Expressões lambda
Interfaces funcionais [Revisitado]

UA.DETI.POO

Cálculo lambda

- As linguagens de programação funcional são baseadas no cálculo lambda *(cálculo-λ)*.
  - Lisp, Haskell, Scheme

- O cálculo lambda pode ser visto como uma linguagem de programação abstrata em que funções podem ser combinadas para formar outras funções.

Cálculo lambda

- **Ideia geral:** formalismo matemático
  - x -> f(x) i.e. x *é transformado em f(x)*

- O cálculo lambda trata as funções como *elementos de primeira classe:*
  - podem ser utilizadas como argumentos e retornadas como valores de outras funções.
  - x -> g(f(x)) i.e., o resultado de *f(x) é transformado por g()*

Sintaxe

- Uma expressão lambda descreve uma função anónima. Representa-se na forma:
  - (argument) -> (body)

```
(int a, int b) -> {  return a + b; }
```

- Pode ter zero, um, ou mais argumentos
  - () -> { body }

```
() -> System.out.println("Hello World");
```

  - (arg1, arg2...) -> { body }
- O tipo dos argumentos pode ser explicitamente declarado ou inferido
  - (type1 arg1, type2 arg2...) -> { body }

```
(int a, int b) -> {  return a + b; }
a -> return a*a // um argumento – podemos omitir os parêntesis
```

- O corpo (body) pode ter uma ou mais instruções

Exemplos

lambda expression	equivalent method
`() -> { System.gc(); }`	`void nn() { System.gc(); }`
`(int x) -> { return x+1; }`	`int nn(int x) return x+1; }`
`(int x, int y)` `-> { return x+y; }`	`int nn(int x, int y)` `{ return x+y; }`
`(String... args)` `->{return args.length;}`	`int nn(String... args)` `{ return args.length; }`

`(String[] args)`
`-> {`
`if (args != null)`
`return args.length;`
`else`
`return 0;`
`}`
	`int nn(String[] args)`
	`{`
	`if (args != null)`
	`return args.length;`
	`else`
	`return 0;`
	`}`

Como usar?

- Uma expressão lambda não pode ser declarada isoladamente

```
(n) -> (n % 2)==0;  // Erro de compilação
```

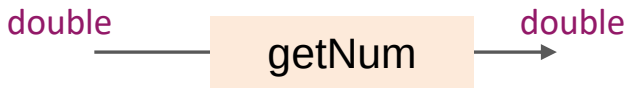
- Precisamos de outro mecanismo adicional
  - Interfaces funcionais
  - onde as expressões lambda passam a ser implementações de métodos abstratos.

  - O compilador Java converte uma expressão lambda num método da classe (isto é um processo interno).

Functional interface

- Contém apenas **um método abstrato**
- Exemplo
  - Dada a interface:

```
@FunctionalInterface
interface MyNum {
    double getNum(double n);
}
```



  - Podemos usar:

```
public class Lamdba1 {
    public static void main(String[] args) {
        MyNum n1 = (x) -> x+1;
            // qualquer expressão que transforme double em double
        System.out.println(n1.getNum(10));
        n1 = (x) -> x*x;
        System.out.println(n1.getNum(10));
    }
}
```

```
11.0
100.0
```

Exemplos

```
@FunctionalInterface
interface Ecra {
	void escreve(String s);
}

public class Lambda2 {

	public static void main(String[] args) {

		Ecra xd = (String s) -> {
			if (s.length() > 2)
				System.out.println(s);
			else
				System.out.println("..");
		};
		xd.escreve("Lambda print");
		xd.escreve("?");
	}
}
```

interface funcional

```
Lambda print
..
```

Exemplos

```
// Another functional interface.
interface NumericTest {
    boolean test(int n);
}

class Lambda3 {
    public static void main(String args[]) {
        // A lambda expression that tests if a number is even.
        NumericTest isEven = (n) -> (n % 2) == 0;
        if (isEven.test(10)) System.out.println("10 is even");
        if (!isEven.test(9)) System.out.println("9 is not even");
        // A lambda expression that tests if a number is non-negative.
        NumericTest isNonNeg = (n) -> n >= 0;
        if (isNonNeg.test(1)) System.out.println("1 is non-negative");
        if (!isNonNeg.test(-1))  System.out.println("-1 is negative");
    }
}
```

```
10 is even
9 is not even
1 is non-negative
-1 is negative
```

Exemplos

```
// Demonstrate a lambda expression that takes two parameters.
interface NumericTest2 {
    boolean test(int n, int d);
}

public class Lambda4 {
    public static void main(String args[]) {
        // This lambda expression determines if one number is
        // a factor of another.
        NumericTest2 isFactor = (n, d) -> (n % d) == 0;
        if (isFactor.test(10, 2))
            System.out.println("2 is a factor of 10");
        if (!isFactor.test(10, 3))
            System.out.println("3 is not a factor of 10");
    }
}
```

```
2 is a factor of 10
3 is not a factor of 10
```

Expressões Lambda como argumento

- Podemos definir interfaces genéricas (com parâmetros).
- Por exemplo:

```
interface MyFunc<T> {
        T func(T n);
}
...
// Função que aceita uma expressão lambda e o seu argumento (T n)
static String stringOp(MyFunc<String> sf, String s) {
        return sf.func(s);
}

...
// Outro exemplo
static Person PersonOp(MyFunc<Person> sf, Person s) {
        return sf.func(s);
}
```

Interface funcional

Argumento da interface

Expressões Lambda como argumento

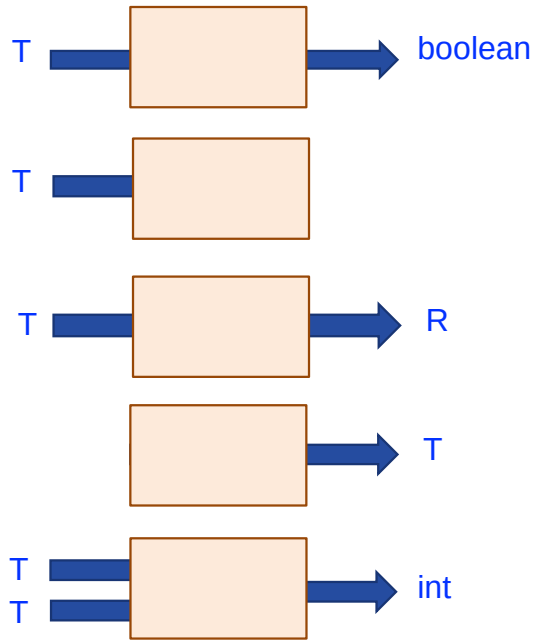
- Utilização

```
String inStr = "Lambdas add power to Java";
String outStr = stringOp((str) -> str.toUpperCase(), inStr);
System.out.println("The string in uppercase: " + outStr);
// This passes a block lambda that removes spaces.
outStr = stringOp((str) -> {
        StringBuilder result = new StringBuilder();
        for(int i = 0; i < str.length(); i++)
                if(str.charAt(i) != ' ')
                        result.append( str.charAt(i) );
                return result.toString();
}, inStr);
System.out.println("The string with spaces removed: " + outStr);
```

```
The string in uppercase: LAMBDAS ADD POWER TO JAVA
The string with spaces removed: LambdasaddpowertoJava
```

Interfaces funcionais pré-definidas

- Geralmente não precisamos de criar novas interfaces funcionais
  - Utilizamos as que já existem definidas em Java.
- Exemplos
  - java.util.function.Predicate<T>
    boolean test(T t)
  - java.util.function.Consumer<T>
    void accept(T t)
  - java.util.function.Function<T, R>
    R apply(T t)
  - java.util.function.Supplier<T>
    T get()
  - java.util.Comparator<T>
    int compare(T o1, T o2)



Referência a métodos

- São um tipo especial de expressões lambda.
  - Permitem substituir expressões lambda que invocam métodos existentes.
- Exemplos
  - Podemos substituir:

    str -> System.out.println(str)

    (s1, s2) -> {return s1.compareToIgnoreCase(s2); }
  - por:

    System.out::println

    String::compareToIgnoreCase

```
String[] names = { "Steve", "Rick", "Aditya", "Negan", "Lucy", "Sansa"};
Arrays.sort(names, String::compareToIgnoreCase);
for(String str: names){
        System.out.println(str);
}
```

Referências a métodos: 4 variedades

Kind	Syntax/Examples	Equivalent to

Reference to a static method	**`Class::staticMethod`**
	`Math::abs`
	`Double::compare`
	`Math::random`
		`(args) -> Class.staticMethod(args)`
		`(x) -> Math.abs(x)`
		`(x, y) -> Double.compare(x, y)`
		`() -> Math.random()`

Reference to an instance method of a particular object	**`obj::method`**
	`System.out::println`
	`"abcdef"::substring`
		`(args) -> obj.method(args)`
		`(s) -> System.out.println(s)`
		`(a, b) -> "abcdef".substring(a, b)`

Reference to an instance method of arbitrary object of a particular type	**`Type::method`**
	`String::compareTo`
	`String::strip`
		`(arg1, args) -> arg1.method(args)`
		`(s, t) -> s.compareTo(t)`
		`(s) -> s.strip()`

Reference to a constructor	**`Class::new`**
	`File::new`
	`int[]::new`
		`(args) -> new Class(args)`
		`(name) -> new File(name)`
		`(size) -> new int[size]`

Method references (Java tutorial)

Utilização de expressões lambda

- Iterar sobre Java Collections

```
// solução 1
List<Integer> list = Arrays.asList(1, 2, 3, 4, 5, 6, 7);
for (Integer n: list) {
   System.out.println(n);
}

// solução 2
List<Integer> list = Arrays.asList(1, 2, 3, 4, 5, 6, 7);
list.forEach(n -> System.out.println(n));

// solução 3, method reference (:: double colon operator)
List<Integer> list = Arrays.asList(1, 2, 3, 4, 5, 6, 7);
list.forEach(System.out::println);
```

TreeSet – ordenação natural

```
public class Test {
	public static void main(String args[]) {
		TreeSet<String> ts = new TreeSet<>();    // implicitamente ordenado pela ordem natural

		ts.add("viagem");
		ts.add("calendário");
		ts.add("prova");
		ts.add("zircórnio");
		ts.add("ilha do sal");
		ts.add("avião");
		for (String element : ts)
			System.out.println(element + " ");
		}
}
```

```
avião
calendário
ilha do sal
prova
viagem
zircórnio
```

TreeSet – ordem definida

TreeSet aceita um java.util.Comparator<T>

```
public class Test {
	public static void main(String args[]) {
		TreeSet<String> ts =
			new TreeSet<>(Comparator.comparing(String::length));

		ts.add("viagem");
		ts.add("calendário");
		ts.add("prova");
		ts.add("zircórnio");
		ts.add("ilha do sal");
		ts.add("avião");
		for (String element : ts)
			System.out.println(element + " ");
		}
}
```

```
prova
viagem
zircórnio
calendário
ilha do sal
```

TreeSet – ordem definida

TreeSet aceita um java.util.Comparator<T>

```
public class Test {
	public static void main(String args[]) {
		Set<String> ts =
			new TreeSet<>(Comparator.comparing(String::length));

		ts.add("viagem");
		ts.add("calendário");
		ts.add("prova");
		ts.add("zircórnio");
		ts.add("ilha do sal");
		ts.add("avião");
		for (String element : ts)
			System.out.println(element + " ");
		}
}
```

código equivalente

```
TreeSet<String> ts = new TreeSet<>((s1, s2) -> {
	if (s1.length() > s2.length())
		return 1;
	else if (s1.length() < s2.length())
		return -1;
	else
	return 0;
});
```

```
prova
viagem
zircórnio
calendário
ilha do sal
```

Algoritmos

- As bibliotecas de Java fornecem um conjunto de algoritmos que podem ser usados em coleções e vetores

- Duas classes abstratas fornecem métodos estáticos de utilização global
  - java.util.Collections - *Note que é diferente de java.util.Collection (interface)!!*
  - java.util.Arrays - Classe que contém vários métodos para manipular vetores (ordenação, pesquisa, ..). Também permite converter vectores para listas.

- Exemplos de métodos:
  - sort, binarySearch, copy, shuffle, reverse, max, min, etc.

java.util.Collections

Ordenação natural

```
public static void main(String[] args) {
	List<Integer> list = new ArrayList<>();

	for (int i=0;i<10;i++) {
		list.add((int) (Math.random() * 100));
	}

	System.out.println("Initial List: "+list);
	Collections.sort(list);
	System.out.println("Sorted List:  "+list);
	Collections.reverse(list);
	System.out.println("Reverse List:  "+list);
}
```

```
Initial List: [53, 46, 6, 93, 13, 57, 76, 56, 40, 93]
Sorted List:  [6, 13, 40, 46, 53, 56, 57, 76, 93, 93]
Reverse List:  [93, 93, 76, 57, 56, 53, 46, 40, 13, 6]
```

java.util.Collections

Ordenação com Comparator

```
public static void main(String[] args) {
        System.out.println("--Sorting with natural order");
        List<String> l1 = createList();
        Collections.sort(l1);
        l1.forEach(System.out::println);

        System.out.println("--Sorting with a lambda expression");
        List<String> l2 = createList();
        l2.sort((s1, s2) -> s1.compareTo(s2));
        l2.forEach(System.out::println);

        System.out.println("--Sorting with a method reference");
        List<String> l3 = createList();
        l3.sort(String::compareTo);
        l3.forEach(System.out::println);
}

private static List<String> createList() {
        List<String> list = new ArrayList<>();
        list.add("Ubuntu");
        list.add("Android");
        list.add("MacOS");
        return list;
}
```

```
--Sorting with natural order
Android
MacOS
Ubuntu
--Sorting with a lambda expression
Android
MacOS
Ubuntu
--Sorting with a method reference
Android
MacOS
Ubuntu
```

java.util.Arrays - Exemplo

```
public static void main(String[] args) {
        String[] vec1 =
                new String[] { "once", "upon", "a", "time", "in", "Aveiro" };
        display(vec1);
        String[] res1 = Arrays.copyOfRange(vec1, 0, 3);
        display(res1);
        Arrays.sort(vec1);
        display(vec1);
        Arrays.sort(vec1, Comparator.comparing(String::length));
        display(vec1);
        String[] vec2 = new String[10];
        Arrays.fill(vec2, "UA");
        System.out.println(Arrays.toString(vec2)); // em vez de display()
        List<String> list1 = Arrays.asList(vec1);
        list1.forEach(System.out::println);
}

public static void display(String[] vec) {
        for (String s : vec) System.out.print(s + " ");
        System.out.println();
}
```

```
once upon a time in Aveiro
once upon a
Aveiro a in once time upon
a in once time upon Aveiro
[UA, UA, UA, UA, UA, UA, UA, UA, UA, UA]
a
in
once
time
upon
Aveiro
```

Sumário

- Funções lambda
- Interfaces funcionais

- Ordenação de vetores, listas, árvores, ..

- java.util.Collections
- java.util.Arrays

Stream API [Revisitado]

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Iterar sobre coleções

- Iterator

```
List<String> names = Arrays.asList("Ana", "Ze", "Rui");
Iterator<String> it = names.iterator();
while (it.hasNext())
  System.out.println(it.next());
```

- ciclo "for each"

```
List<String> names = Arrays.asList("Ana", "Ze", "Rui");
for (String name : names)
   System.out.println(name);
```

- Método forEach

```
List<String> names = Arrays.asList("Ana", "Ze", "Rui");
names.forEach(s -> System.out.println(s)); // forEach com lambda
names.forEach(System.out::println); // forEach com referência de método
```

- Stream operations
  - *Aggregate operations*

Aggregate Operations – Streams API

- The preferred method of iterating over a collection is to obtain a stream and perform aggregate operations on it.
- Aggregate operations are often used in conjunction with lambda expressions
  - to make programming more expressive, using less lines of code.

- Package java.util.stream
  - The key abstraction introduced in this package is stream.

Stream Pipeline

- (1) Obtain a stream from a source
- (2) Perform one or more intermediate operations
- (3) Perform one terminal operation

- Usage: Source.Op1.Op2 .. .Terminal

java.util.stream

- Streams differ from collections in several ways:
- No storage
  - A stream is not a data structure that stores elements; instead, it conveys elements through a pipeline of computational operations.
- Functional in nature
  - An operation on a stream produces a result but does not modify its source.
- Laziness-seeking ('process-only, on-demand' strategy)
  - Many stream operations, such as filtering or mapping, can be implemented lazily, exposing opportunities for optimization. Intermediate operations are always lazy.
- Possibly unbounded
  - While collections have a finite size, streams need not.
- Consumable
  - The elements of a stream are only visited once during the life of a stream. Like an Iterator, a new stream must be generated to revisit the same elements of the source.

Stream concepts

- Lazy because intermediate operations are not evaluated unless terminal operation is invoked
- Each intermediate operation creates a new stream
  - stores the provided operation/function and return the new stream
- When terminal operation is called, traversal of streams begins and the associated function is performed one by one
- Parallel streams don't evaluate streams 'one by one'
  - operations are performed simultaneously, depending on the available cores

java.util.stream – Sources

- Streams sources include:
  - From a Collection via the stream() and parallelStream() methods;
  - From an Array via Arrays.stream(Object[]);
  - *and many more (files, random, ..)*

java.util.stream – Intermediate operations

- **filter** - excludes all elements that don't match a Predicate
- **map** - perform transformation of elements using a Function
- **flatMap** - applies a one-to-many transformation to the elements of the stream, and then flattens the resulting elements into a new Stream
- **peek** - performs some action on each element
- **distinct** - excludes all duplicate elements (equals())
- **sorted** - ordered elements (Comparator)
- **limit** - maximum number of elements
- **skip** - discard first n elements
- *(and many more -> see java.util.stream.Stream<T>)*

```
List<Person> people = ...;
Stream<Person> tenPersonsOver18 = people.stream()
                .filter(p -> p.getAge() > 18)
                .limit(10);
```

java.util.stream – Terminating operations

- Reducers
  - reduce(), count(), findAny(), findFirst()
- Collectors
  - collect()
- forEach
- iterators

```
// Accumulate names into a List
List<Person> people = ...;
List<String> names = people.stream()
        .map(Person::getName)
        .collect(Collectors.toList());
```

Stream.Filter

- Filtering a stream of data is the first natural operation that we would need.
- Stream interface exposes a filter method that takes in a Predicate that allows us to use lambda expression to define the filtering criteria:

```
List<String> l = Arrays.asList("Ana Maria", "Mariana", "Rui");

l.stream().filter(n -> n.length()>3)
                .forEach(System.out::println);
```

Stream.Map

- The map operations allows us to apply a function that takes in a parameter of one type and returns something else.

```
Stream<Student> map = people.stream()
        .filter(p -> p.getAge() > 18)
        .map(person -> new Student(person));


// other example with Map && Consumer

List<String> l = Arrays.asList("Ana", "Ze", "Rui");
l.stream().map(n -> "Nome = " + n)
                    .forEach(System.out::println);
```

Stream.Reduce

- A reduction operation takes a sequence of input elements and combines them into a single summary result by repeated application of a combining operation
- For instance, finding the sum or maximum of a set of numbers, or accumulating elements into a list.

```
// example with Map & Reduce
List<Integer> costBeforeTax = Arrays.asList(100, 200, 300, 400, 500);

double bill = costBeforeTax.stream()
                    .map(cost -> (cost*1.23))
                    .reduce(0.0,(sum, cost) -> sum + cost));

System.out.println("Total : " + bill);
```

Stream.Collect

- The Stream API provides several "terminal" operations.
- The collect() method is one of those, which allows us to collect the results of the operations:

```
List<Student> students = persons.stream()
        .filter(p -> p.getAge() > 18)
        .map(Student::new)
        .collect(Collectors.toList());

// other example with Map && Collect
List<String> l = Arrays.asList("Ana", "Ze", "Rui");
List<String> res = l.stream()
                .map(n -> "Nome: " + n)
                .collect(Collectors.toList());
res.forEach(System.out::println);
```

Some examples using a list of strings

```
public static void listExample() {
   List<String> words = new ArrayList<String>();
   words.add("Prego");
   words.add("no");
   words.add("Prato");
   // old fashioned way to print the words
   for (int i = 0; i < words.size(); i++)
      System.out.print(words.get(i) + " ");
   System.out.println();

   // Java 5 introduced the foreach loop and Iterable<T> interface
   for (String s : words)
      System.out.print(s + " ");
   System.out.println();

   // Java 8 has a forEach method as part of the Iterable<T> interface
   // The expression is known as a "lambda" (an anonymous function)
   words.stream().forEach(n -> System.out.print(n + " "));
   System.out.println();

   // but in Java 8, why use a lambda when you can refer directly to the
   // appropriate function?
   words.stream().forEach(System.out::print);
   System.out.println();

   // Let's introduce a call on map to transform the data before it is printed
   words.stream().map(n -> n + " ").forEach(System.out::print);
   System.out.println();

   // obviously these chains of calls can get long, so the convention is
   // to split them across lines after the call on "stream":
   words.stream()
      .map(n -> n + " ")
      .forEach(System.out::print);
   System.out.println();
}
```

```
Prego no Prato
Prego no Prato
Prego no Prato
PregonoPrato
Prego no Prato
Prego no Prato
```

Some examples with an array of int

```
public static void arraysExample() {
   int[] numbers = {3, -4, 8, 73, 507, 8, 14, 9, 3, 15, -7, 9, 3, -7, 15};

   // want to know the sum of the numbers?  It's now built in
   int sum = Arrays.stream(numbers)
      .sum();
   System.out.println("sum = " + sum);

   // how about the sum of the even numbers?
   int sum2 = Arrays.stream(numbers)
      .filter(i -> i % 2 == 0)
      .sum();
   System.out.println("sum of evens = " + sum2);

   // how about the sum of the absolute value of the even numbers?
   int sum3 = Arrays.stream(numbers)
      .map(Math::abs)
      .filter(i -> i % 2 == 0)
      .sum();
   System.out.println("sum of absolute value of evens = " + sum3);

   // how about the same thing with no duplicates?
   int sum4 = Arrays.stream(numbers)
      .distinct()
      .map(Math::abs)
      .filter(i -> i % 2 == 0)
      .sum();
   System.out.println("sum of absolute value of distinct evens = " + sum4);
}
```

```
sum = 649
sum of evens = 26
sum of absolute value of evens = 34
sum of absolute value of distinct evens = 26
```

Sumário

- JAVA Stream API
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    - IntStream.Builder
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