State and Style

Mihai Maruseac

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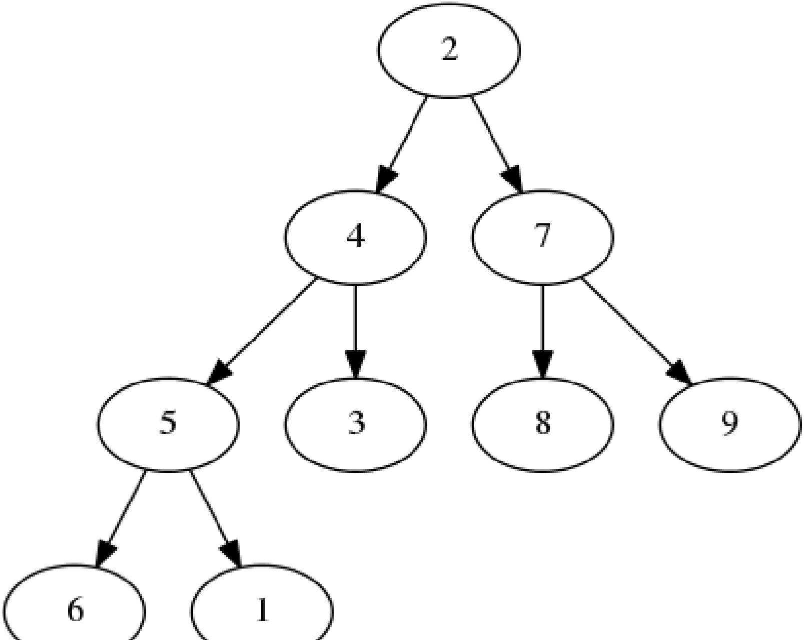
A tree

```
data Tree a
  = Leaf a
  | Node (Tree a) a (Tree a)
  deriving (Show)
```

An example (1)

```
t1 = Node (Leaf 6) 5 (Leaf 1)
t2 = Node t1 4 (Leaf 3)
t3 = Node (Leaf 8) 7 (Leaf 9)
myTree = Node t2 1 t3
```

An example (2)



Computing the minimum (1)

```
minTree :: Ord a => Tree a -> a
minTree (Leaf x)     = ...
minTree (Node l v r) = ...
```

Computing the minimum (2)

```
minTree :: Ord a => Tree a -> a
minTree (Leaf x)       = x
minTree (Node l v r) = minimum [minTree l, v, minTree r]
```

Summing the tree (1)

```
getTreeRoot (Leaf x)       = x
getTreeRoot (Node _ x _ ) = x

sumTree :: Num a => Tree a -> Tree a
```

Summing the tree (2)

```
sumTree (Leaf x)     = Leaf x
sumTree (Node l v r) = Node l' v' r'
  where
    l' = sumTree l
    r' = sumTree r
    v' = v + getTreeRoot l' + getTreeRoot r'
```

Depth of a node (1)

```
depthTree :: Num a => Tree t -> Tree a
```

Depth of a node (2)

```
depthTree t = go t 0
  where
    go (Leaf _)      d = Leaf d
    go (Node l _ r) d = Node (go l $ d + 1)
                             d
                             (go l $ d + 1)
```

Zipping two trees (1)

```
zipTree :: Tree t -> Tree t1 -> Tree (t, t1)
zipTree (Leaf ...) (Leaf ...) = ...
zipTree (Leaf ...) (Node ...) = ...
zipTree (Node ...) (Leaf ...) = ...
zipTree (Node ...) (Node ...) = ...
```

Zipping two trees (2)

```
zipTree (Leaf a)       (Leaf b)       = Leaf (a, b)
zipTree (Leaf a)       (Node _ b _)   = Leaf (a, b)
zipTree (Node _ a _)   (Leaf b)       = Leaf (a, b)
zipTree (Node l1 a r1) (Node l2 b r2) =
    Node (zipTree l1 l2) (a, b) (zipTree r1 r2)
```

Complex transformation (1)

- pair of
  - sum of children's values
  - depth of the node

```
complex :: (Num t1, Num t) => Tree t1 -> Tree (t1, t)
```

Complex transformation (2)

```
complex t = zipTree (sumTree t) (depthTree t)
```

- going twice through the tree
- slight performance hit
  - more obvious on other structures
- own function

Complex transformation (3)

```haskell
complex' t = go t 0
  where
    go (Leaf x) d = Leaf (x, d)
    go (Node l v r) d = Node l' (v', d) r'
      where
        l' = go l $ d + 1
        r' = go r $ d + 1
        v' = v + fst (getTreeRoot l')
               + fst (getTreeRoot r')
```

Complex transformation (4)

- harder to read
- not composable
- harder to extend
- nested `where`
- need *state*

A search problem (1)

- search for element satisfying a predicate

```
find :: (a -> Bool) -> [a] -> Maybe a

find3
  :: (t -> Bool)
     -> [t]
     -> (t1 -> Bool)
     -> [t1]
     -> (t2 -> Bool)
     -> [t2]
     -> Maybe (t, t1, t2)
```

A search problem (2)

```
find3' p1 l1 p2 l2 p3 l3 =
  case find p1 l1 of
    Just t1 -> case find p2 l2 of
      Just t2 -> case find p3 l3 of
        Just t3 -> Just (t1, t2, t3)
        _ -> Nothing
      _ -> Nothing
    _ -> Nothing
```

Ugly :(

IO

- side effects
  - putStr, putStrLn, print
  - getLine, readLn
  - forkIO
  - random number generation
  - main function

```
main = do
  s <- getLine
  print s
```

The Monad typeclass

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

    fail   :: String -> m a
```

The Functor typeclass

```haskell
class Functor f where
    fmap :: (a -> b) -> f a -> f b
```

do notation

```
                 do e -> e
       do { e; stmts } -> e >> do { stmts }
   do { v <- e; stmts } -> e >>= \v -> do { stmts }
do { let decls; stmts} -> let decls in do { stmts }
```

Monad Tutorial Fallacy

A monad is a burrito

A monad is just a monoid in the category of endofunctors, what's the problem?

Maybe instance

```
instance Monad Maybe where
    return = Just
    (Just x) >>= g = g x
    Nothing  >>= _ = Nothing
```

Other interesting Monads

- `State`, `MonadState`
  - `get`, `put`, `modify`
- `Reader`, `Writer`
- lists
- ...

Intuition

- computations
  - combining computations

```
divisorsOf :: Int -> [Int]

map divisorsOf :: [Int] -> [[Int]]

concatMap divisorsOf :: [Int] -> [Int]
```

Complex transformation (5)

```
transform (Leaf x) = do
  depth <- get
  return $ Leaf (x, depth)
transform (Node l v r) = do
  l’ <- transform l
  r’ <- transform r
  depth <- get
  let root_l = fst $ getTreeRoot l’
  let root_r = fst $ getTreeRoot r’
  return $ Node l’ (v + root_l + root_r, depth) r’

complex’’ t = evalState (transform t) 0
```

A search problem (3)

```
find3 p1 l1 p2 l2 p3 l3 = do
  t1 <- find p1 l1
  t2 <- find p2 l2
  t3 <- find p3 l3
  return (t1, t2, t3)
```

Summary

Haskell is the world's best imperative language

Simon Peyton Jones

- monads capture control flow and common patterns
  - less boilerplate
  - more declarative style
- `MonadPlus`
- monad transformers, monad stacks
- Category Theory
- Typeclassopedia

Typeclassopedia