# Project 2 (Deques and Randomized Queues) Checklist

# Prologue

Project goal: implement generic and iterable data structures, such as double-ended and randomized queues, using arrays and linked lists

Files

- ⇝ `project2.pdf` (project description)
- ⇝ `project2_checklist.pdf` (checklist)
- ⇝ `project2.zip` (starter files for the exercises/problems, `report.txt` file for the project report, and `run_tests` file to test your solutions, and test data files)

## Exercises

Exercise 1. (*Iterable Binary Strings*) Implement an immutable, iterable data type `BinaryStrings` in `BinaryStrings.java` to systematically iterate over binary strings of length $n$. The data type must support the following API:

| Method | Description |
|---|---|
| `BinaryStrings(int n)` | constructs an iterable `BinaryStrings` object given the length of binary strings needed |
| `Iterator<String> iterator()` | returns an iterator for binary strings of a given length |

```
>_ ~/workspace/project2

$ java edu.umb.cs210.p2.BinaryStrings 3
000
001
010
011
100
101
110
111
```

# Exercises

BinaryStrings.java

```
package edu.umb.cs210.p2;

import stdlib.StdOut;

import java.util.Iterator;

// An immutable data type to systematically iterate over binary
// strings of length n.
public class BinaryStrings implements Iterable<String> {
    private final int n; // need all binary strings of length n

    // Construct an iterable BinaryStrings object given the length
    // of binary strings needed.
    public BinaryStrings(int n) {
        ...
    }

    // A BinaryStringsIterator object.
    public Iterator<String> iterator() {
        ...
    }

    // Binary strings iterator.
    private class BinaryStringsIterator implements Iterator<String> {
        private int count; // number of binary strings returned
        private int p;     // current number

        // Construct a BinaryStringsIterator object.
        BinaryStringsIterator() {
            ...
        }

        // Are there anymore binary strings left to be iterated?
        public boolean hasNext() {
            ...
        }
```

# Exercises

BinaryStrings.java

```
        // The next binary string.
        public String next() {
            ...
        }

        // Remove is not supported.
        public void remove() {
            // nothing to do
        }

        // The n-bit representation of x.
        private String binary(int x) {
            String s = Integer.toBinaryString(x);
            int padding = n - s.length();
            for (int i = 1; i <= padding; i++) {
                s = "0" + s;
            }
            return s;
        }
    }

    // Test client. [DO NOT EDIT]
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (String s : new BinaryStrings(n)) {
            StdOut.println(s);
        }
    }
}
```

# Exercises

Exercise 2. (*Iterable Primes*) Implement an immutable, iterable data type `Primes` in `Primes.java` to systematically iterate over the first $n$ primes. The data type must support the following API:

| Method | Description |
|---|---|
| `Primes(int n)` | constructs an iterable `Primes` object given the number of primes needed |
| `Iterator<Integer> iterator()` | returns an iterator for the given number of primes |

```
>_ ~/workspace/project2

$ java edu.umb.cs210.p2.Primes 10
2
3
5
7
11
13
17
19
23
29
```

# Exercises

Primes.java

```
package edu.umb.cs210.p2;

import stdlib.StdOut;

import java.util.Iterator;

// An immutable data type to systematically iterate over the
// first n primes.
public class Primes implements Iterable<Integer> {
    private final int n; // need first n primes

    // Construct an iterable Primes object given the number
    // of primes needed.
    public Primes(int n) {
        ...
    }

    // A PrimesIterator object.
    @Override
    public Iterator<Integer> iterator() {
        ...
    }

    // Primes iterator.
    private class PrimesIterator implements Iterator<Integer> {
        private int count; // number of primes returned
        private int p;     // current prime

        // Construct a PrimesIterator object.
        PrimesIterator() {
            count = 0;
            p = 2;
        }

        // Are there anymore primes left to be iterated?
        public boolean hasNext() {
```

# Exercises

Primes.java

```
        ...
    }

    // The next prime.
    public Integer next() {
        // Increment count by 1.
        ...

        // As long as p is not prime, increment p by 1.
        ...


        // Return current value of p and increment it
        // by 1.
        ...
    }

    // Remove is not supported.
    public void remove() {
        // nothing to do
    }

    // Is x (>= 2) prime?
    private boolean isPrime(int x) {
        for (int i = 2; i <= x / i; i++) {
            if (x % i == 0) {
                return false;
            }
        }
        return true;
    }
}

// Test client. [DO NOT EDIT]
public static void main(String[] args) {
    int n = Integer.parseInt(args[0]);
```

# Exercises

Primes.java

```
        for (int i : new Primes(n)) {
            StdOut.println(i);
        }
    }
}
```

# Exercises

Exercise 3. (*Min Max*) Implement the static methods `min()` and `max()` in `MinMax.java` that take a reference `first` to the first node in a linked list of integer-valued items as argument and returns the minimum and the maximum values respectively.

```
>_ ~/workspace/project2

$ java edu.umb.cs210.p2.MinMax
true
```

# Exercises

MinMax.java

```java
package edu.umb.cs210.p2;

import stdlib.StdOut;
import stdlib.StdRandom;
import stdlib.StdStats;

public class MinMax {
    // Linked list class.
    private static class Node {
        private int item;
        private Node next;
    }

    // Return the minimum value in the given linked list.
    public static int min(Node first) {
        // Set min to the largest integer
        int min = Integer.MAX_VALUE;

        // Compare each element in linked list with min and
        // if it is smaller, update min.
        ...

        // Return min
        ...
    }

    // Return the maximum value in the given linked list.
    public static int max(Node first) {
        // Set max to the smallest integer
        int max = Integer.MIN_VALUE;

        // Compare each element in linked list with max and
        // if it is larger, update max.
        ...

        // Return max
```

# Exercises

MinMax.java

```
        ...
    }

    // Test client. [DO NOT EDIT]
    public static void main(String[] args) {
        int[] items = new int[1000];
        for (int i = 0; i < 1000; i++) {
            items[i] = StdRandom.uniform(-10000, 10000);
        }
        Node first = null;
        for (int item : items) {
            Node oldfirst = first;
            first = new Node();
            first.item = item;
            first.next = oldfirst;
        }
        StdOut.println(min(first) == StdStats.min(items)
                       && max(first) == StdStats.max(items));
    }
}
```

## Exercises

Exercise 4. (*Text Editor Buffer*) Develop a data type `Buffer` for a buffer in a text editor that implements the following API:

| Method | Description |
|---|---|
| `Buffer()` | creates an empty buffer |
| `void insert(char c)` | inserts $c$ at the cursor position |
| `char delete()` | deletes and returns the character at the cursor |
| `void left(int k)` | moves the cursor $k$ positions to the left |
| `void right(int k)` | moves the cursor $k$ positions to the right |
| `int size()` | returns the number of characters in the buffer |
| `String toString()` | returns a string representation of the buffer with a '\|' character (not part of the buffer) at the cursor position |

```
>_ ~/workspace/project2

$ java edu.umb.cs210.p2.Buffer
|There is grandeur in this view of life, with its several powers,
having been originally breathed by the Creator into a few forms or
into one; and that, whilst this planet has gone cycling on
according to the fixed law of gravity, from so simple a beginning
endless forms most beautiful and most wonderful have been, and
are being, evolved.
-- Charles Darwin, The Origin of Species
```

Hint: Use two stacks `left` and `right` to store the characters to the left and right of the cursor, with the characters on top of the stacks being the ones immediately to its left and right.

# Exercises

Buffer.java

```
package edu.umb.cs210.p2;

import dsa.LinkedStack;
import stdlib.StdOut;

// A data type representing a text editor buffer.
public class Buffer {
    protected LinkedStack<Character> left;  // chars left of cursor
    protected LinkedStack<Character> right; // chars right of cursor

    // Create an empty buffer.
    public Buffer() {
        ...
    }

    // Insert c at the cursor position.
    public void insert(char c) {
        ...
    }

    // Delete and return the character at the cursor.
    public char delete() {
        ...
    }

    // Move the cursor k positions to the left.
    public void left(int k) {
        ...
    }

    // Move the cursor k positions to the right.
    public void right(int k) {
        ...
    }

    // Return the number of characters in the buffer.
```

# Exercises

Buffer.java

```
    public int size() {
        ...
    }

    // Return a string representation of the buffer with
    // a "|" character (not part of the buffer) at the
    // cursor position.
    public String toString() {
        StringBuilder sb = new StringBuilder();

        // Push chars from left into a temporary stack.
        ...

        // Append chars from temporary stack to sb.
        ...

        // Append "|" to sb.
        ...

        // Append chars from right to sb.
        ...

        // Return the string from sb.
        ...
    }

    // Test client (DO NOT EDIT).
    public static void main(String[] args) {
        Buffer buf = new Buffer();
        String s = "There is grandeur in this view of life, "
            + "with its several powers, having been originally "
            + "breathed into a few forms or into one; and that, "
            + "whilst this planet has gone cycling on according "
            + "to the fixed law of gravity, from so simple a "
            + "beginning endless forms most beautiful and most "
            + "wonderful have been, and are being, evolved. ~ "
```

# Exercises

Buffer.java

```
            + "Charles Darwin, The Origin of Species";
        for (int i = 0; i < s.length(); i++) {
            buf.insert(s.charAt(i));
        }
        buf.left(buf.size());
        buf.right(97);
        s = "by the Creator ";
        for (int i = 0; i < s.length(); i++) {
            buf.insert(s.charAt(i));
        }
        buf.right(228);
        buf.delete();
        buf.insert('-');
        buf.insert('-');
        buf.left(342);
        StdOut.println(buf);
    }
}
```

# Exercises

Exercise 5. (*Josephus Problem*) In the Josephus problem from antiquity, $N$ people are in dire straits and agree to the following strategy to reduce the population. They arrange themselves in a circle (at positions numbered from 0 to $N-1$) and proceed around the circle, eliminating every $M$th person until only one person is left. Legend has it that Josephus figured out where to sit to avoid being eliminated. Implement the `calculateJosephus()` method in `Josephus.java` that takes $N$ and $M$ from the command line and prints out the order in which people are eliminated (and thus would show Josephus where to sit in the circle).

```
>_ ~/workspace/project2

$ java edu.umb.cs210.p2.Josephus 7 2
2
4
6
1
5
3
7
```

# Exercises

Josephus.java

```java
package edu.umb.cs210.p2;

import dsa.LinkedQueue;
import stdlib.StdOut;

public class Josephus {
    protected static LinkedQueue<Integer> calculateJosephus(String[] args) {
        // Get N and M from command line as ints.
        ...

        // Create a queue q and enqueue integers
        // 1, 2, ... N.
        ...

        // Create a queue outQ to store the ordering
        ...

        int i = 0;
        // As long as q is not empty: increment i;
        // dequeue an element pos; if M divides i,
        // enqueue pos to outQ, otherwise enqueue pos to q.
        ...

        // Return outQ
        ...
    }

    // Entry point. [DO NOT EDIT]
    public static void main(String[] args) {
        for (int i : calculateJosephus(args)) {
            StdOut.println(i);
        }
    }
}
```

# Problems


The guidelines for the project problems that follow will be of help only if you have read the description of the project and have a general understanding of the problems involved. It is assumed that you have done the reading.

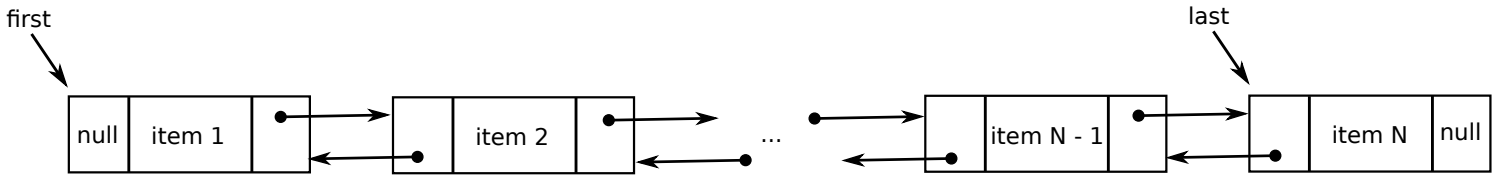
## Problems

Problem 1. (*Deque*) Create a generic iterable data type `LinkedDeque<Item>` that uses a linked list to implement the following deque API:

| Method | Description |
|---|---|
| `LinkedDeque()` | constructs an empty deque |
| `boolean isEmpty()` | returns `true` if the deque empty, and `false` otherwise |
| `int size()` | returns the number of items on the deque |
| `void addFirst(Item item)` | adds *item* to the front of the deque |
| `void addLast(Item item)` | adds *item* to the end of the deque |
| `Item removeFirst()` | removes and returns the item from the front of the deque |
| `Item removeLast()` | removes and returns the item from the end of the deque |
| `Iterator<Item> iterator()` | returns an iterator over items in the deque in order from front to end |
| `String toString()` | returns a string representation of the deque |

Hints

- Use a doubly-linked list `Node` to implement the API, where each node stores a generic `item`, and pointers `next` and `prev` to the next and previous nodes



## Problems

- Instance variables
  - Size of the deque, `int N`
  - Pointer to the head of the deque, `Node first`
  - Pointer to the tail of the deque, `Node last`
- `LinkedDeque()`
  - Initialize instance variables to appropriate values
- `boolean isEmpty()`
  - Return whether the deque is empty or not
- `int size()`
  - Return the size of the deque
- `void addFirst(Item item)`
  - Add the given item at the head end of the deque
  - Increment `N` by one
- `void addLast(Item item)`
  - Add the given item at the tail end of the deque
  - Increment `N` by one

## Problems

- `Item removeFirst()`
  - Remove and return the item at the head end of the deque
  - Decrement `N` by one
- `Item removeLast()`
  - Remove and return the item at the tail end of the deque
  - Decrement `N` by one
- `Iterator<Item> iterator()`
  - Return an object of type `DequeIterator`
- `DequeIterator` :: Instance variable
  - Pointer to current node in the iterator, `Node current`
- `DequeIterator` :: `DequeIterator()`
  - Initialize instance variable appropriately
- `DequeIterator` :: `boolean hasNext()`
  - Return whether the iterator has more items to iterate or not
- `DequeIterator` :: `Item next()`
  - Return the item in `current` and advance `current` to the next node

## Problems

Problem 2. (*Random Queue*) Create a generic iterable data type `ResizingArrayRandomQueue<Item>` that uses a resizing array to implement the following random queue API:

| Method | Description |
|---|---|
| `ResizingArrayRandomQueue()` | constructs an empty queue |
| `boolean isEmpty()` | returns `true` if the queue empty and `false` otherwise |
| `int size()` | returns the number of items on the queue |
| `void enqueue(Item item)` | adds *item* to the queue |
| `Item dequeue()` | removes and returns a random item from the queue |
| `Item sample()` | returns a random item from the queue, but does not remove it |
| `Iterator<Item> iterator()` | returns an independent iterator over items in the queue in random order |
| `String toString()` | returns a string representation of the queue |

Hints

- ⇝ Use a resizing array to implement the API
- ⇝ Instance variables
  - ⇝ Array to store the items of queue, `Item[] q`
  - ⇝ Size of the queue, `int N`

## Problems

- `ResizingArrayRandomQueue()`
  - Initialize instance variables appropriately — create `q` with an initial capacity of 2
- `boolean isEmpty()`
  - Return whether the queue is empty or not
- `int size()`
  - Return the size of the queue
- `void enqueue(Item item)`
  - If `q` is at full capacity, resize it to twice its current capacity
  - Insert the given item in `q` at index `N`
  - Increment `N` by one
- `Item dequeue()`
  - Save `q[r]` in `item`, where `r` is a random integer from the interval `[0, N)`
  - Set `q[r]` to `q[N - 1]` and `q[N - 1]` to `null`
  - If `q` is at quarter capacity, resize it to half its current capacity
  - Decrement `N` by one
  - Return `item`

## Problems

- `Item sample()`
  - Return `q[r]`, where `r` is a random integer from the interval `[0, N)`
- `Iterator<Item> iterator()`
  - Return an object of type `RandomQueueIterator`
- `RandomQueueIterator()` :: Instance variables
  - Array to store the items of `q`, `Item[] items`
  - Index of the current item in `items`, `int current`
- `RandomQueueIterator()` :: `RandomQueueIterator()`
  - Create `items` with capacity `N`
  - Copy the `N` items from `q` into `items`
  - Shuffle `items`
  - Initialize `current` appropriately
- `RandomQueueIterator()` :: `boolean hasNext()`
  - Return whether the iterator has more items to iterate or not
- `RandomQueueIterator()` :: `Item next()`
  - Return the item in `items` at index `current` and advance `current` by one

## Problems

Problem 3. (*Subset*) The client program `Subset.java` takes a command-line integer $k$ and a filename, reads in a sequence of strings from the file, and prints out exactly $k$ of them, uniformly at random. Each item from the sequence is printed out at most once. Implement the `subset()` method in the program that reads strings from the file whose name is `args[1]`, stores the strings in a `ResizingArrayRandomQueue` object, and returns the object.

```
>_ ~/workspace/project2

$ java edu.umb.cs210.p2.Subset 3 data/input10.txt
B
J
A
$ java edu.umb.cs210.p2.Subset 10 data/input10.txt
D
G
B
I
C
A
E
F
J
H
```

Hints

- ⇝ Create an object `q` of type `ResizingArrayRandomQueue`
- ⇝ Read strings from file whose name is `args[1]` and insert them into `q`
- ⇝ Return `q`

## Epilogue

Use the template file `report.txt` to write your report for the project

Your report must include

- ⇝ Time (in hours) spent on the project
- ⇝ Difficulty level (1: very easy; 5: very difficult) of the project
- ⇝ A short description of how you approached each problem, issues you encountered, and how you resolved those issues
- ⇝ Acknowledgement of any help you received
- ⇝ Other comments (what you learned from the project, whether or not you enjoyed working on it, etc.)

# Epilogue

Before you submit your files

- ⇝ Make sure your programs meet the style requirements by running the following command on the terminal

```
>_ ~/workspace/project2
$ check_style <program>
```

  where `<program>` is the fully-qualified name of the program

- ⇝ Make sure your programs meet the input and output specifications by running the following command on the terminal

```
>_ ~/workspace/project2
$ bash ./run_tests
```

  where the optional argument `<items>` lists the exercises/problems (`Exercise1`, `Problem2`, etc.) you want to test, separated by spaces; all the exercises/problems are tested if no argument is given

- ⇝ Make sure your code is adequately commented, is not sloppy, and meets any project-specific requirements, such as corner cases and running time
- ⇝ Make sure your report uses the given template, isn't too verbose, doesn't contain lines that exceed 80 characters, and doesn't contain spelling mistakes

# Epilogue

## Files to submit

1. `BinaryStrings.java`
2. `Primes.java`
3. `MinMax.java`
4. `Buffer.java`
5. `Josephus.java`
6. `LinkedDeque.java`
7. `ResizingArrayRandomQueue.java`
8. `Subset.java`
9. `report.txt`