

```

1 import java.util.*;
2
3
4 /**
5  * Main class - for accessing suffix tree applications
6  * David Manlove, Jan 03. Modified by David Manlove, Jan 07 and Jan 09.
7  */
8
9 public class Main {
10
11     /**
12      * The main method.
13      * @param args the arguments
14      */
15     public static void main(String args[]) {
16
17         Scanner standardInput = new Scanner(System.in);
18         do {
19             // display prompt for user
20             System.out.println();
21             System.out.print("Enter the number of the task or type 'q' to quit: ");
22
23             // read in a line from standard input
24             String line = standardInput.nextLine();
25             System.out.println();
26
27             try {
28                 // try to extract an integer from line if possible
29                 int numTask = Integer.parseInt(line);
30
31                 // variables used in multiple cases
32                 String text, searchWord;
33                 SuffixTree suffixTree;
34                 SuffixTreeAppl suffixTreeAppl;
35                 FileInput newInput;
36                 byte [] readInput;
37
38                 switch (numTask) {
39                     case 1:
40                         // get file name to be found
41                         System.out.print("Enter the name of the text file: ");
42                         text = standardInput.nextLine();
43                         System.out.println();
44
45                         // get string to be located
46                         System.out.print("Enter the string to search for: ");
47                         searchWord = standardInput.nextLine();
48
49                         // read suffix tree into a byte string
50                         newInput = new FileInput(text);
51                         readInput = newInput.readFile();
52
53                         // turn file into suffixTreeAppl instance
54                         suffixTree = new SuffixTree(readInput);
55                         suffixTreeAppl = new SuffixTreeAppl(suffixTree);
56
57                         // search for string and return result
58                         Task1Info task1 = suffixTreeAppl.searchSuffixTree(searchWord.getBytes
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63         System.out.println("Search string " + "'" + searchWord + "'"
64             + " occurs at position " + task1.getPos() + " of " + text);
65     }
66     break;
67
68     case 2:
69         // get file name to be found
70         System.out.print("Enter the name of the text file: ");
71         text = standardInput.nextLine();
72         System.out.println();
73
74         // get string to be located
75         System.out.print("Enter the string to search for: ");
76         searchWord = standardInput.nextLine();
77
78         // read suffix tree into a byte string
79         newInput = new FileInputStream(text);
80         readInput = newInput.readFile();
81
82         // turn file into suffixTreeAppl instance
83         suffixTree = new SuffixTree(readInput);
84         suffixTreeAppl = new SuffixTreeAppl(suffixTree);
85
86         //Search for occurrences and return result
87         Task2Info task2 = suffixTreeAppl.allOccurrences(searchWord.getBytes());
88         if ( task2.getPositions().isEmpty() ) {
89             System.out.println("Search string " + "'" + searchWord + "'"
90                 + " does not occur in " + text);
91         } else {
92             int len = task2.getPositions().size();
93             System.out.println("Search string " + "'" + searchWord + "'"
94                 + " occurs in " + text + " at positions:");
95
96             // display each occurrence location
97             int i = 0;
98             while ( i < task2.getPositions().size() ) {
99                 System.out.println(task2.getPositions().get(i));
100                 i++;
101             }
102             System.out.println("The total number of occurrences is " + len);
103         }
104         break;
105
106     case 3:
107         // get file name to be found
108         System.out.print("Enter the name of the text file: ");
109         text = standardInput.nextLine();
110         System.out.println();
111
112         // read suffix tree into a byte string
113         newInput = new FileInputStream(text);
114         readInput = newInput.readFile();
115
116         // turn file into suffixTreeAppl instance
117         suffixTree = new SuffixTree(readInput);
118         suffixTreeAppl = new SuffixTreeAppl(suffixTree);
119
120         // find lrs
121         Task3Info task3 = suffixTreeAppl.traverseForLrs();
122
123         // check there was a repeated substring
124         if (task3.getLen() == 0) {
```

```

125         System.out.println("There are no repeated substrings in " + text);
126     } else {
127         // get the longest string Found
128         String lrs = new String(readInput).substring(task3.getPos1(),
129             task3.getPos1()+task3.getLen());
130
131         // display results
132         System.out.println("An LRS in " + text + " is " + "'" + lrs + "'");
133         System.out.println("Its Length is " + task3.getLen());
134         System.out.println("Starting position of one occurrence is "
135             + task3.getPos1());
136         System.out.println("Starting position of another occurrence is "
137             + task3.getPos2());
138     }
139     break;
140
141     case 4:
142         // get file names to be found
143         System.out.print("Enter the name of the first text file: ");
144         text = standardInput.nextLine();
145         System.out.println();
146         System.out.print("Enter the name of the second text file: ");
147         String text2 = standardInput.nextLine();
148         System.out.println();
149
150         // read suffix tree into a byte string
151         newInput = new FileInputStream(text);
152         readInput = newInput.readFile();
153
154         newInput = new FileInputStream(text2);
155         byte [] readInput2 = newInput.readFile();
156
157         // turn file into suffixTreeAppl instance
158         suffixTree = new SuffixTree(readInput, readInput2);
159         suffixTreeAppl = new SuffixTreeAppl(suffixTree);
160
161         Task4Info task4 = suffixTreeAppl.traverseForLcs(readInput.length);
162
163         if (task4.getLen() == 0) {
164             System.out.println("There are no common substrings between "
165                 + text + " and " + text2);
166         } else {
167             // display results
168             String lcs = new String(readInput).substring(task4.getPos1(),
169                 task4.getPos1()+task4.getLen());
170             System.out.println("An LCS of " + text + " and " + text2 +
171                 " is " + "'" + lcs + "'");
172             System.out.println("Its Length is " + task4.getLen());
173             System.out.println("Starting position of one occurrence is "
174                 + task4.getPos1());
175             System.out.println("Starting position of another occurrence is "
176                 + task4.getPos2());
177         }
178         break;
179
180     default: throw new NumberFormatException();
181 }
182
183 catch (NumberFormatException e) {
184     if (line.length()==0 || line.charAt(0)!='q')
185         System.out.println("You must enter either '1', '2', '3', '4' or 'q'.");
186     else

```

```
187             break;
188         }
189     } while (true);
190     standardInput.close();
191 }
192 }
```

```

1 package SuffixTreePackage;
2
3 /**
4  * Class for construction and manipulation of suffix trees based on a list
5  * of children at each node.
6  *
7  * Includes naive  $O(n^2)$  suffix tree construction algorithm based on
8  * repeated insertion of suffixes and node-splitting.
9  *
10 * Modifies Ada implementation of naive suffix tree construction algorithm
11 * due to Rob Irving, Jan 00.
12 *
13 * Also incorporates Java code for naive suffix tree construction algorithm
14 * due to Ela Hunt, Jan 01.
15 *
16 * Modifications by David Manlove, Apr 02, Jan 03, Jan 07 and Jan 09.
17 */
18
19 public class SuffixTree {
20
21     /** Root node of the suffix tree. */
22     private SuffixTreeNode root;
23
24     /** String (byte array) corresponding to suffix tree. */
25     private byte [] s;
26
27     /** Length of string corresponding to suffix tree (without termination character). */
28     private int stringLen;
29
30     /**
31      * Builds the suffix tree for a given string.
32      *
33      * @param sInput the string whose suffix tree is to be built
34      * - assumes that '$' does not occur as a character anywhere in sInput
35      * - assumes that characters of sInput occupy positions 0 onwards
36      */
37     public SuffixTree (byte [] sInput) {
38         root = new SuffixTreeNode(null, null, 0, 0, -1); // create root node of suffix
tree;
39         stringLen = sInput.length;
40         s = new byte[stringLen + 1]; // create longer byte array ready for termination
character
41         System.arraycopy(sInput, 0, s, 0, stringLen);
42         s[stringLen] = (byte) '$'; // append termination character to original string
43         buildSuffixTree(); // build the suffix tree
44     }
45
46     /**
47      * Builds a generalised suffix tree for two given strings.
48      *
49      * @param sInput1 the first string
50      * @param sInput2 the second string
51      * - assumes that '$' and '#' do not occur as a character anywhere in sInput1 or
sInput2
52      * - assumes that characters of sInput1 and sInput2 occupy positions 0 onwards
53      */
54     public SuffixTree (byte[] sInput1, byte[] sInput2) {
55         root = new SuffixTreeNode(null, null, 0, 0, -1); // create root node of suffix tree
56         int len1 = sInput1.length;
57         int len2 = sInput2.length;
58         stringLen = len1+len2+1;
59         s = new byte [len1+len2+2]; // create a byte array to hold both texts, # and $

```

```

60     System.arraycopy(sInput1, 0, s, 0, len1);
61     s[len1] = (byte) '#';
62     System.arraycopy(sInput2, 0, s, len1+1, len2);
63     s[len1+len2+1] = (byte) '$';
64     buildSuffixTree();
65 }
66
67 /**
68  * Builds the suffix tree.
69  */
70 private void buildSuffixTree() {
71     try {
72         for (int i=0; i<= stringLen; i++) {
73             // for large files, the following line may be useful for
74             // indicating the progress of the suffix tree construction
75             if (i % 10000==0) System.out.println(i);
76
77             // raise an exception if the text file contained a '$'
78             if (s[i] == (byte) '$' && i < stringLen)
79                 throw new Exception();
80             else
81                 insert(i); // insert suffix number i of z into tree
82         }
83     }
84     catch (Exception e) {
85         System.out.println("Text file contains a $ character!");
86         System.exit(-1);
87     }
88 }
89
90 /**
91  * Given node nodeIn of suffix tree and character ch, search nodeIn,
92  * plus all sibling nodes of nodeIn, looking for a node whose left
93  * label x satisfies ch == s[x].
94  * - Assumes that characters of s occupy positions 0 onwards
95  *
96  * @param nodeIn a node of the suffix tree
97  * @param ch the character to match
98  *
99  * @return the matching suffix tree node (null if none exists)
100 */
101 public SuffixTreeNode searchList (SuffixTreeNode nodeIn, byte ch) {
102
103     SuffixTreeNode next = nodeIn;
104     SuffixTreeNode nodeOut = null;
105
106     while (next != null) {
107         if (next.getLeftLabel() < stringLen && s[next.getLeftLabel()] == ch)
108             {
109                 nodeOut = next;
110                 next = null;
111             }
112         else
113             next = next.getSibling();
114     }
115     return nodeOut; // return matching node if successful, or null otherwise
116 }
117
118 /**
119  * Inserts suffix number i of s into suffix tree.
120  * - assumes that characters of s occupy positions 0 onwards
121  */

```

```

122     * @param i the suffix number of s to insert
123     */
124     private void insert(int i) {
125
126         int pos, j, k;
127         SuffixTreeNode current, next;
128         pos = i; // position in s
129         current = root;
130
131         while (true) {
132             // search for child of current with left label x such that s[x]==s[pos]
133             next = searchList(current.getChild(), s[pos]);
134
135             if (next == null) {
136                 // current node has no such child, so add new one corresponding to
137                 // positions pos onwards of s
138                 current.addChild(pos, stringLen, i);
139                 break;
140             }
141             else {
142                 // try to match s[node.getLeftLabel()+1..node.getRightLabel()] with
143                 // segment of s starting at position pos+1
144                 j = next.getLeftLabel() + 1;
145                 k = pos + 1;
146
147                 while (j <= next.getRightLabel()) {
148                     if (s[j] == s[k]) {
149                         j++;
150                         k++;
151                     }
152                     else
153                         break;
154                 }
155                 if (j > next.getRightLabel()) {
156                     // succeeded in matching whole segment, so go further down tree
157                     pos = k;
158                     current = next;
159                 }
160                 else {
161                     /* succeeded in matching s[next.getLeftLabel()..j-1] with
162                     * s[pos..k-1]. Split the node next so that its right label is
163                     * now j-1. Create two children of next: (1) corresponding to
164                     * suffix i, with left label k and right label s.length-1,
165                     * and (2) with left label j and right label next.getRightLabel(),
166                     * whose children are those of next (if any), and whose suffix
167                     * number is equal to that of next. */
168
169                     SuffixTreeNode n1 = new SuffixTreeNode(null, null, k, stringLen, i);
170                     SuffixTreeNode n2 = new SuffixTreeNode(next.getChild(), n1,
171                                                             j, next.getRightLabel(),
172                                                             next.getSuffix());
173
174                     // now update next's right label, list of children and suffix number
175                     next.setRightLabel(j-1);
176                     next.setChild(n2);
177                     next.setSuffix(-1); // next is now an internal node
178                     break;
179                 }
180             }
181         }
182     }

```

```
183     * Gets the root node.
184     *
185     * @return the root node
186     */
187     public SuffixTreeNode getRoot() { return root; }
188
189     /**
190     * Sets the root node.
191     *
192     * @param node the new root node
193     */
194     public void setRoot(SuffixTreeNode node) { root = node; }
195
196     /**
197     * Gets the string represented by the suffix tree.
198     *
199     * @return the string represented by the suffix tree
200     */
201     public byte[] getString() { return s; }
202
203     /**
204     * Sets the string represented by the suffix tree.
205     *
206     * @param sInput the new string represented by the suffix tree
207     */
208     public void setString(byte [] sInput) { s = sInput; }
209
210     /**
211     * Gets the length of the string represented by the suffix tree.
212     *
213     * @return the length of the string represented by the suffix tree
214     */
215     public int getStringLen() { return stringLen; }
216
217     /**
218     * Sets the length of the string represented by the suffix tree.
219     *
220     * @param len the new length of the string represented by the suffix tree
221     */
222     public void setStringLen(int len) { stringLen = len; }
223 }
224
```



```

1 package SuffixTreePackage;
2
3 /**
4  * Class with methods for carrying out applications of suffix trees
5  * David Manlove, Jan 03. Modified by David Manlove, Jan 07 and Jan 09.
6  */
7
8 public class SuffixTreeAppl {
9
10     /** The suffix tree */
11     private SuffixTree t;
12
13     /**
14      * Default constructor.
15      */
16     public SuffixTreeAppl () {
17         t = null;
18     }
19
20     /**
21      * Constructor with parameter.
22      *
23      * @param tree the suffix tree
24      */
25     public SuffixTreeAppl (SuffixTree tree) {
26         t = tree;
27     }
28
29     /**
30      * Search the suffix tree t representing string s for a target x.
31      * Stores -1 in Task1Info.pos if x is not a substring of s,
32      * otherwise stores p in Task1Info.pos such that x occurs in s
33      * starting at s[p] (p counts from 0)
34      * - assumes that characters of s and x occupy positions 0 onwards
35      *
36      * @param x the target string to search for
37      *
38      * @return a Task1Info object
39      */
40     public Task1Info searchSuffixTree(byte[] x) {
41
42         Task1Info task1 = new Task1Info();
43         int pos, j, len;
44         SuffixTreeNode current;
45         pos = 0; // position in x
46         current = t.getRoot();
47         len = x.length-1;
48
49         while (true) {
50             // search for child which has left edge label equal to our current position in
51             x
52             current = t.searchList(current.getChild(), x[pos]);
53
54             // if no matches are found terminate unsuccessfully
55             // otherwise if all characters have been matched terminate successfully
56             // otherwise continue to check values between left edge label of next node
57             if (current == null) {
58                 task1.setPos(-1);
59                 return task1;
60             } else if (pos == len) {
61                 task1.setPos(current.getLeftLabel()-len);
62                 task1.setMatchNode(current);

```

```

62         return task1;
63     }
64     else {
65         // move to next character and label to continue checking edge
66         j = current.getLeftLabel() + 1;
67         pos++;
68
69         // enters only if the edge above node has multiple characters
70         // terminates when string found or edge label matches fully
71         while (j <= current.getRightLabel()) {
72             if (t.getString()[j] == x[pos]) {
73                 if (pos == len) {
74                     task1.setMatchNode(current);
75                     task1.setPos(j-len);
76                     return task1;
77                 } else {
78                     j++;
79                     pos++;
80                 }
81             }
82             else {
83                 task1.setPos(-1);
84                 return task1;
85             }
86         }
87         // succeeded in matching whole edge, go further down tree
88     }
89 }
90 }
91
92 /**
93  * Search suffix tree t representing string s for all occurrences of target x.
94  * Stores in Task2Info.positions a linked list of all such occurrences.
95  * Each occurrence is specified by a starting position index in s
96  * (as in searchSuffixTree above). The linked list is empty if there
97  * are no occurrences of x in s.
98  * - assumes that characters of s and x occupy positions 0 onwards
99  *
100  * @param x the target string to search for
101  *
102  * @return a Task2Info object
103  */
104 public Task2Info allOccurrences(byte[] x) {
105
106     SuffixTreeAppl suffixTreeAppl = new SuffixTreeAppl(t);
107     Task1Info task1 = suffixTreeAppl.searchSuffixTree(x);
108
109     // matching suffix node means all leaf nodes below are matches
110     SuffixTreeNode start = task1.getMatchNode();
111
112     Task2Info task2 = new Task2Info();
113     if (start == null) {
114         // if no match exists
115         return task2;
116     } else if (start.getSuffix() == -1) {
117         // if multiple instances exist call recursive function to count it
118         task2 = recLeafCount(start.getChild(), task2);
119     } else {
120         // if string is unique return its position
121         task2.addEntry(start.getSuffix());
122     }
123     return task2;

```

```

124     }
125
126     // return a task 2 object with positions of every occurrence of a leaf node
127     public Task2Info recLeafCount(SuffixTreeNode current, Task2Info task2) {
128         Task2Info empty = new Task2Info();
129         // return an empty object to the previous call if no node exists
130         // otherwise is node is a non leaf so we check its child
131         // otherwise add an entry
132         if (current == null) {
133             return empty;
134         } else if (current.getSuffix() == -1 ) {
135             recLeafCount(current.getChild(), task2);
136         } else {
137             task2.addEntry(current.getSuffix());
138         }
139         // repeat process on sibling node
140         recLeafCount(current.getSibling(), task2);
141         return task2;
142     }
143
144     /**
145     * Traverses suffix tree t representing string s and stores ln, p1 and
146     * p2 in Task3Info.len, Task3Info.pos1 and Task3Info.pos2 respectively,
147     * so that s[p1..p1+ln-1] = s[p2..p2+ln-1], with ln maximal;
148     * i.e., finds two embeddings of a longest repeated substring of s
149     * - assumes that characters of s occupy positions 0 onwards
150     * so that p1 and p2 count from 0
151     *
152     * @return a Task3Info object
153     */
154     public Task3Info traverseForLrs () {
155
156         Task3Info task3 = new Task3Info();
157         SuffixTreeNode root = t.getRoot();
158
159         // if 0 children from root
160         if (root.getChild() == null) {
161             return task3;
162         }
163         task3 = recFindLrs(task3, root, 0);
164         return task3;
165     }
166
167     // recursively check for a node with 2 or more children with maximum depth
168     public Task3Info recFindLrs(Task3Info task3, SuffixTreeNode current, int depth) {
169         SuffixTreeNode child = current.getChild();
170
171         // case for only 1 child leaf
172         if (child.getSuffix() != -1 && child.getSibling() == null ) {
173             // not a repeated substring so we return
174             return task3;
175         }
176         // case for 1 child non leaf
177         } else if (child.getSuffix() == -1 && child.getSibling() == null ){
178             // node could have a repeated substring below it so continue downward
179             depth += current.getRightLabel() - current.getLeftLabel() + 1;
180             task3 = recFindLrs(task3, child, depth);
181         } else {
182             // if more than 1 child update depth
183             depth += current.getRightLabel() - current.getLeftLabel() + 1;
184
185             // if child is non leaf continue downward
186             // otherwise check its sibling

```

```

186         while (child != null) {
187             if (child.getSuffix() == -1 ) {
188                 task3 = recFindLrs(task3, child, depth);
189             }
190             child = child.getSibling();
191         }
192         // check if depth is more than current length
193         // if so replace length and occurrence locations
194         if (task3.getLen() < depth) {
195             task3.setLen(depth-1);
196             task3.setPos1(current.getChild().getLeftLabel()-task3.getLen());
197             task3.setPos2(current.getChild().getSibling().getLeftLabel()-task3.getLen
198 ());
199         }
200     }
201 }
202 return task3;
203 }
204
205 /**
206  * Traverse generalised suffix tree t representing strings s1 (of length
207  * s1length), and s2, and store ln, p1 and p2 in Task4Info.len,
208  * Task4Info.pos1 and Task4Info.pos2 respectively, so that
209  * s1[p1..p1+ln-1] = s2[p2..p2+ln-1], with len maximal;
210  * i.e., finds embeddings in s1 and s2 of a longest common substring
211  * of s1 and s2
212  * - assumes that characters of s1 and s2 occupy positions 0 onwards
213  * so that p1 and p2 count from 0
214  *
215  * @param s1Length the length of s1
216  *
217  * @return a Task4Info object
218  */
219 public Task4Info traverseForLcs (int s1Length) {
220     Task4Info task4 = new Task4Info();
221     SuffixTreeNode root = t.getRoot();
222
223     // if 0 children from root
224     if (root.getChild() == null) {
225         return task4;
226     }
227     task4 = recFindLcs(task4, root, 0, s1Length+1);
228     return task4;
229 }
230
231 // recursively check for a node with 2 or more children from opposing strings with
232 // maximum depth
233 public Task4Info recFindLcs(Task4Info task4, SuffixTreeNode current, int depth, int
234 splitPoint) {
235     SuffixTreeNode child = current.getChild();
236
237     // case for only 1 child leaf
238     if (child.getSuffix() != -1 && child.getSibling() == null ) {
239         // not a repeated substring so we return
240         return task4;
241     }
242     // case for 1 child non leaf
243     } else if (child.getSuffix() == -1 && child.getSibling() == null ){
244         // could have a substring below it so continue downward
245         depth += current.getRightLabel() - current.getLeftLabel() + 1;
246         task4 = recFindLcs(task4, child, depth, splitPoint);
247     } else {

```

```
245         // if more than 1 child update depth
246         depth += current.getRightLabel() - current.getLeftLabel() + 1;
247         task4.setString1Leaf(false);
248         task4.setString2Leaf(false);
249         int s1Location = 0;
250         int s2Location = 0;
251
252         // if child is non leaf continue downward
253         // otherwise check its sibling
254         while (child != null) {
255             if (child.getSuffix() == -1 ) {
256                 task4 = recFindLcs(task4, child, depth, splitPoint);
257             }
258             // update booleans to keep track of the node
259             //and also note the edge for which it holds true
260             if (child.getLeftLabel() <= splitPoint) {
261                 task4.setString1Leaf(true);
262                 s1Location = child.getLeftLabel();
263             } else {
264                 task4.setString2Leaf(true);
265                 s2Location = child.getLeftLabel();
266             }
267             child = child.getSibling();
268
269         }
270         // check if depth is more than current length
271         // if so replace length and occurrence locations
272         if (task4.getString1Leaf() == true && task4.getString2Leaf() == true &&
273             task4.getLen() < depth) {
274             task4.setLen(depth-1);
275             task4.setPos1(s1Location-task4.getLen());
276             task4.setPos2(s2Location-task4.getLen()-splitPoint);
277         }
278     }
279     return task4;
280 }
281
282 }
283
```