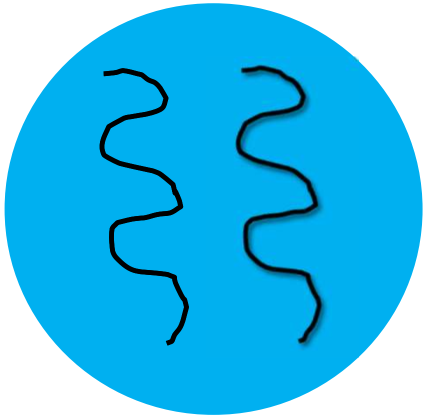
IMPLEMENTAREA CONCURENTEI IN LIMBAJE DE PROGRAMARE

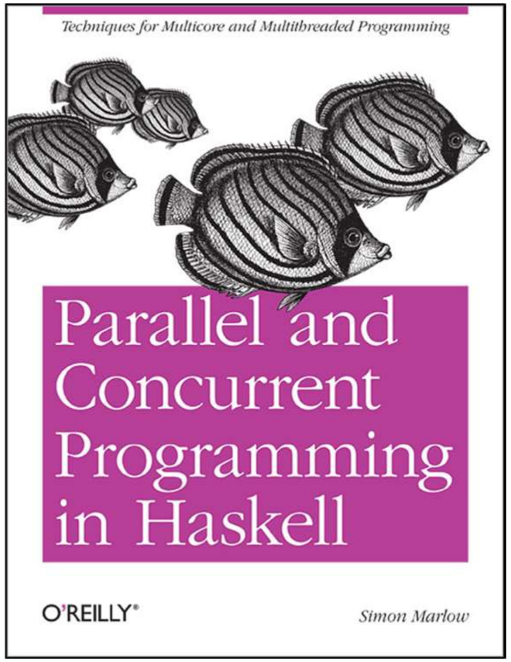
Concurenta

Threaduri

Memorie Partajata

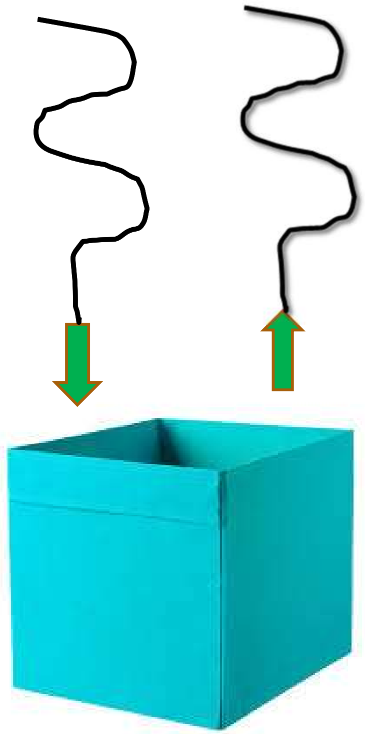
Ioana Leustean





[Part II. Concurrent Haskell Cap.7 & 8]

https://hackage.haskell.org/package/base-4.20.0.1/docs/Control-Concurrent.html



forkIO :: IO () -> IO ThreadId

MVar
mutable variable

➢ data MVar a

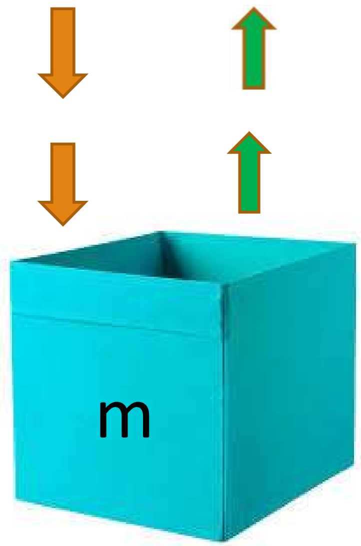
newEmptyMVar :: IO (MVar a) -- m <- newEmptyMVar
-- m este o locatie goala

newMVar :: a -> IO (MVar a) -- m <- newMVar v
-- m este o locatie care contine valoarea v

putMVar :: Mvar a -> a -> IO() -- putMVar m v
-- pune in m valoarea v
-- asteapta (blocheaza thread-ul) daca m este plina

takeMVar :: MVar a -> IO a -- v <- takeMVar m
-- intoarce in v valoarea din m si **goleste** m
-- asteapta (blocheaza thread-ul) daca m este goala

readMVar :: MVar a -> IO a -- v <- readMVar m citeste atomic continutul lui m
-- intoarce in v valoarea din m dar aceasta ramane in m
-- asteapta (blocheaza thread-ul) daca m este goala



- MVar ca semafor binar

```
newLock = newMVar ()      -- MVar care contine ()
aquireLock  m = takeMVar m
releaseLock  m = putMVar m ()
```

```
act1 m = do
        aquireLock m
        print "I have the lock"
        releaseLock m
```

```
act2 m = do
        aquireLock m
        print "Now I am have the  lock"
        releaseLock m
```

```
main = do
      m <- newLock
      forkIO $  act1 m
      forkIO $  act2 m
      getLine
```

- MVar ca semafor binar

```
newLock = newMVar ()      -- MVar care contine ()
aquireLock  m = takeMVar m
releaseLock  m = putMVar m ()
```

```
main = do
        m <- newLock
        forkIO $  forever (act1 m)
        forkIO $  forever (act2 m)
        getLine
```

```
"Now I have the lock"
"I have the lock"
"Now I have the lock"
"I have the lock"
"Now I have the lock"
"I have the lock"
"Now I have the lock"
"I have the lock"
"Now I have the lock"
"I have the lock"
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"Now I have the lock"
"I have the lock"
"Now I have the lock"
"I have the lock"
"Now I have the lock"
"I have the lock"
"Now I have the lock"
```

➢ Cititori/scriitori (Readers/Writers)

- Mai multe threaduri au acces la o resursa.
- Unele threaduri scriu (writers), iar altele citesc (readers).
- Resursa poate fi accesata simultan de mai multi cititori.
- Resursa poate fi acessata de un singur scriitor.
- Resursa nu poate fi accesata simultan de cititori si de scriitori.

```
import  Control.Concurrent.ReadWriteLock
new  :: IO RWLock
acquireRead ::  IO RWLock -> IO ()
releaseRead ::  IO RWLock -> IO ()
acquireWrite ::  IO RWLock -> IO ()
releaseWrite ::  IO RWLock -> IO ()
```

➢ Cititori/scriitori (Readers/Writers)

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Unele thread-uri scriu (writers), iar altele citesc (readers).
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Resursa poate fi acessata de un singur scriitor.
Resursa nu poate fi accesata simultan de cititori si de scriitori.

Pentru **sincronizare** folosim:

- un semafor binar care da acces la citit sau la scris: writeL
- un monitor in care se inregistreaza nr. de cititori: readL

```
data MyRWLock = MyRWL {readL :: MVar Int, writeL :: MVar ()}
```

- Reader/Writer Lock

```
type MyLock = MVar ()
newLock = newMVar ()
aquireLock  m = takeMVar m
releaseLock m = putMVar m ()
```

```
data MyRWLock = MyRWL {readL :: MVar Int, writeL :: MyLock}
```

```
newMyRWLock :: IO MyRWLock
newMyRWLock = do
                    readL  <-  newMVar 0
                    writeL <-  newLock
                    return (MyRWL readL writeL)
```

- Reader/Writer Lock

```
type MyLock = MVar ()
newLock = newMVar ()
aquireLock  m = takeMVar m
releaseLock m = putMVar m ()
```

```
data MyRWLock = MyRWL {readL :: MVar Int, writeL :: MyLock}
```

```
aquireWrite :: MyRWLock -> IO ()
aquireWrite (MyRWL readL  writeL) = aquireLock writeL

releaseWrite :: MyRWLock -> IO ()
releaseWrite (MyRWL readL writeL) = releaseLock writeL
```

➢ Reader/Writer Lock

```
data MyRWLock = MyRWL {readL :: MVar Int, writeL :: MyLock}
```

```
aquireRead :: MyRWLock -> IO ()
aquireRead (MyRWL readL writeL) = do
                    n <- takeMVar readL      -- n cititori
                    if (n == 0)  then do
                                   aquireLock writeL
                                   putMVar readL 1
                    else  putMVar readL (n+1)
```

- Reader/Writer Lock

```
data MyRWLock = MyRWL {readL :: MVar Int, writeL :: MyLock}
```

```
releaseRead :: MyRWLock -> IO ()
releaseRead (MyRWL readL writeL) = do
                                    n <- takeMVar readL
                                    if (n == 1)   then do
                                                   releaseLock writeL
                                                   putMVar readL 0
                                     else  putMVar readL (n-1)
```

- Exemplu: Readers/Writers

lib este resursa partajata
rwl este lacatul care sincronizeaza accesul la resursa

```
reader i rwl lib = do                          -- un thread cititor
                    aquireRead rwl
                    c <- readMVar lib  -- non blocking
                    putStrLn $  "Reader " ++ (show i) ++ " reads: " ++ (show c)
                    releaseRead rwl
```

- Exemplu: Readers/Writers

lib este resursa partajata
rwl este lacatul care sincronizeaza accesul la resursa

```
reader i rwl lib = do                          -- un thread cititor
                    aquireRead rwl
                    c <- readMVar lib  -- non blocking
                    putStrLn $  "Reader " ++ (show i) ++ " reads: " ++ (show c)
                    releaseRead rwl


writer i rwl lib = do                         -- un thread scriitor
                    aquireWrite rwl
                    putStrLn $  "Writer " ++ (show i) ++ " writes "  (show i)
                     c <- takeMVar lib
                     putMVar lib i
                     releaseWrite rwl
```

- Exemplu: Readers/Writers

```
genread n rwl lib = if (n==0)
                    then putStrLn "no more readers"
                    else do
                         reader n rwl lib
                         threadDelay 20
                         genread (n-1) rwl lib
genwrite n rwl lib = if (n==0)
                     then putStrLn "no more writers"
                     else do
                          writer n rwl lib
                          threadDelay 100
                          genwrite (n-1) rwl lib

main = do
        lib <- newMVar 0     -- resursa
        rwl <- newMyRWLock    -- lacatul rw
        forkIO $  genread 10 rwl lib    -- creez 10 thread-uri cititor
        forkIO $  genwrite 5 rwl lib    -- creez 5 thread-uri scriitor
        getLine
```

```
reader i rwl lib = do
                   aquireRead rwl
                   c <- readMVar lib
                   putStrLn $  (show i) ++ (show c)
                   releaseRead rwl

writer i rwl lib = do
                   aquireWrite rwl
                   putStrLn $ show  i
                   c <- takeMVar lib
                   putMVar lib i
                   releaseWrite rwl
```

- Readers/Writers

```haskell
genread n rwl lib = if (n==0)
                        then putStrLn "no more readers"
                        else do
                                reader n rwl lib
                                threadDelay 20
                               genread (n-1) rwl lib
genwrite n rwl lib = if (n==0)
                        then putStrLn "no more writers"
                        else do
                                writer n rwl lib
                                threadDelay 100
                                genwrite (n-1) rwl lib

main = do
          lib <- newMVar 0
          rwl <- newMyRWLock
          forkIO $  genread 10 rwl lib
          forkIO $  genwrite 5 rwl lib
          getLine
```

```haskell
reader i rwl lib = do
                      aquireRead rwl
                      c <- readMVar lib
                      putStrLn $  (show i) ++ (show c)
                      releaseRead rwl

writer i rwl lib = do
                      aquireWrite rwl
                      putStrLn $ show  i
                       c <- takeMVar lib
                       putMVar lib i
                       releaseWrite rwl
```

```
Prelude>  :l myrw.hs
[1 of 1] Compiling Main
Ok, modules loaded: Main.
*Main> main
Reader 10 reads: 0
Writer 5 writes 5
Reader 9 reads: 5
Reader 8 reads: 5
Writer 4 writes 4
Reader 7 reads: 4
Reader 6 reads: 4
Writer 3 writes 3
Reader 5 reads: 3
Writer 2 writes 2
Reader 4 reads: 2
Writer 1 writes 1
Reader 3 reads: 1
no more writers
Reader 2 reads: 1
Reader 1 reads: 1
no more readers
```

- Semafor cu cantitate (quantity semaphore)

```
import Control.Concurrent.QSem

data  QSem

newQSem :: Int -> IO  Qsem



waitQSem ::  QSem -> IO()       -- aquire, il ocupa
signalQSem :: QSem -> IO()      -- release, il elibereaza
```

un semafor care sincronizeaza accesul la n resurse se defineste astfel:

```
qs <- newQsem  n
```

➢ Exemplu: **QSem**

O multime de taskuri acceseaza simultan o resursa reprezentata printr-un **QSem**;
pentru a se executa, fiecare task trebuie sa acceseaze resursa, pe care o elibereaza la sfarsitul executiei.

```
import Control.Concurrent
import Control.Monad


main :: IO ()
main = do
        q <- newQSem 3
        let workers = 5
        mapM_ (forkIO . worker q m) [1..workers]
```

mapM_ :: (Foldable t, Monad m) => (a -> m b) -> t a -> m ()

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main :: IO ()
main = do
        q <- newQSem 3
        let workers = 5
        mapM_ (forkIO . worker q m) [1..workers]
```

q este semaforul care controleaza resursele

```haskell
worker ::  QSem -> MVar String -> Int -> IO ()
worker q m w= do
   waitQSem q
   putStrLn$ "Worker " ++ show w ++ " acquired the lock."
   threadDelay 2000000      -- microseconds
   signalQSem q
   putStrLn $ "Worker " ++ show w ++ "released the lock."
```

http://rosettacode.org/wiki/Metered_concurrency

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main = do
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        mapM_ (forkIO . worker q m) [1..workers]
```

q este semaforul care controleaza resursele

```
worker ::  QSem -> MVar String -> Int -> IO ()
worker q m w= do
    waitQSem q
    putStrLn$ "Worker " ++ show w ++ " acquired the lock."
    y 2000000       -- microseconds
    signalQSem q
    putStrLn $ "Worker " ++ show w ++ "released the lock."
```

```
Ok, one module loaded.
*Main> main
WoWWo*Main> orrekkree rr1   23h  ahhsaa ssa  caaqccuqqiuuriierrdee ddt  httehh eel  ollcookcc.kk
..

WoWWrWWookoorrerrkkrkkee eerr1rr     23h54  a  hhshhaa aassrss  e  rrlaaeeeccllaqqeesuuaaeiissdrree eeddtdd  h
 ttetthh hheelee  o  llcllookoocc.cckk
kk....
```

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➢ Exemplu: **QSem**

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```haskell
import Control.Concurrent
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main :: IO ()
main = do
        q <- newQSem 3
        let workers = 5
        mapM_ (forkIO . worker q ) [1..workers]
```

q este semaforul care controleaza resursele

```haskell
worker :: QSem -> Int -> IO ()
worker q m w= do
    waitQSem q
    putStrLn$ "Worker " ++ show w ++ " acquired the lock."
    y 2000000       -- microseconds
    signalQSem q
    putStrLn $ "Worker " ++ show w ++ "released the lock."
```

```
Ok, one module loaded.
*Main> main
WoWWo*Main> orrekkree rr1   23h  ahhsaa ssa  caaqccuqqiuuriierrdee ddt  httehh eel  ollcookcc.kk
..

WoWWrWWookoorrerrkkrkkee eerr1rr    23h54  a  hhshhaa aassrss  e  rrlaaeeeccllaqqeesuuaaeiissdrree eeddtdd  h
 ttetthh hheelee  o  llcllookoocc.cckk
kk....
```

Atentie!
Accesul la stdout nu este thread-safe, deci trebuie sincronizat

http://rosettacode.org/wiki/Metered_concurrency

➢ Exemplu: **QSem**

O multime de taskuri acceseaza simultan o resursa reprezentata printr-un **QSem**;
pentru a se executa, fiecare task trebuie sa acceseaze resursa, pe care o elibereaza la sfarsitul executiei.

```
import Control.Concurrent
import Control.Monad


main :: IO ()
main = do
        q <- newQSem 3
        stdo <- newEmptyMVar
        let workers = 5
            prints  = 2 * workers
        mapM_ (forkIO . worker q m) [1..workers]
        replicateM_ prints $ takeprint  stdo
```

```
takeprint :: MVar String  -> IO()
takeprint stdo = do
          s <- takeMVar stdo
          print s

worker ::  QSem -> MVar String -> Int -> IO ()
worker q m w= do
    waitQSem q
    putMVar stdo $ "Worker " ++ show w ++ " acquired the lock."
    threadDelay 2000000       -- microseconds
    signalQSem q
    putMVar stdo $ "Worker " ++ show w ++ "released the lock."
```

http://rosettacode.org/wiki/Metered_concurrency

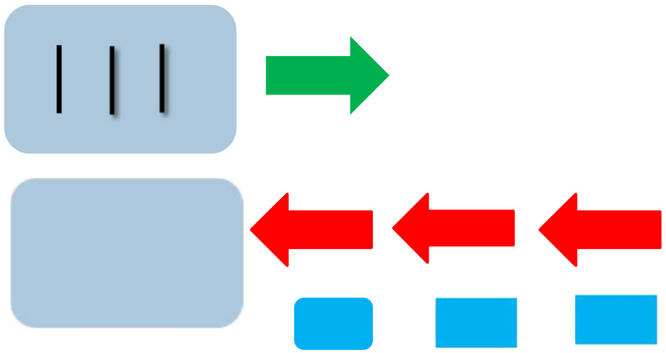
q este semaforul care controleaza resursele
stdo coordoneaza accesul la stdout

```
Prelude> :l qsemrcmy.hs
[1 of 1] Compiling Main             ( qsemrcmy.hs, interpreted )
Ok, modules loaded: Main.
*Main> main
"Worker 1 has acquired the lock."
"Worker 2 has acquired the lock."
"Worker 3 has acquired the lock."
"Worker 2 has released the lock."
"Worker 3 has released the lock."
"Worker 1 has released the lock."
"Worker 5 has acquired the lock."
"Worker 4 has acquired the lock."
"Worker 4 has released the lock."
"Worker 5 has released the lock."
```

```
*Main> main
"Worker 1 has acquired the lock."
"Worker 2 has acquired the lock."
"Worker 3 has acquired the lock."
"Worker 1 has released the lock."
"Worker 5 has acquired the lock."
"Worker 2 has released the lock."
"Worker 4 has acquired the lock."
"Worker 3 has released the lock."
"Worker 4 has released the lock."
"Worker 5 has released the lock."
```

in Concurrent Haskell
concurenta este nedeterminista

- Implementarea QSem



```
type  QSem = MVar (Int, [MVar ()])

newQSem :: Int -> IO  QSem

newQSem n =  newMVar (n,[])
                    --  qsem <- newQSem 3

waitQSem ::  QSem -> IO()        -- ocupa
signalQSem :: QSem -> IO()       -- elibereaza
```

n = nr. de resurse

blki = un thread care cere acces la resursa este blocat pe variabila blki

daca n > 0 atunci qsem = (n, [])

altfel qsem = (0, [blk1, blk2, …])

Implementarea din:
Concurrent Haskell
SL Peyton Jones, A Gordon, S Finne, 1996

- Implementarea QSem - *Concurrent Haskell SL Peyton Jones, A Gordon, S Finne, 1996*

```
type  QSem = MVar (Int, [MVar ()])

newQSem :: Int -> IO  QSem
newQSem n =  newMVar (n,[])
```

daca n > 0 atunci qsem = (n, [])
altfel qsem = (0, [blk1, blk2, …])

Ocuparea resursei

```
waitQSem ::  QSem -> IO()
waitQSem qsem = do
              (avail,blks) <- takeMVar qsem
              if avail > 0
                   then    putMVar qsem (avail-1, [])
                   else
                       do
                         blk <- newEmptyMVar
                         putMVar qsem (0, blk:blks)
                         takeMVar blk  -- threadul e blocat pe  variabila proprie
```

➢ Implementarea QSem - *Concurrent Haskell SL Peyton Jones, A Gordon, S Finne, 1996*

```
type  QSem = MVar (Int, [MVar ()])

newQSem :: Int -> IO  QSem
newQSem n =  newMVar (n,[])
```

daca n > 0 atunci qsem = (n, [])
altfel qsem = (0, [blk1, blk2, …])

Eliberarea resursei

```
signalQSem :: QSem -> IO()
signalQSem qsem = do
                      (avail,blks) <- takeMVar qsem
                      case blks of
                         [] -> putMVar qsem (avail+1,[])
                         (blk:blks') -> do
                                  putMVar qsem (0,blks')
                                  putMVar blk ()
```

- fiecare thread elibereaza variabila proprie a unui thread in asteptare

- **Implementarea QSem** - *Concurrent Haskell SL Peyton Jones, A Gordon, S Finne, 1996*

```
type  QSem = MVar (Int, [MVar ()])

newQSem :: Int -> IO  QSem
newQSem n =  newMVar (n,[])
```

daca n > 0 atunci qsem = (n, [])
altfel qsem = (0, [blk1, blk2, ...])

Ocuparea resursei

```
waitQSem ::  QSem -> IO()
waitQSem qsem = do
            (avail,blks) <- takeMVar qsem
            if avail > 0
                then    putMVar qsem (avail-1, [])
                else
                    do
                      blk <- newEmptyMVar
                      putMVar qsem (0, blk:blks)
                      takeMVar blk
```

– threadul e blocat pe variabila proprie

atentie la ordinea de asteptare!

Eliberarea resursei

```
signalQSem :: QSem -> IO()
signalQSem qsem = do
                (avail,blks) <- takeMVar qsem
                case blks of
                  [] -> putMVar qsem (avail+1,[])
                  (blk:blks') -> do
                        putMVar qsem (0,blks')
                        putMVar blk ()
```

atentie la ordinea de asteptare!

fiecare thread elibereaza variabila proprie a unui thread in asteptare

➢ Canale de comunicare: canale implementate cu MVar

readChan
se
blocheaza
cand
canalul
este gol

writeChan
nu se blocheaza
niciodata

```
import Control.Concurrent.Chan

newChan :: IO (Chan a)

writeChan :: Chan a -> a -> IO ()

readChan :: Chan  a -> IO a
```

➢ Exemplu: doua canale: **cin** si **cout**

- thread –ul parinte citeste siruri si le pune pe canalul **cin**.
- un thread citeste sirurile de pe **cin**, le imparte in cuvinte iar cuvintele le pune pe canalul **cout**.
- un alt thread ia cuvintele de pe **cout**, si le scrie la iesire cu litere mari

```haskell
import Control.Monad
import Control.Concurrent
import Data.Char

mymain = do
        cin  <- newChan
        cout <- newChan
        forkIO $ forever (move cin cout)
        forkIO $ forever (upout cout)
        load cin
```

```haskell
move c1 c2 = do
             v1 <- readChan c1
             let ls = words v1
             mapM_ (writeChan c2) ls

upout c  = do
             str <- readChan c
             putStrLn (map toUpper str)

load c = do
             str <- getLine
             if (str == "exit")
             then return()
             else do
                    writeChan c str
                    load
```

➢ Canale de comunicare formate din variabile MVar

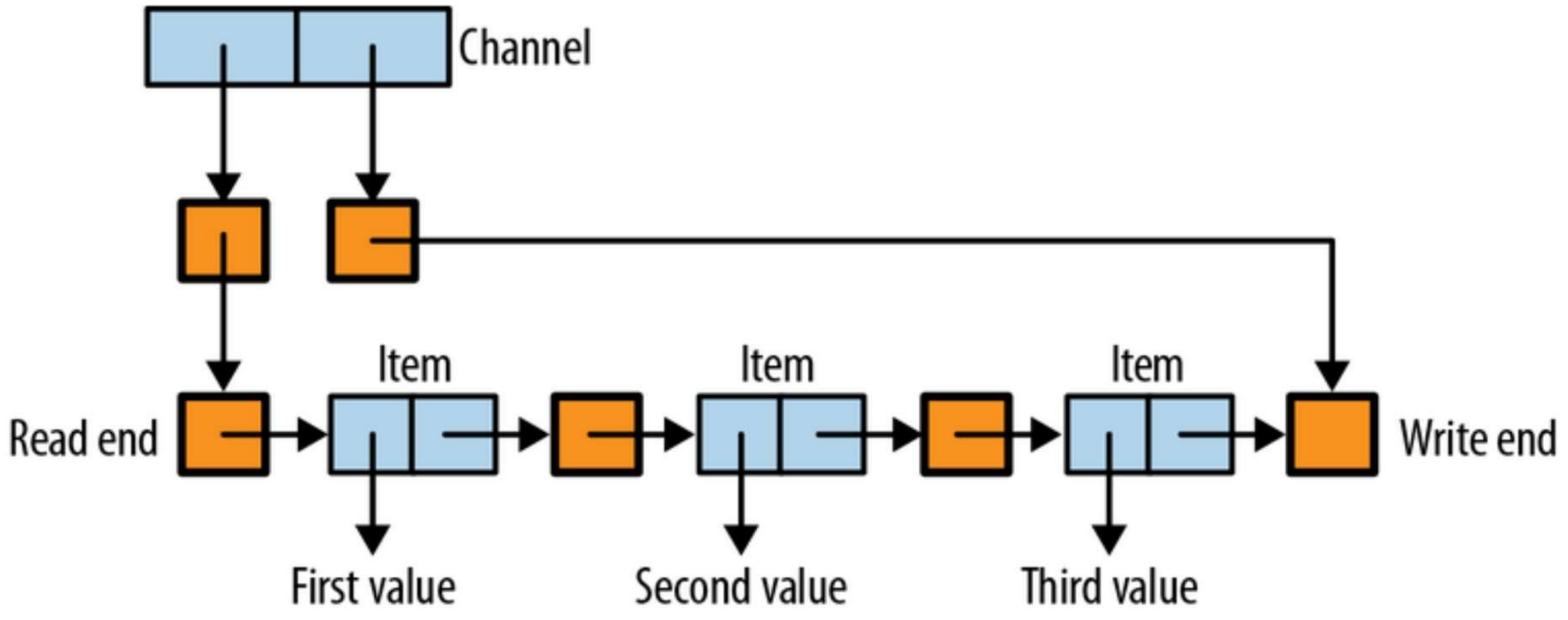
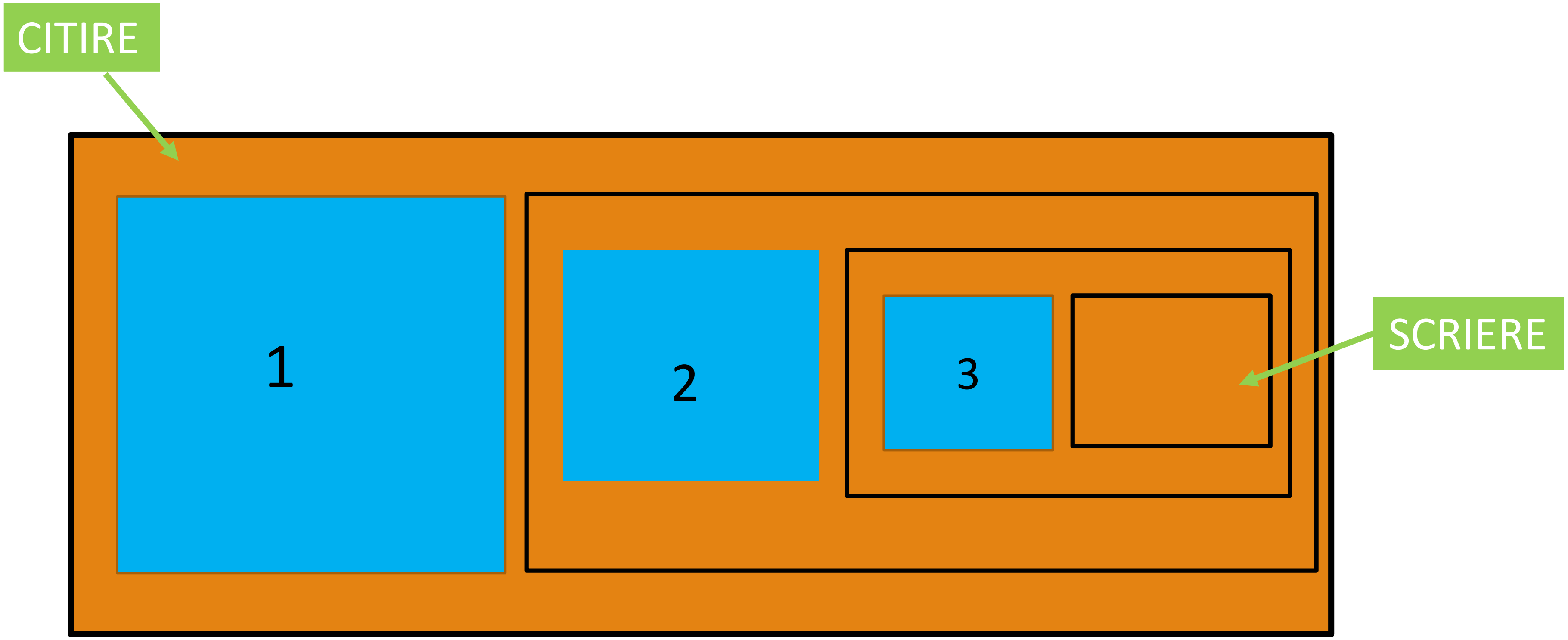
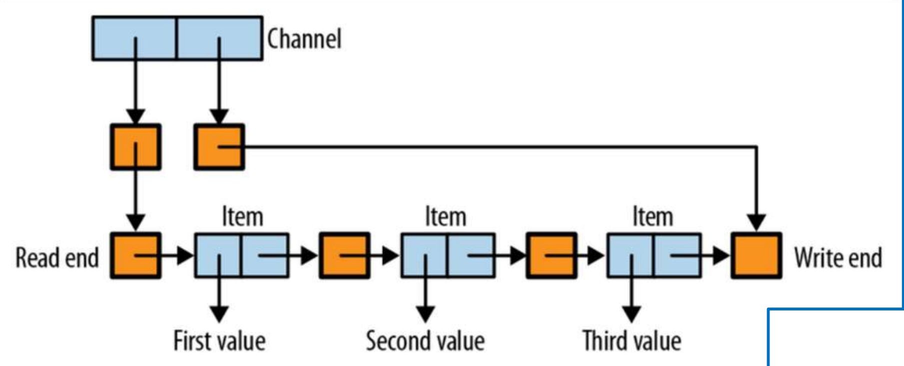


Figure 7-1. Structure of the buffered channel implementation

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels


CITIRE
1
2
3
SCRIERE

➢ Canale formate din variabile MVar



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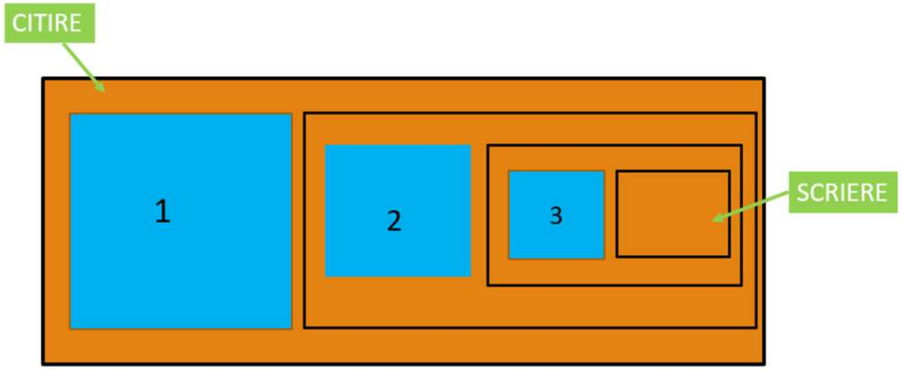
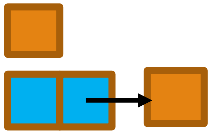



```
type Stream a = MVar (Item a)
data Item a     =  Item a (Stream a)

data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))

c <- newChan
v <- readChan c
putChan c v
```



chan.hs ©2012, Simon Marlow

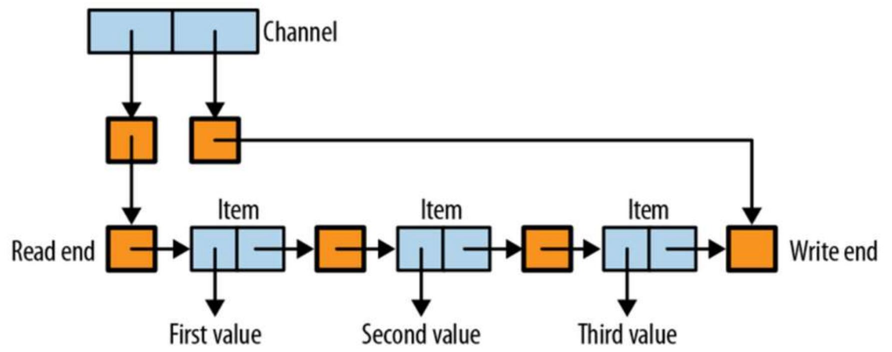


Figure 7-1. Structure of the buffered channel implementation

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))

c <- newChan
v <- readChan c
putChan c v
```

"If multiple threads concurrently call readChan, the first one will successfully call takeMVar on the read end, but the subsequent threads will all block at this point until the first thread completes the operation and updates the read end. If multiple threads call writeChan, a similar thing happens: the write end of the Chan is the synchronization point, allowing only one thread at a time to add an item to the channel. However, the read and write ends, being separate MVars, allow concurrent readChan and writeChan operations to proceed without interference."

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

➢ Implementarea canalelor

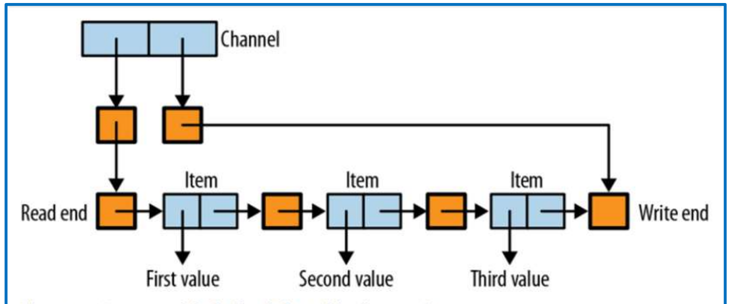


Figure 7-1. Structure of the buffered channel implementation

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))
```

```
newChan :: IO(Chan a)
newChan = do
    emptyStream <-  newEmptyMVar
    readVar <- newMVar emptyStream
    writeVar <-newMVar emptyStream
    return (Chan readVar writeVar)
```

contine Item-ul care va fi citit

contine variabila in care se va scrie noul Item

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

➢ Implementarea canalelor

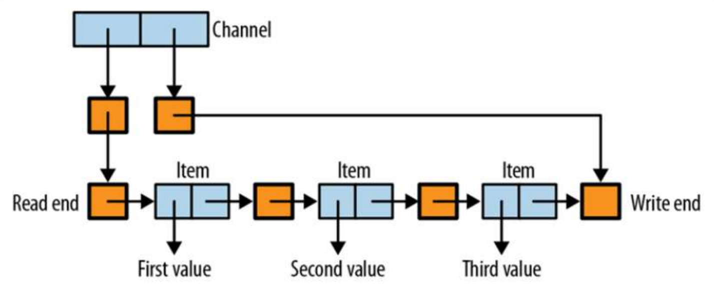


Figure 7-1. Structure of the buffered channel implementation

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))
```

```
readChan :: Chan a -> IO a
readChan (Chan rV wV) = do
                  stream <- takeMVar rV
                  Item val str <- takeMVar stream
                  putMVar rV  str
                  return val
```

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

➢ Implementarea canalelor

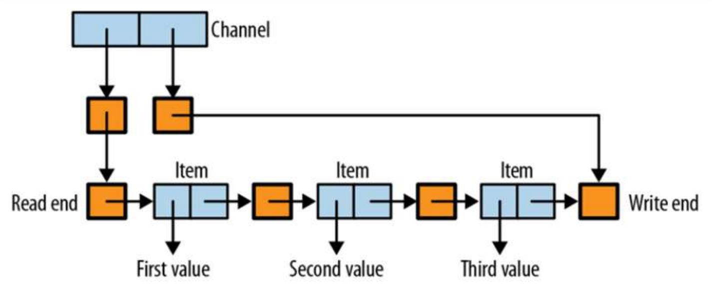


Figure 7-1. Structure of the buffered channel implementation

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))
```

```
writeChan :: Chan a  -> a -> IO()
writeChan (Chan rV wV) val = do
            newStream <- newEmptyMVar
            writeEnd <- takeMVar wV
            putMVar writeEnd (Item val newStream)
            putMVar wV newStream
```

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

➢ Implementarea canalelor

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))
```

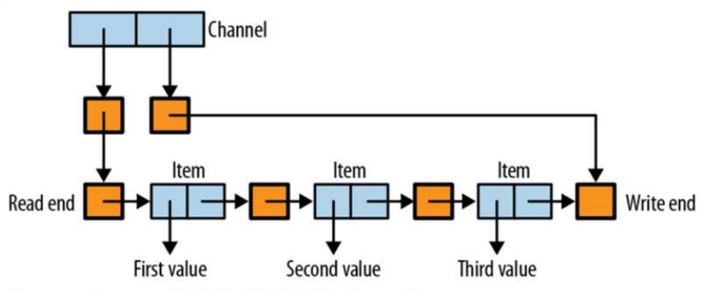


Figure 7-1. Structure of the buffered channel implementation

```
readChan :: Chan a -> IO a
readChan (Chan rV wV) = do
                stream <- takeMVar rV
                Item val str <- takeMVar stream
                putMVar rV  str
                return val
```

```
newChan :: IO(Chan a)
newChan = do
    emptyStream <-  newEmptyMVar
    readVar <- newMVar emptyStream
    writeVar <-newMVar emptyStream
    return (Chan readVar writeVar)
```

```
writeChan :: Chan a  -> a -> IO()
writeChan (Chan rV wV) val = do
          newStream <- newEmptyMVar
          writeEnd <- takeMVar wV
          putMVar writeEnd (Item val newStream)
          putMVar wV newStream
```

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

➢ Exercitiu: implementarea canalelor multicast

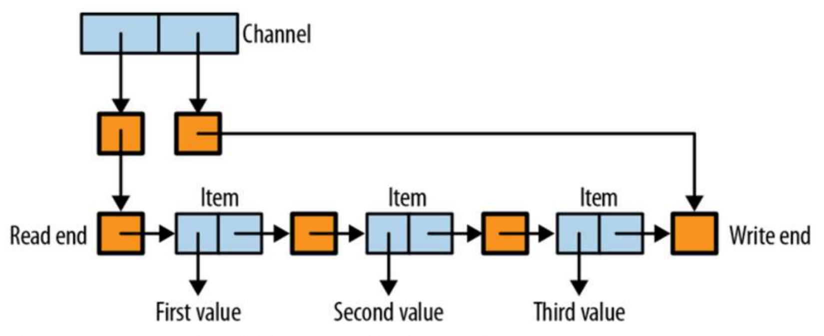


Figure 7-1. Structure of the buffered channel implementation

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar
(Stream a))
newChan :: IO (Chan a)
writeChan :: Chan a -> a -> IO ()
readChan :: Chan a -> IO a
```

```
dupChan  ::  Chan a -> IO (Chan a)
```

- noul canal este initial gol
- dupa crearea canalului duplicat, ceea ce se scrie pe oricare dintre canale poate fi citit de pe oricare dintre cele doua canale
- citirea de pe un canal **nu** elimina elementul de pe celalalt canal.

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

Exercitiu: implementarea canalelor multicast

```
dupChan  ::  Chan a -> IO (Chan a)
```

- noul canal este initial gol
- dupa crearea canalului duplicat, ceea ce se scrie pe oricare dintre canale poate fi citit de pe oricare dintre cele doua canale
- citirea de pe un canal **nu** elimina elementul de pe celalalt canal.

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))
newChan :: IO (Chan a)
writeChan :: Chan a -> a -> IO ()
readChan :: Chan a -> IO a
```

```
main = do  c <- newChan
           writeChan c 'a'
           readChan c >>= print
           c2 <- dupChan c   -- creare canal duplicat
           writeChan c 'b'
           readChan c >>= print
           readChan c2 >>= print
```

```
Prelude> :l chan2.hs
[1 of 1] Compiling Main
Ok, modules loaded: Main.
*Main> main
'a'
'b'
'b'
```

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

Exercitiu: implementarea canalelor multicast

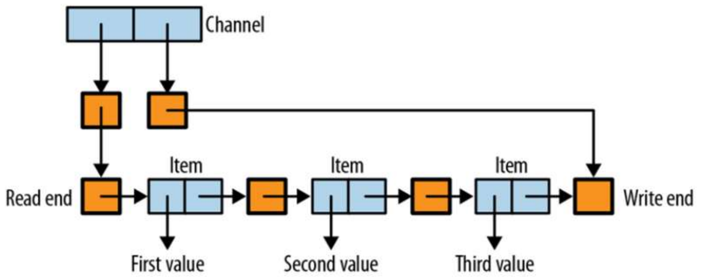


Figure 7-1. Structure of the buffered channel implementation

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))
newChan :: IO (Chan a)
writeChan :: Chan a -> a -> IO ()
readChan :: Chan a -> IO a
```

Canalul duplicat are **acelasi cap de scriere**, dar **un alt cap de citire**

```
dupChan  ::  Chan a -> IO (Chan a)
dupChan (Chan _ wV) = do
        writeEnd <- readMVar wV
        newReadVar <- newMVar writeEnd
        return (Chan newReadVar wV)
```

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

➢ Exercitiu: implementarea canalelor multicast

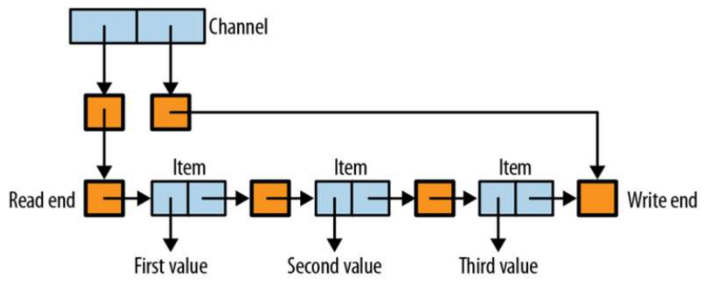


Figure 7-1. Structure of the buffered channel implementation

```
type Stream a = MVar (Item a)
data Item a   = Item a (Stream a)
data Chan a = Chan (MVar (Stream a)) (MVar (Stream a))
newChan :: IO (Chan a)
writeChan :: Chan a -> a -> IO ()
readChan :: Chan a -> IO a
```

```
dupChan  ::  Chan a -> IO (Chan a)
dupChan (Chan _ writeVar) = do
                    writeEnd <- readMVar writeVar
                    newReadVar <- newMVar writeEnd
                    return (Chan newReadVar writeVar)
```

operatia **readChan** trebuie modificata

```
readChan :: Chan a -> IO a
readChan (Chan rV wV) = do
               stream  <- takeMVar rV
               Item val str <- readMVar  stream
               putMVar rV  str
               return val
```

```
readMVar :: MVar a -> IO a
readMVar m =   do
                 v <- takeMVar m
                 putMVar m v
                 return v
```

implementarea reala asigura atomicitate

readMVar este folosit in locul lui **takeMVar** deoarece continutul trebuie sa ramana accesibil celuilalt canal.

http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_channels

➢ Comunicare sincrona

Un thread – reader- citeste un fisier text linie cu linie

Liniile sunt trimise, pe rand,
unui al doilea thread – writer- care le afiseaza
in ordinea trimisa si le numara.

La sfarsit, thread-ul writer trimite thread-ului reader
numarul de linii si acesta il afiseaza,

http://rosettacode.org/wiki/Synchronous_concurrency

```
import Control.Concurrent
import Control.Concurrent.MVar

main = do
      lineVar <- newEmptyMVar
      countVar <- newEmptyMVar
      forkIO $ writer lineVar countVar
      reader  lineVar countVar
```

- Comunicare sincrona

```haskell
import Control.Concurrent
import Control.Concurrent.MVar

main = do
      lineVar <- newEmptyMVar
      countVar <- newEmptyMVar
      forkIO $ writer lineVar countVar
      reader  lineVar countVar
```

```haskell
reader lineVar countVar  = do
          ls <- fmap lines (readFile "input.txt")
          mapM ((putMVar lineVar) . Just) ls
          putMVar lineVar Nothing
          n <- takeMVar countVar
          print n
```

http://rosettacode.org/wiki/Synchronous_concurrency

- Comunicare sincrona

```
import Control.Concurrent
import Control.Concurrent.MVar

main = do
      lineVar <- newEmptyMVar
      countVar <- newEmptyMVar
      forkIO $ writer lineVar countVar
      reader  lineVar countVar
```

```
readFile :: FilePath -> IO String
lines :: String -> [String]
fmap :: Functor f => (a -> b) -> f a -> f b
mapM :: Monad m => (a -> m b) -> [ a] -> m [ b]
```

```
reader lineVar countVar  = do
          ls <- fmap lines (readFile "input.txt")
          mapM ((putMVar lineVar) . Just) ls
          putMVar lineVar Nothing
          n <- takeMVar countVar
          print n

writer lineVar countVar = loop 0
      where
        loop n = do
                    l <- takeMVar lineVar
                    case l of
                       Just x  -> do putStrLn x
                                     loop (n+1)
                       Nothing -> putMVar countVar n
```

http://rosettacode.org/wiki/Synchronous_concurrency

Comunicare sincrona

```haskell
import GetURL
import Data.ByteString as B

action x =  do
            r <- getURL x
            print (B.length r)
```

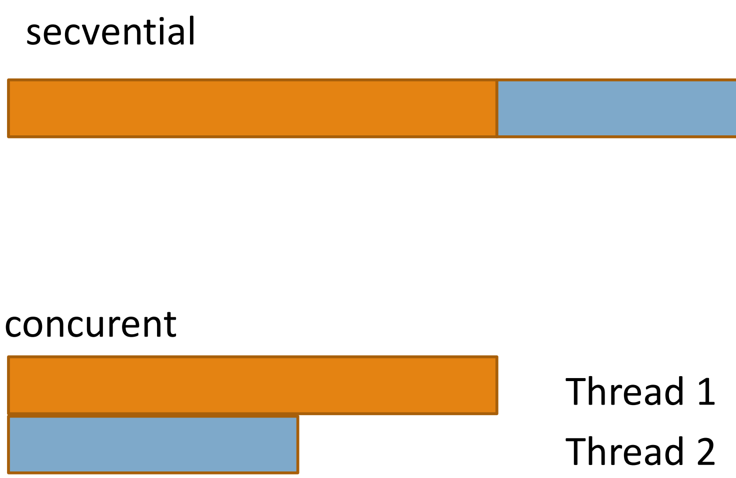
```haskell
reader lineVar countVar  = do
          ls <- fmap lines (readFile "inputurl.txt")
          mapM ((putMVar lineVar) . Just) ls
          putMVar lineVar Nothing
          n <- takeMVar countVar
          print n

writer lineVar countVar = loop 0
      where
        loop n = do
                      l <- takeMVar lineVar
                      case l of
                         Just x  -> do
                                     action x
                                     loop (n+1)
                         Nothing -> putMVar countVar n
```

Fisierul "inputurl.txt" contine adrese web, iar **action** descarca paginile respective

https://hackage.haskell.org/package/parconc-examples-0.1/src/GetURL.hs

"**Concurrent computing** is a form of computing in which several computations are executing during overlapping time periods—*concurrently*—instead of *sequentially* (one completing before the next starts)[...]
A *concurrent system* is one where a computation can advance without waiting for all other computations to complete; where more than one computation can advance at *the same time*."
Operating System Concepts 9th edition, Abraham Silberschatz

Exemplu: incarcarea mai multor pagini web




```
import Data.ByteString as B
import GetURL
main = do
        m1 <- newEmptyMVar
        forkIO $ do
                 r  <- getURL "http://..."
                 putMVar m1 r

        m2 <- newEmptyMVar
        forkIO $ do
                 r <- getURL "http://..."
                 putMVar m2 r

         r1 <- takeMVar m1
         r2 <- takeMVar m2

      print (B.length r1, B.length r2)
```

- Comunicare asincrona

  Se creaza un thread separat pentru fiecare actiune si se asteapta rezultatul

```
var <- newEmptyMVar
forkIO $ do
          r  <- getURL "http://... "
          putMVar var  r
 takeMVar var
```

```
a <- async (getURL "http://... " )
wait a
```

```
data Async a = Async (MVar a)

async :: IO a -> IO (Async a)
async action = do
  var <- newEmptyMVar
  forkIO (do r <- action; putMVar var r)
  return (Async var)

wait :: Async a -> IO a
wait (Async var) = readMVar var
```

readMVar nu devine goala dupa citire (multiple-wakeup) deci mai multe apeluri **wait** pot fi facute pentru aceeasi operatie asincrona

- Comunicare asincrona
  Se creaza un thread separat pentru fiecare actiune si se asteapta rezultatul

```
data Async a = Async (MVar a)

async :: IO a -> IO (Async a)
async action = do
  var <- newEmptyMVar
  forkIO (do r <- action; putMVar var r)
  return (Async var)

wait :: Async a -> IO a
wait (Async var) = readMVar var
```

```
a <- async action
r <- wait a
```

```
import Data.ByteString as B
import GetURL

main = do
        a1 <-  async (getURL "http://..." )
        a2 <-  async (getURL "http://..." )
        r1 <- wait a1
        r2 <- wait a2
        print (B.length r1, B.length r2)
```

➢ Comunicare asincrona

```
data Async a = Async (MVar a)

async :: IO a -> IO (Async a)
async action = do
  var <- newEmptyMVar
  forkIO (do r <- action; putMVar var r)
  return (Async var)

wait :: Async a -> IO a
wait (Async var) = readMVar var
```

```
a <- async action
r <- wait a
```

```
import Data.ByteString as B
import GetURL
import TimeIt
import Text.Printf

timeDownload :: String -> IO ()
timeDownload url = do
        (page, time) <- timeit $ getURL url
        printf " %s (%d bytes, %.2fs)\n" url (B.length page) time


main = do
        a1 <-  async (timeDownload "http://..." )
        a2 <-  async (timeDownload "http://..." )
         wait a1
        wait a2
```

➢ Comunicare asincrona

```
import Data.ByteString as B
import GetURL
import TimeIt
import Text.Printf

timeDownload :: String -> IO ()
timeDownload url = do
        (page, time) <- timeit $ getURL url
        printf "downloaded: %s (%d bytes, %.2fs)\n" url (B.length page) time

main = do
                a1 <-  async (timeDownload "http://..." )
                a2 <-  async (timeDownload "http://..." )
                wait a1
                wait a2
```

vor fi afisate statistici privind timpul de executie

```
*Main> :set +s
*Main> main
downloaded: http://old.uefiscdi.ro/ (74599 bytes, 3.96)
downloaded: http://old.uefiscdi.ro/ (74599 bytes, 4.01)
(4.01 secs, 52,080 bytes)
```

➢ Comunicare asincrona

```haskell
import Control.Concurrent
import Text.Printf
import qualified Data.ByteString as B
import GetURL  --  parconc-examples
import TimeIt   --   parconc-examples

timeDownload :: String -> IO ()
timeDownload url = do
        (page, time) <- timeit $ getURL url
        printf " %s (%d bytes, %.2fs)\n" url (B.length page) time
```

```haskell
data Async a = Async (MVar a)

async :: IO a -> IO (Async a)
async action = do
    var <- newEmptyMVar
    forkIO (do r <- action; putMVar var r)
    return (Async var)

wait :: Async a -> IO a
wait (Async var) = readMVar var
```

```haskell
sites =["url1","url2",...]
main =  do
          as <- mapM (async . timeDownload) sites
          mapM_ wait as
```

geturl3.hs ©2012, Simon Marlow

➢ Async - comunicare asincrona (folosind MVar)

geturl3.hs ©2012, Simon Marlow

```
import Control.Concurrent
import Text.Printf
import qualified Data.ByteString as B
import GetURL  --  parconc-examples
import TimeIt   --   parconc-examples

timeDownload :: String -> IO ()
timeDownload url = do
        (page, time) <- timeit $ getURL url
        printf " %s (%d bytes, %.2fs)\n" url (B.length page) time
```

```
data Async a = Async (MVar a)

async :: IO a -> IO (Async a)
async action = do
    var <- newEmptyMVar
    forkIO (do r <- action; putMVar var r)
    return (Async var)

wait :: Async a -> IO a
wait (Async var) = readMVar var
```

```
main =  do
          as <- mapM (async . timeDownload) sites     -- sites =["url1","url2",...]
          mapM_ wait as
```

asteapta ca toate actiunile asincrone sa se termine, monitorizand fiecare actiune in parte; un alt thread ar putea interveni inainte ca toate actiunile sa se termine

Cum rezolvam aceasta problema?

Pe saptamana viitoare!