Functional programming, Seminar No. 1

Danya Rogozin
Institute for Information Transmission Problems, RAS
Serokell OÜ
Higher School of Economics
The Department of Computer Science

General words on Haskell and History

- The language is named after Haskell Curry, an American logician
- The first implementation: 1990
- The language standard: Haskell2010
- Default compiler: Glasgow Haskell compiler
- Haskell is a strongly-typed, polymorphic, and purely functional programming language

Lambda calculus and type theory. Incomplete and Utter History of Functional Programming

- At the end of the 1920-s, Alonzo Church proposed an alternative approach to the foundations of mathematics where the notion of a function is a primitive one. Informally, lambda-calculus is a formal system that describes abstract functions.

Lambda calculus and type theory. Incomplete and Utter History of Functional Programming

- At the end of the 1920-s, Alonzo Church proposed an alternative approach to the foundations of mathematics where the notion of a function is a primitive one. Informally, lambda-calculus is a formal system that describes abstract functions.
- Moreover, Church used the lambda calculus to show that Peano arithmetic is undecidable.

Lambda calculus and type theory. Incomplete and Utter History of Functional Programming

- At the end of the 1920-s, Alonzo Church proposed an alternative approach to the foundations of mathematics where the notion of a function is a primitive one. Informally, lambda-calculus is a formal system that describes abstract functions.
- Moreover, Church used the lambda calculus to show that Peano arithmetic is undecidable.
- Kleene and Rosser showed that the initial version of the lambda calculus is inconsistent. Initially (due to Bertand Russell), the idea of typing was the instrument that would allow us to avoid paradoxes.

Lambda calculus and type theory. Incomplete and Utter History of Functional Programming

- At the end of the 1920-s, Alonzo Church proposed an alternative approach to the foundations of mathematics where the notion of a function is a primitive one. Informally, lambda-calculus is a formal system that describes abstract functions.
- Moreover, Church used the lambda calculus to show that Peano arithmetic is undecidable.
- Kleene and Rosser showed that the initial version of the lambda calculus is inconsistent. Initially (due to Bertand Russell), the idea of typing was the instrument that would allow us to avoid paradoxes.
- The first system of typed the lambda calculus is a hybrid from the lambda calculus and type theory developed by Bertrand Russell and Alfred North Whitehead in Principia Mathematica (1910-s).

Lambda calculus and type theory. Historical notes

- After Church's works, type theory as the branch of λ calculus and combinatory logic was developed by Haskell Curry and William Howard within the context of proof theory (1950-1960-s)

Lambda calculus and type theory. Historical notes

- After Church's works, type theory as the branch of λ calculus and combinatory logic was developed by Haskell Curry and William Howard within the context of proof theory (1950-1960-s)
- Polymorphic lambda calculus (John Reynolds and Jean-Yves Girard (1970-s))

Lambda calculus and type theory. Historical notes

- After Church's works, type theory as the branch of λ calculus and combinatory logic was developed by Haskell Curry and William Howard within the context of proof theory (1950-1960-s)
- Polymorphic lambda calculus (John Reynolds and Jean-Yves Girard (1970-s))
- Polymorphic type inference (Roger Hindley, Robin Milner and Luis Damas (1970-1980-s))

Lambda calculus and type theory. Historical notes

- After Church's works, type theory as the branch of λ calculus and combinatory logic was developed by Haskell Curry and William Howard within the context of proof theory (1950-1960-s)
- Polymorphic lambda calculus (John Reynolds and Jean-Yves Girard (1970-s))
- Polymorphic type inference (Roger Hindley, Robin Milner and Luis Damas (1970-1980-s))
- ML: the very first language with polymorphic inferred type system (Robin Milner, 1973)

Lambda calculus and type theory. Historical notes

- After Church's works, type theory as the branch of λ calculus and combinatory logic was developed by Haskell Curry and William Howard within the context of proof theory (1950-1960-s)
- Polymorphic lambda calculus (John Reynolds and Jean-Yves Girard (1970-s))
- Polymorphic type inference (Roger Hindley, Robin Milner and Luis Damas (1970-1980-s))
- ML: the very first language with polymorphic inferred type system (Robin Milner, 1973)
- The language Haskell appeared at the beginning of 1990-s. Haskell desinged by Simon Peyton Jones, Philip Wadler, and others

Functional programming and its foundations

The lambda calculus establishes the foundations for functional programming in the same manner as the von Neumann principles for imperative programming.

Functional programming and its foundations

The lambda calculus establishes the foundations for functional programming in the same manner as the von Neumann principles for imperative programming.

- We have no assignment in imperative languages. Variables are nullary constant functions rather than boxes.
- We have no states (in a usual sense)
- We use recursion instead of loops
- Pattern-matching
- …

What are types needed for?

According to Benjamin Pierce

A type system is a tractable syntactic method for proving the absence of certain program behaviours by classifying phrases according to the kinds of values they compute.

What are types needed for?

According to Benjamin Pierce

A type system is a tractable syntactic method for proving the absence of certain program behaviours by classifying phrases according to the kinds of values they compute.

Types in programming languages are about

- A partial specification
- Type preserving
- Type checking allows one to catch simple errors
- Type inference
- Etc

A landscape of typing from a bird's eye view

We may classify possible ways of typing as follows

- Static and dynamic typing
    - C, C++, Java, Haskell, etc
    - JavaScript, Ruby, PHP, etc
- Implicit and explicit typing
    - JavaScript, Ruby, PHP, etc
    - C++, Java, etc
- Inferred typing
    - Haskell, Standard ML, Ocaml, Idris, etc

Ecosystem

The Haskell Platform installation

There are several ways to install the Haskell platform on Mac (if you have M1, don't cry):

- Download the `.pkg` file and install the corresponding package

The Haskell Platform installation

There are several ways to install the Haskell platform on Mac (if you have M1, don't cry):

- Download the `.pkg` file and install the corresponding package
- Run the script

```
curl -sSL https://get.haskellstack.org/ | sh
```

The Haskell Platform installation

There are several ways to install the Haskell platform on Mac (if you have M1, don't cry):

- Download the `.pkg` file and install the corresponding package
- Run the script

      curl -sSL https://get.haskellstack.org/ | sh

- Install ghc, stack, and cabal using Homebrew

The Haskell Platform installation

There are several ways to install the Haskell platform on Mac (if you have M1, don't cry):

- Download the `.pkg` file and install the corresponding package
- Run the script

      curl -sSL https://get.haskellstack.org/ | sh

- Install ghc, stack, and cabal using Homebrew

Choose any way you prefer. All these ways are equivalent to each other.

- GHC is a default Haskell compiler.
- GHC is an open-source project. Don't hesitate to contribute!
- GHC is mostly implemented on Haskell.
- GHC is developed under the GHC Steering committee control.

- GHC is a default Haskell compiler.
- GHC is an open-source project. Don't hesitate to contribute!
- GHC is mostly implemented on Haskell.
- GHC is developed under the GHC Steering committee control.
- Very roughly, compiling pipeline has the following form:

    parsing $\Rightarrow$ compile-time (type-checking mostly) $\Rightarrow$ runtime (program execution)

- GHCi is a Haskell interpreter based on GHC.
- One may run GHCi with the command `ghci`.
- You may play with GHCi as a calculator, arithmetic operators are usual
- You may also have a look at the GHCi chapter in the GHC User's Guide to get familiar with GHCi closer.

```
cylindricalgebra@daniels-mbp ~ % ghci
GHCi, version 8.10.5: https://www.haskell.org/ghc/   :? for help
Loaded package environment from /Users/cylindricalgebra/.ghc/x86_64-dar
win-8.10.5/environments/default
Prelude>
```

- Cabal is a system of library and dependency management
- A `.cabal` file describes the version of a package and its dependencies
- Cabal is also a packaging tool
- Cabal used to cause dependency hell, and it still does.

Stack

- Stack is a *mainstream* cross-platform build tool for Haskell projects
- Stack is about

Stack

- Stack is a *mainstream* cross-platform build tool for Haskell projects
- Stack is about
    - installation of required packages and the latest GHC (and their more concrete versions),
    - building, execution, and testing
    - creating an isolated location.
    - Builds are reproducible

Snapshots

- A *snapshot* is a curated package set used by Stack

Snapshots

- A *snapshot* is a curated package set used by Stack
- Stackage is a stable repository that stores snapshots

Snapshots

- A *snapshot* is a curated package set used by Stack
- Stackage is a stable repository that stores snapshots
- A *resolver* is a reference to a required snapshot

Snapshots

- A *snapshot* is a curated package set used by Stack
- Stackage is a stable repository that stores snapshots
- A *resolver* is a reference to a required snapshot
- A screenshot from Stackage:

News

Stackage nightly snapshots to switch to GHC 9.0.1, 3 months ago

Latest releases per GHC version

- Stackage Nightly 2021-08-24 (ghc-9.0.1), today
- LTS 18.7 for ghc-8.10.6, published 4 days ago
- LTS 18.6 for ghc-8.10.4, published 4 days ago
- LTS 17.2 for ghc-8.10.3, published 7 months ago
- LTS 16.31 for ghc-8.8.4, published 7 months ago
- LTS 16.11 for ghc-8.8.3, published a year ago
- LTS 15.3 for ghc-8.8.2, published a year ago
- LTS 14.27 for ghc-8.6.5, published a year ago
- LTS 13.19 for ghc-8.6.4, published 2 years ago
- LTS 13.11 for ghc-8.6.3, published 2 years ago
- LTS 12.26 for ghc-8.4.4, published 3 years ago
- LTS 12.14 for ghc-8.4.3, published 3 years ago
- LTS 11.22 for ghc-8.2.2, published 3 years ago
- LTS 9.21 for ghc-8.0.2, published 4 years ago
- LTS 7.24 for ghc-8.0.1, published 4 years ago
- LTS 6.35 for ghc-7.10.3, published 4 years ago
- LTS 3.22 for ghc-7.10.2, published 6 years ago
- LTS 2.22 for ghc-7.8.4, published 6 years ago
- LTS 0.7 for ghc-7.8.3, published 7 years ago

Ecosystem encapsulation

The Haskell ecosystem encapsulation can be described as the sequence of the following inclusions:

Creating a Haskell project using Stack

- Figure out how to call your project and run the script `stack new <projectname>`
- You will see the following story after the command `tree .` in the project directory:

Creating a Haskell project using Stack

- Figure out how to call your project and run the script `stack new <projectname>`
- You will see the following story after the command `tree .` in the project directory:

```
cylindricalgebra@daniels-mbp my-first-project % tree .
.
├── ChangeLog.md
├── LICENSE
├── README.md
├── Setup.hs
├── app
│   └── Main.hs
├── my-first-project.cabal
├── package.yaml
├── src
│   └── Lib.hs
├── stack.yaml
└── test
    └── Spec.hs

3 directories, 10 files
```

Let us discuss on how dependency files look like. First of all, we have a look the `stack.yaml` file:

Let us discuss on how dependency files look like. First of all, we have a look the `stack.yaml` file:

```
20  resolver:
21    url: https://raw.githubusercontent.com/commercialhaskell/stackage-snapshots/master/lts/18/7.yaml
22
23  # User packages to be built.
24  # Various formats can be used as shown in the example below.
25  #
26  # packages:
27  # - some-directory
28  # - https://example.com/foo/bar/baz-0.0.2.tar.gz
29  #   subdirs:
30  #   - auto-update
31  #   - wai
32  packages:
33  - .
34  # Dependency packages to be pulled from upstream that are not in the resolver.
35  # These entries can reference officially published versions as well as
36  # forks / in-progress versions pinned to a git hash. For example:
37  #
38  # extra-deps:
39  # - acme-missiles-0.3
40  # - git: https://github.com/commercialhaskell/stack.git
41  #   commit: e7b331f14bcffb8367cd58fbfc8b40ec7642100a
42  #
43  # extra-deps: []
44
45  # Override default flag values for local packages and extra-deps
46  # flags: {}
```

Cabal file

The `.cabal` file describes the relevant version of a project and its dependencies:

Cabal file

The `.cabal` file describes the relevant version of a project and its dependencies:

```
1   cabal-version: 1.12
2
3   -- This file has been generated from package.yaml by hpack version 0.34.4.
4   --
5   -- see: https://github.com/sol/hpack
6
7   name:           my-first-project
8   version:        0.1.0.0
9   description:    Please see the README on GitHub at <https://github.com/githubuser/my-first-project#readme>
10  homepage:       https://github.com/githubuser/my-first-project#readme
11  bug-reports:    https://github.com/githubuser/my-first-project/issues
12  author:         Author name here
13  maintainer:     example@example.com
14  copyright:      2021 Author name here
15  license:        BSD3
16  license-file:   LICENSE
17  build-type:     Simple
18  extra-source-files:
19      README.md
20      ChangeLog.md
21
22  source-repository head
23    type: git
24    location: https://github.com/githubuser/my-first-project
25
26  library
```

The `package.yaml` is used to generate the `.cabal` file automatically:

package.yaml

The `package.yaml` is used to generate the `.cabal` file automatically:

```yaml
 1  name:                my-first-project
 2  version:             0.1.0.0
 3  github:              "githubuser/my-first-project"
 4  license:             BSD3
 5  author:              "Author name here"
 6  maintainer:          "example@example.com"
 7  copyright:           "2021 Author name here"
 8
 9  extra-source-files:
10  - README.md
11  - ChangeLog.md
12
13  # Metadata used when publishing your package
14  # synopsis:          Short description of your package
15  # category:          Web
16
17  # To avoid duplicated efforts in documentation and dealing with the
18  # complications of embedding Haddock markup inside cabal files, it is
19  # common to point users to the README.md file.
20  description:         Please see the README on GitHub at <https://github.com/githubuser/my-first-project#read
21
22  dependencies:
23  - base >= 4.7 && < 5
24
25  library:
26      source-dirs: src
```

Building and running a project

The basic commands:

- `stack build`
- `stack run`
- `stack exec`
- `stack ghci`
- `stack clean`
- `stack test`

Building and running a project

The basic commands:

- `stack build`
- `stack run`
- `stack exec`
- `stack ghci`
- `stack clean`
- `stack test`

The roles of all these commands follow from their quite self-explanatory names.

Hackage

According to its description, 'Hackage is the Haskell community's central package archive of open source software'.

Hackage

According to its description, 'Hackage is the Haskell community's central package archive of open source software'.

- Webpage: `https://hackage.haskell.org`

Hackage

According to its description, 'Hackage is the Haskell community's central package archive of open source software'.

- Webpage: `https://hackage.haskell.org`
- Browsing packages, simplified package search, current uploads.

Hackage

According to its description, 'Hackage is the Haskell community's central package archive of open source software'.

- Webpage: `https://hackage.haskell.org`
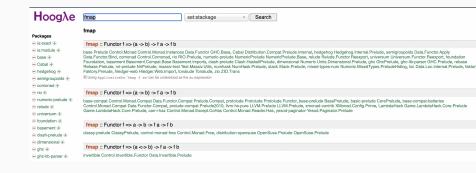- Browsing packages, simplified package search, current uploads.

Hoogle

Hoogle is a sort of Haskell search engine. Webpage:
`https://hoogle.haskell.org`.

Hoogle

Hoogle is a sort of Haskell search engine. Webpage:
`https://hoogle.haskell.org`.

Hackage Search

Hackage Search is a searching tool for Hackage based on regular expressions. This tool is by Vladislav Zavialov, my GHC teammate from Serokell.

https://hackage-search.serokell.io.

Hackage Search

Hackage Search is a searching tool for Hackage based on regular expressions. This tool is by Vladislav Zavialov, my GHC teammate from Serokell.

`https://hackage-search.serokell.io.`

Hackage Search
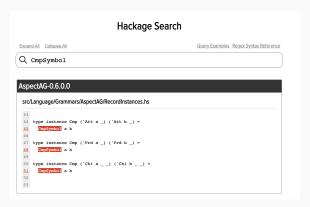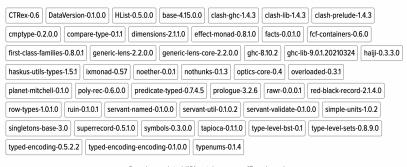
Hackage Search is a searching tool for Hackage based on regular expressions. This tool is by Vlad Zavialov, my GHC teammate from Serokell.

`https://hackage-search.serokell.io.`

CTRex-0.6 | DataVersion-0.1.0.0 | HList-0.5.0.0 | base-4.15.0.0 | clash-ghc-1.4.3 | clash-lib-1.4.3 | clash-prelude-1.4.3

cmptype-0.2.0.0 | compare-type-0.1.1 | dimensions-2.1.1.0 | effect-monad-0.8.1.0 | facts-0.0.1.0 | fcf-containers-0.6.0

first-class-families-0.8.0.1 | generic-lens-2.2.0.0 | generic-lens-core-2.2.0.0 | ghc-8.10.2 | ghc-lib-9.0.1.20210324 | haiji-0.3.3.0

haskus-utils-types-1.5.1 | ixmonad-0.57 | noether-0.0.1 | nothunks-0.1.3 | optics-core-0.4 | overloaded-0.3.1

planet-mitchell-0.1.0 | poly-rec-0.6.0.0 | predicate-typed-0.7.4.5 | prologue-3.2.6 | rawr-0.0.0.1 | red-black-record-2.1.4.0

row-types-1.0.1.0 | ruin-0.1.0.1 | servant-named-0.1.0.0 | servant-util-0.1.0.2 | servant-validate-0.1.0.0 | simple-units-1.0.2

singletons-base-3.0 | superrecord-0.5.1.0 | symbols-0.3.0.0 | tapioca-0.1.1.0 | type-level-bst-0.1 | type-level-sets-0.8.9.0

typed-encoding-0.5.2.2 | typed-encoding-encoding-0.1.0.0 | typenums-0.1.4

Search completed (161 matches across 47 packages)

Summary

We had a look at such topics as

1. General aspects of GHC and GHCi
2. The Haskell Platform installation
3. Dependency management using Stack and Cabal
4. In other words, the Haskell ecosystem in a nutshell

Summary

We had a look at such topics as

1. General aspects of GHC and GHCi
2. The Haskell Platform installation
3. Dependency management using Stack and Cabal
4. In other words, the Haskell ecosystem in a nutshell

On the next seminar, we will discuss:

1. The basic Haskell syntax
2. The underlying aspects of the Haskell type system
3. Functions and lambdas
4. Immutability and laziness