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Grupo de Usuários de Java do Estado do Espírito Santo

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Closures in Java

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- Java:
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Summary

- What are closures?
- Java and closures;
- The BGGA proposal;
- The FCM proposal;
- The CICE+ARM proposal;
- Discussion.

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What are closures?

- FOLDOC:
  A data structure that holds an expression and an environment of variable bindings in which that expression is to be evaluated.
- Wikipedia:
  A function that is evaluated in an environment containing one or more bound variables.
- Most general definitions:
  - Closed variable environment;
  - 1st class citizen.

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What are closures?

- In practice:
  - Blocks of code that access variables in the external scope;
  - Can be created dynamically;
  - Can be stored in variables;
  - Can be passed as parameters;
  - Can be invoked dynamically.

Simple example (Groovy)

```
def clos = { println "Hello, World!" }
clos()
closureMethod(clos)

def closureMethod(closure) {
  closure()
}
```

```
$ groovy Teste
Hello, World!
Hello, World!
```

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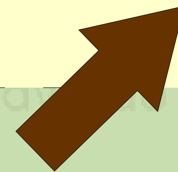
Parameters and variables (Groovy)

```
def sum = { a, b -> a + b }
def result = sum(7, 5)
println result                        // 12

def doubleResult = { println result * 2 }
doubleResult()                        // 24
result++
doubleResult()                        // 26
```



The closure refers to a variable that is external to it

Origins

- The 50's, MIT: Lisp, lambda expressions (anonymous functions);
- The 70's: Scheme - 1st LISP dialect to do static (lexical) binding, producing a closure (term imported from mathematics);
- Smalltalk: 1st OO language to include closures:
  - Motivation: creation of control constructs in the API.

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Creating a for-each using closures

```
void forEach(array, funct) {
  for (i = 0; i < array.size(); i++)
    funct(array[i])
}

def words = ["Closures", "are", "cool!"]
forEach(words) {
  item -> print item + " "
}
println ""
```

- There would have been no need to change the Java language to include the enhanced for if Java had closures before version 5...

And if I need something specific?

- What if we had a statistical framework that times tasks and stores them in a database?
- Would this control structure ever make into the language?
- Now think transaction management...
- Think the amount of frameworks out there...

```
// Times the execution and stores in the DB
// under the name “block-1”:
time("block-1") {
  // Your code here...
}
```

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What about Java and closures?

- First of all: Java is turing-complete;
- Java has closures in the form of anonymous inner classes or the reflection API:
  - Are more verbose;
  - Do not allow compile-time checking;
  - Make refactoring difficult.

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For each in Java using AICs

```
interface Closure<T> {
  void invoke(T arg);
}
public class Test {
  static <T> void forEach(T[] arr, Closure<T> fun) {
    for (int i = 0; i < arr.length; i++) {
      fun.invoke(arr[i]);
    }
  }
  public static void main(String[] args) {
    String[] words = new String[] { "A", "B", "C" };
    forEach(words, new Closure<String>() {
      public void invoke(String arg) {
        System.out.print(arg + " ");
      }
    });
  }
}
```

For each in Java using AICs

- Further complications:
  - The `invoke()` method in the Closure interface does not declare any exceptions. You can't throw them;
  - The `invoke()` method does not declare any return type. You can't return anything;
  - Variables used in an AIC have to be final. To simulate a return value, you'd have to use an array of size 1.

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Should we add closures to Java, then?

- That question generated a lot of debate and three main propositions:
  - BGGA (a.k.a. “Full Closures”):
    - Name after the authors: Gilad **B**racha, Neal **G**after, James **G**osling and Peter von der **A**hé.
  - FCM:
    - First Class Methods;
    - Authors: Stephen Coleburn and Stefan Schulz.
  - CICE+ARM:
    - Concise Instance Creation Expressions + Automatic Resource Management;
    - Authors: Bob Lee, Doug Lea and Joshua Bloch.

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The prototypes

- All proposals come with working prototypes;
- BGGA is being included in OpenJDK 7;
- Installation:
  - Install the latest JDK 6;
  - Copy the files from the prototype over the JDK.
- Useful links:
  - BGGA: www.javac.info
  - OpenJDK: openjdk.java.net/projects/closures
  - FCM: docs.google.com/View?docid=ddhp95vd_0f7mcns
  - CICE+ARM: www.slm888.com/javac

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The BGGA proposal

- Can create closures in Java:
  `{ parameters => commands expression }`
- Changes the type system to add Function Types:
  `{ params => return-type throws exceptions }`
- Variables that are modified inside the closure receive the `@Shared` annotation;
- Can assign closures to variables of a compatible interface type;
- Unrestricted closures allow for control constructs syntax.

BGGA – Hello, World!

```
// Using only the expression.
String msg = { => "Hello, BGGA!" }.invoke();
System.out.println(msg);

// Using only a command.
{ => System.out.println("Hello, BGGA!"); }.invoke();

// Using parameters.
{ String msg =>
System.out.println(msg); }.invoke("Hello, BGGA!");

// Local variables can be declared inside!
int a = { int x => int y = x + 1; y * 2}.invoke(9);
System.out.println(a); // 20
```

BGGA – Function types

```
static void doIt() throws Exception {
  throw new Exception("doIt() threw exception!");
}
public static void main(String[] args) {
  {int, int => int} sum = { int a, int b => a + b };
  print(sum, 7, 8);
  { => void throws Exception } it = { => doIt(); };
  try {
    it.invoke();
  } catch (Exception e) {
    System.out.println(e);
  }
}
static void print({int, int => int} cl, int a, int b)
{
  int x = cl.invoke(a, b);
  System.out.println(x);
}
```

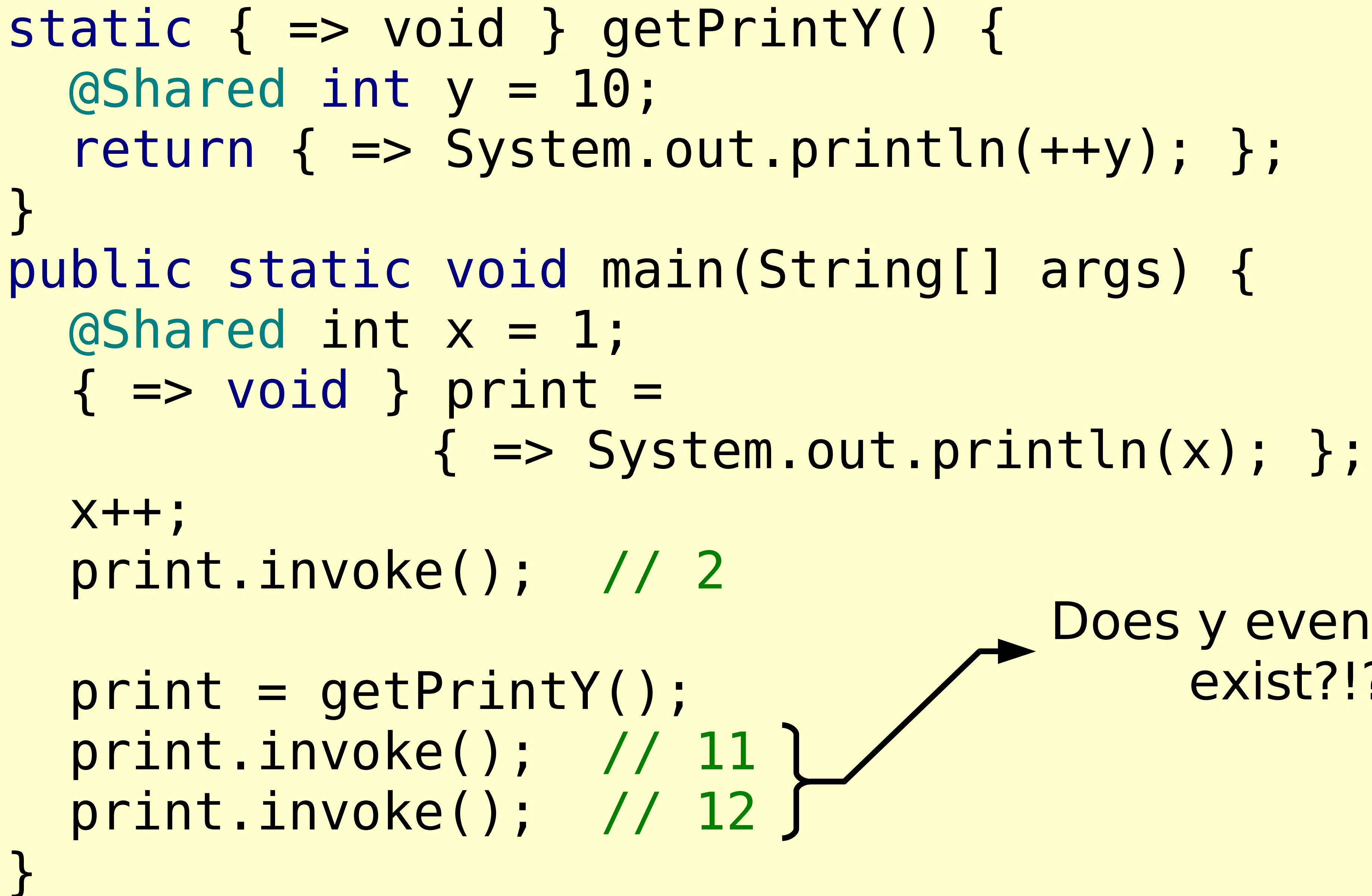
BGGA – Function types hierarchy

```
// { => Integer } is subtype
// of { => Number }
{ => Number } p1;
p1 = { => Integer.valueOf(19) };

// { Object => void } is subtype
// of { String => void }
{ String => void } p2;
p2 = { Object o => System.out.println(o); };
```

Can anyone tell me why?

BGGA – Using shared variables



BGGA – Using compatible interfaces

```
interface Adder {
  int add(int x, int y);
}

/* In some other class' main method: */
Adder adder = { int a, int b => a + b };
int y = adder.add(10, 5);
System.out.println(y);
```

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Are you thinking java.lang.Runnable?

BGGA – Control constructs

```
static void time(String s, { ==> void } f) {
  long t1 = System.nanoTime();
  f.invoke();
  long t = System.nanoTime() - t1;
  System.out.println("Block " + s +
                     " executed in " + t + "ns");
}

public static void main(String[] args) {
  time("block-1") {
    int[] vet = new int[1000];
    for (int i = 0; i < 1000; i++)
      vet[i] = i * i;
  }
}
```

The FCM proposal

- Makes methods 1st class citizens:
  - Methods: `Class#method-name(params);`
  - Constructors: `Class#(params);`
  - Properties: `Class#property-name.`
- Uses reflection under the hood;
- Unlike reflection, visibility rules apply;
- Also adds new type: Method-type
  `#(return-type(param-types) throws exceptions)`
- invoke(), compatible interfaces, anonymous methods (closures).

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FCM – Method literals

```
import java.lang.reflect.*;

public class ExampleFCM {
  String message;

  ExampleFCM(String message) {
    this.message = message;
  }

  void print() {
    System.out.println(message);
  }

  // Continues...
```

FCM – Method literals

```
  // Continued:
  public static void main(String[] args)
                                 throws Exception {
    Constructor<ExampleFCM> constr;
    constr = ExampleFCM#(String);

    ExampleFCM obj;
    obj = constr.newInstance("Hello, FCM!");

    Method method = ExampleFCM#print();
    method.invoke(obj);
  }
}
```

FCM – Bound method references

```
  public static void main(String[] args)
                                    throws Exception {
    // [...]
    ExampleFCM obj;
    obj = constr.newInstance("Hello, FCM!");

    // Before:
    Method method = ExampleFCM#print();
    method.invoke(obj);

    // After:
    Method boundMethod = obj#print();
    boundMethod.invoke();
  }
}
```

FCM – Method-types

```
static int add(int a, int b) {
  return a + b;
}

/* In the main method: */

// Declaring a variable of Method-type
#(int(int, int)) method;
method = ExampleFCM#add(int, int);
System.out.println(method.invoke(10, 5));

// Assigning to a compatible interface.
// Assume same Adder interface shown before.
Adder adder = method;
System.out.println(adder.add(6, 9));
```

FCM – Anonymous methods

```
// Creating an anonymous method.
List<String> list = ...
Collections.sort(list,
               #(String str1, String str2) {
  return str1.length() - str2.length();
});

// With no parameters, parentheses
// can be omitted.
Executor exec = ...
exec.execute(#{
  // Your code here...
});
```

FCM – Java Control Abstraction

```
public static void
          usingFileReader(#(void(FileReader)) block :
          File file) throws IOException {
  FileReader reader = null;
  try {
    reader = new FileReader(file);
    block.invoke(reader);
  }
  finally {
    if (reader != null) {
      try {
        reader.close();
      } catch (IOException e) {
        // Ignore...
      }
  }
} // Continues...
```

FCM – Java Control Abstraction

```
// Continued, somewhere else:
usingFileReader(FileReader reader : file) {
  // Read file...
}
```

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The CICE+ARM proposal

- Java already has closures (anonymous inner classes), we just need some syntactic sugar;
- CICE proposes to simplify AICs syntax:
  - SAM (single abstract method) classes;
  - External variables are automatically final and can be changed if declared public.
- ARM proposes to simplify resource management:
  - Streams, readers/writers, connections... Anything that has to be disposed after use;
  - `java.io.Closable?`

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CICE

```
// Without CICE:
List<String> list = ... ;
Collections.sort(list, new
Comparator<String>() {
  public int compare(String s1, String s2) {
    return s1.length() - s2.length();
  }
});

// With CICE:
List<String> list = ... ;
Collections.sort(list,
  Comparator<String>(String s1, String s2)
{ return s1.length() - s2.length(); });
```

Without ARM

```
BufferedInputStream is1 = null;
BufferedInputStream is2 = null;
try {
  is1 = ...;
  is2 = ...;
  // Use streams for something...
} finally {
  try {
    if (is1 != null)
      is1.close();
  } finally {
    if (is2 != null)
      is2.close();
  }
}
```

With ARM

```
do (BufferedInputStream is1 = ..., is2 = ...)
{
  // Use streams for something...
}
```

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Discussion – Pro-closures arguments

- Closures will:
  - Simplify code and avoid non-elegant solutions;
  - Allow frameworks to specify control constructs;
  - Avoid polluted interfaces* (e.g. could simplify the `java.util.concurrent` API);
  - Closures are complex now as recursive functions were complex some day. For fans of Ruby, Python, Groovy, Scala and C# 2.0, it's not complex anymore...
  - Simplify the evolution of the Java programming language (see for each example).

* see http://gee.cs.oswego.edu/dl/jsr166/dist/jsr166ydocs/jsr166y/forkjoin/Ops.html

Discussion – Anti-closures arguments

- Closures:
  - Are already present in Java in the form of AICs. We just need to simplify the syntax;
  - Are complex by themselves and, if combined with other complex stuff (Generics) becomes too much;
  - Are more related to functional programming and if you mix both programming styles things become nasty;
  - (BGGA) have confusing syntax. { and } are already used with other meanings;
  - Will lead to dialects because of control constructs;
  - Are being added for marketing reasons.

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Discussion

- Joshua Bloch: closures are against the “Feel of Java” (Gosling 1996 talk);
- Gosling says he's misinterpreted the talk. Closures weren't added from the beginning because of time constraints;
- Patrick Naughton confirms Gosling's version, saying that Bill Joy wanted Closures on Java since version 1.0*;
- BGGA has already a draft for a JSR. All authors (except Bloch and Gosling) support it.

* see http://www.blinkenlights.com/classiccmp/javaorigin.html

```
public class ClosuresPuzzler {
  static void test1b({ => void } closure) {
    closure.invoke();
    int x = 20;
    closure.invoke();
    System.out.println(x);
  }
  static void test1() {
    @Shared int x = 10;
    test1b({ => System.out.print((x++) + ", "); });
  }
  static void test2() {
    List<{ => int }> closures = new ArrayList<{ => int }>();
    @Shared int i = 0;
    while (i++ < 10)
      closures.add({ => i });
    int total = 0;
    for ({ => int } c : closures)
      total += c.invoke();
    System.out.println(total);
  }
  public static void main(String[] args) {
    test1();
    test2();
  }
}
```

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