PROGRAMMING IN HASKELL



Chapter 3 - Types and Classes

What is a Type?

A type is a name for a collection of related values. For example, in Haskell the basic type

Bool

contains the two logical values:

False

True

Type Errors

Applying a function to one or more arguments of the wrong type is called a type error.

> > 1 + False error ...

1 is a number and False is a logical value, but + requires two numbers. **Types in Haskell**

z If evaluating an expression e would produce a value of type t, then e has type t, written

e :: t

z Every well formed expression has a type, which can be automatically calculated at compile time using a process called type inference.

- z All type errors are found at compile time, which makes programs safer and faster by removing the need for type checks at run time.
- z In GHCi, the :type command calculates the type of an expression, without evaluating it:

> not False True

> :type not False not False :: Bool **Basic Types**

Haskell has a number of basic types, including:

Bool

logical values

Char

- single characters

String - strings of characters

Int

- integer numbers

Float

- floating-point numbers

List Types

A <u>list</u> is sequence of values of the <u>same</u> type:

```
[False,True,False] :: [Bool]
['a','b','c','d'] :: [Char]
```

In general:

[t] is the type of lists with elements of type t.

Note:

z The type of a list says nothing about its length:

```
[False,True] :: [Bool]
[False,True,False] :: [Bool]
```

z The type of the elements is unrestricted. For example, we can have lists of lists:

```
[['a'],['b','c']] :: [[Char]]
```

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Tuple Types

A <u>tuple</u> is a sequence of values of <u>different</u> types:

```
(False,True) :: (Bool,Bool)
(False,'a',True) :: (Bool,Char,Bool)
```

In general:

(t1,t2,...,tn) is the type of n-tuples whose ith components have type ti for any i in 1...n.

Note:

z The type of a tuple encodes its size:

```
(False,True) :: (Bool,Bool)
(False,True,False) :: (Bool,Bool,Bool)
```

z The type of the components is unrestricted:

```
('a',(False,'b')) :: (Char,(Bool,Char))
(True,['a','b']) :: (Bool,[Char])
```

Function Types

A <u>function</u> is a mapping from values of one type to values of another type:

```
not :: Bool \rightarrow Bool
even :: Int \rightarrow Bool
```

In general:

 $t1 \rightarrow t2$ is the type of functions that map values of type t1 to values to type t2.

Note:

- z The arrow \rightarrow is typed at the keyboard as ->.
- z The argument and result types are unrestricted. For example, functions with multiple arguments or results are possible using lists or tuples:

add :: (Int,Int)
$$\rightarrow$$
 Int add (x,y) = x+y

zeroto :: Int \rightarrow [Int] zeroto n = [0..n]

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Curried Functions

Functions with multiple arguments are also possible by returning <u>functions</u> as <u>results</u>:

add' :: Int
$$\rightarrow$$
 (Int \rightarrow Int) add' x y = x+y

add' takes an integer x and returns a function add' x. In turn, this function takes an integer y and returns the result x+y.

Note:

z add and add' produce the same final result, but add takes its two arguments at the same time, whereas add' takes them one at a time:

add :: (Int,Int)
$$\rightarrow$$
 Int add' :: Int \rightarrow (Int \rightarrow Int)

z Functions that take their arguments one at a time are called <u>curried</u> functions, celebrating the work of Haskell Curry on such functions.

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z Functions with more than two arguments can be curried by returning nested functions:

mult :: Int
$$\rightarrow$$
 (Int \rightarrow (Int \rightarrow Int))
mult x y z = x*y*z

mult takes an integer x and returns a function mult x, which in turn takes an integer y and returns a function mult x y, which finally takes an integer z and returns the result x*y*z.

Why is Currying Useful?

Curried functions are more flexible than functions on tuples, because useful functions can often be made by partially applying a curried function.

For example:

add' 1 :: Int
$$\rightarrow$$
 Int
take 5 :: [Int] \rightarrow [Int]
drop 5 :: [Int] \rightarrow [Int]

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Currying Conventions

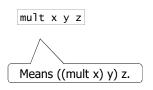
To avoid excess parentheses when using curried functions, two simple conventions are adopted:

z The arrow \rightarrow associates to the right.

$$\boxed{ \text{Int} \rightarrow \text{Int} \rightarrow \text{Int} \rightarrow \text{Int} }$$

$$\boxed{ \text{Means Int} \rightarrow (\text{Int} \rightarrow (\text{Int} \rightarrow \text{Int})). }$$

z As a consequence, it is then natural for function application to associate to the <u>left</u>.

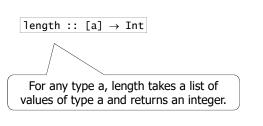


Unless tupling is explicitly required, all functions in Haskell are normally defined in curried form.

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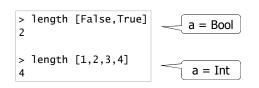
Polymorphic Functions

A function is called <u>polymorphic</u> ("of many forms") if its type contains one or more type variables.



Note:

z Type variables can be instantiated to different types in different circumstances:



z Type variables must begin with a lower-case letter, and are usually named a, b, c, etc.

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z Many of the functions defined in the standard prelude are polymorphic. For example:

fst ::
$$(a,b) \rightarrow a$$

head :: $[a] \rightarrow a$
take :: $Int \rightarrow [a] \rightarrow [a]$
zip :: $[a] \rightarrow [b] \rightarrow [(a,b)]$
id :: $a \rightarrow a$

Overloaded Functions

A polymorphic function is called <u>overloaded</u> if its type contains one or more class constraints.

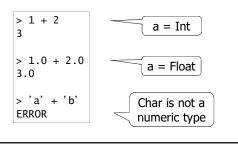
(+) :: Num $a \Rightarrow a \rightarrow a \rightarrow a$

For any numeric type a, (+) takes two values of type a and returns a value of type a.

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Note:

z Constrained type variables can be instantiated to any types that satisfy the constraints:



z Haskell has a number of type classes, including:

Num - Numeric types

Eq - Equality types

Ord - Ordered types

z For example:

(+) :: Num $a \Rightarrow a \rightarrow a \rightarrow a$ (==) :: Eq $a \Rightarrow a \rightarrow a \rightarrow Bool$

(<) :: Ord $a \Rightarrow a \rightarrow a \rightarrow Bool$

Hints and Tips

- z When defining a new function in Haskell, it is useful to begin by writing down its type;
- z Within a script, it is good practice to state the type of every new function defined;
- z When stating the types of polymorphic functions that use numbers, equality or orderings, take care to include the necessary class constraints.

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Exercises

(1) What are the types of the following values?

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(2) What are the types of the following functions?

```
second xs = head (tail xs)
swap (x,y) = (y,x)
pair x y = (x,y)
double x = x*2
palindrome xs = reverse xs == xs
twice f x = f (f x)
```

(3) Check your answers using GHCi.

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