IMPLEMENTAREA CONCURENTEI IN LIMBAJE DE PROGRAMARE

Concurenta

Threaduri takeMVar

Memorie Partajata

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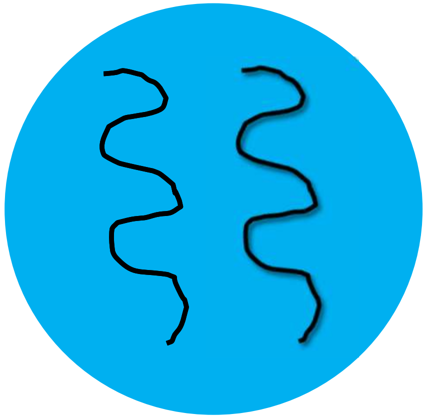
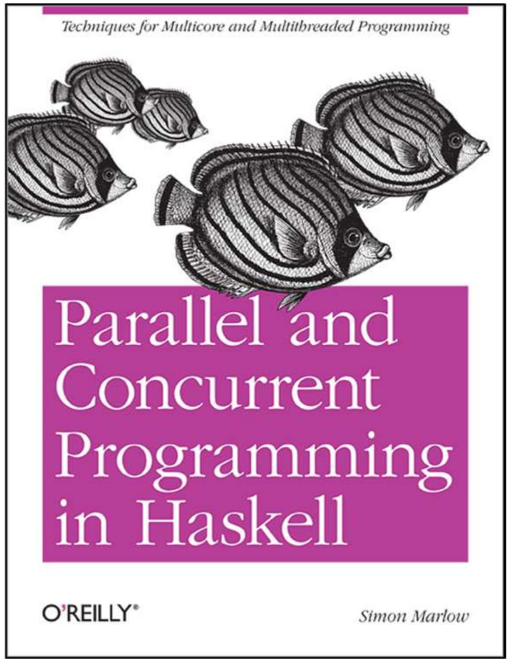


Haskell

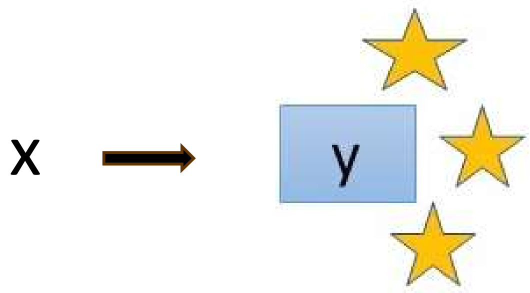


[Part II. Concurrent Haskell Cap.7 & 8]

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

➢ **Monada** este o clasa de tipuri

Intuitie:
functii care calculeaza o valoare si produc un efect




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

   ma >> mb = ma >>= \_ -> mb
```

- **m a** este tipul computatiilor care produc rezultate de tip **a** si au efecte laterale
- **a –> m b** este tipul continuarilor / al functiilor cu efecte laterale
- **>>=** este operatia de „secventiere" a computatiilor
- **return** este o functie care produce efectul nul

do notation

```
x  <- e                  e >>= \x -> rest
 rest
```

```
e                        e >>= \_ -> rest
rest
```

```
e                        e >> rest
rest
```

De exemplu

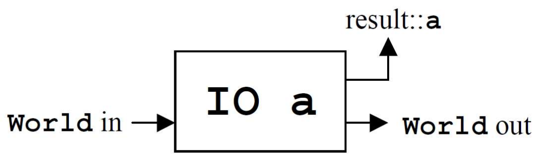
```
e1   >>= \x1 ->
e2   >> e3
```

devine

```
do
    x1 <- e1
    e2
    e3
```

Monada IO

Intrarile si iesirile sunt valori de tipul IO a




```
Prelude> :t getLine
getLine :: IO String
Prelude> :t putStrLn
putStrLn :: String -> IO ()
```

() unit este singura valoare a tipului () (singleton)

IO () este folosit atunci cand actiunile nu intorc valori semnificative

```
Prelude> :t getChar
getChar :: IO Char
Prelude> :t putChar
putChar :: Char -> IO ()
```

Valoarea de tip a dintr-o valoare de tip IO a se obtine folosind <-

```
s <- getLine
c <- getChar
```

```
Prelude> :t print
print :: Show a => a -> IO ()
```

Actiuni IO

O valoare de tip (IO a) este o actiune care, daca este executata, produce o data de tip a.

Actiunile se comporta asemenea instructiunilor.
Secventele de actiuni de obtin folosind notatia do.

```haskell
pg = do  putStrLn "Numele"
         s <- getLine
         putStrLn ("Hello " ++ s)
```

```
*Main> pg
Numele
Ioana
Hello Ioana
*Main> :t pg
pg :: IO ()
```

➢ **Blocul do**

In general un bloc do poate fi descris ca o secventa de Instructiuni, iar o instructiune poate fi:

- actiune, adica o expresie de tipul IO (de ex: getLine)
- o legatura <- (de ex: s <- getLine)
- o declaratie let (fara in)
- un apel al functiei return

```haskell
pg = do putStrLn "introdu sirul"
        s <- getLine
        let n = length s      -- n este din clasa Num a
            t=n*n
        putStrLn (s ++ " are " ++ (show n) ++ " litere")
```

```
*Main> pg
introdu sirul
abcd
abcd are 4 litere
```

- **Functii monadice: sequence, sequence_, mapM, mapM_, foldM, foldM_**

```
Prelude Control.Monad> [l1,l2,l3] <- sequence [getLine, getLine, getLine]
linia 1
linia 2
linia 3
Prelude Control.Monad> l2
"linia 2"
```

```
Prelude Control.Monad> mapM print [1,2,3]
1
2
3
[(),(),()]
Prelude Control.Monad> mapM_ print [1,2,3]
1
2
3
```

```
Prelude Control.Monad> let g = \x y -> (putStrLn  (x ++ show y)) >> (return $ (x ++ show y))
Prelude Control.Monad> let z = g "a" 4
Prelude Control.Monad> z
a4
"a4"
Prelude Control.Monad> foldM g "a" [1,2,3]
a1
a12
a123
"a123"
```

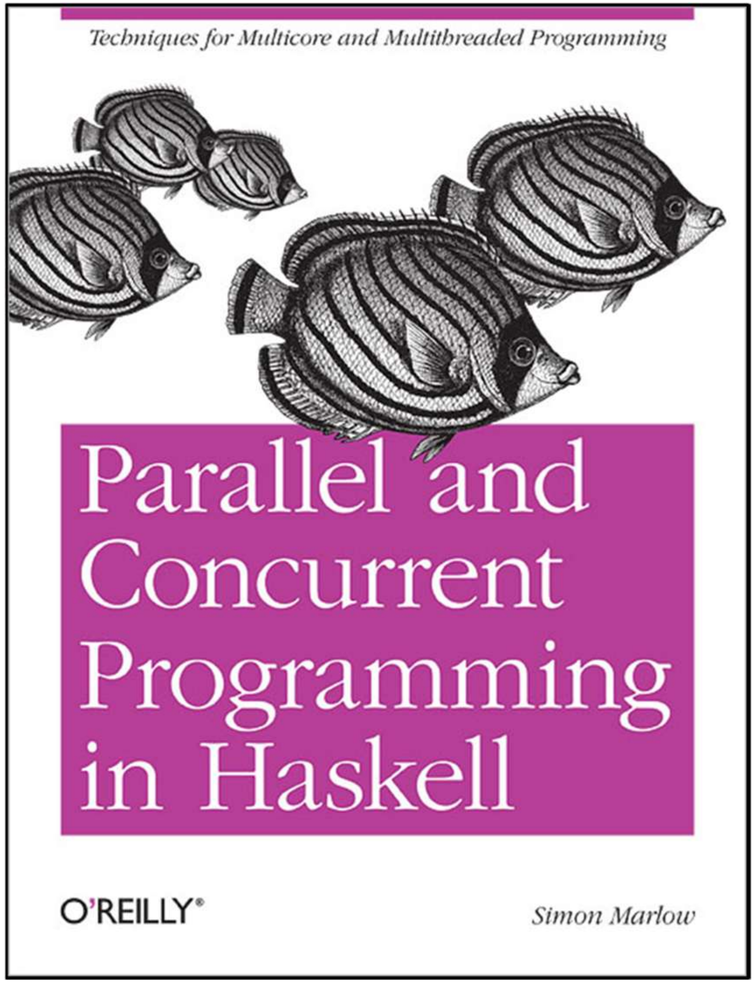
- Variabile mutabile: IORef

```
import Data.IORef
-- variabile mutabile in monada IO

newIORef :: a -> IO (IORef a)
readIORef :: IORef a -> IO a
writeIORef :: IORef a -> a -> IO ()
```

```
add :: IORef Int -> Int ->  IO()
add rref  n = do
              val <- readIORef rref
              writeIORef rref

main = do
          rref <- newIORef 0
          add rref 10
          val <- readIORef rref
          print val
```

"Haskell does not take a stance on which concurrent programming model is best: actors, shared memory, and transactions are all supported, for example."

"Haskell provides all of these concurrent programming models and more - but this flexibility is a double-edged sword. The advantage is that you can choose from a wide range of tools and pick the one best suited to the task at hand, but the disadvantage is that it can be hard to decide which tool is best for the job."



Thread-urile in Haskell:

Thread-urile au efecte si interactioneaza cu lumea exterioara.

Programarea concurenta in Haskell are loc in monada IO.

La rulare, efectele thread-urilor sunt intercalate nedeterminist.

Thread-urile in Haskell sunt create si gestionate intern,
fara a folosi facilitati specifice sistemului de operare.

Implementarea threadurilor asigura verificarea anumitor conditii de corectitudine.

➢ Crearea thread-urilor

forkIO :: IO () -> IO ThreadId

```
Prelude> :m + Control.Concurrent
Prelude Control.Concurrent> :t forkIO
forkIO :: IO () -> IO ThreadId
```

```
import Control.Concurrent
import Control.Monad

main = do
          forkIO (replicateM_ 100 (putChar 'A'))   -- child thread
          replicateM_ 100 (putChar 'B')  -- main thread
```

replicateM

```
Prelude> :m + Control.Monad
Prelude Control.Monad> :t replicateM_
replicateM_ :: Monad m => Int -> m a -> m ()
Prelude Control.Monad> replicateM_ 5 (putStrLn "A")
A
A
A
A
A
```

forkIO :: IO () -> IO ThreadId

```
import Control.Concurrent
import Control.Monad

main = do
        forkIO (replicateM_  100 (putChar 'A'))   -- child thread
        replicateM_ 100 (putChar 'B')  -- main thread
```

```
*Main Control.Monad> main
ABABABABABABABABABABABABABABABABABABABABABABAB
BABABABABABABABABABABABABABABAB
```

La rulari diferite se pot obtine rezultate diferite!

forkIO :: IO () -> IO ThreadId

```haskell
import Control.Concurrent
import Control.Monad

main = do
          forkIO (replicateM_  100 (putChar 'A'))   -- child thread
          replicateM_ 100 (putChar 'B')  -- main thread
```

Daca fisierul se numeste *thread.hs* atunci el poate fi compilat si executat:

ghc thread.hs -threaded
thread

```
C:\Users\igleu\Documents\DIR\ICLP\ICLP2023\haskell2023>ghc thread.hs -threaded
Loaded package environment from C:\Users\igleu\AppData\Roaming\ghc\x86_64-mingw32-8.10
.7\environments\default

C:\Users\igleu\Documents\DIR\ICLP\ICLP2023\haskell2023>thread
BBABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABAB
ABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABAB
ABABABABABABABABABABABABABAA

C:\Users\igleu\Documents\DIR\ICLP\ICLP2023\haskell2023>thread
BBABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABAB
ABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABABAB
ABABABABABABABABABABABABABAA
```

La rulari diferite se pot obtine rezultate diferite!

forkIO :: IO () -> IO ThreadId

myThreadId :: IO ThreadId

```
import Control.Concurrent
import Control.Monad

main = do
          forkIO (replicateM_  100 (myThreadID >>= print))   -- child thread
          replicateM_ 100 (myThreadID >>= print)  -- main thread
```

```
PS C:\Users\igleu\Documents\DIR\ICLP22\Curs-2022\Haskell22\pgh\haskell2022> ./threadID
ThreadId 3
ThreadId 4
ThreadId 3
ThreadId 4
ThreadId 3
ThreadId 4
ThreadId 3
ThreadId 4
ThreadId 3
ThreadId 4
ThreadId 3
ThreadId 4
```

"The computation passed to forkIO is executed in a new thread that runs concurrently with the other threads in the system. If the thread has effects, those effects will be interleaved in an indeterminate fashion with the effects from other threads."
S. Marlow, PCPH

"forkIO is assymetrical: when a process executes a forkIO it spawns a child process that executes concurrently with the continued execution of the parent"
SL Peyton Jones, A Gordon, S Finne, Concurrent Haskell

"**GHC's runtime system treats the program's original thread of control differently from other threads**.
When this thread finishes executing, the runtime system considers the program as a whole to have completed.
If any other threads are executing at the time, they are terminated."
B. O'Sullivan, D. Stewart, J. Goerzen, Real World Haskell

- Interleaving

```
import Control.Concurrent
import Control.Monad

myread1 = do
        putStrLn "thread1"
        s<- getLine
        putStrLn $ "citit 1: " ++ s

myread2 = do
        putStrLn "thread2"
        s<- getLine
        putStrLn $ "citit 2:" ++ s


main = do
          forkIO (replicateM_  10 myread1)
          replicateM_ 10 myread2
```

```
*Main> main
thread1
thread2
e
citit 1: e
thread1
s
citit 2:s
thread2
r
citit 1: r
thread1
e
citit 2:e
thread2
f
citit 1: f
thread1
f
```

- Executie secventiala vs executie concurenta

```haskell
fib 0 =1
fib 1 =2
fib n = fib (n-1) + fib (n-2)

act n =  do
        let x = (fib n)
        putStrLn ("Fib " ++ (show n) ++ " is " ++ (show x))

act4 = do
      act 10
      act 20
      act 30
      act 35
      getLine
```

```haskell
main = do
      forkIO $ act 10
      forkIO $ act 20
      forkIO $ act 30
      forkIO $ act 35
      getLine
```

- Executie secventiala vs executie concurenta

```
act4 = do
      act 10
      act 20
      act 30
      act 35
      getLine

main = do
      forkIO $ act 10
      forkIO $ act 20
      forkIO $ act 30
      forkIO $ act 35
      getLine
```

```
Prelude> :set +s
Prelude> :l test.hs
[1 of 1] Compiling Main          ( test.hs, interpreted )
Ok, one module loaded.
(0.09 secs,)
*Main> act4
Fib 10 is 144
Fib 20 is 17711
Fib 30 is 2178309
Fib 35 is 24157817

""
(115.38 secs, 11,248,521,824 bytes)
*Main> main
FiFFFbiii bbb1   0233 005i   siii sss1   4147
711
2178309
24157817

""
(114.36 secs, 57,352 bytes)
```

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

- Compilare cu -threaded

```haskell
act4 = do
      act 10
      act 20
      act 30
      act 35
      getLine

main = do
      forkIO $ act 10
      forkIO $ act 20
      forkIO $ act 30
      forkIO $ act 35
      getLine
```

```
*Main> :! ghc --make -threaded test.hs
```

programul este compilat cu optiunea **-threaded**

```
> .\test +RTS -N4 -s
Fib 10 is 144
Fib 20 is 17711
Fib 30 is 2178309
Fib 35 is 24157817


  INIT    time    0.000s  (  0.001s elapsed)
  MUT     time    4.672s  (  7.394s elapsed)
  GC      time    0.156s  (  0.120s elapsed)
  EXIT    time    0.000s  (  0.001s elapsed)
  Total   time    4.828s  (  7.515s elapsed)
```

-threaded

"Link the program with the “threaded” version of the runtime system.

The threaded runtime system [...] enables the -N ⟨x⟩ RTS option to be used, which allows threads to run in parallel on amultiprocessor or multicore machine.

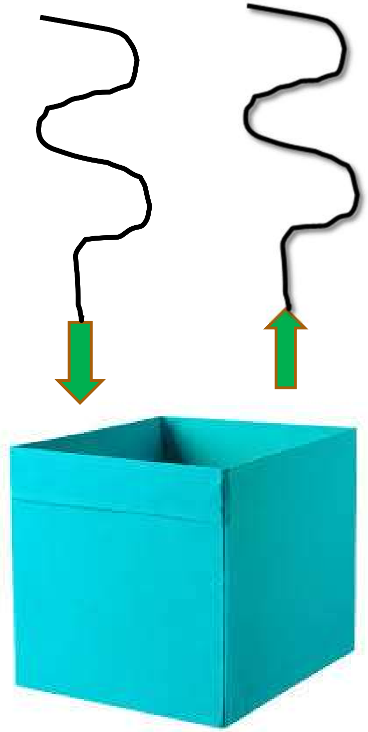
Note that you do not need -threaded in order to use concurrency; the single-threaded runtime supports concurrency between Haskell threads just fine."

https://downloads.haskell.org/~ghc/9.10.1/docs/users_guide/phases.html

"**Concurrent Haskell** is a collective name for the facilities that Haskell provides for programming with multiple threads of control. Unlike parallel programming, where the goal is to make a program run faster by using more CPUs, the goal in concurrent programming is usually to write a program with multiple interactions."

S. Marlow, PCHP

- Comunicarea thread-urilor



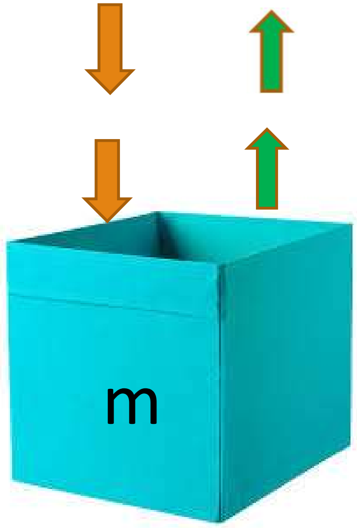
MVar

mutable variable

➢ Comunicarea folosind MVar se face in monada IO

data MVar a

- o data de tipul MVar a reprezinta o locatie mutabila care poate fi goala sau
- poate contine o singura valoare de tip a
- thread-urile pot comunica prin intermediul datelor de tip MVar



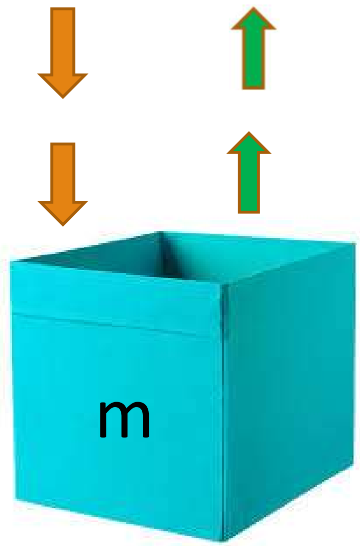
m :: MVar a

poate fi vazuta ca:

- un semafor binar
- un monitor cu o variabila

➢ Comunicarea folosind MVar se face in monada IO

```
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

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

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



➢ takeMVar

- takeMVar este o operatie care blocheaza thread-urile

- takeMVar este *single-wakeup*:
  daca variabila MVar este.. goala, toa.te thread-urile care vor sa execute takeMVar sunt blocate; cand variabila devine plina, un singur thread este trezit si acesta va executa takeMVar

- daca mai multe thread-uri sunt blocate pe acelasi MVar, ele vor fi trezite in ordinea FIFO

https://www.haskell.org/hoogle/?hoogle=MVar

➢ takeMVar vs readMVar

readMVar

Citeste atomic continutul unui MVar.

Daca variabile MVar este goala, thread-ul care apeleaza readMVar va astepta pana cand MVar primeste o valoare si va citi valoarea pusa de urmatoarea operatie putMVar.

readMVar este *multiple-wakeup*, deci toate thread-urile care asteapta sa citeasca din MVar vor fi trezite in acelasi timp.

Implementarea veche

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

Implementarea actuala garanteaza ca readMVar este o operatie atomica.

https://www.haskell.org/hoogle/?hoogle=MVar

- Variabile mutabile: IORef, MVar

```
import Data.IORef
-- variabile mutabile in monada IO

newIORef :: a -> IO (IORef a)
readIORef :: IORef a -> IO a
writeIORef :: IORef a -> a -> IO ()
```

```
add :: IORef Int -> Int -> IO()
add rref n = do
         val <- readIORef rref
         writeIORef rref

main = do
     rref <- newIORef 0
     add rref 10
     val <- readIORef rref
     print val
```

```
import Control.Concurrent.MVar
-- variabile de sincronizare
-- variabile mutabile in monada IO

newEmptyMVar :: IO (MVar a)
newMVar :: a -> IO (MVar a)
takeMVar :: MVar a -> IO a      -- blocheaza thread-ul
putMVar :: MVar a -> a -> IO () -- blocheaza thread-ul
```

```haskell
import Control.Concurrent

main = do
        m <- newEmptyMVar
        forkIO $ do
                putMVar m 'x'
                putMVar m 'y'
        x <- takeMVar m
        print x
        x <- takeMVar m
        print x
```

```
newEmptyMVar :: IO (MVar a)
```

```
putMVar :: MVar a -> a -> IO()
```

```
takeMVar :: MVar a  -> IO a
```

```
*Main> main
'x'
'y'
```

```haskell
import Control.Concurrent

main = do
        m <- newEmptyMVar
        takeMVar m
```

```
*Main> main
*** Exception: thread blocked indefinitely in an MVar operation
```

- **Sincronizare** : doua thread-uri incrementeaza acelasi contor
  vrem sa citim valoarea contorului dupa ce ambele thread-uri au terminat

```
add m  =  replicateM_ 1000 $ do
                                x <- takeMVar m
                                putMVar m (x +1)


main = do
           m <- newMVar 0
           forkIO (add m )
           forkIO (add m )
           x  <- takeMVar m
           print x
```

- Sincronizare : doua thread-uri incrementeaza acelasi contor
  vrem sa citim valoarea contorului dupa ce ambele thread-uri au terminat

```
add m  =  replicateM_ 1000 $ do
                             x <- takeMVar m
                             putMVar m (x +1)

main = do
          m <- newMVar 0
          forkIO (add m )
           forkIO (add m )
           x  <- takeMVar m
           print x
```

```
*Main> :l cont.hs
[1 of 1] Compiling Main
Ok, one module loaded.
*Main> main
0
*Main> main
0
```

- **Sincronizare** : doua thread-uri incrementeaza acelasi contor
  vrem sa citim valoarea contorului dupa ce ambele thread-uri au terminat

```
add m  =  replicateM_ 1000 $ do
                     x <- takeMVar m
                     putMVar m (x +1)

main = do
        m <- newMVar 0
        forkIO (add m )
        forkIO (add m )
        x  <- takeMVar m
        print x
```

```
*Main> :l cont.hs
[1 of 1] Compiling Main
Ok, one module loaded.
*Main> main
0
*Main> main
0
```

trebuie sa ne asiguram ca ambele thred-uri au terminat

- Sincronizare

```
add m  ms1 = do
          replicateM_ 1000 $ do
                   x <- takeMVar m
                   putMVar mv (x +1)
          putMVar ms1 "ok"
```

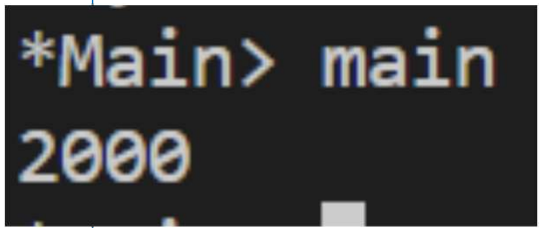
```
main = do
        m <- newMVar 0
        ms1 <- newEmptyMVar
        ms2 <- newEmptyMVar
        forkIO (add m ms1)
        forkIO (add m ms2)
        takeMVar ms1
        takeMVar ms2
        x  <- takeMVar m
        print x
```

variabilele ms1 si ms2 actioneaza ca niste semafoare ; astfel ne asiguram ca ambele thread-uri au terminat

- Sincronizare

```
add m  ms1 = do
            replicateM_ 1000 $ do
                        x <- takeMVar m
                        putMVar mv (x +1)
             putMVar ms1 "ok"
```

```
main = do
        m <- newMVar 0
        ms1 <- newEmptyMVar
        ms2 <- newEmptyMVar
        forkIO (add m ms1)
        forkIO (add m ms2)
        takeMVar ms1
        takeMVar ms2
        x  <- takeMVar m
        print x
```



➢ Sincronizare: doua thread-uri incrementeaza acelasi contor

threadDelay nr
suspenda thread-ul pt.nr microsecunde

```
main = do
        m <- newMVar 0
        ms1 <- newEmptyMVar
        ms2 <- newEmptyMVar
        forkIO (add1 m ms1)
        forkIO (add2 m ms2)
        takeMVar ms1
        takeMVar ms2
        x  <- takeMVar m
        print x
```

```
add1 m  ms1 = do
        replicateM_ 1000 $ do
                x <- takeMVar m
                threadDelay 100 –nu afecteaza sincronizarea
                putMVar mv (x +1)
        putMVar ms1 "ok"
```

Sincronizarea este asigurata de faptul ca ambele thread-uri apeleaza intai takeMVar

```
add2 m ms2   = do
        replicateM_ 1000 $ do
                s<- takeMVar m
                putMVar mv (s + 1)
        putMVar ms2 "ok"
```

➢ 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
```

forever repeta o actiune monadica de un numar infinit de ori

- 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"
```
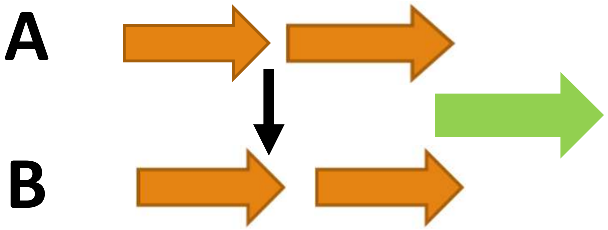

- Comunicarea thread-urilor

primeste o valoare citita **msg**, o pune in **a**

citeste valoarea din **a** si o afiseaza




```
main = do
     aMVar <- newEmptyMVar
     forkIO (threadA aMVar )
     forkIO (threadB aMVar )
     putStrLn ("main thread ends")
     getLine
```

```
threadA a  = do
          putStrLn "mesaj: "
          msg <- getLine
          if (msg == "end")
             then
               putMVar a msg
             else do
                 putMVar a msg
                 threadA a
```

```
threadB a =  do
          x <- takeMVar a
          if x == "end"
             then putStrLn "I will stop now"
             else do
               putStrLn ("primit: " ++ x)
               threadB a
```

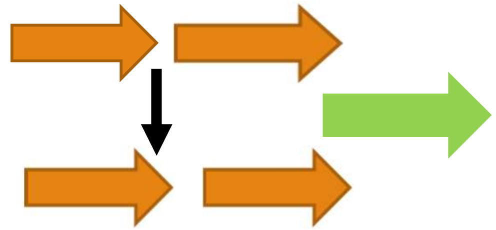
Comunicarea thread-urilor

primeste o valoare citita **msg**, o pune in **a**

A

citeste valoarea din **a** si o afiseaza

B



```
main = do
      aMVar <- newEmptyMVar
      forkIO (threadA aMVar )
      forkIO (threadB aMVar )
      putStrLn ("main thread ends")
      getLine
```

```
threadA a  = do
           putStrLn "mesaj: "
           msg <- getLine
           if (msg == "end")
               then
                 putMVar a msg
               else do
                   putMVar a msg
                   threadA a
```

```
threadB a =  do
          x <- takeMVar a
          if x == "end"
              then putStrLn "I will stop now"
              else do
                putStrLn ("primit: " ++ x)
                threadB a
```

```
*Main> main
mmaeisna jt:h r
ead ends
```

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

➢ Comunicarea thread-urilor

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

```
main = do
    aMVar <- newEmptyMVar
    stdo <- newLock
    forkIO (threadA aMVar stdo)
    forkIO (threadB aMVar stdo)
    putStrLn ("main thread ends")
    getLine
```

```
tswrite stdo msg = do
            aquireLock stdo
            putStrLn msg
            releaseLock stdo

tsread stdo  = do
            aquireLock stdo
            putStrLn "mesaj: "
            msg <- getLine
            releaseLock stdo
            return msg
```

Comunicarea thread-urilor

```haskell
threadA a  s = do
         msg <- tsread s
         if (msg == "end")
            then
              putMVar a msg
            else do
               putMVar a msg
               threadA a
```

```haskell
threadB a s =  do
        x <- takeMVar a
        if x == "end"
           then tswrite s "I will stop now"
           else do
             tswrite s ("primit: " ++ x)
             threadB a
```

```haskell
main = do
    aMVar <- newEmptyMVar
    stdo <- newLock
    forkIO (threadA aMVar stdo )
    forkIO (threadB aMVar  stdo)
    putStrLn ("main thread ends")
    getLine
```

```
*Main> main
main thread ends
mesaj:
m1
"m1"
```

Ce problema de sincronizare poate sa apara?
Thread-ul principal nu asteapta finalizarea activitatii thread-urilor.

➢ Comunicarea thread-urilor

```
threadA a  s = do
             msg <- tsread s
             if (msg == "end")
                  then
                    putMVar a msg
                  else do
                      putMVar a msg
                      threadA a
```

```
threadB a s =  do
             x <- takeMVar a
             if x == "end"
                  then do
                          tswrite s "I will stop now"
                          aquireLock sem
                  else do
                    tswrite s ("primit: " ++ x)
                    threadB a
```

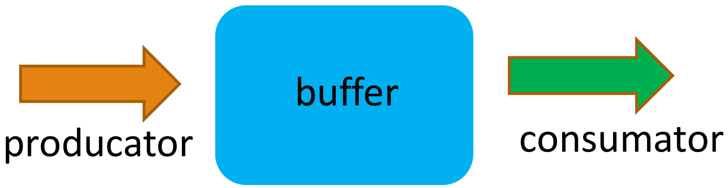
```
main = do
      aMVar <- newEmptyMVar
      stdo <- newLock
      sem <- newLock
      forkIO (threadA aMVar stdo )
      forkIO (threadB aMVar  stdo sem)
      releaseLock sem
      putStrLn ("main thread ends")
      getLine
```

```
*Main> main
mesaj:
m1
mesaj:
m2
primit: m1
mesaj:
end
primit: m2
i will stop now
main thread ends
```

- Producer-Consumer problem
  MVar ca monitor


```
import Control.Concurrent
import Control.Monad


main = do
        m <- newEmptyMVar  --buffer
        forkIO (producer m )
        consumer  m 10 -- consuma 10 produse
```

- Producer-Consumer problem
  MVar ca monitor

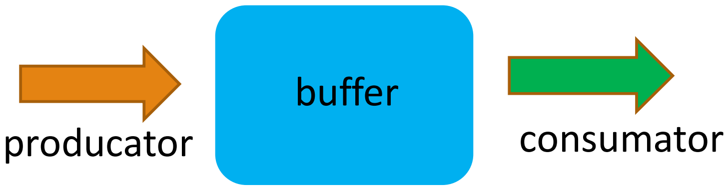



```
import Control.Concurrent
import Control.Monad

main = do
        m <- newEmptyMVar  --buffer
        l <- newLock
        forkIO (producer m )
        consumer  m 10  -- consuma 10 produse
        releaseLock l
       putStrLn "main thread ends"
```

```
producer :: MVar String-> IO ()
producer m = forever $ do
                              mes <- getLine
                              putMVar m mes
```

```
consumer :: MVar String -> Int -> MVar () ->IO()
consumer m  n  l =  if (n == 0)
                        then aquireLock l
                        else
                             do
                              mes <- takeMVar m
                              putStrLn  (">"++ mes)
                              consumer m (n-1)
```

- Producer-Consumer problem
  MVar ca monitor

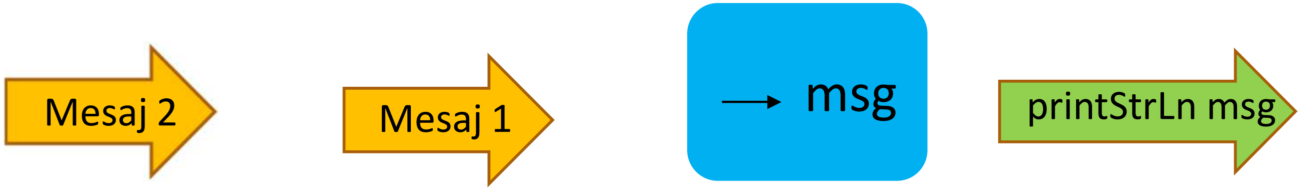



```
*Main> main
m1
>m1
m2
>m2
m3
>m3
m4
>m4
m5
>m5
main thread ends
```

```haskell
import Control.Concurrent
import Control.Monad

main = do
        m <- newEmptyMVar  --buffer
        l <- newLock
        forkIO (producer m )
        consumer  m 5  -- consuma 5 produse
        releaseLock l
       putStrLn "main thread ends"
```

- Sincronizare: serviciu de logare
  modelarea unui canal de comunicare simplu folosind MVar

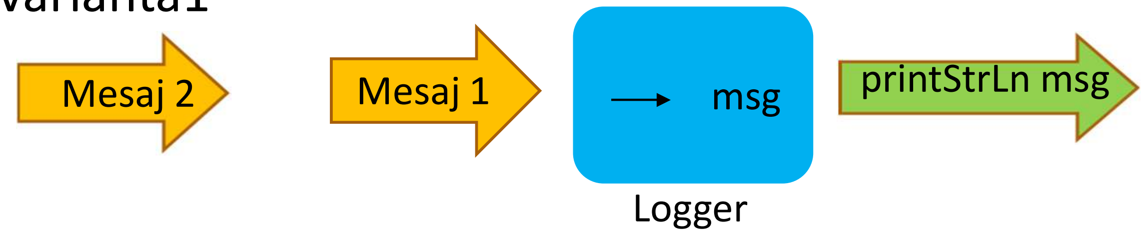
  http://chimera.labs.oreilly.com/books/1230000000929/ch07.html#sec_conc-logger



Cerinte:

- serviciul de logare prelucreaza mesajele intr-un thread separat
- mesajele trebuie prelucrate in ordinea in care sunt logate
- cand programul se termina toate mesajele logate trebuie sa fie prelucrate

Exemplu: serviciu de logare – varianta1




```
data Logger = Logger MVar  String
```

```
initLogger  ::  IO Logger
initLogger = do
              m <- newEmptyMVar

              let log = Logger m        -- log =
```


```
             forkIO (logger log)       -- creeaza
```


```
             return log

logger  :: Logger -> IO()  -- prelucreaza mesajele din Logger
```

```
logger :: Logger -> IO ()
logger (Logger m) = loop
                   where
                      loop = do
                           msg<- takeMVar m
                           putStrLn msg
                           loop
```

Exemplu: serviciu de logare- varianta1


```
logMessage :: Logger -> String -> IO ()
logMessage (Logger m) s = putMVar m s

logMessThread:: Logger -> IO()
logMessThread  l = do
                msg <- getLine
                if (msg == "bye")
                then return()
                else do
                     logMessage log msg
                     logMessTh log
main = do
         log <- initLogger
         logMessThread log
```

Creaza thread-ul logger

Thread-ul principal trimite messajele

```
data Logger = Logger MVar  String

initLogger :: IO Logger
initLogger = do
             m <- newEmptyMVar
             let log = Logger m
             forkIO (logger log)
             return log

logger :: Logger -> IO ()
logger (Logger m) = loop
                    where
                       loop = do
                              msg<- takeMVar m
                              putStrLn msg
```

Thread-ul logger le citeste si le scrie

Exemplu: serviciu de logare- varianta1


```
logMessage :: Logger -> String -> IO ()
logMessage (Logger m) s = putMVar m s

logMessThread:: Logger -> IO()
logMessThread log = do
                msg <- getLine
                if (msg == "bye")
                then return()
                else do
                     logMessage log msg
                     logMessTh log
main = do
        log <- initLogger
        logMessThread log
```

```
data Logger = Logger MVar  String

initLogger :: IO Logger
initLogger = do
            m <- newEmptyMVar
            let log = Logger m
            forkIO (logger log)
            return log
logger :: Logger -> IO ()
logger (Logger m) = loop
                  where
                     loop = do
                          msg<- takeMVar m
                          putStrLn msg
                          loop
```

Ce problema de sincronizare poate sa apara?

Exemplu: serviciu de logare- varianta1


```
logMessage :: Logger -> String -> IO ()
logMessage (Logger m) s = putMVar m s

logMessThread:: Logger -> IO()
logMessThread log = do
                msg <- getLine
                if (msg == "bye")
                then return()
                else do
                    logMessage log msg
                    logMessTh log
main = do
        log <- initLogger
        logMessThread log
```

```
data Logger = Logger MVar  String

initLogger :: IO Logger
initLogger = do
            m <- newEmptyMVar
            let log = Logger m
            forkIO (logger log)
            return log
logger :: Logger -> IO ()
logger (Logger m) = loop
                 where
                    loop = do
                        msg<- takeMVar m
                        putStrLn msg
                        loop
```

programul nu se asigura ca toate mesajele logate sunt prelucrate

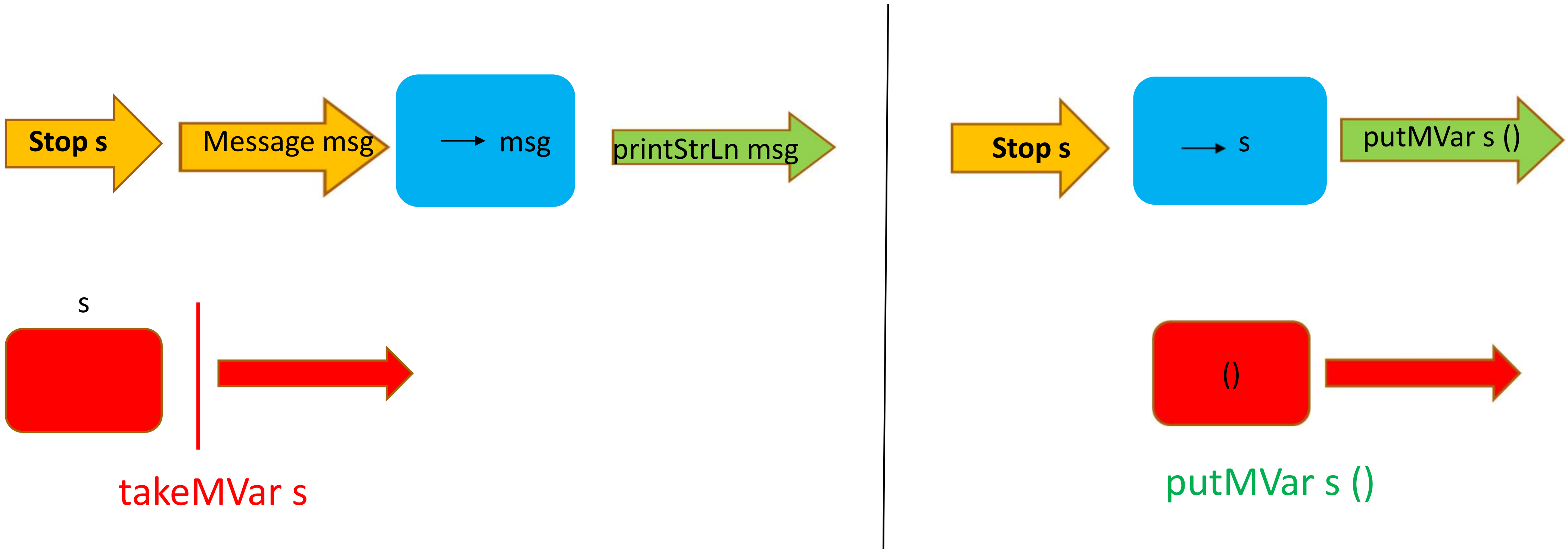
- Exemplu: serviciu de logare

```haskell
logMessage :: Logger -> String -> IO ()
logMessage (Logger m) s = putMVar m s

logMessThread:: Logger -> IO()
logMessThread log = do
                msg <- getLine
                if (msg == "bye")
                then logStop log
                else do
                     logMessage log msg
                     logMessTh log
```

```haskell
-- la fel

initLogger :: IO Logger
initLogger = do
              m <- newEmptyMVar
              let log= Logger m
              forkIO (logger log)
              return log

main = do
         log <- initLogger
         logMessTh log
```

Exemplu: serviciu de logare

```
data Logger = Logger (MVar LogCommand)
data LogCommand = Message String | Stop  (MVar ())
```



➢ Exemplu: serviciu de logare

```
data Logger = Logger (MVar LogCommand)
data LogCommand = Message String | Stop  (MVar ())
```

```
logMessage :: Logger -> String -> IO ()
logMessage (Logger m) s = putMVar m s

logMessThread:: Logger -> IO()
logMessThread log = do
            msg <- getLine
            if (msg == "bye")
            then logStop log
            else do
                logMessage log msg
                logMessTh log
```

```
logStop :: Logger -> IO ()
logStop (Logger m) = do
            s <- newEmptyMVar
            putMVar m (Stop s)
            takeMVar s
```

```
logMessage :: Logger -> String -> IO ()
logMessage (Logger m) s = putMVar m (Message s)
```

Exemplu: serviciu de logare

```haskell
data Logger = Logger (MVar LogCommand)
data LogCommand = Message String | Stop  (MVar ())
```

```haskell
logger :: Logger -> IO ()
logger (Logger m) = loop
        where  loop = do
                 cmd <- takeMVar m
                 case cmd of
                   Message msg -> do
                             putStrLn  ("mesaj: " ++ msg)
                             loop
                   Stop s -> do
                         putStrLn "logger: stop"
                         putMVar s ()
```

Thread-ul logger va debloca s cand cand ajunge la Stop s

```haskell
logStop :: Logger -> IO ()
logStop (Logger m) = do
           s <- newEmptyMVar
           putMVar m (Stop s)
           takeMVar s
```

logger.hs ©2012, Simon Marlow

```
*Main> main
mes:
mes1
mesm:e
saj: mes1
mes2
memseasj::
 mes2
mes3
mesm:e
saj: mes3
bye
```

```haskell
stdo <- newMVar ()

tswrite stdo s = do
            takeMVar stdo
            putStrLn s
            putMVar stdo ()
```

```
*Main> main
mes:
mesajul 1
mesaj: mesajul 1
mes:
mesajul 2
mes:
mesaj: mesajul 2
mesajul 3
mes:
mesaj: mesajul 3
mesajul 4
mes:
mesaj: mesajul 4
bye
```

➢ 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 ()

➢ Exemplu: **QSem**

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

```haskell
import Control.Concurrent
import Control.Monad


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

➢ 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]
```

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....
```

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 acceseze 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 ) [1..workers]
```

q este semaforul care controleaza resursele

```
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....
```

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."
```

q este semaforul care controleaza resursele
stdo coordoneaza accesul la stdout

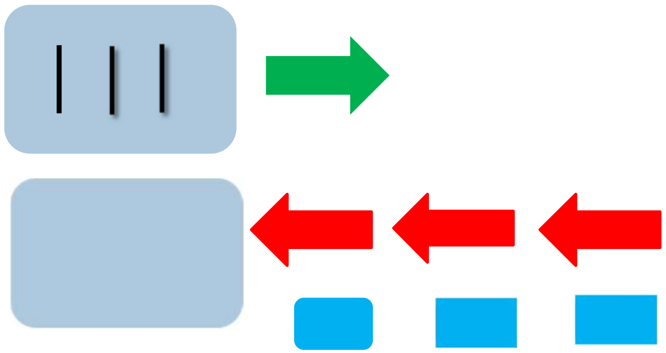
http://rosettacode.org/wiki/Metered_concurrency

```
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