

# (Simile Free) Monad Recipes

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# Outline

- 1 IO
- 2 Reader
- 3 Writer
- 4 State
- 5 Monad Transformers

# Brief IO Example

- This small function writes a text file, uppercases its contents & prints them..

```
import Data.Char
main :: IO ()
main = do
    writeFile "test.txt" "a,b,c,d,e"
    x <- readFile "test.txt"
    let up_cased = map toUpper x
    y <- return up_cased
    print y
=> "A,B,C,D,E"
```

- With types added ...

```
{-# LANGUAGE ScopedTypeVariables #-}  
main :: IO ()  
main = do  
    writeFile "test.txt" "a,b,c,d,e" :: IO ()  
    x :: String <- readFile "test.txt" :: IO String  
    let upCased :: String = map toUpper x  
    y :: String <- return upCased :: IO String  
    print y :: IO ()
```

# Brief IO Example

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main = do
  writeFile "test.txt" "a,b,c,d,e" :: IO ()
  ...
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main = do
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  x :: String <- readFile "test.txt" :: IO String
  let upCased :: String = map toUpper x
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main = do
  let upCased = ...
  y :: String <- return upCased :: IO String
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```
main :: IO ()
main = do
  y <- ...
  print y :: IO ()
```



- Querying a Sqlite database

```
get_users :: IO [(String,String)]
get_users = do
    rows :: [[SqlValue]] <- dbQuery
                                "select * from users"
                                []
    let marshalled :: [(String,String)] =
        map (\(user:pass:[]) ->
            (fromSql user, fromSql pass))
            rows
    return marshalled
where
    dbQuery sql values = ...
```

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    rows
  ...
```

- Querying a Sqlite database

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get_users :: IO [(String,String)]
get_users = do
  ...
  let marshalled = ...
  return marshalled
where ...
```

- The implementation of `dbQuery` isn't important, but here it is ...

```
dbQuery :: String -> [SqlValue] -> IO [[SqlValue]]
dbQuery sql values =
    bracket dbConnect disconnect
        (\conn -> quickQuery' conn sql values)
dbConnect :: IO Connection
dbConnect = connectSqlite3 "test.sqlite"
```

- Reader = Read-only State + Result
- 'runReader' :: Reader Monad -> Read-Only State -> Result
- 'ask' extracts the state from the monad for inspection.

- Authenticating users

```
simple_auth :: (String,String) ->
              Reader [(String,String)] Bool
simple_auth (user,pass) = do
  users :: [(String,String)] <- ask
  case (lookup user users) of
    Nothing -> return False
    Just p   -> return (p == pass)

main =
  let my_auth = ("deech","deechpassword") in
  do users :: [(String,String)] <- get_users
     print (runReader (simple_auth my_auth) users)
=> True
```

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main = ...
```

- $\text{Writer} = \text{Append-Only State} + \text{Result}$
- `'runWriter' :: Writer Monad -> (Result, Accumulated State)`
- State is accumulated using `'tell'`

- Validating input

```
validate :: String -> Writer [String] ()
validate input =
    let hasNumbers = (>= 2) . length . filter isDigit
        hasUppers  = (>= 1) . length . filter isUpper
        noSpaces    = null . filter (== ' ')
        check f msg = if (not (f input))
                        then tell [msg]
                        else return ()
    in do check hasNumbers "Needs 2+ numbers"
         check hasUppers  "Needs 1+ capitals"
         check noSpaces    "Has spaces"
```

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validate input = ...
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validate input =
    let hasNumbers = ...
        hasUppers  = ...
        noSpaces   = ...
        check f msg = if (not (f input))
                        then tell [msg]
                        else return ()
    in do ...
```



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validate input =
    let hasNumbers = ...
        hasUppers  = ...
        noSpaces   = ...
        check f msg = ...
    in do check hasNumbers "Needs 2+ numbers"
         check hasUppers  "Needs 1+ capitals"
         check noSpaces   "Has spaces"
```

- Running

```
main = do
  let ((),errs) = runWriter (validate "abcde1")
      valid      = null errs
  if (not valid) then print errs else print "Valid!"
=> ["Needs 2+ numbers","Needs 1+ capitals"]
```

- State Monad = Mutable State + Result
- 'get', 'put' do what they sound like
- 'runState' :: State Monad -> Initial State -> (Result, New State)
- Initial State is **required**.

- Finding the minimum imperatively. Buggy!

```
minimum :: [Int] -> State Int ()
minimum [] = error "Empty List."
minimum xs =
    forM_ xs (\curr -> do
        old_min <- get
        if (curr < old_min)
        then put curr
        else return ())
main = let numbers = [3,2,1] in
    print (runState (Main.minimum numbers) (-1))
=> -1
```

- Finding the minimum imperatively. Buggy!

```
minimum :: [Int] -> State Int ()  
...  
main = ...
```

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minimum :: [Int] -> State Int ()
minimum [] = ...
minimum xs = ...
main = let numbers = [3,2,1] in
        print (runState (Main.minimum numbers) (-1))
=> -1
```

- 'trace' and 'printf' are your friends

```
import Debug.Trace
import Text.Printf
-- trace :: String -> a -> a
println msg = trace msg (return ())
printf_test = printf "Welcome to %s %d" "LambdaJam" 2013
              => "Welcome to LambdaJam 2013"
```

```
minimum xs = ...
  forM_ xs (\curr -> do
    old_min <- get
    println (printf "old_min: %d curr: %d"
                    old_min curr)
    ...)
=> ((), old_min: -1 curr: 3
    old_min: -1 curr: 2
    old_min: -1 curr: 1
    -1)
```

- Fixed!

```
-- main = let numbers = [3,2,1] in
--         print (runState (Main.minimum numbers) (-1))
main = let (n:ns) = [3,2,1] in
        print (runState (Main.minimum ns) n)
```

- Use all at once.
- The Good: Combining monads is easy.
- The Bad: Type sigs. and runners are more complicated.
- The Sorta Good: It's pretty mechanical

- An interactive version of auth

```
interactive_auth =  
  let puts      msg = liftIO (putStrLn msg)  
      wait_for msg = do {puts msg; liftIO getLine}  
      log_failed  = tell ["Failed login attempt"]  
      set_user u   = do {puts "Welcome!"; put u}  
in do users      <- ask  
    user         <- wait_for "Username:"  
    password     <- wait_for "Password:"  
    case (lookup user users) of  
      Nothing -> do puts "Invalid Login!"  
                   log_failed  
      Just p   -> if (p == password)  
                   then set_user user  
                   else log_failed
```

```
interactive_auth :: ReaderT [(String,String)]  
                  (WriterT [String]  
                    (StateT String  
                      IO))  
  
                  ()
```

- Transformer = Stack of Monads + Result

```
interactive_auth = ... ()
```

```
interactive_auth :: ReaderT [(String,String)]  
                  (WriterT [String]  
                    (StateT String  
                      IO))  
  
                  ()
```

- Outer monad is ReaderT

```
ReaderT [(String,String)] (WriterT ...) ()
```

- Reader

```
simple_auth :: Reader [(String,String)] Bool
```

- Reader Transformer = ReaderT + Environment + M

```
ReaderT [(String,String)] (WriterT ...) ()
```



```
interactive_auth :: ReaderT [(String,String)]  
                  (WriterT [String]  
                    (StateT String  
                      IO))  
  
                  ()
```

- 'runReader' :: Reader Monad -> Read-Only State -> Result
- 'runReaderT' :: ReaderT Monad -> Read-Only State -> M Result

```
let writer :: WriterT [String] (StateT Int IO) () =  
    runReaderT interactive_auth users
```

```
interactive_auth :: ReaderT [(String,String)]  
                  (WriterT [String]  
                    (StateT String  
                      IO))  
                  ()
```

- $\text{Writer} = \text{Writer} + \text{Append-Only State} + (\text{Result}, \text{Accumulated State})$

```
validate :: String -> Writer [String] ()
```

- $\text{WriterT Transformer} = \text{WriterT} + \text{Append-Only State} + M$

```
WriterT [String] (... )
```

```
interactive_auth :: ReaderT [(String,String)]  
                  (WriterT [String]  
                    (StateT String  
                      IO))  
  
                  ()
```

- 'runWriter' :: Writer Monad -> (Result, Accumulated State)
- 'runWriterT' :: WriterT Monad -> M (Result, Accumulated State)

```
let writer = runReaderT interactive_auth users  
let state :: (StateT String IO) ((), [String])  
    = runWriterT writer
```

```
interactive_auth :: ReaderT [(String,String)]  
                  (WriterT [String]  
                    (StateT String  
                      IO))  
                  ()
```

- State = Mutable State + Result  
`(mapM_ compare xs :: State Int ())`
- State Transformer = StateT + Mutable State + Underlying Monad  
`StateT String IO (...)`

```
interactive_auth :: ReaderT [(String,String)]
                  (WriterT [String]
                     (StateT String
                        IO))

                  ()
```

- 'runState' :: State Monad -> Initial State -> (Result, New State)
- 'runStateT' :: StateT Monad -> Mutable State -> M (Result, New State)

```
let writer = runReaderT interactive_auth users
let state  = runWriterT writer
let io :: IO (((), [String]), String) =
    runStateT state ""
```

- Using 'interactive\_auth'

```
interactive_auth_driver = do
  let my_auth = ("deech","deechpassword")
  users <- get_users
  let writer = runReaderT interactive_auth users
  let state  = runWriterT writer
  let io     = runStateT state ""
  final <- io
  print final
```

- Running with Control.Monad.RWS

```
-- runRWS :: RWST Monad ->
           Read-Only State ->
           Mutable State ->
           Lowest Monad

interactive_auth_driver' = do
    let my_auth = ("deech","deechpassword")
    users <- get_users
    final <- runRWS interactive_auth users ""
    print final
```

- Sample session 1

Username :

deech

Password:

wrongpassword

```
((()), ["Failed login attempt"]), ""
```

- Sample session 2

Username :

deech

Password:

deechpassword

Welcome!

```
((()), []), "deech"
```



- Multiple States, Readers, Writers?
- An 'interactive\_auth' with an attempt counter

```
interactive_auth :: ReaderT [(String,String)]  
                  (WriterT [String]  
                    (StateT String  
                      (StateT Int  
                        IO)))  
                  ()
```

- Not recommended!

```
interactive_auth :: ReaderT [(String,String)]
                  (WriterT [String]
                     (StateT String
                        (StateT Int
                           IO)))
                  ()
```

- 'lift' “removes” a monadic layer
- Accessing the counter:

```
do ...
    counter <- lift -- ReaderT
               (lift -- WriterT
                 (lift -- StateT String
                     get))
```

...

- Better off using a record:

```
data Auth_State = Auth_State {  
    counter :: Int,  
    current_user :: String  
}  
increment_attempt_counter = do  
    auth_state <- get  
    put auth_state{counter = (counter auth_state + 1)}
```