Lecture 13
Linked Lists (Jotto)

“The secret to happiness is: Always get as much RAM as you can possibly afford.”

http://www.princeton.edu/~orf201
The Game Jotto

Pick a 5-letter word: *teach*

Your opponent queries 5-letter words. To each, you respond with number of "matches":

<table>
<thead>
<tr>
<th>Query</th>
<th>Matches</th>
</tr>
</thead>
<tbody>
<tr>
<td>baste</td>
<td>3</td>
</tr>
<tr>
<td>ledge</td>
<td>1</td>
</tr>
<tr>
<td>abode</td>
<td>2</td>
</tr>
<tr>
<td>tepid</td>
<td>2</td>
</tr>
<tr>
<td>metro</td>
<td>2</td>
</tr>
<tr>
<td>lathe</td>
<td>4</td>
</tr>
</tbody>
</table>

Game ends when number of matches is 5. That is, when query either matches hidden word exactly or is an anagram of it.
Humans Opponents Use Logic

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<td>lathe</td>
<td>4</td>
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Let’s see, *lathe* has 4 matches. Therefore, *a* and *e* are either both in or only one of them is in. Suppose first that both are in. Then, from *baste*, *b*, *s*, and *t* are out. From *ledge*, *l*, *d*, and *g* are out. From *abode*, *o* is out too. Etc.

Now, suppose that *a* is in but *e* is out. Then from *lathe*, *l*, *t*, and *h* are out too. Etc.
Computer Algorithm for Jotto

(1) Read a list of all 5-letter words (there are 2415).
(2) Pick a word at random from the list as the first query.
(3) After being told the number of matches, strike from the list every word that fails to produce that response.
(4) Go back to step 2.

Here’s a sample output from computer Jotto:

Think of a 5-letter word
Are you ready to begin (y/n)? y

There are 2415 words in my dictionary.
My 1-th guess is: gorge
How many matches? 1

There are 1046 words in my dictionary.
My 2-th guess is: lathe
How many matches? 4

There are 39 words in my dictionary.
My 3-th guess is: slate
How many matches? 3

There are 16 words in my dictionary.
My 4-th guess is: ethyl
How many matches? 3
public static void main(String[] args) {
    int m;
    String guess;
    readDictionary();
    System.out.println("Think of a 5-letter word");

    for (int k=1; ; k++) {
        System.out.println();
        System.out.println("There are " +n+
                         " words in my dictionary");
        if (n==0) {
            System.out.println("Sorry, your word is "+
                                "not in my dictionary");
            break;
        }
        guess = pickRandom();
        System.out.println("My "+k+-th guess is: "+guess);
        m = Console.in.readInt("How many matches? ");
        if (m==5) {
            System.out.println("I win, I win!");
            break;
        }
        if (m>5 || m<0) {
            System.out.println("No Way! Try again.");
            continue;
        }
        removeWords(m, guess);
    }
}
Store Dictionary in a Linked List

```java
class WordLink {
    String word;
    WordLink next;
}

public class Jotto {
    /* Class variables */
    static int n; // size of dictionary
    static WordLink firstWord; // Pointer to first word in linked list
    .
    .
    .
}
```

```
firstword

lemon --------- fjord --------- chafe --------- aback

word  next

null
```
readDictionary()
addWord()

code:
```java
static void addWord(String word) {
    WordLink newlink;

    newlink = new WordLink();
    newlink.word = word;
    newlink.next = firstWord;
    firstWord = newlink;
    n++;
}
```

DIAGRAM:
- `firstWord` is a `WordLink` node.
- `newlink` is a newly created `WordLink` node.
- `null` is the end marker.
- The words `lemon`, `fjord`, `chafe`, and `aback` are linked together with arrows indicating the `next` pointer.
removeWords() and deleteNextWord()

```java
static void removeWords(int m, String guess)
{
    WordLink curr, prev;
    prev = null;
    for (curr = firstWord; curr != null; curr = curr.next) {
        if nmatches(guess, curr.word) != m) {
            deleteNextWord(prev);
        } else {
            prev = curr;
        }
    }
}

static void deleteNextWord(WordLink prev)
{
    if (prev == null) {
        firstWord = firstWord.next;
    } else {
        prev.next = prev.next.next;
    }
    n--;
}
```
pickRandom()

```java
static String pickRandom()
{
    WordLink curr;
    int j = (int) (n*Math.random());

    for (curr=firstWord; curr!=null; curr=curr.next) {
        if (j<=0) break;
        j--;
    }

    return curr.word;
}
```

Note the {	extbf{for}} loop paradigm for linked lists.
static int nmatches(String s1, String s2) {
    int i, j;
    int len1 = s1.length();
    int len2 = s2.length();
    int cnt = 0;
    char[] c1 = new char[len1];
    char[] c2 = new char[len2];
    int[] f = new int[len2];

    s1.getChars(0, len1, c1, 0);
    s2.getChars(0, len2, c2, 0);

    for (j=0; j<len2; j++) { f[j]=0; }

    for (i=0; i<len1; i++) {
        for (j=0; j<len2; j++) {
            if (c2[i] == c1[j] && f[j] == 0) {
                f[j] = 1;
                break; // out of the for(j...) loop
            }
        }
    }
    for (j=0; j<len2; j++) {cnt += f[j];}
    return cnt;
}
# Complexity

<table>
<thead>
<tr>
<th></th>
<th>Searching</th>
<th>Adding</th>
<th>Deleting</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unsorted Array</strong></td>
<td>$n$</td>
<td>1*</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sorted Array</strong></td>
<td>$\log(n)$</td>
<td>$n*$</td>
<td>$n$</td>
<td>1</td>
</tr>
<tr>
<td><strong>Linked List</strong></td>
<td>$n$</td>
<td>1</td>
<td>1</td>
<td>$n$</td>
</tr>
</tbody>
</table>

* Assuming the array is big enough.