CSc 372

Comparative Programming Languages

14 : Haskell — Data Types

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User-defined Datatypes

- Haskell lets us create new datatypes:

  data *Datatype* $a_1 \ldots a_n$ = $constr_1$ | ... | $constr_m$

  where
  1. *Datatype* is the name of a new type constructor
  2. $a_1, \ldots, a_n$ are type variables representing the arguments of *Datatype*
  3. $constr_1, \ldots, constr_m$ are the different ways in which we can create new elements of the new datatype.
- Each *constr* is of the form

  $$Name\ type_1 \ldots type_r$$

  where *Name* is a new name beginning with a capital letter.

Like Enumerations!

- The following definition introduces a new type Day with elements Sun, Mon, Tue, ...:

```
data Day = Sun|Mon|Tue|Wed|Thu|Fri|Sat
```

- Simple functions manipulating elements of type Day can be defined using pattern matching:

```
what_shall_I_do Sun = "relax"
what_shall_I_do Sat = "go shopping"
what_shall_I_do _   = "go to work"
```

Like Enumerations — with arguments!

- We can represent temperatures either using centigrade or fahrenheit:

```
data Temp = Centigrade Float |
            Fahrenheit Float
            deriving Show

freezing                   :: Temp -> Bool
freezing (Centigrade temp) = temp <= 0.0
freezing (Fahrenheit temp) = temp <= 32.0
```

- We add the syntax deriving Show so that we can print out elements of the datatype:

```
> Centigrade 66
Centigrade 66.0
```

Recursive Datatypes

- We can define recursive datatypes.
- In fact, we can use datatypes to define our own kind of lists!
- Here's a list of integers:

```
data IntList =
   IntCons Int IntList |
   IntNil
   deriving Show
```

- As usual, a list is either `Nil` or a `Cons` cell consisting of an integer and the rest of the list.
- Here's the list `[5,6]` in our new representation:

```
IntCons 5 (IntCons 6 IntNil)
```

Polymorphic Recursive Datatypes

- Here's a recursive definition of a polymorphic list:

```
data List a =
   Cons a (List a) |
   Nil deriving Show
```

- We can define our own versions of `head` and `tail`:

```
hd Nil = error "Head of Nil"
hd (Cons a _) = a

tl Nil = error "Tail of Nil"
tl (Cons _ b) = b
```

- And we can construct lists of arbitrary types and take them apart:

```
> hd (tl (Cons 1 (Cons 2 Nil)))
2
> hd (tl (Cons "hello" (Cons "bye" Nil)))
"bye"
```

Polymorphic Binary Tree

- Here's the definition of a binary tree with data in each leaf and internal node:

```
data Tree a =  Leaf a |
               Node (Tree a) a (Tree a)
               deriving Show
```

- For example, here's a binary search tree with the elements `f, 10, 12, 15, 16`:

```
Node
   (Leaf 5)
   10
   (Node
      (Leaf 12)
      15
      (Leaf 16)
   )
```

Polymorphic Binary Search Tree

- Here's a function that looks up a value in a tree:

```
treemem :: Ord a => Tree a -> a -> Bool
treemem (Leaf v) x = x == v
treemem (Node l v r) x
         | x == v = True
         | x < v = treemem l x
         | x > v = treemem r x
```

- Examples:

```
> let t = Node (Leaf 5) 10 (Node (Leaf 12) 15 (Leaf 16))
> treemem t 16
True
> treemem t 5
True
> treemem t 1
False
```

Homework 1

- Write the function `depth` which calculates the depth of a tree, `leaves` which returns the leaves of a tree, and `inorder` which returns a list of the nodes of the tree in inorder:

```
depth :: Tree a -> Int
leaves :: Tree a -> [a]
inorder :: Tree a -> [a]
```

Homework 1...

- Examples:

```
> let t1 = Node (Leaf 5) 10 (Leaf 15)
> let t2 = Node (Leaf 5) 10 (Node (Leaf 12) 15 (Leaf 16))
> depth t1
2
> depth t2
3
> leaves t1
[5,15]
> leaves t2
[5,12,16]
> inorder t1
[5,10,15]
> inorder t2
[5,10,12,15,16]
```

Homework 2

- Here's a datatype for arithmetic expressions:

```
data Expr = Val Int
          | Add Expr Expr
          | Sub Expr Expr
          | Mul Expr Expr
          | Div Expr Expr
          | Neg Expr
          deriving Show
```

- Write a function `eval e` which evaluates an arithmetic expression `e`:

```
eval :: Expr -> Int
```

Homework 2...

- Examples:

```
> eval (Val 5)
5
> eval (Add (Val 6) (Val 5))
11
> eval (Add (Mul (Val 7) (Val 5)) (Val 7))
42
```