Lexicographic rank of a string

Given a string, find its rank among all its permutations sorted lexicographically. For example, rank of “abc” is 1, rank of “acb” is 2, and rank of “cba” is 6.

For simplicity, let us assume that the string does not contain any duplicated characters.

One simple solution is to initialize rank as 1, generate all permutations in lexicographic order. After generating a permutation, check if the generated permutation is same as given string, if same, then return rank, if not, then increment the rank by 1. The time complexity of this solution will be exponential in worst case. Following is an efficient solution.

Let the given string be “STRING”. In the input string, ‘S’ is the first character. There are total 6 characters and 4 of them are smaller than ‘S’. So there can be 4 * 5! smaller strings where first character is smaller than ‘S’, like following

R X X X X X
I X X X X X
N X X X X X
G X X X X X

Now let us Fix S’ and find the smaller strings staring with ‘S’.

Repeat the same process for T, rank is 4*5! + 4*4! +…

Now fix T and repeat the same process for R, rank is 4*5! + 4*4! + 3*3! +…

Now fix R and repeat the same process for I, rank is 4*5! + 4*4! + 3*3! + 1*2! +…

Now fix I and repeat the same process for N, rank is 4*5! + 4*4! + 3*3! + 1*2! + 1*1! +…

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Now fix N and repeat the same process for G, rank is 4*5! + 4*4 + 3*3! + 1*2! + 1*1! + 0*0!

Rank = 4*5! + 4*4! + 3*3! + 1*2! + 1*1! + 0*0! = 597

Since the value of rank starts from 1, the final rank = 1 + 597 = 598

```
#include <stdio.h>
#include <string.h>

// A utility function to find factorial of n
int fact(int n)
{
    return (n <= 1)? 1 :n * fact(n-1);
}

// A utility function to count smaller characters on right
// of arr[low]
int findSmallerInRight(char* str, int low, int high)
{
    int countRight = 0, i;

    for (i = low+1; i <= high; ++i)
        if (str[i] < str[low])
            ++countRight;

    return countRight;
}

// A function to find rank of a string in all permutations
// of characters
int findRank (char* str)
{
    int len = strlen(str);
    int mul = fact(len);
    int rank = 1;
    int countRight;

    int i;
    for (i = 0; i < len; ++i)
    {
        mul /= len - i;

        // count number of chars smaller than str[i]
        // fron str[i+1] to str[len-1]
        countRight = findSmallerInRight(str, i, len-1);
```

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```
        rank += countRight * mul ;
    }

    return rank;
}

// Driver program to test above function
int main()
{
    char str[] = "string";
    printf ("%d", findRank(str));
    return 0;
}
```

Output

```
598
```

The time complexity of the above solution is O(n^2). We can reduce the time complexity to O(n) by creating an auxiliary array of size 256. See following code.

```
// A O(n) solution for finding rank of string
#include <stdio.h>
#include <string.h>
#define MAX_CHAR 256

// A utility function to find factorial of n
int fact(int n)
{
    return (n <= 1)? 1 :n * fact(n-1);
}

// Construct a count array where value at every index
// contains count of smaller characters in whole string
void populateAndIncreaseCount (int* count, char* str)
{
    int i;

    for( i = 0; str[i]; ++i )
        ++count[ str[i] ];

    for( i = 1; i < 256; ++i )
        count[i] += count[i-1];
}

// Removes a character ch from count[] array
```

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```
// constructed by populateAndIncreaseCount()
void updatecount (int* count, char ch)
{
    int i;
    for( i = ch; i < MAX_CHAR; ++i )
        --count[i];
}

// A function to find rank of a string in all permutations
// of characters
int findRank (char* str)
{
    int len = strlen(str);
    int mul = fact(len);
    int rank = 1, i;
    int count[MAX_CHAR] = {0};  // all elements of count[] are initial

    // Populate the count array such that count[i] contains count of
    // characters which are present in str and are smaller than i
    populateAndIncreaseCount( count, str );

    for (i = 0; i < len; ++i)
    {
        mul /= len - i;

        // count number of chars smaller than str[i]
        // fron str[i+1] to str[len-1]
        rank += count[ str[i] - 1] * mul;

        // Reduce count of characters greater than str[i]
        updatecount (count, str[i]);
    }

    return rank;
}

// Driver program to test above function
int main()
{
    char str[] = "string";
    printf ("%d", findRank(str));
    return 0;
}
```

The above programs don’t work for duplicate characters. To make them work for duplicate characters, find all the characters that are smaller (include equal this time also), do the same as

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above but, this time divide the rank so formed by p! where p is the count of occurrences of the repeating character.

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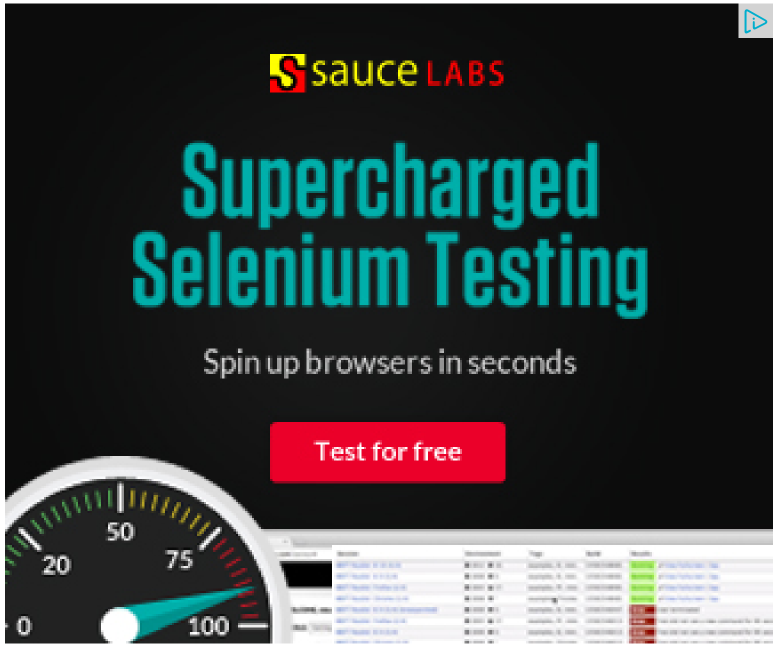

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