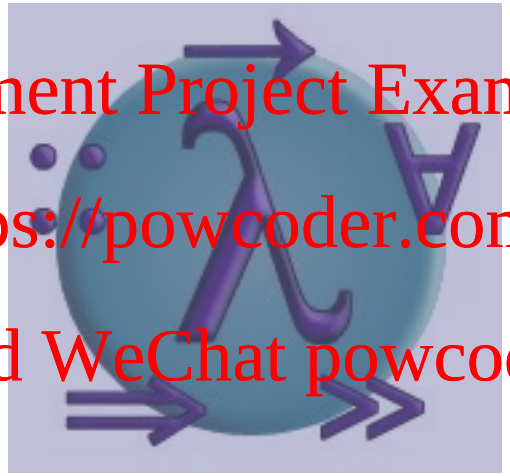
PROGRAMMING IN HASKELL



Monads

Introduction

In the course we have made two uses of the do-notation so far:

- Parsers
- IO

Parsers and IO are two instances of an abstract structure called a monad.

Parsing using the do-notation

A sequence of parsers can be combined as a single composite parser using the keyword do.

For example:


```
p :: Parser (Char,Char)
p = do x ← item
       item
       y ← item
       return (x,y)
```

IO using the do-notation

A sequence of actions can be combined as a single composite action using the keyword do.

For example:


```
a :: IO (Char,Char)
a  = do x ← getChar
        getChar
        y ← getChar
        return (x,y)
```

Monads

- Monads are a structure composed of two basic operations (bind and return), which capture a common pattern that occurs in many types.

- In Haskell Monads are implemented using type classes:


```
class Monad m where
  (>>=)  :: m a -> (a -> m b) -> m b
  return :: a -> m a
```

Do-notation

- The do-notation is just simple syntactic sugar on top of the monad operations:


```
do  pattern <- exp
    morelines
```


Is converted to code using bind:

```
exp >>= (\pattern -> do morelines)
```

Do-notation

- The do-notation is just simple syntactic sugar on top of the monad operations:


```
do   exp
     morelines
```


Is converted to code using bind:

```
exp >>= (\_ -> do morelines)
```

Do-notation

- The do-notation is just simple syntactic sugar on top of the monad operations:


```
do   return exp
```


Is simplified to:

```
return exp
```

Parsing using the do-notation

Lets rewrite a program using the do-notation!


```
do x ← item
   item
   y ← item
   return (x,y)
```

Parsing using the do-notation

Lets rewrite a program using the do-notation!

```
item >>= (\x ->
  item >>= (\_ ->
    item >>= (\y ->
      return (x,y))))
```


What are the steps?

Parsing using the do-notation

Lets rewrite a program using the do-notation!

```
item >>= \x ->
   do  item
       y ← item
       return (x,y)
```

Parsing using the do-notation

Lets rewrite a program using the do-notation!


```
item >>= \x ->
   item >>= \_ ->
     do y ← item
        return (x,y)
```

Parsing using the do-notation

Lets rewrite a program using the do-notation!


```
item >>= \x ->
   item >>= \_ ->
     item >>= \y ->
        do return (x,y)
```

Parsing using the do-notation

Lets rewrite a program using the do-notation!


```
item >>= \x ->
   item >>= \_ ->
     item >>= \y ->
        return (x,y)
```

Creating Monads

- Monads are created using an instance of the Monad type class.

- The Parser monad is a user-defined Monad

- The IO Monad is built-in

Parser Monad

Here is the Parser Monad:

```
data Parser a =  P (String -> [(a,String)])

instance Monad Parser where
   -- return :: a -> Parser a
   return v =  P (\inp -> [(v,inp)])
   -- (>>=) :: Parser a -> (a -> Parser b) -> Parser b
   p >>= f  =  P (\inp -> case parse p inp of
                            []        -> []
                            [(v,out)] -> parse (f v) out)
```

Parser Monad

- Simply providing this instance allows us to use the do-notation!


```
newtype Parser a =  P (String -> [(a,String)])
```



```
instance Monad Parser where
   return v =  P (\inp -> [(v,inp)])
   p >>= f  =  P (\inp -> case parse p inp of
                            []        -> []
                            [(v,out)] -> parse (f v) out)
```

IO

IO is special in Haskell, since it is a type built-in the language. The compiler provides an instance of the Monad class with suitable return and >>= functions:


```
return :: a -> IO a
(>>=) :: IO a -> (a -> IO b) -> IO b
```

Creating a Simple Monad

Once we understand monads it is easy to create our own monads. An example is a variation of the Maybe type


```
data Option a = None | Some a
```



```
instance Monad Option where
   ???
```


Lets create the Option Monad!

Creating a Simple Monad

With option we can create a safer version of arithmetic expressions:


```
sdiv :: Option Int -> Option Int -> Option Int
```



```
sadd :: Option Int -> Option Int -> Option Int
```


That track whether division by 0 errors occur.

Monad Laws

It is not enough to implement bind and return. A proper monad is also required to satisfy some laws:

return a >>= k = k a

m >>= return = m

m >>= (\x -> k x >>= h) = (m >>= k) >>= h

More on Monads

Monads, Functional Programming and Interpreters

- Monads were introduced to Functional Programming by Philip Wadler.
- See the paper below, which motivates monads through interpreters (much like the interpreters in the class)

The essence of Functional Programming, Philip Wadler, 1992