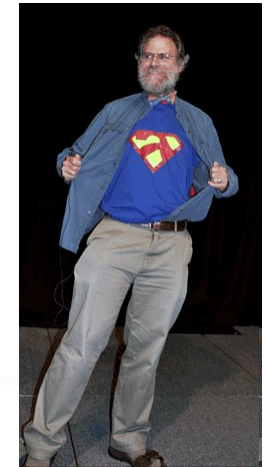


Monády 3

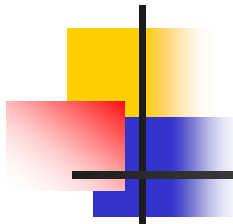


Monady sú použiteľný nástroj pre programátora poskytujúci:

- modularitu – skladať zložitejšie výpočty z jednoduchších (no side-effects),
- flexibilitu – výsledný kód je ľahšie adaptovateľný na zmeny,
- izoluje side-effect operácie (napr. IO) od čisto funkcionálneho zvyšku.

Štruktúra prednášok:

- Monády - prvý dotyk
 - Functor
 - Applicative
 - Monády – princípy a zákony
- Najbežnejšie monády
 - Maybe/Error monad
 - List monad
 - IO monad
 - State monad
 - Reader/Writer monad
 - Continuation monad
- Transformátory monád
- Monády v praxi



Maybe, štruktúra

všetko spolu

```
data Osoba = Osoba { krstne :: String, priezvisko :: String, rc :: Int } deriving(Show)
```

Osoba je konštruktor, ale aj funkcia `Osoba :: String->String->Int->Osoba`

```
osoba :: (String, String, Int) -> Osoba
```

```
osoba (krstne, priezvisko, rc) = Osoba krstne priezvisko rc
```

alternatíva:

```
osoba = uncurry3 Osoba
```

```
  where uncurry3 f (a,b,c) = f a b c
```

```
parse :: String -> Maybe Osoba
```

```
parse input = if length split /= 3 || rc `mod` 11 /= 0 then Nothing
```

```
  else Just $ osoba(krstne, priezvisko, rc)
```

```
  where split = words input
```

```
        [krstne, priezvisko, rcStr] = split
```

```
        rc = read rcStr :: Int
```

```
> parse "Peter Borovansky 2024"
Just (Osoba {krstne = "Peter",
             priezvisko = "Borovansky",
             rc = 2024})
```



Functor

všetko spolu

```
data Papalasi a = Papalasi {  
    premier :: a, vlada :: Map String a, parlament :: [a] } deriving(Show, Eq)
```

instance Functor Papalasi where

```
fmap f paps = Papalasi {  
    premier = f (premier paps),  
    vlada = f <$> vlada paps,  
    parlament = fmap f (parlament paps)  
}
```

--parlament = f <\$> parlament paps

```
inp' :: Papalasi String  
inp' = Papalasi  
    ("Juraj H 121")  
    (Data.Map.fromList  
        [ ("financ", ("Igor M 55"))  
        , ("defenc", ("Roman M 66"))  
        , ("justice", ("Maria K 44"))  
        ])  
    ([("Robert F 38"), ("Peter P 33")])
```

```
> :t fmap parse inp' :: Papalasi (Maybe Osoba)  
> fmap parse inp'
```

```
inp :: Papalasi (String, String, Int)  
inp = Papalasi  
    ("Juraj", "H", 121)  
    (Data.Map.fromList  
        [ ("financ", ("Igor", "M", 55))  
        , ("defenc", ("Roman", "M", 66))  
        , ("justice", ("Maria", "K", 44))  
        ])  
    ([("Robert", "F", 38), ("Peter", "P", 33)])
```

```
> :t fmap osoba inp :: Papalasi Osoba  
> fmap osoba inp  
> osoba <$> inp
```

Papalasi.hs



QuickCheck

všetko spolu

```
instance Arbitrary a => Arbitrary (Papalasi a) where
```

```
  arbitrary = do
```

```
    r_premier <- arbitrary
```

```
    r_vlada <- arbitrary
```

```
    r_parlament <- arbitrary
```

```
    return $ Papalasi {
```

```
      premier = r_premier, vlada = r_vlada, parlament = r_parlament
```

```
    }
```

```
> generate (arbitrary::Gen (Papalasi Bool))
Papalasi {premier = False, vlada = fromList [("\SOH*.
",False)], parlament =
[False,True,True,False,False,True,True,True,True,True,T
rue,True,False,False,True,False,False]}
```

```
functorCheck1 = quickCheck((\paps -> fmap id paps == paps)
  ::Papalasi String -> Bool)
```

```
functorCheck2 = quickCheck((\paps -> \p -> \q -> fmap (p.q) paps == ((fmap p).(fmap q)) paps)
  ::Papalasi String -> (String->String)-> (String->String) -> Bool)
```

```
main :: IO ()
main = do functorCheck1
         functorCheck2
> main
+++ OK, passed 100 tests.
+++ OK, passed 100 tests.
```

```
instance Functor Papalasi where
  fmap f paps = Papalasi {
    premier = f (fromJust (Data.Map.lookup "financ" (vlada paps))), ...
> Main
*** Failed
*** Failed
```



Control.Monad

```
sequence :: (Monad m) => [m a] -> m [a]
mapM     :: (Monad m) => (a -> m b) -> [a] -> m [b]
forM     :: (Monad m) => [a] -> (a -> m b) -> m [b]

mapM f as = sequence (map f as)
forM = flip mapM

zipWithM :: (Monad m) => (a -> b -> m c) -> [a] -> [b] -> m [c]
zipWithM f xs ys = sequence (zipWith f xs ys)

replicateM :: (Monad m) => Int -> m a -> m [a]
replicateM n x = sequence (replicate n x)

filterM :: (Monad m) => (a -> m Bool) -> [a] -> m [a]
foldM   :: (Monad m) => (a -> b -> m a) -> a -> [b] -> m a

guard :: (MonadPlus m) => Bool -> m ()
guard True = return ()
guard False = zero
```

```
sequence_ :: (Monad m) => [m a] -> m ()
mapM_     :: (Monad m) => (a -> m b) -> [a] -> m ()
forM_     :: (Monad m) => [a] -> (a -> m b) -> m ()

mapM_ f as = sequence_ (map f as)
forM_ = flip mapM_

zipWithM_ :: (Monad m) => (a -> b -> m c) -> [a] -> [b] -> m ()
zipWithM_ f xs ys = sequence_ (zipWith f xs ys)

replicateM_ :: (Monad m) => Int -> m a -> m ()
replicateM_ n x = sequence_ (replicate n x)

foldM_ :: (Monad m) => (a -> b -> m a) -> a -> [b] -> m ()
```

mapM, forM

(Control.Monad)

mapM :: (Monad m) => (a -> m b) -> [a] -> m [b]
mapM f = sequence . map f

forM :: (Monad m) => [a] -> (a -> m b) -> m [b] -- len záměna args.
forM = flip mapM

```
> mapM (\x->[x,11*x]) [1,2,3]
[[1,2,3],[1,2,33],[1,22,3],[1,22,33],[11,2,3],[11,2,33],[11,22,3],[11,22,33]]
```

```
> mapM (\x -> [True, False]) [1,2,3]
[[True,True,True],[True,True,False],[True,False,True],[True,False,False],
 [False,True,True],[False,True,False],[False,False,True],[False,False,False]]
```

```
> forM [1,2,3] (\x->[x,11*x])
[[1,2,3],[1,2,33],[1,22,3],[1,22,33],[11,2,3],[11,2,33],[11,22,3],[11,22,33]]
```

```
> mapM print [1,2,3]
1
2
3
[(),(),()]
```

```
> mapM_ print [1,2,3]
1
2
3
```

```
mapM_ (putStrLn.show)
[1,2,3]
1
2
3
```



filterM

(Control.Monad)

filterM :: (Monad m) => (a -> m Bool) -> [a] -> m [a]

```
> filterM (\x->[True, False]) [1,2,3]  
[[1,2,3],[1,2],[1,3],[1],[2,3],[2],[3],[]]
```

-- potenčná množina, powerset

filterM :: (Monad m) => (a -> m Bool) -> [a] -> m [a]

filterM _ [] = return []

filterM p (x:xs) = do

flg <- p x

ys <- filterM p xs

return (if flg then x:ys else ys)



foldM

(Control.Monad)

```
foldM :: (Monad m) => (a -> b -> m a) -> a -> [b] -> m a
foldM _ a [] = return a
foldM f a (x:xs) = f a x >>= \y -> foldM f y xs
```

```
foldM f a1 [x1, ..., xn] =
  do {
    a2 <- f a1 x1;
    a3 <- f a2 x2;
    ...
    an <- f an-1 xn-1;
    return f an xn }
```

```
> foldM (\y -> \x ->
  do { print (show x++"..."++ show y);
    return (x*y)})
  1 [1..10]
???
```

```
> foldM (\y -> \x -> do print (show x++"..."++ show y); return (x*y)) 1 [1..10]
???
```




Error monad

```
newtype Either a b = Right a | Left b
instance (Error e) => Monad (Either e) where
    return x = Right x
    Right x >>= f = f x
    Left err >>= f = Left err
    fail msg = Left (strMsg msg)
```

```
data Term = Con Int | Div Term Term deriving(Show, Read, Eq)
```

```
eval      :: Term -> Either String Int
```

```
eval(Con a) = return a
```

```
eval(Div t u) = do
```

```
    valT <- eval t
```

```
    valU <- eval u
```

```
    if valU == 0 then
```

```
        fail "div by zero"           -- throwError "div by zero"
```

```
    else
```

```
        return (valT `div` valU)
```

```
> eval (Div (Con 1972) (Con 23))
```

```
Right 85
```

```
> eval (Div (Con 1972) (Con 0))
```

```
*** Exception: div by zero
```



Reader monad

(Control.Monad.Reader)

```
main :: IO ()
main = do params <- loadParams
        let result = func1 params
        print result

data Params = Params { p1 :: String, p2 :: String, p3 :: String } deriving (Show)
loadParams :: IO Params
loadParams = do p1 <- lookupEnv "JAVA_HOME"
                p2 <- lookupEnv "OS"
                p3 <- lookupEnv "HOMEDRIVE"
                return $ Params (fromMaybe "no java" p1)
                                (fromMaybe "unknown" p2)
                                (fromMaybe "no drive" p3)

func1 :: Params -> String
func1 params = "Result: " ++ (show (func2 params))

func2 :: Params -> Int
func2 params = 2 + floor (func3 params)

func3 :: Params -> Float
func3 params = (fromIntegral $ length $ p1 params ++ p2 params ++ p3 params)*3.14
```



Reader monad

(Control.Monad.Reader)

Reader monáda sa používa, ak máme **nemenné** prostredie, ktoré zdieľa viac výpočtov

```
newtype Reader r a = Reader (r -> a)
```

```
data Reader r a = Reader { runReader :: (r -> a) }
```

```
class Monad m => MonadReader r m | m -> r where
```

```
func :: Reader Params a
```

```
runReader func params :: a
```

```
-- runReader :: Reader r a -> r -> a
```

```
-- získa prostredie
```

```
ask :: Params
```

```
func :: Reader Params String
```

```
func = do params <- ask
```

```
...
```



Reader monad

(Control.Monad.Reader)

```
main' :: IO ()
main' = do params <- loadParams
        let result = runReader func1' params
        putStrLn result
```

```
func1' :: Reader Params String
func1' = do params <- ask
        result <- func2'
        return $ "Result: " ++ (show result)
```

```
func2' :: Reader Params Int
func2' = do params <- ask
        result <- func3'
        return $ 2+floor(result)
```

```
func3' :: Reader Params Float
func3' = do params <- ask
        let result = (fromIntegral $ length $ p1 params++p2 params++p3 params)*3.14
        return result
```

```
loadParams :: IO Params
params :: Params
func1' :: Reader Params String
runReader :: Reader r a -> r -> a
result :: String
```

```
ask :: m r, Reader Params String
params :: Params
```



Writer monad

(Control.Monad.Writer)

```
newtype Writer w a = Writer { runWriter :: (a, w) }
instance (Monoid w) => Monad (Writer w) where
    return x = Writer (x, mempty)
    (Writer (x,v)) >>= f =
        let (Writer (y, v')) = f x
        in Writer (y, v `mappend` v')
```

Writer monáda sa používa, ak máme výpočet produkujúci stream dát, ktoré akumulujeme

```
data Term = Con Int | Div Term Term deriving(Show, Read, Eq)
```

```
line    :: Term -> Int -> String
```

```
line t a = "eval (" ++ show t ++ ") <=" ++ show a ++ "\n"
```

```
eval    :: Term -> Writer String Int
```

```
eval x@(Con a) =
```

```
    do tell (line x a)
```

```
    return a
```

```
eval x@(Div t u) =
```

```
    do valT <- eval t
```

```
       valU <- eval u
```

```
       tell (line x (valT `div` valU))
```

```
       return (valT `div` valU)
```

```
eval    :: Term -> Writer String Int
```

```
eval x@(Con a) = writer (a, line x a)
```

```
eval x@(Div t u) =
```

```
    do valT <- eval t
```

```
       valU <- eval u
```

```
       let result = (valT `div` valU)
```

```
       writer (result, (line x result))
```



Writer monad

(Control.Monad.Writer)

```
Writer String Int
Writer w a
w = typ akumulátora
a = typ výsledku
-- vráti dvojicu, hodnotu a akumulátor
runWriter :: Writer w a -> (a,w)
-- vráti len akumulátor
execWriter :: Writer w a -> w
-- pripíše hodnotu do akumulátora, žiaden výsledok
tell :: w -> m ()
-- pripíše hodnotu do akumulátora, vráti výsledok
writer :: (a,w) -> m a

out :: Int -> Writer [String] Int
out x = writer (x, ["number: " ++ show x])
mult :: Writer [String] Int
mult = do {a <- out 3; b <- out 5; return (a*b) }
```

```
newtype Writer w a = Writer { runWriter :: (a, w) }
instance (Monoid w) => Monad (Writer w) where
    return x = Writer (x, mempty)
    (Writer (x,v)) >>= f =
        let (Writer (y, v')) = f x
        in Writer (y, v `mappend` v')
```

```
t :: Term
t = (Div (Div (Con 1972) (Con 2)) (Con 23))

> eval t
WriterT (Identity (42,
"eval (Con 1972) <=1972\neval (Con 2) <=2\neval (Div (Con 1972) (Con 2)) <=986\neval (Con 23) <=23\neval (Div (Div (Con 1972) (Con 2)) (Con 23)) <=42\n"))
> runWriter (eval t)
(42,"eval (Con 1972) <=1972\neval (Con 2) <=2\neval (Div (Con 1972) (Con 2)) <=986\neval (Con 23) <=23\neval (Div (Div (Con 1972) (Con 2)) (Con 23)) <=42\n")
> execWriter (eval t)
"eval (Con 1972) <=1972\neval (Con 2) <=2\neval (Div (Con 1972) (Con 2)) <=986\neval (Con 23) <=23\neval (Div (Div (Con 1972) (Con 2)) (Con 23)) <=42\n"

> putStr $ execWriter (eval t)
eval (Con 1972) <=1972
eval (Con 2) <=2
eval (Div (Con 1972) (Con 2)) <=986
eval (Con 23) <=23
eval (Div (Div (Con 1972) (Con 2)) (Con 23)) <=42

> runWriter mult
(15,["number: 3","number: 5"])
> execWriter mult
["number: 3","number: 5"]
> mapM_ putStrLn $ execWriter (mult)
number: 3
number: 5
```

Writer.hs



Writer monad

(Control.Monad.Writer)

```
gcd' :: Int -> Int -> Writer [String] Int
gcd' a b | b == 0 = do
    tell ["result " ++ show a]
    return a
| otherwise = do
    tell [show a ++ " mod " ++ show b ++ " = " ++ show (a `mod` b)]
    gcd' b (a `mod` b)
```

```
gcd' :: Int -> Int -> Writer [String] Int
gcd' a b | b == 0 = writer (a, ["result " ++ show a])
| otherwise = do let modulo = (a `mod` b)
    result <- gcd' b modulo
    writer (result, [show a ++ " mod " ++ show b ++ " = " ++ show modulo])
```

```
> mapM_ putStrLn (execWriter $ gcd' 2024 64)
result 8
16 mod 8 = 0
24 mod 16 = 8
40 mod 24 = 16
64 mod 40 = 24
2024 mod 64 = 40
```



Euclid's Game

hra pre dvoch hráčov

začínajú s dvomi prirodzenými číslami na tabuli

Jediné pravidlo:

- odčítajte väčšie od menšieho a napíšte na tabuľu, ale také, aké tam nie je
- Ten kto napíše posledné číslo vyhráva, prehráva ten, čo už nevie ťahať

Aká je víťazná stratégia ?

| | |
|----|--------------|
| 13 | 6 |
| 7 | |
| 1 | |
| 5 | |
| 2 | |
| 11 | |
| 9 | |
| 4 | |
| 3 | |
| 8 | |
| 10 | |
| 12 | modrý vyhrál |

| | |
|----|--------------|
| 18 | 12 |
| 6 | modrý vyhrál |

| | |
|----|----------------|
| 16 | 6 |
| 10 | |
| 4 | |
| 2 | |
| 14 | |
| 12 | |
| 8 | červený vyhrál |

| | |
|----|--------------|
| 21 | 9 |
| 12 | |
| 3 | |
| 6 | |
| 18 | |
| 15 | modrý vyhrál |

| | |
|----|--------------|
| 23 | 8 |
| 15 | |
| 7 | |
| 1 | |
| 14 | |
| 22 | |
| 21 | |
| 20 | |
| 19 | |
| 18 | |
| 17 | |
| 16 | |
| 13 | |
| 12 | |
| 11 | |
| 10 | |
| 9 | |
| 6 | |
| 5 | |
| 4 | |
| 3 | |
| 2 | modrý vyhrál |



State monad

(Control.Monad.State)

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

```
instance Monad (State s) where  
  return a          = State \s -> (a,s)  
  (State x) >>= f = State \s ->  
                      let (v,s') = x s in runState (f v) s'
```

```
class (Monad m) => MonadState s m | m -> s where  
  get :: m s                -- get vrátí stav z monády  
  put :: s -> m ()          -- put prepíše stav v monáde
```

```
modify :: (MonadState s m) => (s -> s) -> m ()  
modify f = do    s <- get  
                put (f s)
```

Čo je newtype vs. data vs. type

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

`State s a` má rovnakú reprezentáciu ako `(s -> (a,s))`, ale nie je to

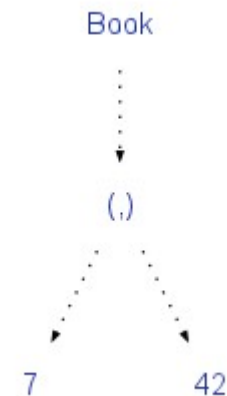
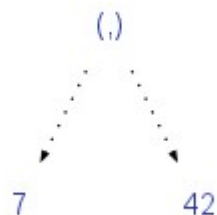
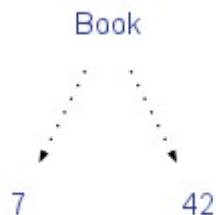
type `State s a = s -> (a,s)`

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

`State s a` je reprezentovaná krabicou `State s` pointrom na `(s -> (a,s))`

Príklad:

data `Book = Book Int Int` **newtype** `Book = Book (Int, Int)` **data** `Book = Book (Int, Int)`



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

State s a

(basics-1)

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

- `runState :: State s a -> (s -> (a, s))` -- vráti funkciu state monády
- `evalState :: State s a -> s -> a` -- vráti výsledok state monády pre stav s
- `execState :: State s a -> s -> s` -- vráti výsledný stav state monády pre vstupný stav s

```
:t runState ((return "hello") :: State Int String)
```

```
runState ((return "hello") :: State Int String) :: Int -> (String, Int)
```

```
runState ((return "hello") :: State Int String) 77 = ("hello",77)
```

```
evalState ((return "hello") :: State Int String) 77 = "hello"
```

```
execState ((return "hello") :: State Int String) 77 = 77
```

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

State s a

(basics-2)

```
return :: a -> State s a      -- monáda s výsledkom x::a, stavom s
return x s = (x,s)            -- return x = \s -> (x,s)

get :: State s s              -- stav state monády je jej výsledkom
get s = (s,s)                 -- get = \s -> (s,s)

runState get 1 = (1,1)

put :: s -> State s ()        -- prepíše stav monády x, výsledok je nezaujímavý
put x s = ((),x)              -- put x = \s -> ((),x)

runState (put 5) 1 = ((),5)
runState (do { put 5; return 'X' }) 1 = ('X',5)

modify :: (s -> s) -> State s ()
modify f = do { x <- get; put (f x) }

runState (modify (+3)) 1 = ((),4)
runState (do { modify (+3); return "hello" }) 1 = ("hello",4)
```

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

State s a

(basics-3)

```
let increment = do { x <- get; put (x+1); return x } in runState increment 77  
= (77,78)
```

```
gets :: (s -> b) -> State s b
```

```
gets f = do { x <- get; return (f x) }
```

```
runState (gets (+1)) 77 = (78,77)
```

```
evalState (gets (+1)) 77 = 78
```

-- vráti výsledok state monády pre
vstupný stav s, po aplikovaní funkcie

```
execState (gets (+1)) 77 = 77
```

-- vráti výsledný stav state monády pre
vstupný stav s, a ten sa nezmenil

```
runState (modify (+1)) 77 = ((),78)
```



Eval s vlastnou State Monad

(bolo minule)

```
data Term = Con Int | Div Term Term deriving(Show, Read, Eq)
```

```
type State = Int
```

```
data SM a    = SM (State-> (a, State))
```

```
instance Functor SM where ...
```

```
instance Applicative SM where ...
```

```
instance Monad SM where ...
```

```
incState    :: SM ()
```

```
incState    = SM (\x -> ((),x+1))
```

```
evalSM'      :: Term -> SM Int
```

```
evalSM'(Con a) = return a
```

```
evalSM'(Div t u) = do valT<-evalSM' t
                    valU<-evalSM' u
                    incState
                    return(valT `div` valU)
```

```
goSM          :: Term -> State
```

```
goSM t        = let SM p = evalSM t, (result,state) = p 0 in state
```

```
> goSM' t
2
```



Eval

```
data Term = Con Int | Div Term Term deriving(Show, Read, Eq)
type Stav = Int
```

stav

výsledok

```
evalSM      :: Term -> State Stav Int
evalSM (Con a)  = return a
evalSM (Div t u) = do valT<-evalSM t
                    valU<-evalSM u
                    modify (+1)
                    return(valT `div` valU)
```

```
> runState (evalSM t) 0
(42,2)
> execState (evalSM t) 0
2
> evalState (evalSM t) 0
42
```

State Stack

```
pop :: State Stack Int
pop = state \(x:xs) -> (x,xs))
```

```
push :: Int -> State Stack ()
push a = state \(xs -> ((),a:xs))
```

```
type Stack = [Int]
```

stav výsledek

```
pushAll :: Int -> State Stack String
pushAll 0 = return ""
pushAll n = do {
    push n;
    str <- pushAll (n-1);
    nn <- pop;
    return (show nn ++ str)}
```

evalState vráti výslednú hodnotu

```
> evalState (pushAll 10) []
"10987654321"
```

execState vráti výsledný stav

```
> execState (pushAll 10) []
[]
```

```
type Stack = [Int]
```

```
pushAll' :: Int -> State Stack String
```

```
pushAll' 0 = return ""
```

```
pushAll' n = do
```

```
    stack <- get -- push n
```

```
    put (n:stack)
```

```
    str <- pushAll (n-1)
```

```
    (nn:stack') <- get -- nn <- pop
```

```
    put stack'
```

```
    return (show nn ++ str)
```

```
> evalState (pushAll' 10) []
```

```
"10987654321"
```

```
> execState (pushAll' 10) []
```

```
[]
```




Parkovací automat

Parkovací automat sa zapína na signal '.', na začiatku je off. Keď je zapnutý, tak počíta počet automobilov, ktoré vošli '(' a počet automobilov, ktoré odišli ')'. Stav automatu je ich rozdiel, výsledok výpočtu je počet automobilov, ktoré na parkovisku zostali, počas obdobia, keď bol zapnutý

type Vysledok = Int

type Stav = (Bool, Int)

loop :: String -> State Stav Vysledok

```
loop [] = do (_, result) <- get
          return result
```

```
loop (x:xs) = do (on, diff) <- get
```

```
  case x of
```

```
    '(' | on -> put (on, diff + 1)
```

```
    ')' | on && diff > 0 -> put (on, diff - 1)
```

```
    '.' -> put (not on, diff)
```

```
    _ -> put (on, diff)
```

```
  loop xs
```

```
main = mapM_ print [ evalState (loop input) (False, 0) |
  input <- [
    "(()(.())())((((.)())",
    "(()(.())())().(.(",
    "(()(.())())().().()",
    "(()(.())())().().().(" ]
```



Dobré zátvorky ???

```
type Value = Int
type Stav = (Bool, Int, Int)
loop :: String -> State Stav Bool
loop [] = do (ok, parents, brackets) <- get
              return $ ok && parents == 0 && brackets == 0
loop (x:xs) = do (ok, parents, brackets) <- get
                  case x of
                    '(' -> put (ok, parents+1, brackets)
                    '[' -> put (ok, parents, brackets+1)
                    ')' | parents > 0 -> put (ok, parents-1, brackets)
                    ']' | parents <= 0 -> put (False, 0, 0)
                    '[' -> put $ if (brackets>0) then (ok, parents, brackets-1)
                                   else (False, 0, 0)
                  loop xs
main = mapM_ print [ evalState (loop input) (True, 0, 0) | input <- [
    "()", "(())", "(()())", "(()()())", ")(", "[()", "[[]]", "][" , "()[]"] ]
```

```
> main
"() -> True"
"(() -> True"
"(()() -> True"
"(()()()) -> True"
")() -> False"
"([)] -> True"
"[[]] -> True"
"][" -> False"
"()[]" -> True"
```

Preorder so stavom

(Control.Monad.State)

```
data Tree a = Nil |  
             Node a (Tree a) (Tree a) deriving (Show, Eq)
```

stav

```
preorder :: Tree a -> State [a] ()  
preorder Nil  
preorder (Node value left right)
```

= return ()

=
do {

-- stav a výstupná hodnota

str :: [a]

```
str <- get; -- get state=preorderlist  
put (value:str); -- modify (value:!)  
preorder left;  
preorder right;  
return () }
```

```
e :: Tree String  
e = Node "c" (Node "a" Nil Nil) (Node "b" Nil Nil)
```

```
> execState (preorder e) [] -- stav  
["b","a","c"]
```

```
> evalState (preorder e) [] -- výsledok  
()
```

stav

výsledok

Prečíslovanie binárneho stromu

```
reindex :: Tree a -> State Int (Tree Int)
```

```
reindex Nil = return Nil
```

```
reindex (Node value left right) =  
  do {
```

```
    i <- get;
```

```
    put (i+1);
```

```
    ileft <- reindex left;
```

```
    iright <- reindex right;
```

```
    return (Node i ileft iright) }
```

-- stav a výstupná hodnota

```
> e'  
Node "d" (Node "c" (Node "a" Nil Nil) (Node "b" Nil Nil)) (Node "c" (Node  
"a" Nil Nil) (Node "b" Nil Nil))
```

```
> evalState (reindex e') 0  
Node 0 (Node 1 (Node 2 Nil Nil) (Node 3 Nil Nil)) (Node 4 (Node 5 Nil Nil)  
(Node 6 Nil Nil))
```

```
> execState (reindex e') 0  
7
```

Prečíslovanie stromu 2

stav

výsledok

```
type Table a = [a]
```

```
numberTree :: Eq a => Tree a -> State (Table a) (Tree Int)
```

```
numberTree Nil = return Nil
```

```
numberTree (Node x t1 t2) = do  num <- numberNode x
                                nt1 <- numberTree t1
                                nt2 <- numberTree t2
                                return (Node num nt1 nt2)
```

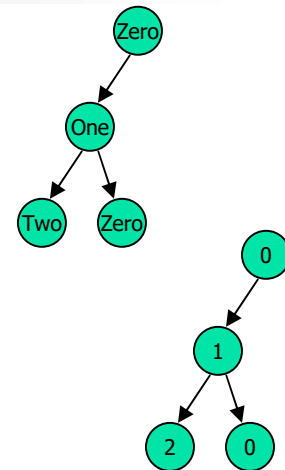
where

```
numberNode :: Eq a => a -> State (Table a) Int
```

```
numberNode x = do  table <- get
                   (newTable, newPos) <- return (addNode x table)
                   put newTable
                   return newPos
```

```
addNode :: (Eq a) => a -> Table a -> (Table a, Int)
```

```
addNode x table = case (findIndexInList (== x) table) of
                    Nothing -> (table ++ [x], length table)
                    Just i -> (table, i)
```

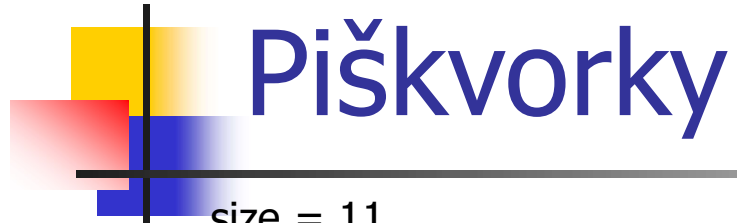




Prečíslovanie stromu 2

```
numTree :: (Eq a) => Tree a -> Tree Int  
numTree t = evalState (numberTree t) []
```

```
> numTree ( Node "Zero"  
              (Node "One" (Node "Two" Nil Nil)  
                (Node "One" (Node "Zero" Nil Nil) Nil)) Nil)  
  
Node 0 (Node 1 (Node 2 Nil Nil) (Node 1 (Node 0 Nil Nil) Nil)) Nil
```



Piškvoriky

```
size = 11
data PiskyState = PiskyState { playground::[[Tile]], onTurn::Bool, generator::StdGen }
data Tile = Empty | X | O deriving (Eq, Show)

-- player True/False
nextPlayer :: Bool->Bool
nextPlayer x = not x

-- player's sign
sign :: Bool -> Tile
sign True = X
sign False = O

-- no Empty on board
finish :: State PiskyState Bool
finish = do pstate <- get
           return $ any (==Empty) ( concat (playground pstate))
```



Piškvorcky

```
move :: State PiskyState (Int,Int)
```

```
move = do pstate <- get
```

```
    let free = [ (i,j) | i<-[0..size-1], j<-[0..size-1], (playground pstate)!!!j == Empty]
```

```
    let gen = generator pstate
```

```
    let (r, gen') = randomR (0, length free - 1) gen
```

```
    put $ pstate { generator = gen' }
```

```
    return $ free !! r
```

```
update :: (Int,Int) -> State PiskyState ()
```

```
update (row,col) = do pstate <- get
```

```
    let player = onTurn pstate
```

```
    let s = sign player
```

```
    let newPG = [[ if i == row && j == col then s else (playground pstate)!!!j  
                  | j<-[0..size-1]] | i<-[0..size-1]]
```

```
    put $ pstate { onTurn = nextPlayer player, playground=newPG }
```

```
oneTurn :: State PiskyState Bool
```

```
oneTurn = do { (row, col) <- move; update (row, col) ; finish }
```




Piškvorcky

```
pinit :: StdGen -> PiskyState
pinit gen = PiskyState (take size (repeat (take size ( repeat Empty))))
                True
                gen

main:: IO()
main = do g <- getStdGen
        let istate = pinit g
        putStr (show $ execState (sequence $ take 100 $ repeat oneTurn) istate)
```

```
> main
.OXXOX.XXXX
0000.XO.OOX
XX000000X00
OXX00000.OX
X.OX.XO.X00
000XXOXOXX
OX000.X..XX
X.X0OXOX.XO
X0XX.OXX.OO
.XXO.X.XX00
.XXXOX..XOX
```



Transformery

(najťažšie je kombinovať monády)

```
main :: IO ()
main = do login <- readLogin
      case login of
        Nothing -> print "Invalid user"
        Just (user) -> do password <- readPassword
                       case password of
                         Nothing -> print "Invalid password"
                         Just password -> putStrLn $ "logged: " ++ user

readLogin :: IO (Maybe String)
readLogin = do putStrLn "login:"
             str <- getLine
             if length str > 5 then return $ Just str else return Nothing

readPassword :: IO (Maybe String)
readPassword = do putStrLn "password:"
                 str <- getLine
                 if length str < 8 || null (filter isUpper str) || null (filter isLower str)
                 then return Nothing
                 else return $ Just str
```



Transformery

(MaybeT)

Monad transformer je wrapper parametrizovaný inou monádou

```
newtype MaybeT m a = MaybeT { runMaybeT :: m (Maybe a) }
```

```
instance (Monad m) => Monad (MaybeT m) where
```

```
  return = lift . return
```

```
  x >>= f = MaybeT $ do v <- runMaybeT x
```

```
    case v of
```

```
      Nothing -> return Nothing
```

```
      Just y  -> runMaybeT (f y)
```

MaybeT IO



Transformery

(MaybeT IO)

```
import Control.Monad.Trans.Maybe

main = do loginPassword <- runMaybeT $ do login <- readLogin
                                              password <- readPassword
                                              return (login, password)

      case loginPassword of
        Nothing -> print "Invalid user or password"
        Just (user, _) -> putStrLn $ "logged: " ++ user

readLogin :: MaybeT IO String
readLogin = MaybeT $ do putStrLn "login:"
                      str <- getLine
                      if length str > 5 then return $ Just str else return Nothing

readPassword :: MaybeT IO String
readPassword = MaybeT $ do putStrLn "password:"
                          str <- getLine
                          if length str < 8 || null (filter isUpper str) || null (filter isLower str)
                          then return Nothing
                          else return $ Just str
```