State Monad – Examples (6C)

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

Game Example (1)

Passes a string of dictionary **{a,b,c}**

Game is to produce a number from the string.

By default the game is off,

a '**c**' toggles the game on and off.

a '**a**' gives +1 and

a '**b**' gives -1.

'ab' = 0 +1-1=0

'ca' = 1 on, +1

'cabca' = 0 on,+1-1,off

State = (game is on/off, current score) = (Bool, Int)

Example use of **State** monad

https://wiki.haskell.org/State_Monad

Game Example (2)

```
module StateGame where
import Control.Monad.State

type GameValue = Int
type GameState = (Bool, Int)

playGame :: String -> State GameState GameValue
playGame [] = do
   (_, score) <- get
   return score
```

State s a

when input string is null

https://wiki.haskell.org/State_Monad

Game Example (3)

```
playGame :: String -> State GameState GameValue
playGame (x : xs) = do
   (on, score) <- get
   case x of
      'a' | on -> put (on, score + 1)
      'b' | on -> put (on, score - 1)
      'c'      -> put (not on, score)
      _        -> put (on, score)
   playGame xs

startState = (False, 0)
```

when input string is not null

https://wiki.haskell.org/State_Monad

Game Example (4)

main = **print** $ **evalState** (**playGame** "abcaaacbbcabbab") **startState**

a	(off, 0)	➡	b	(off, 0)	➡	c	(on, 0)	➡
a	(on, 1)	➡	a	(on, 2)	➡	a	(on, 3)	➡
c	(off, 3)	➡	b	(off, 3)	➡	b	(off, 3)	➡
c	(on, 3)	➡	a	(on, 4)	➡	b	(on, 3)	➡
b	(on, 2)	➡	a	(on, 3)	➡	b	(on, 2)	

https://wiki.haskell.org/State_Monad

Game Example Source Code

```
import Control.Monad.State

type GameValue = Int
type GameState = (Bool, Int)

playGame :: String -> State GameState GameValue
playGame [] = do
    (_, score) <- get
    return score
```

```
playGame (x : xs) = do
    (on, score) <- get
    case x of
        'a' | on -> put (on, score + 1)
        'b' | on -> put (on, score - 1)
        'c'      -> put (not on, score)
        _        -> put (on, score)
    case x of
        'a' | on -> return $ score + 1
        'b' | on -> return $ score - 1
        'c'      -> return $ score
        _        -> return score
    playGame xs

startState = (False, 0::Int)
```

```
*Main> runState (playGame "abcaaacbbcabbab") startState
(2,(True,2))
*Main> execState (playGame "abcaaacbbcabbab") startState
(True,2)
*Main> evalState (playGame "abcaaacbbcabbab") startState
2
```

https://wiki.haskell.org/State_Monad

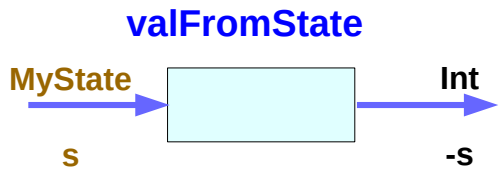
Incrementer Example (1)

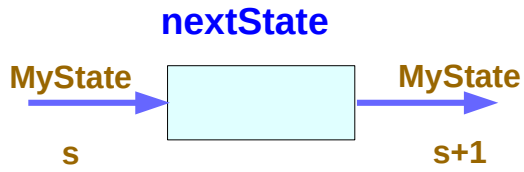
```
-- a concrete and simple example of using the State monad
-- non monadic version of a very simple state example
-- the State is an integer.
-- the value will always be the negative of of the state

import Control.Monad.State

type MyState = Int
type MyStateMonad  = State MyState
```

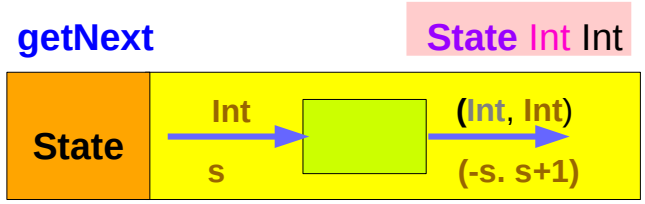
https://wiki.haskell.org/State_Monad

Incrementer Example (2)

```
valFromState :: MyState -> Int
valFromState s = -s

nextState :: MyState->MyState
nextState x = 1+x

-- this is it, the State transformation.
-- add 1 to the state, return -1*the state as the computed value.

getNext ::   MyStateMonad  Int
getNext  = state  (\st -> let st' = nextState(st) in (valFromState(st'),st') )
```







https://wiki.haskell.org/State_Monad

Incrementer Example – (a) inc3

```
-- advance the state three times.
inc3::MyStateMonad Int
inc3 =  getNext >>= \x ->
        getNext >>= \y ->
        getNext >>= \z ->
        return z
```

https://wiki.haskell.org/State_Monad

Incrementer Example – (b) inc3Sugard

```
-- advance the state three times with do sugar
inc3Sugared::MyStateMonad Int
inc3Sugared = do  x <- getNext
                  y <- getNext
                  z <- getNext
                  return z
```

https://wiki.haskell.org/State_Monad

Incrementer Example – (c) inc3DiscardedValues

```
-- advance the state three times without inspecting computed values
inc3DiscardedValues::MyStateMonad Int
inc3DiscardedValues =    getNext >> getNext >> getNext
```

https://wiki.haskell.org/State_Monad

Incrementer Example – (d) inc3DiscardedValuesSugared

```
-- advance the state three times
-- without inspecting computed values with do sugar
inc3DiscardedValuesSugared::MyStateMonad Int
inc3DiscardedValuesSugared =    do
                        getNext
                        getNext
                        getNext
```

https://wiki.haskell.org/State_Monad

Incrementer Example – (e) inc3AlternateResult

```
-- advance state 3 times, compute the square of the state
inc3AlternateResult::MyStateMonad Int
inc3AlternateResult = do  getNext
                          getNext
                          getNext
                          s <- get
                          return (s*s)
```

https://wiki.haskell.org/State_Monad

Incrementer Example – (f) inc4

```
-- advance state 3 times, ignoring computed value, and then once more
inc4::MyStateMonad Int
inc4 = do
        inc3AlternateResult
        getNext
```

https://wiki.haskell.org/State_Monad

Incrementer Example – (g) main

```
main =
    do
        print (evalState inc3 0)                          -- -3
        print (evalState inc3Sugared 0)                   -- -3
        print (evalState inc3DiscardedValues 0)           -- -3
        print (evalState inc3DiscardedValuesSugared 0)    -- -3
        print (evalState inc3AlternateResult 0)           -- 9
        print (evalState inc4 0)                          -- -4
```

https://wiki.haskell.org/State_Monad

randomR type signature

```
import System.Random

randomR :: (Random a, RandomGen g) => (a, a) -> g -> (a, g)
```

(a, a) : **range**

(a, g) : **output**

R in **randomR**

a : type of a **random number**

g : type of a **seed**

g : **input seed**

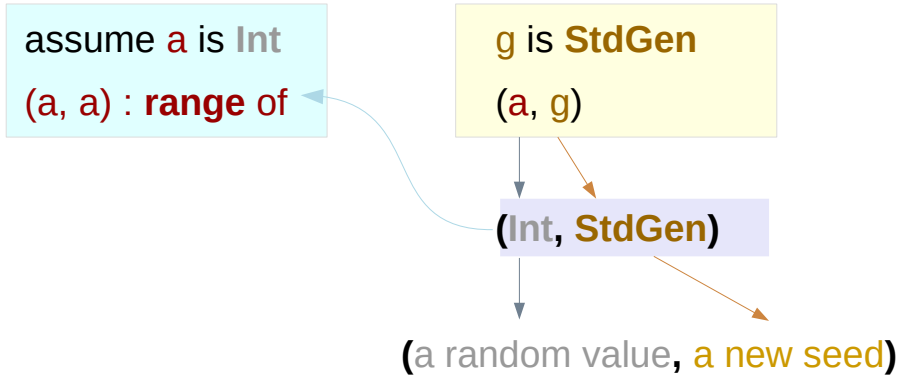
cabal update

cabal install random

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

randomR type signature example

```
import System.Random

randomR :: (Random a, RandomGen g) => (a, a) -> g -> (a, g)
randomR (1, 6) :: StdGen -> (Int, StdGen)
```



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

randomR – updating a seed

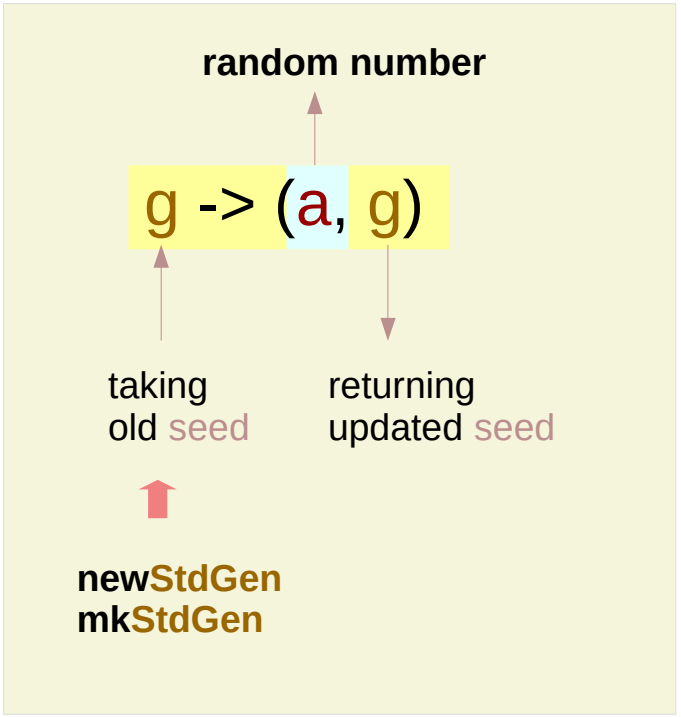
```
randomR :: (Random a, RandomGen g) => (a, a) -> g -> (a, g)
```

randomR updates (generates) a seed

newStdGen or mkStdGen can used
to generate an initial input seed

the type of seed is StdGen

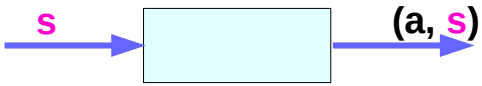
the StdGen type :
an instance of RandomGen and Random



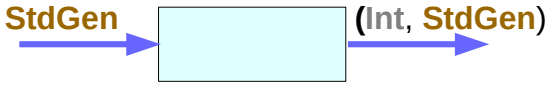
https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

randomR – a state processing function

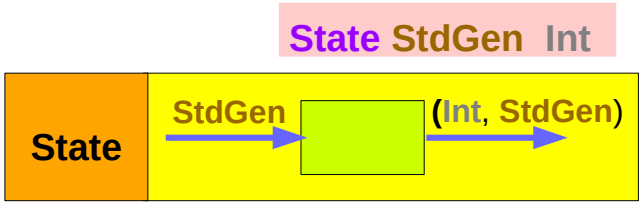
```
import System.Random

randomR (1, 6) :: StdGen -> (Int, StdGen)

randomR a state processing function

rollDie :: State StdGen Int
rollDie = state $ randomR (1, 6)
```



itself a stateful computation



randomR (1, 6)

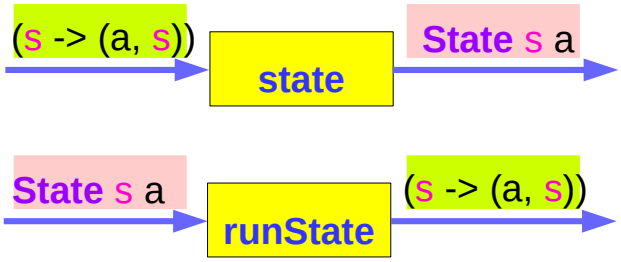


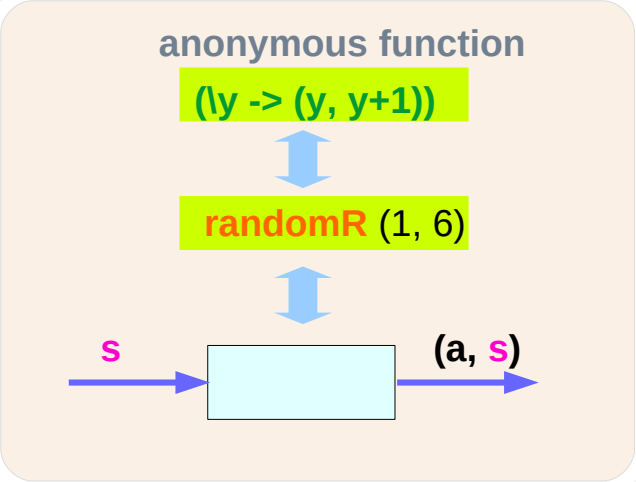
https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

randomR – runState, state

```
newtype State s a = State { runState :: s -> (a, s) }      (1)
newtype State s a = state { runState :: s -> (a, s) }      (2)

1) let stst = State { runState = (\y -> (y, y+1))  }
2) let stst = state (\y -> (y, y+1))

runState stst                (\y -> (y, y+1))  -- no instance error
runState stst   1            (1, 2)
```

```
rollDie :: State StdGen Int
rollDie = state $ randomR (1, 6)

runState rollDie                    StdGen -> (Int, StdGen)
runState rollDie (mkStdGen 1)       (6,80028 40692)
```





a = Int, s = StdGen

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

randomRIO

Otherwise, you can use **randomRIO**

to get a random number directly in the **IO** monad,

Without explicitly using a seed of type **StdGen**

```
import System.Random
randomRIO (1, 10)
6
```

```
randomR :: (Random a, RandomGen g) => (a, a) -> g -> (a, g)
randomRIO :: (a, a) -> IO a
randomIO :: IO a
```

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

Methods of the **random** class

```
randomR    :: RandomGen g => (a, a) -> g -> (a, g)
random     :: RandomGen g => g -> (a, g)
randomRs   :: RandomGen g => (a, a) -> g -> [a]
randoms    :: RandomGen g => g -> [a]
randomRIO  :: (a, a) -> IO a
randomIO   :: IO a
```

```
randomR :: (Random a, RandomGen g) => (a, a) -> g -> (a, g)
randomRIO :: (a, a) -> IO a
randomIO :: IO a
```

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

Making a new seed

mkStdGen :: Int -> StdGen

an alternative way of producing an **initial generator**,
by mapping an **Int** into a **generator**.
distinct **Int** arguments should be likely
to produce distinct **generators**.

newStdGen :: IO StdGen

Applies split to the current **global random generator**,
updates it with one of the results, and returns the other.

mkStdGen 11

12 1

newStdGen

420454863 2147483398 actual seed

mkStdGen 11

12 1

mkStdGen 12

13 1

mkStdGen 132

133 1

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

StdGen Type

```
data StdGen  = StdGen !Int32 !Int32        -- 2 32-bit integers

show :: a -> String
Read :: String -> a
```

show converts a data value of two 32-bit number into a string

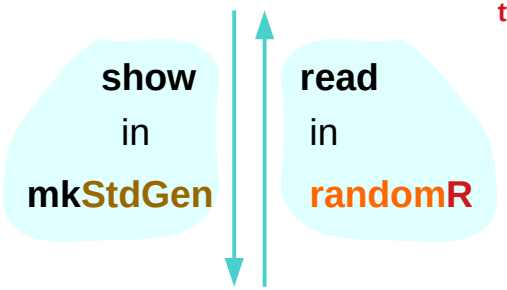
read converts a string into a data value of two 32-bit number

```
read (show g) == g                         -- a constraint

g :: StdGen                                -- a seed
```

! -- a strict declaration

420454863 2147483398 an actual seed

two 32-bit Int's



12 1 a string

reads may be used to map an arbitrary **string**
(not necessarily one produced by show) onto a **value** of type **StdGen**.

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

Generating a random number (1)

to generate a random number with a seed
type **StdGen** must be used,
randomR is used to generate a number
newStdGen is used to create a new seed
(this will have to be done in **IO**).

```
import System.Random
g = newStdGen
randomR (1, 10) g
```
➡ (1,1012529354 2147442707)

A seed of the type **StdGen**
A new seed is generated
by **newStdGen**

The result of **randomR** is a tuple
(a random value, the new seed**)**

a random value = 1
the new seed =
1012529354 2147442707

```
randomR :: (Random a, RandomGen g) => (a, a) -> g -> (a, g)
```

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

Generating a random number (2)

```
g = mkStdGen 58
(x1, y1) =randomR (0,100) g
```

x1 ➡ 62
y1 ➡ 2360826 40692
g ➡ 59 1

randomR (0,100) g ➡ (62,2360826 40692)
(x1, y1) ➡ (62,2360826 40692)
x1 ➡ 62
y1 ➡ 2360826 40692

A seed of the type **StdGen**

A new seed is generated

by **newStdGen**

The result of **randomR** is a tuple

(a random value, the new seed**)**

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

Generating a random number (3)

```
randomRIO (1, 6::Int)   ➡  4
randomRIO (1, 6::Int)   ➡  2

randomIO :: IO Float    ➡  0.24931645
randomIO :: IO Float    ➡  0.1068542
```

```
s1 = mkStdGen 55
(i1, s2) = randomR (1,6::Int) s1
(i2,  _) = randomR (1,6::Int) s2

i1   ➡   6
I2   ➡   1

s1 = mkStdGen 55        -- same seed
(i1, s2) = randomR (1,6::Int) s1
(i2,  _) = randomR (1,6::Int) s2

i1   ➡   6
i2   ➡   1
```

https://lotz84.github.io/haskellbyexample/ex/random-numbers

Dice Example – State

The result type : **Int** dice : a number between 1 and 6

The state type : a pseudo-random generator of type **StdGen**

the type of the **state processors** will be

State StdGen Int

StdGen -> (Int, StdGen)

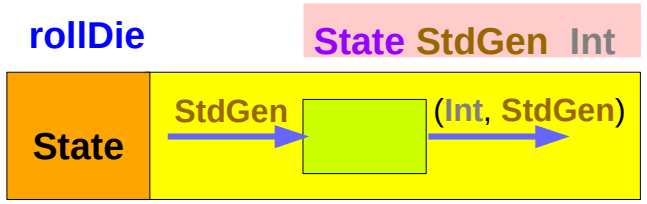
State s a

s -> (a, s)

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

rollDie

```
import Control.Monad.Trans.State
import System.Random

randomR :: (Random a, RandomGen g) => (a, a) -> g -> (a, g)
randomR (1, 6) :: StdGen -> (Int, StdGen)


rollDie :: State StdGen Int
rollDie = state $ randomR (1, 6)
```

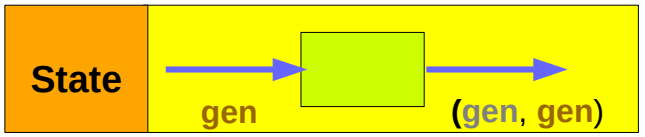


https://en.wikibooks.org/wiki/Haskell/Understanding_monads/State

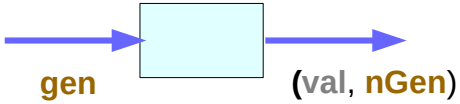
rollDie with get, put, return

```
rollDie :: State StdGen Int
rollDie = state $ randomR (1, 6)

rollDie :: State StdGen Int
rollDie = do
        gen <- get
        let (val, nGen) = randomR (1,6) gen
        put nGen
        return value

GHCi> evalState rollDie (mkStdGen 0)
6
```

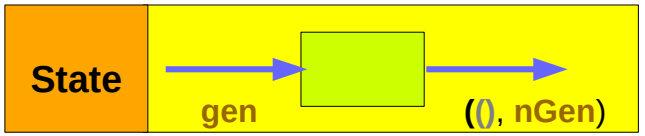
gen <- get



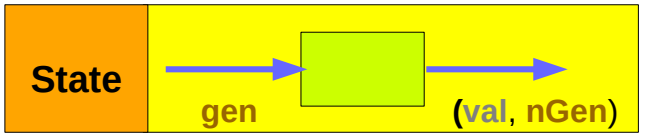
let (val, nGen) = randomR (1,6) gen



put nGen



return value



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

rollDice (1)

```
rollDice :: State StdGen (Int, Int)
rollDice = liftA2 (,) rollDie rollDie

GHCi> evalState rollDice (mkStdGen 123)
 (6,1)
```

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

rollDice (2)

```
rollDice :: State StdGen (Int, Int)
rollDice = liftA2 (,) rollDie rollDie
```

That function rolls two dice.

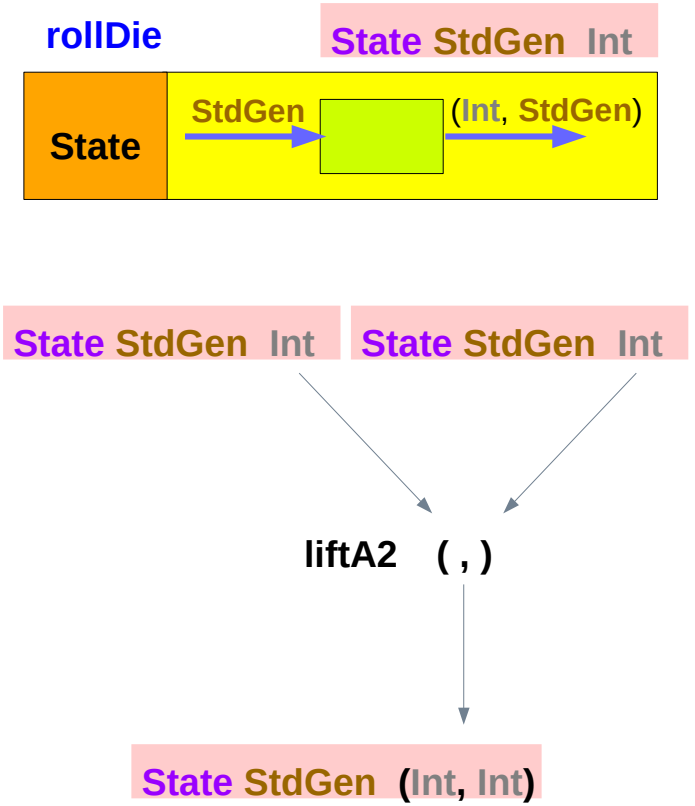
Here, **liftA2** is used to make the two-argument function **(,)** work within a monad or applicative functor, in this case **IO**.

It can be easily defined in terms of **(<*>)**:

```
liftA2 f u v = f <$> u <*> v
```

As for (,), it is the non-infix version of the tuple constructor.

That being so, the two die rolls will be returned as a tuple in **I**



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

Removing IO

```
randomR (1, 6) :: StdGen -> (Int, StdGen)

GHCi> :m System.Random
GHCi> let generator = mkStdGen 0          -- "0" is our seed
GHCi> :t generator
generator :: StdGen
GHCi> generator
1 1
GHCi> :t random
random :: (RandomGen g, Random a) => g -> (a, g)
GHCi> random generator :: (Int, StdGen)
(2092838931,1601120196 1655838864)
(    Int          ,          StdGen              )
```

A seed of the type **StdGen**

A new seed is generated

by **newStdGen**

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

Removing IO

```
GHCi> let randInt = fst . random $ generator :: Int
GHCi> randInt
2092838931

GHCi> let (randInt, generator') = random generator :: (Int, StdGen)
GHCi> randInt                          -- Same value
2092838931
GHCi> random generator' :: (Int, StdGen)
(-2143208520,439883729 1872071452)
-- Using new generator' returned from “random generator”
```

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

Dice without IO

GHCi> **randomR (1,6) (mkStdGen 0)**

(6, 40014 40692)

The resulting tuple combines

the result of throwing a single die with a new generator.

A simple implementation for throwing two dice is then:

```
clumsyRollDice :: (Int, Int)
clumsyRollDice = (n, m)
      where
      (n, g) = randomR (1,6) (mkStdGen 0)
      (m, _) = randomR (1,6) g
```

A seed of the type **StdGen**

A new seed is generated

by **newStdGen**

https://stackoverflow.com/questions/8416365/generate-a-random-integer-in-a-range-in-haskell

References

[1] ftp://ftp.geoinfo.tuwien.ac.at/navratil/HaskellTutorial.pdf

[2] https://www.umiacs.umd.edu/~hal/docs/daume02yaht.pdf