Monads and State machines

Functional Programming and Intelligent Algorithms

Prof Hans Georg Schaathun

Høgskolen i Ålesund

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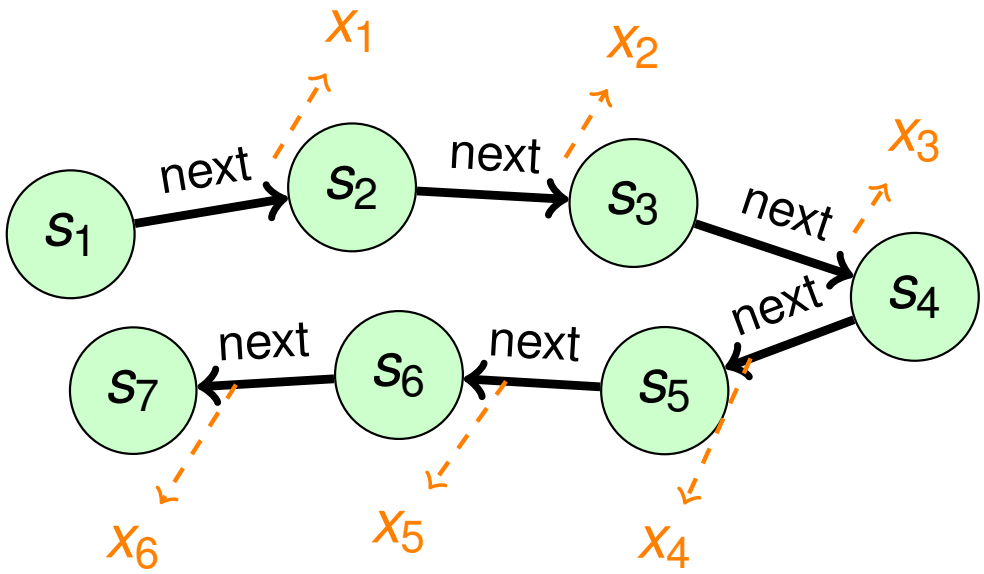
The state machine



- `next :: State -> (State,Int)`
- Lehmer:
```
next s = (s',s')
    where s' = (a + x*s) `mod` m
```
- Cipher: `next s = (s + 1 `mod` m, encrypt k s)`

State machines in functional programming

What is special about state in functional programming?

State machines in functional programming

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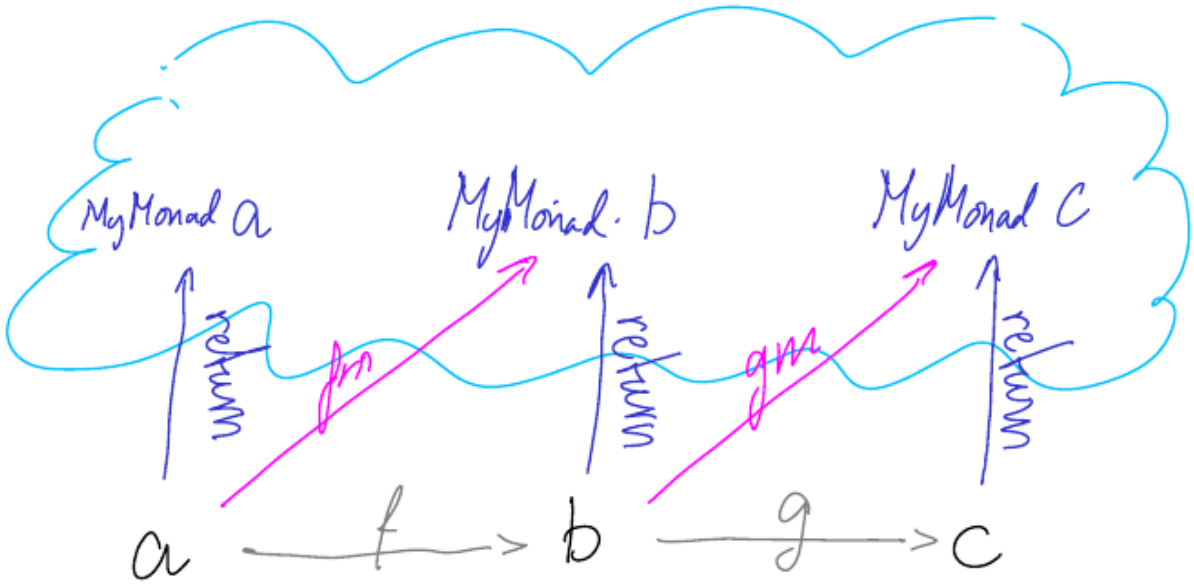
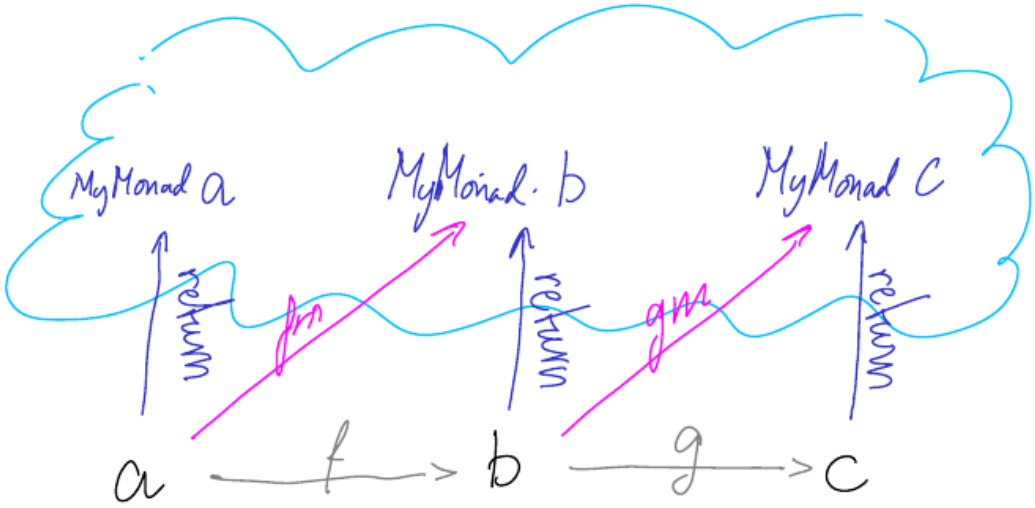
Haskell uses monads

Hiding in the Clouds



Monadic and non-monadic functions



Pure functions	`f :: a -> b`
	`g :: b -> c`
Monadic functions	`fm :: a -> MyMonad b`
	`gm :: b -> MyMonad c`
Return	`return :: x -> MyMonad x`

Function composition

Pure functions	
1. $h = f \circ g$ 2. $h(x) = f(g(x))$	
Or in Haskell	
1. `h = f . g` 2. `h x = f $ g x`	

Function composition

Pure functions	Monads (Binding operations)
1. $h = f \circ g$ 2. $h(x) = f(g(x))$	1. `fm :: a -> MyMonad b` 2. `gm :: b -> MyMonad c` 3. `hm = fm >>= gm` 4. `hm :: a -> MyMonad c`
Or in Haskell	
1. `h = f . g` 2. `h x = f $ g x`	

Function composition

Pure functions	Monads (Binding operations)
1. $h = f \circ g$ 2. $h(x) = f(g(x))$	1. `fm :: a -> MyMonad b` 2. `gm :: b -> MyMonad c` 3. `hm = fm >>= gm` 4. `hm :: a -> MyMonad c`
Or in Haskell	**Equivalently**
1. `h = f . g` 2. `h x = f $ g x`	1. `hm x = do` 1.1 `y <- fm x` 1.2 `gm y`

Mixing pure and monadic functions

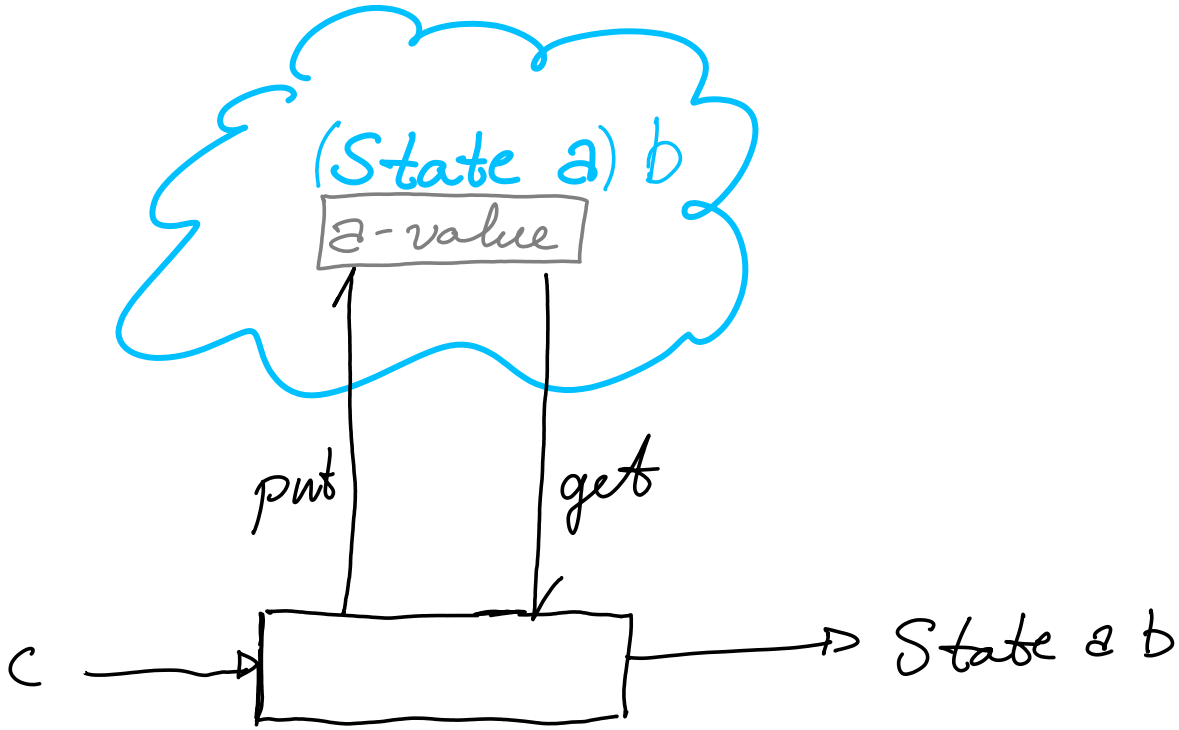
```
hm x = do
     y <- fm x
     let z = g y
     return z
```

Mixing pure and monadic functions

```
hm x = do
     y <- fm x
     let z = g y
     return z
```

`fx :: MyMonad a -> b` *is impossible*

The State Monad



A State Machine for Random Numbers

```
1. import Data.Word32
2. getRandom ::  State TFGen Word32
3. getRandom = do
   3.1 s <- get
   3.2 let (r,s') = next s
   3.3 put s'
   3.4 return r
```

Running the state machine

1. `f :: IO State TFGen a`
2. `g :: TFGen`
3. `runState f g :: (a,TFGen)`

Summary

— The State monad enables a PRNG state
  - without explicitly passing the state in and out of every function

— To use it, functions must be monadic
  - just like IO

— Compose stateful actions using `do`
  - or, if you prefer, `>>=` and `>>`