Vidya Vikas Education Trust's

Universal College of Engineering, Kaman Road, Vasai-401212

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Department of Computer Engineering

ANALYSIS OF ALGORITHMS
(CSL 401)

Lab Manual

S.E.(Comp) / Sem IV/ SE-A/B

Name of the student:

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Roll No:

<u>31</u>

2020-21

Department of Computer Engineering

Vision:
To be recognized globally as a department provides quality technical education that eventually caters to helping and serving the community

Mission:
To develop human resources with sound knowledge in theory and practice of computer science and engineering
To motivate the students to solve real-world problems to help the society grow
To provide a learning ambience to enhance innovations, team spirit and leadership qualities for students

Course Name	Lab Name	Credit
CSL401	**Analysis of Algorithms Lab**	**1**

Prerequisite: Basic knowledge of programming and data structure	
Lab Objectives:	
1	To introduce the methods of designing and analyzing algorithms
2	Design and implement efficient algorithms for a specified application
3	Strengthen the ability to identify and apply the suitable algorithm for the given real-world problem.
4	Analyze worst-case running time of algorithms and understand fundamental algorithmic problems.
Lab Outcomes: At the end of the course, the students will be able to	
1	Implement the algorithms using different approaches.
2	Analyze the complexities of various algorithms.
3	Compare the complexity of the algorithms for specific problem.

Lab Plan		
Name of the Course		Analysis of Algorithms (AoA)
Year/Sem/Class		S.E.(Comp) / Sem IV/ A/B
Sr. No.	**Module**	**List of Practical Experiments**
1	Introduction to Analysis of Algorithm	Comparative analysis on the basis of Algorithm required to sort list is expected for large values of n using Selection Sort and Insertion Sort
2	Divide and Conquer	a. Merge Sort b. Quick Sort
3	Greedy Method	Minimum Cost Spanning Tree a. Kruskal Algorithm b. Prim's Algorithm
4	Dynamic Programming	a. 0/1 Knapsack b. Longest common subsequence algorithm
5	Backtracking and Branch-and-bound	a. 8 queen problem(N-queen problem) b. Graph Coloring
6	String Matching Algorithm	a. Naive String Matching b. Rabin Karp
7	Other than the syllabus	a. Binary Search Tree

I N D E X

Name: Vivek S Hotti **Roll:** 31 **Class:** SE-Sem4 **Div.:** A

Sr. No.	Module	List of Practical Experiments	From PG	To PG
1	Introduction to Analysis of Algorithm	Comparative analysis on the basis of Algorithm required to sort list is expected for large values of n using Selection Sort and Insertion Sort	5	9
2	Divide and Conquer	a) Merge Sort b) Quick Sort	10	15
3	Greedy Method	Minimum Cost Spanning Tree a) Kruskal Algorithm b) Prim's Algorithm	16	22
4	Dynamic Programming	a) 0/1 Knapsack b) Longest common subsequence algorithm	23	29
5	Backtracking and Branch-and-bound	a) 8 queen problem(N-queen problem) b) Graph Coloring	30	35
6	String Matching Algorithm	a) Naive String Matching b) Rabin Karp	36	41
7	Other than the syllabus	a) Binary Search Tree	42	46

➡ EXPERIMENT NO. 1 ⬅

AIM:

Program to implement Selection sort & Insertion sort.

THEORY:

- Selection Sort

A selection sort is one in which successive elements are selected in order and placed in their proper sorted positions. The elements of the input array may have to be preprocessed to make the ordered selection possible. This algorithm is called the general selection sort.

Straight Selection Sort or push down sort implements the descending priority queue as an unordered array. Therefore, the straight selection sort consists entirely of a selection phase in which the largest of the remaining elements large is repeatedly placed in its proper position i.e. the end of the array. To do so, large is interchanged with the element x[i].

Algorithm:

1. Establish the array a[0...n-1] of n elements.

2. Set variables large to x[0] and index to 0.

3. Compare large with remaining elements of the

   array x if any x[i] is found to be greater the

   large

   then 3.1 change large to x[i]

   3.2 change index to i

4. Swap the values of x[0] with x[index]

5. Repeat steps 1 to 4 for different values of large ranging from x[i+1] to x[n - 1]

6. Return the sorted array.

Analysis of Selection Sort:

Selection sort is not difficult to analyze compared to other sorting algorithms since none of the loops depend on the data in the array. Selecting the lowest element requires scanning all

elements (this takes $n-1$ comparisons) and then swapping it into the first position. Finding the next lowest element requires scanning the remaining $n-1$ elements and so on, for

$(n-1) + (n-2) + \ldots + 2 + 1 = n(n-1) / 2 \in \Theta(n^2)$ comparisons. Each of these scans

requires one swap for $n-1$ elements (the final element is already in place).

- Insertion Sort:

An insertion sort is one that sorts a set of records by inserting records into an existing sorted file. The simplest way to insert next element into the sorted part is to sift it down, until it occupies correct position. Initially the element stays right after the sorted part. At each step algorithm compares the element with one before it and, if they stay in reversed order, swap them

Algorithm:

```
functioninsertionSort(array A)
   fori from1 tolength[A]-1 do

      y = A[i]

      j = i-1
      whilej >= 0 andA[j] > value do
         A[j+1] = A[j]

         j = j-1
      done
      A[j+1] = y
   Done
```

Analysis of Insertion Sort:

The best case input is an array that is already sorted. In this case insertion sort has a linear running time (i.e., $\Theta(n)$). During each iteration, the first remaining element of the input is only compared with the right-most element of the sorted subsection of the array.

The simplest worst case input is an array sorted in reverse order. The set of all worst case inputs consists of all arrays where each element is the smallest or second-smallest of the elements before it. In these cases every iteration of the inner loop will scan and shift the entire sorted subsection of the array before inserting the next element. This gives insertion sort a quadratic running time (i.e., $O(n^2)$).

The average case is also quadratic, which makes insertion sort impractical for sorting large arrays.

<u>CODE for Insertion Sort: -</u>

```
#include <stdio.h>
#include <math.h>
void insertionSort(int arr[], int n)
{
   int i, key, j,temp;
   for (i = 1; i < n; i++)
   {
       j = i;
       key = arr[j];
       while (j > 0 && arr[j-1] > key)
       {
          temp=arr[j];
          arr[j]=arr[j-1];
          arr[j-1]=temp;
          j = j-1;
       }
   }
}
void main()
{
    int arr[100],i,n;
    printf("ENTER THE NO. OF ELEMENTS: \n");
    scanf("%d", &n);
    printf("ENTER THE ELEMENTS: \n");
       for (i=0; i < n; i++)
       {
       scanf("%d",&arr[i]);
       }
    insertionSort(arr, n);
    printf("THE SORTED ARRAY IS: \n");
       for (i=0; i < n; i++)
       {
       printf("%d \n", arr[i]);
       }
}
```

Output obtained from the above code for Insertion Sort:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
ENTER THE NO. OF ELEMENTS:
5
ENTER THE ELEMENTS:
24
233
10
492
9
THE SORTED ARRAY IS:
9
10
24
233
492

C:\Users\Vivek hotti\Desktop>
```

CODE for Selection Sort: -

```
#include <stdio.h>
void main()
{
   int array[100], n, i, j, position, swap;
   printf("Enter number of elements\n");
   scanf("%d", &n);
   printf("Enter %d integers\n", n);
   for ( i = 0 ; i < n ; i++ )
      scanf("%d", &array[i]);
   for ( i = 0 ; i < ( n - 1 ) ; i++ )
   {
      position = i;
      for ( j = i + 1 ; j < n ; j++ )
      {
        if ( array[position] > array[j] )
          position = j;
      }
      if ( position != i )
      {
        swap = array[i];
        array[i] = array[position];
        array[position] = swap;
      }
   }
   printf("Sorted list in ascending order:\n");
   for ( i = 0 ; i < n ; i++ )
      printf("%d\n", array[i]);
}
```

Output obtained from the above code for Selection Sort:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
Enter number of elements
5
Enter 5 integers
1492
231
587
10
484
Sorted list in ascending order:
10
231
484
587
1492

C:\Users\Vivek hotti\Desktop>
```

<u>CONCLUSION:</u>

Insertion sort is very similar in that after the *k*th iteration, the first *k* elements in the array are in sorted order. Insertion sort's advantage is that it only scans as many elements as it needs in order to place the *k*+ 1st element, while selection sort must scan all remaining elements to find the *k*+ 1st element.

Insertion sort is one of the fastest algorithms for sorting very small arrays. Insertion sort typically makes fewer comparisons than selection sort.

➡ EXPERIMENT NO. 2 ⬅

AIM:
Program to implement Merge sort analysis and Quick Sort Analysis.

THEORY:

- Merge Sort:

Merge sort is based on the divide-and-conquer paradigm.
It consists of three steps as given below:

1. Divide Step
2. Conquer Step
3. Combine Step

Algorithm: Merge Sort

To sort entire sequence A[1 .. n], make the initial call to the procedure MERGE-SORT (*A* ,1, *n*).

Analyzing Merge Sort

For simplicity, assume that n is a power of 2 so that each divide step yields two subproblems, both of size exactly $n/2$. The base case occurs when $n= 1$.
Time complexity of Merge sort is **O(n log n)**

- Quick Sort

Quicksort also known as "partition-exchange sort" is a comparison sort.Let x be an array and n the number of elements in the array to be sorted. Choose an element a from a specific position within the array.(e.g. a can be chosen as the first element, so that a= x[0]). Suppose the elements of x are partitioned so that a is placed in position j and the following conditions hold:

1. Each of the elements in positions 0 through j -1 is less than or equal to 1.
2. Each of the elements in positions j + 1 through n -1 is greater than or equal to a.

If these two conditions hold for a particular a and jth smallest element of x, so that a remains in position j when the array is completely sorted. If the above process is repeated with the sub arrays x[0] through x[j-1] and x[j+1] through x[n-1] and any sub arrays created by the process in successive iterations, the final result is a sorted file.

Algorithm: Quick Sort

Step 1 − Make the right-most index value pivot
Step 2 − partition the array using pivot value
Step 3 − quicksort left partition recursively
Step 4 − quicksort right partition recursively

Complexity of Quicksort

Worst-case: $O(N^2)$

This happens when the pivot is the smallest (or the largest) element.

Then one of the partitions is empty, and we repeat recursively the procedure for N-1 elements.

Best-case O(NlogN)
The best case is when the pivot is the median of the array, and then the left and the right part will have same size.

There are **logN**partitions, and to obtain each partitions we do **N** comparisons (and not more than **N/2**swaps). Hence the complexity is **O(NlogN)**

Average-case- O(NlogN)

When $n \geq 2$, time for merge sort steps:

- **Divide**: Just compute $q$as the average of $p$and r,which takes constant time i.e. $\Theta(1)$.
- **Conquer**: Recursively solve 2 subproblems, each of size $n/2$, which is $2T(n/2)$.
- **Combine**: MERGE on an n-element subarray takes $\Theta(n)$ time.

Summed together they give a function that is linear in n,which is $\Theta(n)$. Therefore, the recurrence for merge sort running time is

$$T(n) = \begin{cases} \Theta(1) & \text{if } n = 1 , \\ 2T(n/2) + \Theta(n) & \text{if } n > 1 . \end{cases}$$

So solving these using Master's theorem best and average time complexity is **O(n log n)**

CODE for Merge Sort: -

```
#include<stdlib.h>
#include<conio.h>
#include<stdio.h>
void merge(int arr[], int l, int m, int r)
{
    int i, j, k;
    int n1 = m - l + 1;
    int n2 =  r - m;

    int L[100], R[100];

    for (i = 0; i < n1; i++)
       L[i] = arr[l + i];
    for (j = 0; j < n2; j++)
       R[j] = arr[m + 1+ j];

    i = 0;
    j = 0;
    k = l;
    while (i < n1 && j < n2)
    {
       if (L[i] <= R[j])
       {
           arr[k] = L[i];
           i++;
       }
       else
       {
           arr[k] = R[j];
           j++;
       }
       k++;
    }

    while (i < n1)
    {
       arr[k] = L[i];
       i++;
       k++;
    }

    while (j < n2)
    {
       arr[k] = R[j];
       j++;
       k++;
    }
}

void mergeSort(int arr[], int l, int r)
{
    if (l < r)
    {
```

```
        int m = l+(r-l)/2;

        mergeSort(arr, l, m);
        mergeSort(arr, m+1, r);

        merge(arr, l, m, r);
    }
}

void printArray(int A[], int size)
{
    int i;
    for (i=0; i < size; i++)
       printf("%d ", A[i]);
    printf("\n");
}

void main()
{
    int arr[100],i,a,n;
    printf("ENTER THE NO. OF ELEMENTS: \n");
    scanf("%d",&n);
    printf("ENTER THE ELEMENTS: \n");
    for(i=0;i<n;i++)
    scanf("%d", &arr[i]);
 printf("Given array is \n");
    printArray(arr,n);
 mergeSort(arr, 0, n - 1);
printf("\nSorted array is \n");
    printArray(arr, n);
}
```

Output obtained from the above code for Merge Sort:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
ENTER THE NO. OF ELEMENTS:
5
ENTER THE ELEMENTS:
24
332
12
3
765
Given array is
24 332 12 3 765

Sorted array is
3 12 24 332 765
```

CODE for Quick Sort: -

```c
#include <conio.h>
#include <stdio.h>
void quick_sort(int[],int,int);
int partition(int[],int,int);
void main()
{
    int a[50],n,i;
    printf("How many elements?\n");
    scanf("%d",&n);
    printf("Enter array elements:\n");
 for(i=0;i<n;i++)
        scanf("%d",&a[i]);
quick_sort(a,0,n-1);
 printf("Array after sorting using Quick Sort is:\n");
 for(i=0;i<n;i++)
        printf("%d ",a[i]);
getch();
}

void quick_sort(int a[],int l,int u)
{
    int j;
    if(l<u)
    {
        j=partition(a,l,u);
        quick_sort(a,l,j-1);
        quick_sort(a,j+1,u);
    }
}

int partition(int a[],int l,int u)
{
    int v,i,j,temp;
    v=a[l];
    i=l;
    j=u+1;
   do
    {
        do
            i++;
     while(a[i]<v&&i<=u);
          do
            j--;
        while(v<a[j]);
        if(i<j){
            temp=a[i];
            a[i]=a[j];
            a[j]=temp;
        }
    }while(i<j);
    a[l]=a[j];
    a[j]=v;
     return(j);
}
```

Output obtained from the above code for Quick Sort:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
How many elements?
5
Enter array elements:
147
23
156
1560
01
Array after sorting using Quick Sort is:
1 23 147 156 1560
```

CONCLUSION:

- One of the fastest algorithms on average.
- Does not need additional memory (the sorting takes place in the array - this is called **in-place** processing). Compare with merge sort: merge sort needs additional memory for merging. In sorting *n*objects, merge sort has an averageand worst-case performance of O(*n*log *n*).

➡ EXPERIMENT NO. 3 ⬅

AIM:

a) To implement 0/1 Knapsack.

THEORY:

Problem Statement: A thief robbing a store knapsack. There are n items and i^{th} item weigh take? and can carry a maximal weight of W into their $w_i$and is worth $v_i$dollars. What items should thief 0-1 knapsack problem

- Exhibit No greedy choice property.
- No greedy algorithm exists.
- Exhibit optimal substructure property.
- Only dynamic programming algorithm exists.

Given weights and values of n items, put these items in a knapsack of capacity W to get the maximum total value in the knapsack. In other words, given two integer arrays val[0..n-1] and wt[0..n-1] which represent values and weights associated with n items respectively. Also given an integer W which represents knapsack capacity, find out the maximum value subset of val[] such that sum of the weights of this subset is smaller than or equal to W. You cannot break an item, either pick the complete item, or don't pick it (0-1 property).

Algorithm:

```
for w = 0 to W
B[0,w] = 0
for i = 1 to n
 B[i,0] = 0
for i = 1 to n
for w = 0 to W
     if wi <= w // item i can be part of the solution
if bi + B[i-1,w-wi ] > B[i-1,w]
          B[i,w] = bi + B[i-1,w- wi ]
             else B[i,w] = B[i-1,w]
     else B[i,w] = B[i-1,w] // wi > w
```

Example: Selection of n=4 items, capacity of knapsack M=8

Item i	Value v_i	Weight w_i
1	15	1
2	10	5
3	9	3
4	5	4

f(0,g) = 0, f(k,0) = 0

Recursion formula:

$$f(k,g) = \begin{cases} f(k-1,g) & \text{if } w_k > g \\ \max\{v_k + f(k-1,g-w_k), f(k-1,g)\} & \text{if } w_k \le g \text{ and } k>0 \end{cases}$$

Solution tabulated:

		Capacity remaining g=0	g=1	g=2	g=3	g=4	g=5	g=6	g=7	g=8
k=0	f(0,g) =	0	0	0	0	0	0	0	0	0
k=1	f(1,g) =	0	**15**	15	15	15	15	15	15	15
k=2	f(2,g) =	0	**15**	15	15	15	15	25	25	25
k=3	f(3,g) =	0	15	15	15	**24**	24	25	25	25
k=4	f(4, g) =	0	15	15	15	24	24	25	25	**29**

Last value: k=n, g=M f = f(n,M) = f(4,8) = 29

CODE for Knapsack Problem: -

```
#include<stdio.h>

int max(int a, int b) { return (a > b)? a : b; }

int knapSack(int W, int wt[], int val[], int n)
{
   int i, w;
   int K[n+1][W+1];

   for (i = 0; i <= n; i++)
   {
       for (w = 0; w <= W; w++)
       {
           if (i==0 || w==0)
               K[i][w] = 0;
           else if (wt[i-1] <= w)
```

```
                K[i][w] = max(val[i-1] + K[i-1][w-wt[i-1]],  K[i-1][w]);
            else
                K[i][w] = K[i-1][w];
        }
    }

    return K[n][W];
}

int main()
{
    int i, n, val[20], wt[20], W;

    printf("Enter number of items: \n");
    scanf("%d", &n);

    printf("Enter value and weight of items:\n");
    for(i = 0;i < n; ++i){
        scanf("%d%d", &val[i], &wt[i]);
    }

    printf("Enter size of knapsack: \n");
    scanf("%d", &W);

    printf("Answer is: %d", knapSack(W, wt, val, n));
    return 0;
}
```

Output obtained from the above code for Knapsack Problem:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
Enter number of items:
3
Enter value and weight of items:
100 20
50 10
150 30
Enter size of knapsack:
50
Answer is: 250
C:\Users\Vivek hotti\Desktop>
```

CONCLUSION:

Time complexity O(nW) where n is the number of items and W is the capacity of knapsack.

AIM:

b) To implement LCS problem using dynamic programming approach.

THEORY:

Definition 1: Given a sequence X=x1x2...xm, another sequence Z=z1z2...zk is a subsequence of X, if there exists a strictly increasing sequence i1i2...ik of indices of X such that for all j=1,2,...k, we have xij=zj.

Example 1:
If X=abcdefg, Z=abdg is a subsequence of X.
X=abcdefg,
Z=ab d g

Definition 2:
Given two sequences X and Y. A sequence Z is a common subsequence of X and Y if Z is a subsequence of both X and Y.

Example 2: X=abcdefg and Y=aaadgfd. Z=adf is a common subsequence of X and Y.
X=abc defg
Y=aaaadgfd
Z=a d f

Definition 3:
A longest common subsequence of X and Y is a common subsequence of X and Y with the longest length. (The length of a sequence is the number of letters in the sequence.)
Longest common subsequence may not be unique.

Theorem (Optimal substructure of an LCS)

Let X=x1x2...xm, and Y=y1y2...yn be two sequences, and
Z=z1z2...zk be any LCS of X and Y.
1. If xm=yn, then zk=xm=yn and Z[1..k-1] is an LCS of X[1..m-1] and Y[1..n-1].
2. If xm≠yn, then zk≠xm implies that Z is an LCS of X[1..m−1] and Y.
3. If xm≠yn, then zk≠yn implies that Z is an LCS of X and Y[1..n−1].

The recursive equation
Let c[i,j] be the length of an LCS of X[1...i] and X[1...j].

c[i,j] can be computed as follows:

0	**if i=0 or j=0,**
c[i,j]= c[i-1,j-1]+1	**if i,j>0 and xi=yj,**
max{c[i,j−1],c[i−1,j]}	**if i,j>0 and xi≠yj.**

Computing the length of an LCS

• There are n×m c[i,j]'s. So we can compute them in a specific order.

The algorithm to compute an LCS

```
for i=1 to m do
      c[i,0]=0;
for j=0 to n do
      c[0,j]=0;
for i=1 to m do
      for j=1 to n do
            {
                        if xi ==yj then
                          c[i,j]=c[i-1,j-1]=1;
                          b[i,j]=1;
                        else if c[i-1,j]>=c[i,j-1] then
                          c[i,j]=c[i-1,j]
                          b[i,j]=2;
                        else c[i,j]=c[i,j-1]
                          b[i,j]=3;
            }
```

Constructing an LCS (back-tracking)

- We can find an LCS using b[i,j]'s.
- We start with b[n,m] and track back to some cell b[0,i] or b[i,0].

The algorithm to construct an LCS

```
1. i=m
2. j=n;
3. if i==0 or j==0 then exit;
4. if b[i,j]=1 then
    {
        i=i-1;
        j=j-1;
        print "xi";
    }
5. if b[i,j]==2 i=i-1
6. if b[i,j]==3 j=j-1
7. Goto Step 3.
```

CODE for LCS Problem using DP: -

```
#include<stdio.h>
#include<string.h>
int i,j,m,n,c[20][20];
char x[20],y[20],b[20][20];

void print(int i,int j)
{
if(i==0 || j==0)
return;
  if(b[i][j]=='c')
    {
  print(i-1,j-1);
  printf("%c",x[i-1]);}
else if(b[i][j]=='u')
  print(i-1,j);
  else
  print(i,j-1);
}
void lcs()
{
  m=strlen(x);
  n=strlen(y);
  for(i=0;i<=m;i++)
   c[i][0]=0;
for(i=0;i<=n;i++)
c[0][i]=0;
for(i=1;i<=m;i++)
   for(j=1;j<=n;j++)
{
  if(x[i-1]==y[j-1])
  {
  c[i][j]=c[i-1][j-1]+1;
b[i][j]='c';
      }
   else if(c[i-1][j]>=c[i][j-1])
    {
      c[i][j]=c[i-1][j];
      b[i][j]='u';
    }
    else
    {
      c[i][j]=c;
      b[i][j]='l';
    } }
}
void main()
{
  printf("Enter 1st sequence: \n");
  scanf("%s",x);
  printf("Enter 2nd sequence: \n");
   scanf("%s",y);
   printf("\nThe Longest Common Subsequence is: \n ");
    lcs();
   print(m,n);
}
```

Output obtained from the above code for LCS Problem using Dynamic Programming:

```
C:\Users\Vivek hotti\Desktop>a
Enter 1st sequence:
ACFGHD
Enter 2nd sequence:
ABFHD

The Longest Common Subsequence is:
 AFHD
```

CONCLUSION:

Time Complexity of the above implementation is O(mn).

➡ EXPERIMENT NO. 4 ⬅

AIM:

To implement Minimum Spanning Tree Algorithm Prim's & Kruskal's algorithm.

THEORY:

Minimum Spanning Tree:

Given a connected and undirected graph, a *spanning tree*of that graph is a subgraph that is a tree and connects all the vertices together. A single graph can have many different spanning trees. A *minimum spanning tree (MST)*or minimum weight spanning tree for a weighted, connected and undirected graph is a spanning tree with weight less than or equal to the weight of every other spanning tree. The weight of a spanning tree is the sum of weights given to each edge of the spanning tree.

A minimum spanning tree has (V – 1) edges where V is the number of vertices in

the given graph.

Prim's Algorithm:

Prim's algorithm is also a Greedy algorithm.It starts with an empty spanning tree. The idea is to maintain two sets of vertices. The first set contains the vertices already included in the MST, the other set contains the vertices not yet included. At every step, it considers all the edges that connect the two sets, and picks the minimum weight edge from these edges. After picking the edge, it moves the other endpoint of the edge to the set containing MST.

A group of edges that connects two set of vertices in a graph is called cut in graph theory. So, at every step of Prim's algorithm, we find a cut (of two sets, one contains the vertices already included in MST and other contains rest of the vertices), pick the minimum weight edge from the cut and include this vertex to MST Set (the set that contains already included vertices).

How does Prim's Algorithm Work? The idea behind Prim's algorithm is simple; a spanning tree means all vertices must be connected. So the two disjoint subsets (discussed above) of vertices must be connected to make a *Spanning* Tree. And they must be connected with the minimum weight edge to make it a *Minimum* Spanning Tree.

Algorithm

1)Create a set *mstSet* that keeps track of vertices already included in MST.

2)Assign a key value to all vertices in the input graph. Initialize all key values as INFINITE.

Assign key value as 0 for the first vertex so that it is picked first.

3)While mstSet doesn't include all vertices
….**a)**Pick a vertex *u*which is not there in *mstSet* and has minimum key value.
….**b)**Include *u* to mstSet.
….**c)**Update key value of all adjacent vertices of *u*.To update the key values, iterate through all

adjacent vertices. For every adjacent vertex *v*,if weight of edge *u-v*is less than the previous key value of *v*,update the key value as weight of *u-v*

The idea of using key values is to pick the minimum weight edge from cut.The key values are used only for vertices which are not yet included in MST, the key value for these vertices indicate the minimum weight edges connecting them to the set of vertices included in MST.

Analysis

The algorithm spends most of its time in finding the smallest edge. So, time of the algorithm basically depends on how do we search this edge.

Straightforward method. Just find the smallest edge by searching the adjacency list of the vertices in V. In this case, each iteration costs O(m) time, yielding a total running time of O(mn).

<u>Kruskal's Algorithm:</u>

Kruskal's algorithm is a greedy algorithm **in** graph theory **that** finds a minimum spanning tree for a connected weighted graph.This means it finds a subset of the edges that forms a tree that includes every vertex, where the total weight of all the edges in the tree is minimized. If the graph is not connected, then it finds a *minimum spanning forest* (a minimum spanning tree for each connected component.

Below are the steps for finding MST using Kruskal's algorithm **1.**Sort all the edges in non-decreasing order of their weight.

2.Pick the smallest edge. Check if it forms a cycle with the spanning tree formed so far. If cycle is not formed, include this edge. Else, discard it.

3.Repeat step#2 until there are (V-1) edges in the spanning tree.

Algorithm

Start with an empty set A, and select at every stage the shortest edge that has not been chosen or

rejected, regardless of where this edge is situated in the graph.

KRUSKAL(V, E, *w*)

A ← { } ▹ Set A will ultimately contains the edges of the

MST **for**each vertex *v*in V

do MAKE-SET(*v*)
sort E into nondecreasing order by weight *w*
for each (*u*,*v*) taken from the sorted list
do if FIND-SET(*u*) = FIND-SET(*v*)
then A ← A ∪ {(*u*,*v*)}

UNION(*u*,*v*)
returnA

Analysis

The edge weight can be compared in constant time. Initialization of priority queue takes O(E time by repeated insertion. At each iteration of while-loop, minimum edge can be removed in O(log E) time, which is O(log V), since graph is simple. The total running time is O((V + E) log V), which is O(E lg V) since graph is simple and connected.

CODE for PRIMS Algorithm: -

```
#include<stdio.h>
#include<conio.h>
int a,b,u,v,n,i,j,ne=1;
int visited[10]= {0},min,mincost=0,cost[10][10];
void main()
{
	printf("\n Enter the number of nodes:");
	scanf("%d",&n);
	printf("\n Enter the adjacency matrix:\n");
	for (i=1;i<=n;i++)
	  for (j=1;j<=n;j++)
	{
		scanf("%d",&cost[i][j]);
		if(cost[i][j]==0)
		    cost[i][j]=999;
	}
	visited[1]=1;
```

```c
        printf("\n");
        while(ne<n)
         {
                for (i=1,min=999;i<=n;i++)
                   for (j=1;j<=n;j++)
                    if(cost[i][j]<min)
                     if(visited[i]!=0)
                        {
                        min=cost[i][j];
                        a=u=i;
                        b=v=j;
                        }
                if(visited[u]==0 || visited[v]==0)
                {
                        printf("\n Edge %d:(%d %d) cost:%d",ne++,a,b,min);
                        mincost+=min;
                        visited[b]=1;
                }
                cost[a][b]=cost[b][a]=999;
        }
        printf("\n Minimun cost=%d",mincost);
        getch();
}
```

Output obtained from the above code for PRIMS Algorithm:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a

 Enter the number of nodes:7

 Enter the adjacency matrix:
0 28 0 0 0 10 0
28 0 16 0 0 0 14
0 16 0 12 0 0 0
0 0 12 0 22 0 18
0 0 0 22 0 25 24
10 0 0 0 25 0 0
0 14 0 18 24 0 0


 Edge 1:(1 6) cost:10
 Edge 2:(6 5) cost:25
 Edge 3:(5 4) cost:22
 Edge 4:(4 3) cost:12
 Edge 5:(3 2) cost:16
 Edge 6:(2 7) cost:14
 Minimun cost=99
```

CODE for Kruskal's Algorithm: -

```
#include<stdio.h>
#include<conio.h>
#include<stdlib.h>
int i,j,k,a,b,u,v,n,ne=1;
int min,mincost=0,cost[9][9],parent[9];
int find(int);
int uni(int,int);
void main()
{
 printf("Implementation of Kruskal's algorithm \n");
 printf("Enter the no. of vertices: \n");
 scanf("%d",&n);
 printf("Enter the cost adjacency matrix: \n");
 for(i=1;i<=n;i++)
 {
  for(j=1;j<=n;j++)
  {
   scanf("%d",&cost[i][j]);
   if(cost[i][j]==0)
    cost[i][j]=999;
  }
 }
 printf("The edges of Minimum Cost Spanning Tree are: \n");
 while(ne<n)
 {
  for(i=1,min=999;i<=n;i++)
  {
   for(j=1;j<=n;j++)
   {
    if(cost[i][j]<min)
    {
     min=cost[i][j];
     a=u=i;
     b=v=j;
    }
   }
  }
  u=find(u);
  v=find(v);
  if(uni(u,v))
  {
   printf("%d edge (%d,%d) =%d \n",ne++,a,b,min);
   mincost +=min;
  }
  cost[a][b]=cost[b][a]=999;
 }
 printf("tMinimum cost = %d \n",mincost);
 getch();
}
int find(int i)
```

```
{
 while(parent[i])
  i=parent[i];
 return i;
}
int uni(int i,int j)
{
 if(i!=j)
 {
  parent[j]=i;
  return 1;
 }
 return 0;
}
```

Output obtained from the above code for Kruskal's Algorithm:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
Implementation of Kruskal's algorithm
Enter the no. of vertices:
7
Enter the cost adjacency matrix:
0 28 0 0 0 10 0
28 0 16 0 0 0 14
0 16 0 12 0 0 0
0 0 12 0 22 0 18
0 0 0 22 0 25 24
10 0 0 0 25 0 0
0 14 0 18 24 0 0
The edges of Minimum Cost Spanning Tree are:
1 edge (1,6) =10
2 edge (3,4) =12
3 edge (2,7) =14
4 edge (2,3) =16
5 edge (4,5) =22
6 edge (5,6) =25
tMinimum cost = 99
```

CONCLUSION:

- Prim’s algorithm initializes with a node, whereas Kruskal’s algorithm initiates with an edge.

- Prim’s algorithms span from one node to another while Kruskal’s algorithm select the edges in a way that the position of the edge is not based on the last step.
- In prim’s algorithm, graph must be a connected graph while the Kruskal’s can function on disconnected graphs too.
- Prim’s algorithm has a time complexity of $O(V^2)$, and Kruskal’s time complexity is $O(\log V)$.

➡ EXPERIMENT NO. 5 ⬅

AIM:

a) To implement n queen problem

THEORY:

The **eight queens puzzle** is the problem of placing eight chess queens on an 8×8 chessboard so that no two queens attack each other. Thus, a solution requires that no two queens share the same row, column, or diagonal. The eight queens puzzle is an example of the more general ***n*-queens problem** of placing *n* queens on an *n*×*n* chessboard, where solutions exist for all natural numbers *n*with the exception of *n*=2 and *n*=3

A way to place all n queens on the board such that no queens are attacking another queen. Using backtracking, this algorithm prints all possible placements of n queens on an n*n chessboard so that they are non attacking. Place (k, i) – Returns true if a queen can be placed in kth row and ith column. Otherwise it returns false. X [] is a Global array whose first (k –1) values have been set. Abs(r) returns the absolute value of r.

Algorithm:

Algorithm NQueens (k, n) //Prints all Solution to the n-queens problem

```
{
for i := 1 to n do
{
if Place (k, i) then{
x[k] := i;
if ( k = n) then write ( x [1 : n]
else NQueens(k+1,n)
}}}
```

Algorithm Place (k, i)

```
{
for j := 1 to k-1 do

if (( x[ j ] = // in the same column

or (Abs( x [ j ] - i) =Abs ( j – k ))) // or in the same diagonal

then return false;

return true;
}
```

CODE for 'N' Queen Problem: -

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
#include<process.h>
int board[20];
int count;
void main(){
int n,i,j;
void Queen(int row,int n);
printf("\n\t Program for n-Queen's Using Backtracking");
printf("\nEnter Number of Queen's");
scanf("%d",&n);
Queen(1,n);//trace using backtrack
getch();
}
/* This function is for printing the solution
 Second Year Computer Engineering AOA
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to n-queen's problem
*/
void print_board(int n)
{
int i,j;
printf("\n\nSolution %d : \n\n",++count);
 //number of solution
for(i=1;i<=n;i++)
{
printf("\t%d",i);
}
for(i=1;i<=n;i++)
{
printf("\n\n%d",i);
for(j=1;j<=n;j++)// for board
{
if(board[i]==j)
printf("\tQ");//Queen at i,j position
else
printf("\t-");// empty slot
}
}
printf("\n Press any key to continue...");
getch();
}
int place(int row,int column)
{
int i;
for(i=1;i<=row-1;i++)
{ //checking for column and diagonal conflicts
if(board[i] == column)
return 0;
else
if(abs(board[i] - column) == abs(i - row))
return 0;
```

```
}
//no conflicts hence Queen can be placed
return 1;
}
void Queen(int row,int n)
{
int column;

for(column=1;column<=n;column++)
{
if(place(row,column))
{
board[row] = column;//no conflict so place queen
if(row==n)//dead end
print_board(n);
//printing the board configuration
else //try next queen with next position
Queen(row+1,n);
}
}
}
```

Output obtained from the above code for ‘N’ Queen Problem:

```
C:\Users\Vivek hotti\Desktop>a

         Program for n-Queen's Using Backtracking
Enter Number of Queen's5


Solution 1 :

        1       2       3       4       5

1       Q       -       -       -       -

2       -       -       Q       -       -

3       -       -       -       -       Q

4       -       Q       -       -       -

5       -       -       -       Q       -
 Press any key to continue...
```

CONCLUSION:

- Backtracking provides the hope to solve some problem instances of nontrivial sizes by pruning non-promising branches of the state-space tree.

- The success of backtracking varies from problem to problem and from instance to instance.

- Backtracking possibly generates all possible candidates in an exponentially growing state-space tree.

AIM:

b) To implement Graph Coloring

THEORY:

Given an undirected graph and a number m, determine if the graph can be colored with at most m colors such that no two adjacent vertices of the graph are colored with same color. Here coloring of a graph means assignment of colors to all vertices.

For the graph-coloring problem we are interested in assigning colors to the vertices of an undirected graph with the restriction that no two adjacent vertices are assigned the same color. The optimization version calls for coloring a graph using the minimum number of colors. The decision version, known as k-coloring, asks whether a graph is colorable using at most k colors. The 3-coloring problem is a special case of the k-coloring problem where k=3 (i.e., we are allowed to use at most 3 colors).

Input:

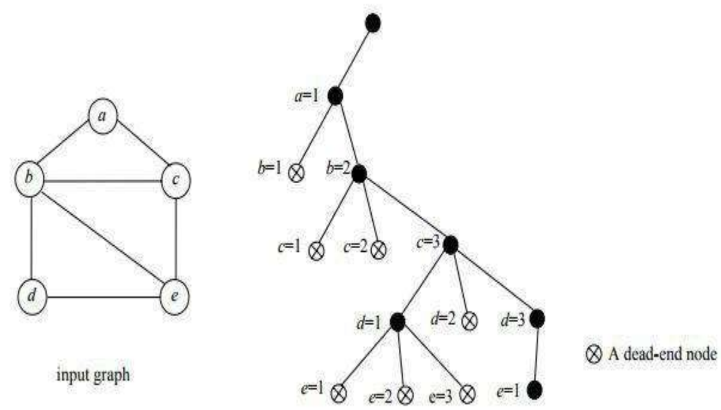
1) A 2D array graph[V][V] where V is the number of vertices in graph and graph[V][V] is adjacency matrix representation of the graph. A value graph[i][j] is 1 if there is a direct edge from i to j, otherwise graph[i][j] is 0.

2) An integer m which is maximum number of colors that can be used.

Output:

An array color[V] that should have numbers from 1 to m. color[i] should represent the color assigned to the ith vertex. The code should also return false if the graph cannot be colored with m colors.

Example



Algorithm:

If all colors are assigned,

print vertex assigned colors

Else a. Trying all possible colors, assign a color to the vertex

b. If color assignment is possible, recursively assign colors to next vertices

c. If color assignment is not possible, de-assign color, return False

CODE to implement GRAPH COLORING: -

```
#include<stdio.h>
int G[50][50],x[50];  //G:adjacency matrix,x:colors
void next_color(int k){
   int i,j;
   x[k]=1;  //coloring vertex with color1
   for(i=0;i<k;i++){ //checking all k-1 vertices-backtracking
     if(G[i][k]!=0 && x[k]==x[i])  //if connected and has same color
       x[k]=x[i]+1;  //assign higher color than x[i]
   }
}

int main(){
```

```c
  int n,e,i,j,k,l;
  printf("Enter no. of vertices : ");
  scanf("%d",&n);  //total vertices
  printf("Enter no. of edges : ");
  scanf("%d",&e);  //total edges

  for(i=0;i<n;i++)
    for(j=0;j<n;j++)
      G[i][j]=0;  //assign 0 to all index of adjacency matrix

  printf("Enter indexes where value is 1-->\n");
  for(i=0;i<e;i++){
    scanf("%d %d",&k,&l);
    G[k][l]=1;
    G[l][k]=1;
  }

  for(i=0;i<n;i++)
    next_color(i);  //coloring each vertex

  printf("Colors of vertices -->\n");
  for(i=0;i<n;i++)  //displaying color of each vertex
    printf("Vertex[%d] : %d\n",i+1,x[i]);

  return 0;
}
```

Output obtained from the above code for Graph Coloring:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
Enter no. of vertices : 4
Enter no. of edges : 5
Enter indexes where value is 1-->
0 1
1 2
1 3
 2 3
3 0
Colors of vertices -->
Vertex[1] : 1
Vertex[2] : 2
Vertex[3] : 1
Vertex[4] : 3

C:\Users\Vivek hotti\Desktop>
```

➡EXPERIMENT NO. 6 ⬅

AIM:

a) To implement Naive String Matching

THEORY:

Given a text txt[0..n-1] and a pattern pat[0..m-1], write a function search(char pat[], char txt[]) that prints all occurrences of pat[] in txt[]. You may assume that n > m.

Input : txt[] = "THIS IS A TEST TEXT"

pat[] =
"TEST"

Output : Pattern found at index
10

Input : txt[] = "AABAACAADAABAABA"

pat[] = "AABA"

Output : Pattern found at index
0

Pattern found at index
9

Pattern found at index
12

Pattern searching is an important problem in Computer Science. When we do search for a string in notepad/word file or browser or database, pattern searching algorithms are used to show the search results.

Naive Pattern Searching:

Slide the pattern over text one by one and check for a match. If a match is found, then slides by 1 again to check for subsequent matches.

PSEUDOCODE:

```
search(txt,
pat) {
   int m =
   pat.length; int n
   = txt.length;

   for( i = 0 to n-m
   ) {
      int j; for( j = 0
      to M )
         if (txt[i + j] != pat[j])
            break
            ;

if (j == M) // if pat[0...M-1] = txt[i, i+1, ...i+M-1] printf("Pattern found at index %d n",
i); } } /* Driver program to test above function */ int main() {
char txt[] = "AABAACAADAABAAABAA";
char pat[] = "AABA"; search(txt, pat);
return 0; }
```

What is the best case?

The best case occurs when the first character of the pattern is not present in text at all.

txt[] = "AABCCAADDEE"; pat[] = "FAA";
The number of comparisons in best case is O(n).

What is the worst case ?

The worst case of Naive Pattern Searching occurs in following scenarios.

1) When all characters of the text and pattern are same.

txt[] = "AAAAAAAAAAAAAAAAAA"; pat[] = "AAAAA"; 2) Worst case also occurs when only the last character is different.

txt[] = "AAAAAAAAAAAAAAAAAB"; pat[] = "AAAAB"; Number of comparisons in worst case is O(m*(n-m+1)). Although strings which have repeated characters are not likely to appear in English text, they may well occur in other applications (for example, in binary texts). The KMP matching algorithm improves the worst case to O(n). We will be covering KMP in the next post. Also, we will be writing more posts to cover all pattern searching algorithms and data structures.

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

CODE for Naïve String Machine: -

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

int main()
{
	int str_length, pattern_length, j, i, count = 0;
	char str[30], pattern[30] ;
	printf("\nEnter a String:\t");
	scanf("%s", str);
	printf("\nEnter a Pattern to Match:\t");
	scanf("%s", pattern);
	str_length = strlen(str);
	pattern_length = strlen(pattern);
	printf("\nPattern Matched at Position:\t");
	for(i = 0; i < str_length - pattern_length; i++)
	{
		for(j = 0; j < pattern_length; j++)
		{
			if(str[i + j] == pattern[j]) count++;
		}
		if(count == pattern_length)
		{
			printf("%d\t", i);
		}
		count = 0;
	}
	printf("\n");
	return 0;
}
```

Output obtained from the above code for Naive String Machine:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a

Enter a String: VIVEKHOTTI

Enter a Pattern to Match:       EKH

Pattern Matched at Position:    3
```

AIM:
b) To implement Rabin Karp

THEORY:

Given a text *txt[0..n-1]* and a pattern *pat[0..m-1]*, write a function *search(char pat[], char txt[])* that prints all occurrences of *pat[]* in *txt[]*. You may assume that n > m.

Input : txt[] = "THIS IS A TEST TEXT"

pat[] =
"TEST"

Output : Pattern found at index
10

Input : txt[] = "AABAACAADAABAABA"

pat[] = "AABA"

Output : Pattern found at index
0

Pattern found at index
9

Pattern found at index
12

Like the Naive Algorithm, Rabin-Karp algorithm also slides the pattern one by one. But unlike the Naive algorithm, Rabin Karp algorithm matches the hash value of the pattern with the hash value of current substring of text, and if the hash values match then only it starts matching

individual characters. So Rabin Karp algorithm needs to calculate hash values for following strings.

1) Pattern itself.

2) All the substrings of text of length m.

Since we need to efficiently calculate hash values for all the substrings of size m of text, we must have a hash function which has following property.

Hash at the next shift must be efficiently computable from the current hash value and next character in text or we can say *hash(txt[s+1 .. s+m])* must be efficiently computable from *hash(txt[s .. s+m-1])* and *txt[s+m]* i.e., *hash(txt[s+1 .. s+m])*= *rehash(txt[s+m], hash(txt[s .. s+m-1])*and rehash must be O(1) operation.

The hash function suggested by Rabin and Karp calculates an integer value. The integer value for a string is numeric value of a string. For example, if all possible characters are from 1 to 10, the numeric value of "122" will be 122. The number of possible characters is higher than 10 (256 in general) and pattern length can be large. So the numeric values cannot be practically stored as an integer. Therefore, the numeric value is calculated using modular arithmetic to make sure that the hash values can be stored in an integer variable (can fit in memory words). To do rehashing, we need to take off the most significant digit and add the new least significant digit for in hash value. Rehashing is done using the following formula.

*hash(txt[s+1 .. s+m]) = (d (hash(txt[s .. s+m-1]) – txt[s]*h) + txt[s + m]) mod q*

hash(txt[s .. s+m-1]) : Hash value at shift *s*.

hash(txt[s+1 .. s+m]) : Hash value at next shift (or shift *s*+1)

d: Number of characters in the alphabet

q: A prime number

h: d^(m-1)

CODE for Rabin Karp: -

```
#include <stdio.h>
#include <conio.h>
#include <string.h>
#include <math.h>
#define d 10
void RabinKarpStringMatch(char*, char*, int);
void main()
{
    char *Text, *Pattern;
    int Number = 11; //Prime Number
    printf("Enter Text String : \n");
    gets(Text);
    printf("Enter Pattern String : \n");
    gets(Pattern);

    RabinKarpStringMatch(Text, Pattern, Number);
    getch();
}

void RabinKarpStringMatch(char* Text, char* Pattern, int Number)
{
    int M, N, h, P = 0, T = 0, TempT, TempP;
    int i, j;
```

```
    M = strlen(Pattern);
    N = strlen(Text);
    h = (int)pow(d, M - 1) % Number;
    for (i = 0; i < M; i++) {
        P = ((d * P) + ((int)Pattern[i])) % Number;
        TempT = ((d * T) + ((int)Text[i]));
        T = TempT % Number;
    }
    for (i = 0; i <= N - M; i++) {
        if (P == T) {
            for (j = 0; j < M; j++)
                if (Text[i + j] != Pattern[j])
                    break;
            if (j == M)
                printf("\nPattern Found at Position: %d", i + 1);
        }
        TempT = ((d * (T - Text[i] * h)) + ((int)Text[i + M]));
        T = TempT % Number;
        if (T < 0)
            T = T + Number;
    }
}
```

Output obtained from the above code for Rabin Karp:

```
Enter Text String : farheen khan

Enter Pattern String : kh

Pattern Found at Position: 9_
```

CONCLUSION:

The average and best case running time of the Rabin-Karp algorithm is O(n+m), but its worst-case time is O(nm). Worst case of Rabin-Karp algorithm occurs when all characters of pattern and text are same as the hash values of all the substrings of txt[] match with hash value of pat[]. For example pat[] = “AAA” and txt[] = “AAAAAAA”.

➡EXPERIMENT NO. 7 ⬅

AIM:

To implement Binary Search Tree

THEORY:

A Binary Search Tree (BST) is a tree in which all the nodes follow the below-mentioned properties −

The left sub-tree of a node has a key less than or equal to its parent node's key.

The right sub-tree of a node has a key greater than to its parent node's key.

Thus, BST divides all its sub-trees into two segments; the left sub-tree and the right sub-tree and can be defined as −

left_subtree (keys) $\leq$ node (key) $\leq$ right_subtree (keys)
Representation
BST is a collection of nodes arranged in a way where they maintain BST properties. Each node has a key and an associated value. While searching, the desired key is compared to the keys in BST and if found, the associated value is retrieved.

Following is a pictorial representation of BST −

Binary Search Tree
We observe that the root node key (27) has all less-valued keys on the left sub-tree and the higher valued keys on the right sub-tree.

Basic Operations
Following are the basic operations of a tree −

Search − Searches an element in a tree.

Insert − Inserts an element in a tree.

Pre-order Traversal − Traverses a tree in a pre-order manner.

In-order Traversal − Traverses a tree in an in-order manner.

Post-order Traversal − Traverses a tree in a post-order manner.

Search Operation

Whenever an element is to be searched, start searching from the root node. Then if the data is less than the key value, search for the element in the left subtree. Otherwise, search for the element in the right subtree. Follow the same algorithm for each node.

Algorithm
```
struct node* search(int data){
   struct node *current = root;
   printf("Visiting elements: ");

   while(current->data != data){

      if(current != NULL) {
         printf("%d ",current->data);

         //go to left tree
         if(current->data > data){
            current = current->leftChild;
         }  //else go to right tree
         else {
            current = current->rightChild;
         }

         //not found
         if(current == NULL){
            return NULL;
         }
      }
   }

   return current;
}
```
Insert Operation
Whenever an element is to be inserted, first locate its proper location. Start searching from the root node, then if the data is less than the key value, search for the empty location in the left subtree and insert the data. Otherwise, search for the empty location in the right subtree and insert the data.

Algorithm
```
void insert(int data) {
   struct node *tempNode = (struct node*) malloc(sizeof(struct node));
   struct node *current;
   struct node *parent;

   tempNode->data = data;
   tempNode->leftChild = NULL;
```

```
   tempNode->rightChild = NULL;

   //if tree is empty
   if(root == NULL) {
      root = tempNode;
   } else {
      current = root;
      parent = NULL;

      while(1) {
         parent = current;

         //go to left of the tree
         if(data < parent->data) {
            current = current->leftChild;
            //insert to the left

            if(current == NULL) {
               parent->leftChild = tempNode;
               return;
            }
         }  //go to right of the tree
         else {
            current = current->rightChild;

            //insert to the right
            if(current == NULL) {
               parent->rightChild = tempNode;
               return;
            }
         }
      }
   }
}
```

CODE to implement Binary Search Tree: -

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

struct node
{
    int key;
    struct node *left, *right;
};

// A utility function to create a new BST node
struct node *newNode(int item)
{
    struct node *temp =  (struct node *)malloc(sizeof(struct node));
    temp->key = item;
    temp->left = temp->right = NULL;
    return temp;
}

// A utility function to do inorder traversal of BST
void inorder(struct node *root)
{
    if (root != NULL)
    {
        inorder(root->left);
        printf("%d \n", root->key);
        inorder(root->right);
    }
}

/* A utility function to insert a new node with given key in BST */
struct node* insert(struct node* node, int key)
{
    /* If the tree is empty, return a new node */
    if (node == NULL) return newNode(key);

    /* Otherwise, recur down the tree */
    if (key < node->key)
        node->left  = insert(node->left, key);
    else if (key > node->key)
        node->right = insert(node->right, key);

    /* return the (unchanged) node pointer */
    return node;
}

// Driver Program to test above functions
int main()
{
    /* Let us create following BST
              50
```

```
           /      \
         30       70
        /  \     /  \
      20   40   60   80 */
    struct node *root = NULL;
    root = insert(root, 50);
    insert(root, 30);
    insert(root, 20);
    insert(root, 40);
    insert(root, 70);
    insert(root, 60);
    insert(root, 80);

    // print inoder traversal of the BST
    inorder(root);

    return 0;
}
```

Output obtained from the above code for Binary Search Tree:

```
C:\Users\Vivek hotti\Desktop>gcc exp1.c

C:\Users\Vivek hotti\Desktop>a
20
30
40
50
60
70
80
```

<u>CONCLUSION:</u>

Hence we have implemented a C program to implement a Binary Search Tree.

(((((( ))))))