



A computer science portal for geeks

[Practice](#)[GATE CS](#)[Placements](#)[GeeksQuiz](#)[Login/Register](#)

Dynamic Programming I Set 4 (Longest Common Subsequence)

We have discussed Overlapping Subproblems and Optimal Substructure properties in [Set 1](#) and [Set 2](#) respectively. We also discussed one example problem in [Set 3](#). Let us discuss Longest Common Subsequence (LCS) problem as one more example problem that can be solved using Dynamic Programming.

LCS Problem Statement: Given two sequences, find the length of longest subsequence present in both of them. A subsequence is a sequence that appears in the same relative order, but not necessarily contiguous. For example, “abc”, “abg”, “bdf”, “aeg”, “acefg”, .. etc are subsequences of “abcdefg”. So a string of length n has 2^n different possible subsequences.

It is a classic computer science problem, the basis of [diff](#) (a file comparison program that outputs the differences between two files), and has applications in bioinformatics.

Examples:

LCS for input Sequences “ABCDGH” and “AEDFHR” is “ADH” of length 3.

LCS for input Sequences “AGGTAB” and “GXTXAYB” is “GTAB” of length 4.

We strongly recommend that you click here and practice it, before moving on to the solution.

The naive solution for this problem is to generate all subsequences of both given sequences and find the longest matching subsequence. This solution is exponential in term of time complexity. Let us see how this problem possesses both important properties of a Dynamic Programming (DP) Problem.

1) Optimal Substructure:

Let the input sequences be $X[0..m-1]$ and $Y[0..n-1]$ of lengths m and n respectively. And let $L(X[0..m-1], Y[0..n-1])$ be the length of LCS of the two sequences X and Y . Following is the recursive definition of $L(X[0..m-1], Y[0..n-1])$.



If last characters of both sequences do not match (or $X[m-1] \neq Y[n-1]$) then
 $L(X[0..m-1], Y[0..n-1]) = \text{MAX} (L(X[0..m-2], Y[0..n-1]), L(X[0..m-1], Y[0..n-2]))$

Examples:

1) Consider the input strings "AGGTAB" and "GXTXAYB". Last characters match for the strings. So length of LCS can be written as:
 $L(\text{"AGGTAB"}, \text{"GXTXAYB"}) = 1 + L(\text{"AGGTA"}, \text{"GXTXAY"})$

	A	G	G	T	A	B
G	-	-	4	-	-	-
X	-	-	-	-	-	-
T	-	-	-	3	-	-
X	-	-	-	-	-	-
A	-	-	-	-	2	-
Y	-	-	-	-	-	-
B	-	-	-	-	-	1

2) Consider the input strings "ABCDGH" and "AEDFHR". Last characters do not match for the strings. So length of LCS can be written as:
 $L(\text{"ABCDGH"}, \text{"AEDFHR"}) = \text{MAX} (L(\text{"ABCDG"}, \text{"AEDFHR"}), L(\text{"ABCDGH"}, \text{"AEDFH"}))$

So the LCS problem has optimal substructure property as the main problem can be solved using solutions to subproblems.

2) Overlapping Subproblems:

Following is simple recursive implementation of the LCS problem. The implementation simply follows the recursive structure mentioned above.

C/C++

```
/* A Naive recursive implementation of LCS problem */
#include<bits/stdc++.h>

int max(int a, int b);

/* Returns length of LCS for X[0..m-1], Y[0..n-1] */
int lcs( char *X, char *Y, int m, int n )
```



Direct Mail Made for Developers. Integrate in Minutes.

Get Started x

```

if (X[m-1] == Y[n-1])
    return 1 + lcs(X, Y, m-1, n-1);
else
    return max(lcs(X, Y, m, n-1), lcs(X, Y, m-1, n));
}

/* Utility function to get max of 2 integers */
int max(int a, int b)
{
    return (a > b)? a : b;
}

/* Driver program to test above function */
int main()
{
    char X[] = "AGGTAB";
    char Y[] = "GTXAYB";

    int m = strlen(X);
    int n = strlen(Y);

    printf("Length of LCS is %d\n", lcs( X, Y, m, n ) );

    return 0;
}

```

Run on IDE

Python

A Naive recursive Python implementation of LCS problem

```

def lcs(X, Y, m, n):
    if m == 0 or n == 0:
        return 0;
    elif X[m-1] == Y[n-1]:
        return 1 + lcs(X, Y, m-1, n-1);
    else:
        return max(lcs(X, Y, m, n-1), lcs(X, Y, m-1, n));

```

Driver program to test the above function

```

X = "AGGTAB"
Y = "GTXAYB"
print "Length of LCS is ", lcs(X , Y, len(X), len(Y))

```

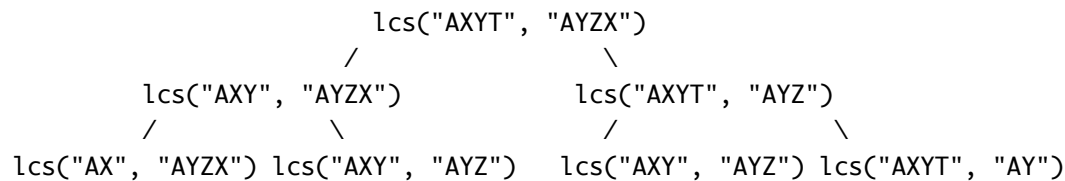


Output:

Length of LCS is 4

Time complexity of the above naive recursive approach is $O(2^n)$ in worst case and worst case happens when all characters of X and Y mismatch i.e., length of LCS is 0.

Considering the above implementation, following is a partial recursion tree for input strings "AXYT" and "AYZX"



In the above partial recursion tree, lcs("AXY", "AYZ") is being solved twice. If we draw the complete recursion tree, then we can see that there are many subproblems which are solved again and again. So this problem has Overlapping Substructure property and recomputation of same subproblems can be avoided by either using Memoization or Tabulation. Following is a tabulated implementation for the LCS problem.

C/C++

```

/* Dynamic Programming C/C++ implementation of LCS problem */
#include<bits/stdc++.h>

int max(int a, int b);

/* Returns length of LCS for X[0..m-1], Y[0..n-1] */
int lcs( char *X, char *Y, int m, int n )
{
    int L[m+1][n+1];
    int i, j;

    /* Following steps build L[m+1][n+1] in bottom up fashion. Note
       that L[i][j] contains length of LCS of X[0..i-1] and Y[0..j-1] */
    for (i=0; i<=m; i++)
    {
        for (j=0; j<=n; j++)
        {
            if (i == 0 || j == 0)

```



Direct Mail Made for Developers. Integrate in Minutes.

Get Started

x

```

        L[i][j] = L[i-1][j-1] + 1,

    else
        L[i][j] = max(L[i-1][j], L[i][j-1]);
    }
}

/* L[m][n] contains length of LCS for X[0..n-1] and Y[0..m-1] */
return L[m][n];
}

/* Utility function to get max of 2 integers */
int max(int a, int b)
{
    return (a > b)? a : b;
}

/* Driver program to test above function */
int main()
{
    char X[] = "AGGTAB";
    char Y[] = "GXTXAYB";

    int m = strlen(X);
    int n = strlen(Y);

    printf("Length of LCS is %d\n", lcs( X, Y, m, n ) );

    return 0;
}

```

Run on IDE

Python

```

# Dynamic Programming implementation of LCS problem

def lcs(X , Y):
    # find the length of the strings
    m = len(X)
    n = len(Y)

    # declaring the array for storing the dp values
    L = [[None]*(n+1) for i in xrange(m+1)]

    """Following steps build L[m+1][n+1] in bottom up fashion
    Note: L[i][j] contains length of LCS of X[0..i-1]

```



Direct Mail Made for Developers. Integrate in Minutes.

[Get Started](#) x

```
if i == 0 or j == 0:
    L[i][j] = 0
elif X[i-1] == Y[j-1]:
    L[i][j] = L[i-1][j-1] + 1
else:
    L[i][j] = max(L[i-1][j], L[i][j-1])

# L[m][n] contains the length of LCS of X[0..n-1] & Y[0..m-1]
return L[m][n]
#end of function lcs

# Driver program to test the above function
X = "AGGTAB"
Y = "GXTXAYB"
print "Length of LCS is ", lcs(X, Y)

# This code is contributed by Nikhil Kumar Singh(nickzuck_007)
```

[Run on IDE](#)

Time Complexity of the above implementation is $O(mn)$ which is much better than the worst case time complexity of Naive Recursive implementation.

The above algorithm/code returns only length of LCS. Please see the following post for printing the LCS.

[Printing Longest Common Subsequence](#)

You can also check the space optimized version of LCS at

[Space Optimized Solution of LCS](#)



Direct Mail Made for Developers. Integrate in Minutes.

[Get Started](#) x



Please write comments if you find anything incorrect, or you want to share more information about the topic discussed above.

References:

<http://www.youtube.com/watch?v=V5hZoJ6uK-s>

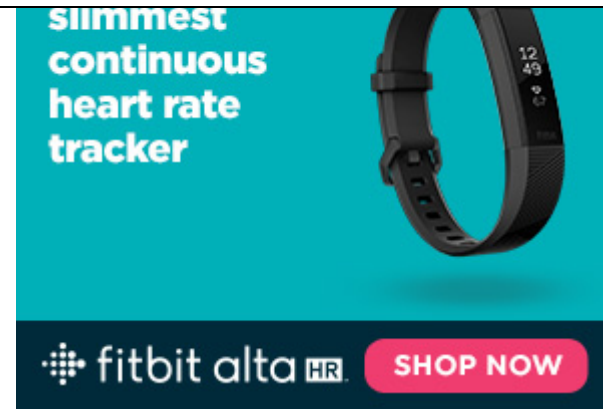
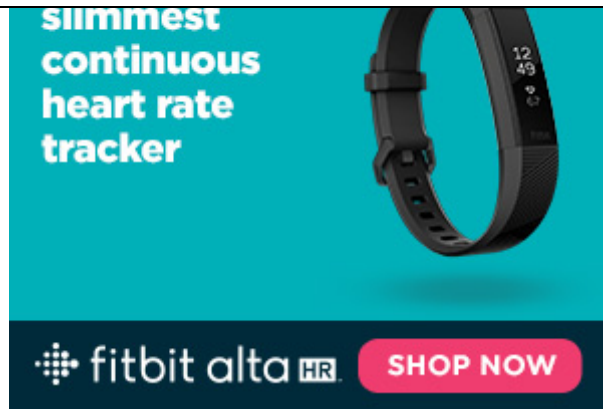
http://www.algorithmist.com/index.php/Longest_Common_Subsequence

<http://www.ics.uci.edu/~eppstein/161/960229.html>

http://en.wikipedia.org/wiki/Longest_common_subsequence_problem



Direct Mail Made for Developers. Integrate in Minutes.

[Get Started](#) x

GATE CS Corner Company Wise Coding Practice

[Dynamic Programming](#) [Dynamic Programming](#) [LCS](#) [subsequence](#)

Recommended Posts:

- [Dynamic Programming I Set 5 \(Edit Distance\)](#)
- [Dynamic Programming I Set 3 \(Longest Increasing Subsequence\)](#)
- [Dynamic Programming I Set 1 \(Overlapping Subproblems Property\)](#)
- [Dynamic Programming I Set 6 \(Min Cost Path\)](#)
- [Dynamic Programming I Set 29 \(Longest Common Substring\)](#)

([Login](#) to Rate and Mark)

2.7

Average Difficulty : 2.7/5.0
Based on 200 vote(s)

☐

Add to TODO List

☐

Mark as DONE

Writing code in comment? Please use code.geeksforgeeks.org, generate link and share the link here.

Load Comments

Share this post!

@geeksforgeeks, Some rights reserved

[Contact Us!](#)

[About Us!](#)

[Advertise with us!](#)

[Privacy Policy](#)