

Operatsioonid listidega

Listi iga elemendi korrutamine kahega

```
doubleList :: [Int] → [Int]
doubleList []      = []
doubleList (x : xs) = (2 * x) : doubleList xs
```

Stringi kõikide tähtede muutmine suurteks

```
upperString :: String → String
upperString []      = []
upperString (c : cs) = toUpper c : upperString cs
```

NB!

Mõlemal juhul on rekursiooniskeem täpselt sama!

Operatsioonid listidega

Funktsioon *map*

$$\text{map } f [x_1, x_2, \dots, x_n] \Longrightarrow [f x_1, f x_2, \dots, f x_n]$$

Definitsioon

$$\text{map} :: (a \rightarrow b) \rightarrow [a] \rightarrow [b]$$

$$\text{map } f [] = []$$

$$\text{map } f (x : xs) = f x : \text{map } f xs$$

Näited

$$\text{doubleList} = \text{map } (\lambda x \rightarrow 2 * x)$$

$$\text{upperString} = \text{map } \text{toUpper}$$

NB! — Kehtib võrdus

$$\text{map } f xs = [f x \mid x \leftarrow xs]$$

Operatsioonid listidega

Listi elementide summa

$$\text{sum} :: [Int] \rightarrow Int$$
$$\text{sum} [] = 0$$
$$\text{sum} (x : xs) = x + \text{sum} xs$$

Listide listi konkateneerimine

$$\text{concat} :: [[a]] \rightarrow [a]$$
$$\text{concat} [] = []$$
$$\text{concat} (xs : xss) = xs ++ \text{concat} xss$$

NB!

Jällegi on rekursiooniskeemid samad!

Operatsioone listidega

Funktsioon *foldr*

$$\begin{aligned} \text{foldr } (\oplus) e (x_1 : (x_2 : (x_3 : []))) \\ \implies (x_1 \oplus (x_2 \oplus (x_3 \oplus e))) \end{aligned}$$

Definitsioon

$$\begin{aligned} \text{foldr} &:: (a \rightarrow b \rightarrow b) \rightarrow b \rightarrow [a] \rightarrow b \\ \text{foldr } f \ b \ [] &= b \\ \text{foldr } f \ b \ (x : xs) &= f \ x \ (\text{foldr } f \ b \ xs) \end{aligned}$$

foldr näiteid

$$\begin{aligned} \text{sum} &= \text{foldr } (+) \ 0 \\ \text{concat} &= \text{foldr } (++) \ [] \\ \text{and} &= \text{foldr } (\wedge) \ \text{True} \\ \text{or} &= \text{foldr } (\vee) \ \text{False} \\ \text{map } f &= \text{foldr } (\lambda x \ ys \rightarrow f \ x : ys) \ [] \end{aligned}$$

Operatsioone listidega

Täisarvude listi maksimaalne element

$maximum :: [Integer] \rightarrow Integer$

$maximum = foldr\ max\ ???$

NB!

Sobivat baaselementi ei leidu!

Funktsioon *foldr1*

$foldr1 :: (a \rightarrow a \rightarrow a) \rightarrow [a] \rightarrow a$

$foldr1\ f\ [x] = x$

$foldr1\ f\ (x : xs) = f\ x\ (foldr1\ f\ xs)$

foldr1 näiteid

$maximum = foldr1\ max$

$minimum = foldr1\ min$

Operatsioonid listidega

Funktsioon *foldl*

$$\text{foldl } (\oplus) e (x_1 : (x_2 : (x_3 : []))) \implies (((e \oplus x_1) \oplus x_2) \oplus x_3)$$

Definitsioon

$$\text{foldl} :: (a \rightarrow b \rightarrow a) \rightarrow a \rightarrow [b] \rightarrow a$$

$$\text{foldl } f \ a \ [] = a$$

$$\text{foldl } f \ a \ (x : xs) = \text{foldl } f \ (f \ a \ x) \ xs$$

foldl näiteid

$$\text{sum} = \text{foldl } (+) \ 0$$

$$\text{product} = \text{foldl } (*) \ 1$$

$$\text{length} = \text{foldl } (\lambda a _ \rightarrow 1 + a) \ 0$$

$$\text{reverse} = \text{foldl } (\lambda a \ x \rightarrow x : a) \ []$$

$$\text{decimal} = \text{foldl } (\lambda a \ x \rightarrow 10 * a + x) \ 0$$

Operatsioonid listidega

Funktsioon *scanl*

$$\begin{aligned} \text{scanl} &:: (a \rightarrow b \rightarrow a) \rightarrow a \rightarrow [b] \rightarrow [a] \\ \text{scanl } f \ a \ [] &= [a] \\ \text{scanl } f \ a \ (x : xs) &= a : \text{scanl } f \ (f \ a \ x) \ xs \end{aligned}$$

Funktsioon *filter*

$$\begin{aligned} \text{filter} &:: (a \rightarrow \text{Bool}) \rightarrow [a] \rightarrow [a] \\ \text{filter } p \ [] &= [] \\ \text{filter } p \ (x : xs) \mid p \ x &= x : \text{filter } p \ xs \\ &\mid \text{otherwise} = \text{filter } p \ xs \end{aligned}$$

Funktsioon *zipWith*

$$\begin{aligned} \text{zipWith} &:: (a \rightarrow b \rightarrow c) \rightarrow [a] \rightarrow [b] \rightarrow [c] \\ \text{zipWith } f \ (x : xs) \ (y : ys) &= f \ x \ y : \text{zipWith } f \ xs \ ys \\ \text{zipWith } _ \ _ \ _ &= [] \end{aligned}$$

Kalender

Väljastada etteantud aasta kalender

Calendar> calendar 2007

January 2007

Sun		7	14	21	28
Mon	1	8	15	22	29
Tue	2	9	16	23	30
Wed	3	10	17	24	31
Thu	4	11	18	25	
Fri	5	12	19	26	
Sat	6	13	20	27	

February 2007

Sun		4	11	18	25
Mon		5	12	19	26
Tue		6	13	20	27
Wed		7	14	21	28
Thu	1	8	15	22	
Fri	2	9	16	23	
Sat	3	10	17	24	

March 2007

Sun		4	11	18	25
Mon		5	12	19	26
Tue		6	13	20	27
Wed		7	14	21	28
Thu	1	8	15	22	29
Fri	2	9	16	23	30
Sat	3	10	17	24	31

April 2007

Sun	1	8	15	22	29
Mon	2	9	16	23	30
Tue	3	10	17	24	
Wed	4	11	18	25	
Thu	5	12	19	26	
Fri	6	13	20	27	
Sat	7	14	21	28	

May 2007

Sun		6	13	20	27
Mon		7	14	21	28
Tue	1	8	15	22	29
Wed	2	9	16	23	30
Thu	3	10	17	24	31
Fri	4	11	18	25	
Sat	5	12	19	26	

June 2007

Sun		3	10	17	24
Mon		4	11	18	25
Tue		5	12	19	26
Wed		6	13	20	27
Thu		7	14	21	28
Fri	1	8	15	22	29
Sat	2	9	16	23	30

Pildid

Piltide esitamine

```
type Picture = [[Char]]  
height, width :: Picture → Int  
height p      = length p  
width p       = length (head p)
```

```
["  ##  ",  
 " #  #  ",  
 " #    #  ",  
 " #####  ",  
 "   ##  "]
```

Tühja pildi konstrueerimine

```
empty :: (Int, Int) → Picture  
empty (h, w) = replicate h (replicate w ' ')
```

Pildi väljastamine

```
printPicture :: Picture → IO ()  
printPicture = putStr ∘ unlines
```

Piltide kombinaatorid

Piltide vertikaalne kompositsioon

```
[ "   ##   ",
  "  #  #  ",
  " #    #  ",
  " #####  ",
  "   ##   " ]    $$    [ "   ##   ",
                        "  #  #  ",
                        " #    #  ",
                        " #####  ",
                        "   ##   " ]    => [ "   ##   ",
                              "  #  #  ",
                              " #    #  ",
                              " #####  ",
                              "   ##   ",
                              "   ##   ",
                              "  #  #  ",
                              " #    #  ",
                              " #####  ",
                              "   ##   " ]
```

Definitsioon

$(\$\$) :: \text{Picture} \rightarrow \text{Picture} \rightarrow \text{Picture}$

$(\$\$) = (+)$

$\text{stack} :: [\text{Picture}] \rightarrow \text{Picture}$

$\text{stack} = \text{foldr1 } (\$\$)$

Piltide kombinaatorid

Piltide horisontaalne kompositsioon

```
[ "  ##  ", [ "  ##  ", [ "  ##  ##  ",
 "  #  #  ", "  #  #  ", "  #  #  #  #  ",
 "  #  #  ", <> "  #  #  ", => "  #  #  #  #  ",
 " ##### ", " ##### ", " ##### ##### ",
 "  ##  "] "  ##  "]" "  ##  "]"
```

Definitsioon

$(\langle \rangle) :: \text{Picture} \rightarrow \text{Picture} \rightarrow \text{Picture}$

$(\langle \rangle) = \text{zipWith } (+)$

$\text{spread} :: [\text{Picture}] \rightarrow \text{Picture}$

$\text{spread} = \text{foldr1 } (\langle \rangle)$

Piltide paigutamine

Piltide tabelisse paigutamine

```
block, blockT :: Int → [Picture] → Picture  
block n = stack ∘ map spread ∘ groups n  
blockT n = spread ∘ map stack ∘ groups n  
groups :: Int → [a] → [[a]]  
groups n [] = []  
groups n xs = take n xs : groups n (drop n xs)
```

Pildi paigutamine tühja pildi vasakul ülemisse nurka

```
lframe :: (Int, Int) → Picture → Picture  
lframe (m, n) p = (p <> empty (h, n - w))  
                  $$ empty (m - h, n)  
          where h = height p  
                  w = width p
```

Kalender

Kalendri põhifunktsioon

```
calendar :: Int → IO ()  
calendar = printPicture ◦ block 3  
           ◦ map picture ◦ months
```

Ühe kuu pildi konstrueerimine

```
picture (mn, yr, fd, ml) = title mn yr $$ table fd ml
```

Ühe kuu pildi päis

```
title mn yr = lframe (2, 25) [mn ++ " " ++ show yr]
```

Kalender

Ühe kuu ülejäänud pilt

```
table fd ml = lframe (8, 25) (dnames <> entries fd ml)
```

Nädalapäevade nimed

```
dnames = ["Sun", "Mon", "Tue", "Wed",  
          "Thu", "Fri", "Sat"]
```

Kuupäevade tabeli konstrueerimine

```
entries fd ml = blockT 7 (dates fd ml)
```

Kalender

Kuupäevade listi genereerimine

```
dates fd ml = map (date ml) [1 - fd .. 42 - fd]
```

Liigsete kuupäevade eemaldamine

```
date ml d | d < 1 ∨ ml < d = ["  "]  
           | otherwise      = [rjustify 3 (show d)]
```

Paremale reastamine

```
rjustify n s = replicate (n - length s) ' ' ++ s
```

Kalender

Kalendri konstrueerimine

```
months year = zip4 mnames (replicate 12 year)  
                  (fstdays year) (mlengths year)
```

Kuude nimed

```
mnames = ["January", "February", "March",  
          "April",   "May",       "June",  
          "July",   "August",   "September",  
          "October", "November", "December"]
```

Kuude pikkused

```
mlengths year = [31, feb, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31]  
                  where feb | leap year = 29  
                              | otherwise = 28
```


Kalender

Kas on liigaasta?

$$\begin{array}{l|l} \textit{leap year} & \textit{year} \textit{'mod'} 100 \equiv 0 = \textit{year} \textit{'mod'} 400 \equiv 0 \\ & \textit{otherwise} \quad \quad \quad = \textit{year} \textit{'mod'} 4 \equiv 0 \end{array}$$

Aasta esimese päeva leidmine

$$\begin{aligned} \textit{jan1st year} &= (\textit{year} + \textit{last} \textit{'div'} 4 \\ &\quad - \textit{last} \textit{'div'} 100 \\ &\quad + \textit{last} \textit{'div'} 400) \textit{'mod'} 7 \\ &\textbf{where } \textit{last} = \textit{year} - 1 \end{aligned}$$

Kuude esimeste päevade leidmine

$$\begin{aligned} \textit{fstdays year} &= \textit{take} 12 (\textit{map} (\textit{'mod'} 7) \\ &\quad (\textit{scanl} (+) (\textit{jan1st year}) \\ &\quad \quad (\textit{mlengths year}))) \end{aligned}$$