Haskell
Functional Programming

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

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Everybody's talking about functional programming

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Erlang

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

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Elixir

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

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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.

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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.

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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.)

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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.

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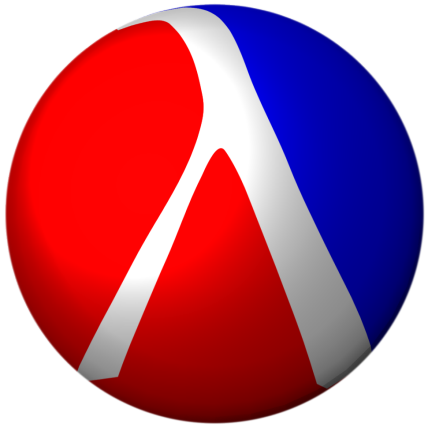

Racket

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

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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.

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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.

Everybody's talking about functional programming

There are 4 primary reasons for FP's newly established popularity:

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!

FP offers concurrency/parallelism with tears

Moore's law has held up for years but it is starting to reach its limits due to physical constraints. Chips aren't getting much faster but multi-core, hyper-threaded, etc machines are becoming far more commonplace.

If you want to take advantages of your machine's full processing power, you can no longer rely on continuous chip advances alone. You need to really start thinking about concurrency, parallelism and multi-threaded if you wish to better performance and use all available CPUs.

Of course, these are not easily implemented concepts so coders need to start considering ways (like FP!) to make these approaches more available and practical.

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/`

FP is becoming more accessible

More language options.

Tooling, IDEs.

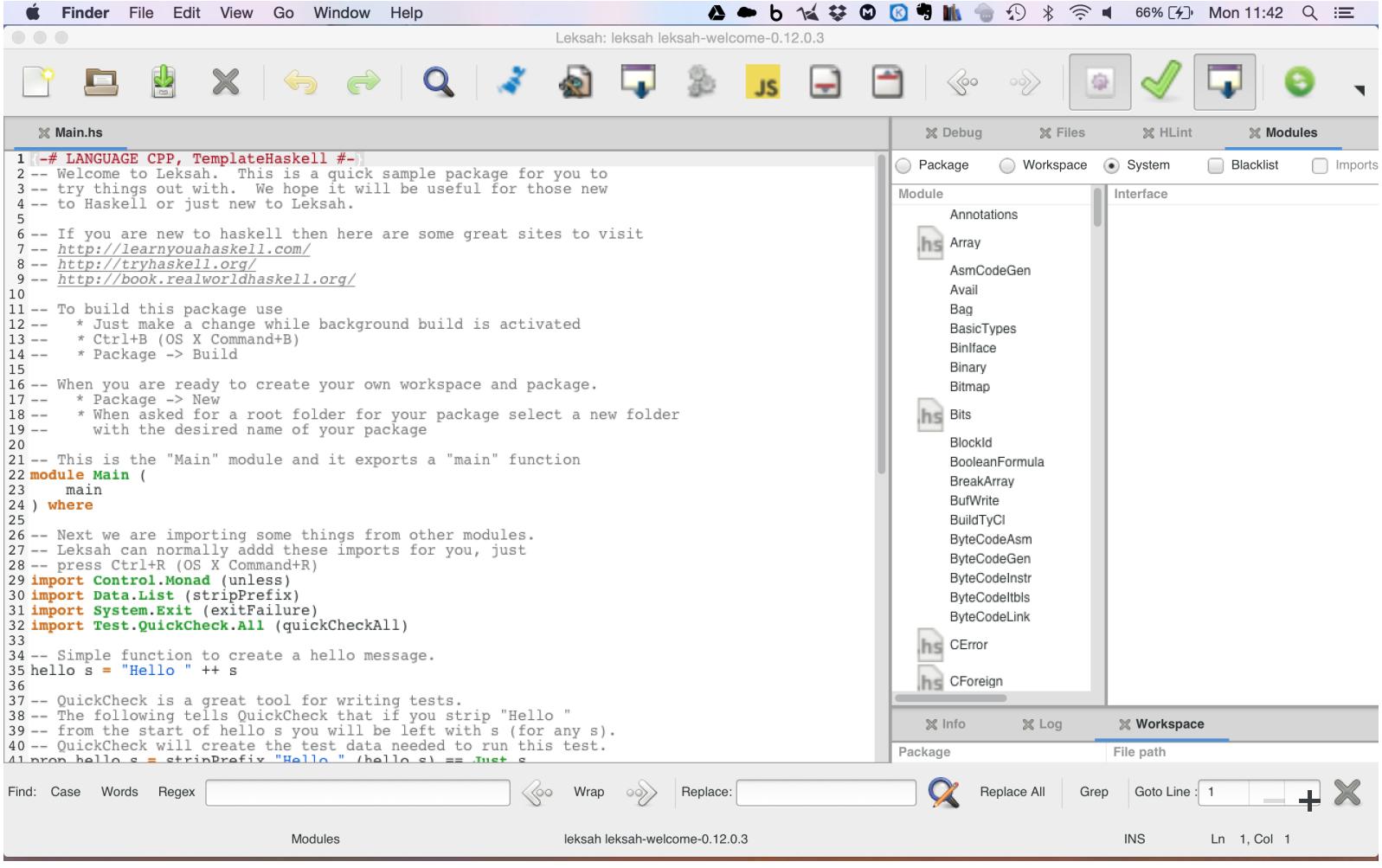
Supports.

Books.

Blogs, podcasts and screencasts.

Conferences and user groups.

Haskell is becoming more accessible



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.

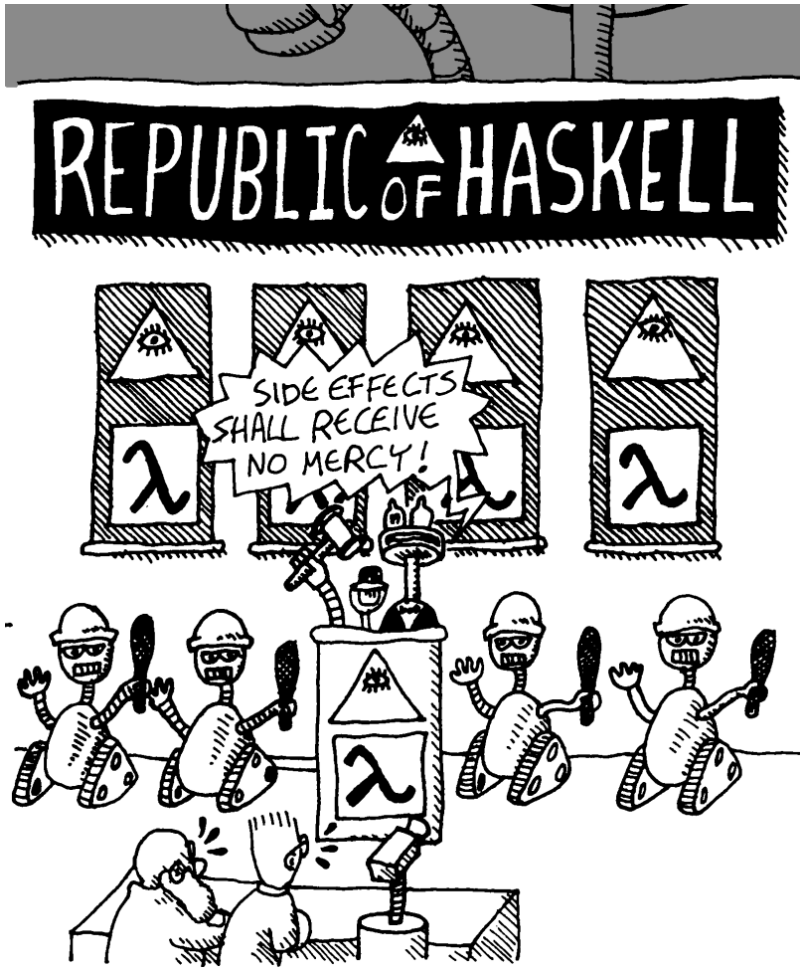
Haskell

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: Unlike some other functional programming languages Haskell is pure. It doesn't allow any side-effects. This is probably the most important feature of Haskell.

Laziness: Haskell is lazy (technically speaking, it's "non-strict"). This means that nothing is evaluated until it has to be evaluated.

Strong typing: Haskell is strongly typed, this means just what it sounds like. It's impossible to inadvertently convert a `Double` to an `Int`, or follow a null pointer. Unlike other strongly typed languages types in Haskell are automatically inferred.

Elegance: Another property of Haskell that is very important to the programmer, even though it doesn't mean as much in terms of stability or performance, is the elegance of Haskell. To put it simply: stuff just works like you'd expect it to.

Haskell and bugs

Pure. There are no side effects.

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

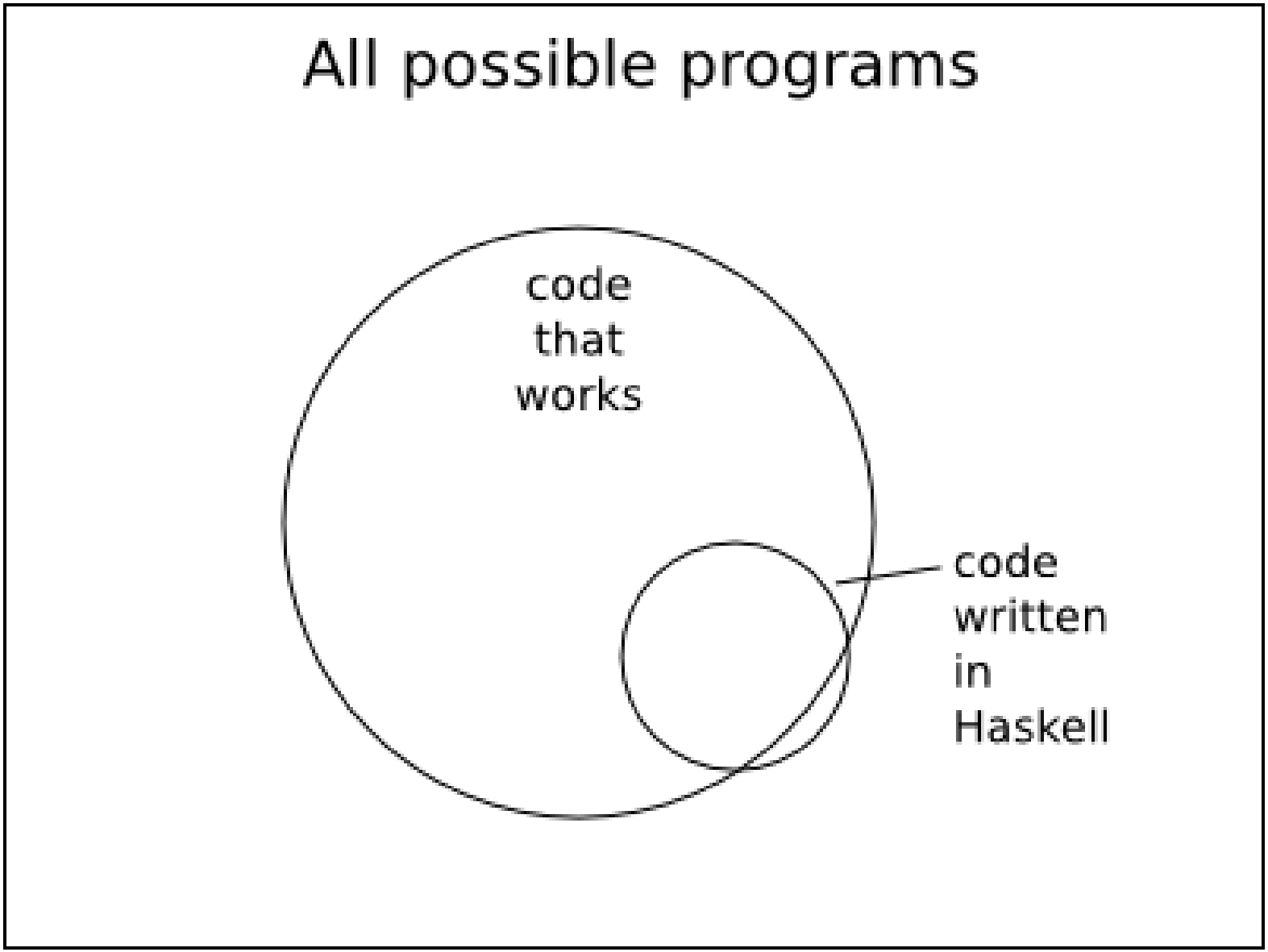
Concise. Programs are shorter which make it easier to look at a function and "take it all in" at once, convincing yourself that it's correct.

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.

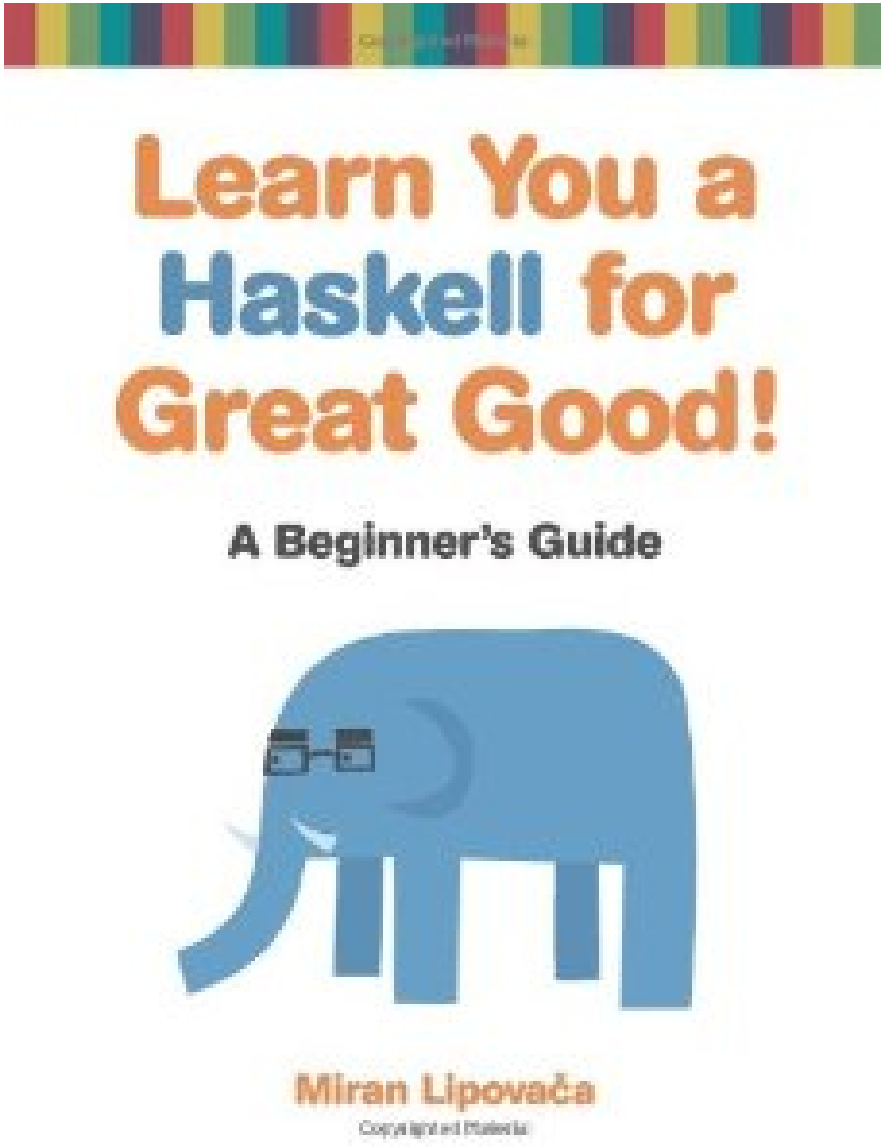
Memory managed. There's no worrying about dangling pointers, the Garbage Collector takes care of all that.

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
```

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.

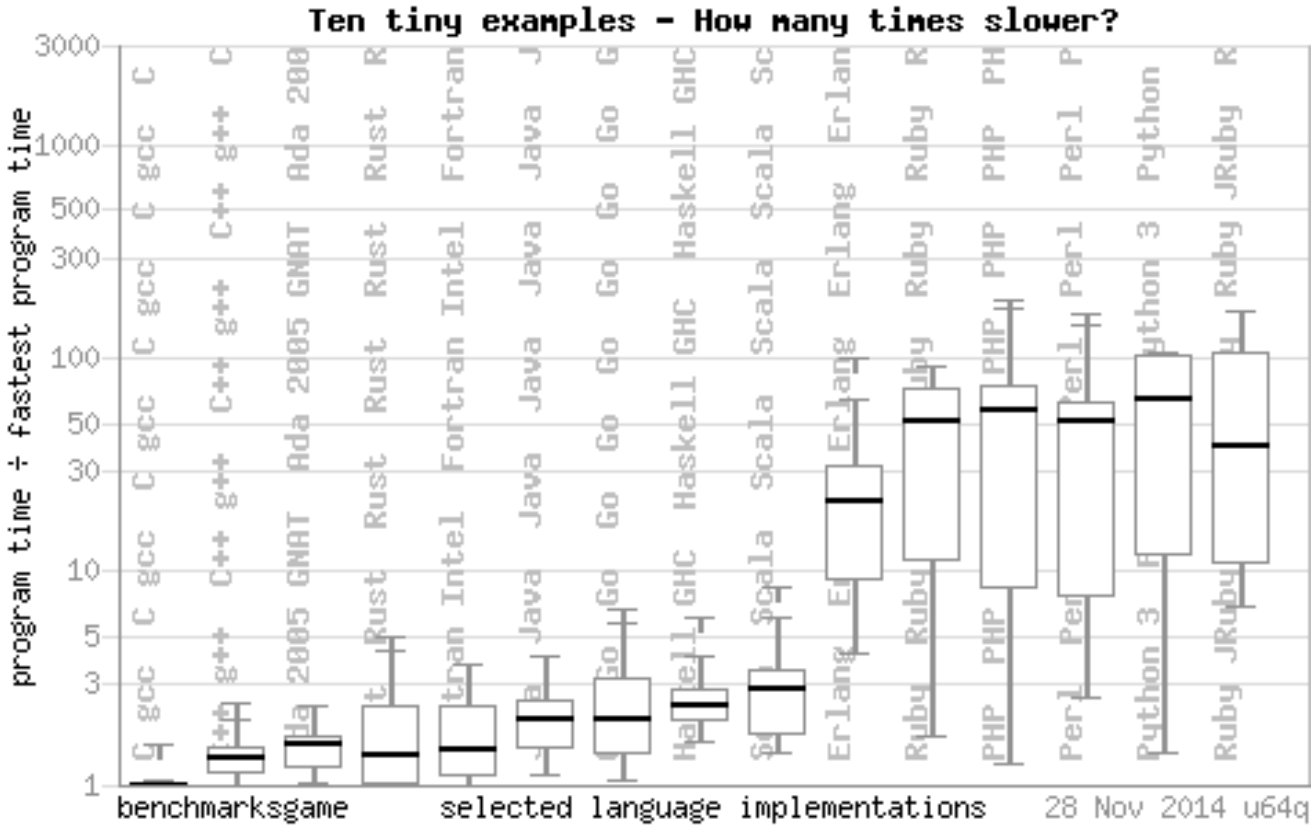
The Utrecht Haskell Compiler (UHC) is a Haskell implementation from Utrecht University. UHC supports almost all Haskell 98 features plus many experimental extensions.

Jhc is a Haskell compiler written by John Meacham emphasising speed and efficiency of generated programs as well as exploration of new program transformations.

Ajhc is a fork of Jhc.

The speed of Haskell

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



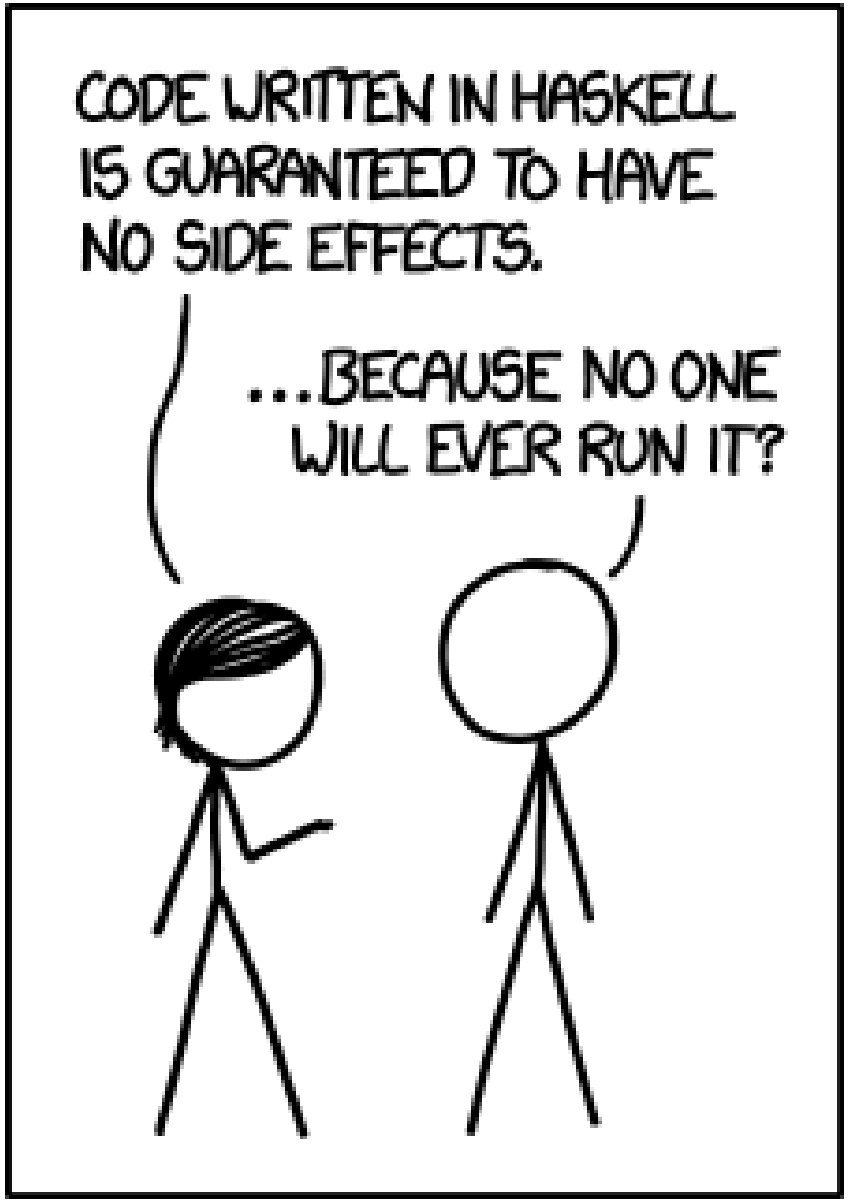
The speed of Haskell

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



Haskell in Industry

ABN AMRO Amsterdam, The Netherlands
ABN AMRO is an international bank headquartered in Amsterdam. For its investment banking activities it needs to measure the counterparty risk on portfolios of financial derivatives.

Aetion Technologies LLC, Columbus, Ohio, USA
Aetion was a defense contractor in operation from 1999 to 2011, whose applications use artificial intelligence.

Alcatel-Lucent
A consortium of groups, including Alcatel-Lucent, have used Haskell to prototype narrowband software radio systems, running in (soft) real-time.

Haskell in Industry

Soostone, New York, NY, USA
Soostone is an advanced analytics technology provider specializing in algorithmic optimization opportunities in marketing, pricing, advertising, sales and product management.

NRAO
NRAO has used Haskell to implement the core science algorithms for the Robert C. Byrd Green Bank Telescope (GBT) Dynamic Scheduling System (DSS).

IMVU, Inc
IMVU, Inc. is a social entertainment company connecting users through 3D avatar-based experiences.

Functor AB, Stockholm, Sweden
Functor AB offers new tools for ground-breaking static analysis with pre-test case generation of programs to eliminate defects and bugs in software very early in development.

Functional programming languages