

CSE143X: Computer Programming I & II

Programming Assignment #9

due: Monday, 11/27/17, 11:00 pm

This assignment will give you practice with recursive backtracking. You are to create a class called `AnagramSolver` that uses a dictionary to find all combinations of words that have the same letters as a given phrase (see the sample log for examples).

Your class must include the following public methods.

Method	Description
<code>AnagramSolver(List<String> list)</code>	This method constructs an anagram solver that will use the given list as its dictionary. You should not change the list in any way. You may assume that the dictionary is a nonempty collection of nonempty sequences of letters and that it contains no duplicates.
<code>void print(String s, int max)</code>	This is your method that will use recursive backtracking to find combinations of words that have the same letters as the given string. It should print to <code>System.out</code> all combinations of words from the dictionary that are anagrams of <code>s</code> and that include at most <code>max</code> words (or unlimited number of words if <code>max</code> is 0). It should throw an <code>IllegalArgumentException</code> if <code>max</code> is less than 0.

Your `print` method must produce the anagrams in the same format as in the sample log. One good way to do this is to build up your answer in a list. Then you can simply call `println` on the structure and it will have the appropriate format.

You are required to solve this problem by using recursive backtracking. In particular, you are to write a recursive method that builds up an answer one word at a time. On each recursive call, you are to search the dictionary from beginning to end and to explore each word that is a match for the current set of letters. The possible solutions are to be explored in dictionary order. For example, in deciding what word might come first, you are to examine the words in the same order in which they appear in the dictionary. The solution to the 8-queens problem provides a good example to follow for your own code.

An important aspect of the 8-queens solution was the separation of the recursive code (`Queens.java`) from the code that managed low-level details of the problem (`Board.java`). You are required to follow a similar strategy here. The low-level details for the anagram problem involve keeping track of various letters and figuring out when one group of letters can be formed from another group of letters. We are providing you with a class called `LetterInventory` to handles these details (see the description at the end of the writeup). We are giving you a compiled version of this class. You should include `LetterInventory.class` in the same directory as your code so that the Java compiler can find it.

For any given word or phrase, what matters to us is how many of each letter there are. This is exactly what the `LetterInventory` keeps track of. In addition, the `subtract` method of `LetterInventory` is the key to solving this problem. For example, if you have a `LetterInventory` for the phrase “george bush” and ask whether or not you can subtract the `LetterInventory` for “bee”, the answer is yes. Every letter in the “bee” inventory is also in the “george bush” inventory. That means that you need to explore this possibility. Of

course, the word “bee” alone is not enough to account for all of the letters of “george bush”, which is why you’d want to work with the new inventory formed by subtracting the letters from “bee” as you continue the exploration.

Part of your grade will be based on elements of efficiency of your solution. Recursive backtracking is, in general, highly inefficient because it is a brute force technique that checks every possibility, but there are some simple things you can do to improve the efficiency. Be careful not to compute something twice if you don’t need to, and don’t continue to explore branches that you know will never be printed. In addition, you are required to implement the following two optimizations:

- There is no reason to convert dictionary words into inventories more than once. You should “preprocess” the dictionary in your constructor to compute all of the inventories in advance (once per word). You’ll want fast access to these inventories as you explore the possible combinations. A map will give you fast access. Remember that we used the combination of the `SortedMap` interface and the `TreeMap` implementation for the grammar solver. For that program, it was important to keep the keys in sorted order. That is not true for this program, so you should instead use the more general `Map` interface and the slightly faster `HashMap` implementation.
- For any given phrase, you can reduce the dictionary to a smaller dictionary of “relevant” words. A word is relevant if it can be subtracted from the given phrase. Only a fraction of the dictionary will, in general, be relevant to any given phrase. So reducing the dictionary before you begin the recursion will allow you to speed up the searches that happen on each recursive invocation. To implement this, you should construct a short dictionary for each phrase you are asked to explore that includes just the words relevant to that phrase. You’ll do this once before the recursion begins, not on each recursive call. Students who want to prune the dictionary on each recursive call are allowed to do so, but keep in mind that it is not required and it might make the code more difficult to write. If you decide to prune on each recursive call, you should clearly document that you are doing so.

In terms of correctness, your class must provide all of the functionality described above. In terms of style, we will be grading on use of comments, good variable names, consistent indentation, and otherwise good coding style to implement these operations. Remember that you will lose points if you declare variables as data fields that can instead be declared as local variables. You should also be making correct use of generics and you should declare fields and variables using interfaces when possible (e.g., using `List<String>` for your variable even if the object is of type `ArrayList<String>`). You should also avoid extraneous cases (e.g., don’t make something into a special case if it doesn’t have to be) and should be careful to include the optimizations described above.

The constructor for your class is passed a reference to a dictionary stored as a list of `String` objects. You can use this dictionary for your own object as long as you don’t change it (that is expressly forbidden in the specification). In other words, you don’t need to make your own independent copy of the dictionary as long as you don’t modify the one that is passed to you in the constructor.

Some people try to use their map in place of their dictionary. There is some space efficiency to this in that the map will store all of the dictionary words as keys of the map, but this isn’t really an appropriate use of the map. Plus, the dictionary might have a different order than what the map uses and you are required to explore the possibilities in dictionary order.

Don’t make this problem harder than it needs to be. You are doing a fairly exhaustive search of the possibilities. You have to avoid dead ends and you have to implement the optimizations listed above, but otherwise you are exploring every possibility. For example, in one of the sample logs you will see that one solution for “Barbara Bush” is [abash, bar, rub]. Because this is found as a solution, you know that every other permutation of these words will also be included ([abash, rub, bar], [bar, abash, rub], [bar, rub, abash], and so

on). But you don't have to write any special code to make that work. That is a natural result of the exhaustive nature of the search. It will locate each of these possibilities and print them out when they are found. Similarly, you don't need any special cases for words that have already been used. If someone asks you for the anagrams of "bar bar bar", you should include [bar, bar, bar] as an answer.

A collection of files needed for the assignment is included on the web page as `assign9.zip`. You will need to have `AnagramMain.java` and `LetterInventory.class` in the same directory as `AnagramSolver.java` in order to run `AnagramMain`. The `.zip` file also contains five dictionary files called `dict0.txt` (very short dictionary of 4 words used for demonstration in lecture), `dict1.txt` (short dictionary of 56 words that has lots of matches for the Bush family—appropriate for testing), `dict2.txt` (medium-sized dictionary of approximately 4 thousand words), `dict3.txt` (large dictionary of approximately 20 thousand words), and `dict4.txt` (large dictionary in a different order).

Your program is to produce exactly the same output in exactly the same order as in the sample logs of execution that are on the class web page. The output comparison tool available from the class web page includes the sample executions if you want to compare your results to the expected output.

For those using Eclipse (or other similar IDEs), the `.zip` file includes `LetterInventory.jar`. To add the `.jar` file to your project, select your project, go to the Projects menu and select Properties, then Java Build Path, Libraries and select "add External JARs." When you add `LetterInventory.jar` to the build path, everything should work.

Sometimes this program produces a lot of output. When you run it in jGRASP, it will display just 500 lines of output. If you want to see more, go to the Build menu and select the "Run in MSDOS Window" option. Then when the window pops up, right-click on the title bar of the window, select Properties, and under the "Layout" tab you should be able to adjust the "Screen Buffer Size" Height to something higher (like 9999 lines).

Sample execution

```
Welcome to the csel43 anagram solver.
```

```
What is the name of the dictionary file? dict3.txt
```

```
phrase to scramble (return to quit)? Howard Dean
```

```
Max words to include (0 for no max)? 2
```

```
[ahead, drown]
```

```
[don, warhead]
```

```
[drown, ahead]
```

```
[hadron, wade]
```

```
[head, onward]
```

```
[nod, warhead]
```

```
[onward, head]
```

```
[wade, hadron]
```

```
[warhead, don]
```

```
[warhead, nod]
```

```
phrase to scramble (return to quit)? Wesley Clark
```

```
Max words to include (0 for no max)? 2
```

```
[creaky, swell]
```

```
[seller, wacky]
```

```
[swell, creaky]
```

```
[wacky, seller]
```

```
phrase to scramble (return to quit)?
```

LetterInventory class

You are to use a class called `LetterInventory` that can be used to keep track of an inventory of letters of the alphabet. The constructor for the class takes a `String` and computes how many of each letter are in the `String`. This is the information the object keeps track of (how many a's, how many b's, etc). It ignores the case of the letters and ignores anything that is not an alphabetic character (e.g., it ignores punctuation characters, digits and anything else that is not a letter). The `LetterInventory` class has the following public methods.

Method	Description
<code>LetterInventory(String data)</code>	Constructs an inventory (a count) of the alphabetic letters in the given string, ignoring the case of letters and ignoring any non-alphabetic characters.
<code>int get(char letter)</code>	Returns a count of how many of this letter are in the inventory. Letter might be lowercase or uppercase (the method shouldn't care). If a non-alphabetic character is passed, the method will throw an <code>IllegalArgumentException</code> .
<code>void set(char letter, int value)</code>	Sets the count for the given letter to the given value. Letter might be lowercase or uppercase. If a non-alphabetic character is passed or if value is negative, the method will throw an <code>IllegalArgumentException</code> .
<code>int size()</code>	Returns the sum of all of the counts in this inventory. This operation should be fast in that it should store the size rather than having to compute it each time this method is called.
<code>boolean isEmpty()</code>	Returns <code>true</code> if this inventory is empty (all counts are 0). This operation should be fast in that it should not need to examine each of the 26 counts when it is called.
<code>String toString()</code>	Returns a string representation of the inventory with the letters all in lowercase and in sorted order and surrounded by square brackets. The number of occurrences of each letter matches its count in the inventory. For example, an inventory of 4 a's, 1 b, 1 l and 1 m would be represented as "[aaaablm]".
<code>LetterInventory add(LetterInventory other)</code>	Constructs and returns a new <code>LetterInventory</code> object that represents the sum of this letter inventory and the other given <code>LetterInventory</code> . The counts for each letter will be added together. The two <code>LetterInventory</code> objects being added together (<code>this</code> and <code>other</code>) will not be changed by this method.
<code>LetterInventory subtract(LetterInventory other)</code>	Constructs and returns a new <code>LetterInventory</code> object that represents the result of subtracting the other inventory from this inventory (i.e., subtracting the counts in the other inventory from this object's counts). If any resulting count would be negative, the method will return <code>null</code> . The two <code>LetterInventory</code> objects being subtracted (<code>this</code> and <code>other</code>) will not be changed by this method.

On the next page are some examples of how the `add` and `subtract` methods would be called:

```
LetterInventory inventory1 = new LetterInventory("George W. Bush");
LetterInventory inventory2 = new LetterInventory("SHRUG!!");
LetterInventory sum = inventory1.add(inventory2);
LetterInventory difference1 = inventory1.subtract(inventory2);
LetterInventory difference2 = inventory2.subtract(inventory1);
LetterInventory inventory2 = new LetterInventory("Hillary Clinton");
```

The first inventory would correspond to [beegghorsuw], the second would correspond to [ghrsu], the sum would be [beeggghorrssuuw], the first difference would be [beegow] and the second difference would be null.