

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 Merrill 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*

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

- ▶ 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

A scatter plot showing the distribution of well-known functional programming languages. The languages are plotted as text labels on a white background. The languages included are Scheme, Erlang, Clojure, ML, F#, Miranda, OCaml, Haskell, (Java 8), Lisp, Scala, and (JavaScript).

Language	Approximate X-Coordinate	Approximate Y-Coordinate
Scheme	10	30
Erlang	45	25
Clojure	75	25
ML	30	35
F#	55	35
Miranda	10	50
OCaml	85	50
Haskell	40	60
(Java 8)	60	60
Lisp	10	80
Scala	30	80
(JavaScript)	60	80

Well-known functional languages

Scheme Erlang Clojure
ML F#
Miranda OCaml
Haskell
Lisp Scala (JavaScript)

Now, what is so special about functional programming?

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Immutability

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Functions are „first order citizens“

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Immutability

Each variable can only be assigned to once

Functions are „first order citizens“

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

Functions are values

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JavaScript:

```
function times(x, y) { return x * y; }
```

```
var timesVar = times;
```

```
timesVar(3, 5) === 15;
```

Functions are values

JavaScript:

```
function times(x, y) { return x * y; }  
  
var timesVar = times;  
  
timesVar(3, 5) === 15;
```

Haskell:

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

Functions are function parameters

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JavaScript:

```
function times3(y) { return 3 * y; };  
  
function apply(func, arg) { return func(arg); }  
  
apply(times3, 5) === 15;
```

Functions are function parameters

JavaScript:

```
function times3(y) { return 3 * y; };  
  
function apply(func, arg) { return func(arg); }  
  
apply(times3, 5) === 15;
```

Haskell:

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

Functions are return values

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JavaScript:

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function times(x) { return function (y) { return x * y; }; }  
  
times(3)(5) === 15;
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```
function times(x) { return function (y) { return x * y; }; }  
  
times(3)(5) === 15;
```

Haskell:

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

Strange... ?!

JavaScript: Two different invocations

```
function times(x, y) { return x * y; }  
times(3, 5) === 15;
```

```
function times(x) { return function (y) { return x * y; }; }  
times(3)(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 real functional languages we write:

```
times x y = x * y
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but actually the following happens:

```
times x = (\y -> x * y)
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Because functions always take exactly one argument

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In real functional languages we write:

```
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but actually the following happens:

```
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
```

And what if I don't want an argument?

- ▶ In real functional languages, functions always take exactly one argument!
- ▶ What if I don't want to pass anything?

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- ▶ In real functional languages, functions always take exactly one argument!
- ▶ What if I don't want to pass anything?
- ▶ Unit to the rescue!
- ▶ Unit is a type with only one element
- ▶ In Haskell, this element is called `()`

Important library functions: filter

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JavaScript: (using the lodash-library)

```
_.filter([1, 2, 3, 4], function (x) { return x % 2 === 0; }) === [2, 4]
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Important library functions: filter

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JavaScript: (using the lodash-library)

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_.filter([1, 2, 3, 4], function (x) { return x % 2 === 0; }) === [2, 4]
```

Haskell:

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


Important library functions: map

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JavaScript:

```
_.map( [1, 2, 3, 4], function (x) { return x + 5; } ) === [6, 7, 8, 9]
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Important library functions: fold

- ▶ fold or reduce or inject

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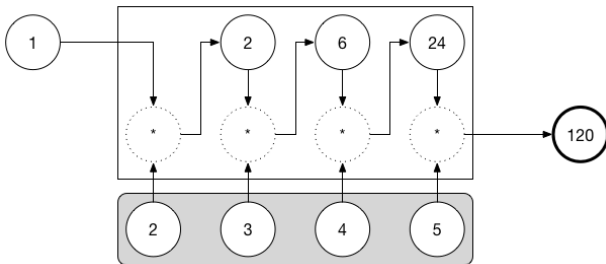
- ▶ fold or reduce or inject
- ▶ Takes a collection, a function and an initial value
- ▶ Merges initial value and first collection entry using the function
- ▶ Merges the result and the next collection entry
- ▶ Continues for all collection entries, yielding a single result

Important library functions: fold

- fold or reduce or inject

JavaScript:

```
_.foldl( [2, 3, 4, 5], function (x, y) { return x * y; }, 1 ) === 120
```



Important library functions: fold

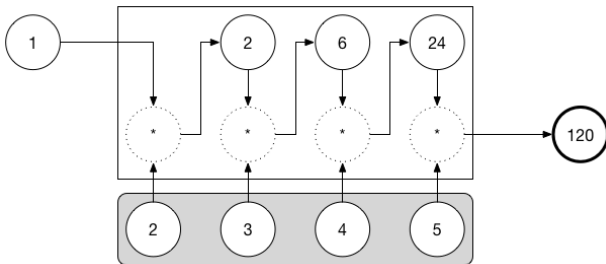
- fold or reduce or inject

JavaScript:

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_.foldl( [2, 3, 4, 5], function (x, y) { return x * y; }, 1 ) === 120
```

Haskell:

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



Type inference

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- ▶ Lightweight usage thanks to type inference
- ▶ Derivation of the most general type

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```
foldl :: (a -> b -> a) -> a -> [b] -> a
```

```
(*) :: Num a => a -> a -> a
```

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

Type inference

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- ▶ Lightweight usage thanks to type inference
- ▶ Derivation of the most general type

```
foldl :: (a -> b -> a) -> a -> [b] -> a
(*) :: Num a => a -> a -> a

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

Compile error for:

```
foldl  (*) "x" [2,3,4,5]
```

No instance for (Num [Char]) arising from a use of `*'
Possible fix: add an instance declaration for (Num [Char])

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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How many responsibilities does this code have?

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- ▶ Calculating the sum of two numbers

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- ▶ Calculating the square of each number in the sequence
- ▶ Calculating the sum of two numbers
- ▶ Calculating the sum of all squares

Separation of Concerns

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Separation of Concerns

- ▶ Creating the sequence of numbers from 1 to 10

```
var sequence = _.range(1, 11);
```

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- ▶ Calculating the square of each number in the sequence
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- ▶ Creating the sequence of numbers from 1 to 10

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- ▶ Calculating the square of each number in the sequence

```
var squaredSequence = _.map(sequence, square)
```

- ▶ Calculating the sum of two numbers

- ▶ Calculating the sum of all squares

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```
var add = function (s1, s2) { return s1 + s2; };
```

- ▶ Calculating the sum of all squares

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- ▶ Creating the sequence of numbers from 1 to 10

```
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- ▶ Calculating the square of a number

```
var square = function (i) { return i * i; };
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```

- ▶ Calculating the sum of two numbers

```
var add = function (s1, s2) { return s1 + s2; };
```

- ▶ Calculating the sum of all squares

```
var sum = _.reduce(squaredSequence, add);
```

Combining the components

JavaScript:

```
var square = function (i) { return i * i; };  
var add = function (s1, s2) { return s1 + s2; };
```

```
_.reduce(_.map(_.range(1, 11), square), add) === 385;
```

Combining the components

JavaScript:

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var square = function (i) { return i * i; };  
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```

```
_.reduce(_.map(_.range(1, 11), square), add) === 385;
```

or

```
_(1).range(11).map(square).reduce(add) === 385;
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JavaScript:

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_(1).range(11).map(square).reduce(add) === 385;
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Haskell:

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

Combining the components

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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“:

```
fib x = if x < 2 then x else fib (x-1) + fib (x-2)
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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:

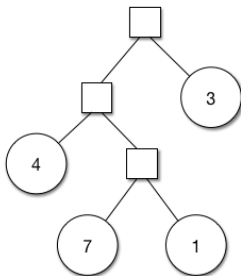
```
data Tree =  
    Node Tree Tree  
  | Leaf Int
```

Algebraic Datatypes

Binary tree:

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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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Summary function:

```
treeSum (Leaf x) = x
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Summary function:

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treeSum (Leaf x) = x  
treeSum (Node m n) = treeSum m + treeSum n
```

```
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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References:

- ▶ Functional JS-Library: <http://ramdajs.com>
- ▶ Haskell: <http://www.haskell.org>

Thank you very much!

Code & slides on GitHub:

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

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