Modular Evaluation and Interpreters Using Monads and Type Classes

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based on papers provided by the Haskell community and some other resources.
Anglo Haskell 2008

Universitatea din Bacău

Abstract

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As a consequence of our research, we are able to introduce a new kind of *modular interpreter or expression evaluator*, which can be build by importing *modular components* into a main Haskell program.

Modularity,OK ! But how to get it ?:

1) Modular parser = ?   Problem solved ! Parser comb.

2) Modular trees = ? Nobody seems to try it !

3) Modular implementation of the interpreter = ?

interpret :: Term -> Env -> M Value – not modular

should be replaced by something else.

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3)This gave us the general idea of *the replacement of data constructors by functions over monadic actions*, called by us *"pseudoconstructors"*.

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As a consequence, the useful data declarations which usually appears in DSL implementations are completely missing, shortening the source and reducing the work of the programmer.

1) Tree declarations like this are harmfull (from the modularity point of view)

```
data Exp =  Constant Int
          | Variable String
          | Minus Exp Exp
          | Greater Exp Exp
          | Times Exp Exp
          deriving Show
```

1') Drop the declarations like this one,too !

```
data Com =  Assign String Exp
         | Seq Com Com
         | Cond Exp Com Com
         | While Exp Com
         | Declare String Exp Com
         | Print Exp
        deriving Show
```

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Plus :: Exp -> Exp -> Exp

will be replaced by a plus:

plus :: [a] -> [a] -> [a] or a plus :: M a -> M a -> M a

2) A new vision of monadic semantics . Consequences:

1. The data declarations of the trees will be absent being replaced by a set of functions.

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          | Times Exp Exp
```

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. . . are replaced by . . .

```
constant :: Integer -> [Integer]

variable :: String  -> [Integer]

minus :: [Integer] -> [Integer] -> [Integer]

greater  :: [Integer] -> [Integer] -> [Integer]

times  :: [Integer] -> [Integer] -> [Integer]
```

2) A new vision of monadic semantics . Consequences:

1. The data declarations of the trees will be absent being replaced by a set of functions. . . . or even more generally . . .

```
constant :: Integer -> M Integer
variable :: String  -> M Integer
minus :: M Integer -> M Integer -> M Integer
greater :: M Integer -> M Integer -> M Integer
times  :: M Integer -> M Integer -> M Integer
```

... M being an other monad, not only the list monad.

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So: Minus (Variable "x") (Variable "y")

will be replaced by a slightly different version:

minus (variable "x") (variable "y") (*)

where minus, variable and so ...are called "pseudoconstructors".

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where minus, variable and so ...are called “pseudoconstructors”.

Remark: The relation (*) are representing *both syntax* (being unevaluated) *and semantics* (when Haskel's lazy evaluation mechanism decides to compute the final value) in the same time!

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2. There is no needs for such functions to be together, in the same module.

We can describe / declare:

log :: [Float] -> [Float] -> [Float]   in a module and
plus :: [Float] -> [Float] -> [Float]   in an other module

and still be able to mix them in syntax and computations:

(plus (variable “x”) (log (constant 2)(variable “y”))

2) A new vision of monadic semantics . Consequences:

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Or even more, we can describe / declare:

log :: [Float] -> [Float] -> [Float]   in a module and
plus :: [Float] -> [Float] -> [Float]   in an other module

and still be able to mix them in syntax and computations:

(plus (variable “x”) (log (constant 2)(variable “y”))
. . . M being any other selected monad . . . .

2) A new vision of monadic semantics . Consequences:

1. The data declarations of the trees will be absent, being replaced by a set of functions.
2. There is no needs for such functions to be together, in the same module.
We can spread such functions in different modules, providing modularity.And, last but not least, because of the monad:

3. We can use the do-notation in order to express computations:

```
plus x y  =   do { vx <-  x;
                   vy <-  y;
                   return  (vx +  vy); }
                    :: [Float]
```

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3.Remember: The traditional solution was usually more complex and all those “do”-s were stick together in the same function.

```
do { vx <- interp x env;
     vy <- interp y env;
     return  (vx +  vy); }     :: M Float
```

2) A new vision of monadic semantics. Conclusions:

A new vision of monadic semantics is now introduced. The semantics is not a function:

interp :: Term -> Environment -> Monad

but more likely a sort of

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specification in contrast with the papers [P.W.123] of Philip. Wadler.

Remember idea and definition of pseudoconstructors functions over monadic actions. The pseudoconstructors are replacing the data values constructors from the right side of a data declaration.

3)Where is the environment when we need it ?

```
plus x y =  do {      vx <-  x;
                      vy <-  y;
                      return  (vx +  vy); }
                            :: M Float
```

The code seems to have the environment hidden or no environment at all !

Idea: If an *environment* is needed (and usually it is !) the list monad may be replaced with an other state or writer monad. Anyway, for simple expres-sions using constants and operators the list monad is enough.

4) May we have overloaded functions ?

Usually, some arithmetic operators are overloaded:

```
plus x y  =   do { vx <-  x;
                   vy <-  y;
                   return  (vx +  vy); }
                    :: [Float]


plus x y  =   do { vx <-  x;
                   vy <-  y;
                   return  (vx +  vy); }
                    :: [Integer]
```

Can we use two or more kind of plus in different modules?

4) May we have overloaded functions ? Answer: YES, using multiparameter type classes

```
module MyPlusFloat where
import MyFloat
import ClassPlus

instance Plus Float Float Float where
  plus x y  =   do { vx <-  x;
                     vy <-  y;
                     return  (vx +  vy); }
                             :: [Float]

Exercise: Write similars modules: MyPlusInt,
  MyPlusChar, MyPlusComplex, ...
```

4) May we have overloaded functions ? Answer: YES, using multiparameter type classes

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import MyFloat
import ClassPlus

instance Plus Float Float Float where
  plus x y  =   do { vx <-  x;
                     vy <-  y;
                     return  (vx +  vy); }
                              :: [Float]

-- Example: modular specification for an
  overloaded "plus" using a multiparameter
  type class: ClassPlus. It looks like...
```

4) Example: modular specification for an overloaded "plus" using a multiparameter type class: ClassPlus. It looks like...

```
module ClassPlus where

class Plus a b c where
  plus :: [a] -> [b] -> [c]

{-------------------------------------------
  A triple of types a b c belongs to the Plus
  Class "ClassPlus" if (and only if)
  there exist a function "plus" having the
  signature as above.
  The hypothesis that three types belongs (as
  a triple) to the ClassPluss will be
  provided by an instantiation of that
  class ...Pleas go back to see it again !!!
--}
```

4) May we have overloaded functions ? YES, even with a different monad, M.

```
module ClassPlus where

class Plus a b c where
  plus :: M a -> M b -> M c

{-----------------------------------------
 You are free to use any traditionaly used
  monad, for example the StOut monad from the
  paper of [Tim Sheared], or any other monad
  built by help of transformers.

--}
```

4) But how are the numbers defined ?

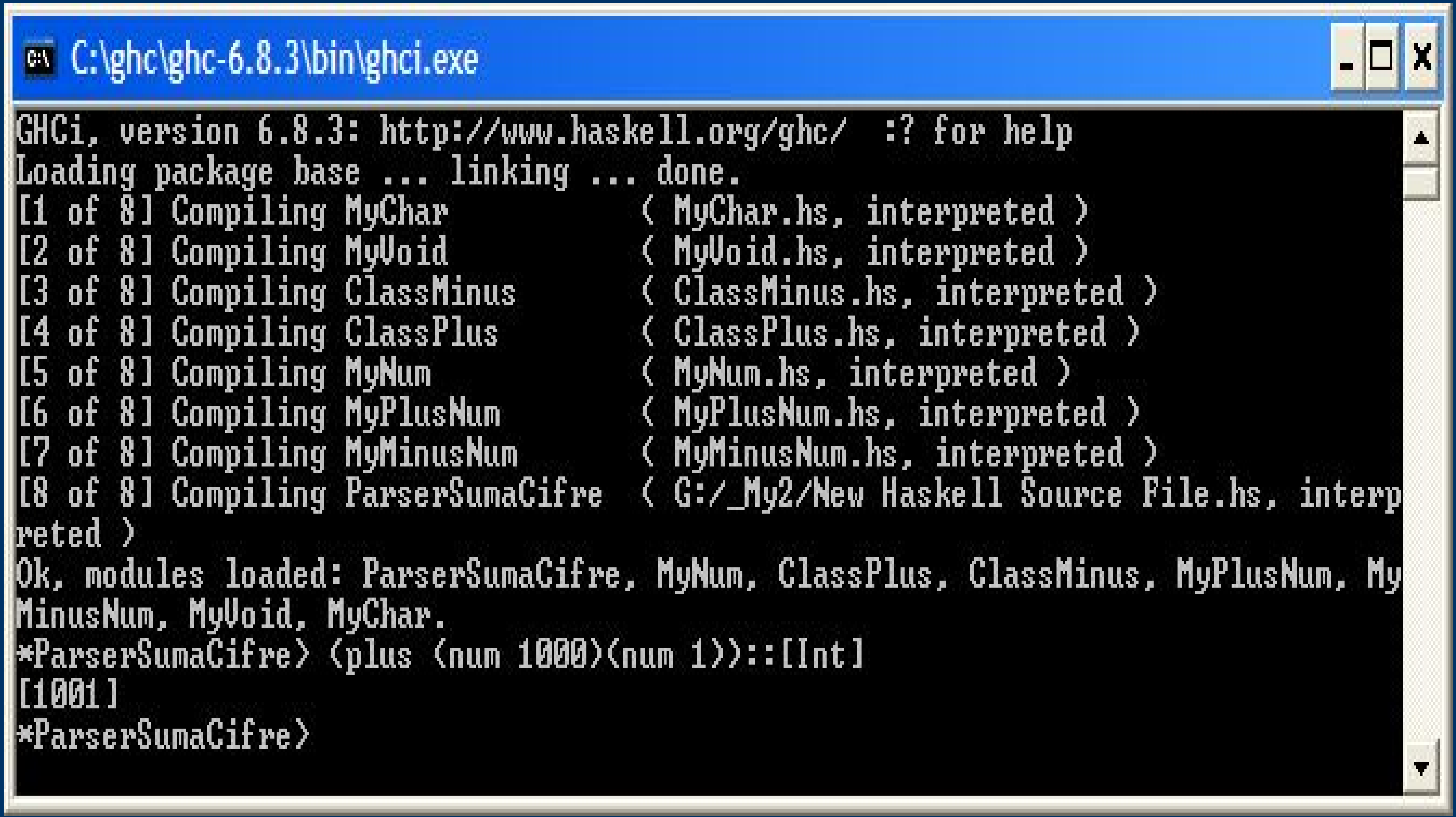
4) But how are the numbers defined ? First solution:

```
module MyNum where
--- Modular evaluator for Integers producing
  monadic values [Integer] in the list monad.

evalnum :: Integer -> [Integer]
evalnum x = [x]

---The pseudoconstructor is producing monadic
  values, in this case (one element) lists .

constant :: Integer -> [Integer]
constant x     = do { vx <- evalnum x ;
                      return vx ; }

...well,we will not discuss optimization,yet!
```

4)When an evaluator / interpreter is build all the requierd modules are used:

```
module ParserSumaCifre where      --main prg.
import Monad                      --use monads,
import ParseLib                   --parsers,
import MyNum                      --numbers,
import ClassPlus                  --plus,
import ClassMinus                 --minus:
import MyPlusNum                  --one plus
import MyMinusNum                 --one minus


-- Remark: Other parser combinators (like
  Parsec) may be used instead of ParseLib, or
  we can work only with pseudoconstructors:
```

4') Run an evaluation: pseudoconstructor and overloading specification



4'') Optimizing a module using monad's laws:

```
module MyChar where
evalchar :: Char -> [Char]
evalchar x = [x]
----Old implementation of the pseudoconstructor
--char ::Char -> [Char]
--char x = do { vx <- evalchar x;
--                  return vx; }    ----Applying monad's law  =>

----New implementation of the pseudoconstructor
char ::Char -> [Char]
char x = [x]
```

5)Have we lost space, gaining modularity?

Three solutions was compared:

Cyclam = Standard evaluator:
Parser , Trees, Integer

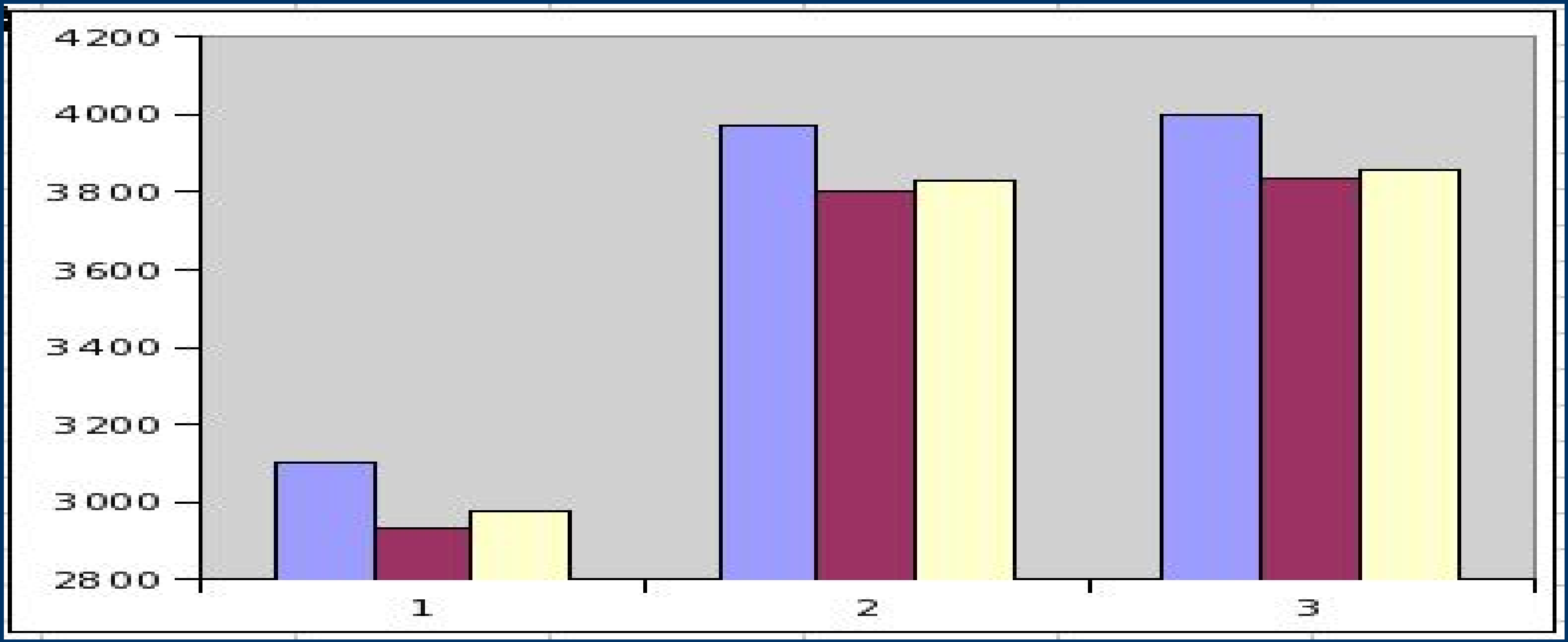
Yellow = Modified std.evaluator:
Parser, Trees, [Integer], Lists
--to see how much overload is got by lists

Magenta = New monadic evaluator:
Parser, no Trees, Modularity, [Integer],ListMonad

5) Space consumed adding lists and modularization: Conclusions

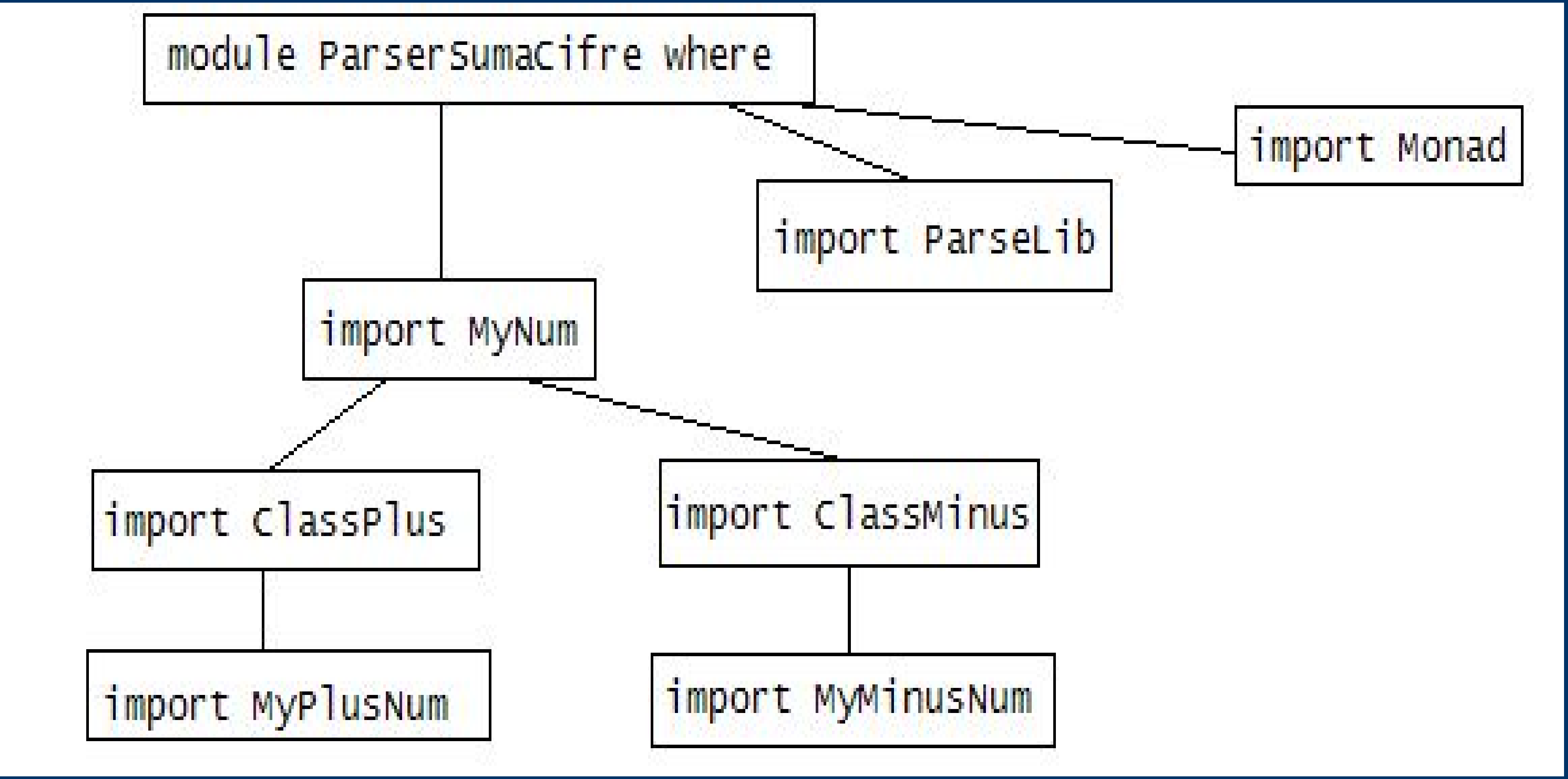
Ading lists increases space with aprox 2.5%

Adding modularity increases space again with aprox 2-3%



5') Final conclusion: +10% space is an acceptable price for the modularity of the languages

Diagram of our small example:



6)Anexa: Traditional evaluator

Usually, an evaluator receive an expresion, a context and produces a result stored by a monadic “capsule”.

```
eval1            :: Exp -> Index -> M Int
eval1 exp index = case exp of
                     Constant n  -> return n
                     Variable x  -> let loc = position x index
                                    in getfrom loc
                     Minus x y   -> do { a <- eval1 x index ;
                                         b <- eval1 y index ;
                                         return (a-b) }
```

6)Anexa: Traditional evaluator (cont.)

```
Greater x y -> do { a <- eval1 x index ;
                    b <- eval1 y index ;
                    return (if a > b
                            then 1
                            else 0) }
Times x y   -> do { a <- eval1 x index ;
                    b <- eval1 y index ;
                    return ( a * b )  }
```

6) Selective Bibliography:

References, names, papers, books, sites used:

- Peyton Jones Simon : Haskell 98 Language and Libraries- The Revised Report, Cambridge , September 2002
- Leijen Daan – a lot of papers concerning Parsec
- Tim Sheard and Abidine, DSL implementation using staging and monads...
- Hutton Graham; Meijer Erik - a lot of papers on monadic parsing
- Peyton Jones Simon - The History of Haskell
- Espinosa David, Semantic Lego, PhD Thesis, Columbia University, 1995
- haskell org – pages including those of monad laws
- Autrijus/Audrey Tang- all about Perl 6
- Philip Wadler - a lot of papers concerning monadic interpreters
- Zenger Matthias – his Ph.D Thesis

- Extra readings: -- interpreters evaluators and virtual machines, the list monad

... sorry if somebody else is missing...