CSc 372

Comparative Programming Languages

4 : Haskell — Basics

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The Hugs Interpreter

- The Haskell implementation we will be using is called Hugs.
- You interact with Hugs by typing commands to the interpreter, much like you would to a powerful calculator:

```
$ hugs
> 6 * 7
42
> 126 `div` 3
4
```

The Hugs Interpreter...

- Haskell programs (known as scripts) are just text files with function definitions that can be loaded into the interpreter using the `:load script` command:

```
$ hugs
> :load file.hs
```

- Haskell scripts take the file extension `.hs`.

Haskell Types

Expressions

- When we "run" a Haskell program, we actually evaluate an expression, and the result of the program is the value of that expression.
- Unlike Java programs. Haskell programs have no statements — there is no way to assign a new value to a variable for example.

Haskell Types

- Haskell is strongly typed. This means that every expression has exactly one type.
- Haskell is statically typed. This means that the type of an expression can be figured out before we run the program.
- The basic types in Haskell include
  1. Int (word-sized integers)
  2. Integer (arbitrary precision integers)
  3. Float (Floating point numbers)
  4. Tuples and Lists
  5. Strings (really just lists)
  6. Function types

Type inference

- In Java and most other languages the programmer has to declare what type variables, functions, etc have.
- We can do this too, in Haskell:

```
> 6*7 :: Int
42
```

  :: Int asserts that the expression 6*7 has the type Int.
- Haskell will check for us that we get our types right:

```
> 6*7 :: Bool
ERROR
```

Type inference...

- We can let the Haskell interpreter infer the type of expressions, called type inference.
- The command `:type expression` asks Haskell to print the type of an expression:

```
> :type "hello"
"hello" ::  String

> :type True && False
True && False ::  Bool

> :type True && False ::  Bool
True && False ::  Bool
```

Simple Types

Int

- The Int type is a 32-bit signed integer, similar to Java's int type:

  ```
  Prelude> (3333333 :: Int) * (44444444444444 :: Int)
  Program error: arithmetic overflow
  ```

  Some Haskell versions may instead overflow the integer (yielding a negative number).

Int — Operators

- The normal set of arithmetic operators are available:

Op	Precedence	Associativity	Description
`^`	8	right	Exponentiation
`*, /`	7	left	Mul, Div
`` `div` ``	7	free	Division
`` `rem` ``	7	free	Remainder
`` `mod` ``	7	free	Modulus
`+, -`	6	left	Add, Subtract
`==,/=`	4	free	(In-) Equality
`<,<=,>,>=`	4	free	Relational Comparison

Int. . .

- Note that the `div` operator has to be in backquotes when used as an infix operator:

```
> 4*12-6
42
> 126 `div` 3
42
> div 126 3
42
```

Int. . .

- The standard precedence and associativity rules apply:

`1+2-3`	⇒ `(1+2)-3`	`4==5==6`	⇒ `ERROR`
`1+2*3`	⇒ `1+(2*3)`	`12/6/3`	⇒ `0.6666666666666667`
`2^3^4`	⇒ `2^(3^4)`	`12/(6/3)`	⇒ `6.0`

Integer

- Haskell also has an infinte precision integer type, similar to Java's `java.math.BigInteger` class:

```
> (3333333 :: Integer) * (44444444444444 :: Integer)
148148133333331851852
```

- `Integers` are the default integer type:

```
> 2^64
18446744073709551616
```

Integer...

- Ints and Integers aren't compatible:

```
> (3333333 :: Integer) * (44 :: Int)
ERROR - Type error in application
```

- but we can convert from an Int to an Integer:

```
> (toInteger (55 :: Int)) * (66 :: Integer)
3630
```

Float and Double

- Haskell also has built-in floating point numbers `Float` and `Double`:

```
> sqrt 2 :: Float
1.414214
> sqrt 2 :: Double
1.4142135623731
```

- `sqrt` is a built-in library function.
- Double is the default:

```
> sqrt 2
1.4142135623731
```

Char

- Literals: `'a'`, `'b'`. Special characters: `'\n'` (newline).
- ASCII: `'\65'` (decimal), `'\x41'` (hex).
- There are standard functions on characters (`toUpper`, `isAlpha`, etc) defined in the a separate module Char:

```
> :load Char
> toUpper 'A'
'A'
> toUpper 'a'
'A'
> ord 'a'
97
```

Char — Built-in Functions

```
ord :: Char -> Int
chr :: Int -> Char
toUpper, toLower :: Char -> Char
isAscii,isDigit,··· :: Char -> Bool
isUpper,isLower,··· :: Char -> Bool
```

ord 'a' ⇒ 97 toUpper 'a' ⇒ 'A'
chr 65 ⇒ 'A' isDigit 'a' ⇒ False

String

- Strings are really lists of characters.

```
> "hello"
"hello"
> :type "hello"
"hello" ::  String
> "hello" ::  String
"hello"
> length "hello"
5
> "hello" ++ " world!"
"hello world!"
```

- ++ does string/list concatenation.

Bool

- There are two boolean literals, `True` and `False`

Op	Precedence	Associativity	Description
`&&`	3	right	logical and
`||`	2	right	logical or
`not`	9	–	logical not

```
3 < 5 && 4 > 2              ⇔ (3 < 5) && (4 > 2)
True || False && True       ⇔ True || (False && True)
```

Haskell Functions

Functions

- Here's the ubiquitous factorial function:

```
fact ::  Int -> Int
fact n =    if n == 0 then
               1
            else
               n * fact (n-1)
```

- The first part of a function definition is the type signature, which gives the domain and range of the function:

```
      fact ::  Int -> Int
```

- The second part of the definition is the function declaration, the implementation of the function:

```
fact n = if n == 0 then ···
```

Functions...

- The syntax of a type signature is

  `fun_name :: arg_types`

  `fact` takes one integer input argument and returns one integer result.
- The syntax of function declarations:

  `fun_name param_names = fun_body`
- `fact` is defined recursively, i.e. the function body contains an application of the function itself.
- Function application examples:

  `fact 1` $\Rightarrow$ `1`
  `fact 5` $\Rightarrow$ `120`
  `fact (3+2)` $\Rightarrow$ `120`

List and Tuple Types

Lists

- A list in Haskell consists of a sequence of elements, all of the same type:

```
> [1,2,3]
[1,2,3]
> [True,False] :: [Bool]
[True,False]
> :type [True,False]
[True,False] :: [Bool]
> :type [['A','B'],['C','D'],[]]
[['A','B'],['C','D'],[]] :: [[Char]]
> [1,True]
ERROR
> length [1,2,3]
3
```

Tuples

- A Haskell tuple is similar to a record/struct in C – it is a collection of objects of (a limited number of) objects, possibly of different types. Each C struct elements has a unique name, whereas in Haskell you distinguish between elements by their position in the tuple.
- Syntax: $(t_1, t_2, \cdots, t_n)$.

Examples:

```
type Complex = (Float,Float)
mkComplex ::  Float -> Float -> Complex
mkComplex re im = (re, im)
```

Tuples...

```
type Complex = (Float,Float)
mkComplex ::  Float -> Float -> Complex
mkComplex re im = (re, im)
```

mkComplex 5 3 ⇒ (5, 3)

```
addComplex ::  Complex -> Complex -> Complex
addComplex (a,b) (c,d) = (a+c,b+d)
```

addComplex (mkComplex 5 3) (mkComplex 4 2) ⇒ (9,5)

Haskell Scripts

Editing and Loading Scripts

- `:load name` (or `:l name`) loads a new Haskell program.
- `:reload` (or `:r`) reloads the current script.
- `:edit name` (or `:e name`) edits a script. On Unix you can set the `EDITOR` environment variable to control which editor to use:

```
setenv EDITOR emacs
```

- `:?` shows all available commands.
- `:quit` quits Hugs.

The Offside Rule

- When does one function definition end and the next one begin?

```
square x =  x * x
            +2
cube x = ···
```

- Textual layout determines when definitions begin and end.

The Offside Rule...

- The first character after the "=" opens up a box which holds the right hand side of the equation:

```
square x = | x * x
           | +2
           v
```

- Any character to the left of the line closes the box and starts a new definition:

```
square x = | x * x
           | +2
           |__________

cube x = ...
```

Comments

- Line comments start with `--` and go to the end of the line:

```
-- This is a comment.
```

- Nested comments start with `{-` and end with `-}`:

```
{-
   This is a comment.
   {-
      And here's another one....
   -}
-}
```

Editing Scripts

Emacs

- On Unix, `emacs` is the editor of choice.
- Depending on your system, it may be called `emacs` or `xemacs`.
- For a list of common commands, see the links below.

Readings and References

- In addition to our textbook, chapters 1-3 of *Programming in Haskell*, by Graham Hutton, is a good introduction to Haskell:
  http://www.cs.nott.ac.uk/~gmh/book.html
- Emacs Guide: http://www.cs.arizona.edu/classes/cs372/fall03/04.html
- Emacs Reference Card:
  http://www.cs.arizona.edu/classes/cs372/fall03/emacs.html

Summary

- Haskell has all the basic types one might expect: `Ints`, `Chars`, `Floats`, and `Bools`.
- Haskell functions come in two parts, the signature and the declaration:

```
fun_name ::  argument_types
fun_name param_names = fun_body
```

- Many Haskell functions will use recursion.
- Haskell doesn't have assignment statements, loop statements, or procedures.
- Haskell tuples are similar to records in other languages.

Exercise

1. Start Hugs.
2. Enter the `commaint` function and try it out.
3. Enter the `addComplex` and `mkComplex` functions and try them out.
4. Try the standard functions `fst x` and `snd x` on complex values. What do `fst` and `snd` do?
5. Try out the Eliza application in `/usr/local/hugs98/lib/hugs/demos/Eliza.hs` on lectura.

Exercise. . .

- Write a Haskell function to check if a character is alphanumeric, i.e. a lower case letter, upper case letter, or digit.

```
?  isAlphaNum 'a'
   True
?  isAlphaNum '1'
   True
?  isAlphaNum 'A'
   True
?  isAlphaNum ';'
   False
?  isAlphaNum '@'
   False
```

Exercise. . .

- Define a Haskell exclusive-or function.

```
eOr ::  Bool -> Bool -> Bool
eOr x y = ···
```

```
?  eOr True True
   False
?  eOr True False
   True
?  eOr False True
   True
?  eOr False False
   False
```

Exercise. . .

- Define a Haskell function `charToInt` which converts a digit like `'8'` to its integer value 8. The value of non-digits should be taken to be 0.

```
charToInt ::  Char -> Int
charToInt c = ···

?  charToInt '8'
   8
?  charToInt '0'
   0
?  charToInt 'y'
   0
```