Haskell
Category Theory & Monads

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Investigating Monadic Composition & Category Theory using Haskell.

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Presentation Overview

1. Haskell
2. Category Theory
3. Monads
4. The Problem
5. Difficulties Encountered

What is Haskell?

1. Haskell is a computer programming language.
2. It is a polymorphically statically typed, lazy, purely functional language.
3. Haskell programs are also shorter, clearer, and the rigorous control of side effects eliminates a lot of potential problems at compile time.

Category Theory 101

$$\begin{tikzcd}
 & B \arrow[dr, bend left, "g"] & \\
A \arrow[ur, bend left, "f"] \arrow[rr, "g \circ f"] & & C
\end{tikzcd}$$

A way of representing ***things*** and ***ways to go between things***.

A *category* has three things:

1. A collection of ***objects***.
2. A collection of ***morphisms***.
3. A notion of ***composition*** of these morphisms.

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What’s A Monad?

The Long Answer:

A Monad in X is just a Monoid in the Category of Endofunctors of X, with product × replaced by Composition of Endofunctors and unit set by the Identity Endofunctor.

What’s A Monad?

The Short Answer:

It's a specific way of chaining operations together while observing a set of rules.

What's so good about Monads?

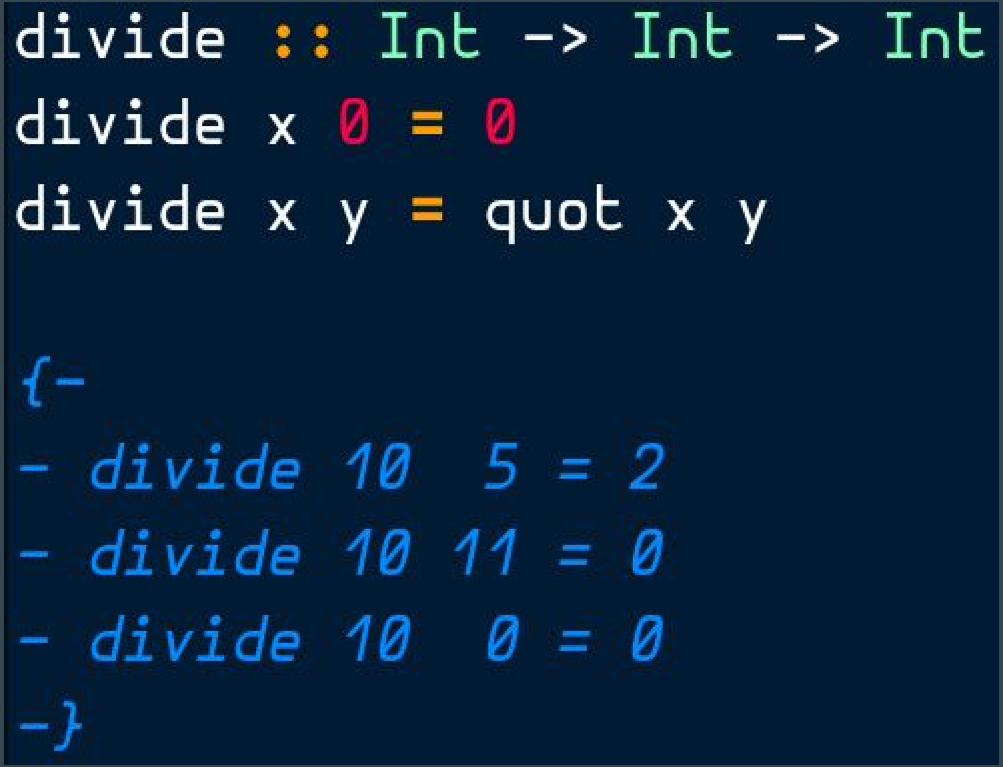
- Reduce code duplication
- Remove Side-Effects
- Hide complexity
- Encapsulate implementation details
- Allow composability

The naïve way

This is an example of a Badly designed Function.

Dividing by Zero should not be possible.

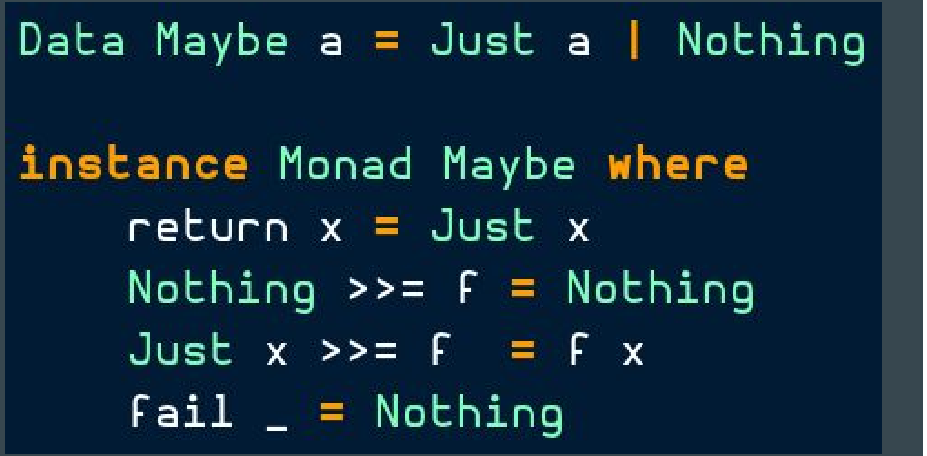
There is no way to know whether the result is Zero or if you divided by Zero.



```haskell
divide :: Int -> Int -> Int
divide x 0 = 0
divide x y = quot x y

{-
- divide 10  5 = 2
- divide 10 11 = 0
- divide 10  0 = 0
-}
```

The Maybe Monad

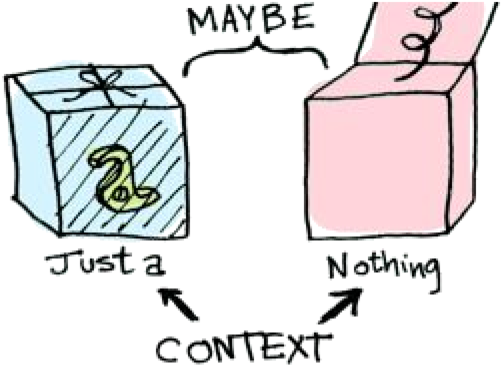


```
Data Maybe a = Just a | Nothing

instance Monad Maybe where
    return x = Just x
    Nothing >>= f = Nothing
    Just x >>= f   = f x
    fail _ = Nothing
```

The Maybe Monad can Either have Something (Just) or Nothing.

It allows the programmer to specify something may not be there.



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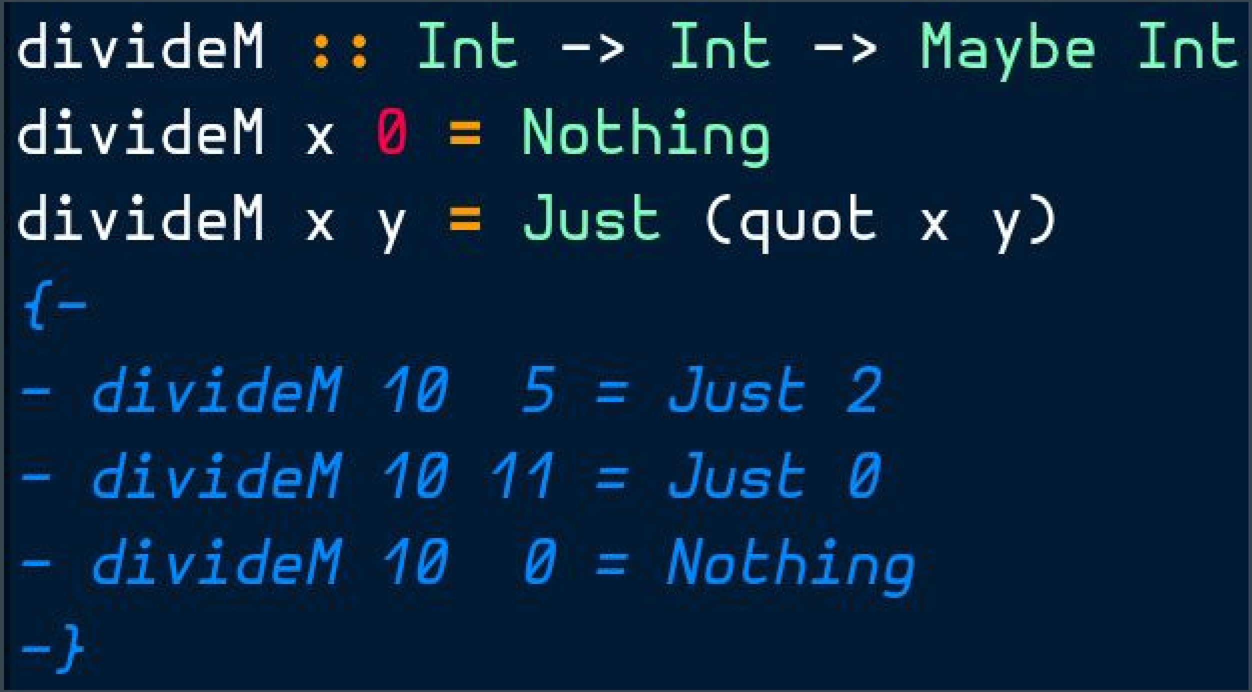
Monads to the Rescue!

The previous example has been upgraded with A Maybe.

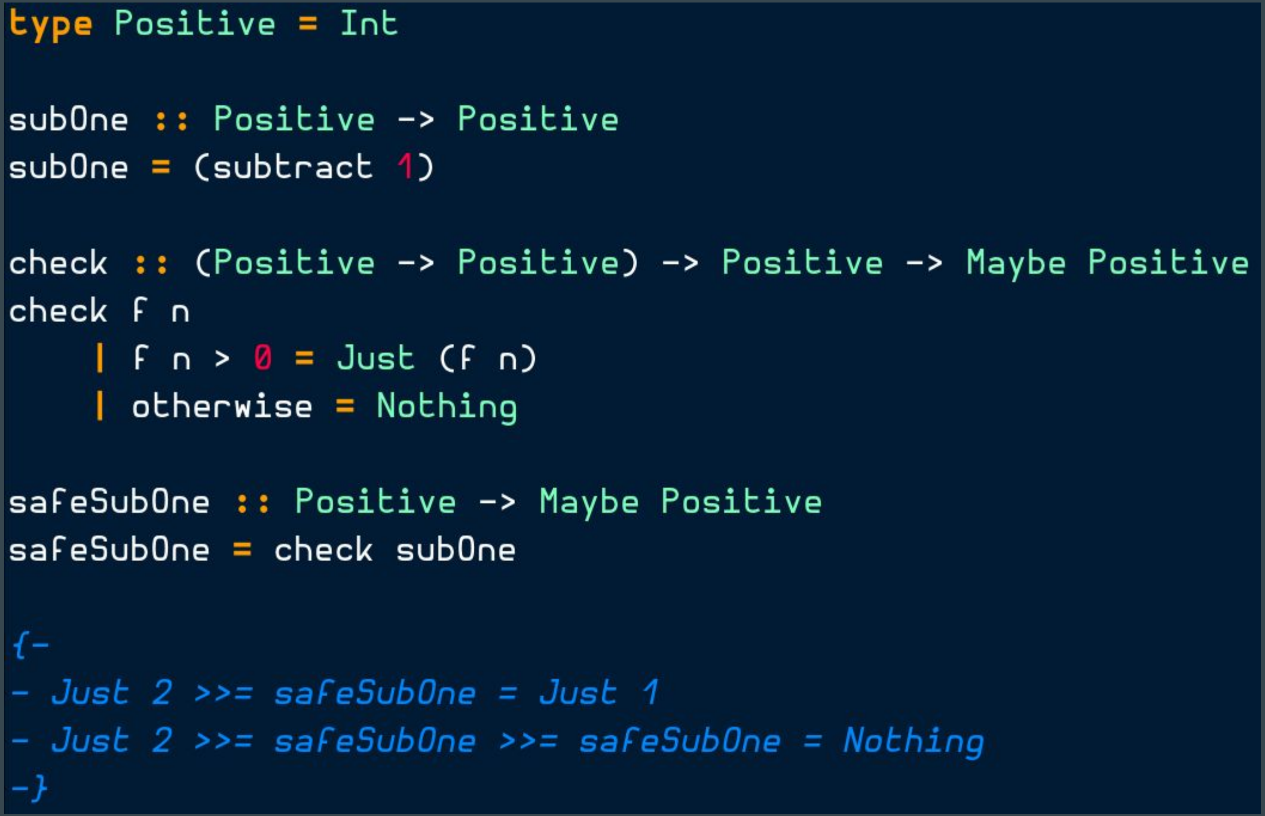
Instead of returning Zero when dividing by Zero; It returns Nothing.



```haskell
divideM :: Int -> Int -> Maybe Int
divideM x 0 = Nothing
divideM x y = Just (quot x y)
{-
- divideM 10  5 = Just 2
- divideM 10 11 = Just 0
- divideM 10  0 = Nothing
-}
```

Monadic Composition

The purpose of this program is to subtract 1 from a given Positive number, while making sure the number stays Positive (> 0)



```haskell
type Positive = Int

subOne :: Positive -> Positive
subOne = (subtract 1)

check :: (Positive -> Positive) -> Positive -> Maybe Positive
check f n
    | f n > 0 = Just (f n)
    | otherwise = Nothing

safeSubOne :: Positive -> Maybe Positive
safeSubOne = check subOne

{-
- Just 2 >>= safeSubOne = Just 1
- Just 2 >>= safeSubOne >>= safeSubOne = Nothing
-}
```

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The Problem

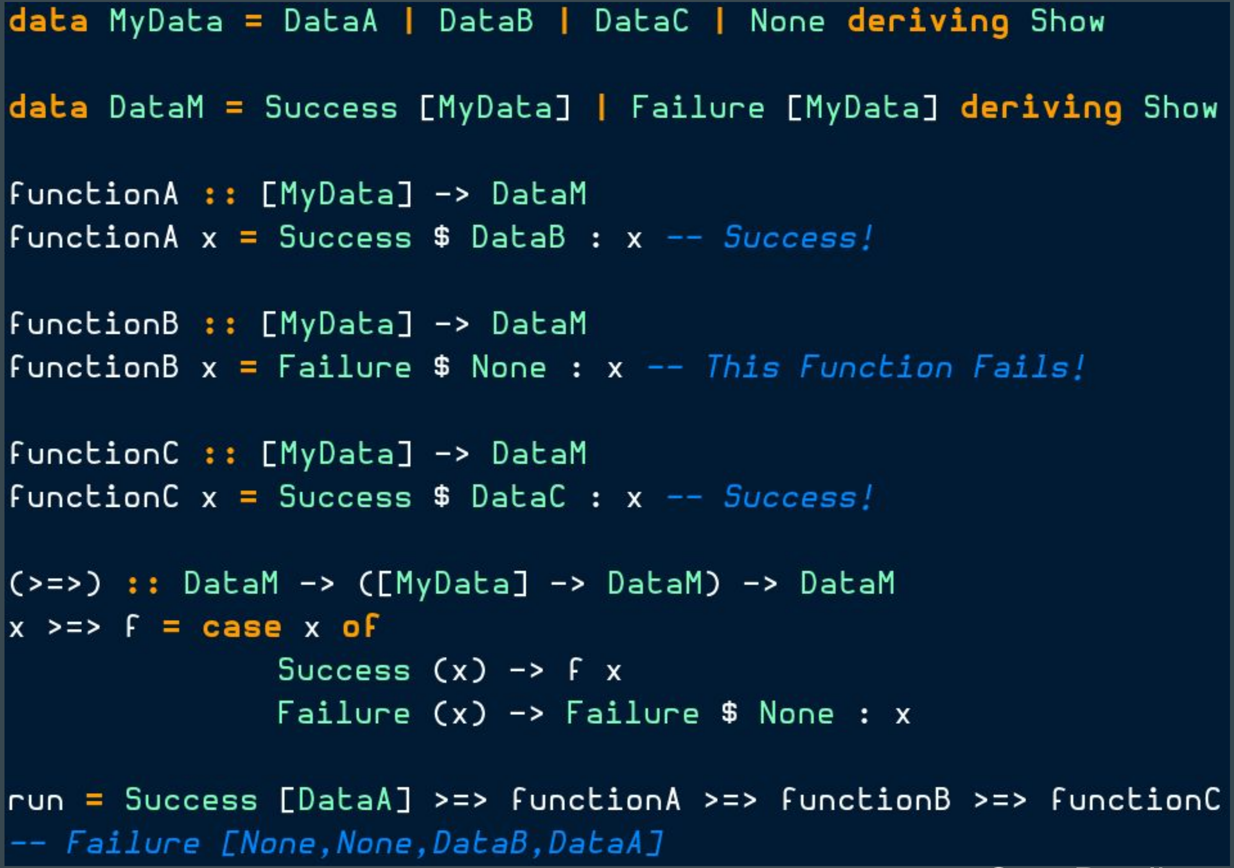
My Solution: Monads!

1. First we create our data types

2. Then we create our Monad, which contains a list of MyData

3. We then create our functions A, B and C all of which take a list of MyData and returns a DataM Monad

4. next we define our Monadic Operator >=>



```
data MyData = DataA | DataB | DataC | None deriving Show

data DataM = Success [MyData] | Failure [MyData] deriving Show

functionA :: [MyData] -> DataM
functionA x = Success $ DataB : x -- Success!

functionB :: [MyData] -> DataM
functionB x = Failure $ None : x -- This Function Fails!

functionC :: [MyData] -> DataM
functionC x = Success $ DataC : x -- Success!

(>=>) :: DataM -> ([MyData] -> DataM) -> DataM
x >=> f = case x of
              Success (x) -> f x
              Failure (x) -> Failure $ None : x

run = Success [DataA] >=> functionA >=> functionB >=> functionC
-- Failure [None,None,DataB,DataA]
```

Encountered Problems

- Due to Haskell's purity there are strict regulations on I/O which makes writing I/O heavy applications in Haskell very time-consuming.

- Gentle entry-level tutorials are few and hard to find & explanations are largely math based, so the initial learning curve is pretty steep.

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More Examples?

All research availiable online at https://github.com/SamDowling96/HaskellResearch

- Catamorphisms
- Concurrency
- Conduits
- Error Handling
- I/O
- Monoids
- Orderings
- Persistence
- Database Interactivity
- Mutable State
- Natural Transformations
- Parallelism
- Kleisli Categories

The End

Thank you for your time.

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