

Lecture 2 – Basic Introduction of Scala

COSE215: Theory of Computation

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2023 Spring

- ① Mathematical Notations
 - Notations in Logics
 - Notations in Set Theory
- ② Inductive Proofs
 - Inductions on Integers
 - Structural Inductions
 - Mutual Inductions
- ③ Notations in Languages
 - Symbols & Words
 - Languages

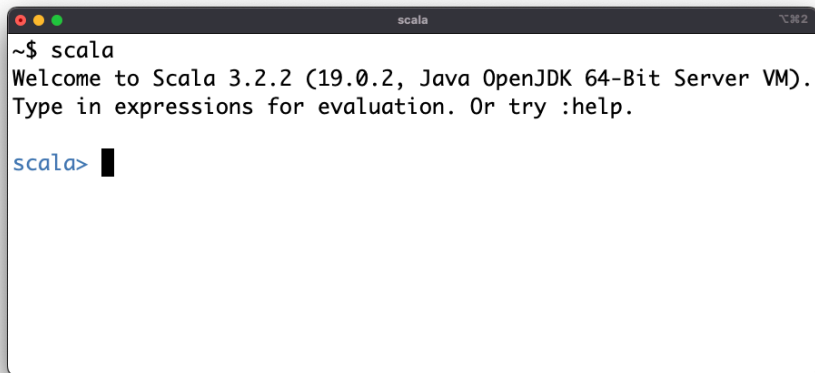


Scala stands for **Scalable Language**.

- A general-purpose programming language
- **Java Virtual Machine (JVM)**-based language
- A **statically typed** language
- A **object-oriented programming (OOP)** language
- A **functional programming (FP)** language

Read Eval Print Loop (REPL)

- Please download Scala REPL:
<https://www.scala-lang.org/download/>



```
scala  
~$ scala  
Welcome to Scala 3.2.2 (19.0.2, Java OpenJDK 64-Bit Server VM).  
Type in expressions for evaluation. Or try :help.  
  
scala> █
```

1. Basic Features

- Primitive Values

- Immutable Variables

- Functions

- Conditional Branches

2. Object-Oriented Programming (OOP)

- Case Classes

- Traits

- Pattern Matching

3. Functional Programming (FP)

- Higher-Order Functions (Functions as Values)

- Recursion

4. Immutable Collections (Data Structures)

- Lists

- Options and Pairs

- Maps

- Sets

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```
// You can write comments using `// ...` or `/* ... */`
// Integers
1 + 2          // 3: Int
3 - 2          // 1: Int
2 * 3          // 6: Int

// Booleans
true && false // false: Boolean
true || false // true : Boolean
! true        // false: Boolean
1 == 2        // false: Boolean
1 < 2         // true : Boolean

// Characters (Symbols) and Strings (Words)
'a'           // 'a'           : Char
"abc"         // "abc"         : String
"hello" + "world" // "helloworld" : String
"hello".length // 5           : Int
"hello"(0)    // 'h'          : Char
```

variable name initial value

`val` `x`: `Int` = `1`

variable type

```
// An immutable variable `x` of type `Int` with 1
val x: Int = 1
x + 2           // 1 + 2 == 3
x = 2           // Reassignment to val

// An immutable variable `s` of type `String` with "abc"
val s = "abc"

// Type Mismatch: `Boolean` required but `Int` found: 42
val b: Boolean = 42
```


While Scala supports mutable variables (`var`), **DO NOT USE MUTABLE VARIABLES IN THIS COURSE.**

```
var x: Int = 1
```

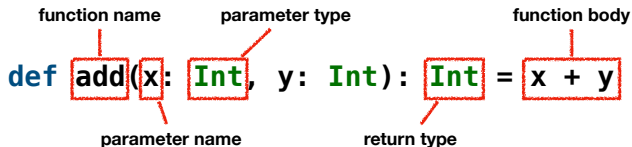
```
// A mutable variable `x` of type `Int` with 1
var x: Int = 1
x + 2           // 1 + 2 == 3

// You can reassign a mutable variable `x`
x = 2           // x == 2
x + 2           // 2 + 2 == 4
```

function name parameter type function body

```
def add(x: Int, y: Int): Int = x + y
```

parameter name return type



```
// A function `add` of type `(Int, Int) => Int`
```

```
def add(x: Int, y: Int): Int = x + y
```

```
add(1, 2)            // 1 + 2 == 3
```

```
add(5, 6)           // 5 + 6 == 11
```

```
// Type Error: wrong number of arguments
```

```
add(1)              // Too few arguments
```

```
add(1, 2, 3)        // Too many arguments
```

```
// Type Mismatch
```

```
add(1, "abc")      // `Int` required but `String` found: "abc"
```

if (x < 0) -x else x

then body else body

condition

```
// a function `abs` of type `Int => Int`  
def abs(x: Int): Int = if (x < 0) -x else x  
abs(-3)           // 3  
abs(42)           // 42
```

Note that the conditional branch is an **expression**, not a **statement**.

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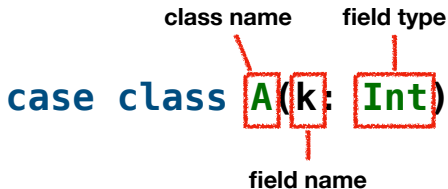
Object-oriented programming (OOP) is a programming paradigm based on the concept of "**objects**", which can contain data and code. The data is in the form of **fields** (often known as attributes or properties), and the code is in the form of **procedures** (often known as methods).¹

¹https://en.wikipedia.org/wiki/Object-oriented_programming

class name field type

case class **A**(**k**: **Int**)

field name



```
// A case class `A` having a field `k` of type `Int`  
case class A(k: Int)  
  
// An instance object `a` of type `A` whose field `k` has 10  
val a: A = A(10)  
  
// You can access fields using the dot operator  
a.k // 10
```

trait name

trait **Shape**

case class Rectangle(width: Int, height: Int) **extends** Shape

case class Square(side: Int) extends Shape

```
// A `Rectangle` type is a `Shape` type
val rectangle: Rectangle = Rectangle(20, 30)
rectangle.width // 20
rectangle.height // 30
val shape1: Shape = Rectangle(20, 30)
shape1.width // `width` is not a field of `Shape`
shape1.height // `height` is not a field of `Shape`

// A `Square` type is a `Shape` type
val square: Square = Square(10)
square.side // 10
val shape2: Shape = Square(10)
shape2.side // `side` is not a field of `Shape`
```

You can use **pattern matching** to match a value against a pattern.

```
def is42(n: Int): Boolean = n match
  case 42          => true    // exact matching for 42
  case 1 | 2 | 3   => false   // `|` denotes disjunction
  case k if k > 43 => false   // `if` denotes a guard
  case _          => false   // `_` denotes a wildcard

is42(42) // true
is42(1)  // false
is42(44) // false
is42(10) // false
```

```
def perimeter(sh: Shape): Int = sh match
  case Rectangle(w, h) => 2 * (w + h)
  case Square(s)       => 4 * s

perimeter(Rectangle(20, 30)) // 100
perimeter(Square(10))       // 40
```


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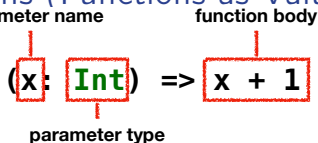
In computer science, **functional programming** is a programming paradigm where programs are constructed by applying and composing **functions**. It is a **declarative programming paradigm** in which function definitions are trees of expressions that map values to other values, rather than a sequence of **imperative statements** which update the running state of the program.²

- If a function always returns the same result when given the same, it is a **pure function**. **PLEASE DEFINE ONLY PURE FUNCTIONS IN THIS COURSE**. How about the following function `f`?

```
var y: Int = 1
def f(x) = x + y
f(1) // 1 + 1 = 2
y = 2
f(1) // 1 + 2 = 3
```

²https://en.wikipedia.org/wiki/Functional_programming

Higher-Order Functions (Functions as Values)



```
// An arrow function that increments its input
(x: Int) => x + 1        // Int => Int

// A function `inc` that increments its input
val inc: Int => Int = (x: Int) => x + 1
inc(1)    // 2

// A function `twice` that applies a function twice
def twice(f: Int => Int, x: Int): Int = f(f(x))
twice(inc, 5)                      // 7
twice((x: Int) => x + 1, 5)        // 7
twice(x => x + 1, 5)                // 7 - Type Inference
twice(_ + 1, 5)                    // 7 - Placeholder Syntax
```

You can **recursively** invoke a function.

```
// Sum of all the numbers from 1 to n
def sum(n: Int): Int = n match
  case 0 => 0
  case k => k + sum(k - 1)
sum(10) // 55
sum(100) // 5050
```

```
// A tree is either a branch or a leaf
trait Tree
case class Branch(l: Tree, n: Int, r: Tree) extends Tree
case class Leaf(n: Int) extends Tree
// Sum of all the values in a tree
def sum(t: Tree): Int = t match
  case Branch(l, n, r) => sum(l) + n + sum(r)
  case Leaf(n) => n
sum(Branch(Leaf(1), 2, Leaf(3))) // 6
sum(Branch(Branch(Leaf(1), 2, Leaf(3)), 4, Leaf(5))) // 15
```

While Scala supports while loops, **PLEASE DO NOT USE WHILE LOOPS IN THIS COURSE.**

```
// Sum of all the numbers from 1 to n
def sum(n: Int): Int =
  var s: Int = 0
  var k: Int = 1
  while (k <= n) do
    s = s + k
    k = k + 1
  s
sum(10) // 55
sum(100) // 5050
```

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A **list** is a sequence of elements of the same type.

```
// A list of integers: 3, 1, 2, 5, 4
val list: List[Int] = List(3, 1, 2, 5, 4)
val list2 = 3 :: 1 :: 2 :: 5 :: 4 :: Nil
list == list2           // true
// Pattern matching on lists
def countOdd(list: List[Int]): Int = list match
  case Nil              => 0
  case x :: xs if x % 2 == 1 => 1 + countOdd(xs)
  case _ :: xs          => countOdd(xs)
countOdd(list)         // 3 (three odd numbers: 3, 1, 5)
// Operations/functions on lists
6 :: list              // List(6, 3, 1, 2, 5, 4)
list ++ List(6, 7, 8) // List(3, 1, 2, 5, 4, 6, 7, 8)
list.reverse           // List(4, 5, 2, 1, 3)
list.filter(_ % 2 == 1) // List(3, 1, 5)
list.map(_ * 2)        // List(6, 2, 4, 10, 8)
list.foldLeft(0)(_ + _) // 15
list.sorted            // List(1, 2, 3, 4, 5)
```

An **option** is a container that may or may not contain a value. **DO NOT USE NULL IN THIS COURSE.**

```
val some: Option[Int] = Some(42)
val none: Option[Int] = None
// Operations/functions on options
some.map(_ + 1)      // Some(43)
none.map(_ + 1)     // None
some.getOrElse(7)   // 42
none.getOrElse(7)   // 7
some.fold(3)(_ * 2) // 84
none.fold(3)(_ * 2) // 3
```

A **pair** is a container that contains two values.

```
val pair: (Int, String) = (42, "foo")
// Operations/functions on options
pair(0)                // 42 - NOT RECOMMENDED
pair(1)                // "foo" - NOT RECOMMENDED
val (x, y) = pair      // x = 42, y = "foo"
```


A **map** is a mapping from keys to values.

```
val map: Map[String, Int] = Map("a" -> 1, "b" -> 2)

// Operations/functions on maps
map + ("c" -> 3)           // Map("a" -> 1, "b" -> 2, "c" -> 3)
map + ("a" -> 3)           // Map("a" -> 3, "b" -> 2)
map - "a"                  // Map("b" -> 2)
map.get("a")               // Some(1)
map.get("c")               // None
map.getOrElse("a", 42)     // 1
map.getOrElse("c", 42)     // 42
map.toList                 // List(("a", 1), ("b", 2))
map.keySet                 // Set("a", "b")
map.values.toList          // List(1, 2)
```

A **set** is a collection of distinct elements.

```
val set1: Set[Int] = Set(1, 2, 3)
val set2: Set[Int] = Set(2, 3, 5)

// Operations/functions on sets
set1 + 4           // Set(1, 2, 3, 4)
set1 + 2           // Set(1, 2, 3)
set1 - 2           // Set(1, 3)
set1.contains(2)   // true
set1 ++ set2       // Set(1, 2, 3, 5)
set1.intersect(set2) // Set(2, 3)
set1.diff(set2)    // Set(1)
set1.subsetOf(set2) // false
set1.toList        // List(1, 2, 3)
```

- Please see <https://github.com/ku-plrg-classroom/docs/tree/main/scala-tutorial>.
- The due date is Mar. 21 (Tue.).
- Please only submit `Implementation.scala` file to **Blackboard**.

Summary

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- Deterministic Finite Automata (DFA)

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