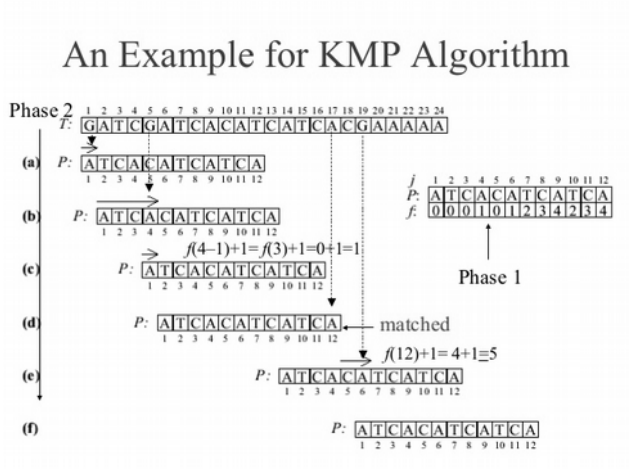
// String Matching
// Knuth Morris Pratt
// Complexity : O(String + Token)

```
char P[2000010], T[1000010];          //T is the string that we need to find
int P_Size, T_Size, Table[1000010]; //S is the string in which we have to find

void PrefixTable() {                        // Builds the prefix table
   int i = 0, j = -1;                       // Table contains the prefix table
   Table[0] = -1;
   while(i < T_Size) {                      // Pre-process the pattern string T
      while(j >= 0 && T[i] != T[j])         // If different, reset j using Table
         j = Table[j];                  // j = last point where i'th element = j'th element
      i++, j++;                             // If same, advance both pointers
      Table[i] = j;
} }
```




```
int KmpSearch() {

   register int i = 0, j = 0, cnt = 0;
   while(i < P_Size) {
      while(j >= 0 && P[i] != T[j])          // Search through string P
         j = Table[j];                       // If different, reset j using T
      i++, j++;                              // if same, advance both pointers
      if(j == T_Size) {                      //the match found in i-j, if i-j = 0, then the  whole string is matched
         cnt++;                              // This happens when the string is equal in length of the token
         //printf("%d'th Match found at %d\n", cnt, i-j);  //the leftmost index
         j = Table[j];                       //j contains the first segment index that is matched in token
    } }
   return cnt;                               // Return the number of successful matches
}
```

// Trie Basic
// Complexity : Build : O(S), Search : O(S)

```
struct node {
   //int visited;                  // Add if repeated substring needed
   bool isEnd;                     // Indicates if this node contains a string that ends at this character
   node *next[11];                 // How many child a root/parent node may contain
   node() {                        // Initializer
      isEnd = false;
      for(int i = 0; i < 10; i++)
         next[i] = NULL;
}};
```

```
bool create(char str[], int len, node *current) {      // Insert string in trie
   for(int i = 0; i < len; i++) {
      int pos = str[i] - '0';
      if(current->next[pos] == NULL)                   // If this point don't have child
         current->next[pos] = new node();              // Initialize child
      current = current - > next[pos];
      current - >visited++;   // Use this line if number of times visited in a node is
   }                          //required
   current->isEnd = true;
   return false;
}

void del(node *current) {                              // Deletes trie
   for(int i = 0; i < 10; i++)
      if(current->next[i] != NULL)
         del(current→next[i]);
   delete current;
}
```

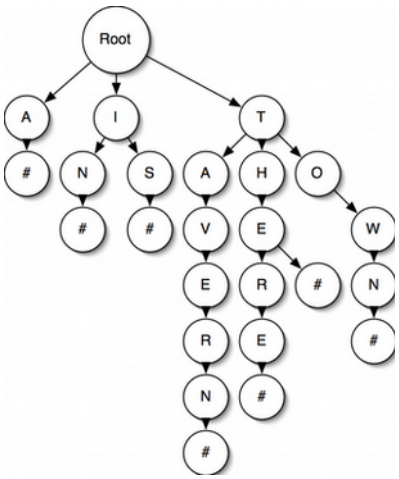


Fig: Trie, # are isEnd = True

```
bool found = 0;
void search(node *current) {
   for(int i = 0; i < 10; i++) {
      if(current->next[i] != NULL)
         check(current->next[i]);
   }
   if(found)  return;
   if(current->isEnd && !found) {
      for(int i = 0; i < 10 && !found; i++)
         if(current->next[i] != NULL) {
            found = 1;
} } }

main() { ……
         node* root = new node();                      // Creating root node
         // Use this to build Prefix Trie
         for(int i = 0; i < string_len; i++)
                  create(Str+i, string_len-i, 0, root);   // Both LCS and LRS will need this
         // To make trie with normal string
         create(Str, strLen, root);
         del(root);
……..}
```

//Longest Repeated Substring
// Prefix Trie

```
// 'ATGATGAT' : longest repeated substring : 'ATG'

struct node {
   int visited;          // Indicates how many times this node is used
   bool isEnd;           // Indicates if this node contains a string that ends at this character
   node *next[4];        // How many child a root/parent node may contain
```

```
   node() {                // Initialization
      visited = 0;
      isEnd = false;
      for(int i = 0; i < 4; i++)
         next[i] = NULL;
}};

string LongestRrepeatedSubstr(node *current, string past) {          // Longest Repeated Substring
   int pos;                                                          // string past contains the past matched part
   string longestRepeated;                                  // y will contain the best repeated string longest and repeated
   longestRepeated += past;
   for(int i = 0; i < 4; i++) {                                      // Here every node contains four (4) child
      if(current->next[i] != NULL) {                                 // Change this line according to child
         if(current->next[i]->visited > 1) {                         // If this segment/char is visited more than once
            string tmp;
            tmp += map_to_str[i];                                    // Take this str as tmp
            tmp += LRS(current->next[i], "");                        // Find next LRS
            if(tmp.size() > y.size())                  // If the string found in this node is larger than previous found string
               longestRepeated = tmp;                                // Take the largest
            else if(tmp.size() == y.size())                          // If both found in this search and the previous
               if(tmp < longestRepeated)                             // If tmp is lexicographically smaller
                  longestRepeated = tmp;                             // take tmp as repeated substring
} } }
   return longestRepeated;                  // LRS of 'AGAGAG' is 2, 'AGAG' and 'AGAG' both AG is common
}

main() { …….
      string LRS =  LongestRrepeatedSubstr(root, “”);                // Gives the longest repeated substring
      node *current = root;
      for(int i = 0; i < LRS.size(); i++) {
         if(current - > next[ LRS[i]-’a’ ] != NULL)                  // lrs[i] – ‘a’ = index of that string
               current = current - > next[ LRS[i]- ‘0’ ];
      }
      printf("%d\n", current - >visited);                            // Prints how many times the string is repeated
…….}
```

//Longest Common Substring
// Prefix Trie

// For two string Longest Common Substring is the longest substring that is the node is visited by two or more strings
// This code is for two LCS in two strings

```
struct node {
   node *next[5];                  // How many child a root/parent node may contain
   bitset<2>visited;               // Indicates which string visited this node
   node() {                        // Initialization
      visited.reset();
      for(int i = 0; i < 5; i++)
         next[i] = NULL;
}};
```

```
int max_len = -1;                    // Maximum length of substring is set to -1 by default
vector<string>lcs_str;               // This contains all the substring

void create(char str[], int len, int strNo, node *current) {        //Same as create in Trie
   for(int i = 0; i < len; i++) {                                   // Change strNo according to new strings
      int pos = str[i] - 'a';
      if(current->next[pos] == NULL)
         current->next[pos] = new node();
      current = current->next[pos];
      current->visited[on] = 1;                                     // Only this line is extra
}}

void longestCommonSubstrring(string past, node *current, int totalStr) {
   for(int i = 0; i < 4; i++) {                                     // Here every node contains four (4) child
      if(current->next[i] != NULL) {                                // Change this line according to child
         if(current->next[i]->visited.count() == totalStr) {        // If the node is visited from both strings
            string tmp;
            tmp += past;                                            // Take past string + new found string
            tmp += map_str_to_int[i];
            max_len = max(max_len, (int)tmp.size());                // Find the maximum length string
            LCS(tmp, current - > next[i], totalStr);    // Go for deeper match, this will add the deeper strings before this substr
            if(tmp.size() == mx_len)                                // If This substring is the longest
               lsc_str.push_back(tmp);                              // push to lcs_str
} } } }

main() {……..
        for(int i = 0; i < len; i++)                    // Building Prefix Trie with string
                build(S1+i, len-i, 0, root);            // Change the strNo according to different string
        for(int i = 0; i < len; i++)
                build(S+i, len-i, 1, root);             // strNo changed in other string
        mx_len = -1;
        longestCommonSubstrring("", root, 2);           // Here 2 is used as we are finding LCS in two string

        for(int i = 0; i < lcs_str.size(); i++)
           if(lcs_str[i].size() == mx_len)              //Only Printing the Longest Substring
                printf("%s\n", lcs_str[i].c_str());     // Other substrings are also in this vector
        del(root);
…….}
```

Scanf Tricks :

```
// %* is used for skipping
// %[words that will be a valid input]
// %[^ words what will be invalid input,  in this case, scanf will break]

scanf(" %*[(] %[^+] %*[+] %[^)] %s", a, b, n);      // Input : (alpha+omega)^2   ||  a = alpha, b = omega = n = 2

// %*[(] skipping (
// %[^+] take input until +
// %*[+] skipping +
// %*[^)] skipping ^ and )
```

Empty Line Input: If the input contains empty lines that also should be processed, use fgets()

// Longest Common Subsequence (Not Substring!)
// Complexity : O(len_a*len_b) (Dynamic Programming)
// Bottom Up DP

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

Fig: Longest Common Substring DP table

```
int LCS(char a, char b, int len_a, int len_b) {
        int dp[210][210];
   for(register int i = 0; i <= len_a; i++)
      for(register int j = 0; j <= len_b; j++) {
         if(i == 0 || j == 0)                    //base case
            dp[i][j] = 0;
         else if(a[i-1] == b[j-1])               //if a match found
            dp[i][j] = dp[i-1][j-1] + 1;
         else
            dp[i][j] = max(dp[i-1][j], dp[i][j-1]);     // dp[i][j] = max(ignoring a[i-1] (taking b[j]),  (taking a[i]) ignoring b[j-1])
      }
   return dp[len_a][len_b];
}
```

// Longest Palindrom
// Dynamic Programming

```
char S[1010];
int dp[1010][1010], len;

int palindrom(int l, int r) {                      // function call: palindrom(0, length_of_string)
   if(dp[l][r] != -1)                              //memorization
      return dp[l][r];
   else if(l == r)                                 //if the middle point reached (odd length of a string)
      return dp[l][r] = 1;
   else if(l+1 == r) {                             //if the two points are middle (even length of a string)
      if(S[l] == S[r])
         return dp[l][r] = 2;                      //if matches, we can take them both
      else
         return dp[l][r] = 1;                      //else we can take only one of them
   }
   else {
      if(S[l] == S[r])                 //if the first and the last character is matched, then we can take them both and go deeper
         dp[l][r] = 2 + palindrom(l+1, r-1);
      else                                         //else we will search for the best choice
         dp[l][r] = max(palindrom(l+1, r), palindrom(l, r-1));
   }
   return dp[l][r];
}
```