Week 1: Getting Started with Haskell

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CWI

September 5, 2011

A short history of Haskell

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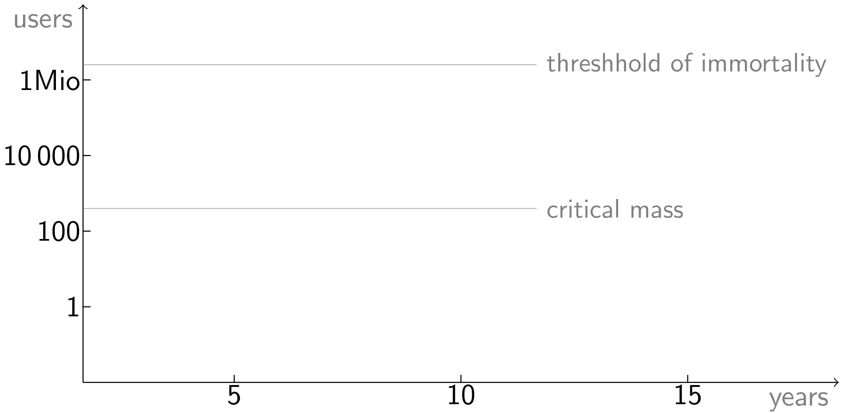
In the 80s, efforts of researchers working on functional programming were scattered across many languages (Lisp, SASL, Miranda, ML,. . .).
In 1987 a dozen functional programmers decided to meet in order to reduce unnecessary diversity in functional programming languages by **designing a common language** that is

- based on ideas that enjoy a wide consensus
- suitable for further language research as well as applications, including building large systems
- freely available

A short history of Haskell

In 1990, they published the first **Haskell** specification, named after the logician and mathematician Haskell B. Curry (1900-1982).

Simon Peyton-Jones: The life cycle of programming languages



Simon Peyton-Jones: The life cycle of programming languages

Most research languages (the quick death)

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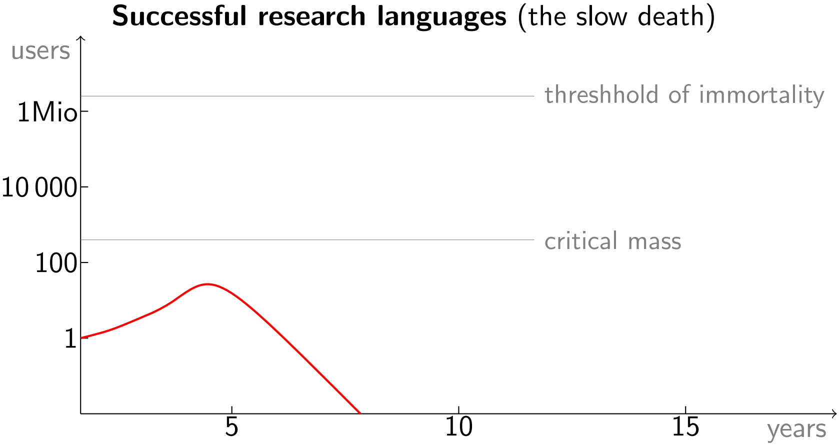
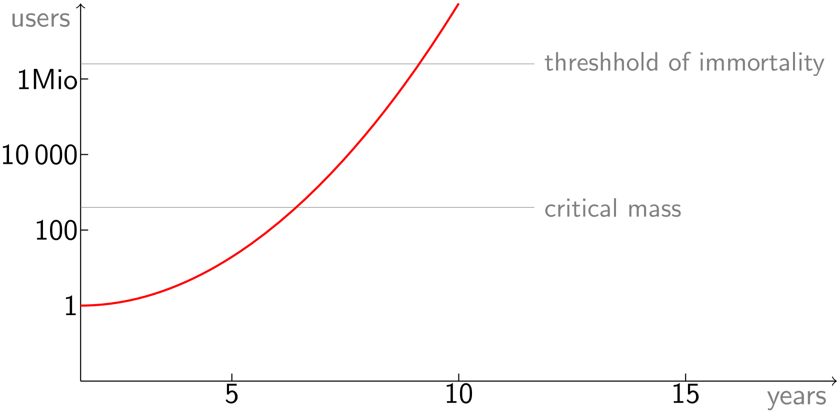


Simon Peyton-Jones: The life cycle of programming languages

C++, Java, Perl (the absence of death)



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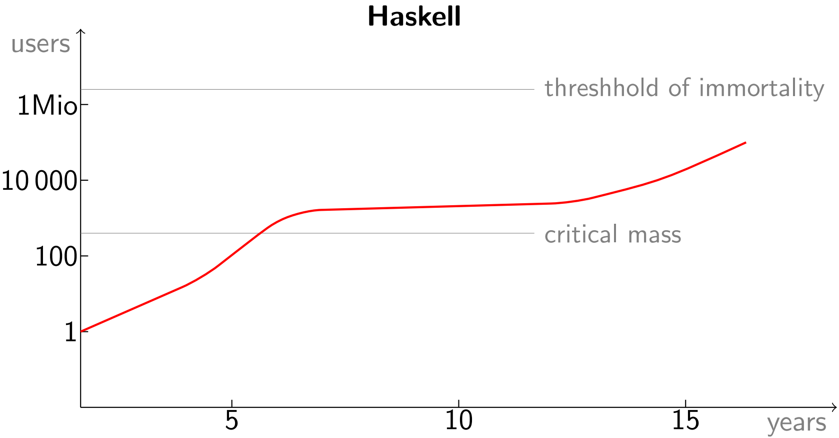

Haskell is functional

A program consists entirely of functions.

- The main program itself is a function with the program's input as argument and the program's output as result.
- Typically the main function is defined in terms of other functions, which in turn are defined in terms of still more functions, until at the bottom level the functions are language primitives.

Running a Haskell program consists in evaluating expressions (basically functions applied to arguments).

A shift in thinking

Imperative thinking:

- Variables are pointers to storage locations whose value can be updated all the time.
- You give a sequence of commands telling the computer what to do step by step.

Examples:

- initialize a variable `examplelist` of type integer list, then add 1, then add 2, then add 3
- in order to compute the factorial of n, initialize an integer variable `f` as 1, then for all `i` from 1 to n, set `f` to `f`$\times$`i`

A shift in thinking

Functional thinking:

- Variables are identifiers for an immutable, persistent value.
- You tell the computer what things are.

Examples:

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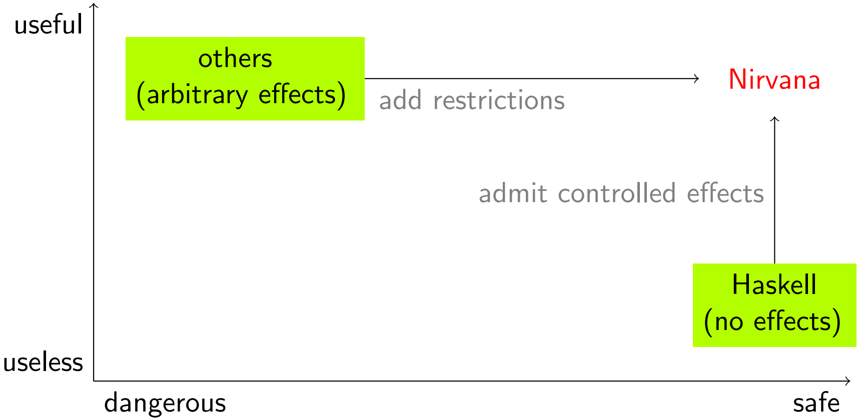
```
factorial :: Int -> Int
factorial n = product [1..n]
```

A shift in thinking

Stop thinking in variable assignments, sequences and loops.
Start thinking in functions, immutable values and recursion.

Haskell is pure: Safety vs power



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- Your Haskell understanding will influence the way you look at programming: you will start to appreciate abstraction.
- Haskell comes with great tools for automated test generation: a tool we will study is QuickCheck.

Resources

- **For everything Haskell-related:** `haskell.org`.
- **Tutorials:**
  - Chapter 1 of “The Haskell Road”
  - Real World Haskell
    `book.realworldhaskell.org/read/`
  - Learn you a Haskell for great good
    `learnyouahaskell.com`
  - A gentle introduction to Haskell
    `haskell.org/tutorial`

Getting started

Get the Haskell Platform:

- `http://hackage.haskell.org/platform/`

This includes the Glasgow Haskell Compiler (GHC) together with standard libraries and the interactive environment GHCi.

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GHCi, version 6.12.3: http://www.haskell.org/ghc/  :? for help
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GHCi can be used to interactively evaluate expressions.

```
Prelude> 2 + 3
Prelude> 2 + 3 * 4
Prelude> 2^10
Prelude> (42 - 10) / 2
```

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4. With `:t` you can ask GHCi about the type of an expression.
5. Leave the interactive environment with `:q`.

Some Simple Examples

```
module Week1

where

import Data.List
import Data.Char
```

Sentences can go on . . .

Sentences can go on

Sentences can go on . . .

Sentences can go on and on

Sentences can go on . . .

Sentences can go on and on and on

Sentences can go on . . .

Sentences can go on and on and on and on

Sentences can go on . . .

Sentences can go on and on and on and on and on

Sentences can go on . . .

Sentences can go on and on and on and on and on and on

Sentences can go on . . .

Sentences can go on and on and on and on and on and on and on

Sentences can go on ...

Sentences can go on and on and on and on and on and on and on

```
gen :: Int -> String
gen 0 = "Sentences can go on"
gen n = gen (n-1) ++ " and on"

genS :: Int -> String
genS n = gen n ++ "."
```

A lazy list

```
sentences = "Sentences can go " ++ onAndOn

onAndOn = "on and " ++ onAndOn
```

Lambda Abstraction in Haskell

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- The result, the squared number, also has type `Int`.
- The function `sqr` is a function that, when combined with an argument of type `Int`, yields a value of type `Int`.
- This is precisely what the type-indication `Int -> Int` expresses.

String Functions in Haskell

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The types:

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Prelude> :t (\ x -> x ++ " emeritus")
\x -> x ++ " emeritus" :: [Char] -> [Char]
Prelude> :t "professor"
"professor" :: String
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The type indicates that (++) not only concatenates strings. It works for lists in general.

More String Functions in Haskell

```
Prelude> (\ x -> "nice " ++ x) "guy"
"nice guy"
Prelude> (\ f -> \ x -> "very " ++ (f x))
                (\ x -> "nice " ++ x) "guy"
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- Examples of strings are `"Turing"` and `"Chomsky"` (note the double quotes).
- In fact, `"Chomsky"` can be seen as an abbreviation of the following character list:

  `['C','h','o','m','s','k','y']`.

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- The operation combines an object of type `a` with a list of objects of the same type to a new list of objects, again of the same type.

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- the list pattern `(x:xs)` matches any non-empty list.

List Reversal

CHOMSKY
GNIRUT

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Reversal works for any list, not just for strings.

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Note that the name of a type always starts with a capital letter.
To denote arbitrary types, Haskell allows the use of *type variables*. For these, `a`, `b`, . . . , are used.

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- By function definition: `a -> b` is the type of a function that takes arguments of type `a` and returns values of type `b`.
- By defining your own datatype from scratch, with a `data` type declaration. More about this in due course.

Mapping

If you use the Hugs command `:t` to find the types of the function `map`, you get the following:

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map :: forall a b. (a -> b) -> [a] -> [b]
```

The function `map` takes a function and a list and returns a list containing the results of applying the function to the individual list members.

Mapping

If you use the Hugs command `:t` to find the types of the function `map`, you get the following:

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The function `map` takes a function and a list and returns a list containing the results of applying the function to the individual list members.
If `f` is a function of type `a -> b` and `xs` is a list of type `[a]`, then `map f xs` will return a list of type `[b]`. E.g., `map (^2) [1..9]` will produce the list of squares

```
[1, 4, 9, 16, 25, 36, 49, 64, 81]
```

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- Thus `(2^)` is the operation that computes powers of 2, and `map (2^) [1..10]` will yield

  `[2, 4, 8, 16, 32, 64, 128, 256, 512, 1024]`

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- `(op)` is the prefix version of the operator.
- Thus `(2^)` is the operation that computes powers of 2, and `map (2^) [1..10]` will yield

  `[2, 4, 8, 16, 32, 64, 128, 256, 512, 1024]`
- Similarly, `(>3)` denotes the property of being greater than 3, and `(3>)` the property of being smaller than 3.

Map

If p is a property (an operation of type `a -> Bool`) and `l` is a list of type `[a]`, then `map p l` will produce a list of type `Bool` (a list of truth values), like this:

```
Prelude> map (>3) [1..6]
[False, False, False, True, True, True]
Prelude>
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map :: (a -> b) -> [a] -> [b]
```

```
map f [] = []
map f (x:xs) = (f x) : map f xs
```

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A function for filtering out the elements from a list that satisfy a given property.

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```

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

```
filter p [] = []
filter p (x:xs) | p x       = x : filter p xs
                | otherwise =     filter p xs
```

List comprehension

List comprehension is defining lists by the following method:

```
[ x | x <- xs, property x ]
```

This defines the sublist of `xs` of all items satisfying `property`. It is equivalent to:

```
filter property xs
```

Examples

```
someEvens     = [ x | x <- [1..1000], even x ]

evensUntil n = [ x | x <- [1..n], even x ]

allEvens      = [ x | x <- [1..], even x ]
```

Examples

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someEvens     = [ x | x <- [1..1000], even x ]

evensUntil n = [ x | x <- [1..n], even x ]

allEvens      = [ x | x <- [1..], even x ]
```

Equivalently:

```
someEvens     = filter even [1..1000]

evensUntil n = filter even [1..n]

allEvens      = filter even [1..]
```

Nub

`nub` removes duplicates, as follows:

```
nub :: Eq a => [a] -> [a]
nub [] = []
nub (x:xs) = x : nub (filter (/= x) xs)
```

Function Composition

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- Haskell implementation:

```
(.) :: (a -> b) -> (c -> a) -> (c -> b)
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- Note the types!

elem, all, and

```
elem :: Eq a => a -> [a] -> Bool
elem x []     = False
elem x (y:ys) = x == y || elem x ys
```

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all :: Eq a => (a -> Bool) -> [a] -> Bool
all p = and . map p
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Note the use of `.` for function composition.

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elem x []      = False
elem x (y:ys) = x == y || elem x ys

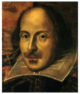
all :: Eq a => (a -> Bool) -> [a] -> Bool
all p = and . map p
```

Note the use of . for function composition.

```
and :: [Bool] -> Bool
and [] = True
and (x:xs) = x && and xs
```

Sonnet 73

```
sonnet73 =
 "That time of year thou mayst in me behold\n"
 ++ "When yellow leaves, or none, or few, do hang\n"
 ++ "Upon those boughs which shake against the cold,\n"
 ++ "Bare ruin'd choirs, where late the sweet birds sang.\n"
 ++ "In me thou seest the twilight of such day\n"
 ++ "As after sunset fadeth in the west,\n"
 ++ "Which by and by black night doth take away,\n"
 ++ "Death's second self, that seals up all in rest.\n"
 ++ "In me thou see'st the glowing of such fire\n"
 ++ "That on the ashes of his youth doth lie,\n"
 ++ "As the death-bed whereon it must expire\n"
 ++ "Consumed with that which it was nourish'd by.\n"
 ++ "This thou perceivest, which makes thy love more strong,\n"
 ++ "To love that well which thou must leave ere long."
```



Counting

```
count :: Eq a => a -> [a] -> Int
count x []                   = 0
count x (y:ys) | x == y      = succ (count x ys)
               | otherwise = count x ys
```

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count x []                   = 0
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```

```
average :: [Int] -> Rational
average [] = error "empty list"
average xs = toRational (sum xs) / toRational (length xs)
```

Some Commands to Try Out

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- `putStrLn sonnet73`

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- `map toUpper sonnet73`
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- `count ’t’ (map toLower sonnet73)`

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- `count ’t’ (map toLower sonnet73)`
- `count "thou" (words sonnet73)`

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- `count "thou" (words sonnet73)`
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Next, attempt the programming exercises from Chapter 1 and 2 of “The Haskell Road”.