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524. Longest Word In Dictionary Through Deletion

May 12, 2017 | 31.6K views

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Given a string and a string dictionary, find the longest string in the dictionary that can be formed by deleting some characters of the given string. If there are more than one possible results, return the longest word with the smallest lexicographical order. If there is no possible result, return the empty string.

Example 1:

```
Input:
s = "abpcplea", d = ["ale","apple","monkey","plea"]

Output:
"apple"
```

Example 2:

```
Input:
s = "abpcplea", d = ["a","b","c"]

Output:
"a"
```

Note:

1. All the strings in the input will only contain lower-case letters.
2. The size of the dictionary won't exceed 1,000.
3. The length of all the strings in the input won't exceed 1,000.

Solution

Approach 1: Brute Force

Algorithm

The idea behind this approach is as follows. We create a list of all the possible strings that can be formed by deleting one or more characters from the given string s. In order to do so, we make use of a recursive function `generate(s, str, i, l)` which creates a string by adding and by removing the current character(i^{th}) from the string s to the string str formed till the index i. Thus, it adds the i^{th} character to str and calls itself as `generate(s, str + s.charAt(i), i + 1, l)`. It also omits the i^{th} character to str and calls itself as `generate(s, str, i + 1, l)`.

Thus, at the end the list l contains all the required strings that can be formed using s. Then, we look for the strings formed in l into the dictionary available to see if a match is available. Further, in case of a match, we check for the length of the matched string to maximize the length and we also take care to consider the lexicographically smallest string in case of length match as well.

Java | Copy

```java
public class Solution {
    public String findLongestWord(String s, List < String > d) {
        HashSet < String > set = new HashSet < > (d);
        List < String > l = new ArrayList < > ();
        generate(s, "", 0, l);
        String max_str = "";
        for (String str: l) {
            if (set.contains(str))
                if (str.length() > max_str.length() || (str.length() == max_str.length() &&
str.compareTo(max_str) < 0))
                    max_str = str;
        }
        return max_str;
    }
    public void generate(String s, String str, int i, List < String > l) {
        if (i == s.length())
            l.add(str);
        else {
            generate(s, str + s.charAt(i), i + 1, l);
            generate(s, str, i + 1, l);
        }
    }
}
```

Complexity Analysis

- Time complexity : $O(2^n)$. `generate` calls itself 2^n times. Here, n refers to the length of string s.
- Space complexity : $O(2^n)$. List l contains 2^n strings.

Approach 2: Iterative Brute Force

Algorithm

Instead of using recursive `generate` to create the list of possible strings that can be formed using s by performing delete operations, we can also do the same process iteratively. To do so, we use the concept of binary number generation.

We can treat the given string s along with a binary represenation corresponding to the indices of s. The rule is that the character at the position i has to be added to the newly formed string str only if there is a boolean 1 at the corresponding index in the binary representation of a number currently considered.

We know a total of 2^n such binary numbers are possible if there are n positions to be filled(n also corresponds to the number of characters in s). Thus, we consider all the numbers from 0 to 2^n in their binary representation in a serial order and generate all the strings possible using the above rule.

The figure below shows an example of the strings generated for the given string s:"sea".

Given String: "sea"

Decimal Number	Binary Representation	String Formed
0	000	""
1	001	"a"
2	010	"e"
3	011	"ea"
4	100	"s"
5	101	"sa"
6	110	"se"
7	111	"sea"

A problem with this method is that the maximum length of the string can be 32 only, since we make use of an integer and perform the shift operations on it to generate the binary numbers.

Java | Copy

```java
public class Solution {
    public String findLongestWord(String s, List < String > d) {
        HashSet < String > set = new HashSet < > (d);
        List < String > l = new ArrayList < > ();
        for (int i = 0; i < (1 << s.length()); i++) {
            String t = "";
            for (int j = 0; j < s.length(); j++) {
                if (((i >> j) & 1) != 0)
                    t += s.charAt(j);
            }
            l.add(t);
        }
        String max_str = "";
        for (String str: l) {
            if (set.contains(str))
                if (str.length() > max_str.length() || (str.length() == max_str.length() &&
str.compareTo(max_str) < 0))
                    max_str = str;
        }
        return max_str;
    }
}
```

Complexity Analysis

- Time complexity : $O(2^n)$. 2^n strings are generated.
- Space complexity : $O(2^n)$. List l contains 2^n strings.

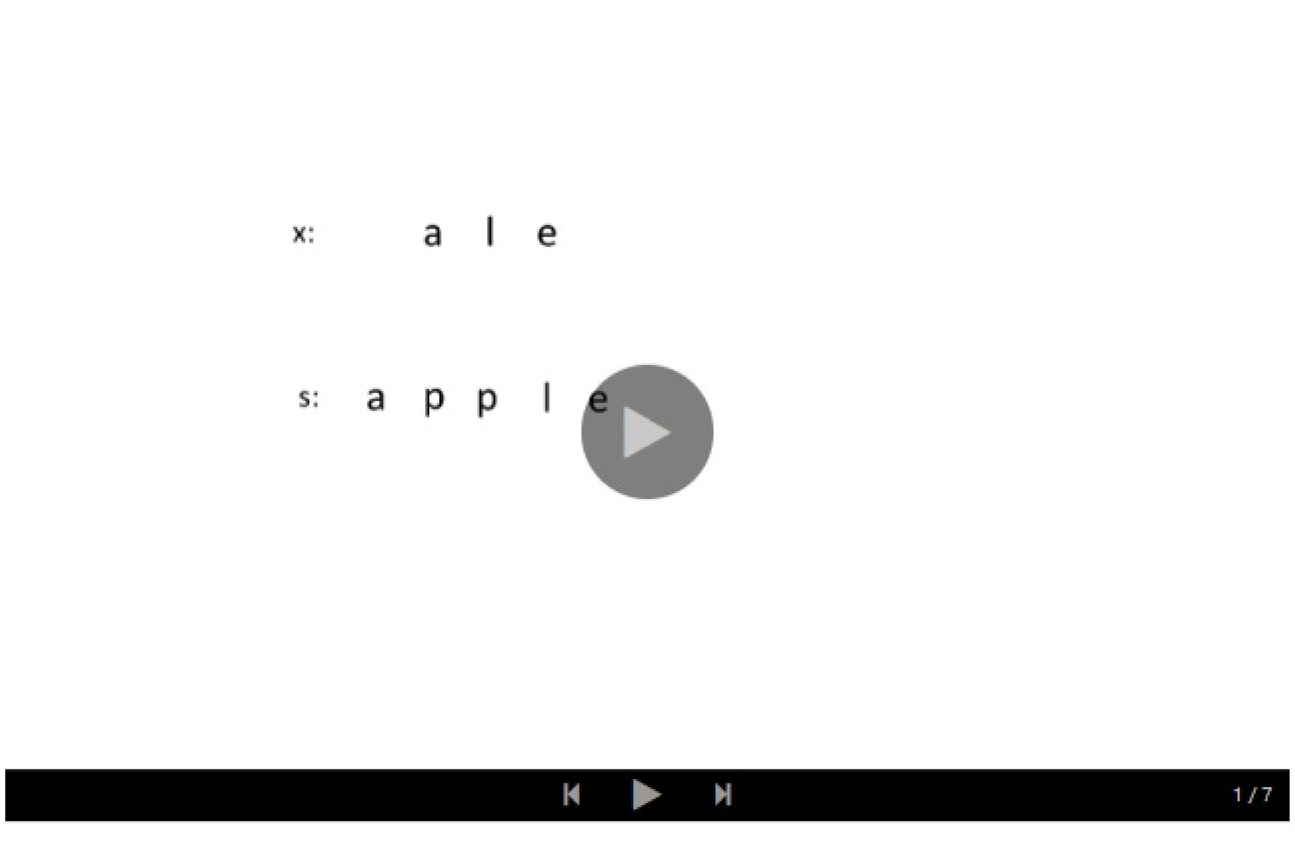
Approach 3: Sorting and Checking Subsequence

Algorithm

The matching condition in the given problem requires that we need to consider the matching string in the dictionary with the longest length and in case of same length, the string which is smallest lexicographically. To ease the searching process, we can sort the given dictionary's strings based on the same criteria, such that the more favorable string appears earlier in the sorted dictionary.

Now, instead of performing the deletions in s, we can directly check if any of the words given in the dictionary(say x) is a subsequence of the given string s, starting from the beginning of the dictionary. This is because, if x is a subsequence of s, we can obtain x by performing delete operations on s.

If x is a subsequence of s every character of x will be present in s. The following figure shows the way the subsequence check is done for one example:



As soon as we find any such x, we can stop the search immediately since we've already processed d to our advantage.

Java | Copy

```java
public class Solution {
    public boolean isSubsequence(String x, String y) {
        int j = 0;
        for (int i = 0; i < y.length() && j < x.length(); i++)
            if (x.charAt(j) == y.charAt(i))
                j++;
        return j == x.length();
    }
    public String findLongestWord(String s, List < String > d) {
        Collections.sort(d, new Comparator < String > () {
            public int compare(String s1, String s2) {
                return s2.length() != s1.length() ? s2.length() - s1.length() : s1.compareTo(s2);
            }
        });
        for (String str: d) {
            if (isSubsequence(str, s))
                return str;
        }
        return "";
    }
}
```

Complexity Analysis

- Time complexity : $O(n \cdot x \log n + n \cdot x)$. Here n refers to the number of strings in list d and x refers to average string length. Sorting takes $O(n \log n)$ and `isSubsequence` takes $O(x)$ to check whether a string is a subsequence of another string or not.
- Space complexity : $O(\log n)$. Sorting takes $O(\log n)$ space in average case.

Approach 4: Without Sorting

Algorithm

Since sorting the dictionary could lead to a huge amount of extra effort, we can skip the sorting and directly look for the strings x in the unsorted dictionary d such that x is a subsequence in s. If such a string x is found, we compare it with the other matching strings found till now based on the required length and lexicographic criteria. Thus, after considering every string in d, we can obtain the required result.

Java | Copy

```java
public class Solution {
    public boolean isSubsequence(String x, String y) {
        int j = 0;
        for (int i = 0; i < y.length() && j < x.length(); i++)
            if (x.charAt(j) == y.charAt(i))
                j++;
        return j == x.length();
    }
    public String findLongestWord(String s, List < String > d) {
        String max_str = "";
        for (String str: d) {
            if (isSubsequence(str, s)) {
                if (str.length() > max_str.length() || (str.length() == max_str.length() &&
str.compareTo(max_str) < 0))
                    max_str = str;
            }
        }
        return max_str;
    }
}
```

Complexity Analysis

- Time complexity : $O(n \cdot x)$. One iteration over all strings is required. Here n refers to the number of strings in list d and x refers to average string length.
- Space complexity : $O(x)$. max_str variable is used.

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robbiefj ★ 39 December 22, 2017 9:37 AM

I do not think that your time complexities are correct. The isSubsequence method is O(m) where m is the size of the input string s. This means that the complexity overall should be O(n*m).

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raptor16 ★ 512 June 30, 2019 3:54 AM

There's actually a better solution: It's explained in the google former coding interview resource here: https://techdevguide.withgoogle.com/paths/foundational/find-longest-word-in-dictionary-that-subsequence-of-given-string/#!

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davidhuangdw ★ 79 February 28, 2019 8:58 AM

we can improve it to O(min(x,y)) to compare S and word using nxt[] info, instead of O(x)
share the O(26* x + n* min(x,y)) and O(26*x) space solution:

```
class Solution:
    def findLongestWord(self, s: 'str', d: 'List[str]') -> 'str':
```

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piku ★ 13 March 12, 2018 5:30 AM

Can someone please tell me how the time complexity of sorted solution is O(nxlogn + nx) ? i thought it is O(nlogn + nx).

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Dird ★ 65 February 28, 2018 1:07 AM

Nevermind, it'd fail on d of "bb" and s of "b"

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calvinchankf ★ 2997 May 12, 2019 9:19 AM

Here is my approach, i think it is easier to understand.
The basic idea is to check if each of the words can be formed by deleting characters from s

Time O(nk)
Space O(k)

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Dird ★ 65 February 28, 2018 12:58 AM

I had a similar idea as #4 but my isSequence is wrong somehow (fails on #29), can anyone see what is wrong?

int i = 0;
for(char c : dict.toCharArray()) {

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YuhuiDai ★ 0 December 7, 2017 9:09 PM

isn't in place merge sort O(1) space?

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vinod23 ★ 461 June 20, 2017 11:20 AM

@zestypanda Yes, you are right. Updated. Thanks

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zestypanda ★ 2263 June 20, 2017 4:13 AM

Why is sorting O(nlogn)? Is the worst case O(nlogn*x) when you have to compare s1 and s2 for n/2 times?

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