FUNCTIONAL AND CONCURENT PROGRAMMING

SI4

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FUNCTIONAL PROGRAMMING INTRODUCTION

History, languages, usage, immutability

HISTORY

- Main models of computation
  - Lambda calculus (A. Church, 1930s)
  - Turing machine (A. Turing, 1936)
  - Petri nets (1962) / Khan process networks (1974)
- Main programming paradigm famillies
  - Functional programming (what?)
  - Imperative programming (how?)
  - Concurrent programming (when?)

LAMBDA CALCULUS

- A formal system in mathematical logic
- Syntax (lambda terms)
  - x – variable
  - $(\lambda x.\, M)$ – function definition (aka abstraction).
  - $(M\ N)$ – function application, with M and N lambda terms.
- Operations
  - $(\lambda x.\, M[x]) \rightarrow (\lambda y.\, M[y])$ – α-conversion (renaming)
  - $\big((\lambda x.\, M)\ E\big) \rightarrow (M[x\ :=\ E])$ – β-reduction

LET NUMERALS BE!

- Numbers
  - 0: $(\lambda f\ x.x)$
  - 1: $(\lambda f\ x.f\ x)$
  - 2: $(\lambda f\ x.f\ (f\ x))$ ...
  - n: $(\lambda f\ x.f\ (\ldots\ f\ (f\ x))$
- Sum
  - $(\lambda n1\ n2\ f\ x.n1\ f\ (n2\ f\ x))$

FUNCTIONAL PROGRAMING

- Functional programming languages
  - LISP dialects (fully parenthesized prefix notation), J. McCarthy 1958
    - Common Lisp, Scheme, Clojure, Racket
  - Erlang (Prolog-style, distributed), 1988
  - Haskell, OCaml, Scala (strong static typing)
  - Many others…
- Functional programming in imperative languages
  - C++ (since 11), C#, JavaScript, PHP (since 5.3), Python, Go, Rust, **Java (since 8)**, …

MAIN CONCEPTS OF FUNCTIONAL PROGRAMMING

- Pure functions
  - No side-effect!, idempotence → **Thread-Safe, tests, …**
- Recursion
  - Loop are recursion, tail recursion
- First-class and higher-order functions
  - Functions as argument or result
- *Optionally*:
  - *Type systems, Lazy evaluation, Curryfication, …*

ADVANTAGES OF FUNCTIONAL PROGRAMMING

- For algorithmic
  - Focus on what, not how
  - Higher order programming
- For computer engineering
  - Better tests (pure function)
  - Many design parterns are functional (MVC, factory, decorator, strategy, …)
- For interactive systems
  - Handlers are functions
- For distributed systems
  - Non-mutable states
    - No race condition
    - Easier to reason about
    - Efficient use of ressources
  - Micro-services, AWS lambda, are functions

PURE FONCTIONS

- Computer Science 101
- How to order a list ?
  - *Return a new list that contains the same elements ordered*
- **Purely functional data structure**
  - **Strongly immutable**
- In Java :
  - Immutable collections libraries (Guava, Eclipse, …)
  - Collections.unmodifiableXXX
  - Records (since Java 16)

JAVA RECORDS

- **Immutable data classes**
- Fields declaration (private, final)
- Automatic definition of
  - Constructor
  - Accessors
  - toString
  - equals, hashCode

```java
public class Person {

    private final String name;
    private final String address;

    public Person(String name, String address) {
        this.name = name;
        this.address = address;
    }

    @Override
    public int hashCode() {
        return Objects.hash(name, address);
    }

    @Override
    public boolean equals(Object obj) {
        if (this == obj) {
            return true;
        } else if (!(obj instanceof Person)) {
            return false;
        } else {
            Person other = (Person) obj;
            return Objects.equals(name, other.name)
              && Objects.equals(address, other.address);
        }
    }

    @Override
    public String toString() {
        return "Person [name=" + name + ", address=" + address + "]";
    }

    // standard getters
}
```

EXAMPLE

VS

```java
public record Person (String name, String address) {}
```

SOME DETAILS

- Record inherit from java.lang.Record (abstract : no other)
- Record are final (no inheritance)
- Record can be generic
- Accessor are fieldName() (not getFieldName())
- You can personalise automatic defintions
- You can add (class) methods / constructors / class fields

```
record Rectangle(double length, double width) {
    public Rectangle(double length, double width) {
        if (length <= 0 || width <= 0) {
            throw new java.lang.IllegalArgumentException(
                    String.format("Invalid dimensions: %f, %f", length, width));
        }
        this.length = length;
        this.width = width;
    }
```

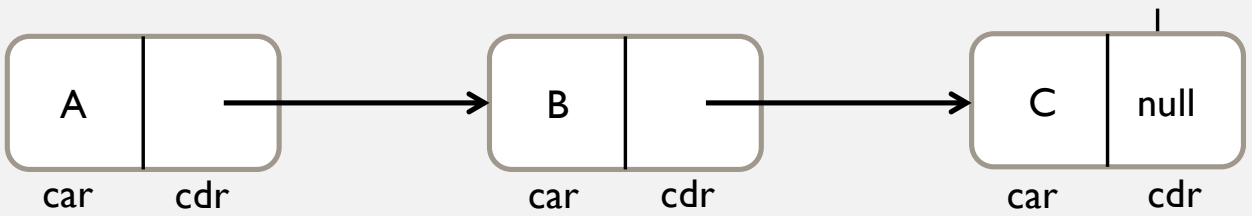
Or better :

```
record Rectangle(@GreaterThanZero double length,
                 @GreaterThanZero double width) { }
```

IMMUTABLE LIST

- Singly linked list

```
public record Lst<T>(T car, Lst<T> cdr) {
}
```




```
Lst<String> L = new Lst<>( car: "A", new Lst<>( car: "B", new Lst<>( car: "C",  cdr: null)));
System.out.println(L.car());
System.out.println(L.cdr().car());
System.out.println(L.cdr().cdr().car());
```

LIST USAGE EXAMPLE

Recusive style

```
public static int sumRec(Lst<Integer> l) {
    if (l == null) {
        return 0;
    } else {
        return l.car() + sumRec(l.cdr());
    }
}
```

Iterative style

```
public static int sumIt(Lst<Integer> l) {
    int s = 0;
    while (l != null) {
        s += l.car();
        l = l.cdr();
    }
    return s;
}
```

LIST “UPDATE” EXAMPLE

- Recursive style
- Immutable data structure

```
public static <T> Lst<T> replaceAll(Lst<T> l, T x, T y) {
    if (l == null) {
        return null;
    } else if (l.car().equals(x)) {
        return new Lst<>(y, replaceAll(l.cdr(), x, y));
    } else {
        return new Lst<>(l.car(), replaceAll(l.cdr(), x, y));
    }
}
```