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Wild Haskell

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Chapter 1

Your first Haskell program

1.1 Build Tools

1.1.1 Stack

<https://docs.haskellstack.org/en/stable/README/>

make sure ‘stack –version’ outputs latest stack version, currently ‘Version 1.6.5’.

‘stack upgrade’

Add Nix and Cabal

1.2 Editor Integration

1.2.1 VScode with Haskell IDE Engine

[haskell-ide-engine](https://github.com/haskell/haskell-ide-engine)

Install on MacOS, you need to install ‘icu4c’ on your machine.

git clone https://github.com/haskell/haskell-ide-engine cd haskell-ide-engine make

```
stack install hoogle
```

```
hoogle generate
```

```
stack install
```

1.3 Your first haskell program

1.3.1 Using stack

```
stack new guessNumber
```

```
module Main where
```

```
import           Control.Monad
```

1.3. YOUR FIRST HASKELL PROGRAM. YOUR FIRST HASKELL PROGRAM

```
import      Data.Ord      (compare)
import      System.IO     (readLn)
import      System.Random (randomRIO)

guess :: Int -> IO ()
guess secretNumber = do
    print "guess a number"
    guessNumber <- readLn :: IO Int
    case compare guessNumber secretNumber of
        LT -> (print "Too Small!") >> (guess secretNumber)
        EQ -> print "You Win!"
        GT -> (print "Too big!") >> (guess secretNumber)

main :: IO ()
main = do
    secretNumber <- randomRIO (0, 100) :: IO Int
    guess secretNumber
```


Chapter 2

Monad

Tackling the Awkward Squad

Chapter 3

Applicative

Applicative Programming with Effects

Chapter 4

From State to Monad Transformers

4.1 State Monad

First, let's look what is State.

```
newtype State s a = State { runState :: s -> (a, s) }
```

In case you are not familiar with `newtype`. It is just like `data` but it can only has **exactly one** constructor with exactly one field in it. In this case `State` is the constructor and `runState` is the single field. The type of `State` constructor is `(s -> (a, s)) -> State s a`, since `State` uses record syntax, we have a field accessor `runState` and its type is `State s a -> (a, s)`. "A State is a function from a state value" to (a produced value, and a resulting state). An importance takeaway which might not so oblivious to Haskell beginner is that: `State` is merely a function with type `s -> (a,s)`, (a function wrapped inside constructor `State`, to be exact, and we can unwrap it using `runState`).

Secondly, `State` function takes a `s` representing a state, and produces a tuple contains value `a` and new state `s`.

`exec`

The first exercise is to implement `exec` function, it takes a `State` function and initial `state` value, returns the new state.

It is pretty straightforward, we just need to apply `State` function with `state` value, and takes the second element from the tuple.

A simple solution can be

```
exec :: State s a -> s -> s
exec f initial = \ (_, y) -> y (runState f initial)
```

Since the state value `initial` appears on both sides of `=`, we rewrite it a little more point-free. `runState f` is a partial applied function takes `s` returns `(a,s)`

```
exec f = (\(_, y) -> y) . runState f
```

```
exec f = P.snd . runState f
```

We could also write ‘exec’
‘exec (State f) = P.snd . f’

4.1.1 Basic Usage of State

```
module Dice where

import Control.Applicative
import Control.Monad.Trans.State
import System.Random

rollDiceIO :: IO (Int, Int)
rollDiceIO = liftA2 (,) (randomRIO (1, 6)) (randomRIO (1, 6))

rollNDiceIO :: Int -> IO [Int]
rollNDiceIO 0 = pure []
rollNDiceIO count = liftA2 (:) (randomRIO (1, 6)) (rollNDiceIO (count - 1))

clumsyRollDice :: (Int, Int)
clumsyRollDice = (n, m)
  where
    (n, g) = randomR (1, 6) (mkStdGen 0)
    (m, _) = randomR (1, 6) g

-- rollDice :: StdGen -> ((Int, Int), StdGen)
-- rollDice g = ((n, m), g'')
--   where
--     (n, g') = randomR (1, 6) g
--     (m, g'') = randomR (1, 6) g'

-- use state to construct
rollDie :: State StdGen Int
rollDie = state $ randomR (1, 6)

-- use State as Monad
rollDieM :: State StdGen Int
rollDieM = do generator <- get
  let (value, generator') = randomR (1, 6) generator
  put generator'
  return value

rollDice :: State StdGen (Int, Int)
```

```
rollDice = liftA2 (,) rollDieM rollDieM

rollNDice :: Int -> State StdGen [Int]
rollNDice 0 = state (\s -> ([], s))
rollNDice count = liftA2 (:) rollDieM (rollNDice (count - 1))
```

How about draw card from a deck

```
module Deck where

import Control.Applicative
import Control.Monad.Trans.State
import Data.List
import System.Random

data Rank = One | Two | Three | Four | Five | Six | Seven | Eight | Nine | Ten | Jack | Queue | King
data Suit = Diamonds | Clubs | Hearts | Spades deriving (Bounded, Enum, Show, Eq, Ord)
data Card = Card Suit Rank deriving (Show, Eq, Ord)

type Deck = [Card]

fullDeck :: Deck
fullDeck = [Card suit rank | suit <- enumFrom minBound,
                             rank <- enumFrom minBound]

removeCard :: Deck -> Int -> Deck
removeCard [] _ = []
removeCard deck index = deck' ++ deck''
    where (deck', remain) = splitAt (index + 1) deck
          deck''          = drop 1 remain

drawCard :: State (StdGen, Deck) Card
drawCard = do (generator, deck) <- get
              let (index, generator') = randomR (0, length deck) generator
              put (generator', removeCard deck index)
              return $ deck !! index

drawNCard :: Int -> State (StdGen, Deck) [Card]
drawNCard 0 = state (\s -> ([], s))
drawNCard count = liftA2 (:) drawCard (drawNCard $ count - 1)
```

How about folding a list using ‘State’ <https://github.com/yuanw/applied-haskell/blob/2018/monad-transformers.md#how-about-state>

4.2. MONAD TRANSFORMERS. FROM STATE TO MONAD TRANSFORMERS

```
foldState :: (b -> a -> b) -> b -> [a] -> b
foldState f accum0 list0 =
    execState (mapM_ go list0) accum0
  where
    go x = modify' (\accum -> f accum x)
```

4.2 Monad Transformers

4.2.1 Motivation

Why we cannot compose any two monad

```
import Control.Applicative

newtype Compose f g a = Compose (f (g a))

instance (Functor f, Functor g) => Functor (Compose f g) where
    fmap f (Compose h) = Compose ((fmap . fmap) f h)

instance (Applicative f, Applicative g) => Applicative (Compose f g) where
    pure = Compose . pure . pure
    (Compose h) <*> (Compose j) = Compose $ pure (<*>) <*> h <*> j

instance (Monad f, Monad g) => Monad (Compose f g) where
    (Compose fga) >=> m = Compose $ fga >=> \ ga -> let gfgb = ga >=> (return . m) in
```

<https://stackoverflow.com/questions/7040844/applicatives-compose-monads-dont>

4.2.2 Build a composed monad by hand

```
newtype StateEither s e a = StateEither
    { runStateEither :: s -> (s, Either e a)
    }
```

Let's implement the functor instance of this typeP

```
newtype StateEither s e a = StateEither
    { runStateEither :: s -> (s, Either e a)
    }

instance Functor (StateEither s e) where
    f `fmap` StateEither se = StateEither (\ s -> let (s', eitherA) = se s in (s', f `fmap` eitherA))

instance Applicative (StateEither s e) where
    pure a = StateEither (\ s -> (s, Right a))
```



```

StateEither h <*> StateEither g = StateEither (\ s -> let (s', eitherF) = h s
                                                         (s'', a)          = g s in (s', eitherF s'', a))

instance Monad (StateEither s e) where
  StateEither f >=> g = StateEither $ \ s ->
    case f s of
      (s', Left e) -> (s', Left e)
      (s', Right a) -> (runStateEither $ g a) s'

execStateEither :: StateEither s e a -> s -> s
execStateEither stateE = fst . runStateEither stateE

modify' :: (s -> Either e s) -> StateEither s e ()
modify' f = StateEither $ \ s ->
  case f s of
    Left e -> (s, Left e)
    Right s' -> (s', Right ())

foldTerminate :: (b -> a -> Either b b) -> b -> [a] -> b
foldTerminate f accum xs =
  execStateEither (mapM_ go xs) accum
  where go x = modify' (\f` x)

```

<https://mmhaskell.com/blog/2017/3/6/making-sense-of-multiple-monads>

References https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State <https://haskell.fpcomplete.com/library/rio>

4.2. MONAD TRANSFORMERS. FROM STATE TO MONAD TRANSFORMERS

Chapter 5

Learning Lens

The content of this chapter comes from Simon Peyton Jones's [Lenses: Compositional data access and manipulation](#) talk.

5.1 Motivation

The record problem often represented as the hello world for Lens.

The problem: heterogeneous composite data

Worse: consider access to the A in a composition data structure $\text{Maybe } (A \times B)$ built using both sums and products.

Sum part comes with `Maybe` 'data `Maybe a = Just a — Nothing`'

```
data Person = Person { name    :: String,
                      , address :: Address
                      , salary  :: Int  }

data Address = Address { road :: String
                      , city  :: String
                      , zip   :: String }
```

The goals for lens

- To access and update a given field
- Compose Lense

5.2 Native Approach

```
data LensR s a = LensR { viewR :: s -> a
                      , setR   :: a -> s -> s }
```

Type `s` represent the overall record we try to access or update, Type `a` represent the field we are try to access or update.

How to compose **LensR**

```
composeL :: LensR s1 s2 -> LensR s2 a -> LensR s1 a
composeL (LensR v1 s1) (LensR v2 s2)
  = LensR (\ s -> v2 (v1 s))
        (\ a s -> s1 (s2 a (v1 s)) s)
```

The two big problems with this approach is to inefficient, and inflexible.

5.2.1 A step further on this Native Approach

```
data LensR s a
  = L { viewR :: s -> a
      , setR   :: a -> s -> a
      , mod    :: (a -> a) -> s -> s
      , modM   :: (a -> Maybe a) -> s -> Maybe s
      , modIO  :: (a -> IO a) -> s -> IO s }
```

The last two (or three if you know your functor well) share lots of commonality.

If we can abstract the common pattern

```
data LensR s a
  = L { viewR :: s -> a
      , setR   :: a -> s -> a
      , mod    :: (a -> a) -> s -> s
      , modF   :: Functor f => (a -> f a) -> s -> f s }

type Lens' s a = forall f. Functor f => (a -> f a) -> s -> f s
```

You may think ‘Lens’ looks nothing like ‘LensR’, but they are actually isomorphic.

Before proving ‘Lens’ and ‘LensR’ is isomorphic, allow me introduce two oddly looking functors ‘Const’ and ‘Identity’.

Break Down::

Isomorphic If ‘A’ and ‘B’ are isomorphic, it means we are getting ‘B’ to ‘A’ without lost any information, and vice verse.

```
view :: Lens' s a -> s -> a => ((a -> f a) -> s -> f s) -> s -> a
view ln s = getConst (ln const s)

let fred = P {_name = "Fred", _salary = 100}
name :: Lens' Person String
name fn (P n s) -> (\ n' -> P n' s) <$> fn n

view name fred
= (getConst . name . const) fred
= getConst ((\n' -> P n' s) <$> Const "Fred")
= getConst . Const "Fred"
= "Fred"
```

```

set name "John" fred
= getID $ name (Id . Const "John") fred
= getID $ (\ n' -> P n' 100) <$> ((ID. Const "John" ) fred)
= getID $ (\ n' -> P n' 100) <$> Id "John"
= getID $ ID (P "John" 100 )
= P "John" 100

```

Compose Lens'

Function application

<https://www.youtube.com/watch?v=sfWzUMViP0M&t=441s>

<https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiS6dD65PfdAhVSJjQIHRzzC9url=http%3A%2F%2Fwww.cs.ox.ac.uk%2Fpeople%2Fjeremy.gibbons%2Fpublications%2Fpoptics.pdf&usg=AOvVaw3KgxUg3x37WIToXgmRu79C>

```

data Prisms s a = Prisms { match :: s -> Either s a
                           , build :: a -> s }

```

```

*Main Lib> import Control.Lens
*Main Lib Control.Lens> ("hello","world") ^. _2
"world"
*Main Lib Control.Lens>

```

5.3 What is a Lens ?

Lenses address some part of a “structure” that always exists, either look that part, or set that part. “structure” can be a computation result, for example, the hour in time. Functional setter and getter. Data.Lens

```

data Lens s a = Lens { set  :: s -> a -> a
                      , view :: s -> a
                      }
view :: Lens s a -> s -> a
set  :: Lens s a -> s -> a -> s

```

view looks up an attribute a from s view is the getter, and set is the setter. Laws 1. $\text{set l (view l s)} = s$ 2. $\text{view l (set l s a)} = a$ 3. $\text{set l (set l s a) b} = \text{set l s b}$ Law 1 indicates lens has no other effects since set and view in Lens both start with s -, so we can fuse the two functions into a single function ‘s -> (a -> s, a)’.

So we could define Lens as

```

data Lens s a = Lens (s -> (a -> s), a)
data Store s a = Store (s -> a) s
data Lens s a = Lens (s -> Store a s)

```

Semantic Editor Combinator

The Power is in the dot

```
(.) :: (b -> c) -> (a -> c) -> (a -> c)
(.) . (.) :: (b -> c) -> (a1 -> a2 -> b) -> a1 -> a2 -> c
(.) . (.) . (.) :: (b -> c) -> (a1 -> a2 -> a3 -> b) -> a1 -> a2 -> a3 -> c
```

Detail Explantation

$$\begin{aligned} & (.) :: (b \rightarrow c) \rightarrow (a \rightarrow b) \rightarrow a \rightarrow c \\ & f . g = \lambda t \rightarrow f (g t) \end{aligned}$$

$$\begin{aligned} ((.) . (.)) (+1) (+) 1010 &= 21 \\ ((.) . (.)) (+1) (+) 1010 \\ &= (.) ((.) (+1)) (+) 1010 \\ &= ((.) (+1)) (+10) 10 \\ &= ((+1) . (+10)) 10 \\ &= (+1) ((+10) 10) \\ &= (+1) (10 + 10) \\ &= 21 \end{aligned}$$

```
(.) . (.) :: (b -> c) -> (a -> b) -> a -> c
dotF . dotG :: (b -> c) -> (a -> c) -> a -> c
dotF :: b -> c
dotG :: a -> b
```

since **dotF** is just an alias to **(.)**

$$dotF :: (u > v) \rightarrow (s > u) \rightarrow s > v (u > v) \rightarrow (s > u) \rightarrow s > v == b > c \quad (5.1)$$

therefore

$$b \equiv (u \rightarrow v)c \equiv (s \rightarrow u) \rightarrow s \rightarrow v \quad (5.2)$$

'dotG' is also an alias to '(.)'

$$dotG :: (y > z) \rightarrow (x > y) \rightarrow x > z (y > z) \rightarrow (x > y) \rightarrow x > z === a > b \quad (5.3)$$

therefore

$$a \equiv (y \rightarrow z)b \equiv (x \rightarrow y) \rightarrow x \rightarrow z \quad (5.4)$$

since \mathbf{b} appears on both side

$$a \equiv y \rightarrow zb \equiv (u \rightarrow v)b \equiv (x \rightarrow y) \rightarrow x \rightarrow zc \equiv (s \rightarrow u) \rightarrow s \rightarrow v \quad (5.5)$$

we can deduct

$$\begin{aligned} u &=== x -> y \\ v &=== x -> z \end{aligned}$$

therefore

$$c === (s -> x -> y) -> s -> x -> z \quad (5.6)$$

$$\begin{aligned} (.) . (.) &=== a -> c \\ (.) . (.) &=== (y -> z) -> (s -> x -> y) -> s -> x -> z \end{aligned}$$

we can generalize this to any functor

```
fmap      :: Functor f => (a -> b) -> f a -> f b
fmap . fmap :: (Functor f, Functor g) => (a -> b) -> f (g a) -> f (g b)
fmap . fmap . fmap :: (Functor f, Functor g, Functor h) => (a -> b) -> f (g (h a)) -> f (g (h b))
```

it means we compose a function under arbitrary level deep nested context Semantic Editor Combinator

‘type $\text{SEC } s \ t \ a \ b = (a \rightarrow b) \rightarrow s \rightarrow t$ ’ it like a functor $(a \rightarrow b) \rightarrow f \ a \rightarrow f \ b$ `fmap` is Semantic Editor Combinator ‘`fmap . fmap`’ is also a SEC

so we use ‘`s`’ to generalize ‘`f a`’, ‘`f (g a)`’, ‘`f (g (h a))`’ and ‘`t`’ to generalize ‘`f b`’, ‘`f (g b)`’, ‘`f (g (h b))`’. It may seems counterintuitive at first, we lost the relation between `a` and `s`, `b` and `t`. Functor is a semantic Editor Combinator `map :: Functor f => SEC (f a) (f b) a b`

first is a also SEC ?

```
first :: SEC (a, c) (b, c) a b
first f (a, b) = (f a, b)
```

Setters We can compose Traversable the way as we can compose ‘`(.)`’ and ‘`fmap`’

```
traverse :: (Traversable f, Applicative m)
=> (a -> m b) -> f a -> m (f b)
traverse . traverse :: (Traversable f, Traversable g, Applicative m)
=> (a -> m b) -> f (g a) -> m (f (g b))
traverse . traverse . traverse :: (Traversable f, Traversable g, Traversable h, Applicative m)
=> (a -> m b) -> f (g (h a)) -> m (f (g (h b)))
```

`traverse` is a generalized version of `mapM`, and work with any kind of Foldable not just List.

```
class (Functor f, Foldable f) => Traversable f where
  traverse :: Applicative m => (a -> m b) -> f a -> m (f b)

fmapDefault :: forall t a b. Traversable t => (a -> b) -> t a -> t b
fmapDefault f = runIdentity . traverse (Identity . f)
```

build ‘fmap’ out from traverse we can change ‘fmapDefault’

```
over l f = runIdentity . l (Identity . f)
over traverse f = runIdentity . traverse (Identity . f)
                = fmapDefault f
                = fmap f
```

```
over :: ((a -> Identity b) -> s -> Identity t) -> (a -> b) -> s -> t
type Setter s t a b = (a -> Identity b) -> s -> Identity t so we could rewrite over as
over :: Setter s t a b -> (a -> b) -> s -> t
```

Let’s apply setter

```
mapped :: Functor f => Setter (f a) (f b) a b
mapped f = Identity . fmap (runIdentity . f)
over mapped f = runIdentity . mapped (Identity . f)
               = runIdentity . Identity . fmap (runIdentity . Identity . f)
               = fmap f
```

Examples

```
over mapped (+1) [1,2,3] ==> [2,3,4]
over (mapped . mapped) (+1) [[1,2], [3]] ==> [[2,3], [4]]
chars :: (Char -> Identity Char) -> Text -> Identity Text
chars f = fmap pack . mapped f . unpack
```

Laws for setters Functor Laws: 1. ‘fmap’ id = id 2. fmap f . fmap g = fmap (f . g)

Setter Laws for a legal Setter l. 1. over l id = id 2. over l f . over l g = over l (f . g)

Practices Simplest lens (1,2,3) ^ . _2 ==> 2 view _2 (1, 2, 3)

Third Program: Upload Spreadsheet to google bigquery

In this chapter, we are going to write a command line program to upload a spreadsheet file’s content to Google BigQuery. There is awesome library Gogol provides Haskell binding to Google API.

We need gogol 0.3.0 or higher, Make sure your project’s resolver version is lts-9.0 or later. You can verify it by doing ‘stack list-dependencies’.

Starting Point

So how to use Gogol library ? The lib provides an [example](https://github.com/brendanhay/gogol/blob/develop/example/main.hs) for Google Cloud Storage.

Let’s do a little change, so it fetch all the bigquery project the current default google credential has access to.

You need to install gcloud, and setup default

```
gcloud init
gcloud auth application-default login
```

and let’s put the following code into our ‘Main.hs’.

```
module Main where
```



```

import Control.Lens                ((&), (.), (<&>), (?~))
import Control.Monad.Trans.Resource (runResourceT)
import Control.Monad.IO.Class

import System.IO (stdout)
import Network.Google.Auth (Auth, Credentials (..), initStore)
import qualified Network.Google as Google
import qualified Network.Google.BigQuery as BigQuery
import Network.HTTP.Conduit (Manager, newManager, tlsManagerSettings)
import Network.Google.Auth.Scope (AllowScopes (..),

example :: IO BigQuery.ProjectList
example = do
  lgr <- Google.newLogger Google.Debug stdout
  m <- liftIO (newManager tlsManagerSettings) :: IO Manager
  c <- Google.getApplicatIonDefault m
  -- Create a new environment which will discover the appropriate
  -- AuthN/AuthZ credentials, and explicitly state the OAuth scopes
  -- we will be using below, which will be enforced by the compiler:
  env <- Google.newEnvWith c lgr m <&>
    (Google.envLogger .~ lgr)
    . (Google.envScopes .~ BigQuery.bigQueryScope)
  runResourceT . Google.runGoogle env $ Google.send BigQuery.projectsList

main :: IO ()
main = do
  projects <- example
  print projects

```

You need add following build depends to make stack build succeeded.

```

build-depends:      base >= 4.7 && < 5
                   , bytestring
                   , conduit
                   , conduit-extra
                   , gogol
                   , gogol-bigquery
                   , gogol-core
                   , http-conduit
                   , lens
                   , resourcet

```

Quite few things need to unpack here.
Create a bigquery dataset

```

{-# LANGUAGE RankNTypes      #-}
{-# LANGUAGE TemplateHaskell #-}

```

```

module Main where

import           Control.Lens

data Point = Point
  { _postionX :: Double
  , _postionY :: Double } deriving (Show)

makeLenses ''Point

data Segment = Segment {
  _segmentStart :: Point,
  _segmentEnd   :: Point
} deriving (Show)
makeLenses ''Segment

makePoint :: (Double , Double) -> Point
makePoint = uncurry Point

makeSegment :: (Double, Double) -> (Double, Double) -> Segment
makeSegment start end = Segment (makePoint start) (makePoint end)

updateSegment :: Segment -> Segment
updateSegment = (segmentStart .~ makePoint (10, 10)) . (segmentEnd .~ makePoint (10, 10))

http://www.scs.stanford.edu/16wi-cs240h/slides/concurrency-slides.html#(1)
catchJust]

```

Add exception handle in the guess number program

References

- [SPJ Lenses: compositional data access and manipulation](#)
- [Edward Kmett's NYC Haskell Meetup talk](#)
- <http://comonad.com/haskell/Lenses-Folds-and-Traversals-NYC.pdf> Edward Kmett's NYC Haskell Meetup talk slide
- <http://hackage.haskell.org/package/lens-tutorial-1.0.3/docs/Control-Lens-Tutorial.html>
- <https://www.youtube.com/watch?v=H01dw-BMmlE>
- <https://www.youtube.com/watch?v=QZy4Yml3LTY>
- <https://www.youtube.com/watch?v=T88TDS7L5DY>
- <http://lens.github.io/tutorial.html>

- https://www.reddit.com/r/haskell/comments/9ded97/is_learning_how_to_use_the_lens_library_worth_it/e5hf9ai/
- <https://blog.jle.im/entry/lenses-products-prisms-sums.html>

Chapter 6

Exception

References

- [stanford cs240](#)
- [fp Complete](#)