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Technology and Engineering

Introduction to Computer Science II (ITI 1221)
Final Examination

Instructor: Marcel Turcotte

April 2006, duration: 3 hours

Identification

Last name: ______________________ First name: ______________________

Student number: __________ Signature: ______________________

Instructions

1. This is a closed book examination;
2. No calculators or other aids are permitted;
3. Write comments and assumptions to get partial marks;
4. Beware, poor hand writing can affect grades;
5. Do not remove the staple holding the examination pages together;
6. Write your answers in the space provided. Use the backs of pages if necessary.
   You may **not** hand in additional pages;

Marking scheme

Question	Maximum	Result
1	15	
2	15	
3	10	
4	15	
5	15	
6	5	
7	15	
8	10	
Total	**100**	

Question 1: isPalindrome (15 marks)

Complete the implementation of the static method **boolean isPalindrome(CharReader r)**. Let's define a **palindrome** as a word or a phrase that reads the same forward and backward if the punctuation symbols and spaces are ignored. Examples of palindromes include:

- i prefer pi
- never odd or even
- was it a cat i saw

Follow all the directives.

- **boolean isPalindrome(CharReader r)**; returns **true** if the whole word or phrase specified by the reader is a palindrome according to the above definition, and **false** otherwise;
- The parameter of the method is a **CharReader**. A **CharReader** has two instance methods.
  - **boolean hasMoreChars()**; returns **true** if the reader has more characters to return, that is if a call to **char nextChar()** would succeed, and **false** otherwise;
  - **char nextChar()**; returns the next character of the input.
- You can only use instances of a **Stack** and/or a **Queue** as temporary storage (in particular, you cannot use arrays or strings);
- The class **StackImpl** implements the interface **Stack**. For this question, a **Stack** stores characters.

```
public interface Stack {
    public abstract boolean isEmpty();
    public abstract char peek();
    public abstract char pop();
    public abstract void push( char element );
}
```

- The class **QueueImpl** implements the interface **Queue**. For this question, a **Queue** stores characters.

```
public interface Queue {
    public abstract boolean isEmpty();
    public abstract char dequeue();
    public abstract void enqueue( char element );
}
```

- **StackImpl** and **QueueImpl** can store an arbitrarily large number of characters;
- **Character.isLetter(c)** can be used to determine if the character **c** is a letter.

```
public static boolean isPalindrome( CharReader reader ) {

    boolean answer = true;






    while ( reader.hasMoreChars() ) {

        char c = reader.nextChar();
























    return answer;
}
```

Question 2: CircularStack (15 marks)

Complete the implementation of the class **CircularStack**. The context for this question is an application that is required to support a fixed number of **undo** operations. You can imagine a text editor that allows to add, delete or replace characters. For every operation that is performed (add, delete or replace) an object is pushed onto a stack. Whenever the application is required to undo an operation, it retrieves an element from the stack. However, since the stack has a fixed capacity, the maximum number of operations that can be undone is equal to the size of stack. Follow all the directives.

- Because of memory constraints, only a fixed number of undo operations are allowed;
- Whenever the stack is full, the method **push** discards the oldest (bottom) element to make room for the new element to be inserted;
- However, the method **push** should not move the elements that are currently stored in the stack. Instead, it overwrites the oldest (bottom) element. Notice the similarity with the circular array implementation of the **Queue** seen in class;
- **void push(Object o)**; pushes an element onto the top of **this** stack, **null** is a valid value;
- **Object pop()**; removes and returns the top element of the stack. If the stack is empty, the method must throw an exception of type **EmptyStackException**.

```
import java.util.EmptyStackException;

public class CircularStack {

    private Object[] stack;
    private int top = 0;
    private int size = 0;

    public CircularStack( int capacity ) {
        if ( capacity < 0 ) {
            throw new IllegalArgumentException( "negative number" );
        }
        stack = new Object[ capacity ];
    }

    public boolean isEmpty() {
        return size == 0;
    }
```

Complete the implementation of the methods **push** and **pop** on the next page.

```
    public void push( Object item ) {















    }

    public Object pop() {
















    }

} // End of CircularStack
```

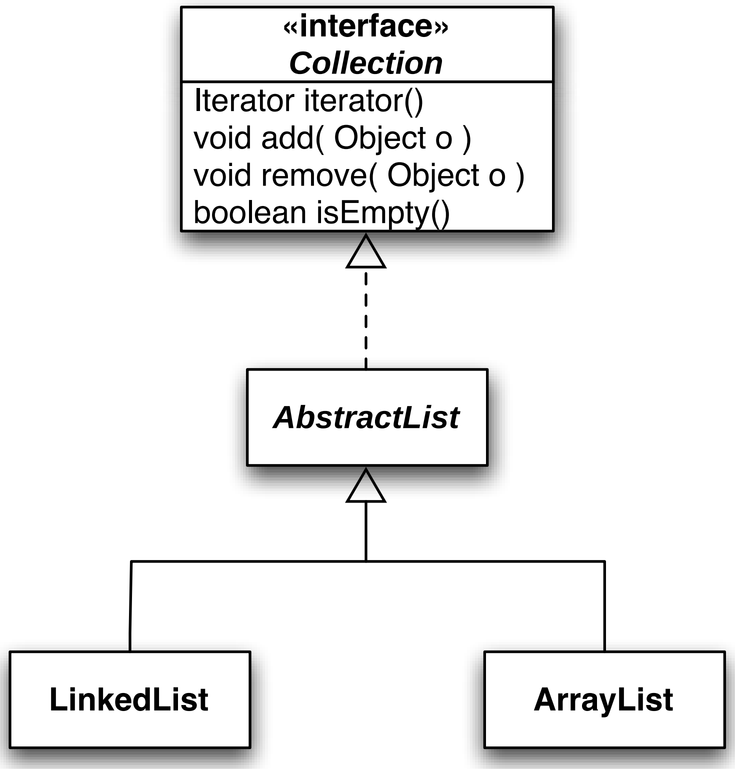
Question 3: ArrayListIterator (10 marks)

In the class **ArrayList** below, complete the implementation of the iterator. For this question, the declaration of the interface **Iterator** is as follows.

```
public interface Iterator {

    // Returns true if the iteration has more elements.

    public abstract boolean hasNext();

    // Returns the next element in the interation. Throws
    // NoSuchElementException if the iteration has no next element.

    public abstract Object next();
}

import java.util.NoSuchElementException;

public class ArrayList {

    // Instance variables
    private Object[] elems;
    private int size = 0;

    // Constructor
    public ArrayList( int capacity ) {
        if ( capacity < 0 ) {
            throw new IllegalArgumentException();
        }
        elems = new Object[ capacity ];
    }
    public boolean isEmpty() {
        return size == 0;
    }
    public void addLast( Object element ) {
        if ( size == elems.length ) {
            increaseSize();
        }
        elems[ size ] = element;
        size++;
    }
    private void increaseSize() {
        Object[] newElems;
        newElems = new Object[ 2 * elems.length ];
        System.arraycopy( elems, 0, newElems, 0, elems.length );
        elems = newElems;
    }
```

```
    public Object remove( int index ) {
        if ( index < 0 || index > (size - 1) ) {
            throw new IndexOutOfBoundsException( "Index: "+index );
        }
        Object savedElem = elems[ index ];
        System.arraycopy( elems, index+1, elems, index, size - index - 1 );
        size--;
        elems[ size ] = null;
        return savedElem;
    }

    public Iterator iterator() {
        return ______________________________;
    }

    private _______________ class ArrayListIterator implements Iterator {

        private _______________ current = _______________;

        public boolean hasNext() { // implement hasNext()
            boolean answer;






            return answer;
        }

        public Object next() { // implement next()
            Object answer;











            return answer;
        }
    } // end of ArrayListIterator

} // end of ArrayList
```

Question 4: equals (15 marks)



In the abstract class **AbstractList** found on the next page, override the method **boolean equals(Object other)**. Follow all the directives for writing the method.

- Compares **other** with **this** list for equality;
- Returns **true** if and only if **other** is also an **AbstractList** (more precisely, the object designated by **other** is an instance of a subclass of **AbstractList**), both lists have the same size, and all the corresponding pairs of elements in the two lists are equal. Otherwise, the method returns **false**;
- The value **null** is a valid element;
- **AbstractList** implements the interface **Collection**;
- **LinkedList** and **ArrayList** are two examples of subclasses of **AbstractList** but there could be more;
- Use iterators to implement the method.

The declarations of the interfaces **Collection** and **Iterator** can be found on page 10.

```
public class AbstractList implements Collection {

    public boolean equals( Object other ) {




    } // End of equals
} // End of AbstractList
```

```
public interface Collection {

    /* Returns an iterator over the elements in this collection.
     */

    public abstract Iterator iterator();

    /* Add the item to the Collection and return true if the
     * collection changed as a result of this call.
     */

    public abstract boolean add( Object item );

    /* Removes a single instance of the specified element from this
     * collection, if it is present.  Returns true if this collection
     * changed as a result of the call.
     */

    public abstract boolean remove( Object item );

    /* Returns true if this collection contains no elements.
     */

    public abstract boolean isEmpty();
}

public interface Iterator {

    /* Returns true if the iteration has more elements.
     */

    public abstract boolean hasNext();

    /* Returns the next element in the interation. Throws
     * NoSuchElementException if the iteration has no next element.
     */

    public abstract Object next();
}
```

Question 5: splitAt (15 marks)

Complete the implementation of the instance method **LinkedList splitAt(int n)**. The method **splitAt** splits this **LinkedList** in two parts. The first **n** elements remain part of this list while the rest is returned in a new **LinkedList**. In particular,

- After the call **t = l.splitAt(0)**, **l** is empty and **t** contains all the elements that were initially present in **l**;
- After the call **t = l.splitAt(1)**, **l** contains one element and **t** contains all the elements that were initially present in **l** except one;
- After the call **t = l.splitAt(i)**, **l** contains **i** elements and **t** contains **size-i** elements, where **size** is the length of **l** before the call;
- After the call **t = l.splitAt(l.size())**, **l** is unchanged and **t** designates an empty **LinkedList**;
- An exception, **IllegalArgumentException**, is thrown if the parameter **n** is larger than the size of the list.

The implementation of the **LinkedList** has the same characteristics as the one of the assignment 4.

- This implementation always starts off with a dummy node, which serves as a marker for the start of the list. The dummy node is never used to store data. The empty list consists of the dummy node only;
- In the implementation for this question, the nodes of the list are doubly linked;
- In this implementation, the list is circular, i.e. the reference **next** of the last node of the list is pointing at the dummy node, the reference **previous** of the dummy node is pointing at the last element of the list. In the empty list, the dummy node is the first and last node of the list, its references **previous** and **next** are pointing at the node itself;
- Since the last node is easily accessed, it is always the previous node of the dummy node, the header of the list does not need (have) a tail pointer.

Write your answer in the class **LinkedList** on the next page. No method calls are allowed.

Hint: draw the memory diagram for the special and general cases.

```
public class LinkedList {
    private static class Elem { // Implementation of the doubly linked nodes
        private Object value;
        private Elem previous;
        private Elem next;
        private Elem( Object value, Elem previous, Elem next ) {
            this.value = value;
            this.previous = previous;
            this.next = next;
        }
    }
    private Elem head;
    private int size;
    public LinkedList() {
        head = new Elem( null, null, null );
        head.next = head.previous = head;
        size = 0;
    }

    public LinkedList splitAt( int n ) {
        if ( ______________________________ ) {
            throw new IllegalArgumentException();
        }
        _______________ answer = ______________________________;
        Elem p = ______________________________;

        for ( int i=0; i<_______________; i++ ) {
            p = p.next;
        }
        if ( ______________________________ ) { // complete











            answer.size = ______________________________;
            size = ______________________________;
        }
        return answer;
    }
}
```

Question 6: foo (5 marks)

The **recursive** method **SinglyLinkedList foo()** was applied to a list containing the following integers (objects of the class **Integer**): "[1,2,3,4,5,6,7,8,9]". Which of the following lists represents the result of the execution of the method **SinglyLinkedList foo()**? Circle the right answer.

A. [1,2,3,4,5,6,7,8,9];

B. [1,2];

C. [2,5,8,7,4,1];

D. [1,4,7,9,6,3];

E. [3,6,9,7,4,1];

F. [1,4,7,8,5,2];

G. [2,1];

H. [2,4,8,9,3,1];

I. [9,8,7,6,5,4,3,2,1];

J. [].

```
public SinglyLinkedList foo() {
    SinglyLinkedList answer;
    answer = new SinglyLinkedList();
    foo( first, 0, answer );
    return answer;
}

private static void foo( Node p, int index, SinglyLinkedList answer ) {
    if ( p == null ) {
        return;
    } else {
        if ( index % 3 == 0 ) {
            answer.addFirst( p.value );
        }
        foo( p.next, index+1, answer );
        if ( index % 3 == 1 ) {
            answer.addFirst( p.value );
        }
        return;
    }
}
```

The implementation of the class **SinglyLinkedList** can be found on the next page.

```
public class SinglyLinkedList {

    // Objects of the static nested class Node are used to create
    // the structure of the linked list.

    private static class Node {
        private Object value;
        private Node next;
        private Node( Object value, Node next ) {
            this.value = value;
            this.next = next;
        }
    }

    // The first Node of the linked list.

    private Node first;

    // Adds an element at the start of the list.

    public void addFirst( Object item ) {
        first = new Node( item, first );
    }

    // Override the method String toString().

    public String toString() {
        StringBuffer answer = new StringBuffer( "[" );
        Node p = first;
        while ( p != null ) {
            if ( p != first ) {
                answer.append( "," );
            }
            answer.append( p.value );
            p = p.next;
        }
        answer.append( "]" );
        return answer.toString();
    }
}
```

Question 7: zip (15 marks)

Complete the implementation of the method **LinkedList zip(Operator op, LinkedList l1, LinkedList l2)** on the next page.

- Returns a new **LinkedList** that is of the same length as the two input lists and such that the values of this list are the result of applying the operator **op** to the elements at the respective position within each list;
- The interface **Operator** is defined as follows:

```
public interface Operator {
    public abstract Object apply( Object a, Object b );
}
```

- Both arguments must be of the same length, otherwise an **IllegalArgumentException** is thrown;
- Both **LinkedList** arguments remain unchanged by a call to **zip**;
- The method **zip** is implemented outside of the class **LinkedList**. Here are the public methods that you can use to implement **zip**:
  - **LinkedList()**; constructor;
  - **void addFirst(Object item)**; adds **item** at the start of **this** list;
  - **void addLast(Object item)**; adds **item** at the end of **this** list;
  - **void deleteFirst()**; deletes the first element of **this** list;
  - **boolean isEmpty()**; returns **true** if and only if **this** list is empty;
  - **Object head()**; returns a reference to the object stored in the first node of **this** list;
  - **LinkedList split()**; returns the tail of **this** list, **this** list now contains a single element;
  - **void join(LinkedList other)**; appends **other** at the end of **this** list, **other** is now empty.
- Given two lists of integers (objects of the class **Integer**) **l1** and **l2**:

```
l1 is [1,3,5,7,9]
l2 is [0,2,4,6,8]
```

  The execution of **l3 = zip(new Plus(), l1, l2)** produces a list where each element is the sum of the elements at the respective position within each list; **l1** and **l2** remain unchanged:

```
l3 is [1,5,9,13,17]
```

```
public static LinkedList zip( Operator op, LinkedList l1, LinkedList l2 ) {

    LinkedList answer;

    if ( ______________________________ ) {
        throw new IllegalArgumentException( "first list is shorter" );
    }
    if ( ______________________________ ) {
        throw new IllegalArgumentException( "second list is shorter" );
    }

    if ( l1.isEmpty() && l2.isEmpty() ) {

        answer = new LinkedList();

    } else {

        LinkedList t1, t2;

        t1 = ______________________________;

        t2 = ______________________________;

        answer = zip( op, __________, __________ );

        Object current = ______________________________;

        answer.______________( current );

        ______________________________;

        ______________________________;
    }
    return answer;
}
```

Question 8: getLeavesCount (10 marks)

For the class **BinarySearchTree**, implement the instance method **int getLeavesCount()**. It returns an integer equal to the number of leaves in this binary tree.

```
public class BinarySearchTree {

    // Objects of the static nested class Node are used to create
    // the structure of the binary tree.

    private static class Node {
        private Comparable value;
        private Node left;
        private Node right;
        private Node( Comparable value ) {
            this.value = value;
            left = null;
            right = null;
        }
    }

    private Node root = null;











} // End of BinarySearchTree
```

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