EDAF40

2nd June 2017

14:00 - 19:00

WRITE ONLY ON ONE SIDE OF THE PAPER - the exams will be scanned in and only the front/ odd pages will be read.

DO NOT WRITE WITH OTHER COLOUR THAN BLACK - coloured text may disappear during scanning

PUT YOUR ID AND PAGE NUMBER ON EACH PAGE YOU SUBMIT - make sure that the amount of pages is equal to the amount you note on the front information page

WRITE CLEARLY - if we cannot read you we cannot grade you.

PRELIMINARY AMOUNT OF POINTS: 6 (1,5 + 1 + 1 + 1 + 1,5)

```
{-A list of selected functions from the Haskell modules:
  Prelude
  Data.List
  Data.Maybe
  Data.Char -}
-------------------------------------------------------
-- standard type classes
class Show a where
  show :: a -> String

class Eq a where
  (==), (/=)           :: a -> a -> Bool

class (Eq a) => Ord a where
  (<), (<=), (>=), (>) :: a -> a -> Bool
  max, min             :: a -> a -> a

class (Eq a, Show a) => Num a where
  (+), (-), (*)        :: a -> a -> a
  negate               :: a -> a
  abs, signum          :: a -> a
  fromInteger          :: Integer -> a

class (Num a, Ord a) => Real a where
  toRational           :: a -> Rational

class (Real a, Enum a) => Integral a where
  quot, rem            :: a -> a -> a
  div, mod             :: a -> a -> a
  toInteger            :: a -> Integer

class (Num a) => Fractional a where
  (/)                  :: a -> a -> a
  fromRational         :: Rational -> a

class (Fractional a) => Floating a where
  exp, log, sqrt       :: a -> a
  sin, cos, tan        :: a -> a

class (Real a, Fractional a) => RealFrac a where
  truncate, round      :: (Integral b) => a -> b
  ceiling, floor       :: (Integral b) => a -> b

-----------------------------------------------------
-- numerical functions

even, odd   :: (Integral a) => a -> Bool
even n      = n `rem` 2 == 0
odd         = not . even
-------------------------------------------------------
-- monadic functions

sequence     :: Monad m => [m a] -> m [a]
sequence     = foldr mcons (return [])
                 where mcons p q = do x <- p; xs <- q; return (x:xs)

sequence_    :: Monad m => [m a] -> m ()
sequence_ xs = do sequence xs; return ()

------------------------------------------------------
-- functions on functions

id         :: a -> a
id x       = x

const      :: a -> b -> a
const x _  = x

(.)        :: (b -> c) -> (a -> b) -> a -> c
f . g      = \x -> f (g x)

flip       :: (a -> b -> c) -> b -> a -> c
flip f x y = f y x

($)        :: (a -> b) -> a -> b
f $ x      = f x

-----------------------------------------------------
-- functions on Bools

data Bool = False | True

(&&), (||)  :: Bool -> Bool -> Bool
True  && x  = x
False && _  = False
True  || _  = True
False || x  = x
not         :: Bool -> Bool
not True    = False
not False   = True

------------------------------------------------------
-- functions on Maybe
data Maybe a = Nothing | Just a

isJust              :: Maybe a -> Bool
isJust (Just a)     = True
isJust Nothing      = False

isNothing           :: Maybe a -> Bool
isNothing           = not . isJust

fromJust            :: Maybe a -> a
fromJust (Just a)   = a

maybeToList         :: Maybe a -> [a]
maybeToList Nothing  = []
maybeToList (Just a) = [a]
```

```
listToMaybe          :: [a] -> Maybe a
listToMaybe []       = Nothing
listToMaybe (a:_)    = Just a

--------------------------------------------------------
-- a hidden goodie

instance Monad [] where
  return x = [x]
  xs >>= f = concat (map f xs)

---------------------------------------------------------
-- functions on pairs

fst         :: (a, b) -> a
fst (x, y)  = x

snd         :: (a, b) -> b
snd (x, y)  = y

curry       :: ((a, b) -> c) -> a -> b -> c
curry f x y = f (x, y)

uncurry     :: (a -> b -> c) -> (a, b) -> c
uncurry f p = f (fst p) (snd p)
---------------------------------------------------------
-- functions on lists

map      :: (a -> b) -> [a] -> [b]
map f xs = [ f x | x <- xs ]

(++)             :: [a] -> [a] -> [a]
xs ++ ys         = foldr (:) ys xs

filter           :: (a -> Bool) -> [a] -> [a]
filter p xs      = [ x | x <- xs, p x ]

concat           :: [[a]] -> [a]
concat xss       = foldr (++) [] xss

concatMap        :: (a -> [b]) -> [a] -> [b]
concatMap f      = concat . map f

head, last       :: [a] -> a
head (x:_)       = x

last [x]         = x
last (_:xs)      = last xs

tail, init       :: [a] -> [a]
tail (_:xs)      = xs

init [x]         = []
init (x:xs)      = x : init xs

null             :: [a] -> Bool
null []          = True
null (_:_)       = False

length           :: [a] -> Int
length []        = 0
length (_:l)     = 1 + length l

(!!)             :: [a] -> Int -> a
(x:_)  !! 0      = x
(_:xs) !! n      = xs !! (n-1)

foldr            :: (a -> b -> b) -> b -> [a] -> b
foldr f z []     = z
foldr f z (x:xs) = f x (foldr f z xs)

foldl            :: (a -> b -> a) -> a -> [b] -> a
foldl f z []     = z
foldl f z (x:xs) = foldl f (f z x) xs

iterate          :: (a -> a) -> a -> [a]
iterate f x      = x : iterate f (f x)

repeat           :: a -> [a]
repeat x             = xs where xs = x:xs

replicate            :: Int -> a -> [a]
replicate n x        = take n (repeat x)

cycle                :: [a] -> [a]
cycle []             = error "Prelude.cycle: empty list"
cycle xs = xs' where xs' = xs++xs'

take, drop           :: Int -> [a] -> [a]
take n _ | n <= 0    = []
take _ []            = []
take n (x:xs)        = x : take (n-1) xs

drop n xs | n <= 0   = xs
drop _ []            = []
drop n (_:xs)        = drop (n-1) xs

splitAt              :: Int -> [a] -> ([a],[a])
splitAt n xs         = (take n xs, drop n xs)

takeWhile, dropWhile :: (a -> Bool) -> [a] -> [a]
takeWhile p []       = []
takeWhile p (x:xs)
      | p x          = x : takeWhile p xs
      | otherwise    = []

dropWhile p []       = []
dropWhile p xs@(x:xs')
      | p x          = dropWhile p xs'
      | otherwise    = xs
```

```
lines, words         :: String -> [String]
-- lines "apa\nbepa\ncepa\n" == ["apa","bepa","cepa"]
-- words "apa bepa\n cepa"   == ["apa","bepa","cepa"]

unlines, unwords     :: [String] -> String
-- unlines ["apa","bepa","cepa"] == "apa\nbepa\ncepa"
-- unwords ["apa","bepa","cepa"] == "apa bepa cepa"

and, or              :: [Bool] -> Bool
and                  = foldr (&&) True
or                   = foldr (||) False

any, all             :: (a -> Bool) -> [a] -> Bool
any p            = or . map p
all p            = and . map p

elem, notElem    :: (Eq a) => a -> [a] -> Bool
elem x           = any (== x)
notElem x        = all (/= x)

lookup           :: (Eq a) => a -> [(a,b)] -> Maybe b
lookup key []    = Nothing
lookup key ((x,y):xys)
    | key == x   = Just y
    | otherwise  = lookup key xys

sum, product     :: (Num a) => [a] -> a
sum              = foldl (+) 0
product          = foldl (*) 1

maximum, minimum :: (Ord a) => [a] -> a
maximum []       = error "Prelude.maximum: empty list"
maximum xs       = foldl1 max xs

minimum []       = error "Prelude.minimum: empty list"
minimum xs       = foldl1 min xs

zip              :: [a] -> [b] -> [(a,b)]
zip              = zipWith (,)

zipWith          :: (a->b->c) -> [a]->[b]->[c]
zipWith z (a:as) (b:bs)
                 = z a b : zipWith z as bs
zipWith _ _ _    = []

unzip            :: [(a,b)] -> ([a],[b])
unzip            = foldr (\(a,b) ~(as,bs) -> (a:as,b:bs)) ([],[])

nub              :: (Eq a) => [a] -> [a]
nub []           = []
nub (x:xs)       = x : nub [ y | y <- xs, x /= y ]

delete           :: Eq a => a -> [a] -> [a]
delete y []      = []
```

```
delete y (x:xs)  = if x == y then xs else x : delete y xs

(\\)             :: Eq a => [a] -> [a]-> [a]
(\\)             = foldl (flip delete)

union            :: Eq a => [a] -> [a] -> [a]
union xs ys      = xs ++ ( ys \\ xs )

intersect                :: Eq a => [a] -> [a]-> [a]
intersect xs ys          = [ x | x <- xs, x `elem` ys ]

intersperse              :: a -> [a] -> [a]
-- intersperse 0 [1,2,3,4] == [1,0,2,0,3,0,4]

transpose                :: [[a]] -> [[a]]
-- transpose [[1,2,3],[4,5,6]] == [[1,4],[2,5],[3,6]]

partition                :: (a -> Bool) -> [a] -> ([a],[a])
partition p xs           = (filter p xs, filter (not . p) xs)

group                    :: Eq a => [a] -> [[a]]
-- group "aapaabbbeee"   == ["aa","p","aa","bbb","eee"]

isPrefixOf, isSuffixOf   :: Eq a => [a] -> [a] -> Bool
isPrefixOf [] _          = True
isPrefixOf _ []          = False
isPrefixOf (x:xs) (y:ys) = x == y && isPrefixOf xs ys

isSuffixOf x y           = reverse x `isPrefixOf` reverse y

sort                     :: (Ord a) => [a] -> [a]
sort                     = foldr insert []

insert                   :: (Ord a) => a -> [a] -> [a]
insert x []              = [x]
insert x (y:xs)          = if x <= y then x:y:xs else y:insert x xs

------------------------------------------------------------
-- functions on Char

type String = [Char]

toUpper, toLower  :: Char -> Char
-- toUpper 'a'    == 'A'
-- toLower 'Z'    == 'z'

digitToInt        :: Char -> Int
-- digitToInt '8' == 8

intToDigit        :: Int -> Char
-- intToDigit 3   == '3'

ord               :: Char -> Int
chr               :: Int -> Char
```

Lund University
Department of Computer Science

EDAF40: Functional Programming
2nd June 2017, 14–19

Exam

1. Type derivation

   (a) Assume that the type of reduce is

   ```
   reduce :: a -> a
   ```

   Find the type of

   ```
   prepare = reduce . words . map toLower . filter
                                           (not . flip
                                                elem ".,:;*!#%&|")
   ```

   (b) Given that

   ```
   map2 :: (a -> b, c -> d) -> (a, c) -> (b, d)
   ```

   find the destination type `b` of the following function:

   ```
   rulesCompile :: [(String, [String])] -> b
   rulesCompile = (map . map2) (words . map toLower, map words)
   ```

   (c) Given that

   ```
   transformationApply :: Eq a => a -> ([a] -> [a]) -> [a] -> ([a], [a])
                                                                -> Maybe [a]
   orElse :: Maybe a -> Maybe a -> Maybe a
   ```

   find the type of

   ```
   foldr1 orElse (map (transformationApply wildcard f x) pats)
   ```

2. Let `k` be defined as follows:

   ```
   k = 0 : 1 : zipWith (+) k (tail k)
   ```

   (a) What is the type of `k`?

   (b) What are the first ten elements of `k`?

3. Define a function `altMap`

   ```
   altMap :: (a -> b) -> (a -> b) -> [a] -> [b]
   ```

   that alternately applies its two functional arguments to successive elements of a list, in turn about order. For example:

   ```
   altMap (+10) (+100) [0, 1, 2, 3, 4] = [10, 101, 12, 103, 14]
   ```

   Using `if` in your solution will cause a substantial deduction of available points.

4. Consider the following two versions of similarity score computations. The difference is in the expression defining value for `simEntry i j` .

   (a) Which of the versions is much faster than the other?

   (b) Why?

   Answering (a) but not (b) does not give much credit. Wrong answer is worth less than "I don't know".

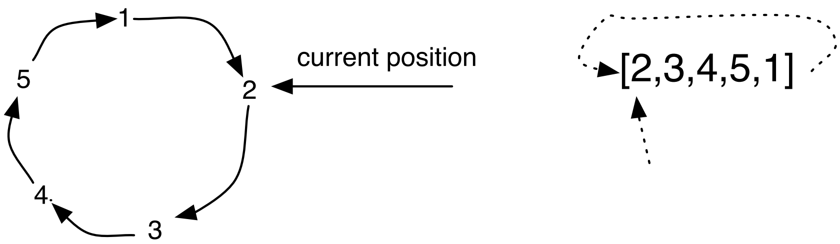
   VERSION 1:

```
similScore :: String -> String -> Int
similScore xs ys = simScore (length xs) (length ys)
  where
     simScore i j = simTable!!i!!j
     simTable = [[ simEntry i j | j<-[0..]] | i<-[0..] ]

     simEntry :: Int -> Int -> Int
     simEntry 0 0 = 0
     simEntry i 0 = (i * scoreSpace)
     simEntry 0 j = (scoreSpace * j)
     simEntry i j = maximum [((simScore (i-1) (j-1)) + (score x y)),
                             ((simScore (i-1) j) + (score x '-')),
                             ((simScore i (j-1)) + (score '-' y))]
                   where
                      x = xs!!(i-1)
                      y = ys!!(j-1)
```

   VERSION 2:

```
similScore :: String -> String -> Int
similScore xs ys = simScore (length xs) (length ys)
  where
     simScore i j = simTable!!i!!j
     simTable = [[ simEntry i j | j<-[0..]] | i<-[0..] ]

     simEntry :: Int -> Int -> Int
     simEntry 0 0 = 0
     simEntry i 0 = (i * scoreSpace)
     simEntry 0 j = (scoreSpace * j)
     simEntry i j = maximum [((simEntry (i-1) (j-1)) + (score x y)),
                             ((simEntry (i-1) j) + (score x '-')),
                             ((simEntry i (j-1)) + (score '-' y))]
                    where
                      x = xs!!(i-1)
                      y = ys!!(j-1)
```

5. Define a type `CircList` (or `CL` for short, if you prefer) defining a circular list of arbitrary length (and holding arbitrary elements). Our examples below will use elements of type `Int`. You have to make sure that the *current position* is well-defined and accessible for the operations defined for this type. The picture below illustrates the concept and its possible representation using a standard list (with the assumption that the first element defines the current position and that the last position in the list is glued to the first one in a circular fashion):



Please note that it is your task to define the appropriate type constructor! Define then for this type the following functions:

```
perimeter    :: CircList a -> Int
currentelem  :: CircList a -> Maybe a
nextelem     :: CircList a -> Maybe a
previouselem :: CircList a -> Maybe a
insert       :: a -> CircList a ->  CircList a
delete       :: Int -> CircList a -> CircList a
takefromCL   :: Int -> CircList a -> [a]
```

returning the number of elements (positions) in the list; returning the current element in the list; returning the next element in the list; returning the previous element in the list; inserting an element between the current and the previous element in the list but keeping the current element intact; deleting n first elements from the list; and taking n first elements of the circular list (possibly circling if necessary), respectively. You may, and are actually encouraged to, define any helper functions you deem appropriate. Examples of the intended functionality:

```
perimeter (CircList [1, 2, 3, 4, 5]) = 5
currentelem (CircList [1, 2, 3, 4, 5]) = Just 1
currentelem (CircList []) = Nothing
nextelem (CircList [1, 2, 3, 4, 5]) = Just 2
nextelem (CircList [1]) = Just 1
previouselem (CircList [1, 2, 3, 4, 5]) = Just 5
insert 6 (CircList [1, 2, 3, 4, 5]) = CircList [1, 2, 3, 4, 5, 6]
delete 2 (CircList [1, 2, 3, 4, 5]) = CircList [3, 4, 5]
takefromCL 4 (CircList [1, 2, 3]) = [1, 2, 3, 1]
```

Finally, define a predicate

```
equalCL :: CircList a -> CircList a -> Bool
```

yielding `True` if and only if both lists contain the same elements in the same order, but not necessarily with the same current position. E.g., if we used the standard list representation for circular lists (assuming the end is glued to the beginning) then

```
equalCL (CircList [1, 2, 3, 4, 5]) (CircList [3, 4, 5, 1, 2]) = True
equalCL (CircList [1, 2, 3, 4, 5]) (CircList [3, 4, 5, 2, 1]) = False
equalCL (CircList [1, 2, 3, 4, 5]) (CircList [3, 4, 5, 1, 2, 3]) = False
equalCL (CircList [1, 2, 3]) (CircList [2, 3, 1, 2, 3, 1]) = False
```

Good Luck!