The Joy of Functional Programming

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Functional, isn't that a totally esoteric subject?!

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- ABN AMRO Amsterdam *Risk analysis in investment banking*
- AT&T *Network security: processing of internet abuse complaints*
- Bank of America Merril Lynch
  Backend data transformation and loading
- Barclays Capital Quantitative Analytics Group
  Mathematical modelling of equity derivatives
- Bluespec, Inc. *Modelling & verification of integrated circuits*
- Credit Suisse *Checking, manipulating and transforming spreadsheets*
- Deutsche Bank Equity Proprietary Trading, Directional Credit Trading *All its software infrastructure*
- Facebook *Internal tools*
- Factis Research, Freiburg *Mobile solutions (backend)*
- fortytools gmbh *web-based productivity tools - REST-backend*
- Functor AB, Stockholm *static analysis*

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- Galois, Inc *Security, information assurance and cryptography*
- Google *Internal projects*
- IMVU, Inc. *Social entertainment*
- JanRain *Network and web software*
- MITRE *Analysis of kryptographic protocols*
- New York Times *Image processing for the New York Fashion Week*
- NVIDIA *In-house tools*
- Parallel Scientific *High-availability cluster management system*
- Sankel Software *CAD/CAM, gaming and computer animation*
- Silk, Amsterdam *Filter and visualize large amounts of information*
- Skedge Me *Online scheduling platform*
- Standard Chartered *Wholesale banking business*
- Starling Software, Tokio *Commercial automated options trading system*
- Suite Solutions *Management of large sets of technical documentation*

(Quelle: `http://www.haskell.org/haskellwiki/Haskell_in_industry`)

Well-known functional languages

Scheme

Erlang

Clojure

ML

F#

Miranda

OCaml

Haskell

Lisp

Scala

Well-known functional languages

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(Java 8)

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Immutability

- Each variable can only be assigned to once
- Not directly supported in Java
- Can easily be put into effect:

```
class Point {
  private int x, y;
  public Point (int x, int y) {
    this.x = x;
    this.y = y;
  }
  // only read x and y in the remaining code
}
```

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  - Exceptions
  - Logging
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  - Nondeterminism (e.g. use of a random number generator)
- Some languages even indicate side-effects in the type signature

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```
class SeparationOfSideEffects {

  public void withSideEffect(){
    String initialValue = System.console().readLine();
    String result = withoutSideEffect(initialValue);
    System.out.println("The Result: " + result);
  }

  public static String withoutSideEffect(String initialValue){
    return /* function result */ ;
  }
}
```

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Functions are „first order citizens“

Functions can be treated in the same way as strings or numbers

Functions are values

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Java 8: Static Methods

```
class Examples { static int staticTimes (int x, int y) { return x * y; } }

IntBinaryOperator timesVar = Examples::staticTimes;

timesVar.applyAsInt(3, 5);                         // 15
```

Functions are values

Java 8: Object methods

```
class Examples { int times (int x, int y) { return x * y; } }

Examples examples = new Examples();
IntBinaryOperator timesVar = examples::times;

timesVar.applyAsInt(3, 5);                    // 15
```

Functions are values

Java 8: Lambdas

```
IntBinaryOperator times = (x, y) -> x * y;

times.applyAsInt(3, 5);                          // 15
```

Functions are values

Java 8: Lambdas (with self-defined function interface)

```
interface TimesFunction { int eval(int x, int y); }

TimesFunction times = (x, y) -> x * y;

times.eval(3, 5);                                    // 15
```

Functions are values

Java 8: Lambdas (with self-defined function interface)

```
interface TimesFunction { int eval(int x, int y); }

TimesFunction times = (x, y) -> x * y;

times.eval(3, 5);                                    // 15
```

Haskell:

```
times x y = x * y

timesVar = times

timesVar 3 5                                        -- 15
```

Functions are function parameters

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Java 8:

```
class Examples {
    static int apply(IntUnaryOperator func, int arg) {
        return func.applyAsInt(arg);
    }
}

Examples.apply(x -> 3 * x, 5);                 // 15
```

Functions are function parameters

Java 8:

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class Examples {
    static int apply(IntUnaryOperator func, int arg) {
        return func.applyAsInt(arg);
    }
}

Examples.apply(x -> 3 * x, 5);                    // 15
```

Haskell:

```
apply func arg = func arg

apply (\ x -> 3 * x) 5                            -- 15
```

Functions are return values

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Java 8:

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interface FunctionFunction { IntUnaryOperator eval(int x); }

FunctionFunction times = x -> { return y -> x * y; };

times.eval(3).applyAsInt(5);                    // 15
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Haskell:

```
times x = (\y -> x * y)

times 3 5                                       -- 15
```

Strange... ?!

Java 8: Two different invocations

```
IntBinaryOperator times = (x, y) -> x * y;
times.applyAsInt(3, 5);                                   // 15

FunctionFunction times = x -> { return y -> x * y; };
times.eval(3).applyAsInt(5);                              // 15
```

Haskell: Two identical invocations

```
times x y = x * y
times 3 5                                                 -- 15

times x = (\y -> x * y)
times 3 5                                                 -- 15
```

Currying! (also known as Schönfinkeling)

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In some functional languages we write:

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but actually the following happens:

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times x = (\y -> x * y)
```

Because functions always take exactly one argument

Useful for partial evaluation:

```
times x y = x * y

times3 = times 3

times3 5                          -- 15
```

Important library functions: filter

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Java 8:

```
Stream<Integer> filteredStream =
        asList(1, 2, 3, 4).stream().filter(x -> x % 2 == 0);

filteredStream.toArray();                             // new Integer[]{2, 4}
filteredStream.collect(Collectors.toList());          // Liste mit 2 und 4
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Haskell:

```
filter (\x -> x `mod` 2 == 0) [1,2,3,4]                         -- [2,4]
```

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                                                  // new Integer[]{6, 7, 8, 9}
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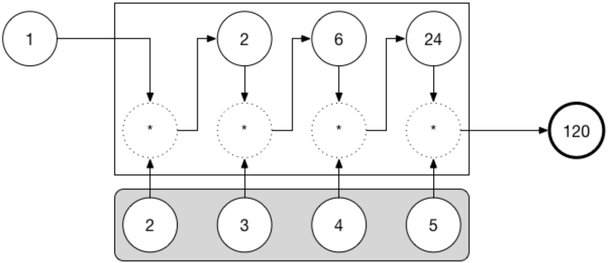
- Takes a collection, a function and an initial value
- Merges initial value and first collection entry using the function
- Merges the result and the next collection entry
- Continues for all collection entries, yielding a single result

Important library functions: reduce

- reduce or foldl / foldr or inject

Java 8:

```
Arrays.asList(2, 3, 4, 5).stream().reduce(1, (x, y) -> x*y);        // 120
```



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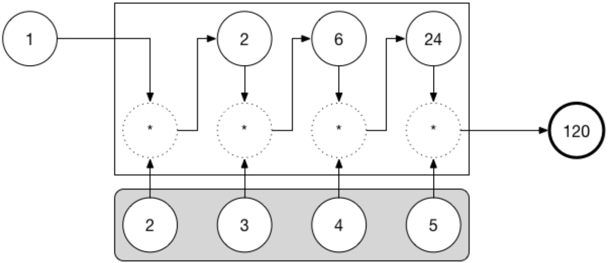
Haskell:

```
foldl (*) 1 [2,3,4,5]                                                 -- 120
```



Type Inference

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Type:

```
f :: a -> a
```

a : Type variable (comparable to generics in Java etc.)
-> Function type (argument type to the left, result type to the right)

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```
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`Num a` : Type class: Restricts the type variable a to numerical types

Recommended: Always annotate type signature! Helps to validate your assumptions.

A simple calculation

$$sum = \sum_{i=1}^{10} i^2$$

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int sum = 0;
for(int i = 1; i <= 10; i++) {
  sum = sum + i * i;
}
```

Excursion: Clean Code

Single Responsibility Principle

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```
IntStream squaredSequence = sequence.map(square);
```

- Calculating the sum of two numbers

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```
Integer sum = squaredSequence.reduce(0, add);
```

Combining the components

Java 8:

```
IntStream.rangeClosed(1, 10).map(x -> x*x).reduce(0, (x,y) -> x+y);  // 385
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foldl (+) 0 (map (\x -> x*x) [1..10])                                 -- 385
```

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```

Haskell:

```
foldl (+) 0 (map (\x -> x*x) [1..10])                                -- 385
```

or

```
(>.>) x f = f x
[1..10] >.> map (\x -> x*x) >.> foldl (+) 0                          -- 385
```

Phew!

OK, everybody take a deep breath :-)

Pattern Matching

Fibonacci-Function „naïve“:

```
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Fibonacci-Function with Pattern Matching:

```
fib 0 = 0
fib 1 = 1
fib x = fib (x-1) + fib (x-2)
```

Algebraic Datatypes

Binary tree:

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data Tree =
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      | Leaf Int
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myTree = Node (Node (Leaf 4) (Node (Leaf 7) (Leaf 1))) (Leaf 3)
```

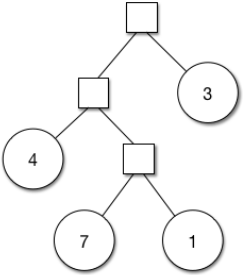

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Summary function:

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```
treeSum myTree                                   -- 15
```

Bottom line

- Functional programming is more common than you may have expected
- Some of it can be integrated into non-functional coding
- Many languages have functional aspects or additional modules

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Reference:

- Haskell: `http://www.haskell.org`

Thank you very much!

Code & slides on GitHub:

`https://github.com/NicoleRauch/FunctionalProgrammingForBeginners`

Nicole Rauch

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