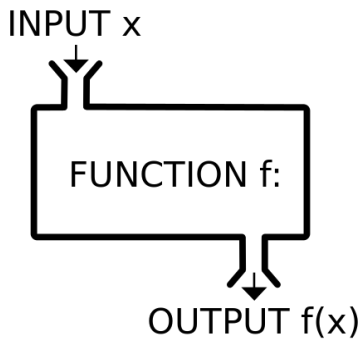
Functional Programming



Functions II

Christoph Denzler / Daniel Kröni
University of Applied Sciences Northwestern Switzerland
Institute for Mobile and Distributed Systems

Learning Targets

You

- know the concept of currying
- understand how partial application relates to currying
- are able to apply lambda expressions
- know how to define and use operators
- can compose functions

Content

- Currying / Partial Application
- Lambda Expressions
- Function Composition
- Operators

Functions with Multiple Parameters

- **Every function in Haskell takes only one parameter**

```
add :: Int -> Int -> Int
add a b = a + b
```

- **The function type arrow '->' associates to the right**

```
add :: (Int -> (Int -> Int))
```

```
add :: ((Int -> Int) -> Int)
```

  – The function add takes a single `Int` parameter
  and returns a function which accepts another `Int` parameter
  and which finally returns a result of type `Int`

- **Function application associates to the left**

```
add 1 2 == ((add 1) 2)
```

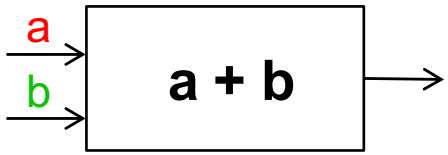
```
(add (1 2))
```

- **These two rules allow for concise function application syntax**

Partial Application

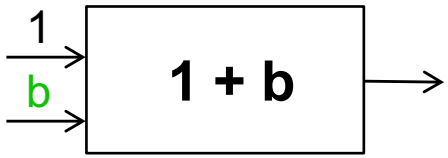
- **Applying add to zero arguments**

```
Prelude>  :t add
add  :: Int -> Int -> Int
```



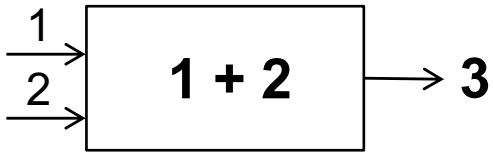
- **Applying add to the first argument**

```
Prelude>  :t add 1
add 1 :: Int -> Int
```



- **Applying add to both arguments**

```
Prelude>  :t (add 1) 2
(add 1) 2 :: Int
```



- **Functions are values an can be bound to a name**

```
inc  :: Int -> Int
inc  = add 1
```

Worksheet: Currying

Lambda Expressions

- **The following function definition does two things**

```
inc x = x + 1
```

  - It constructs a function: The function which adds one to its argument
  - It binds the name 'inc' to this function
- **These two things are conceptually independent of each other**
- **Many reasons to bind names to values (functions are values btw.)**
  - The value is referred to more than once
  - The value is recursively used in its own declaration
  - The value needs a type signature

Lambda Expressions

- **But not everything needs a name**

```
inc x = x + one
one = 1
```

  – There is no good reason for naming the value 1

- **What about functions which are used only once**

```
incAll :: [Int] -> [Int]
incAll xs = map inc xs

inc :: Int -> Int
inc x = x + 1
```

  – There is no good reason for naming the increment function

- **We want the functionality without the name**

```
incAll :: [Int] -> [Int]
incAll xs = map (\x -> x + 1) xs
```

Lambda Expressions

- **Functions can be defined anonymously**

```
\x -> x + 1
```

- **This is called a lambda expression**
- **General form**

```
\p -> e
```

parameter / pattern

result, defined in terms of parameter

- **Translation**

```
\p1 ... pn -> e
```

==

```
\x1 -> ... -> \xn =
   case (x1, ... ,xn)
     of (p1, ... ,pn) -> e
```

Lambda Expressions and Currying

- **All four functions have the same type**

```
prod1, prod2, prod3, prod4 :: Int -> Int -> Int -> Int
```

```
prod1 x y z = x * y * z
prod2 x y   = \z -> x * y * z
prod3 x     = \y -> \z -> x * y * z
prod4       = \x -> \y -> \z -> x * y * z
```

  – Actually the definitions of prod1, prod2 and prod3 all get translated to prod4 by the compiler.

Lambda Expressions in Java 8

LambdaTest.java

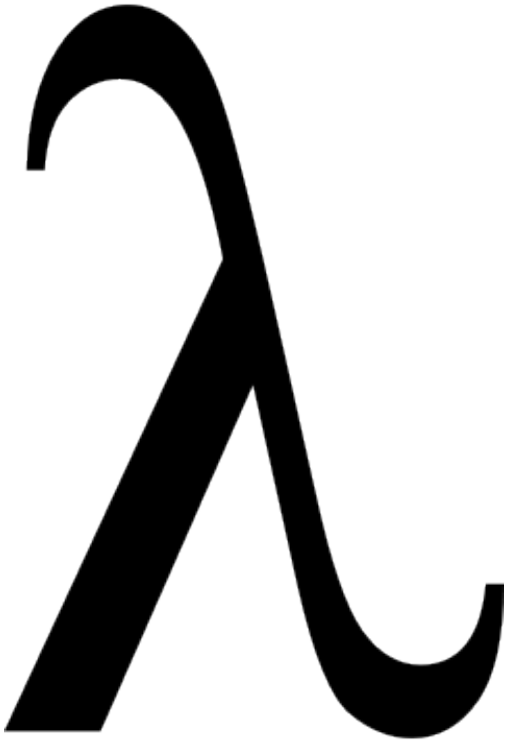
```java
package lambda;

import java.util.Arrays;
import java.util.List;

public class LambdaTest {

    public static void main(String[] args) {
        List<String> list = Arrays.asList("abcd", "ef", "abc");

        list.stream().filter(s -> s.length() >= 3)
                     .map(s -> s.toUpperCase())
                     .forEach(s -> System.out.println(s));
    }
}
```

http://jdk8.java.net/lambda/

News zu **lambda**

Code statt Wiesn: München lernt **Lambda**-Ausdrücke kennen
JAXenter - vor 18 Stunden
Lambda-Expressions begeistern die deutsche Entwickler-Gemeinde.

Worksheet: Lambda Expressions



HOFs : Higher-Order Functions

- **A function can return another function as its result**

```
add :: Int -> Int -> Int
```

==

```
add :: Int -> (Int -> Int)
```

- **A function can also take another function as its argument**

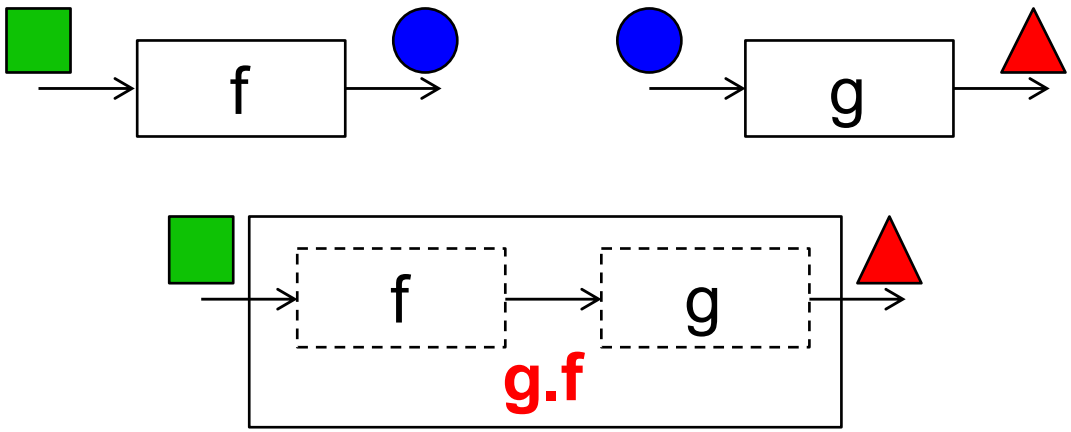
```
filter :: (a -> Bool) -> [a] -> [a]
```

  – First parameter is a function from a -> Bool

- **Functions are just values! They can be**
  – input and output to functions
  – put into and retrieved from data structures
- **Functions that have functions as input and/or output are called higher-order functions**

Function Composition: Pipelines of functions

- **Functions can be combined into pipelines if the types line up**



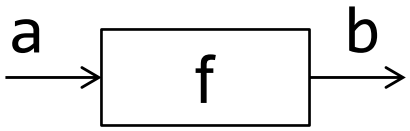
- **Function composition of two functions takes the output of one function as the input of a second one.**
- **The argument order origins from mathematics g(f(x))**
  - First apply f to x and then apply g to the result: g followed by f

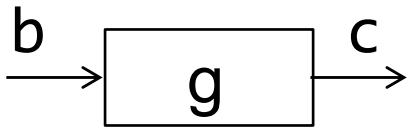
Function Composition: Pipelines of functions

- **Functions can be combined into pipelines if the types line up**

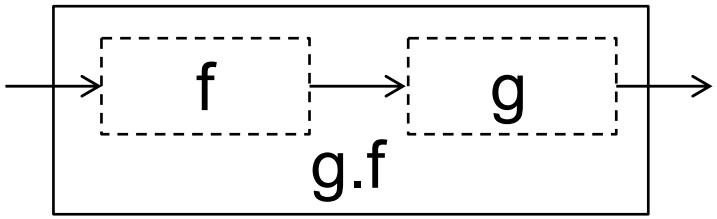
```
f :: a -> b
```

```
g :: b -> c
```






```
(.) :: (b -> c) -> (a -> b) -> a -> c
g . f = \x -> g (f x)
```




```
map (\xs -> negate (sum (tail xs))) [[1,2,3],[4,5,6],[7,8]]
```

```
map (negate . sum . tail) [[1,2,3],[4,5,6],[7,8]]
```

Operators

- **Function names start with a lower case letter ['a'..'z']**
  - Function names are written in front of their arguments (prefix)

```
add :: Int -> Int -> Int
add a b = a + b
```

```
add 1 2 ~> 3
```

- **Operator symbols are formed form one or more symbol characters `!#$%&*+./<=>?@\^|-~`** Haskell 2010 Report §2.4
  - Operator symbols are written between its arguments (infix)

```
(!+!) :: Int -> Int -> Int
a !+! b = a + b
```

```
1 !+! 2 ~> 3
```

Operators

- **An Operator can be used as a function by wrapping it with parentheses (op)**

```
Prelude>  :t (+)
(+) :: Num a => a -> a -> a
Prelude> (+) 1 2
3
```

- **A function can be used as an operator by quoting it with backticks `fun`** (not to be confused with ')

```
Prelude>  :t div
div :: Integral a => a -> a -> a
Prelude> 9 `div` 2
4
```

- The syntax changes but the semantics (meaning) remains the same

Sections

- **Infix operators can be partially applied as well.**
  - This is called a section
  - The parentheses are mandatory

```
(2+) is interpreted as \y -> 2+y
(+3) is interpreted as \x -> x+3
```

- **If the operator is applied to no argument at all haskell essentially treats an infix operator as an equivalent functional value.**

```
(+)  = \x y -> x+y
```

Operator Precedence

- **Operators have a defined precedence**

```
1 + 2 * 3 == 1 + (2 * 3)
```

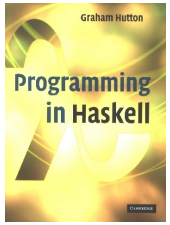
```
not: (1 + 2) * 3
```

- **This can be defined using a fixity declaration**
  - Declares a precedence level from 0 to 9 (with 9 being the strongest)
    - Normal function application is assumed to have a precedence level of 10
  - Specifies the operator to be
    - left-associative: infixl righ-associative: infixr
    - non-associative: infix

```
Prelude> :info (+)
class Num a where
  (+) :: a -> a -> a
  ...
infixl 6 +
```

```
Prelude> :info (*)
class Num a where
  (*) :: a -> a -> a
  ...
infixl 7 *
```

Further Reading



Chapter 3

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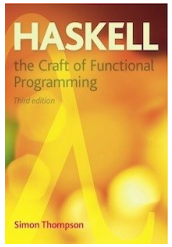

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