Programming in Haskell: Lecture 1

S P Suresh

August 5, 2019

Administrative

- Mondays 10.30 am and Wednesdays 02.00 pm at Seminar Hall

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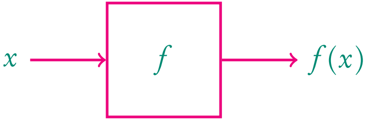
Programs as functions

- Functions transform inputs to outputs



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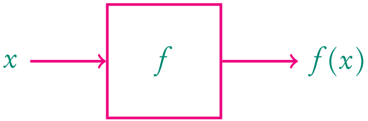

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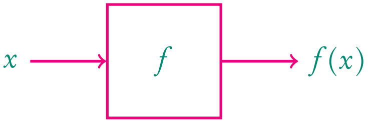

- **Program**: rules to produces outputs from inputs
- **Computation**: process of applying the rules

Building up programs

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- ...and the **successor function** `succ`

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succ 0 = 1
succ 1 = 2
succ 2 = 3
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- **Note**: We write `succ 0`, not `succ(0)`

Building up programs ...

- We can compose `succ` twice to get a new function

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plusTwo n = succ (succ n)
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- How do we get `plus` in general? `plus n m` applies the `succ` function `n` times to `m`
  - **Note**: `plus n m`, not `plus(n, m)`!

Inductive/recursive definitions

- `plus n m` applies the `succ` function `n` times to `m`

```
plus 1 m = succ m
plus 2 m = succ (succ m) = succ (plus 1 m)
plus 3 m = succ (succ (succ m)) = succ (plus 2 m)
...
plus n m = succ (succ (... (succ m)...)) = ??
```

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- How do we capture the general rule for `plus`, for all `n` and `m`?

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- `plus 1 m = succ m = succ (plus 0 m)`
- Assume we know how to compute `plus n m`
- Then `plus (succ n) m = succ (plus n m)`
- We thus have the following definition

```
plus 0        m = m
plus (succ n) m = succ (plus n m)
```

Computation

- Unravel the definition

```
  plus 3 7
= plus (succ 2) 7
= succ (plus 2 7)
= succ (plus (succ 1) 7)
= succ (succ (plus 1 7))
= succ (succ (plus (succ 0) 7))
= succ (succ (succ (plus 0 7)))
= succ (succ (succ 7))
= 10
```

Recursive definitions ...

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- We have the following definition

```
mult 0        m = 0
mult (succ n) m = plus m (mult n m)
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Types

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- `succ` takes a natural number as input and outputs a natural number
- `plus` and `mult` take two natural numbers as input, and produce a natural number as output
- Can define analogous functions for real numbers

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- Even if the input is a natural number, the output need not be a natural number (or even rational)
- Fractions and irrational numbers are wholly different types from natural numbers
- This distinction is important in programming, even though in mathematics, natural numbers are often treated as a subset of the reals

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- Consider the following definition

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capitalize 'a' = 'A'
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- Inputs and outputs for `capitalize` are letters (or **characters**)
- We will be careful to ensure that any function we define has a well defined type
- The function `plus` that adds two natural numbers will be different from another function `plus` that adds two real numbers

Functions have types

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- In Mathematics, we write $f : S \to T$ for a function with domain S and codomain T
- A type is a just a set of permissible values
- So $f : S \to T$ says that f is of type $S \to T$

Collections

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- A list of integers
- A sequence of characters – **words** or **strings**
- Pairs of numbers
- Such collections are also types of values

Haskell

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- A function description has two parts
- **Type** – of inputs and outputs
- **Definition** or **rule** for computing outputs from inputs
- Example function

```
sqr :: Int -> Int                   -- Type specification
sqr x = x * x                       -- Computation rule
```

Basic types

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- `Int` – Integers
  - Operations: `+`, `-`, `*`, `/` (Note: `/` produces `Float`)
  - Functions: `div`, `mod`
- `Float` – Floating point ("real numbers")
- `Char` – Characters: `'a'`, `'%'`, `'7'`, …

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- Operations: `&&`, `||`, `not`, …
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- `==`, `/=`, `<`, `<=`, `>`, `>=`

Defining functions

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- `xor` (Exclusive or)
- Input two values of type **`Bool`**
- Check that exactly one of them is **`True`**

```
xor :: Bool -> Bool -> Bool            -- why?
xor b1 b2 = (b1 && (not b2)) || ((not b1) && b2)
```

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Defining functions

- `isOrdered`
- Input three values of type **`Int`**
- Check that the numbers are in order

```
isOrdered :: Int -> Int -> Int -> Bool
isOrdered x y z = (x <= y) && (y <= z)
```

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- Call functions interactively within `ghci`

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- `ghc hello.hs` produces the executable `hello`)
- Run the executable by issuing `./hello` from the command line
- We will concentrate on `ghci` for most of the course