State Monad Methods (3G)

Young Won Lim
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Please send corrections (or suggestions) to youngwlim@hotmail.com.

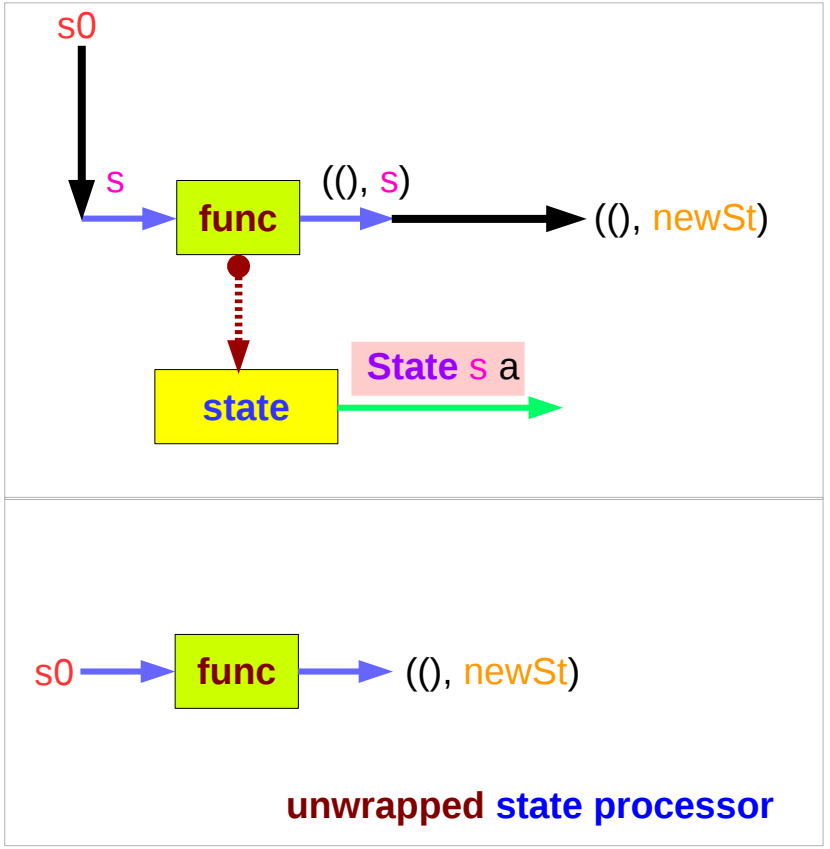
This document was produced by using LibreOffice.

Based on

Haskell in 5 steps
https://wiki.haskell.org/Haskell_in_5_steps

Setting the State : **put**

```
put :: s -> State s a
put newSt = state $ \_ -> ((), newSt)
```



Given a wanted state newState,

put generates a **state processor**

- ignores whatever the state it receives,
- updates the state to newState
- doesn't care about the result of this processor

- all we want to do is to change the state
- the tuple will be ((), newState)
- () : the **universal placeholder value**.

https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

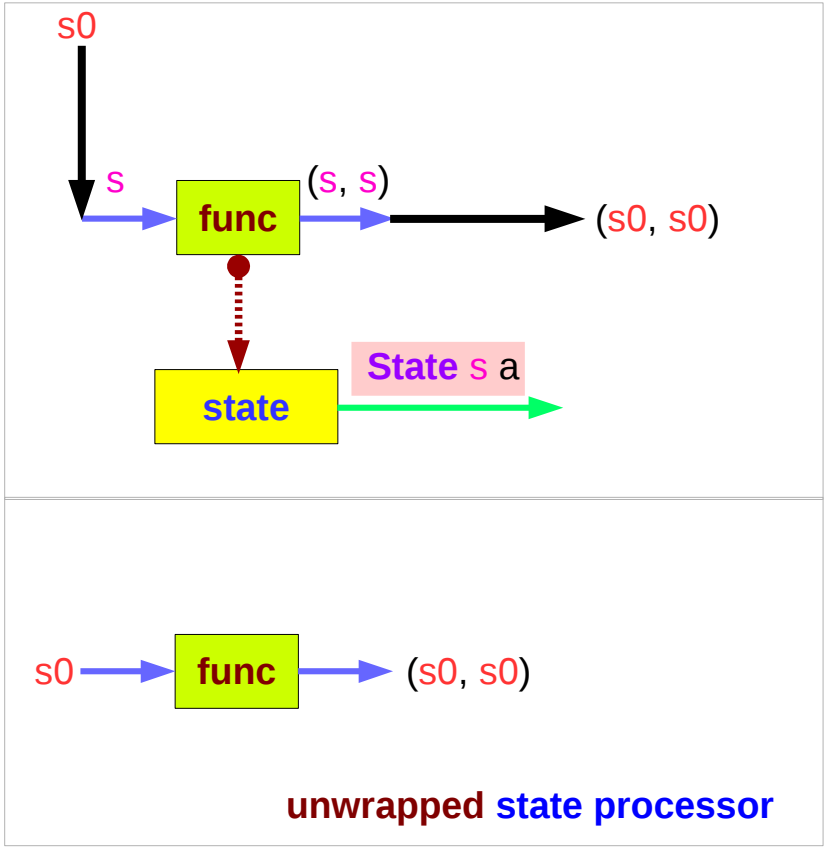
Getting the State : **get**

```
get :: State s s
get = state $ \s -> (s, s)
```

get generates a **state processor**

- gives back the state s0
- as a result and as an updated state – (s0, s0)

- the state will remain unchanged
- a copy of the state will be made available through the result returned



https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

Example Codes

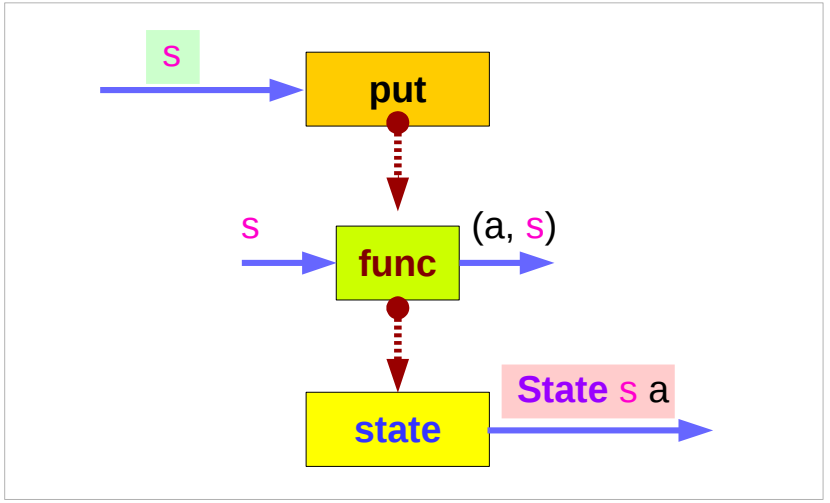
```
import Control.Monad.Trans.State

runState get 1
(1,1)
runState (return 'X') 1
('X',1)
runState get 1
(1,1)
runState (put 5) 1
((),5)

let postincrement = do { x <- get; put (x+1); return x }
runState postincrement 1
(1,2)
let predecrement = do { x <- get; put (x-1); get }
 runState predecrement 1
(0,0)
```

```
runState (modify (+1)) 1
((),2)
runState (gets (+1)) 1
(2,1)
evalState (gets (+1)) 1
2
execState (gets (+1)) 1
1
```

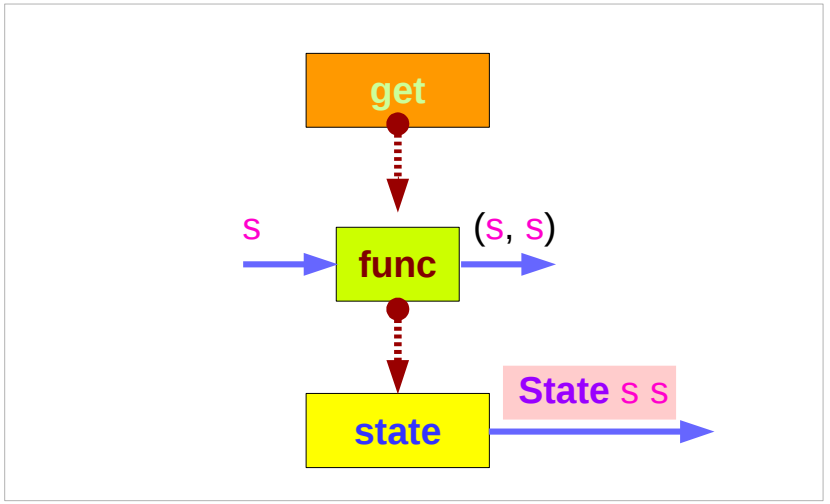
https://wiki.haskell.org/State_Monad

Setting and Getting the State

```
put :: s -> State s a
put s ::  State s a

put newState = state $ \_ -> ((), newState)

-- setting a state to newState
-- regardless of the old state
-- setting the result to ()
```

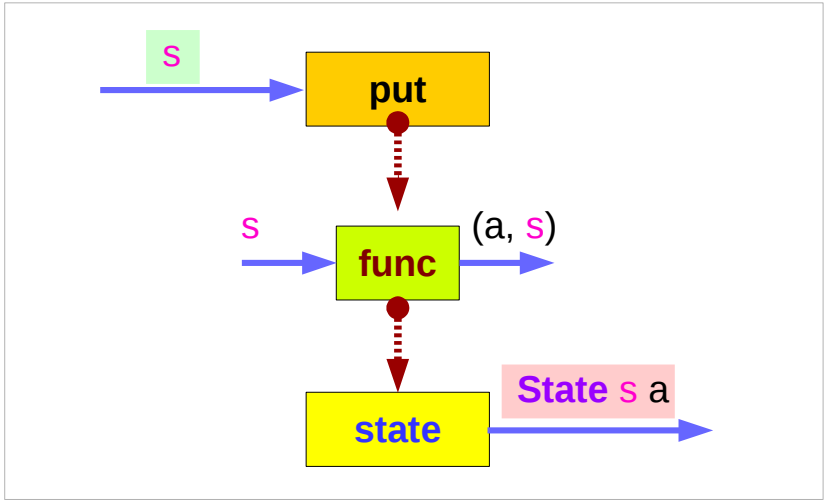


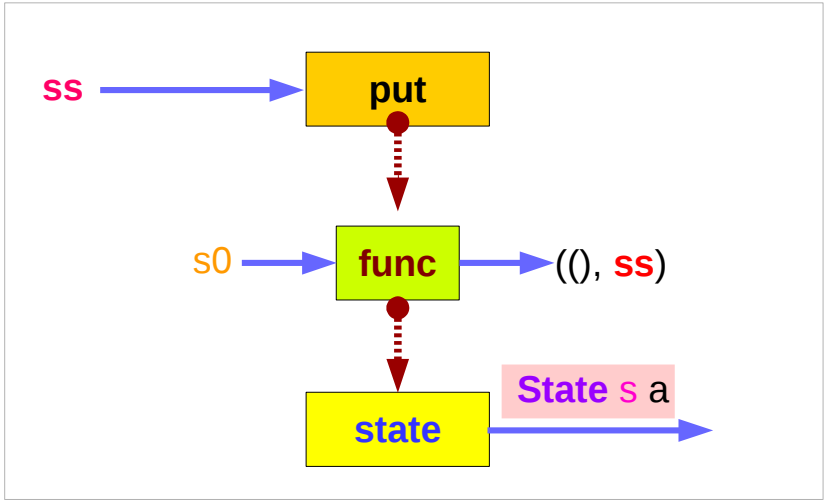

```
get :: State s s

get = state $ \s -> (s, s)

-- getting the current state s
-- also setting the result to s
```

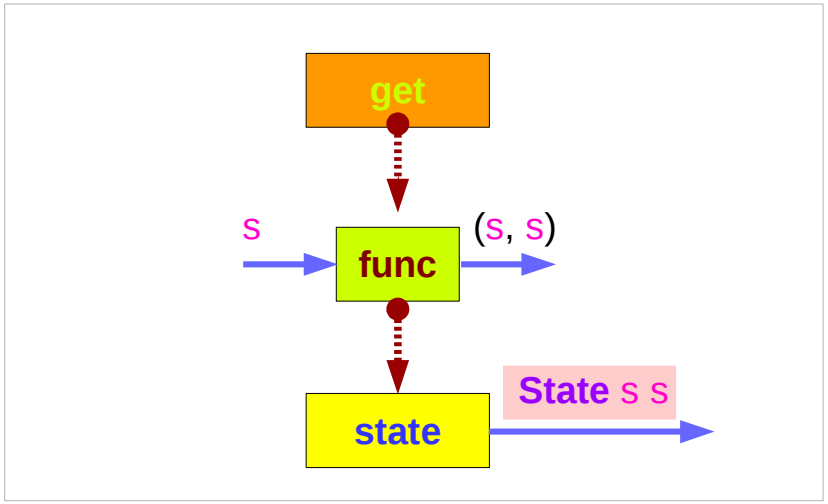


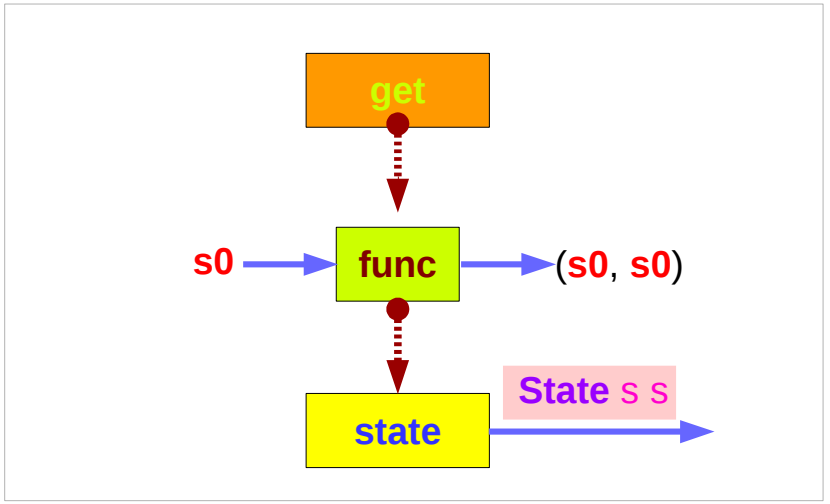
https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

Types and Values of **put** and **get**



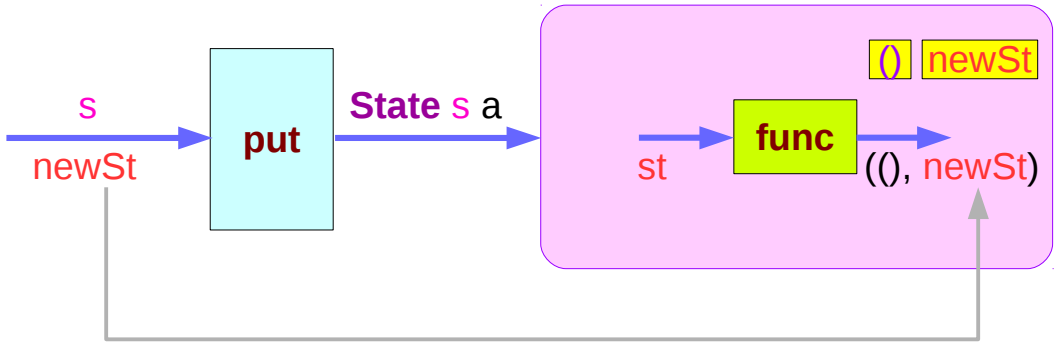




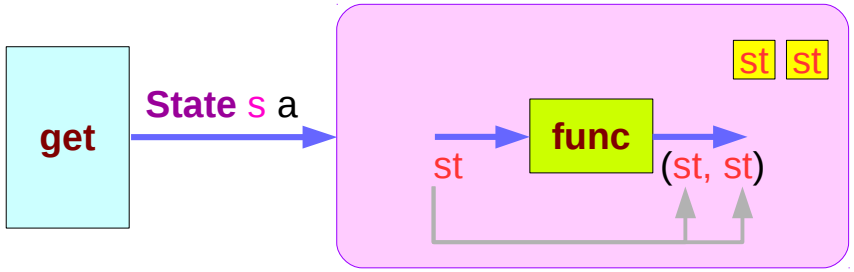


wrapped version of **put** and **get**

```
put :: s -> State s a
put s ::  State s a
put newSt = state $ \_ -> ((), newSt)
```



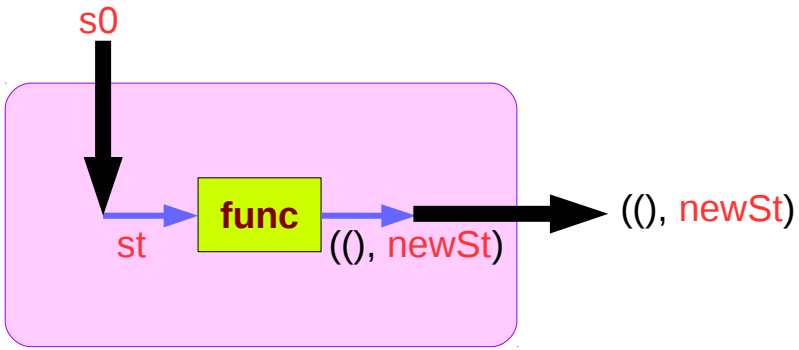

```
get :: State s s
get = state $ \s -> (s, s)
```



https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

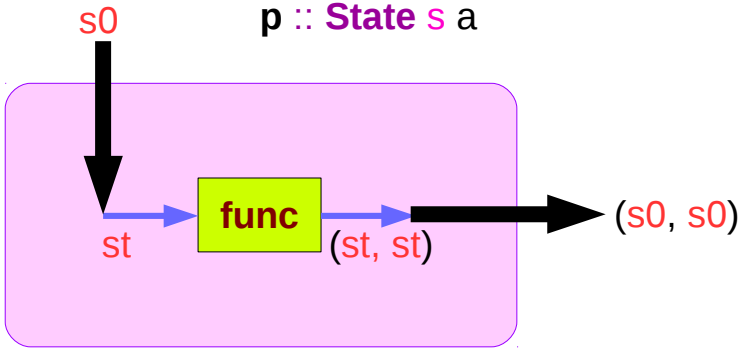
Executing the state processor

```
put :: s -> State s a
put newSt = state $  \_ -> ((), newSt)

runState (put newSt) s0  ➔  ((), newSt)
```



applying the function

```
get :: State s s
get = state $  \s -> (s, s)

runState (get) s0 ➔ (s0, s0)
```



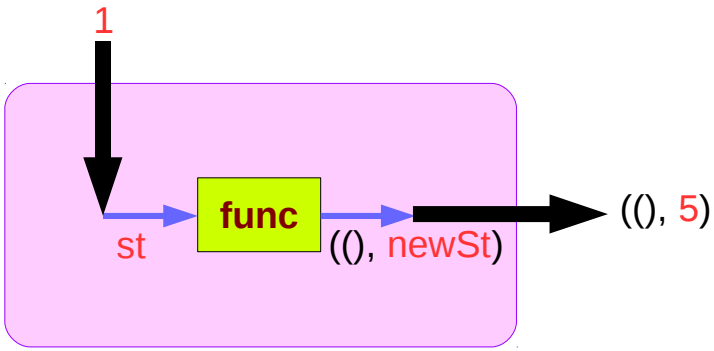
applying the function

https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

State Monad Examples – **put**

```
runState (put 5) 1

  ((),5)
```

put
set the result value to () and set the state value.



Comments:

```
put 5 :: State Int ()
runState (put 5) :: Int -> ((),Int)
initial state = 1 :: Int
final value = () :: ()
final state = 5 :: Int
```

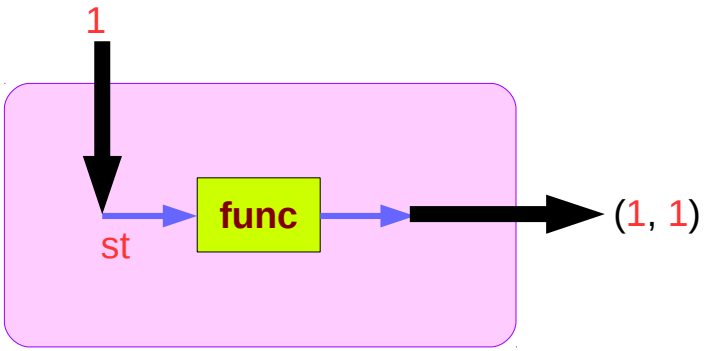
```
put :: s -> State s a
put newState = state $ \_ -> ((), newState)
```

https://wiki.haskell.org/State_Monad

State Monad Examples – **get**

```
runState get 1

  (1,1)
```

get
set the result value to the state and leave the state unchanged.



Comments:

```
get :: State Int Int
runState get :: Int -> (Int, Int)
initial state = 1 :: Int
final value = 1 :: Int
final state = 1 :: Int
```

```
get :: State s s
get = state $ \s -> (s, s)
```

https://wiki.haskell.org/State_Monad

Think an unwrapped state processor

```
(return 5)  ➔   1 -> (5,1)   -- a way of thinking
get         ➔   1 -> (1,1)   -- a way of thinking
(put 5)     ➔   1 -> ((),5)  -- a way of thinking
```

Think an **unwrapped** state processor

a value of type (**State** s a) is
a **function** from initial state s
to final value a and final state s: (a,s).

these are usually wrapped,
but shown here unwrapped for simplicity.

```
(return 5)  ➔   state( 1 -> (5,1) )   -- an actual way
get         ➔   state( 1 -> (1,1) )   -- an actual way
(put 5)     ➔   state( 1 -> ((),5) )  -- an actual way
```

wrapping the state processor

https://wiki.haskell.org/State_Monad

State Monad Examples – **return**, **get**, and **put**

Return leaves the state unchanged and sets the result:

-- ie: (**return** 5) ➔ 1 -> (5,1) -- a way of thinking

runState (**return** 5) 1 ➔ (5,1)

Get leaves state unchanged and sets the result to the state:

-- ie: **get** ➔ 1 -> (1,1) -- a way of thinking

runState get 1 ➔ (1,1)

Put sets the result to () and sets the state:

-- ie: (**put** 5) ➔ 1 -> ((),5) -- a way of thinking

runState (**put** 5) 1 ➔ ((),5)

https://wiki.haskell.org/State_Monad

State Monad Examples – **modify** and **gets**

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

gets :: (s -> a) -> State s a
gets f = do { x <- get; return (f x) }
```

```
runState (modify (+1)) 1                    (+1) 1 → 2 :: s
➔  ((),2)

runState (gets (+1)) 1                      (+1) 1 → 2 :: a
➔  (2,1)
```

```
evalState (gets (+1)) 1                     → :: s state
➔  2

execState (gets (+1)) 1                     → :: a result
➔  1
```

https://wiki.haskell.org/State_Monad

```
x <- get; put (f x)
x <- get; return (f x)
```

- inside a monad instance
- unwrapped implementations of **modify** and **gets**

Unwrapped Implementation – **return**, **get**, and **put**

Return leaves the state unchanged and sets the result:

-- ie: (**return** 5) ➔ 1 -> (5,1) -- a way of thinking

return :: a -> **State** s a

return x s = (x,s)

Get leaves state unchanged and sets the result to the state:

-- ie: **get** ➔ 1 -> (1,1) -- a way of thinking

get :: **State** s s

get s = (s,s)

Put sets the result to () and sets the state:

-- ie: (**put** 5) ➔ 1 -> ((),5) -- a way of thinking

put :: s -> **State** s ()

put x s = ((),x)

https://wiki.haskell.org/State_Monad

(x,s)

(s,s)

((),x)

- inside a monad instance
- unwrapped implementations of **return**, **get**, and **put**

Default Implementations

```
class Monad m => MonadState s m | m -> s where
  -- | Return the state from the internals of the monad.
  get :: m s
  get = state (\s -> (s, s))

  -- | Replace the state inside the monad.
  put :: s -> m ()
  put s = state (\_ -> ((), s))
```

```
  -- | Embed a simple state action into the monad.
  state :: (s -> (a, s)) -> m a
  state f = do
    s <- get
    let ~(a, s') = f s
    put s'
    return a
```

https://stackoverflow.com/questions/23149318/get-put-and-state-in-monadstate

No dead loop

the definitions of **get**, **put**,**state** in the **Monad class declaration**

- the default implementations,
- to be overridden in actual **instances** of the class.

the dead loop in the default definition does not happen:

- **put** and **get** in terms of **state**
- **state** in terms of **put** and **get**

* minimal definition is *either* both of get and put *or* just state

```
get :: m s
get = state (\s -> (s, s))

put :: s -> m ()
put s = state (\_ -> ((), s))
```

```
state :: (s -> (a, s)) -> m a
state f = do
  s <- get
  let ~(a, s') = f s
  put s'
  return a
```

https://stackoverflow.com/questions/23149318/get-put-and-state-in-monadstate

Functional Dependency |

```
class Monad m => MonadState s m | m -> s where …
```

functional dependencies

to constrain the parameters of type classes.

in a multi-parameter type class,

one of the parameters can be determined from the others,

so that the parameter determined by the others can be the return type

but none of the argument types of some of the methods.

s can be determined from **m**,

so that **s** can be the return type — **m** → **s**

but **m** can not be the return type — **State s** → **s**

```
class Monad m where
  return :: a -> m a
  (>>=) :: m a -> (a -> m b) -> m b
  (>>) :: m a -> m b -> m b
  fail :: String -> m a
```

m a

- **Maybe a**
- **IO a**
- **ST a**
- **State s a**

https://stackoverflow.com/questions/23149318/get-put-and-state-in-monadstate

Typeclass Constrain MonadState s m

```
class Monad m => MonadState s m | m -> s where …
```

```
get :: MonadState s m => m s
put :: MonadState s m => s -> m ()
```

MonadState s m is a typeclass constraint, not a type.

the more concrete (less-overloaded) version of State

```
get :: State s s
put :: s -> State s ()
```

:t get

:t put

s ← m functional dependencies

m ➡ State s

https://stackoverflow.com/questions/25438575/states-put-and-get-functions

Typeclass Constrain MonadState s m (1)

```
class Monad m => MonadState s m | m -> s where …
```

```
get :: MonadState s m => m s
```

for some monad **m**

storing some state of type **s**,

get is an action in **m**

that returns a value of type **s**.

https://stackoverflow.com/questions/25438575/states-put-and-get-functions

Typeclass Constrain MonadState s m (2)

```
class Monad m => MonadState s m | m -> s where …
```

```
put :: MonadState s m => s -> m ()
```

for some monad **m**

put is an action in **m**

storing the given state of type **s**,

but returns nothing **()**.

https://stackoverflow.com/questions/25438575/states-put-and-get-functions

Counter using **State** Monad

execState get 0 ➡ 0

set the value of the counter using put:
execState (put 1) 0 ➡ 1

set the state multiple times:
execState (do put 1; put 2) 0 ➡ 2

modify the state based on its current value:
execState (do x <- get; put (x + 1)) 0 ➡ 1

execState (do modify (+ 1)) 0 ➡ 1
execState (do modify (+ 2); modify (* 5)) 0 ➡ 10

https://stackoverflow.com/questions/25438575/states-put-and-get-functions

Default Implementations

MonadState is the class of types that are monads with state.

State is an instance of that class:

```
instance MonadState s (State s) where
  get = Control.Monad.Trans.State.get
  put = Control.Monad.Trans.State.put
```

So are StateT (the state monad transformer,
which adds state to another monad) and various others.

This overloading was introduced so that
if you're using a stack of monad transformers,
you don't need to explicitly lift operations
between different transformers.
If you're not doing that,
you can use the simpler operations from transformers.

https://stackoverflow.com/questions/25438575/states-put-and-get-functions

The Result of a Stateful Computation

a **stateful computation** is a **function** that

takes some **state** and

returns a **value** along with some **new state**.

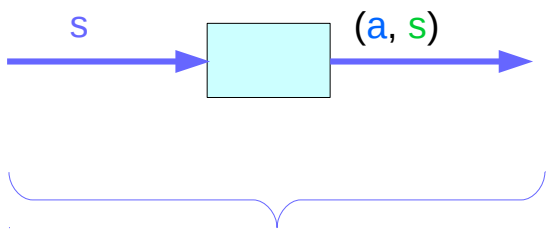
That function would have the following type:

```
s -> (a,s)
```

s is the type of the **state** and

a the **result** of the **stateful computation**.

```
s -> (a, s)
```



a function is an executable data

when executed, a result is produced

action, execution, result

```
s -> (a, s)
```

http://learnyouahaskell.com/for-a-few-monads-more

Stateful Computations Inside the State Monad

inside a monad,
when **sc** is a **s**tateful **c**omputation
then the result of the stateful computation **sc**
can be assigned to x

x <- sc

sc :: State s a

x :: a (the execution result of **sc**)

s -> (a, s)

the result type

https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

get inside the State Monad

inside the **State** monad,

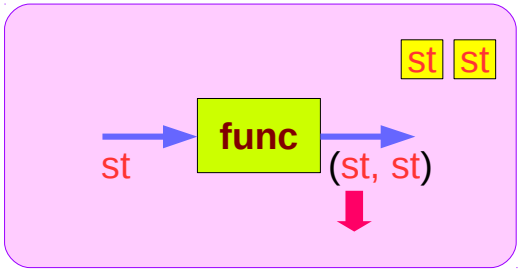
get returns the current monad instance
whose type is **State** s a

x <- **get**

the stateful computation is performed
over the current monad instance returned by **get**

the result of the stateful computation is st::s
thus x will get the st

x :: a the execution result of **get**



https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Getting the current state inside the State Monad

inside the **State** monad,

get returns the current monad instance
whose type is **State** s a

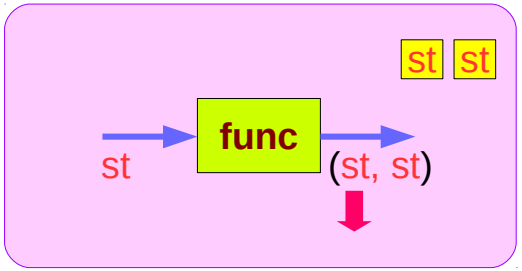
to get the current state st, do

```
s <- get
```

s will have the value of the current state st

this is like **evalState** is called with the current monad instance

- **get**
- **current monad instance**
- **stateful computation**
- **result :: s**



https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

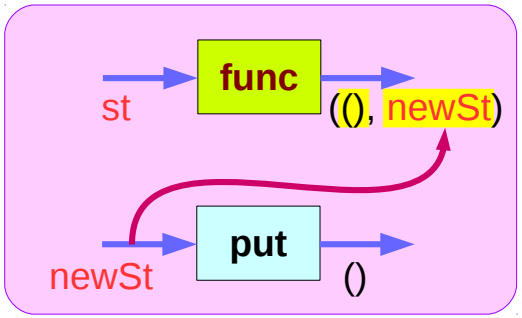
put and get inside State Monad

```
put :: s -> State s a
put newSt = state $ \_ -> ((), newSt)
```

put :: s -> ()

the result type :: ()

stateful computation of **put**

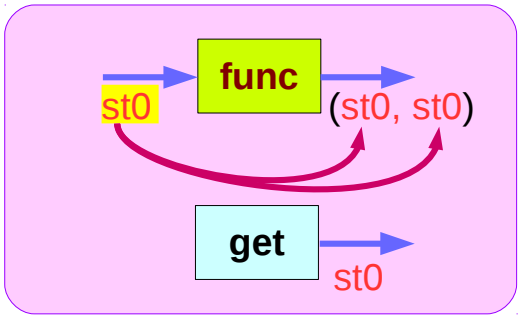



```
get :: State s s
get = state $ \s -> (s, s)
```

get :: s

the result type :: s

stateful computation of **get**



https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

Inside Functions and runState Functions

Most monads are equipped with some "*run*" functions
such as **runState**, **execState**, and so forth.

But, frequent calling such functions inside the monad
shows that the functionality of the monad does not fully exploited

```
s0 <- get
let (a,s1) = runState p s0
put s1
```

-- read the state of the current instance
-- pass the state to **p**, get new state
-- save new state

```
a <- p
```

-- the stateful computation **p** updates the state to s1
-- the result of the state returned is assigned to a

```
let p = state (\y -> (y, y+1))
```

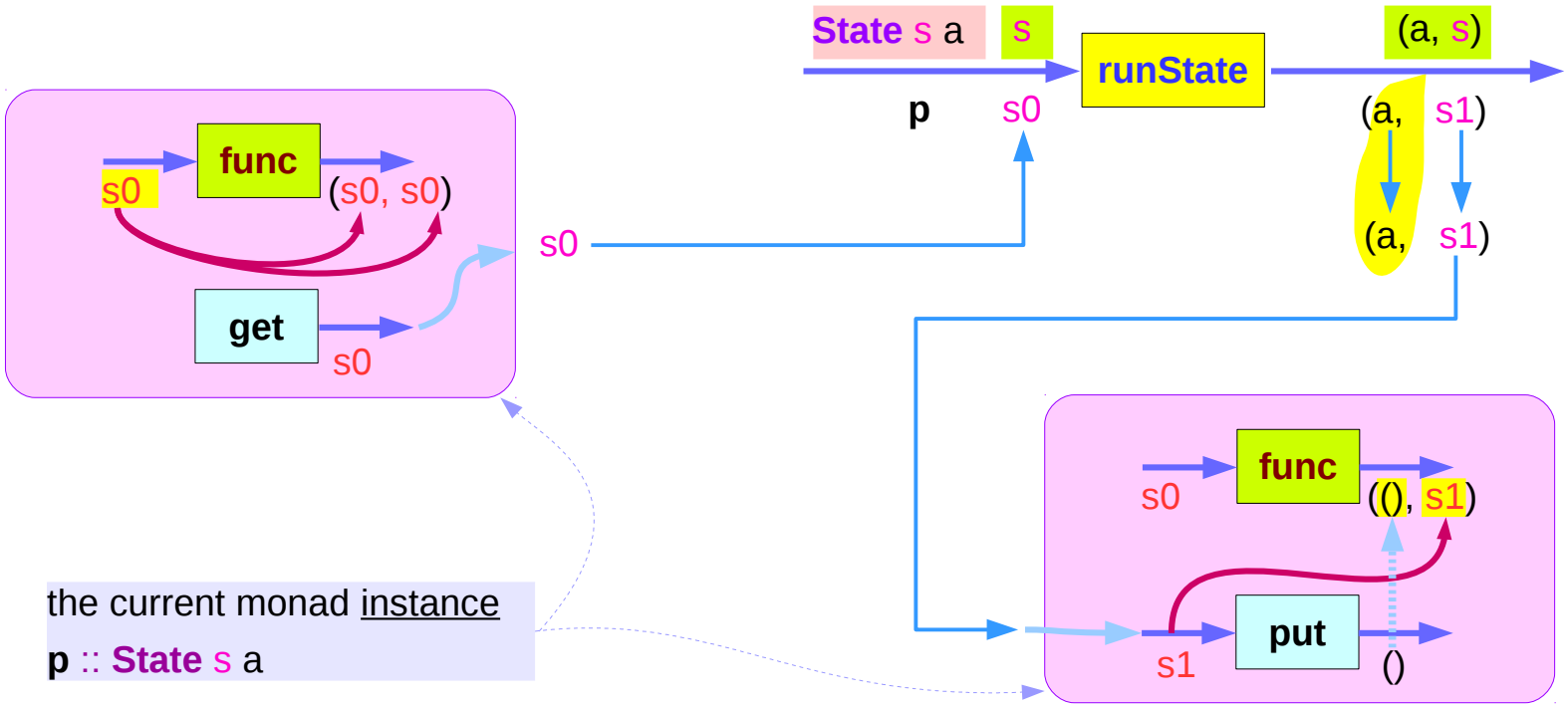
https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Redundant computation examples (1)

```
s0 <- get
let (a,s1) = runState p s0
put s1
```

the same binding variable a
the same state s1

```
a <- p
```



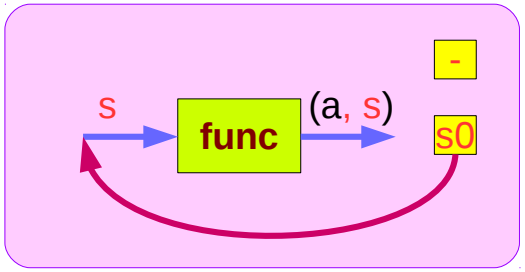
https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Redundant computation examples (2)

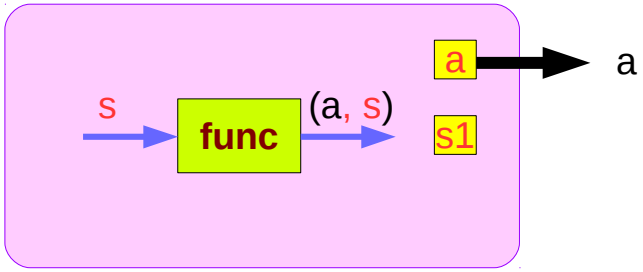
```
a <- p
```

-- the stateful computation **p** updates the state to s1
-- the result of the state returned is assigned to a

p :: **State** s a



stateful computation **p**



return the result a

https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Example of collecting returned values (1)

Inferred Function Type

```
collectUntil :: Monad State t m => (t -> Bool) -> m a -> m [a]
```

m ➜ State t

Specific Function Type

```
collectUntil :: (t -> Bool) -> State t a -> State t [a]
```

https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

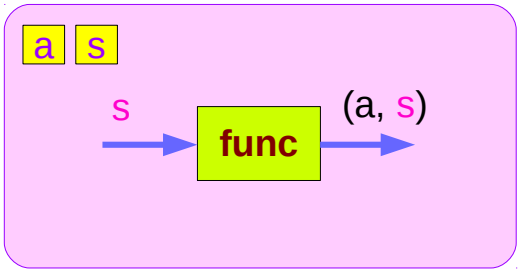
Example of collecting returned values (2)

```
collectUntil f comp = do
   st <- get                    -- Get the current state
   if f st then return [ ]      -- If it satisfies predicate, return
        else do                 -- Otherwise...
           x  <- comp           -- Perform the computation s
           xs <- collectUntil f comp   -- Perform the rest of the computation
           return (x:xs)        -- Collect the results and return them
```

```
comp :: State s a
st  :: s
x  :: a
xs  :: [a]
```

```
simpleState = state (\x -> (x,x+1))
```

```
simpleState :: State s a
```




```
*Main> evalState (collectUntil (>10) simpleState) 0
[0,1,2,3,4,5,6,7,8,9,10]
```

https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Example of collecting returned values (3)

```
collectUntil f comp = do
   st <- get
   if f st then return [ ]
        else do
           x  <- comp   -- stateful computation
           xs <- collectUntil f comp
           return (x:xs)
```

```
simpleState = state (\x -> (x,x+1))
```

```
get  st←0   comp :   0 → (0, 1)   x←0
get  st←1   comp :   1 → (1, 2)   x←1
get  st←2   comp :   2 → (2, 3)   x←2
get  st←3   comp :   3 → (3, 4)   x←3
get  st←4   comp :   4 → (4, 5)   x←4
get  st←5   comp :   5 → (5, 6)   x←5
get  st←6   comp :   6 → (6, 7)   x←6
get  st←7   comp :   7 → (7, 8)   x←7
get  st←8   comp :   8 → (8, 9)   x←8
get  st←9   comp :   9 → (9, 10)  x←9
get  st←10  comp :  10 → (10, 11) x←10
```

```
*Main> evalState (collectUntil (>10) simpleState) 0
[0,1,2,3,4,5,6,7,8,9,10]
```

https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Example of collecting returned values (5)

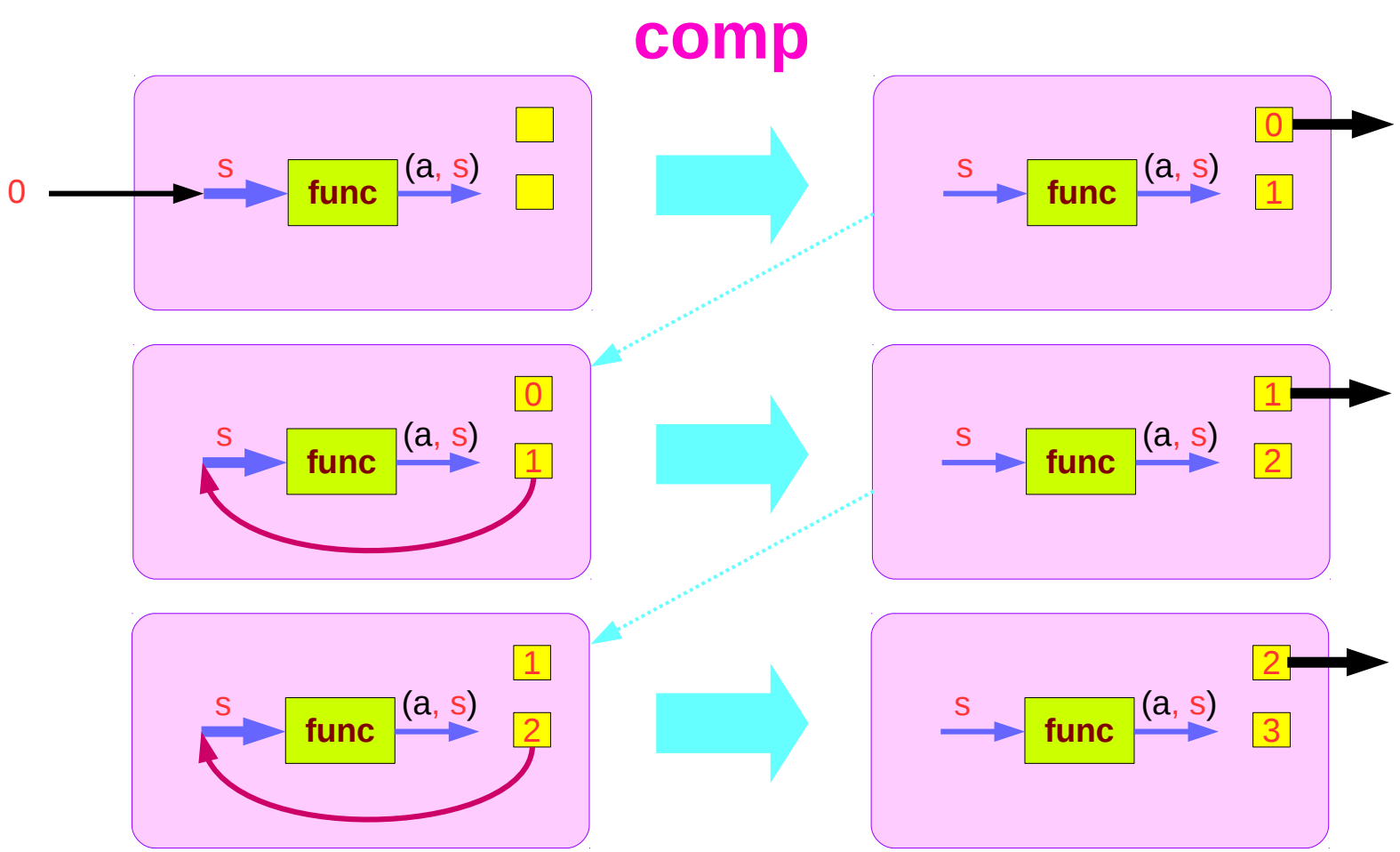
```
collectUntil f comp = do
   st <- get
   if f st then return [ ]       ---------------------------------- return State t [a] type
        else do
           x  <- comp   -- stateful computation
           xs <- collectUntil f comp
           return (x:xs)       ---------------------------------- return State t [a] type
```

nesting do statements is possible
if they are within the same monad

enables **branching** within one do block,
as long as both branches of the **if statement**
results in the same monadic type.

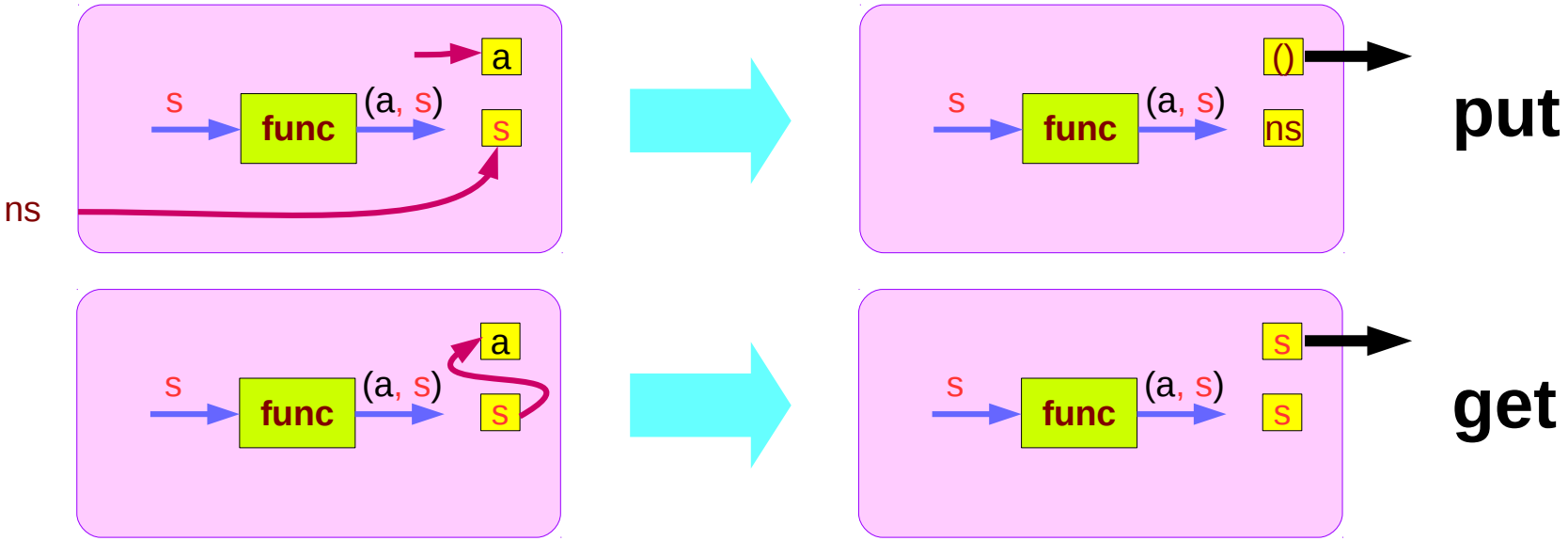
https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Stateful Computation of comp



https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Stateful Computations of **put** & **get**



https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Another example of collecting returned values (1)

```
collectUntil :: (s -> Bool) -> State s a -> State s [a]
collectUntil f s = step
  where
    step = do a <- s
              liftM (a : ) continue
    continue = do s' <- get
                  if f s' then return [] else step
```

```
simpleState = state (\x -> (x,x+1))

*Main> evalState (collectUntil (>10) simpleState) 0
[0,1,2,3,4,5,6,7,8,9,10]
```

https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

Another example of collecting returned values (2)

```
collectUntil :: (s -> Bool) -> State s a -> State s [a]
collectUntil f s = step
  where
    step = do a <- s
              liftM (a : ) continue
    continue = do s' <- get
                  if f s' then return [] else step
```

Since a is part of the result
in both branches of the 'if'

```
collectUntil f comp = do
    st <- get
    if f st then return [ ]
            else do
                x  <- comp   -- stateful computation
                xs <- collectUntil f comp
                return (x:xs)
```

https://stackoverflow.com/questions/11250328/working-with-the-state-monad-in-haskell

liftM and mapM

liftM :: (**Monad m**) => (a -> b) -> **m** a -> **m** b
mapM :: (**Monad m**) => (a -> **m** b) -> [a] -> **m** [b]

liftM lifts a function of type a -> b to a monadic counterpart.
mapM applies a function which yields a monadic value to a list of values,
yielding list of results embedded in the monad.

> **liftM** (**map toUpper**) **getLine**
Hallo
"HALLO"

> :t **mapM** return "monad"
mapM return "monad" :: (**Monad** m) => m [Char]

https://stackoverflow.com/questions/5856709/what-is-the-difference-between-liftm-and-mapm-in-haskell

References

[1] ftp://ftp.geoinfo.tuwien.ac.at/navratil/HaskellTutorial.pdf
[2] https://www.umiacs.umd.edu/~hal/docs/daume02yaht.pdf