Advanced Recursion

Recursion and Strings

Here, we are going to discuss the different problems that can be solved using recursion on strings:

- **Finding the length of a String**

```
#include <iostream>
using namespace std;

int length(char s[]) {
	if (s[0] == '\0') {	// Base case
		return 0;
	}
	int smallStringLength = length(s + 1);  // Recursive call
	return 1 + smallStringLength;           //Small calculation
}


int main() {
	char str[100];
	cin >> str;

	int l = length(str);
	cout << l << endl;
}
```

- **Remove X from a given string**

```
#include <iostream>
using namespace std;

void removeX(char s[]) {
	if (s[0] == '\0') {                    // Base case
		return;
	}

	if (s[0] != 'x') {                     // Small calculation
		removeX(s + 1);                    // Recursive call
	} else {
		int i = 1;
		for (; s[i] != '\0'; i++) {
			s[i - 1] = s[i];
		}
		s[i - 1] = s[i];
		removeX(s);
	}
}

int main() {
	char str[100];
	cin >> str;
	removeX(str);
	cout << str << endl;
}
```

Merge Sort

Consider the example below that shows the working of merge sort over the given array and also how it divides and conquers the array.

Let's now look at the algorithm associated with it...

Algorithm for Merge Sort:

Merge sort keeps on dividing the list into equal halves until it can no longer be divided. By definition, if there is only one element in the list, it is sorted. Then, merge sort combines the smaller sorted lists, keeping the new list sorted too.

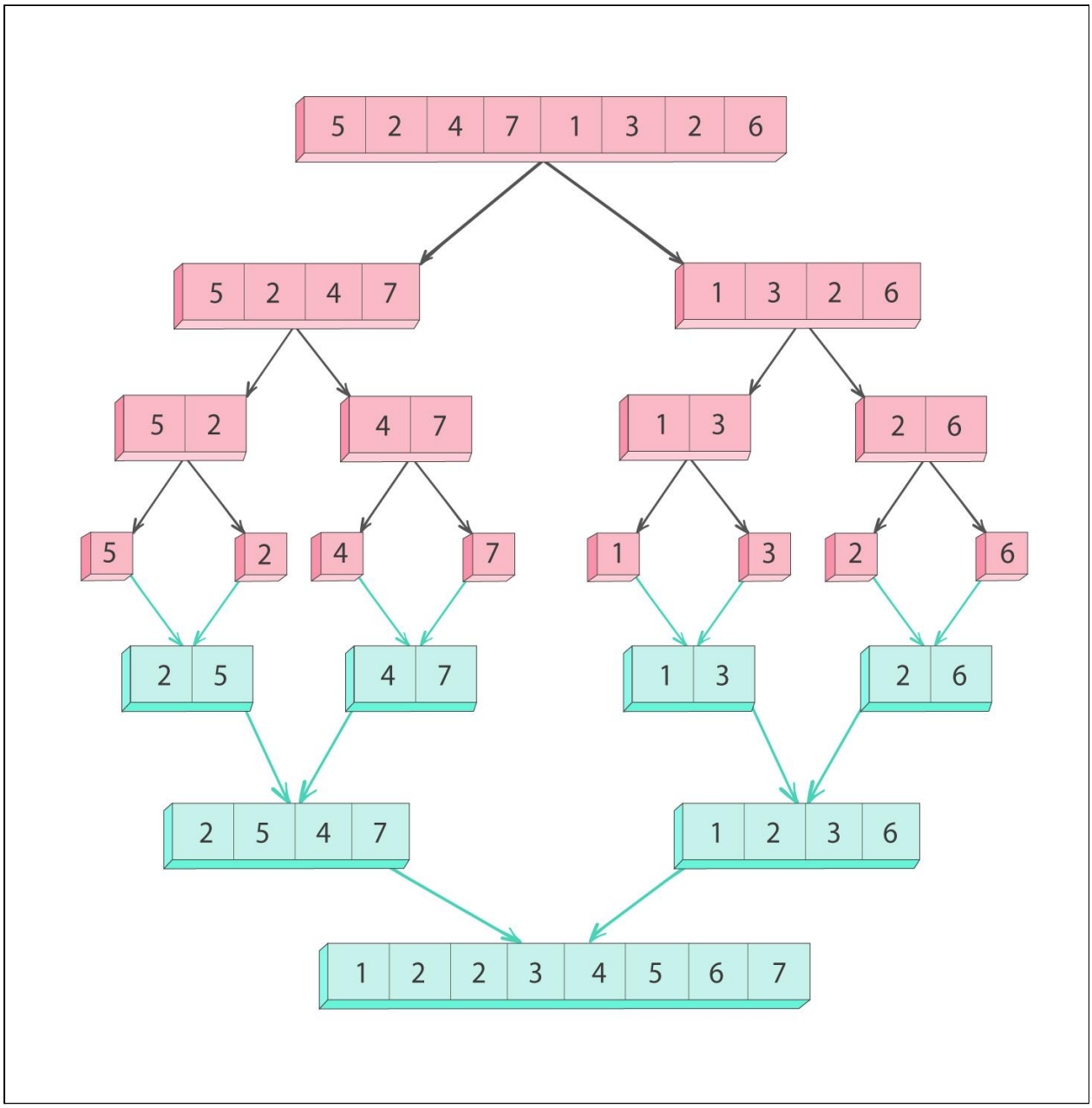
Step 1 – If it is only one element in the list it is already sorted, return.

Step 2 – Divide the list recursively into two halves until it can no longer be divided.

Step 3 – Merge the smaller lists into new lists in sorted order.

Now, you can code it easily by following the above three steps.

It has just one disadvantage and it is that it's not an in-place sorting technique, which means it creates a copy of the array and then works on that copy.



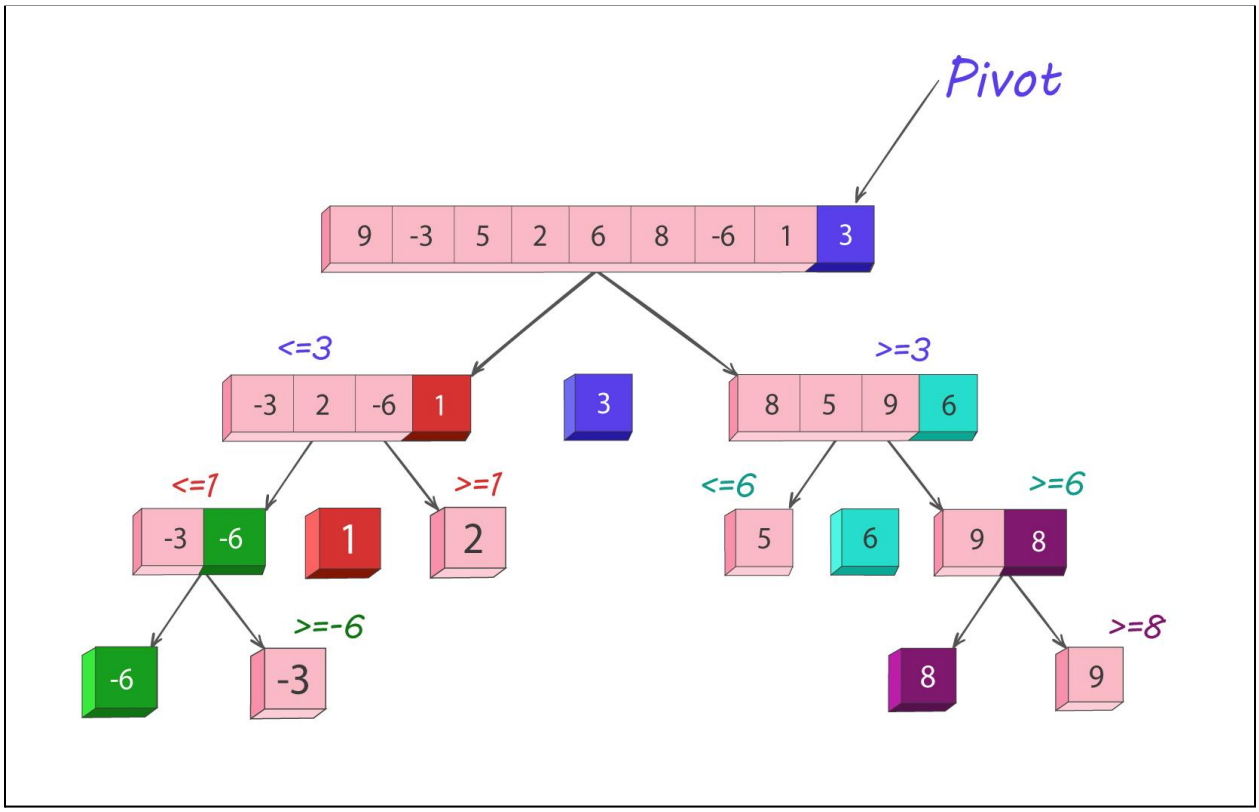
Time Complexity : O(Nlog(N))

Extra Space Complexity : O(N)

Quick Sort

Quick sort is based on the divide-and-conquer approach based on the idea of choosing one element as a pivot element and partitioning the array around it, such that: Left side of pivot contains all the elements that are less than the pivot element and Right side contains all elements greater than the pivot.
It reduces the space complexity and removes the use of the auxiliary array that is used in merge sort. Selecting a random pivot in an array results in an improved time complexity in most of the cases.
To get a better understanding of the approach consider the following example where a pictorial representation of the quick sort on an array is shown.

Algorithm for Quick Sort:
On the basis of Divide and Conquer approach, quicksort algorithm can be explained as:
Divide
The array is divided into subparts, taking pivot as the partitioning point. The elements smaller than the pivot are placed to the left of the pivot and the elements greater than the pivot are placed to the right side.
Conquer
The left and right sub-parts are again partitioned by selecting pivot elements for them. This can be achieved by recursively passing the subparts into the algorithm.
Combine
This part does not play a significant role in quicksort. The array is already sorted at the end of the conquer step.
Advantage of quicksort over merge sort is that it does not require any extra space to sort the given array, therefore, it is an in-place sorting technique.



Time Complexity : O(Nlog(N))

Extra Space Complexity : O(1)

Strings

Let us think of string as a class, instead of a data type. We all already know that strings are the character arrays that end with a NULL character itself.

Syntax for declaring a string:
string str;

Syntax for declaring a string dynamically:
string *str = new string;

To take input of the string, we can use the **getline()** function. Newline is the delimiter for the getline() function. Follow the syntax below:
getline(cin, str); // where str is the name of the string

You can treat the string like any other character array as well. You can go to any specific index (indexing starts from 0), assign any string value by using equals to (=) operator, etc.

To concatenate two strings you can use the '+' operator. For example, to concatenate two strings s1 and s2 and put it in another string str, syntax is as below:
string str = s1 + s2;

To calculate the length of the string you can use the in-built function (.length()) for that:
int len = str.length();

You can do the same using the following syntax also:
int len = str.size();

To extract a particular segment of the string, we can use the .substr() function.
string s = str.substr(beginning_index, length_ahead_of_starting_index);

Here, if you omit the second argument, then automatically the function takes the complete string, after the specified starting index.
You can also find any particular substring in the given string using .find() function. It will return the starting index of the substring to be found in the given string.
int index = str.find(name_of_the_pattern_to_be_checked);

Note: .find() function finds the first occurring index of the given pattern.

Return Subsequences of a String

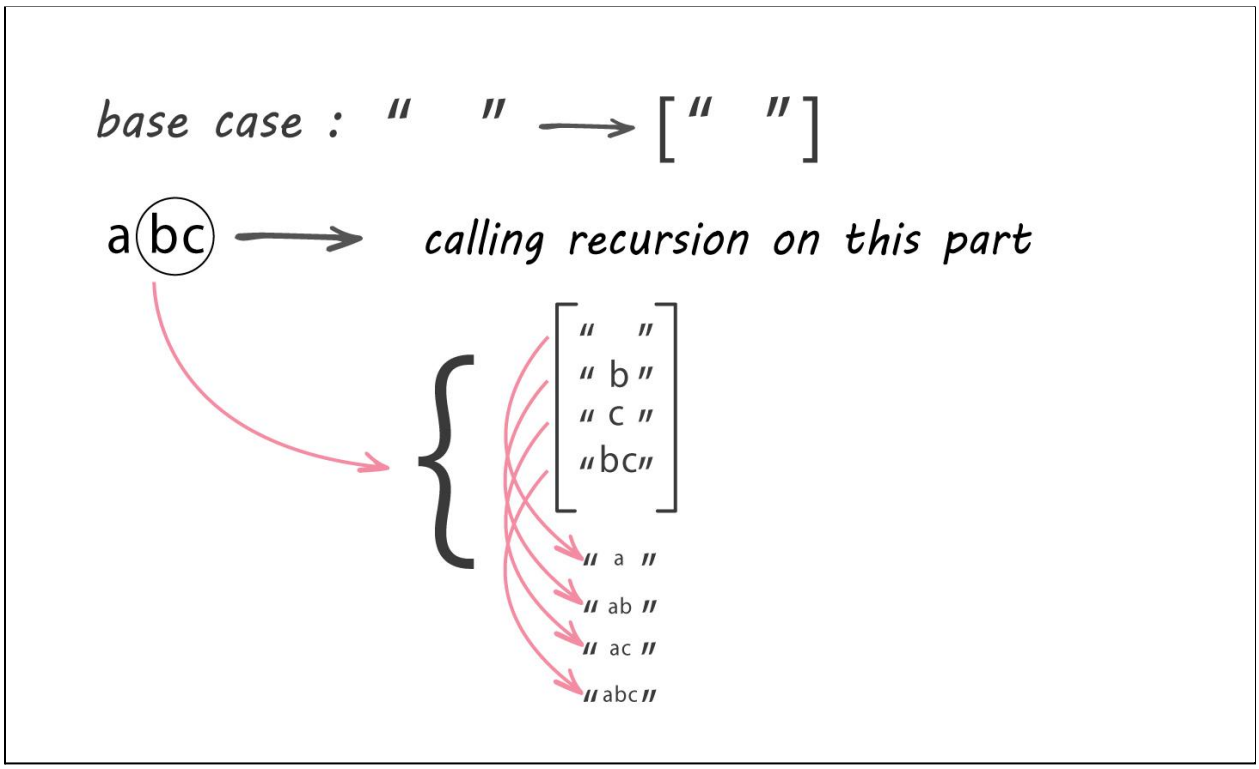
A subsequence can be any combination of the characters present in the string, may these characters be next to each other or far apart doesn't matter.

For example, in string = **"abc"**, we have the following subsequences:

" ", ac, a, b, c, ab, abc, bc

If the length of the string is n, then the total number of substrings that can be generated from it are 2^n.

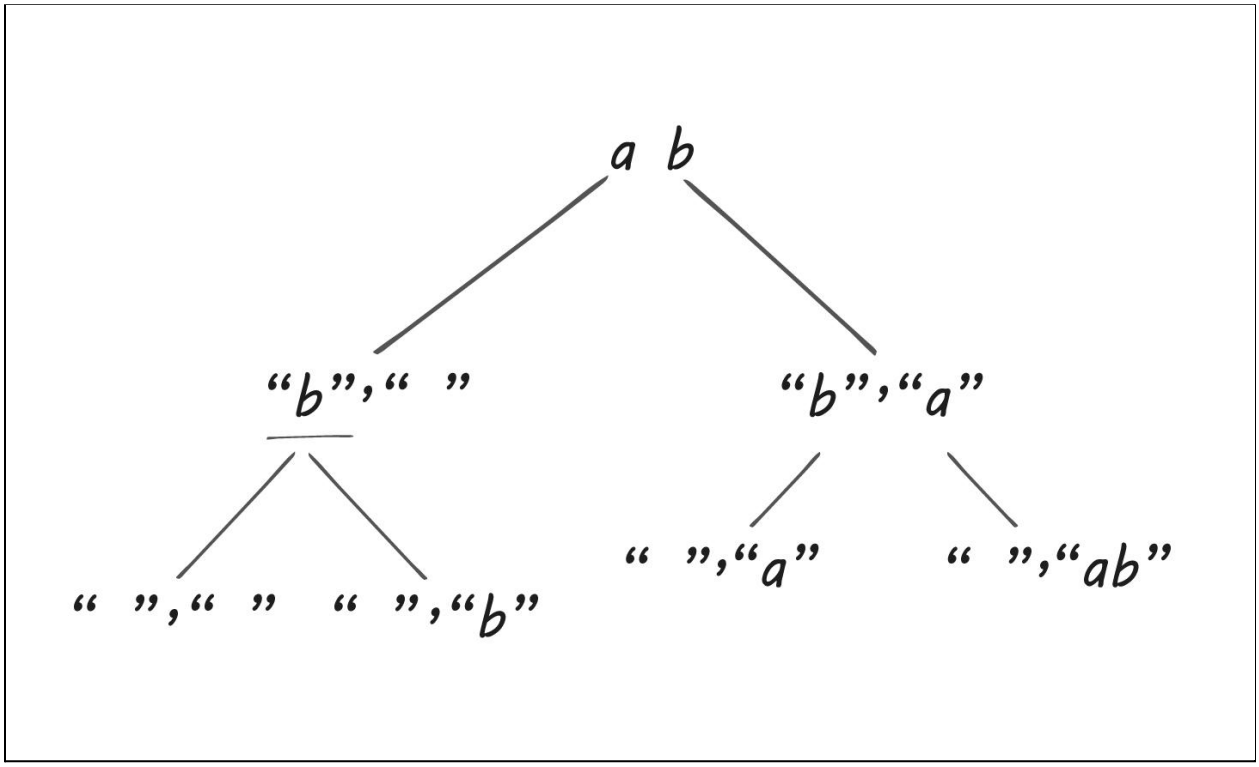
We'll call recursion on **bc** and then in front of all the substrings we add **a** to generate all the substrings inclusive of **a**.



```cpp
#include <iostream>
using namespace std;

int subs(string input, string output[]) {

	// base case

	if (input.empty()) {
		output[0] = "";
		return 1;
	}

	 // calling recursion in smaller part

	string smallString = input.substr(1);
	int smallOutputSize = subs(smallString, output);

	// calculation

	for (int i = 0; i < smallOutputSize; i++) {
		output[i + smallOutputSize] = input[0] + output[i];
	}
	return 2 * smallOutputSize;
}

int main() {
	string input;
	cin >> input;
	string* output = new string[1000];
	int count = subs(input, output);
	for (int i = 0; i < count; i++) {
		cout << output[i] << endl;
	}
}
```

Print Subsequences in a different way

String = "**abc**"
Earlier we were calling recursion on **bc** and then calculating corresponding subsequences in which **a** was inclusive.
Now, for every step we go in two different directions and at every step we decide whether to include a character in the output string or not. So basically we hit the base case 2^n times.




```
#include <iostream>
using namespace std;

void print_subs(string input, string output) {
    if (input.length() == 0) {
        cout << output << endl;
        return;
```

```
    }

    print_subs(input.substr(1), output);
    print_subs(input.substr(1), output + input[0]);
}

int main() {
    string input;
    cin >> input;
    string output = "";
    print_subs(input, output);
}
```