Admin AfterAcademy
6 Apr 2020

Longest Common Prefix

Difficulty: Hard

Asked in: Amazon, Google

Understanding the problem

Problem Description

Given the array of strings S**,** write a program to find the **longest common prefix** string which is the prefix of all the strings in the array.

Problem Note

- The longest common prefix for a pair of strings S1 and S2 is the longest string which is the prefix of both S1 and S2.
- All given inputs are in lowercase letters a-z.
- If there is no common prefix, return `"-1"` .

Example 1

```
Input: S[] = [“apple", "ape", "april”]
Output: "ap"
```

Example 2

```
Input: S[] = ["flower","flow","flight"]
Output: "fl"
```

Example 3

```
Input: S[] = [“after”, ”academy, ”mindorks”]
Output: “-1”
Explanation: There is no common prefix among the input strings.
```

Solutions

We will be discussing four different approaches to solve this problem

1. **Horizontal Scanning**—Find the LCP of strs[0] with strs[1] with strs[2] and so on.
2. **Vertical Scanning**—Scan all the characters at index 0 then index 1 then index 2 and so on.
3. **Divide and Conquer**—Divide the strs array to two parts and merge the LCP of both the subparts.
4. **Binary Search**—Compare the substrings[0 to mid] of the smallest string with each string and keep on updating `front` and `behind` accordingly.

1. Horizontal Scanning

A simple way to find the longest common prefix shared by a set of strings *LCP*(*S*1…*Sn*) could be found under the observation that

$$LCP(S1 \ldots Sn) = LCP(LCP(LCP(S1, S2), S3), \ldots . Sn)$$

To achieve it, simply iterate through the strings [*S*1…*Sn*], finding at each iteration i the longest common prefix of strings *LCP*(*S*1…*Si*). When the *LCP*(*S*1…*Si*) is an empty string, then you can return an empty string. Otherwise, after *n* iterations, the algorithm will returns *LCP*(*S*1…*Sn*).

Solution steps

- take a variable `prefix` and initialize it with `strs[0]`
- compare the prefix of each string in the `strs` array with the `prefix` variable and update the `prefix` accordingly
- if at any point length of `prefix` becomes `0` then return `-1`
- return `prefix` after comparing with each string of the `strs` array

Pseudo Code

```
string longestCommonPrefix(string[] strs, int size) {
    if (size == 0)
        return "-1"
    string prefix = strs[0]
    for (int i = 1 to size)
        while (strs[i].indexOf(prefix) != 0) {
            prefix = prefix.substring(0, prefix.length() - 1)
            if (prefix.isEmpty())
                return "-1"
        }
    return prefix
}
```

Complexity Analysis

Time complexity: $O(S)$, where S is the sum of all characters in all strings.

Space complexity: $O(1)$.

Critical Ideas to Think

- Do you think that if all the strings in the array would be same then it would be the worst-case for this approach? If yes, Why?

- What does the `prefix.substring(0, prefix.length() -1)` mean?
- What is the initial value of `prefix` the variable and why?
- Can you think of any other approach?

2. Vertical scanning

Imagine a very short string is the common prefix of the array. The above approach will still do *S* comparisons. One way to optimize this case is to do vertical scanning. We compare characters from top to bottom on the same column (same character index of the strings) before moving on to the next column.

Example—

```
[
"AfterAcademy",
"AfterLife",
"Affirmative",
"Adjective",
]

Vertically scan the 0th index of all the strings, in this case its "A" for e
```

Solution Step

Start comparing the `ith` character for each string, if all the character for `ith` position are all same, then add it to the prefix, otherwise, return prefix till now.

Pseudo Code

```
string longestCommonPrefix(String[] strs, int size) {
    if (strs.length == 0)
        return "-1"
    for (int i = 0 to i < strs[0].length()){
        char c = strs[0][i]
        for (int j = 1 to j < strs.length) {
            if (i == strs[j].length() or strs[j][i] != c)
                return strs[0].substring(0, i)
        }
    }
    return strs[0]
}
```

Complexity Analysis

Time complexity: $O(S)$, where S is the sum of all characters in all strings.

In the best case there are at most $n*minLen$ comparisons where $minLen$ is the length of the shortest string in the array.

Space complexity: $O(1)$. We only used constant extra space.

Critical Ideas to Think

- Do you think the worst case for this approach is exactly the same as in the horizontal scanning?
- Why we are returning `strs[0]` at the end of the function in pseudocode?

3: Divide and conquer

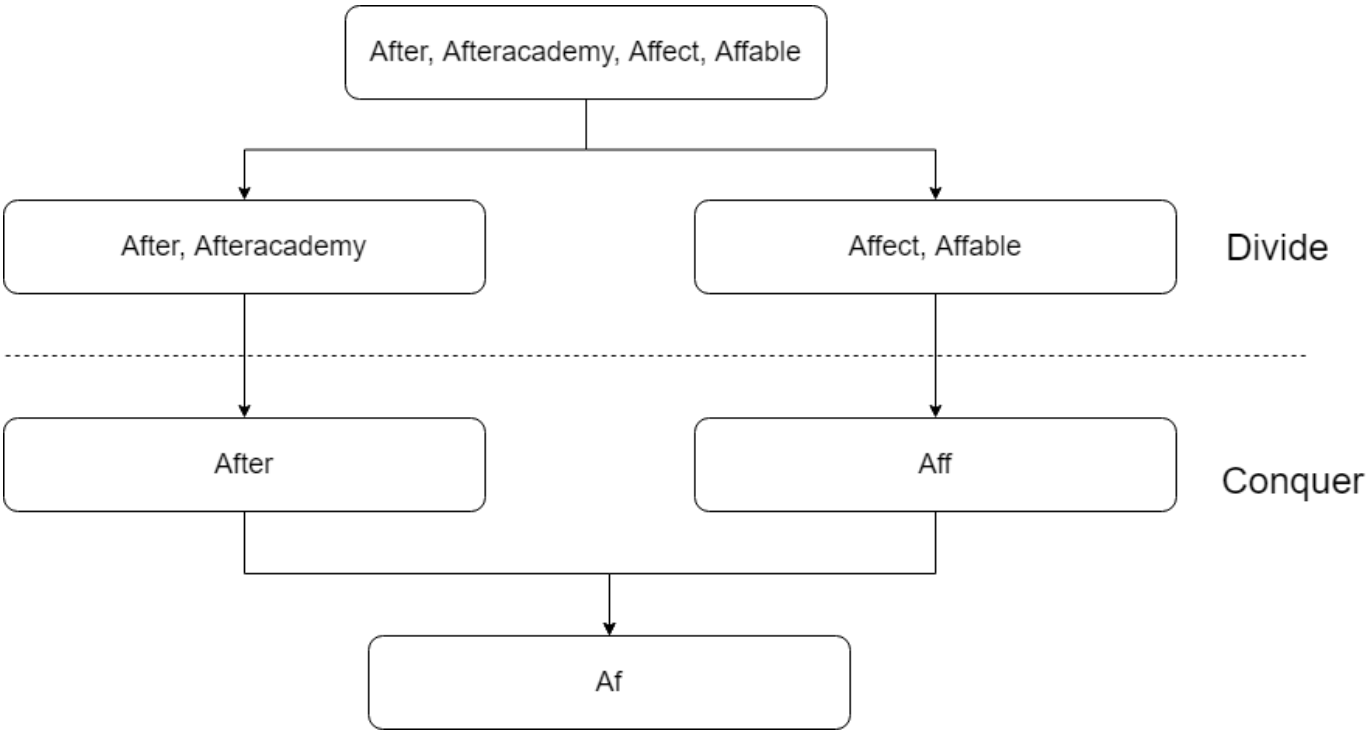
The thought of this algorithm is related to the associative property of LCP operation. Notice that: $LCP(S1...Sn) = LCP(LCP(S1...Sk), LCP(Sk+1...Sn))$, where $LCP(S1...Sn)$ is the longest common prefix in the set of strings $[S1...Sn]$, $1 < k < n1 < k < n$

Thus, the divide and conquer approach could be implied here by dividing the $LCP(Si...Sj)$ problem into two subproblems $LCP(Si...Smid)$ and $LCP(Smid+1...Sj)$, where mid is the middle of the Si and Sj.

We can keep on dividing the problems into two subproblems until they cannot

be divided further.

Now to conquer the solution, we compare the solutions of the two subproblems till there is no character match at each level. The found common prefix would be the solution of `LCP(Si....Sj)` .



Solution Steps

- Recursively divide the strs array into two sub-arrays.
- In the conquer step, merge the result of the two sub-arrays which will be `LCP(LCP(strs[left...mid], LCP([mid+1...right]))` and return it.

Pseudo Code

```
string longestCommonPrefix(string[] strs, int size) {
    if (size == 0) return "-1"
        return longestCommonPrefixutil(strs, 0 , size - 1)
```

```
}

string longestCommonPrefixutil(string[] strs, int left, int right) {
    if (left == right) {
        return strs[left]
    }
    else {
        int mid = (left + right)/2;
        string left_lcp =   longestCommonPrefixutil(strs, left , mid)
        string right_lcp =  longestCommonPrefixutil(strs, mid + 1,right)
        return commonPrefix(left_lcp, right_lcp)
   }
}

string commonPrefix(String left, String right) {
    int smaller = min(left.length(), right.length())
    for (int i = 0 to i < smaller) {
        if ( left[i] != right[i] )
            return left.substring(0, i)
    }
    return left.substring(0, smaller)
}
```

Complexity Analysis

Time complexity: $O(S)$, where S is the number of all characters in the array.

Space complexity: $O(m \cdot \log n)$ **(Why?)**

There are $\log n$ recursive calls and each store need m space to store the result

Critical ideas to think

- How we are dividing the problems set to subproblems?
- Do you think divide and conquer is similar to horizontal scanning?
- Do you think that the best case complexity will be `O(minLen*n)` ?
- What does the `commonPrefix` function do?

4: Binary search

The idea is to apply a binary search method to find the string with maximum value `L` , which is the common prefix of all of the strings. The algorithm searches space is the interval (0...*minLen*), where `minLen` is minimum string length and the maximum possible common prefix. Each time the search space is divided into two equal parts, one of them is discarded because it is sure that it doesn't contain the solution. There are two possible cases: *`S[1...mid]` is not a common string. This means that for each `j > i`, `S[1..j]` is not a common string and we discard the second half of the search space.* `S[1...mid]` is a common string. This means that for each `i < j`, `S[1..i]` is a common string and we discard the first half of the search space because we try to find a longer common prefix.

Solution steps

1. Pick the smallest string
2. Take variable `front = 0` and `behind = len(smallest string)`
3. Do binary search

- Compare the substring up to middle character of the smallest string with every other string at that index.
- if all the strings have the same substring(0, mid) then move `front` to

`mid + 1` else move `behind` to `mid-1` .

- If `front` becomes equal to `behind` then return the `strs[0].substring(0, mid)`

Pseudo Code

```
string longestCommonPrefix(string[] strs, int size) {
    if(size==0)
        return "-1"
    minLen=INT_MAX
    for(i = 0 to i < size){
        minLen = min(minLen,strs[i].length())
    }
    front = 1
    behind = minLen

    prefix = ""
    while(front <= behind) {
        mid = (front+behind)/2
        string temp=strs[0].substring(0, mid)
        int j = 1
        for(j=1 to j < size) {
           if(!strs[j].startsWith(temp)) {
                behind = mid-1
                break
            }
        }
        if(j==strs.length){

            prefix = temp
            front=mid+1
        }
    }
    return prefix
}
```

Complexity Analysis

Time complexity: $O(S \cdot \log n)$, where S is the sum of all characters in all strings

Space complexity: $O(1)$

Critical Ideas to Think

- Do you think that the binary search approach is not better than the approaches described above?
- Why we are comparing substrings(0 to mid) instead of comparing only the middle character of every other string in the strs array? Can you think of a case in this scenario when we will compare only the mid character?
- Why did we start this algorithm by finding the minLen?
- Do you think that the best case and average case are the same in the binary search approach?
- Can you take some example and compare the time complexity of each of the approaches described above.

Comparison of Different Approaches

Approach	Time Complexity	Space Complexity
Horizontal Scanning	O(s)	O(1)
Vertical Scanning	O(s)	O(1)
Divide and Conquer	O(s)	O(m. logn)

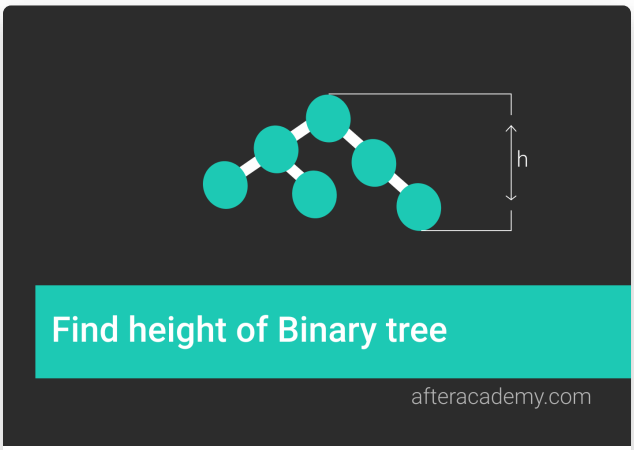
Binary Search	**O(s.logn)**	**O(1)**
Where S is the sum of all characters in all of the strings of the input string array		

Suggested Problems to Solve

- Longest Common Prefix using Trie
- Find the shortest unique prefix for every word in the given list
- Find Longest common prefix using linked list
- Find minimum shift for longest common prefix

If you have any more approaches or you find an error/bug in the above solutions, please comment down below.

Happy Coding! Enjoy Algorithms!



Find The Height Of a Binary Tree

Given a binary tree, write a program to find the maximum depth of the binary tree. The maximum depth is the number of nodes along the longest path from the root node to the leaf node. A leaf is a node with no child nodes.

Admin AfterAcademy
3 Nov 2020

Longest Arithmetic Progression

The problem requires knowledge of dynamic programming and Arithmetic progression. Given a set of integers in an array A[] of size n, write a program to find the length of the longest arithmetic subsequence in A.

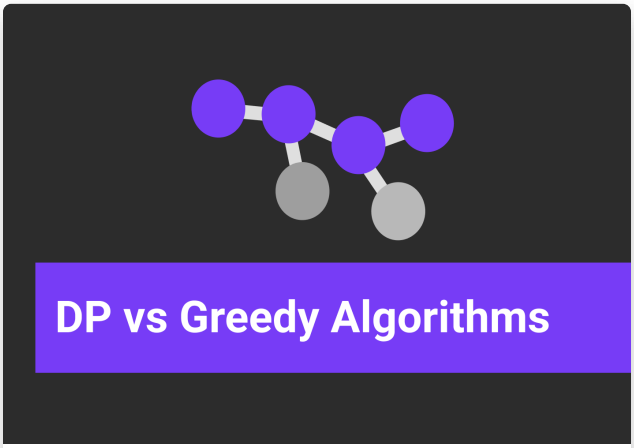
Admin AfterAcademy
1 Jun 2020

Admin AfterAcademy
6 Apr 2020

Admin AfterAcademy
10 Feb 2020

Longest Increasing Subsequence - Interview

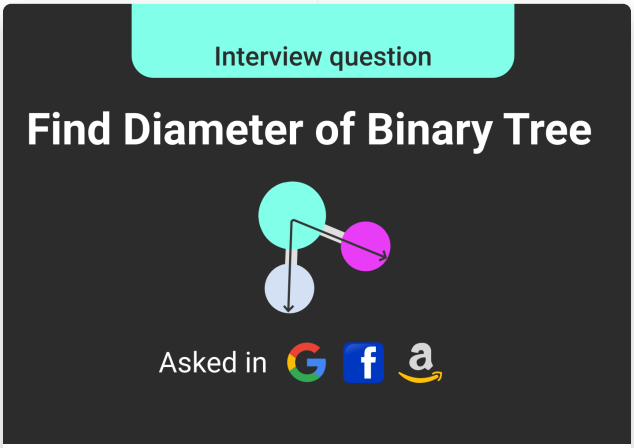
Greatest Common Divisor- Interview Problem



Dynamic Programming vs Greedy Algorithms

These are two very useful and commonly used algorithmic paradigms for optimization and we shall compare the two in this blog and see when to use which approach.

Admin AfterAcademy
29 Feb 2020



Find Diameter of Binary Tree

Given a binary tree, you need to compute the length of the diameter of the tree. The diameter of a binary tree is the length of the longest path between any two nodes in a tree. This path may or may not pass through the root.

Admin AfterAcademy
2 Mar 2020

Our Learners Work At

make my trip zomato Paytm GO JEK Directi
Intelligent People. Uncommon Ideas.
hike Microsoft Rakuten zalando SWIGGY

AfterAcademy

Stay up to date. Follow us on

Quick Links

Contact Us
Privacy Policy
Terms And Conditions
Cookie Policy

About Us

MindOrks
Amit Shekhar
Janishar Ali

Free Resources

Publication
Medium
Video Lessons
Open Source