Lazy evaluation and currying in Haskell

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Agenda

- Lazy programming
  - Lazy evaluation
  - Infinite lists
  - Infinite loops
- Currying and uncurrying

Lazy evaluation

http://salatkapogrecku.blog.pl/2012/07/28/na-leniwego-kota-czyli-rozwiazanie-drugie-sobota-28-lipca-2012/


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FITNESS
BlogHack.ru - Интересное в сети

Lazy evaluation

Questions

http://siriusbuzz.com/what-happens-with-that-sirius-lifetime-subscription.php/big-question-mark

Lazy evaluation

- No expression is evaluated until its value is needed.
- No shared expression is evaluated more than once; if the expression is ever evaluated then the result is shared between all those places in which it is used.

Non-strict & strict

- Lazy functions are also called **non-strict** and evaluate their arguments **lazily** or **by need**.
- C# and Java methods are **strict** and evaluate their arguments eagerly.

Passing arguments to a function

- By value
- By reference
- By name
- By need

listFrom

```haskell
{- infinity list
--
-- listFrom 10
-- 10 : listFrom 11
-- 10 : 11 : listFrom 12
-- ...
-}
listFrom :: Integer -> [Integer]
listFrom n = n : (listFrom (n + 1))
```

repeat

```haskell
{- repeat value
--
-- repeat 1
-- 1 : repeat 1
-- 1 : 1 : repeat 1
-- ...
-}
repeat   :: a -> [a]
repeat e = ls where ls = e : ls
```

cycle

```haskell
{- cycle value
--
-- cycle "123"
-- "123" : cycle "123"
-- "123" : "123" : cycle "123"
-}
cycle     :: [a] -> [a]
cycle xs = ls where ls = xs ++ ls
```

sumFirst

```haskell
{- sum of list
--
-- sumFirst 0 [1, 2, 3]
-- 0
--
-- sumFirst 3 [1, 2, 3]
-- 1 + sumFirst (3-1) [2, 3]
-- 1 + 2 + sumFirst (3-1-1) [3]
-- 1 + 2 + 3 + sumFirst 0 []
-- 6
-}
sumFirst :: Integer -> [Integer] -> Integer
sumFirst 0 _ = 0
sumFirst n (x:xs) = x + sumFirst (n-1) xs
```

iterate

```haskell
{-
--
-- iterate (+1) 2
-- 2 : iterate (+1) ((+1) 2)
-- 2 : 3 : iterate (+1) ((+1) 3)
-- ...
-}
iterate :: (a -> a) -> a -> [a]
iterate f e = e : iterate f (f e)
```

diff

```
-- take 10 (diff [x*x | x <- [1..]])
-- [3,5,7,9,11,13,15,17,19,21]

-- take 10 (filter (\x -> mod x 5 == 0) (diff [x*x | x <- [1..]]))
-- [5,15,25,35,45,55,65,75,85,95]

-- take 10 (filter (\x -> mod x 115 == 0) (diff [x*x | x <- [1..]]))
-- [115,345,575,805,1035,1265,1495,1725,1955,2185]
diff :: (Num a) => [a] -> [a]
diff (x:xs@(y:ys)) = y-x : diff xs
```

Sieve of Eratosthenes

	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120

Prime numbers

http://en.wikipedia.org/wiki/Sieve_of_Eratosthenes

primes

```
{- prime numbers
--
-- primes
-- sieve [2..]
-- 2 : (sieve [x | x <- [3..], mod x 2 /= 0])
-}
primes :: [Integer]
primes  = sieve [2..] where
            sieve (e:ls) = e : (sieve [x | x <- ls, mod x e /= 0])
```

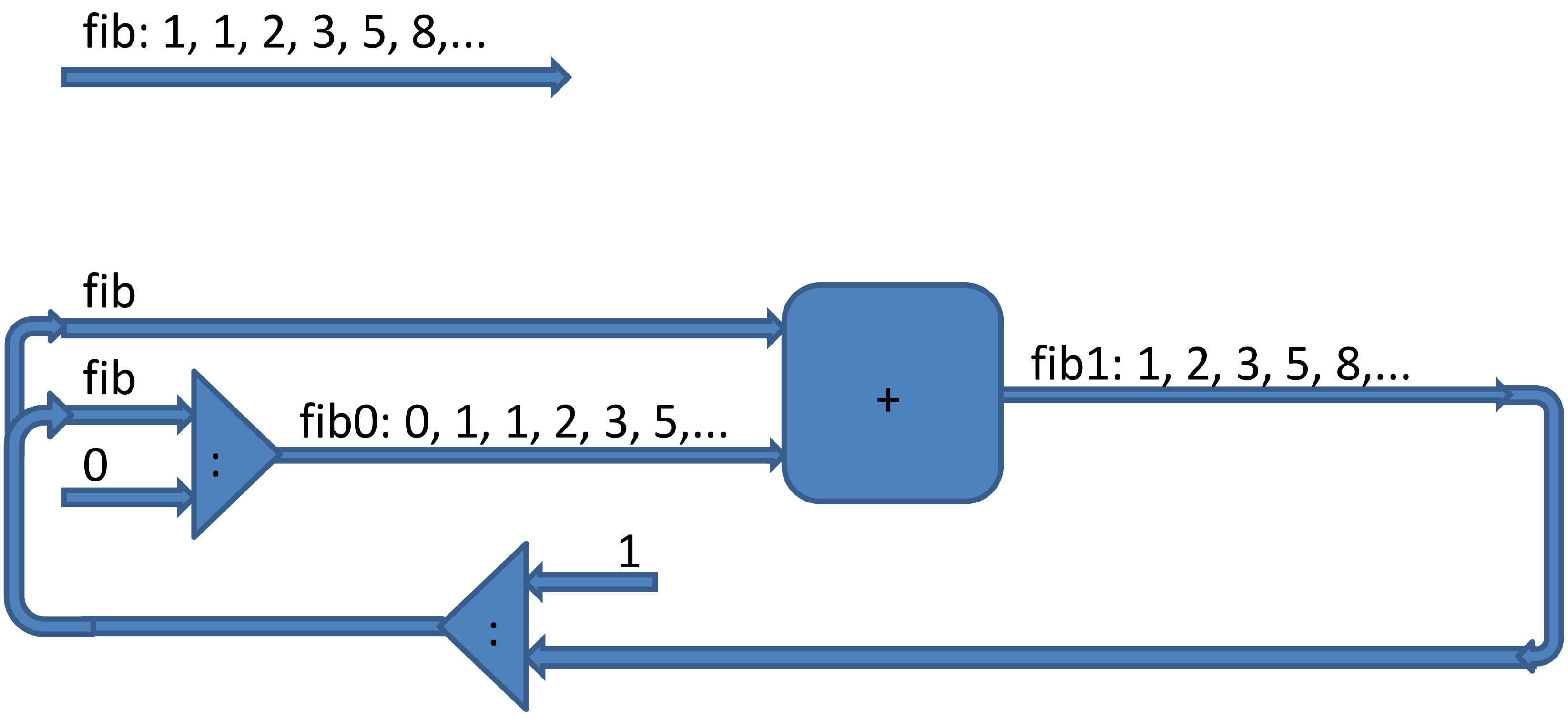
pairs

```haskell
{-
--
-- take 3 (pairs primes)
-- [(2,3),(3,5),(5,7)]
-}
pairs :: [Integer] -> [(Integer, Integer)]
pairs (x:xs@(y:ys)) = (x,y):pairs xs
```

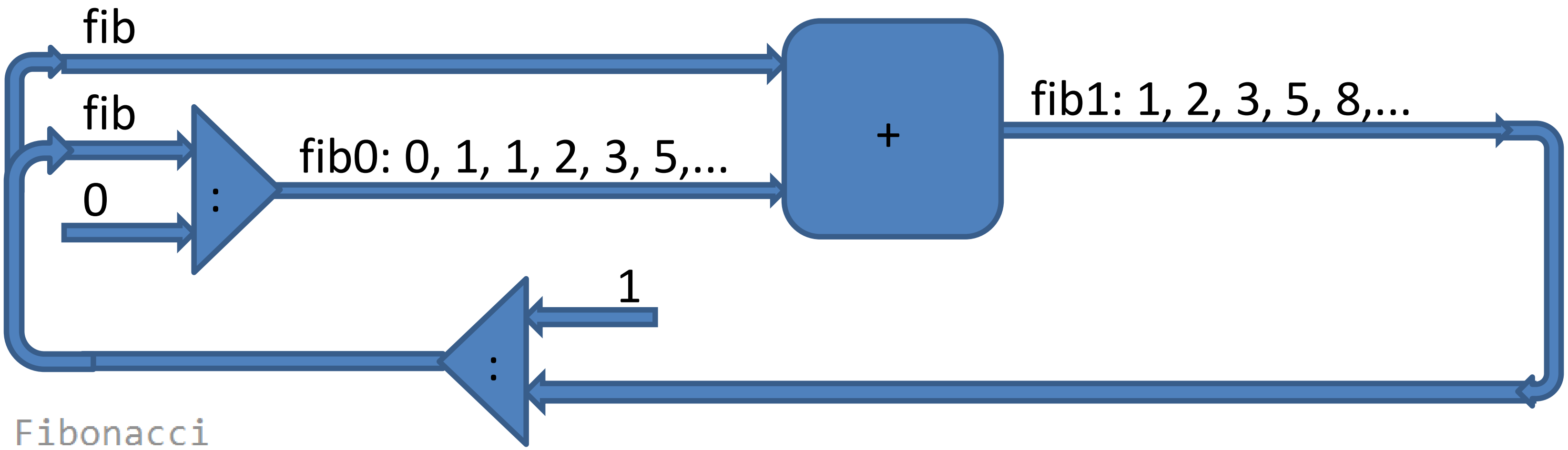
twins

```
{-
--
-- take 5 twins
-- [(3,5),(5,7),(11,13),(17,19),(29,31)]
-}
twins :: [(Integer, Integer)]
twins = [(x,y) | (x,y) <- pairs primes, y - x == 2]
```

Fibonacci



Fibonacci




```haskell
{- Fibonacci
--
-- fib
-- 1 : fib1
-- 1 : zipWith (+) fib fib0
-- 1 : zipWith (+) (1:fib1) (0:fib)
-- 1 : zipWith (+) (1:(zipWith (+) fib fib0)) (0:1:fib1)
-- 1 : zipWith (+) (1:(zipWith (+) fib fib0)) (0:1:(zipWith (+) fib fib0))
-}
fib0 = 0:fib
fib1 = zipWith (+) fib fib0
fib  = 1:fib1
```

Currying

It is the process of transforming a function that takes multiple arguments into a function that takes just a single argument and returns another function if any arguments are still needed.

http://www.haskell.org/haskellwiki/Currying

raiseList

```haskell
{-
-- raiseList [1, 2, 3]
-- [2, 3, 4]
--
-}
raiseList :: (Num a) => [a] -> [a]
raiseList ls = map (+1) ls
```

raiseList

```
{-
-- raiseList [1, 2, 3]
-- [2, 3, 4]
--
-}
raiseList :: (Num a) => [a] -> [a]
```

raiseList ~~ls~~ = map (+1) ~~ls~~

raiseList

```haskell
{-
-- raiseList [1, 2, 3]
-- [2, 3, 4]
-- map (+1) is -- \ls -> map (+1) ls
-}
raiseList :: (Num a) => [a] -> [a]
raiseList    = map (+1)
```

plus

```
plus      :: Integer -> Integer -> Integer
plus x y = x + y

plus      :: Integer -> Integer -> Integer
plus x y = \x y -> x + y

plus    :: Integer -> (Integer -> Integer)
plus x = \y -> x + y
```

mult & plus1

```haskell
{-
-- mult 3 5
-- 15
-}
mult :: Integer -> Integer -> Integer
mult  x y = x * y

{-
-- plus1 3
-- 4
-}
plus1 :: Integer -> Integer
plus1 x = 1 + x
```

```haskell
{-
-- plus1AndMult 3 5
-- 16
-}
plus1AndMult      :: Integer -> Integer -> Integer
plus1AndMult x y = plus1 (mult x y)

plus1AndMultShort :: Integer -> Integer -> Integer
plus1AndMultShort  x = plus1 . (mult x)
--plus1AndMultShort  x = \y -> plus1 (mult x y)
```

Composition

```haskell
-- | Function composition.
-- Make sure it has TWO args only on the left, so that it inlines
-- when applied to two functions, even if there is no final argument
(.)    :: (b -> c) -> (a -> b) -> a -> c
(.) f g = \x -> f (g x)

-- f . g = \y -> f (g y)
-- plus1 . (mult x) = \y -> plus1 (mult x y)
```

curried & uncurried

```
{-
-- is the curried form
-}
plusFirst      :: Integer -> Integer -> Integer
plusFirst x y = x + y

{-
-- is the uncurried form
-}
plusSecond          :: (Integer -> Integer) -> Integer
plusSecond (x, y) = x + y

curry plusSecond == plusFirst
uncurry plusFirst == plusSecond
```

Partial application

```haskell
{- Partial application
-}
(+) :: (Num a) => a -> a -> a
(+) 2 3 ->  5
(+) 2   -> \x -> 2 + x
(5 +)

{-
-- (+1) 1 :: map (+1) [2, 3]
-- 2 :: (+1) 2 :: map (+1) [3]
-}
map (+1) [1, 2, 3]
```

checkedList

```haskell
{-
-- map (== 2) [1, 2]
-- 1 == 2 : map (==2) [2]
-- 1 == 2 :: 2 == 2
-- [False, True]
-}
checkedList :: (Eq a) => a -> [a] -> [Bool]
checkedList e ls = map (== e) ls
```

anyTrue

```
{-
-- foldr (||) False [False, True]
-- False || (foldr (||) False [True])
-- False || (True || False)
-- False || True
-- True
-}
anyTrue :: [Bool] -> Bool
anyTrue ls = foldr (||) False ls
```

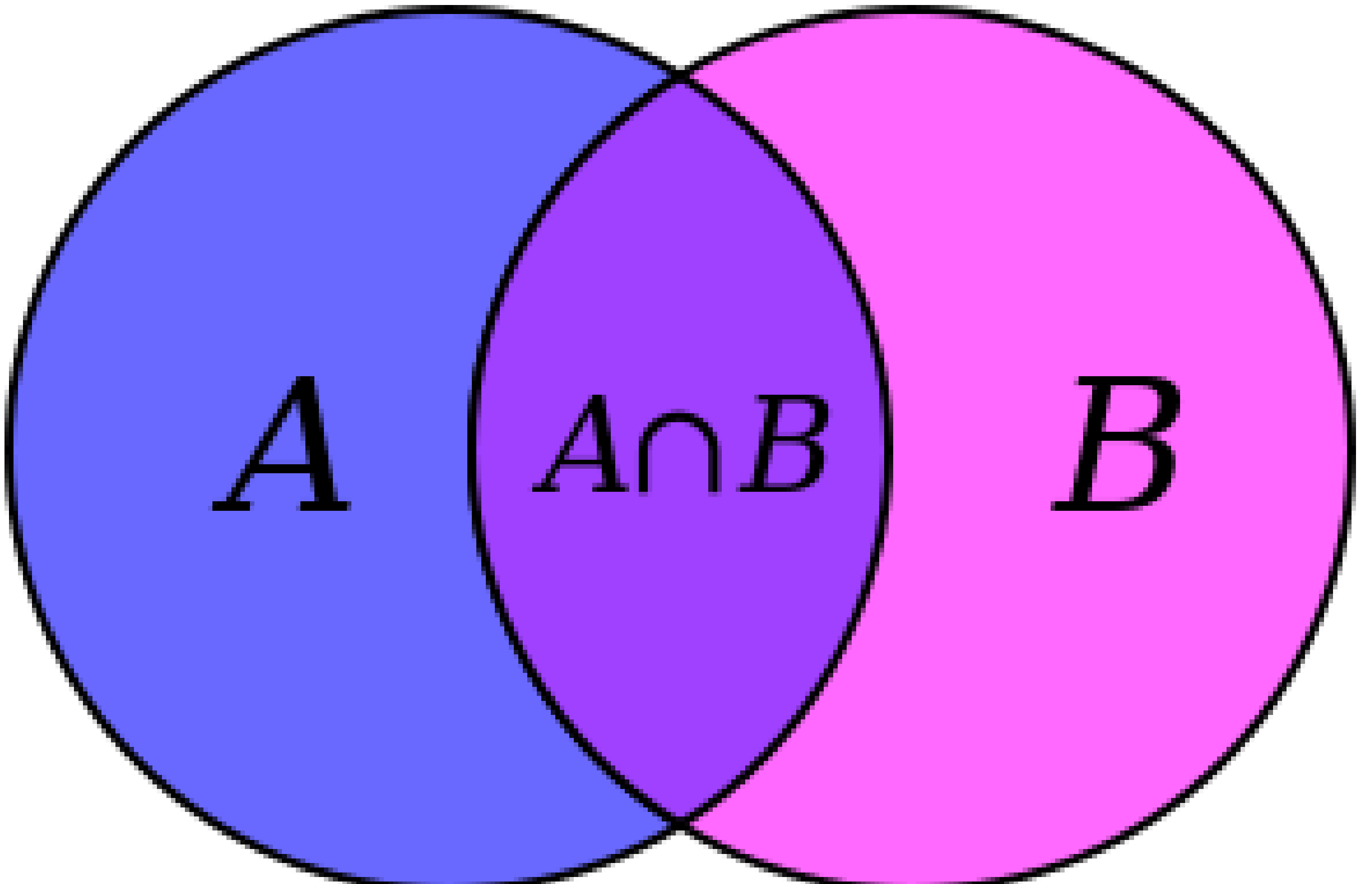
searchList

```
searchList :: (Eq a) => a -> [a] -> Bool
searchList e ls =  anyTrue (checkedList e ls)

searchList2      :: (Eq a) => a -> [a] -> Bool
searchList2 e ls = foldr (||) False (map (== e) ls)

{-
-- searchList3 3 [1, 2, 3, 4, 5]
-- (foldr (||) False) . (map (== 3) [1, 2, 3, 4, 5])
-- foldr (||) False [1 == 3, 2 == 3, 3 == 3, 4 == 3, 5 == 3]
-- foldr (||) False [False, False, True, False, False]
-- True
-}
searchList3      :: (Eq a) => a -> [a] -> Bool
searchList3 e    = (foldr (||) False) . (map (== e))
```

Partial application

```
{- Partial application
-}
(+) :: (Num a) => a -> a -> a
(+) 2 3 -> 15
(+) 2   -> \x -> 2 + x
(5 +)

{-
-- (+1) 1 :: map (+1) [2, 3]
-- 2 :: (+1) 2 :: map (+1) [3]
-}
map (+1) [1, 2, 3]
```

The math set



http://en.wikipedia.org

IntSet & empty

```haskell
type IntSet = (Integer -> Bool)
empty    :: IntSet
empty e = False
```

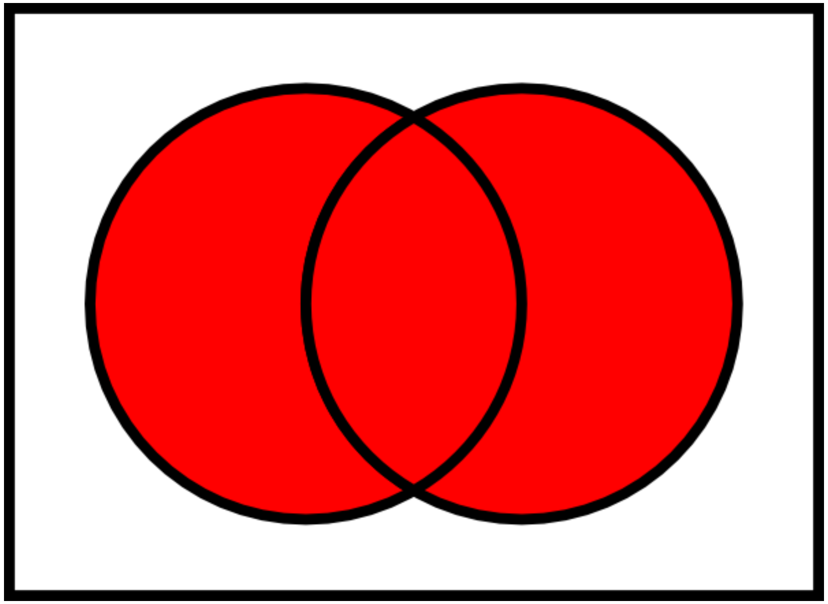
from2to100

```haskell
{- (e > 1) && (e < 101)
--
-- from2to100 1
-- False
--
-- from2to100 100
-- True
-}
from2to100 e = (e >= 2) && (e <= 100)
```

odds

```
{- The set of odd numbers
--
-- odds 39129
-- True
--
-- odds 3290
-- False
-}
odds    :: IntSet
odds e = mod e 2 == 1
```

Unions



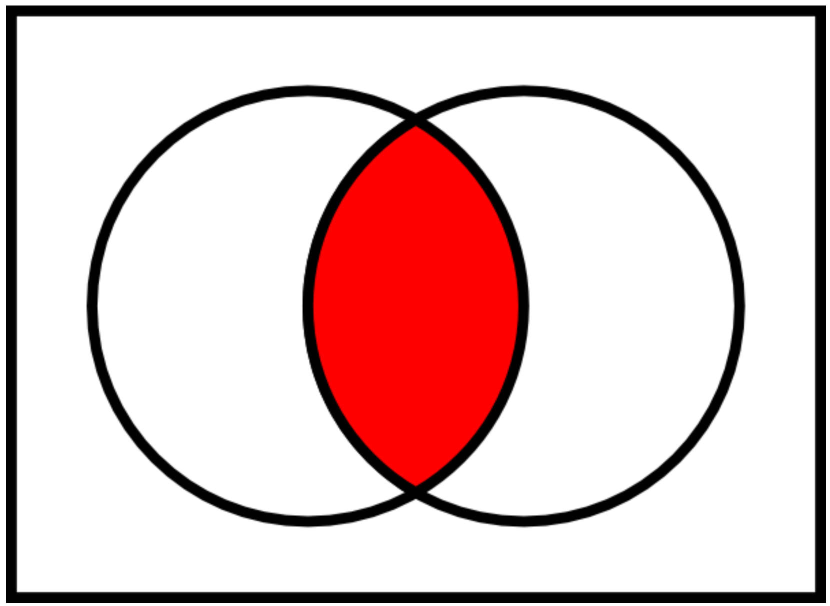
The **union** of *A* and *B*, denoted $A \cup B$.

http://en.wikipedia.org/wiki/Set_(mathematics)

union

```haskell
{- Unions
-- Two sets can be "added" together.
-- The union of A and B, denoted by A ∪ B,
-- is the set of all things that are members of either A or B.
-}
union                :: IntSet -> IntSet -> IntSet
(union s0 s1) e = (s0 e) || (s1 e)
```

Intersections



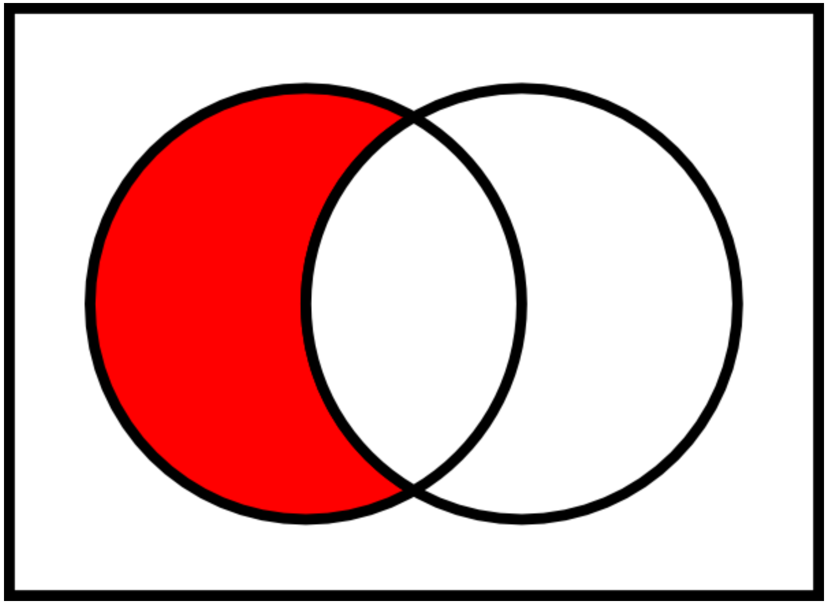
The **intersection** of *A* and *B*, denoted $A \cap B$.

http://en.wikipedia.org/wiki/Set_(mathematics)

intersec

```
{- Intersections
--
-- A new set can also be constructed by determinin
-- The intersection of A and B, denoted by A ∩ B,
--
-- intersec empty empty is empty
-- intersec odds  from2to100 is [3,5..99]
-}
intersec              :: IntSet -> IntSet -> IntSet
(intersec s0 s1) e = (s0 e) && (s1 e)
```

Complements



The **relative complement** of *B* in *A*.

http://en.wikipedia.org/wiki/Set_(mathematics)

compl

```
{- Complements
--
-- Two sets can also be "subtracted".
-- The relative complement of B in A
-- denoted by A \ B (or A – B),
-- is the set of all elements that are members of A but not members of B.
--
-- compl odds from2to100 is [1, 101, 103, 105 ...]
-}
compl              :: IntSet -> IntSet -> IntSet
(compl s0 s1) e = (s0 e) && False == (s1 e)
```

addElem

```haskell
{- add new element
--
-- addElem 1 empty
-- \e -> (1 == e) || (empty e)
-- \e -> (1 == e) || False
-}
addElem :: Integer -> IntSet -> IntSet
addElem new s e = (new == e) || (s e)
```

remElem

```haskell
{- remove element
--
-- remElem 1 empty
-- \e -> (1 /= e) && (empty e)
-- \e -> (1 /= e) && False
--
-- remElem 1 (addElem 1 empty)
-- \e -> (1 /= e) && (addElem 1 empty)
-- \e -> (1 /= e) && ((1 == e) || (empty e))
-- \e -> (1 /= e) && ((1 == e) || False)
--
-}
remElem :: Integer -> IntSet -> IntSet
remElem a s e = (e /= a) && (s e)
```

Resources

- **Real World Haskell** by *Bryan O'Sullivan, Don Stewart, John Goerzen.*
- **Learn You a Haskell for Great Good!** by *Miran Lipovača.*
- **Haskell: The Craft of Functional Programming** by *Simon Thompson*.