

Assignment Project Exam Help

COMP9141

Software System Design and Implementation

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GADTs Practice

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Exercise 5

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- Parse a series of tokens.
- Stack push and pop.
- Evaluate a sequence of tokens.
- Calculate a string.

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Recall: GADTs

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Generalised Algebraic Datatypes (*GADTs*) is an extension to Haskell that, among other things, allows data types to be specified by writing the types of their constructors:

```
{-# LANGUAGE GADTs, KindSignatures #-}
-- Unary natural numbers, e.g. 3 is S (S (S Z))
data Nat = Z | S Nat
```

```
-- is the same as
```

```
data Nat :: * where
  Z :: Nat
  S :: Nat -> Nat
```

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The printf function

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Consider the well known C function printf:

```
printf("Hello %s You are %d years old!", "Nina", 22)
```

In C, the type (and number) of parameters passed to this function are dependent on the first parameter (the format string).

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The printf function

To do a similar thing in Haskell, we would like to use a richer type that allows us to define a function whose subsequent parameter is determined by the first.

```
data Format :: * -> * where
  End :: Format ()           -- Empty format
  Str :: Format t -> Format (String, t) -- %s
  Dec :: Format t -> Format (Int, t)    -- %d
  L :: String -> Format t -> Format t  -- literal strings
deriving instance Show (Format ts)
-- just like deriving (Show) for normal data types.
```

Our format strings are indexed by a tuple type containing all of the types of the %directives used.

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The printf function

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"Hello %s You are %d years old!"

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is written:

```
L "Hello" $ Str $ L " You are "
$ Dev $ L " years old!" End
```

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The printf function

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```
printf :: Format ts -> ts -> IO ()
printf End () =
  pure () -- type is ()
printf (Str fmt) (s,ts) =
  do putStr s; printf fmt ts -- type is (String, ...)
printf (Dec fmt) (i,ts) =
  do putStr (show i); printf fmt ts -- type is (Int, ...)
printf (L s fmt) ts =
  do putStr s; printf fmt ts
```

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Vectors

Define a natural number kind to use on the type level:

```
data Nat = Z | S Nat
```

Our length-indexed list can be defined, called a Vec:

```
data Vec (a : *) :: Nat -> * where
  Nil  :: Vec a Z
  Cons :: a -> Vec a n -> Vec a (S n)
```

The functions `hd` and `tl` can be total:

```
hd :: Vec a (S n) -> a
hd (Cons x xs) = x
tl :: Vec a (S n) -> Vec a n
tl (Cons x xs) = xs
```


Vectors, continued

Our `map` for vectors is as follows:

```
mapVec :: (a -> b) -> Vec a n -> Vec b n
```

```
mapVec f Nil = Nil
```

```
mapVec f (Cons x xs) = Cons (f x) (mapVec f xs)
```

Properties

Using this type, it's impossible to write a `mapVec` function that changes the length of the vector.

Properties are verified by the compiler!

Appending Vectors

Example (Problem)

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```
appendV :: Vec a m -> Vec a n -> Vec a ???
```

We want to write $m + n$ in the `???` above, but we do not have addition defined for kind `Nat`.

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We can define a normal Haskell function easily enough:

```
plus :: Nat -> Nat -> Nat
plus Z y = y
plus (S x) y = S (plus x y)
```

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This function is not applicable to **type-level** Nats, though.

⇒ we need a **type level function**.

Type Families

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Type level functions, also called *type families*, are defined in Haskell like so.

```
{-# LANGUAGE TypeFamilies #-}
type family Plus (x :: Nat) (y :: Nat) :: Nat where
  Plus Z      y = y
  Plus (S x) y = S (Plus x y)
```

We can use our type family to define appendV:

```
appendV :: Vec a n -> Vec a m -> Vec a (Plus n m)
appendV Nil      ys = ys
appendV (Cons x xs) ys = Cons x (appendV xs ys)
```

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Concatenating Vectors

Example (Problem)

```
concatV :: Vec (Vec a m) n -> Vec a ???
```

We want to write $m * n$ in the ??? above, but we do not have times defined for kind `Nat`.

```
{-# LANGUAGE TypeFamilies #-}
```

```
type family Times (a :: Nat) (b :: Nat) :: Nat where
```

```
  Times Z n = Z
```

```
  Times (S m) n = Plus m (Times m n)
```

We can use our type family to define `concatV`:

```
concatV :: Vec (Vec a m) n -> Vec a (Times n m)
```

```
concatV Nil = Nil
```

```
concatV (Cons v vs) = v `appendV` concatV vs
```

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Filtering Vectors

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Example (Problem)

```
filterV :: (a -> Bool) -> Vec a n -> Vec a ???
```

What is the size of the result of filter?

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Filtering Vectors

Example (Problem)

```
filterV :: (a -> Bool) -> Vec a n -> [a]
```

We do not know the size of the result.

We can use our type family to define concatV:

```
filterV :: (a -> Bool) -> Vec a n -> [a]
```

```
filterV p Nil = []
```

```
filterV p (Cons x xs)
```

```
    | p x = x : filterV p xs
```

```
    | otherwise = filterV p xs
```

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Homework

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- ➊ Assignment 2 is **released**. Due on **5th August, 3 PM** (in 14 days).
- ➋ Week 7's quiz is due on Friday. Make sure you submit your answers.
- ➌ The sixth programming exercise is due by the start of my next lecture (in 7 days).
- ➍ This week's quiz is also up, it's due Friday week (in 9 days).

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Consultations

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- Consultations will be made on request. Ask on piazza or email `cs3141@cse.unsw.edu.au`.
- If there is a consultation it will be announced on Piazza with a link a room number for Hopper.
- Will be in the Thursday lecture slot, 9am to 11am on Blackboard Collaborate.
- Make sure to join the queue on Hopper. Be ready to share your screen with REPL (`ghci` or `stack repl`) and editor set up.

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