master course

Functional Languages

in english (also exams)
6 credits

what will we learn

- we explore the «joys» of the functional approach using Haskell as vehicle
- learn about pure, lazy languages (but also some impure things are needed)
- that types are useful for many things, among which debugging, polymorphism, and subtyping

- that types are inferred automatically (and we see how)
- we will also see how Haskell is compiled (project?)
- learn something about run-time management

Material

Programming in Haskell
by Graham Hutton, Cambridge Univ. Press, 2ns edition

Learn you a Haskell for great good
by Miran Lipovaca
http://learnyouahaskell.com/chapters

- Course CIS194 of University of Pennsylvania

http://www.seas.upenn.edu/~cis194/spring13/lectures.html

- http://www.seas.upenn.edu/~cis194/fall16/

- Real World Haskell

by Bryan O'Sullivan, Don Stewart, and John Goerzen

http://book.realworldhaskell.org/read/

- slide del corso altro materiale sul moodle : elearning.studenti.math.unipd.it/labs

- per l'ambiente GHC di Haskell (Glasgow Haskell Compiler)

https://www.haskell.org/ghc/

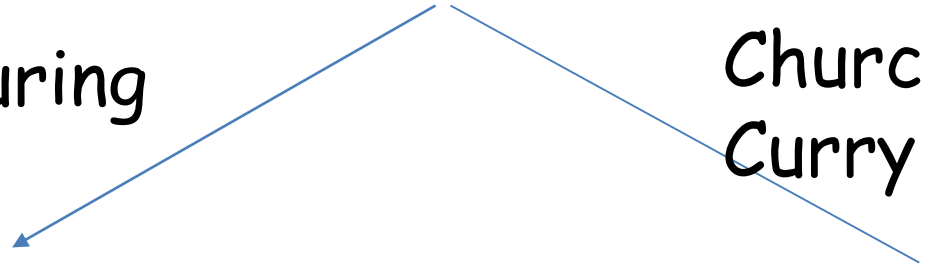
my mail: gilberto@math.unipd.it

- exam

  written exam + project
  (+ homeworks?)

Put the course in a historical context

in the 1930's the big problem was to define computable functions



computer model

with mutable memory

rules to define

and compose functions

all is immutable

lambda-calculus

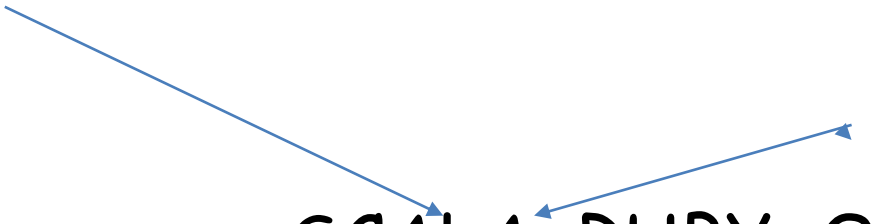
they define the same set of functions that are therefore, the computable functions

dai modelli di computer si passa a computer veri

dal lambda-calculus

FORTRAN
Pascal
C
Modula
C++
Java

LISP
ISWIM
FP
ML
Miranda
Haskell 87
Haskell report
2003 and 2010



SCALA, RUBY, Occaml

A taste of Haskell

1. Summing lists of numbers

```
sum [] = 0
sum (n:ns)= n + sum ns

sum [1,2,3]
= {applying sum}
  1 + sum [2,3]
= {applying sum}
 1 + (2 + sum [3])
= 1 + (2 + (3 + sum [])) = 1 + (2 + (3+0))
= {applying +}
  6
```

:t sum
Num a => [a] -> a

for any type a of numbers

Haskell supports many types of numbers
integers and floating point

type is inferred automatically from 0 and +

types are useful to find errors:
sum [‘a‘, ‘b’] ➔ error

2. Sorting values

```
qsort [] = []
qsort (x:xs) = qsort smaller ++ [x] ++qsort larger
                    where
                         smaller = [a | a <-xs, a<=x]
                         larger   = [b | b <- xs, b>x]
```

++ = list concatenation

where is a keyword that introduces local definitions

[a | a <-xs, a<=x] is list comprehension

qsort implements the quick-sort algorithm

```
----qsort [x] = [x]
```

```
qsort [x]
= {applying qsort}
qsort [] ++ [x] ++ qsort []
= {applying qsort}
[] ++ [x] ++ []
= {applying ++}
[x]
```

```
qsort [3,5,1,4,2]
={applying qsort}
qsort [1,2] ++ [3] ++ [5,4]
={applying qsort}
(qsort [] ++ [1] ++ qsort [2]) ++ [3]
  ++ (qsort [4] ++ [5] ++ qsort [])
={applying qsort and above property}
([] ++ [1] ++ [2]) ++ [3] ++ ([4] ++ [5] ++ [])
= {applying ++}
[1,2] ++ [3] ++ [4,5]
= {applying ++}
[1,2,3,4,5]

:t qsort
qsort :: Ord a => [a] ->[a]
```

Ord is the class of all types whose values have a total order

numbers, characters. strings are ordered types

3. Sequencing actions

```
seqn [] = return []
seqn (act: acts) = do  x <- act
                       xs <- seqn acts
                       return (x:xs)
```

```
seqn [getChar, getChar, getChar]
```

reads the next to char from standard input and returns their list

```
:t seqn
seqn :: [IO a] -> IO [a]   seqn has side effect
```

IO type shows functions with side effect

IO type shows that seqn is doing i/o, i.e. operations with side effects

but seqn can do more

```
: t seqn
seqn :: Monad m => [m a] -> m [a]
```

Monad is a particular type class, IO is a monad

seqn is a generic function

functional languages are pure
--don't have storable and mutable variables, they only have names that hold a constant value, instead of changing the values of variables, new values are computed

--functions don't produce side-effects

advantages: abstraction, simplicity, correctness, parallel implementation

disadvantages: difficult relation with i/o and exceptions

Haskell solves this problem and by means of the IO type allows to combine elegantly pure and inpure parts (in particular i/o)

Glasgow Haskell Compiler

www.haskell.org

GHC = compiler
GHCi = interpreter

once installed, ghci runs the interpreter

Prelude> here we can type expressions that are immediately executed
>2+4
6
Prelude is a library

Prelude contains many built-in functions

```
>head  [1,2,3]
1
>tail [1,2,3]
[2,3]
>[1,2,3] !! 1
2
>take 2 [1,2,3]
[1,2]
>drop 2 [1,2,3]
[3]
>length [1,2,3]
3
>sum [1,2,3]
6
```

```
>[1,2] ++ [3,4]
[1,2,3,4]
>reverse [1,2,3,4]
[4,3,2,1]
```

Notation

in mathematics f(a,b) +cd

in Haskell f a b + c*d

function application has higher priority than all other operations
f a + b ??

f a g x ?? f a (g x)

Haskell scripts .hs

we write in file test.hs

```
double x = x + x
quadruple x = double (double x)
```

ghci test.hs

```
>quadruple 10
40
>take (double 2) [1,2,3,4]
[1,2,3,4]
```

reload
variables and functions start with lower-case letters, after there may be letters, digits, _, '

layout is very important

```
a = b + c
      where
        b=1
        c=2
d=a * 2
```

```
a= b + c
      where
         {b=1;
         c=2 };
d=a * 2
```

comments : -- or {-.....-}