IO Monad (3C)

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Based on

Haskell in 5 steps
https://wiki.haskell.org/Haskell_in_5_steps

https://www.schoolofhaskell.com/user/EFulmer/currying-and-partial-application

http://www.idryman.org/blog/2014/01/23/yet-another-monad-tutorial/

A Type Monad

Haskell does not have states

But its powerful type system enable to construct the stateful program flow

Defining a Monad type is like defining a class in an object oriented language
A Monad can do much more than a class:

A Monad is a type that can be used for

- exception handling
- constructing parallel program workflow
- a parser generator

http://www.idryman.org/blog/2014/01/23/yet-another-monad-tutorial/

Types: rules and data

types are the **rules** associated with the **data**, not the actual data itself.

Object-Oriented Programming enable us

to use classes/interfaces

to define **types**,

the **rules** (**methods**) that interacts with the actual **data**.

to use **templates**(c++) or **generics**(java)

to define more **abstracted rules** that are more reusable

Monad is pretty much like **generic class**.

http://www.idryman.org/blog/2014/01/23/yet-another-monad-tutorial/

Monad Rules

A type is just a set of rules, or methods in Object-Oriented terms

A Monad is just yet another type, and the definition of this type is defined by four rules:

1) **bind (>>=)**
2) **then (>>)**
3) **return**
4) **fail**

http://www.idryman.org/blog/2014/01/23/yet-another-monad-tutorial/

Monad Applications

1. Exception Handling

2. Accumulate States

3. IO Monad

http://www.idryman.org/blog/2014/01/23/yet-another-monad-tutorial/

Monad Class Function >>= & >>

both **>>=** and **>>** are functions from the Monad class.

Monad Sequencing Operator with value passing

>>= passes the result of the expression on the left
as an argument to the expression on the right,
in a way that respects the context the argument and function use

Monad Sequencing Operator

>> is used to **order** the evaluation of expressions within some context;
it makes evaluation of the right depend on the evaluation of the left

https://www.quora.com/What-do-the-symbols-and-mean-in-haskell

Data Constructor

data **Color** = **Red** | **Green** | **Blue**

Color is a type
Red is a *constructor* that contains a *value* of type **Color**.
Green is a *constructor* that contains a *value* of type **Color**.
Blue is a *constructor* that contains a *value* of type **Color**.

data **Color** = **RGB** *Int Int Int*

Color is a type
RGB is not a value but a *function* taking three Ints and *returning a value*

RGB :: Int -> Int -> Int -> Colour

RGB is a **data constructor** that is a *function*
taking three Int values as its arguments,
and then uses them to construct a new value.

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Type Constructor (1)

Consider a binary tree to store Strings

```
data SBTree = Leaf String  |  Branch String SBTree SBTree
```

a type

```
    SBTree     is a type
    Leaf       is a data constructor (a function)
    Branch     is a data constructor (a function)

    Leaf :: String -> SBTree
    Branch :: String -> SBTree -> SBTree -> SBTree
```

Consider a binary tree to store Bool

```
data BBTree = Leaf Bool  |  Branch Bool BBTree BBTree
```

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Type Constructor (2)

Type constructors

Both **SBTree** and **BBTree** are type constructors

data **SBTree** = **Leaf** String | **Branch** String **SBTree SBTree**
data **BBTree** = **Leaf** Bool | **Branch** Bool **BBTree BBTree**

data **BTree** a = **Leaf** a | **Branch** a (**BTree** a) (**BTree** a)

Now we introduce a type variable a as a parameter to the type constructor.

BTree has become a function.
It takes a type as its argument and it returns a new tUype.

https://stackoverflow.com/questions/18204308/haskell-type-vs-data-constructor

Monad Definition

A **monad** is defined by

a **type constructor** m;
a function **return**;
an operator (**>>=**) "**bind**"

The function and operator are methods of the Monad type class and have types

```
return :: a -> m a

(>>=)  :: m a -> (a -> m b) -> m b
```

and are required to obey three laws

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Monad Definition

```
class Monad m where
    return :: a -> m a

    (>>=) :: m a -> (a -> m b) -> m b

    (>>) :: m a -> m b -> m b
    x >> y = x >>= \_ -> y

    fail :: String -> m a
    fail msg = error msg
```

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maybe Monad

the Maybe monad.

The **type constructor** is m = **Maybe**,

```
return :: a -> Maybe a

return x  = Just x
```

```
(>>=)  :: Maybe a -> (a -> Maybe b) -> Maybe b

m >>= g         = case m of
                        Nothing -> Nothing
                        Just x  -> g x
```

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Monad Class Function >>= & >>

Maybe is the monad
return brings a value into it
by wrapping it with **Just**

(**>>=**) takes
a value m :: **Maybe** a
a function g :: a -> **Maybe** b

if m is **Nothing**,
there is nothing to do and the result is **Nothing**.
Otherwise, in the **Just** x case,
the underlying value x is wrapped in **Just**
g is applied to x, to give a **Maybe** b result.

Note that this result *may* or *may not* be **Nothing**,
depending on what g does to x.

```
(>>=)  :: Maybe a -> (a -> Maybe b) -> Maybe b
m >>= g = case m of
            Nothing -> Nothing
            Just x  -> g x
```

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Monad Class Function >>= & >>

```
(>>=)  :: Maybe a -> (a -> Maybe b) -> Maybe b
m >>= g = case m of
            Nothing -> Nothing
            Just x  -> g x
```

if there is an underlying value of type a in m,
we apply **g** to it, which brings the underlying value back into the **Maybe** monad.

The key first step to understand how return and (>>=) work is tracking
- which values and arguments are monadic and
- which ones aren't.

As in so many other cases, type signatures are our guide to the process.

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maybe Monad Examples

a family database that provides two functions:

father :: Person -> **Maybe** Person
mother :: Person -> **Maybe** Person

Input the name of someone's father or mother.

If some relevant information is missing in the database
Maybe returns a **Nothing** value
to indicate that the lookup failed,
rather than crashing the program.

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maybe Monad Examples

functions to query various grandparents.
the following function looks up the maternal grandfather (the father of one's mother):

```
maternalGrandfather :: Person -> Maybe Person
maternalGrandfather p =
    case mother p of
        Nothing -> Nothing
        Just mom -> father mom
```

```
maternalGrandfather p = mother p >>= father
```

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

Maybe Monad Examples

https://en.wikibooks.org/wiki/Haskell/Understanding_monads

```
bothGrandfathers :: Person -> Maybe (Person, Person)
bothGrandfathers p =
    case father p of
        Nothing -> Nothing
        Just dad ->
            case father dad of
                Nothing -> Nothing
                Just gf1 ->                     -- found first grandfather
                    case mother p of
                        Nothing -> Nothing
                        Just mom ->
                            case father mom of
                                Nothing -> Nothing
                                Just gf2 ->         -- found second grandfather
                                    Just (gf1, gf2)
```

```
bothGrandfathers p =
  father p >>=
    (\dad -> father dad >>=
      (\gf1 -> mother p >>=   -- gf1 is only used in the final return
        (\mom -> father mom >>=
          (\gf2 -> return (gf1,gf2) ))))
```

Maybe Monad Examples

```
data Maybe a    = Just a
                | Nothing
```

a type definition: **Maybe** a
a parameter of a type variable a,

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe Monad Examples

```
data Maybe a     = Just a
                 | Nothing
```

two constructors: **Just** a and **Nothing**

a value of **Maybe** a type must be constructed via either **Just** or **Nothing**
there are no other (non-error) possibilities.

Nothing has no parameter type,
names a constant value that is a member of type **Maybe** a for all types a.

Just constructor has a type parameter,
acts like a function from type a to **Maybe** a,
i.e. it has the type a -> **Maybe** a

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe Monad Examples

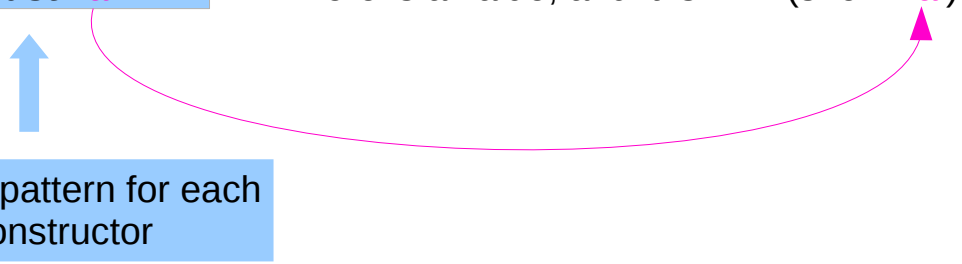
the (data) constructors of a type build a value of that type;

when using that value,
pattern matching can be applied

- Unlike functions, constructors can be used in pattern binding expressions
- **case analysis** of values that belong to types with more than one constructor.
- need to provide **a pattern** for each constructor

case maybeVal **of**

Nothing -> "There is nothing!"
Just val -> "There is a value, and it is " ++ (show val)



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Maybe

Maybe : Algebraic Data Type (ADT)

Widely used because it effectively extends a type
Integer into a new context in which it has an extra value (Nothing)
that represents a lack of value

Check for that extra value before accessing the possible Integer

Good for debugging

Many other languages have this sort of "no-value" value via NULL references.

The Haskel Maybe type handle this no-value more effectively.

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe as a functor

Functor type class:

- transforming one type to another
- transforming operations of one type to those of another

Maybe a has a useful instance of a **functor** type class

Functor provides **fmap** method

maps functions of the base type (such as Integer)

to *functions* of the lifted type (such as Maybe Integer).

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe as a functor

A *function* **f** transformed with **fmap**
cab work on a Maybe value

```
case maybeVal of
  Nothing  -> Nothing       -- there is nothing, so just return Nothing
  Just val -> Just (f val)  -- there is a value, so apply the function to it
```

```
   father :: Person -> Maybe Person
   mother :: Person -> Maybe Person
```

```
       f :: Int                -> Int
fmap   f :: Maybe Integer -> Maybe Integer
```

a **Maybe Integer** value: **m_x**

```
fmap  f   m_x
```

In fact, you could apply a whole chain of
lifted Integer -> **Integer** functions to **Maybe Integer** values
and only have to worry about explicitly checking for **Nothing** once when you're finished.

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe as a functor

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Maybe as a monad

the type signature **IO a** looks remarkably similar to **Maybe a**.

- IO doesn't expose its constructors
- only be "run" by the Haskell runtime system
- a Functor
- a Monad

a Monad is just a special kind of Functor with some extra features

Monads like **IO** *map* types to new types
that represent "computations that result in values"

Can *lift* **functions** into **Monad types**
via a very fmap-like function called **liftM**
that turns a regular function into a
"computation that results in the value obtained by evaluating the function."

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Maybe as a monad

Maybe is also a Monad
represents "computations that could fail to return a value"

Just like with the fmap example,
this lets you do a whole bunch of computations
without having to explicitly check for errors after each step.

And in fact, the way the Monad instance is constructed,
a computation on Maybe values stops as soon as a Nothing is encountered,

an immediate abort or
a valueless return
in the middle of a computation.

https://stackoverflow.com/questions/18808258/what-does-the-just-syntax-mean-in-haskell

Monad – List Comprehension Examples

```
[x*2 | x<-[1..10], odd x]
```

```
do
  x <- [1..10]
  if odd x
     then [x*2]
     else []
```

```
[1..10] >>= (\x -> if odd x then [x*2] else [])
```

https://stackoverflow.com/questions/44965/what-is-a-monad

Monad – I/O Examples

```
do
   putStrLn "What is your name?"
   name <- getLine
   putStrLn ("Welcome, " ++ name ++ "!")
```

https://stackoverflow.com/questions/44965/what-is-a-monad

Monad – A Parser Example

```
parseExpr = parseString <|> parseNumber

parseString = do
        char ""
        x <- many (noneOf "\"")
        char ""
        return (StringValue x)

parseNumber = do
    num <- many1 digit
    return (NumberValue (read num))
```

https://stackoverflow.com/questions/44965/what-is-a-monad

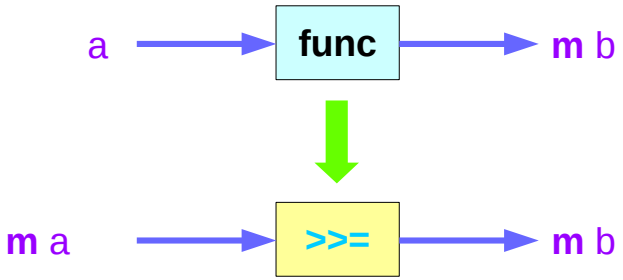
Monad – Asynchronous Examples

```
let AsyncHttp(url:string) =
    async {  let req = WebRequest.Create(url)
             let! rsp = req.GetResponseAsync()
             use stream = rsp.GetResponseStream()
             use reader = new System.IO.StreamReader(stream)
             return reader.ReadToEnd() }
```

https://stackoverflow.com/questions/44965/what-is-a-monad

Monad – Asynchronous Examples

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



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