

## Homework 8

You have to submit your solutions as announced in the lecture.  
**Unless mentioned otherwise, all problems are due 2017-04-06, 11:00.**  
There will be no deadline extensions unless mentioned otherwise in the lecture.

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### Problem 8.1 *List Sets*

Points: 8

Implement an abstract class for iterable sets. The iterator should return the elements in the order of insertion. Extend it to a concrete class for mutable list-backed sets.

Write a test program that

- creates a set of integers,
- inserts some elements,
- prints all elements using the iterator.

Depending on your programming language, this might look as follows:

```
abstract class Set[A]() extends Iterable[A]
  fun contains(x : A) : bool
  fun insert(x : A) : unit
  fun delete(x : A) : unit
  fun iterator() : Iterator[A]

class ListSet[A]() extends Set[A]
  private elements := Nil[A]                                the immutable linked list backing the set, initially empty

  fun contains(x : A) : bool =
    ...
  fun insert(x : A) : unit =
    ...
  fun delete(x : A) : unit =
    ...
  fun iterator() : Iterator[A] =
    ...

test := new ListSet[int]()
test.insert(4)
test.insert(2)
test.insert(4)
foreach(test.iterator, x ↦ print x)                        prints 2,4 or 4,2
```

### Problem 8.2 *Binary Search Trees*

Points: 8

Implement an iterable data structure for  $BST[int, \leq]$ . The iterator should return the elements in  $\leq$ -order.

Write a test program that

- creates a set of integers,
- inserts some elements,
- prints all elements using the iterator.

If you combine it with the previous problem, this might look as follows:

```
class IntBST() extends Set[int]
  private elements : Tree[Option[int]] = new Tree[int](None, Nil)
                                                                the tree backing the set, initially a single node
```

```

fun contains( $x : A$ ) : bool =
  ...
fun insert( $x : A$ ) : unit =
  ...
fun delete( $x : A$ ) : unit =
  ...
fun iterator() : Iterator[ $A$ ] =
  ...

```

Make sure that

- the implementations of *insert* and *delete* preserve the necessary BST property,
- the implementations of *insert*, *delete*, and *contains* are logarithmic in the best case.

### Problem 8.3 Hash Sets

Points: 8

Implement an abstract class for *HashSet*[ $A$ ] sets for an arbitrary hash function  $hash : A \rightarrow \mathbb{Z}_m$ . The iterator may return elements in any order. Extend it to a concrete class *LastDigitHashSet* that hashes integers based on their last digit.

Write a test program that

- creates a *LastDigitHashSet* of integers,
- inserts some elements,
- prints all elements using the iterator.

Depending on your programming language, this may look as follows:

```

abstract class HashSet[ $A$ ]( $m : int$ ) extends Set[ $A$ ]
    the array backing the hash set, initially all buckets empty
    private bucket : Array[ListSet[ $A$ ]] = new Array[ListSet[ $A$ ]]( $m$ )
    for  $x$  from 0 to  $m - 1$ 
        bucket[ $i$ ] := new ListSet[ $A$ ]()

    the abstract hash function that subclasses must provide
    postcondition: return value between 0 and  $m - 1$ 

    fun hash( $x : A$ ) : int

    the functions implemented in this class

    fun contains( $x : A$ ) : bool =
      ...
    fun insert( $x : A$ ) : unit =
      ...
    fun delete( $x : A$ ) : unit =
      ...
    fun iterator() : Iterator[ $A$ ] =
      ...

class LastDigitHashSet() extends HashSet[int](10)
    fun hash( $x : A$ ) : int = { $x \bmod 10$ }

```

Make sure that your implementation exploits the hashing, i.e., *contains*( $x$ ), *insert*( $x$ ), and *delete*( $x$ ) should only access *bucket*[*hash*( $x$ )].