Programming in Haskell

Introduction

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Coordinates

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- **Homepage:**
  https://github.com/proglang/HaskellKurs2017

Contents

- Basics of functional programming using Haskell
- Haskell development tools
- Writing Haskell programs
- Using Haskell libraries
- Your first Haskell project

What is Haskell?

In September of 1987 a meeting was held at the conference on Functional Programming Languages and Computer Architecture in Portland, Oregon, to discuss an unfortunate situation in the functional programming community: there had come into being more than a dozen non-strict, purely functional programming languages, all similar in expressive power and semantic underpinnings. There was a strong consensus at this meeting that more widespread use of this class of functional languages was being hampered by the lack of a common language. It was decided that a committee should be formed to design such a language, providing faster communication of new ideas, a stable foundation for real applications development, and a vehicle through which others would be encouraged to use functional languages.

From "History of Haskell"

What is Functional Programming?

A different approach to programming

Functions and values

rather than

Assignments and pointers

What is Functional Programming?

A different approach to programming

Functions and values

rather than

Assignments and pointers

It will make you a better programmer

Why Haskell?

- Haskell is a very high-level language
  (many details taken care of automatically).
- Haskell is expressive and concise
  (can achieve a lot with a little effort).
- Haskell is good at handling complex data and combining components.
- Haskell is a high-productivity language
  (prioritize programmer-time over computer-time)

Functional Programming: Variables

Functional (Haskell)

```
x :: Int
x = 5
```

Variable `x` has value `5` forever

Functional Programming: Variables

Functional (Haskell)

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x :: Int
x = 5
```

Variable `x` has value `5` forever

Imperative (Java)

```
int x = 5;
...
x = x+1;
```

Variable `x` can change its content over time

Functional Programming: Functions

Functional (Haskell)

```
f :: Int -> Int -> Int
f x y = 2*x + y

f 42 16 // always 100
```

Value of a function **only** depends on its inputs

Functional Programming: Functions

Functional (Haskell)

```
f :: Int -> Int -> Int
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```

Value of a function **only** depends on its inputs

Imperative (Java)

```
boolean flag;
static int f (int x, int y) {
  return flag ? 2*x + y , 2*x - y;
}

f (42, 16); // who knows?
```

Return value depends on non-local variable `flag`

Functional Programming: Laziness

Haskell

```
x = expensiveComputation
g anotherExpensiveComputation
```

- The expensive computation will only happen if `x` is ever used.
- Another expensive computation will only happen if `g` uses its argument.

Functional Programming: Laziness

Haskell

```
x = expensiveComputation
g anotherExpensiveComputation
```

- The expensive computation will only happen if `x` is ever used.
- Another expensive computation will only happen if `g` uses its argument.

Java

```
int x = expensiveComputation;
g (anotherExpensiveComputation)
```

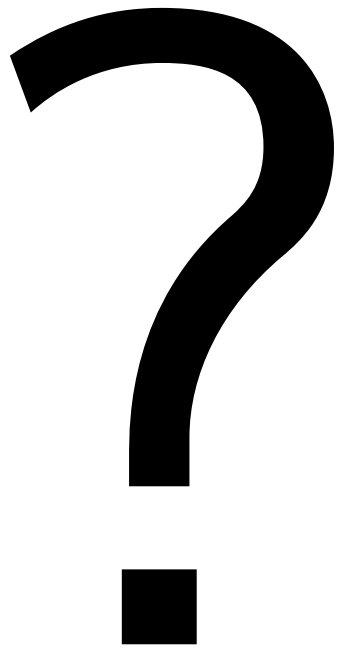
Both expensive computations will happen anyway.

Many more features that make programs more concise

- Algebraic datatypes
- Polymorphic types
- Parametric overloading
- Type inference
- Monads & friends (for IO, concurrency, . . .)
- Comprehensions
- Metaprogramming
- Domain specific languages
- . . .

References

- Paper by the original developers of Haskell in the conference on History of Programming Languages (HOPL III): http://dl.acm.org/citation.cfm?id=1238856
- The Haskell home page: `http://www.haskell.org`
- Haskell libraries repository: `https://hackage.haskell.org/`
- Haskell Tool Stack: `https://docs.haskellstack.org/en/stable/README/`



Let's get started!

Haskell Demo

- Let's say we want to buy a game in the USA and we have to convert its price from USD to EUR
- A **definition** gives a name to a value
- Names are case-sensitive, must start with lowercase letter
- Definitions are put in a text file ending in `.hs`

Examples.hs

```
dollarRate = 1.3671
```

Using the definition

- Start the Haskell interpreter GHCi

```
> stack ghci
```

```
Configuring GHCi with the following packages:
GHCi, version 8.0.1: http://www.haskell.org/ghc/  :? for h
Loaded GHCi configuration from /private/var/folders/f1/7mm
Prelude>
```

- Load the file

```
Prelude> :l Examples.hs
```

```
[1 of 1] Compiling Main                ( Examples.hs, interpr
Ok, modules loaded: Main.
*Main>
```

- Use the definition

```
*Main> dollarRate
1.3671
*Main> 53 * dollarRate
72.4563
```

A function to convert EUR to USD

Examples.hs

```
dollarRate = 1.3671

-- |convert EUR to USD
usd euros = euros * dollarRate
```

- line starting with `--`: comment
- `usd`: function name (defined)
- `euros`: argument name (defined)
- `euros * dollarRate`: expression to compute the result

Using the function

- load into GHCi
  - as before or
  - use `:r` to reload

```
*Main> usd 1
1.3671
*Main> usd 73
99.7983
```

Converting back

Write a function `euro` that converts back from USD to EUR!

```
*Main> euro (usd 73)
73.0
*Main> euro (usd 1)
1.0
*Main> usd (euro 100)
100.0
```

Converting back

Write a function `euro` that converts back from USD to EUR!

```
*Main> euro (usd 73)
73.0
*Main> euro (usd 1)
1.0
*Main> usd (euro 100)
100.0
```

Your turn

Testing properties

Is this function correct?

A reasonable property of `euro` and `usd`

```
prop_EuroUSD x = euro (usd x) == x
```

`==` is the equality operator

```
*Main> prop_EuroUSD 79
True
*Main> prop_EuroUSD 1
True
```

Testing properties

Is this function correct?

A reasonable property of `euro` and `usd`

```
prop_EuroUSD x = euro (usd x) == x
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`==` is the equality operator

```
*Main> prop_EuroUSD 79
True
*Main> prop_EuroUSD 1
True
```

Does it hold?

Aside: Writing Properties

Convention

Function names beginning with `prop_` are properties we expect to be True

Writing properties in a file

- Tells us how functions should behave
- Tells us what has been tested
- Lets us repeat tests after changing a definition

Testing

At the beginning of Examples.hs

```
import Test.QuickCheck
```

A widely used Haskell library for automatic random testing

Running tests

```
*Main> quickCheck prop_EuroUSD
*** Failed! Falsifiable (after 10 tests and 1 shrink):
7.0
```

- Runs 100 randomly chosen tests
- Result: The property is wrong!
- It fails for input 7.0

Running tests

```
*Main> quickCheck prop_EuroUSD
*** Failed! Falsifiable (after 10 tests and 1 shrink):
7.0
```

- Runs 100 randomly chosen tests
- Result: The property is wrong!
- It fails for input 7.0

Check what happens for 7.0!

What happens for 7.0

```
*Main> usd 7
9.5697
*Main> euro 9.5697
6.999999999999999
```

The Problem: Floating Point Arithmetic

- There is a very tiny difference between the initial and final values

```
*Main> euro (usd 7) - 7
-8.881784197001252e-16
```

- Calculations are only performed to about 15 significant figures
- The property is wrong!

Fixing the problem

- NEVER use equality with floating point numbers!
- The result should be *nearly* the same
- The difference should be small – smaller than 10E-15

Comparing Values

```
*Main> 2<3
True
*Main> 3<2
False
```

Defining "Nearly Equal"

- Can define new operators with names made up of symbols

In Examples.hs

```
x ~== y = abs(x - y) < 10e-15 * abs x
```

```
*Main> 3 ~== 3.0000001
True
*Main> 3 ~== 4
True
```

Fixing the property

In Examples.hs

```
prop_EuroUSD' x = euro (usd x) ~== x
```

```
*Main> prop_EuroUSD' 3
True
*Main> prop_EuroUSD' 56
True
*Main> prop_EuroUSD' 7
True
```

Name the price

Let's define a name for the price of the game we want in Examples.hs

```
price = 79
```

Name the price

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```

After reload: Ouch!

```
*Main> euro price

<interactive>:57:6:
    Couldn't match expected type 'Double' with actual type 'In
    In the first argument of 'euro', namely 'price'
    In the expression: euro price
    In an equation for 'it': it = euro price
```

Every Value has a type

The `:i` command prints information about a nae

```
*Main> :i price
price :: Integer
   -- Defined at ...
*Main> :i dollarRate
dollarRate :: Double
   -- Defined at ...
```

More types

```
*Main> :i True
data Bool = ... | True  -- Defined in ‘GHC.Types’
*Main> :i False
data Bool = False | ...  -- Defined in ‘GHC.Types’
*Main> :i euro
euro :: Double -> Double
   -- Defined at...
*Main> :i prop_EuroUSD'
prop_EuroUSD' :: Double -> Bool
   -- Defined at...
```

- `True` and `False` are **data constructors**

Types matter

- Types determine how computations are performed
- A type annotation specifies which type to use

```
*Main> 123456789*123456789 :: Double
1.524157875019052e16
*Main> 123456789*123456789 :: Integer
15241578750190521
```

- `Double`: double precision floating point
- `Integer`: exact computation
- GHCi must know the type of each expression before computing it.

Type checking

- Infers (works out) the type of every expression
- Checks that all types match — before running the program

Our example

```
*Main> :i price
price :: Integer
   -- Defined at...
*Main> :i euro
euro :: Double -> Double
   -- Defined at...
*Main> euro price

<interactive>:70:6:
    Couldn't match expected type 'Double' with actual type 'In
    In the first argument of 'euro', namely 'price'
    In the expression: euro price
    In an equation for 'it': it = euro price
```

Why did it work before?

- Numeric literals are **overloaded**
- Giving the number a name fixes its type

```
*Main> euro 79
57.78655548240802
*Main> 79 :: Integer
79
*Main> 79 :: Double
79.0
*Main> price :: Integer
79
*Main> price :: Double

<interactive>:76:1:
    Couldn't match expected type 'Double' with actual type 'In
    In the expression: price :: Double
    In an equation for 'it': it = price :: Double
```

Fixing the problem

A definition can be given a **type signature** which specifies its type

In Examples.hs

```
-- |price of the game in USD
price' :: Double
price' = 79
```

```
*Main> :i price'
price' :: Double
   -- Defined at...
*Main> euro price'
57.78655548240802
```

Break Time — Questions?