Haskell
Functional Programming

http://igm.univ-mlv.fr/~vialette/?section=teaching

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Everybody's talking about functional programming

Lisp

Lisp (historically, LISP) is a family of computer programming languages with a long history and a distinctive, fully parenthesized prefix notation. Originally specified in 1958, Lisp is the second-oldest high-level programming language in widespread use today. (Only Fortran is older, by one year.)

Everybody's talking about functional programming

Erlang

Erlang (`https://www.erlang.org/`) is a general-purpose, concurrent, functional programming language, as well as a garbage-collected runtime system.

Everybody's talking about functional programming

Elixir

Elixir (`https://elixir-lang.org/`) is a functional, concurrent, general-purpose programming language that runs on the Erlang virtual machine (BEAM).

Everybody's talking about functional programming

F#

F# (`http://fsharp.org/` is a strongly typed, multi-paradigm programming language that encompasses functional, imperative, and object-oriented programming methods. It is being developed at Microsoft Developer Division and is being distributed as a fully supported language in the .NET framework.

Everybody's talking about functional programming

Ocaml

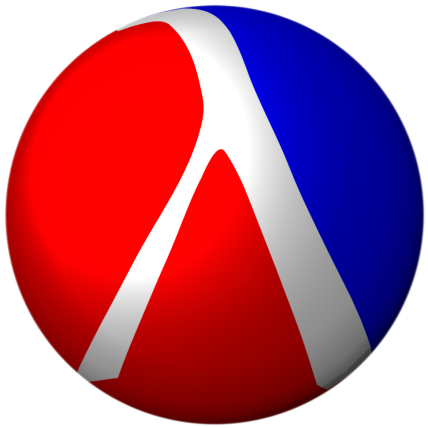
Ocaml (`http://ocaml.org/` originally named Objective Caml, is the main implementation of the programming language Caml. OCaml's toolset includes an interactive top-level interpreter, a bytecode compiler, a reversible debugger, a package manager (OPAM), and an optimizing native code compiler.

Everybody's talking about functional programming

Clojure

Clojure (`https://clojure.org/`) is a dialect of the Lisp programming language. Clojure is a general-purpose programming language with an emphasis on functional programming. It runs on the Java virtual machine and the Common Language Runtime.

Everybody's talking about functional programming



Racket

Racket (`http://racket-lang.org/`), formerly PLT Scheme, is a general purpose, multi-paradigm programming language in the Lisp-Scheme family. One of its design goals is to serve as a platform for language creation, design, and implementation

Everybody's talking about functional programming

Elm

Elm (`http://elm-lang.org/`) is a domain-specific programming language for declaratively creating web browser-based graphical user interfaces. Elm is purely functional, and is developed with emphasis on usability, performance, and robustness.

Everybody's talking about functional programming

Scala

Scala (`https://www.scala-lang.org/`) is a general-purpose programming language providing support for functional programming and a strong static type system. Designed to be concise, many of Scala's design decisions aimed to address criticisms of Java.

Everybody's talking about functional programming

Haskell

Haskell (`https://www.haskell.org/`) is a standardized, general-purpose purely functional programming language, with non-strict semantics and strong static typing. The latest standard of Haskell is Haskell 2010. As of May 2016, a group is working on the next version, Haskell 2020.

FP

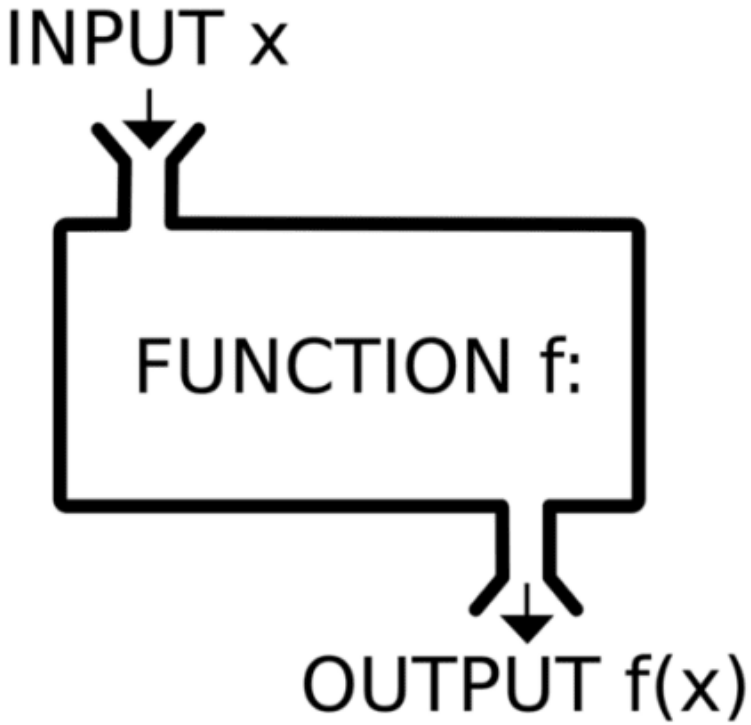
- Programming with **pure** functions.
- The output of a function is **solely** determined by the input (much like mathematical functions).
- No **side-effects**.
- No **assigments**.
- Functions **compose**.
- **Expression-oriented programming**.

Why FP matters?

1. FP offers concurrency/parallelism with tears.
2. FP has succint, concise and understandable syntax.
3. FP offers a different programming perspective.
4. FP is becoming more accessible.

FP is fun!

Functions everywhere



Design patterns

OO patterns	**FP patterns**
Single responsability	Functions
Open / Closed	Functions
Interface segregation	Functions
Factory	Functions
Strategy	Functions
Decoration	Functions again
Visitor	Resistance is futile !

Seriously, FP patterns are different.

FP has succint, concise and understandable syntax

The abstract nature of FP leads to considerably simpler programs. It also supports a number of powerful new ways to structure and reason about programs.

`x = x+1;` We understand this syntax because we often resort to telling the computer what to do, but this equation really makes no sense at all!

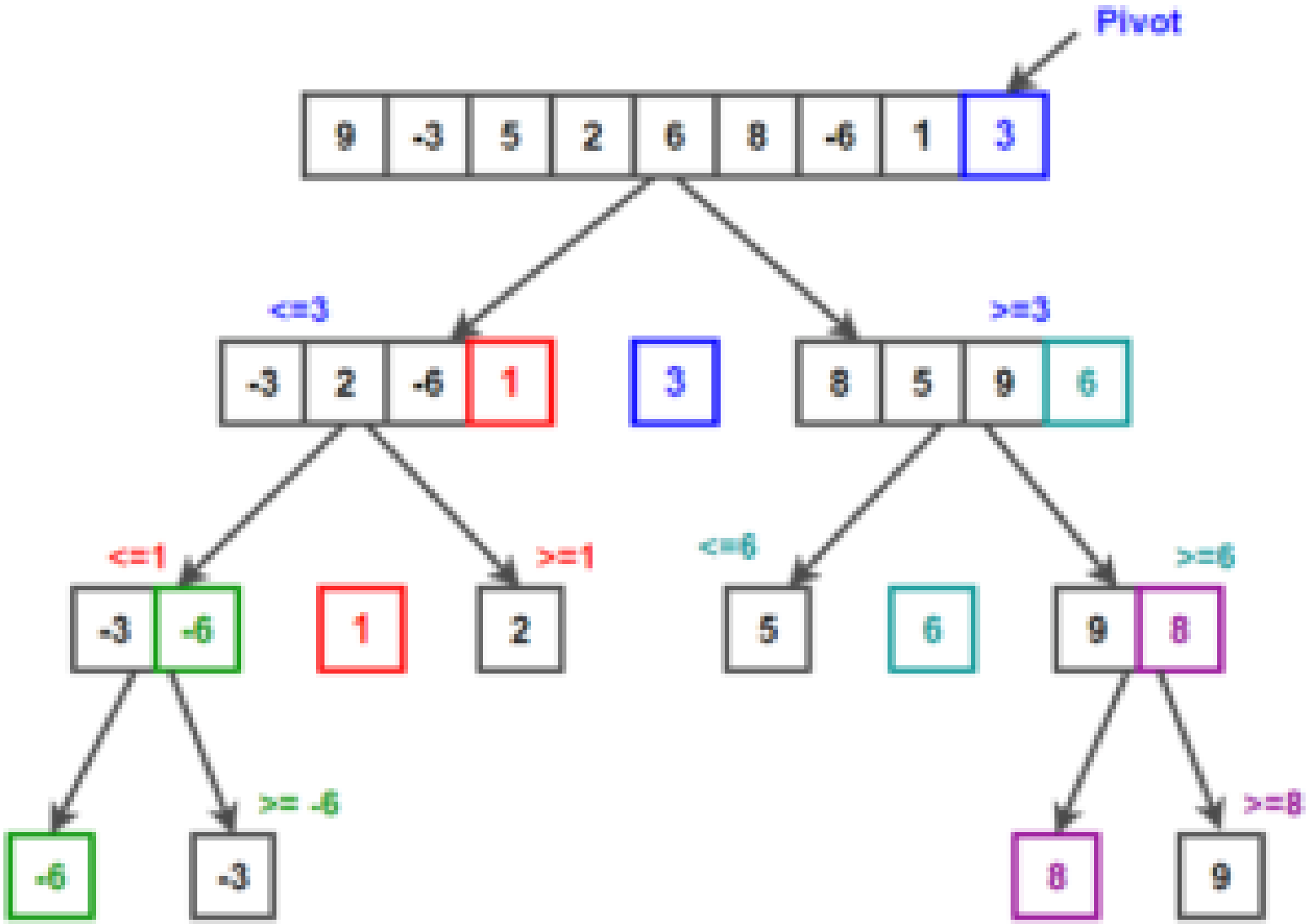
Ask, don't tell.

FP offers a different programming perspective

For me, the most important thing about FP isn't that functional languages have some particular useful language features, but that it allows to think differently and simply about problems that you encouter when designing and writing applications. This is much more important than understanding any new technology or a programming language.

Tomas Petricek
`http://tomasp.net/blog/`

Quicksort



Quicksort

Erlang

```
-module(quicksort).

-export([qsort/1]).

qsort([]) -> [];
qsort([X|Xs]) ->
  qsort([Y || Y <- Xs, Y < X]) ++ [X] ++ qsort([Y || Y <- Xs, Y >= X]).
```

Quicksort

Elixir

```
defmodule Sort do
  def qsort([]), do: []
  def qsort([h | t]) do
    {lesser, greater} = Enum.split_with(t, &(&1 < h))
    qsort(lesser) ++ [h] ++ qsort(greater)
  end
end
```

Quicksort

Ocaml

```
let rec qsort = function
  hd :: tl ->
    let less, greater = List.partition ((>=) hd) tl
    List.concat [qsort less; [hd]; qsort greater]
  | _ -> []
```

Quicksort

Lisp

```
(defun qsort (list &aux (pivot (car list)) )
(if (cdr list)
    (nconc (qsort (remove-if-not #'(lambda (x) (< x pivot)) list))
           (remove-if-not #'(lambda (x) (= x pivot)) list)
           (qsort (remove-if-not #'(lambda (x) (> x pivot)) list)))
    list))
```

Quicksort

Clojure

```
(defn qsort [L]
(if (empty? L)
    '()
    (let [[pivot & L2] L]
         (lazy-cat (qsort (for [y L2 :when (<  y pivot)] y))
                   (list pivot)
                   (qsort (for [y L2 :when (>= y pivot)] y))))))
```

Quicksort

Racket

```
#lang racket
(define (qsort < l)
(match l
  ['() '()]
  [(cons x xs)
   (let-values ([(xs-gte xs-lt) (partition (curry < x) xs)])
     (append (qsort < xs-lt)
             (list x)
             (qsort < xs-gte)))]))
```

Quicksort

Scala

```scala
def qsort(xs: List[Int]): List[Int] = xs match {
case Nil => Nil
case head :: tail =>
  val (less, notLess) = tail.partition(_ < head)
  qsort(less) ++ (head :: qsort(notLess))  // Sort each half
}
```

Quicksort

Haskell

```
qsort [] = []
qsort (x:xs) = qsort [y | y <- xs, y < x] ++
               [x]                        ++
               qsort [y | y <- xs, y >= x]
```

Quicksort

Haskell

```haskell
import Data.List (partition)

qsort' :: Ord a => [a] -> [a]
qsort' [] = []
qsort' (x:xs) = qsort' ys ++ x : qsort' zs
  where
    (ys, zs) = partition (< x) xs
```

FP is becoming more accessible

More language options.

Tooling, IDEs.

Supports.

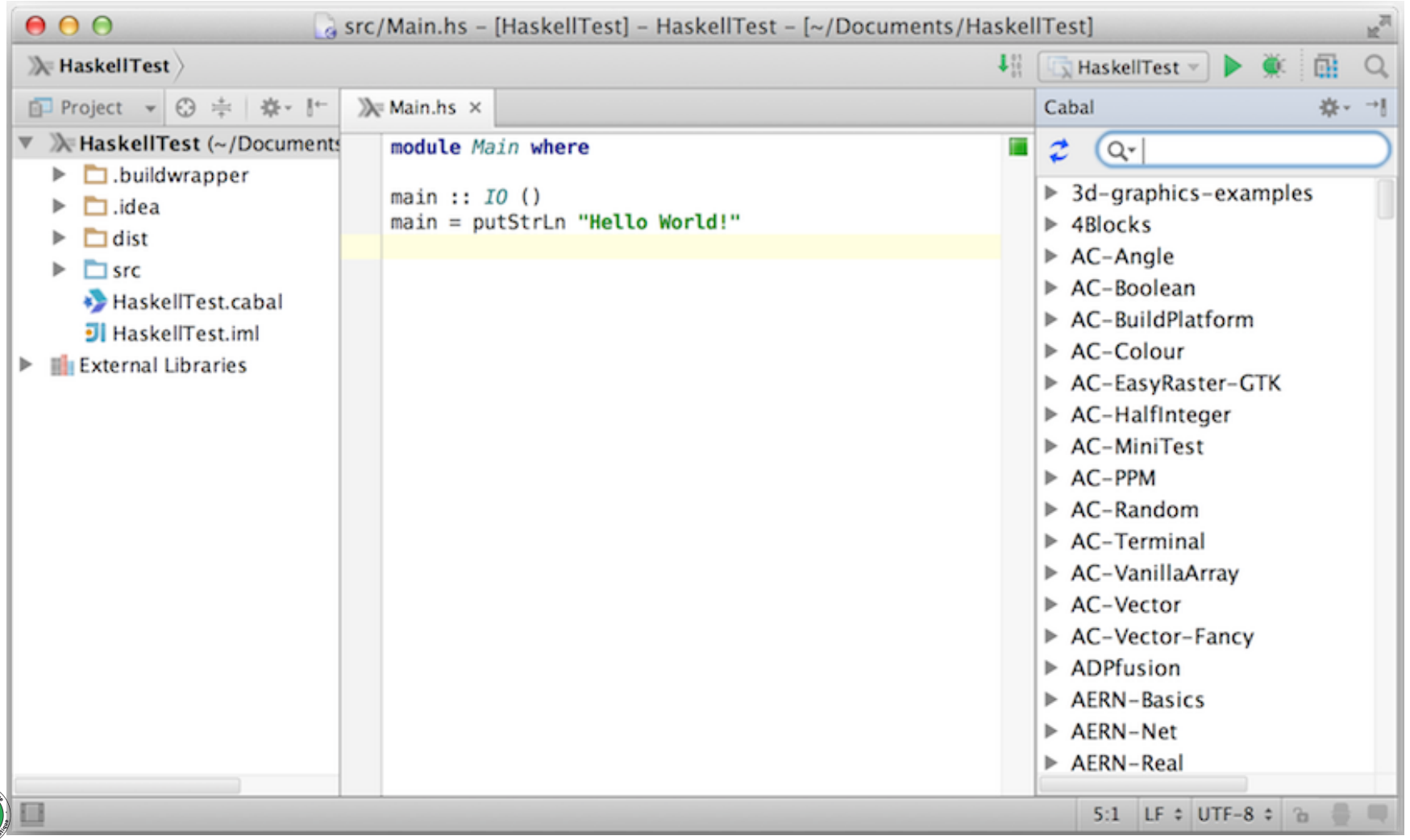
Books.

Blogs, podcasts and screencasts.

Conferences and user groups.

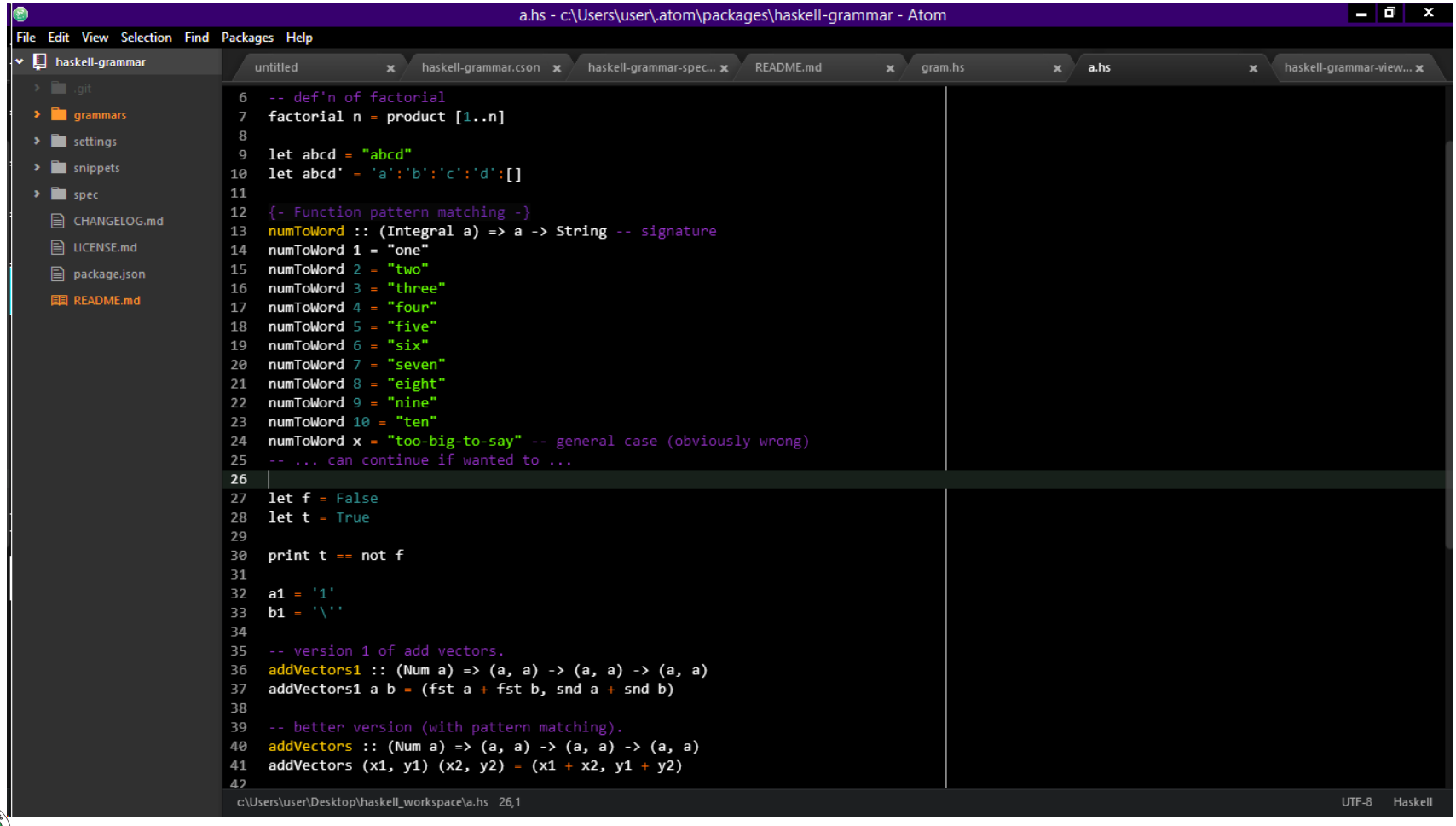
Haskell is becoming more accessible

IntelliJ IDEA



Haskell is becoming more accessible

Atom



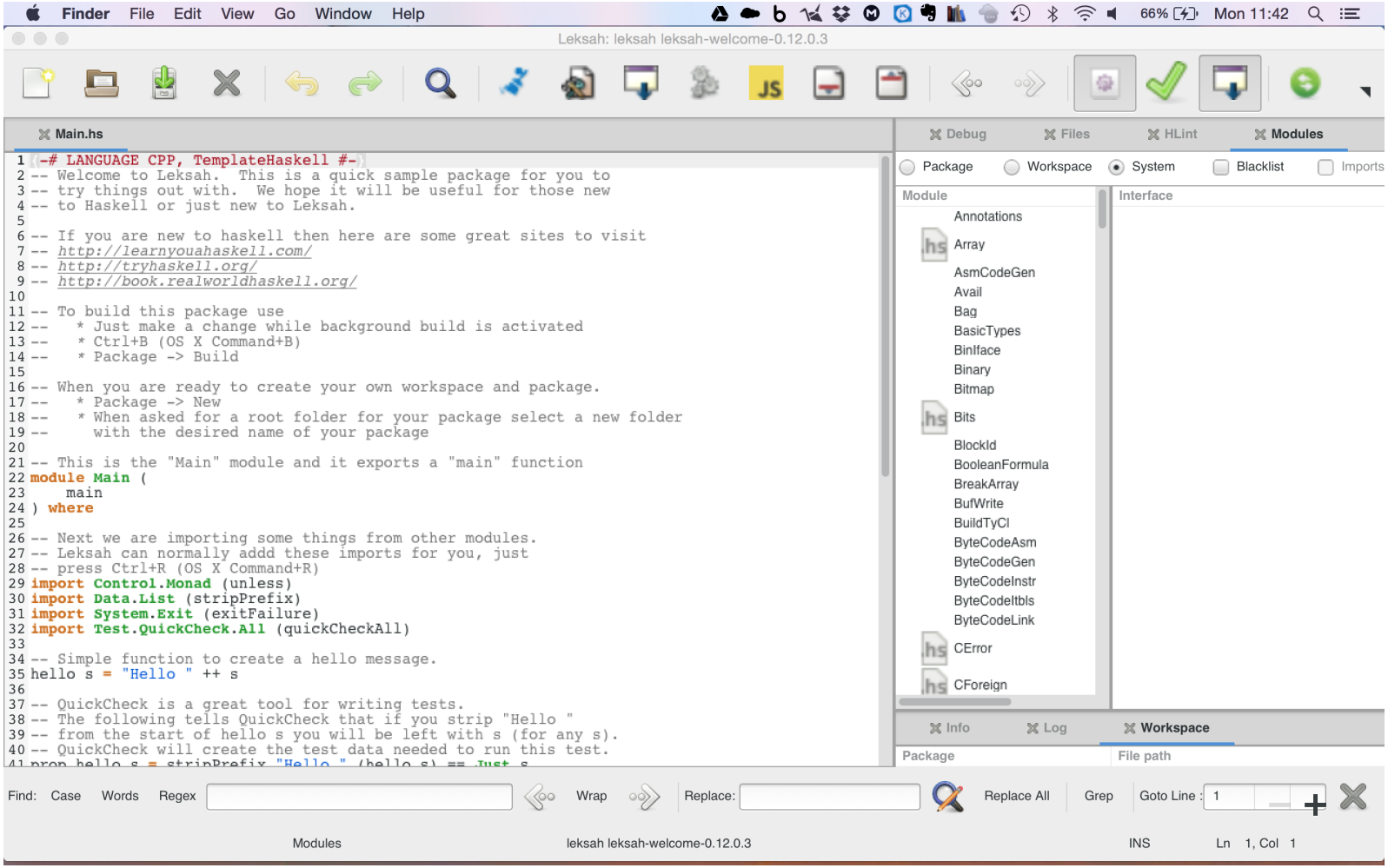
Haskell is becoming more accessible

Emacs

```
File Edit Options Buffers Tools Haskell Help

import qualified Data.Hashable as Hash
import Data.Time

-- | Task priority
data Priority
    = L -- ^ low priority
    | M -- ^ medium priority
    | H -- ^ high priority
      deriving (Eq, Ord, Show, Read, Bounded, Enum)

-- | A single task
data Task = Task {
      tId      :: Int          , -- ^ task id, might change after display
      tHashID  :: Int          , -- ^ unique hash, never changes
      tDesc    :: String       , -- ^ task description
      tCreated :: UTCTime      , -- ^ creation time (October 23, 4004 BC?)
      tDue     :: Maybe UTCTime  , -- ^ task due time
      tPri     :: Maybe Priority , -- ^ task priority
      tProj    :: Maybe String     -- ^ assocaiated project
    } deriving (Show, Read)

-- | Constructs a new Task. tHashID of a task is calculated
-- automatically based on the description and creation time
createTask :: Int            -- ^ id of a new task
           -> String         -- ^ task description
           -> UTCTime        -- ^ creation time
           -> Maybe UTCTime  -- ^ task due time
           -> Maybe Priority -- ^ task priority
           -> Maybe String   -- ^ project to assign a task to
           -> Task           -- ^ the new task
createTask taskId taskDesc taskCreated taskDue taskPri taskProj =
    Task taskId taskHashID taskDesc taskCreated taskDue taskPri taskProj
    where taskHashID = hashTask taskCreated taskDesc

-- | Create unique hash of a task based on creation time and description
-UU-:----F1  Tasks.hs        6% L15   Git-master  (Haskell WS Ind Doc)----------------------------------------------------------
data [context =>] simpletype = constrs [deriving]
```

Haskell is becoming more accessible

Leksah



Key Haskell concepts

High order functions, map, filter reduce (*i.e.*, fold).

Recursion.

Pattern matching.

Currying.

Lazy/eager evaluation.

Strict/non-strict semantics.

Type inference.

Monads.

Continuations.

Closures.

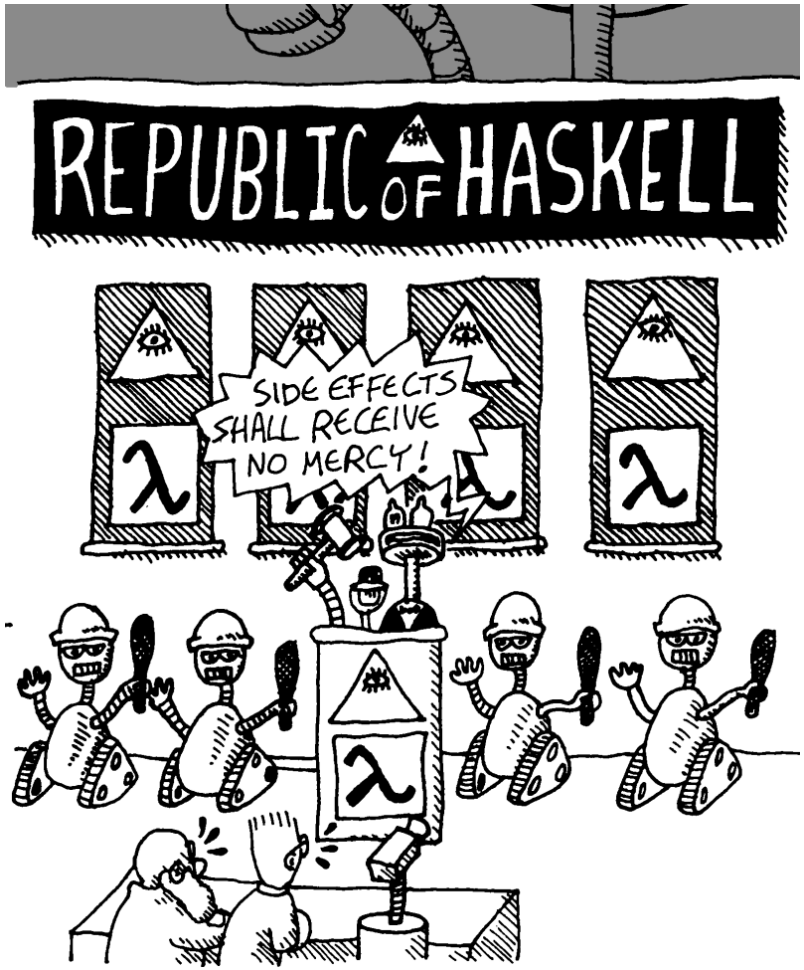
Haskell

Haskell

Haskell is a standardized, general-purpose purely functional programming language, with non-strict semantics and strong static typing.

It is named after logician Haskell Curry.

Haskell


REPUBLIC OF HASKELL
SIDE EFFECTS SHALL RECEIVE NO MERCY!
λ
λ
λ
λ
λ

What can Haskell offer the programmer?

Purity

- No **side-effects**.
- Keep the code involving state and I/O to the minimum.
- The most important feature of Haskell.

What can Haskell offer the programmer?

Higher-order functions

- Functions that take other functions as their arguments.
- Useful for refactoring code.
- Reduce the amount of repetition.

```
quicksort :: (Ord a) => [a] -> [a]
quicksort []     = []
quicksort (x:xs) = smallerSorted ++ [x] ++ biggerSorted
  where
    smallerSorted = quicksort (filter (<=x) xs)
    biggerSorted  = quicksort (filter (>x)  xs)
```

What can Haskell offer the programmer?

Immutable data

- Expressions in Haskell are immutable. They cannot change after they are evaluated.
- Immutability makes refactoring super easy and code much easier to reason about.
- To **change** an object, most data structures provide methods taking the old object and creating a new copy.

```
>> let a = [1,2,3]
>> reverse a
[3,2,1]
>> a
[1,2,3]
```

What can Haskell offer the programmer?

Referential transparency

- Pure computations yield the same value each time they are invoked.
- Side effects like (uncontrolled) imperative update break this desirable property.
- Make it easier to reason about the behavior of programs.

  If `y = f x` and `g = h y y` then `g = h (f x) (f x)`.

What can Haskell offer the programmer?

Referential transparency

```haskell
random :: Int
random = 4 -- chosen by fair dice rool, guaranted to be random.

today :: String
today = "Mon 21 Sep 2020" -- guaranted at the time of writing.

getInputChar:: Char
getInputChar = 'a' -- The user did type 'a', so what!?
```

What can Haskell offer the programmer?

Lazy evaluation

- Defer the computation of values until they are needed (since pure computations are referentially transparent they can be performed at any time and still yield the same result).
- Lazy evaluation avoids unnecessary computations.
- Allow, for example, infinite data structures to be defined and used.

Consider the function `f x y = x+1`.

In a strict language, evaluating `f 5 (29^35792)` will first completely evaluate `5` (already done) and `29^35792` (which is a lot of work) before passing the results to `f`.

What can Haskell offer the programmer?

Lazy evaluation

```
>>> 1 `div` 0
*** Exception: divide by zero
>>> (1 == 2-1) || (1 `div` 0 == 1)
True
>>> (1 /= 2-1) && (1 `div` 0 == 1)
False
>>> head [1, 2 `div` 0, 3]
1
>>> last (tail [1, 2 `div` 0, 3])
3
```

What can Haskell offer the programmer?

Elegance

- Haskell code is elegant, concise and intuitive.
- Shorter programs are easier to maintain than longer ones and have less bugs.
- But elegance is not an excuse for bad performance.

```
import qualified data.List as L

fibs :: [Integer]
fibs = 1 : 1 : L.zipWith (+) fibs (L.tail fibs)
```

Haskell and bugs

Pure. There are no side effects.

Strongly typed. There can be no dubious use of types. And No Core Dumps!

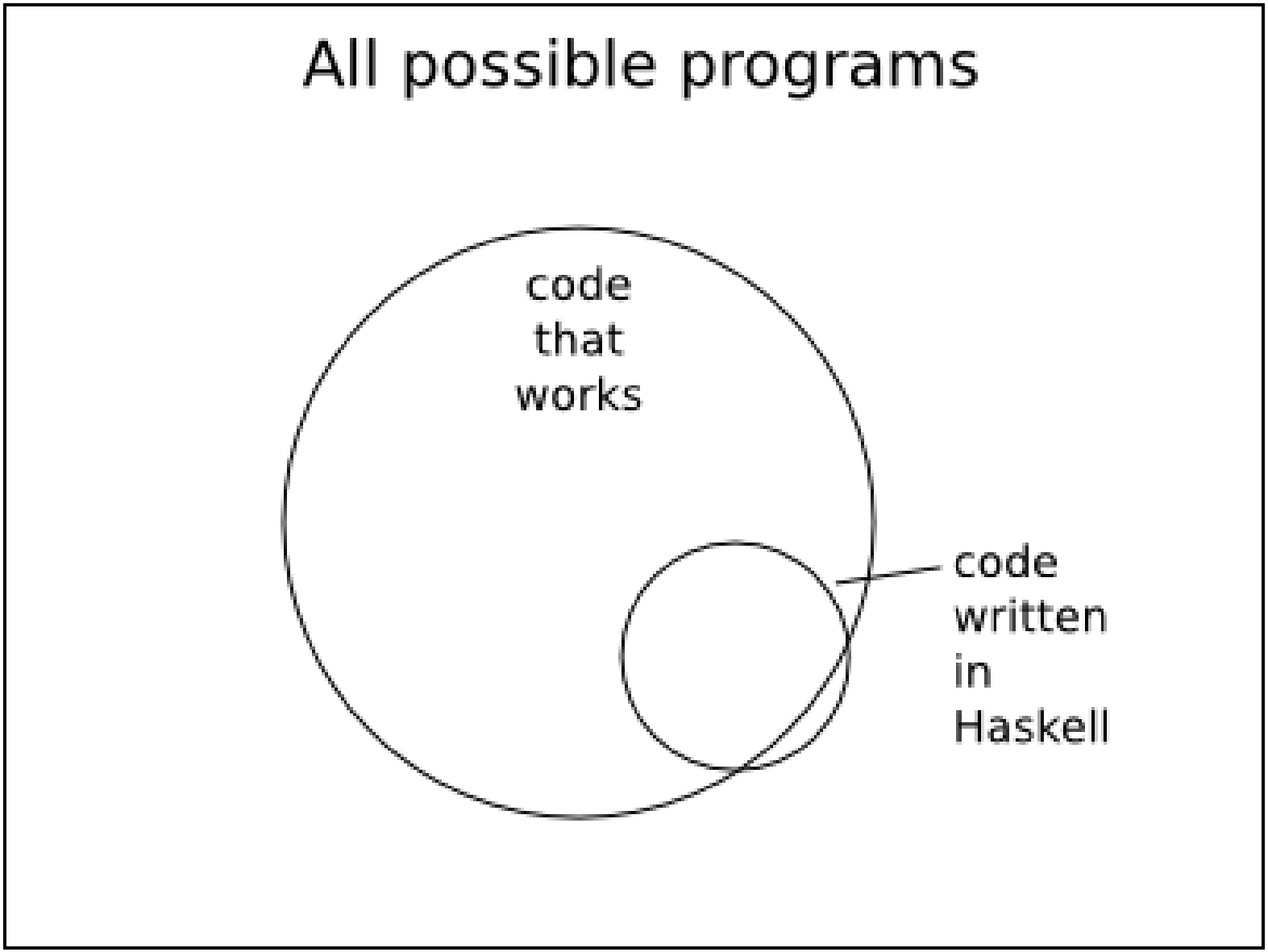
Concise. Programs are shorter which make it easier to look at a function and "take it all in" at once, convincing yourself that it's correct.

High level. Haskell programs most often reads out almost exactly like the algorithm description. Which makes it easier to verify that the function does what the algorithm states.

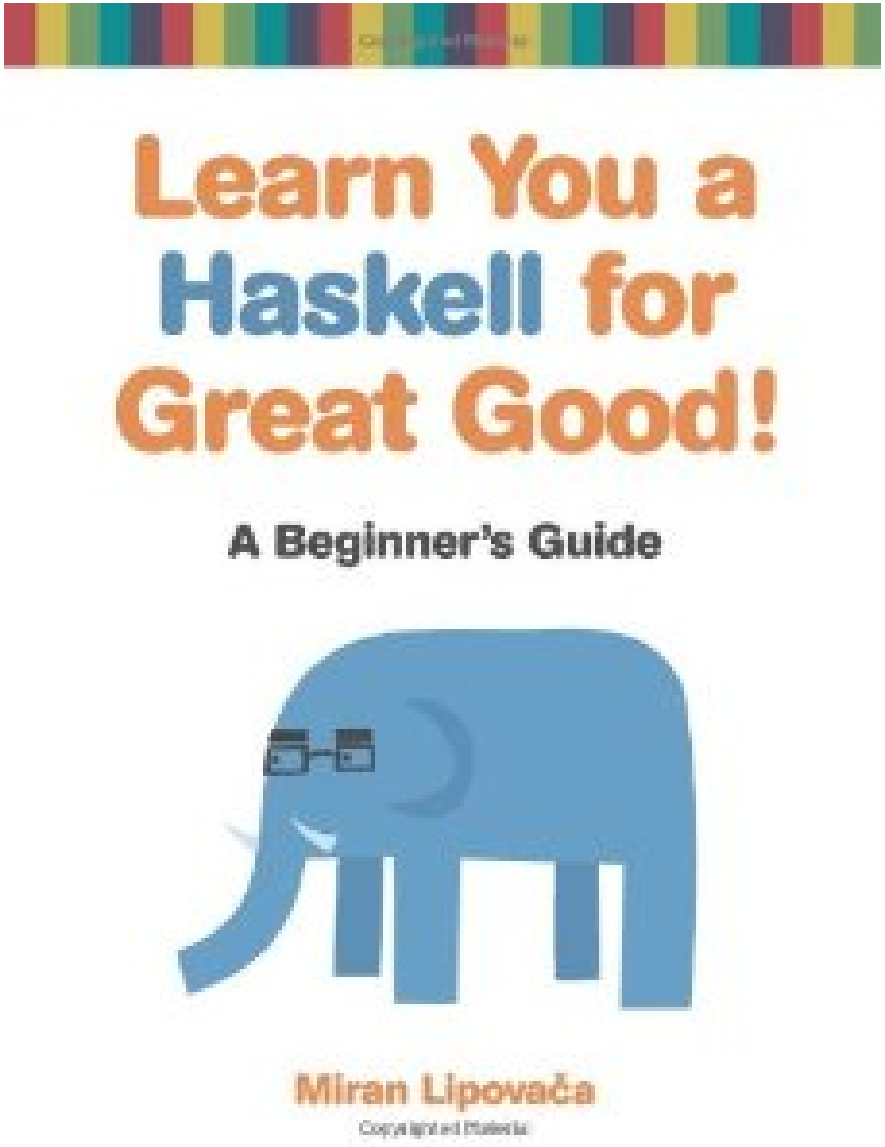
Memory managed. There's no worrying about dangling pointers, the Garbage Collector takes care of all that.

Modular. Haskell offers stronger and more "glue" to compose your program from already developed modules.

So what !?


All possible programs
code
that
works
code
written
in
Haskell

Reference book



Hello, World!

```haskell
module Main where

main :: IO ()
main = putStrLn "Hello, World!"
```

Hello, World!: Compile to native code

```
barbalala: ghc -o Hello Hello.hs
[1 of 1] Compiling Main                ( Hello.hs, Hello.o )
Linking Hello ...
barbalala: ./Hello
Hello, World!
barbalala:
```

Hello, World!: Interpreter

```
barbalala: ghci
GHCi, version 7.8.3: http://www.haskell.org/ghc/
:? for help
Loading package ghc-prim ... linking ... done.
Loading package integer-gmp ... linking ... done.
Loading package base ... linking ... done.
Prelude> :load "Hello"
[1 of 1] Compiling Main ( Hello.hs, interpreted )
Ok, modules loaded: Main.
*Main> main
Hello, World!
*Main>
```

Quicksort in Haskell

```
quicksort :: Ord a => [a] -> [a]
quicksort []     = []
quicksort (p:xs) = quicksort lesser ++
                   [p]              ++
                   quicksort greater
    where
        lesser  = filter (< p)  xs
        greater = filter (>= p) xs
```

The Fibonacci sequence

```haskell
fib :: (Eq a, Num a, Num b) => a -> b
fib 0 = 0
fib 1 = 1
fib n = fib (n-1) + fib (n-2)
```

or

```haskell
fib :: (Integral b, Integral a) => a -> b
fib n = round $ phi ** fromIntegral n / sq5
  where
    sq5 = sqrt 5 :: Double
    phi = (1 + sq5) / 2
```

or

```haskell
fibs :: Num a => [a]
fibs = 0 : 1 : zipWith (+) fibs (tail fibs)
```

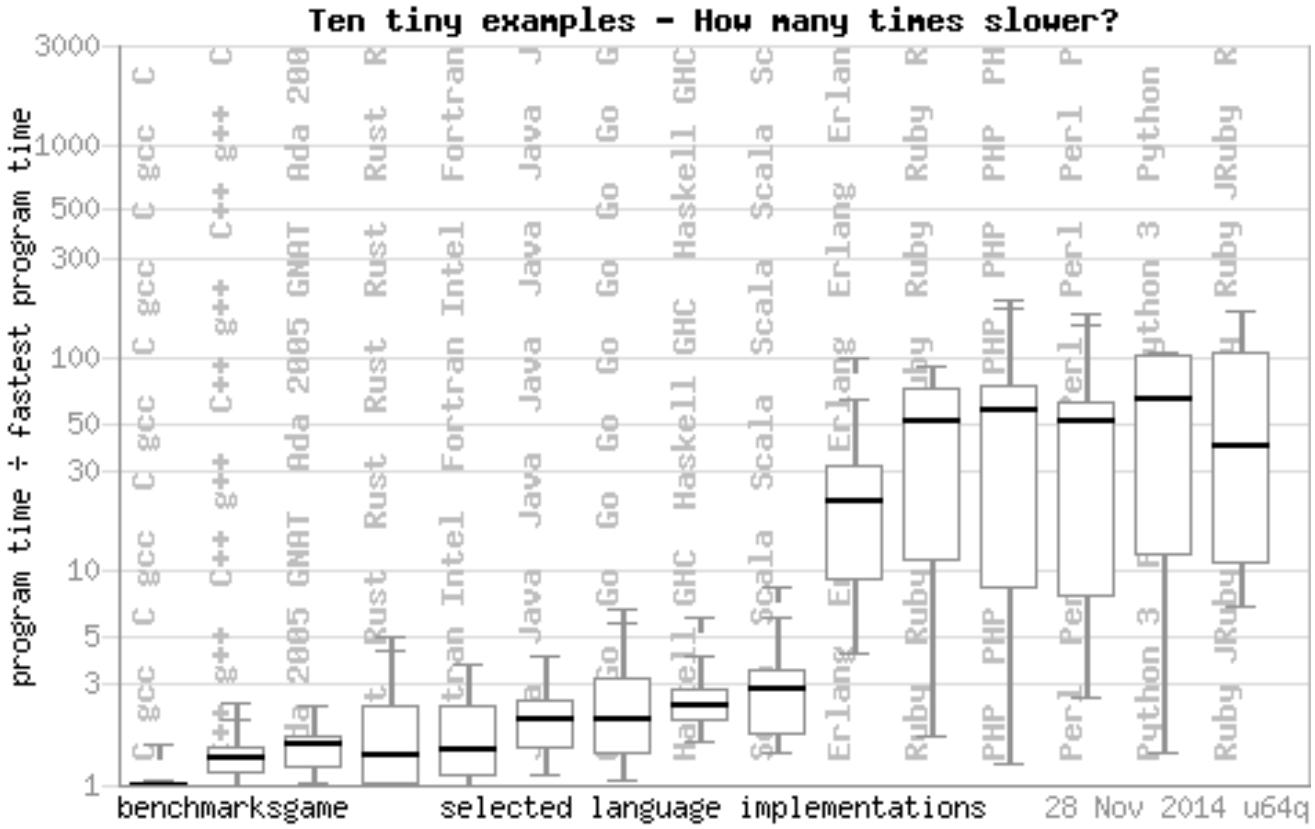
or ...

Implementations

The Glasgow Haskell Compiler (GHC) compiles to native code on a number of different architectures. GHC has become the de facto standard Haskell dialect. There are libraries (e.g. bindings to OpenGL) that will work only with GHC. GHC is also distributed along with the Haskell platform.

The speed of Haskell

For most applications the difference in speed between C++ and Haskell is so small that it's utterly irrelevant



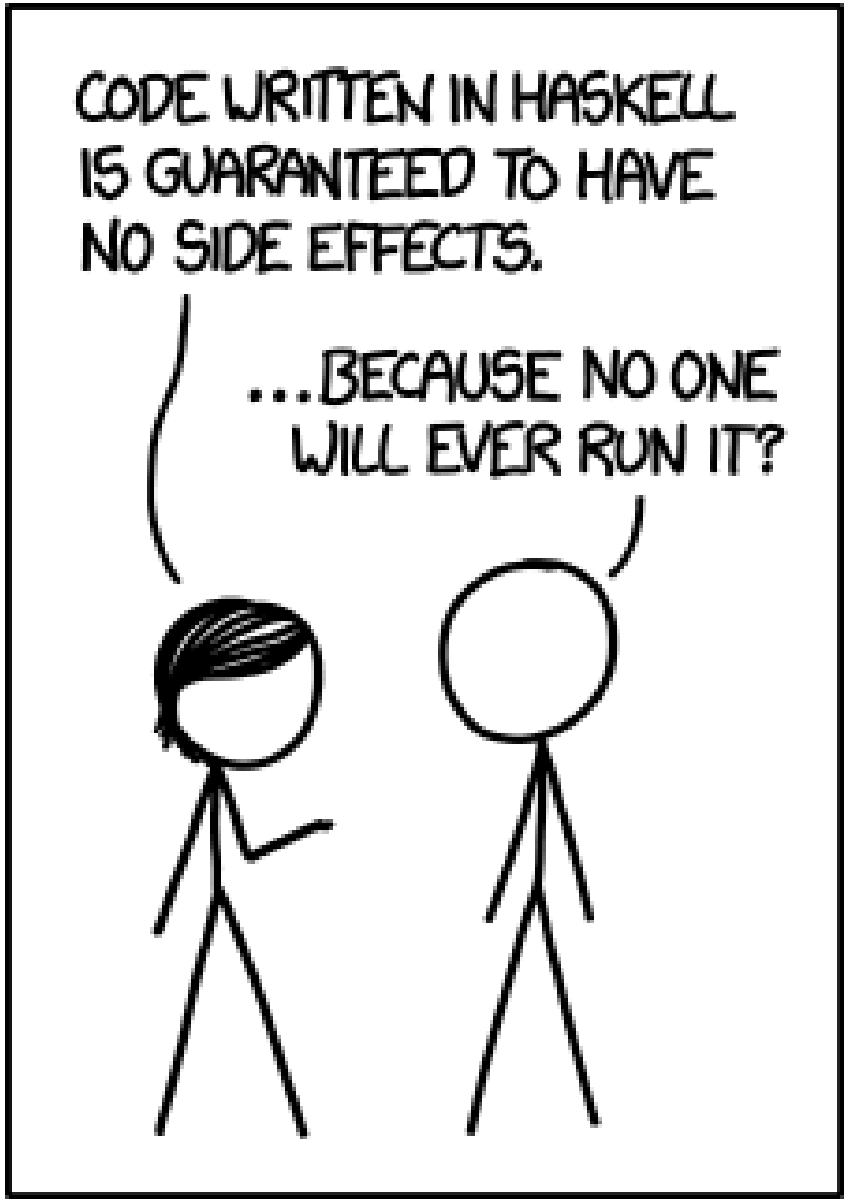
The speed of Haskell

There's an old rule in computer programming called the "*80/20 rule*". It states that 80% of the time is spent in 20% of the code. The consequence of this is that any given function in your system will likely be of minimal importance when it comes to optimizations for speed. There may be only a handful of functions important enough to optimize.

Remember that algorithmic optimization can give much better results than code optimization.

Last but not least, Haskell offers substantially increased programmer productivity (Ericsson measured an improvement factor of between 9 and 25 using Erlang, a functional programming language similar to Haskell, in one set of experiments on telephony software.)

Haskell in Industry



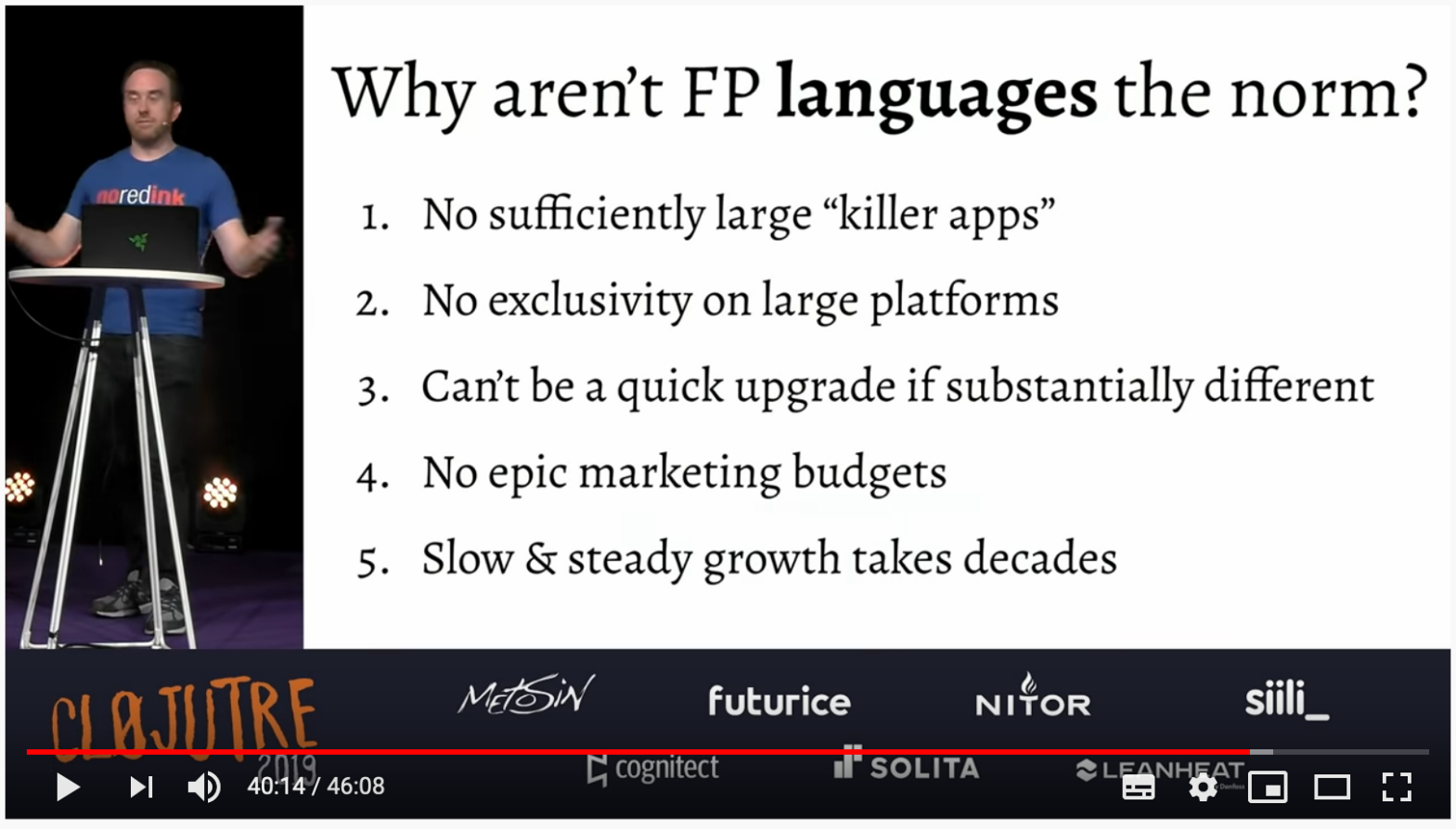
Why is Haskell not used in the software industry?

even though it is a popular functional programming language!

- Integration with the companies' existing codebase.
- There are not enough people with Haskell experience.
- Colleges and universities do little to popularize Haskell.
- Clojure and Scala are not purely functional but have done a lot to popularize functional programming.

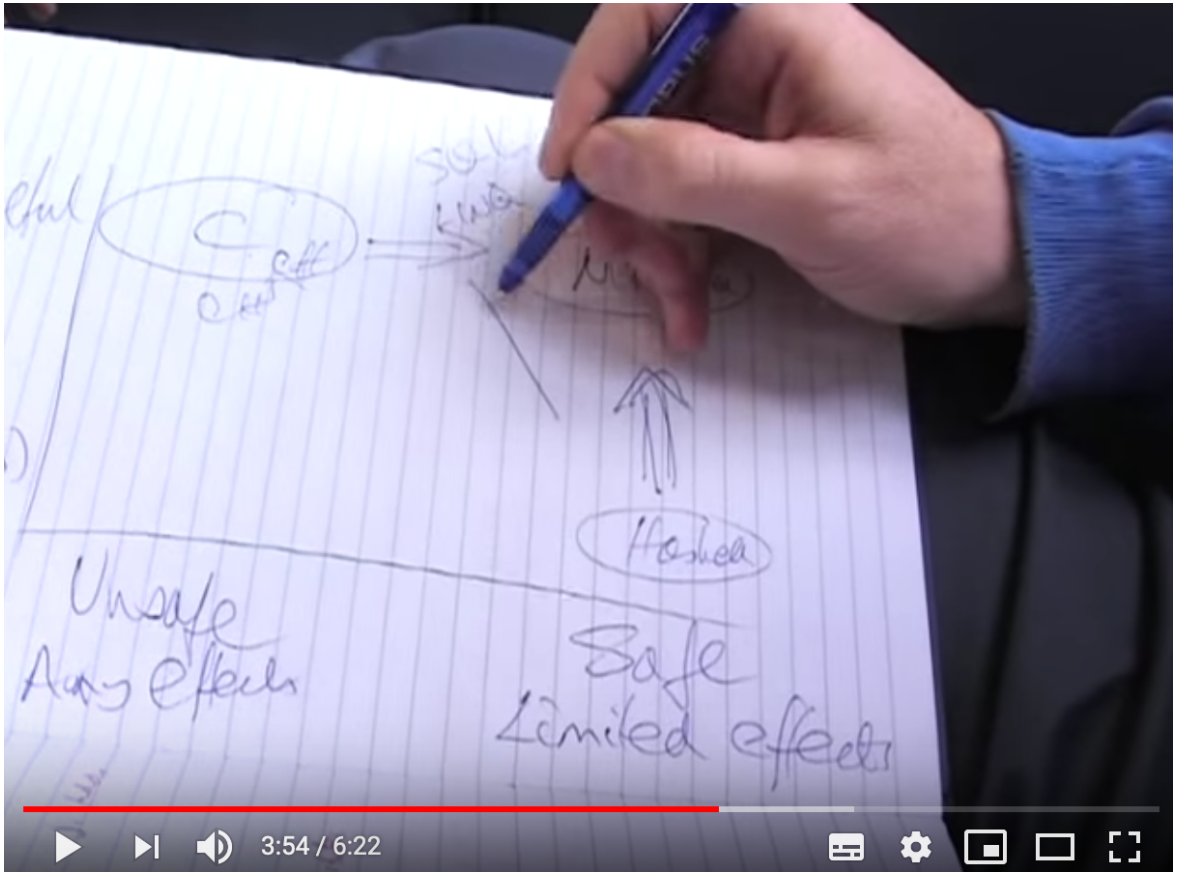
  Using these languages, the management and programmers can claim to be trained in functional programming and yet know of nothing more than map, reduce and fold.

Why Isn't Functional Programming the Norm?



https://www.youtube.com/watch?v=QyJZzq0v7Z4

Haskell is useless



https://www.youtube.com/watch?v=iSmkqocn0oQ

Tutorials

Haskell Tutorial : Learn you a Haskell

15 vidéos • 121 803 vues • Dernière modification le 27 janv. 2015

Haskell is a purely functional programming language. In imperative languages you get things done by giving the computer a sequence of tasks and then it executes them.

Haskell is lazy. That means that unless specifically told otherwise, Haskell won't execute functions and calculate things until it's really forced to show you a result. That goes well with referential transparency and it allows you

1 

Haskell 1 Introduction : About Haskell
Ram Krishna

2 

Haskell 2a : Haskell as a Calculator
Ram Krishna

3 

Haskell 2b : Functions, if, and let
Ram Krishna
Haskell 2b : Functions, if, and let

4 

Haskell 2c: Lists
Ram Krishna

5 

Haskell 2d List comprehensions
Ram Krishna

6 

Haskell 2e : Tuples
Ram Krishna

https://www.youtube.com/playlist?list=PLwiOlW12BuPZUxA2gISnWV32mp26gNq56

Why Is Haskell So Hard To Learn? How To Deal With It?

https://www.youtube.com/watch?v=RvRVn8jXoNY

Functional programming languages