

Compression

Due Sunday February 22, 2015

Objectives

For this assignment, you will:

- Gain more experience using JUnit
- Practice implementing and using a doubly linked list data structure
- Gain experience designing and implementing a non-trivial algorithm

Description

Sometimes we need to store massive amounts of information about an object. A good example is storing graphic images. To save space on disks and in transmission of information across the internet, researchers have designed algorithms to compress data. In this lab you will learn one of these compression techniques.

A graphic image can be represented by a two dimensional array of information about the colors of various picture elements (or pixels). At high resolution the image may be composed of 1000 rows and 1000 columns of information, leading to the need to store information on 1,000,000 pixels per image. Needless to say this creates serious problems for storing and transmitting these images. However most images tend to have many contiguous groups of pixels, each of which are the same color. We can take advantage of this by trying to encode information about the entire block in a relatively efficient manner.

The basic idea of our encoding will be to represent a block of pixels with the same color by simply recording the first place where we encounter the new color and only recording information when we see a new color. For instance suppose we have the following table of information (where each number represents a color):

2	2	2	3	3
2	3	3	3	3
3	1	1	1	3

If we imagine tracing through the table from left to right starting with the top row and going through successive rows then we notice that we only need to record the following entries:

2	-	-	3	-
2	3	-	-	-
-	1	-	-	3

Rather than recording this in a two-dimensional table, it will now generally be more efficient to keep this information in a linear list where it is assumed we sweep across an entire row before going on to the next:

(0,0)*2	(0,3)*3	(1,0)*2	(1,1)*3	(2,1)*1	(2,4)*3
---------	---------	---------	---------	---------	---------

This assignment asks you to design a class which will represent one of these compressed tables. A working demo of this program can be found at

<http://www.cs.pomona.edu/classes/cs062/assignments/CompressedGrid/CompressedGrid.html>.

We have provided you with a lot of code here, but you will find that much of the code you must write is quite tricky. This project will require you to be very careful in developing the code for the methods. Look carefully at the provided code and design your methods very carefully. In particular, be sure to test your code carefully *as it is developed* as you will likely make several logical errors if you are not extremely careful.

This is your most complex program yet. You should start early on this assignment and make a very complete design for your program before you ever sit down at the computer to program.

CurDoublyLinkedList class

The `CurDoublyLinkedList` extends the `DoublyLinkedList` class from Bailey's `structure5` package¹. Think carefully about what it means for one class to extend another.

The `CurDoublyLinkedList` class has the extra capability of being able to move to any desired node in the linked list, which we call the *current* node, and then either add a new node after the current node or remove the current node.

`CurDoublyLinkedList` should support all of the old methods of the `List` interface². In addition, the new class should support the following methods:

- `first()`, `last()`
- `next()`, `back()`
- `isOffRight()`, `isOffLeft()`
- `getCurrent()`
- `addAfterCurrent(Object value)`, `deleteCurrent()`

Specifications for these methods can be found in the starter code. You should start this assignment by finishing the `CurDoublyLinkedList` class.

TestCurDoublyLinkedList class

This is a JUnit test class for the `CurDoublyLinkedList` class. There are already a few tests provided for you. You must finish this class by adding at least one test for each method in the `CurDoublyLinkedList` class. The more thorough your tests, the easier time you will have when you implement the `CompressedTable` class.

CompressedTable class

The `CompressedTable` class represents the compressed table. `CompressedTable` implements the `TwoDTable` interface. It has an instance variable `tableInfo` of type:

```
CurDoublyLinkedList<Association<RowOrderedPosn, ValueType>>
```

The instance variable `tableInfo` is a `CurDoublyLinkedList` where each node in the list is an `Association` whose key is an entry in the table and value is a generic type parameter. Feel free to add other instance variables to this class.

You must fill in the constructor for the `CompressedTable` class as well as the two methods:

- `updateInfo(row,col,newInfo)`
- `getInfo(row,col)`

The `updateInfo` method of `CompressedTable` is probably the trickiest code to write. Here is a brief outline of the logic.

¹The code for the `DoublyLinkedList` class is provided at the end of this document. Alternatively, you can go to the "Documentation and Handouts" page on the course website and click on "Bailey structure5 package source code"

²Since `CurDoublyLinkedList` extends the `DoublyLinkedList` class, and the `DoublyLinkedList` class extends `AbstractList`, and `AbstractList` implements the `List` interface, what do you need to do to ensure that your new class `CurDoublyLinkedList` class implements the methods specified in the `List` interface?

1. We have provided you with code to find the node of the list that encodes the position being updated. Of course not every position is in the list, only those representing changes to the array. If the node is not there, the method returns the node before the given position in the list. The class `RowOrderedPosn` (see the startup code) not only encodes a position, but, because it also contains information on the number of rows and columns in the table, can determine if one position would come before or after another.
2. If the new information in the table is the same as that in the node found in step 1, then nothing needs to be done. Otherwise determine if the node represents exactly the position being updated.
If it is the same, update the value of the node, otherwise add a new node representing the new position
3. If you are not careful you may accidentally change several positions in the table to the new value. Avoid this by considering putting in a new node representing the position immediately after the position with the new value. (Draw pictures of the list so you can see what is happening!)
4. If there is already a node with this successor position then nothing needs to be done. Otherwise add a new node with the successor position and the original value. (Do you see why this is necessary? Look at the demo program to see why.)

Try to draw examples of this logic with several sample lists so that you can understand how it works!

RowOrderedPosn class

The `RowOrderedPosn` class represents a single entry in a row-ordered table. The constructor takes four parameters: the row of the entry in the table, the column of the entry in the table, the total number of rows in the table, and the total number of cols in the table. Thus,

```
new RowOrderedPosn(0, 0, 5, 3)
```

represents the entry at location (0,0) – i.e. the upper-left corner – in a table with 5 rows and 3 columns. This class also contains methods to compare compare two entries in a table.

DrawingPanel class

This class is responsible for displaying the two-dimensional grid of colored rectangles. It is also responsible for any mouse actions performed on the two-dimensional grid. This class is already implemented for you.

GridTest class

This class creates an applet that lets the user manipulate a grid of rectangles that form an image. The user interacts with the application by clicking on a color button to set the current color and then clicking on rectangles in the grid to change the colors of individual rectangles. Along with the color buttons there is a button that will display the results of sending the `toString` method to the object of type `CompressedTable` to show the current state of the representation. This can help you as you attempt to debug your `CurDoublyLinkedList` and `CompressedTable` classes.

TwoDTable interface

This interface represents a two-dimensional table.

Getting Started

1. Read through this writeup completely before you start. Then, get a sheet of paper and pencil and draw pictures to help you understand how the doubly linked list works and how the compressed table should work. These examples can also help you form your unit tests. Don't forget to think about special cases.

2. After reading the writeup and going through examples, start working on the design of the program. How will you keep track of whether current is off the right or left side of the list? Look out for methods that you can implement in terms of the other existing methods in either the `CurDoublyLinkedList` or `DoublyLinkedList` class.
3. Create a new project in `Eclipse` and copying the starter files from `/common/cs/cs062/assignments/assignment04/` into the `src` directory of your newly created project.
4. Try to interweave testing your code and writing your code. It is much better to write a method and then stop and test it instead of writing all of the code for a class and only afterwards testing

Grading

You will be graded based on the following criteria:

criterion	points
No change if new color same as curr color	2
Change color of position already in list	2
Change color of position not already in list	2
Correctly adds second node to list when needed	2
JUnit tests for <code>CurDoublyLinkedList</code>	4
General correctness	3
Appropriate comments (including <code>JavaDoc</code>)	2
Style and formatting	2
Submitted correctly	1

NOTE: Code that does not compile will not be accepted! Make sure that your code compiles before submitting it.

Submitting Your Work

As usual, export the entire folder from `Eclipse` to your desktop, change the name of the folder to **Assignment04_LastNameFirstName** where you should replace **LastNameFirstName** by your own last name and first name. Make sure the folder contains both your `.java` and `.class` files. Then drag it into the dropbox folder.

Be sure that your code is clear, formatted properly, and commented appropriately (using `Javadoc`). See the “CS62 Style Guide” on the Handouts page for details on what’s expected for comments.

Extra Credit

As you add more information to the table, you will notice that the table is no longer as efficient in space, because several consecutive entries may have the same values. Make the representation more efficient by dropping later values if they can be subsumed by earlier ones.

For example, the list

$(0,0)*2$	$(0,3)*3$	$(1,0)*3$	$(1,1)*3$	$(2,1)*1$	$(2,4)*3$
-----------	-----------	-----------	-----------	-----------	-----------

can be replaced by the much simpler list:

$(0,0)*2$	$(0,3)*3$	$(2,1)*1$	$(2,4)*3$
-----------	-----------	-----------	-----------

For extra credit, modify the `updateInfo` method of `CompressedTable` to eliminate consecutive items with the same value. The amount of extra credit received will be proportional to the efficiency of your algorithm. Ideally this optimization will only take $O(1)$ time each time something is inserted in the table.

DoublyLinkedList class from structure5

```
// Implementation of lists, using doubly linked elements.
// (c) 1998, 2001 duane a. bailey
package structure5;
import java.util.Iterator;
/**
 * An implementation of lists using doubly linked elements, similar to that of {@link java.util.LinkedList}.
 * This class is a basic implementation of the {@link List} interface.
 * Operations accessing or modifying either the head or the tail of
 * the list execute in constant time.
 * Doubly linked lists are less space-efficient than singly linked lists,
 * but tail-related operations are less costly.
 * Example usage:
 *
 * To place a copy of every unique parameter passed to a program into a
 * DoublyLinkedList, we would use the following:
 * <pre>
 * public static void main({@link java.lang.String String[]} arguments)
 * {
 *     {@link DoublyLinkedList} argList = new {@link #DoublyLinkedList()};
 *     for (int i = 0; i < arguments.length; i++){
 *         if (!argList.{@link #contains(Object) contains(arguments[i])}){
 *             argList.{@link #add(Object) add(arguments[i])};
 *         }
 *     }
 *     System.out.println(argList);
 * }
 * </pre>
 * @version $Id: DoublyLinkedList.java 31 2007-08-06 17:19:56Z bailey $
 * @author, 2001 duane a. bailey
 */
public class DoublyLinkedList<E> extends AbstractList<E>
{
    /**
     * Number of elements within list.
     */
    protected int count;
    /**
     * Reference to head of list.
     */
    protected DoublyLinkedListNode<E> head;
    /**
     * Reference to tail of list.
     */
    protected DoublyLinkedListNode<E> tail;

    /**
     * Constructs an empty list.
     *
     * @post constructs an empty list
     */
    public DoublyLinkedList()
```

```

{
    head = null;
    tail = null;
    count = 0;
}

/**
 * Add a value to head of list.
 *
 * @post adds value to beginning of list
 *
 * @param value value to be added.
 */
public void add(E value)
{
    addFirst(value);
}

/**
 * Add a value to head of list.
 *
 * @pre value is not null
 * @post adds element to head of list
 *
 * @param value value to be added.
 */
public void addFirst(E value)
{
    // construct a new element, making it head
    head = new DoublyLinkedListNode<E>(value, head, null);
    // fix tail, if necessary
    if (tail == null) tail = head;
    count++;
}

/**
 * Remove a value from head of list.
 * Value is returned.
 *
 * @pre list is not empty
 * @post removes first value from list
 *
 * @return value removed from list.
 */
public E removeFirst()
{
    Assert.pre(!isEmpty(), "List is not empty.");
    DoublyLinkedListNode<E> temp = head;
    head = head.next();
    if (head != null) {
        head.setPrevious(null);
    } else {
        tail = null; // remove final value
    }
}

```

```

        temp.setNext(null);// helps clean things up; temp is free
        count--;
        return temp.value();
    }

    /**
     * Add a value to tail of list.
     *
     * @pre value is not null
     * @post adds new value to tail of list
     *
     * @param value value to be added.
     */
    public void addLast(E value)
    {
        // construct new element
        tail = new DoublyLinkedListNode<E>(value, null, tail);
        // fix up head
        if (head == null) head = tail;
        count++;
    }

    /**
     * Remove a value from tail of list.
     *
     * @pre list is not empty
     * @post removes value from tail of list
     *
     * @return value removed from list.
     */
    public E removeLast()
    {
        Assert.pre(!isEmpty(),"List is not empty.");
        DoublyLinkedListNode<E> temp = tail;
        tail = tail.previous();
        if (tail == null) {
            head = null;
        } else {
            tail.setNext(null);
        }
        count--;
        return temp.value();
    }

    /**
    public void addLast(E value)
    {
        // construct new element
        tail = new DoublyLinkedListNode<E>(value, null, tail);
        count++;
    }

    public E removeLast()
    {
        Assert.pre(!isEmpty(),"List is not empty.");

```

```

        DoublyLinkedListNode<E> temp = tail;
        tail = tail.previous();
        tail.setNext(null);
        count--;
        return temp.value();
    }
}
*/

/**
 * Get a copy of first value found in list.
 *
 * @pre list is not empty
 * @post returns first value in list
 *
 * @return A reference to first value in list.
 */
public E getFirst()
{
    return head.value();
}

/**
 * Get a copy of last value found in list.
 *
 * @pre list is not empty
 * @post returns last value in list
 *
 * @return A reference to last value in list.
 */
public E getLast()
{
    return tail.value();
}

/**
 * Check to see if a value is within list.
 *
 * @pre value not null
 * @post returns true iff value is in list
 *
 * @param value A value to be found in list.
 * @return True if value is in list.
 */
public boolean contains(E value)
{
    DoublyLinkedListNode<E> finger = head;
    while ((finger != null) && (!finger.value().equals(value)))
    {
        finger = finger.next();
    }
    return finger != null;
}

/**

```



```

* Remove a value from list.  At most one value is removed.
* Any duplicates remain.  Because comparison is done with "equals,"
* actual value removed is returned for inspection.
*
* @pre value is not null.  List can be empty
* @post first element matching value is removed from list
*
* @param value value to be removed.
* @return value actually removed.
*/
public E remove(E value)
{
    DoublyLinkedListNode<E> finger = head;
    while (finger != null &&
           !finger.value().equals(value))
    {
        finger = finger.next();
    }
    if (finger != null)
    {
        // fix next field of element above
        if (finger.previous() != null)
        {
            finger.previous().setNext(finger.next());
        } else {
            head = finger.next();
        }
        // fix previous field of element below
        if (finger.next() != null)
        {
            finger.next().setPrevious(finger.previous());
        } else {
            tail = finger.previous();
        }
        count--; // fewer elements
        return finger.value();
    }
    return null;
}

/**
 * Determine number of elements in list.
 *
 * @post returns number of elements in list
 *
 * @return number of elements found in list.
 */
public int size()
{
    return count;
}

/**
 * Determine if list is empty.

```

```

*
* @post returns true iff list has no elements
*
* @return True iff list has no values.
*/
public boolean isEmpty()
{
    return size() == 0;
}

/**
 * Remove all values from list.
 *
 * @post removes all elements from list
 */
public void clear()
{
    head = tail = null;
    count = 0;
}

/**
 * Get value at location i.
 *
 * @pre 0 <= i < size()
 * @post returns object found at that location
 *
 * @param i position of value to be retrieved.
 * @return value retrieved from location i (returns null if i invalid)
 */
public E get(int i)
{
    if (i >= size()) return null;
    DoublyLinkedListNode<E> finger = head;
    // search for ith element or end of list
    while (i > 0)
    {
        finger = finger.next();
        i--;
    }
    // not end of list, return value found
    return finger.value();
}

/**
 * Set value stored at location i to object o, returning old value.
 *
 * @pre 0 <= i < size()
 * @post sets ith entry of list to value o, returns old value
 * @param i location of entry to be changed.
 * @param o new value
 * @return former value of ith entry of list.
 */
public E set(int i, E o)

```

```

{
    if (i >= size()) return null;
    DoublyLinkedListNode<E> finger = head;
    // search for ith element or end of list
    while (i > 0)
    {
        finger = finger.next();
        i--;
    }
    // get old value, update new value
    E result = finger.value();
    finger.setValue(o);
    return result;
}

/**
 * Insert value at location.
 *
 * @pre 0 <= i <= size()
 * @post adds ith entry of list to value o
 * @param i index of this new value
 * @param o value to be stored
 */
public void add(int i, E o)
{
    Assert.pre((0 <= i) &&
              (i <= size()), "Index in range.");
    if (i == 0) addFirst(o);
    else if (i == size()) addLast(o);
    else {
        DoublyLinkedListNode<E> before = null;
        DoublyLinkedListNode<E> after = head;
        // search for ith position, or end of list
        while (i > 0)
        {
            before = after;
            after = after.next();
            i--;
        }
        // create new value to insert in correct position
        DoublyLinkedListNode<E> current =
            new DoublyLinkedListNode<E>(o,after,before);
        count++;
        // make after and before value point to new value
        before.setNext(current);
        after.setPrevious(current);
    }
}

/**
 * Remove and return value at location i.
 *
 * @pre 0 <= i < size()
 * @post removes and returns object found at that location

```

```

*
* @param i position of value to be retrieved.
* @return value retrieved from location i (returns null if i invalid)
*/
public E remove(int i)
{
    Assert.pre((0 <= i) &&
               (i < size()), "Index in range.");
    if (i == 0) return removeFirst();
    else if (i == size()-1) return removeLast();
    DoublyLinkedListNode<E> previous = null;
    DoublyLinkedListNode<E> finger = head;
    // search for value indexed, keep track of previous
    while (i > 0)
    {
        previous = finger;
        finger = finger.next();
        i--;
    }
    previous.setNext(finger.next());
    finger.next().setPrevious(previous);
    count--;
    // finger's value is old value, return it
    return finger.value();
}

/**
 * Determine first location of a value in list.
 *
 * @pre value is not null
 * @post returns the (0-origin) index of value,
 *       or -1 if value is not found
 *
 * @param value value sought.
 * @return index (0 is first element) of value, or -1
 */
public int indexOf(E value)
{
    int i = 0;
    DoublyLinkedListNode<E> finger = head;
    // search for value or end of list, counting along way
    while (finger != null && !finger.value().equals(value))
    {
        finger = finger.next();
        i++;
    }
    // finger points to value, i is index
    if (finger == null)
    { // value not found, return indicator
        return -1;
    } else {
        // value found, return index
        return i;
    }
}

```

```

}

/**
 * Determine last location of a value in list.
 *
 * @pre value is not null
 * @post returns the (0-origin) index of value,
 *       or -1 if value is not found
 *
 * @param value value sought.
 * @return index (0 is first element) of value, or -1
 */
public int lastIndexOf(E value)
{
    int i = size()-1;
    DoublyLinkedListNode<E> finger = tail;
    // search for last matching value, result is desired index
    while (finger != null && !finger.value().equals(value))
    {
        finger = finger.previous();
        i--;
    }
    if (finger == null)
    { // value not found, return indicator
        return -1;
    } else {
        // value found, return index
        return i;
    }
}

/**
 * Construct an iterator to traverse list.
 *
 * @post returns iterator that allows traversal of list
 *
 * @return An iterator that traverses list from head to tail.
 */
public Iterator<E> iterator()
{
    return new DoublyLinkedListIterator<E>(head);
}

/**
 * Construct a string representation of list.
 *
 * @post returns a string representing list
 *
 * @return A string representing elements of list.
 */
public String toString()
{
    StringBuffer s = new StringBuffer();
    s.append("<DoublyLinkedList:");

```

```
    Iterator li = iterator();
    while (li.hasNext())
    {
        s.append(" "+li.next());
    }
    s.append(">");
    return s.toString();
}
}
```