecosystems of libraries.

More answers to "Why use Scala?"

Scala combines object-oriented and functional programming in one concise, high-level language. **Scala's static types help avoid bugs in complex applications**, and its JVM and JavaScript runtimes let you build high-performance systems with easy access to huge ecosystems of libraries.

Some definitions

- **Type:** restricts the possible values to which a variable can refer, or an expression can produce, at run time

Scala value types have equivalent Java types

Scala types

- `scala.Double`
- `scala.Float`
- `scala.Long`
- `scala.Int`
- `scala.Short`
- `scala.Byte`
- `scala.Char`
- `scala.Boolean`
- `scala.Unit`

Java types

- `java.lang.Double`
- `java.lang.Float`
- `java.lang.Long`
- `java.lang.Integer`
- `java.lang.Short`
- `java.lang.Byte`
- `java.lang.Character`
- `java.lang.Boolean`

Some definitions

- **Type:** restricts the possible values to which a variable can refer, or an expression can produce, at run time
- **Compile time:** when source code is translated into machine code, i.e., code that a computer can read
- **Run time:** when the program is executing commands (after compilation, if compiled)

Type systems

Static type systems

A language is statically typed if the type of a variable is known at compile time. That is, types checked before run-time.

- C/C++
- Fortran
- Java
- Scala

Dynamic type systems

A language is dynamically typed if types are checked on the fly. That is, types are checked during execution (i.e., run time).

- JavaScript
- Python
- Ruby
- R

Pros of static type systems

- Increased performance at run time
- Properties of your program verified (i.e., prove the absence of common type-related bugs)
- Safe refactorings
- Documentation in the form of type annotations (`: Int` in `val fourHearts: Int = 4`)

Cons of static type systems

- It takes time to check types (i.e., delay before execution)
- Code is verbose (i.e., code is longer/more annoying to write)
- The language is not flexible (e.g., one strict way of composing a type)

Reducing verbosity (with variables)

Without type inference

```
scala> val fourHearts: Int = 4
```

```
fourHearts: Int = 4
```

With type inference

```
scala> val fourHearts = 4
```

```
fourHearts: Int = 4
```

Reducing verbosity (with collections)

Without type inference

```
scala> val players: Array[String] = Array("Alex", "Chen", "Marta")
```

```
players: Array[String] = Array(Alex, Chen, Marta)
```

With type inference

```
scala> val players = Array("Alex", "Chen", "Marta")
```

```
players: Array[String] = Array(Alex, Chen, Marta)
```

Promoting flexibility

- Pattern matching
- Innovative ways to write and compose types

Compiled, statically-typed languages

Compiled languages

- Increased performance at run time

Statically-typed languages

- Increased performance at run time

Let's practice!
INTRODUCTION TO SCALA

Make decisions with if and else

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A program for playing Twenty-One

Variables

```
val fourHearts: Int = 4  
var aceClubs: Int = 1
```

Collections

```
val hands: Array[Int] = new Array[Int](3)
```

Functions

```
// Define a function to determine if hand busts  
def bust(hand: Int) = {  
  hand > 21  
}
```

Control structures

A control structure is a block of programming that analyses variables and chooses a direction in which to go based on given parameters. The term flow control details the direction the program takes (which way program control "flows").

- `if / else`

¹ https://en.wikiversity.org/wiki/Control_structures

A single if

```
// This hand's point value
val hand = 24

// If this hand busts, print to output
if (hand > 21) {
  println("This hand busts!")
}
```

This hand busts!

A single if

```
// This hand's point value
val hand = 18

// If this hand busts, print to output
if (hand > 21) {
  println("This hand busts!")
}
```

if-else control flow

```
def maxHand(handA: Int, handB: Int): Int = {  
  if (handA > handB) handA  
  else handB  
}
```

if-else control flow

```
// Point values for two competing hands
val handA = 17
val handB = 19

// Print the value of the hand with the most points
if (handA > handB) println(handA)
else println(handB)
```

if-else control flow

```
// Point values for two competing hands
val handA = 17
val handB = 19

// Print the value of the hand with the most points
if (handA > handB) {
  println(handA)
}
else {
  println(handB)
}
```

if-else control flow

```
// Point values for two competing hands
val handA = 17
val handB = 19

// Print the value of the hand with the most points
if (handA > handB)
  println(handA)
else
  println(handB)
```

if-else control flow

```
// Point values for two competing hands  
val handA = 17  
val handB = 19  
  
// Print the value of the hand with the most points  
if (handA > handB) println(handA)  
else println(handB)
```

19

if-else control flow

```
// Point values for two competing hands
val handA = 17
val handB = 19

// Print the value of the hand with the most points
if (handA > handB) println(handA) else println(handB)
```

19

if-else if-else

```
// Point values for two competing hands
val handA = 26
val handB = 20

// If both hands bust, neither wins
if (bust(handA) & bust(handB)) println(0)
// If hand A busts, hand B wins
else if (bust(handA)) println(handB)
// If hand B busts, hand A wins
else if (bust(handB)) println(handA)
// If hand A is greater than hand B, hand A wins
else if (handA > handB) println(handA)
// Hand B wins otherwise
else println(handB)
```

if-else if-else

```
// Point values for two competing hands
val handA = 26
val handB = 20

// Find and print the best hand
if (bust(handA) & bust(handB)) println(0)
else if (bust(handA)) println(handB)
else if (bust(handB)) println(handA)
else if (handA > handB) println(handA)
else println(handB)
```

20

if expressions result in a value

```
scala> val handA = 17
```

```
handA: Int = 17
```

```
scala> val handB = 19
```

```
handB: Int = 19
```

```
scala> val maxHand = if (handA > handB) handA else handB
```

```
maxHand: Int = 19
```

Relational and logical operators

Relational

Greater than: `>`

Less than: `<`

Greater than or equal to: `>=`

Less than or equal to: `<=`

Equal to: `==`

Not equal to: `!=`

Logical

And: `&&`

Or: `||`

Not: `!`

These "operators" are actually methods!

Relational

Greater than: `>`

Less than: `<`

Greater than or equal to: `>=`

Less than or equal to: `<=`

Equal to: `==`

Not equal to: `!=`

Logical

And: `&&`

Or: `||`

Not: `!`

These "operators" are actually methods!

Relational

Greater than: `>`

Less than: `<`

Greater than or equal to: `>=`

Less than or equal to: `<=`

Equal to: `==`

Not equal to: `!=`

Logical

And: `&&`

Or: `||`

Not: `!`

¹ "Future music" is an oft-used phrase within DataCamp. It means "something you want or aspire to have but not for the near future" and is of Dutch origin.

Let's practice!

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while and the imperative style

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Control structures

- `if` `else`
- `while`

Hip hip hooray



Dancing smiley by Krabat der Zauberlehrling

¹ https://en.wikipedia.org/wiki/Hip_hip_hooray

Loop with while

```
// Define counter variable
var i = 0

// Define the number of times for the cheer to repeat
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  // BODY OF LOOP
}
```

Loop with while

```
// Define counter variable
var i = 0

// Define the number of times for the cheer to repeat
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  println("Hip hip hooray!")
  i = i + 1
}
```

Loop with while

```
// Define counter variable
var i = 0

// Define the number of times for the cheer to repeat
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  println("Hip hip hooray!")
  i += 1 // i = i + 1
}
```

Loop with while

```
// Define counter variable
var i = 0

// Define the number of times for the cheer to repeat
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  println("Hip hip hooray!")
  i += 1 // ++i and i++ don't work!
}
```

i = 0

```
// Define variables for while loop
var i = 0
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  println("Hip hip hooray!")
  i = i + 1
}
```

Hip hip hooray!

i = 1

```
// Define variables for while loop
var i = 0
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  println("Hip hip hooray!")
  i = i + 1
}
```

```
Hip hip hooray!
Hip hip hooray!
```


i = 2

```
// Define variables for while loop
var i = 0
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  println("Hip hip hooray!")
  i = i + 1
}
```

```
Hip hip hooray!
Hip hip hooray!
Hip hip hooray!
```

i = 3

```
// Define variables for while loop
var i = 0
val numRepetitions = 3

// Loop to repeat the cheer
while (i < numRepetitions) {
  println("Hip hip hooray!")
  i = i + 1
}
```

```
Hip hip hooray!
Hip hip hooray!
Hip hip hooray!
```

Loop with while over a collection

```
// Define counter variable
var i = 0

// Create an array with each player's hand
var hands = Array(17, 24, 21)

// Loop through hands and see if each busts
while (i < hands.length) {
  // BODY OF LOOP
}
```

Scala is object-oriented

- Rule of thumb: pretty much everything is an object in Scala

```
scala> var hands = Array(17, 24, 21)  
scala> hands.length
```

```
res0: Int = 3
```

Loop with while over a collection

```
// Define counter variable
var i = 0

// Create an array with each player's hand
var hands = Array(17, 24, 21)

// Loop through hands and see if each busts
while (i < hands.length) {
  println(bust(hands(i)))
  i = i + 1
}
```

Loop with while over a collection

```
var i = 0
var hands = Array(17, 24, 21)
while (i < hands.length) {
  println(bust(hands(i)))
  i += 1
}
```

```
false
true
false
```

Like if, parentheses required for while

The `while` loop:

```
while (i < hands.length)
```



The `maxHand` function:

```
if (handA > handB)
```



Like if, parentheses required for while

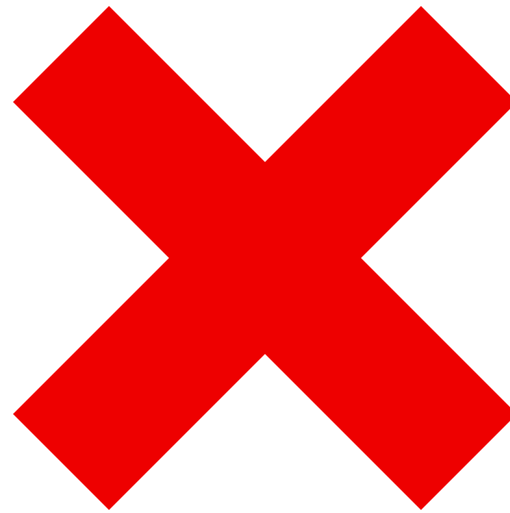
The `while` loop:

```
while i < hands.length
```



The `maxHand` function:

```
if handA > handB
```



The imperative style

```
var i = 0
var hands = Array(17, 24, 21)
while (i < hands.length) {
  println(bust(hands(i)))
  i += 1
}
```

```
false
true
false
```

Let's practice!
INTRODUCTION TO SCALA

foreach and the functional style

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Scala is functional

Scala is functional

1. Functions are first-class values
2. Operations of a program should map input values to output values rather than change data in place

Scala is a imperative/functional hybrid

Scala *usually* is functional but can also be imperative
sometimes

Scala is functional:

1. Functions are first-class values
2. Operations of a program should map input values to output values rather than change data in place

Scala nudges us towards the functional style



functional

"imperative" according to Oxford Dictionary

Imperative (English):

- Definition: Of the nature of or expressing a command.

¹ <https://www.thefreedictionary.com/imperative>

The imperative style

Scala *usually* is functional but can also be imperative sometimes

Scala can be imperative:

- One command at a time
- Iterate with loops
- Mutate shared state (e.g., mutating variables out of scope)
- Examples: C, Java, Python

The imperative style

```
// Define counter variable
var i = 0

// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// Loop through hands and see if each busts
while (i < hands.length) {
  println(bust(hands(i)))
  i = i + 1
}
```

The imperative style

```
// Define counter variable
var i = 0

// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// Loop through hands and see if each busts
while (i < hands.length) {
  println(bust(hands(i)))
  i = i + 1
}
```

¹ http://bit.ly/state_wikipedia

The functional style

Scala *usually* is functional but can also be imperative sometimes

Scala is functional:

1. Functions are first-class values

The functional style

- Functions are first-class values

```
// Define counter variable
var i = 0

// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// Loop through hands and see if each busts
while(i < hands.length) {
  println(bust(hands(i)))
  i += 1
}
```

The functional style

- Functions are first-class values

```
// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// See if each hand busts
hands.foreach(INSERT FUNCTION HERE)
```

Scala fuses OOP and FP -> Scala is scalable

- Functions are first-class values

```
// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// See if each hand busts
hands.foreach(INSERT FUNCTION HERE)
```

From Chapter 1:

Scala combines object-oriented and functional programming

Modify the bust function

```
// Define a function to determine if hand busts
def bust(hand: Int) = {
  println(hand > 21)
}
```

The functional style

- Functions are first-class values

```
// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// See if each hand busts
hands.foreach(INSERT FUNCTION HERE)
```


The functional style

- Functions are first-class values

```
// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// See if each hand busts
hands.foreach(bust)
```

```
false
true
false
```

What is a side effect?

Scala *usually* is functional but can also be imperative sometimes

Scala is functional:

1. Functions are first-class values
2. Operations of a program should map input values to output values rather than change data in place

Side effect: code that modifies some variable outside of its local scope

¹ http://bit.ly/side_effect_wikipedia

What is a side effect?

```
def bust(hand: Int) = {  
  println(hand > 21)  
}
```

```
scala> val myHand = bust(22)
```

```
true  
myHand: Unit = ()
```

What is a side effect?

```
// Define counter variable
var i = 0

// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// Loop through hands and see if each busts
while (i < hands.length) {
  println(bust(hands(i)))
  i = i + 1
}
```

The spectrum of functional style

Less functional than before

```
// Define a function to determine if hand busts
def bust(hand: Int) = {
  println(hand > 21)
}
```

More functional than before

```
// Initialize array with each player's hand
var hands = Array(17, 24, 21)

// See if each hand busts
hands.foreach(bust)
```

¹ http://bit.ly/array_foreach_documentation

Signs of style

Imperative

- `var`
- Side effects
- `Unit`

Functional

- `val`
- No side effects
- Non-`Unit` value types
 - `Int`
 - `Boolean`
 - `Double`

¹ http://bit.ly/scala_unit_documentation

Let's practice!
INTRODUCTION TO SCALA

The essence of Scala

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The final video!



¹ Dancing smiley by Krabat der Zauberlehrling

The functional style

- Operations of a program should map input values to output values rather than change data in place



Non-functional code

- **WHEN** operations of a program **DON'T** map input values to output values and **DO** change data in place



The functional style

- Operations of a program should map input values to output values rather than change data in place



Benefits of the functional style

- Your data won't be changed inadvertently
- Your code is easier to reason about
- You have to write fewer tests
- Functions are more reliable and reusable

Scala is a hybrid imperative/functional language

Prefer

- `val`
- Immutable objects
- Functions without side effects

If necessary

- `var`
- Mutable objects
- Functions with side effects

What's next

Programming

- Functions
- More collections
- More types
- Object-oriented programming
- Functional programming
- Pattern matching
- Concurrency
- More...

Data

- Scala for the data engineer
- Scala for the data scientist
- Scala for the machine learning engineer



The essence of Scala



The essence of Scala



Fusing functional and object-oriented programming

¹ http://bit.ly/scala_days_odersky_2018

The essence of Scala



Fusing functional and object-oriented programming **in a statically-typed setting**

¹ http://bit.ly/scala_days_odersky_2018

Congratulations!

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