Programming in Haskell

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Lecture 1

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Administrative

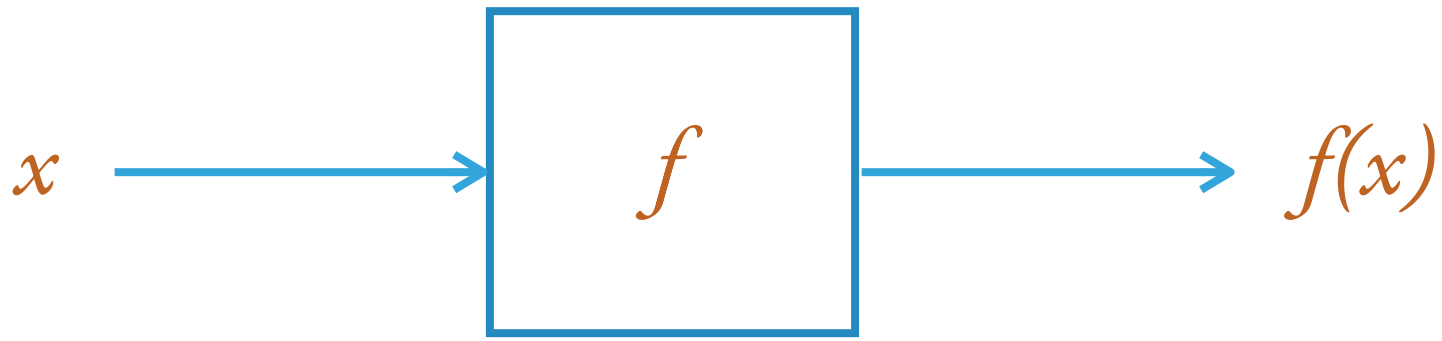
- Mondays and Wednesdays at 9.10 am at Lecture Hall 6
- Evaluation: Quizzes, 4–5 programming assignments, exams
- TAs: Agnishom Chattopadhyay, Kishlaya Jaiswal
- Moodle page: `http://moodle.cmi.ac.in/course/view.php?id=231`
- Course page: `http://www.cmi.ac.in/~spsuresh/teaching/prgh17`

Resources

- `http://www.haskell.org`
- Introduction to Functional Programming using Haskell (Richard Bird)
- Thinking Functionally with Haskell (Richard Bird)
- Real World Haskell `http://book.realworldhaskell.org/read/`
- Learn You a Haskell for Great Good!
  `http://learnyouahaskell.com/chapters`
- Haskell Programming: from first principles (Christopher Allen & Julie Moronuki) `http://haskellbook.com`
- Plenty of other resources

Programs as functions

- Functions transform inputs to outputs



- Program: rules to produce output from input
- Computation: process of applying the rules

Building up programs

How do we describe the rules?

- Start with built in functions
- Use these to build more complex functions

Building up programs …

Suppose

- … we have the whole numbers, **`{0,1,2,…}`**
- … and the successor function, **`succ`**

```
succ 0 = 1
succ 1 = 2
succ 2 = 3
...
```

- Note: we that write **`succ 0`**, not **`succ(0)`**

Building up programs …

- We can compose `succ` twice to build a new function
- `plusTwo n = succ (succ n)`
- If we compose `plusTwo` and `succ` we get
- `plusThree n = succ (plusTwo n)`

Building up programs …

- How do we define `plus`?
- `plus n m` means apply `succ` to `n`, `m` times
  - Again note: `plus n m`, not `plus(n,m)`
- ```
  plus n 1 = succ n
  plus n 2 = succ (plus n 1) = succ (succ n)
  …
  plus n i = succ(succ(…(succ n)…)
  ```
  i times
- How do we capture this rule for all `n`, `i`
  ```

Inductive/recursive definitions

- `plus n 0 = n`, for every `n`
- `plus n 1 = succ n = succ (plus n 0)`
- Assume we know how to compute `plus n m`
- Then, `plus n (succ m)` is `succ (plus n m)`

Computation

- Unraveled the definition

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

Recursive definitions ...

- Multiplication is repeated addition
- `mult n m` means apply `plus n`, `m` times
- `mult n 0 = 0`, for every `n`
- `mult n (succ m) = plus n (mult n m)`

Summary

- Functional programs are rules describing how outputs are derived from inputs
- Basic operation is function composition
- Recursive definitions allow repeated function composition, depending on the input

Building up programs

- Start with built in functions
- Use function composition, recursive definitions to build more complex functions
- What kinds of values do functions manipulate?

Types

- Functions work on values of a fixed type
- succ takes a whole number as input and produces a whole number as output
- plus and mult take two whole numbers as input and produce a whole number as output
  - Can also define analogous functions for real numbers

Types

- How about `sqrt`, the square root function?
- Even if the input is a whole number, the output need not be—may have a fractional part
- Number with fractional values are a different type from whole numbers
  - In Mathematics, whole numbers are often treated as a subset of fractional or real numbers

Types

- Other types
- `capitalize ‘a’ = ‘A’,`
  `capitalize ‘b’ = ‘B’, …`
- Inputs and outputs are letters or **“characters”**

Functions and types

- We will be careful to ensure that any function we define has a well defined type
    - The function `plus` that adds two whole numbers will be different from another function `plus` that adds two fractional numbers

Functions have types

- A function that takes inputs of type A and produces output of type B has a type $A \to B$
  - 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 this is equivalent to providing the type of f

Collections

- It is often convenient to deal with collections of values of a given type
  - A list of integers
  - A sequence of characters — words or strings
  - Pairs of numbers
- Such collections are also types of values

Summary

- Functions manipulate values
- Each input and output value comes from a well defined set of possible values — a type
- We will only allow functions whose type can be defined
  - Functions themselves inherit a type
- Collections of values also types

Haskell

- A programming language for describing functions
- A function description has two parts
    - Type of inputs and outputs
    - Rule for computing outputs from inputs
- Example

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

Basic types

- `Int`, Integers
  - Operations: `+, -, *, /` (Note: `/` produces `Float`)
  - Functions: `div, mod`
- `Float`, Floating point (“real numbers”)
- `Char`, Characters, `’a’, ’%’, ’7’, …`
- `Bool`, Booleans, `True` and `False`

Basic types ...

- `Bool`, Booleans, `True` and `False`
- Boolean expressions
  - Operations: `&&, ||, not`
  - Relational operators to compare `Int`, `Float`, ...
    - `==, /=, <, <=, >, >=`

Defining functions

- `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)
```

Defining functions

- `inorder`
  - Input three values of type `Int`
  - Check that the numbers are in order
    - ```
      inorder :: Int -> Int -> Int -> Bool
      inorder x y z = (x <= y) && (y <= z)
      ```
      ```

Pattern matching

- Multiple definitions, by cases

    - ```
      xor :: Bool -> Bool -> Bool
      xor True  False = True
      xor False True  = True
      xor b1    b2    = False
      ```

- Use first definition that matches, top to bottom

    - `xor False True` matches second definition

    - `xor True True` matches third definition
      ```

Pattern matching ...

- When does a function call match a definition?
  - If the argument in the definition is a constant, the value supplied in the function call must be the same constant
  - If the argument in the definition is a variable, any value supplied in the function call matches, and is substituted for the variable (the "usual" case)

Pattern matching …

- Can mix constants and variables in a definition

  - ```
    or :: Bool -> Bool -> Bool
    or True  b    = True
    or b     True = True
    or b1    b2   = False
    ```

- `or True False` matches first definition

- `or False True` matches second definition

- `or False False` matches third definition
    ```

Pattern matching ...

- Another example

  - ```
    and :: Bool -> Bool -> Bool
    and True  b = b
    and False b = False
    ```

- In the first definition, the argument `b` is used in the definition

- In the second, `b` is ignored
    ```

Summary

- A Haskell function consists of a type definition and a computation rule
- Can have multiple rules for the same function
  - Rules are matched top to bottom
  - Use patterns to split cases

Running Haskell programs

- Haskell interpreter `ghci`
  - Interactively call builtin functions
  - Load user-defined Haskell code from a text file
  - Similar to how Python works

Setting up ghci

- Download and install the Haskell Platform
  - `https://www.haskell.org/platform/`
  - Available for Windows, Linux, macOS

Using ghci

- Create a text file (extension `.hs`) with your Haskell function definitions
- Run `ghci` at the command prompt
- Load your Haskell code
  - `:load myfile.hs`
- Call functions interactively within `ghci`

Compiling

- `ghc` is a compiler that creates a standalone executable from a .hs file
  - `ghc` stands for Glasgow Haskell Compiler
  - `ghci` is the associated interpreter
- Using `ghc` requires some advanced concepts
  - We will come to this later in the course

Summary

- `ghci` is a user-friendly interpreter
    - Can load and interactively execute user defined functions
- `ghc` is a compiler
    - But we need to know more Haskell before we can use it